Assessing Biological Integrity of Great Lakes Coastal Wetlands Using Marsh Bird and Amphibian Communities

Project # WETLAND3-EPA-01 Technical Report

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ABSTRACT

Marsh bird and amphibian Indices of Biotic Integrity (IBI) were developed for Great Lakes coastal wetlands using existing Marsh Monitoring Program marsh bird and amphibian volunteer-gathered data, in order to evaluate coastal wetland condition. To develop IBIs, marsh bird and amphibian population attributes were examined for response to a disturbance gradient that reflected the amount of marsh, woodland, agriculture and urban development surrounding a wetland at four spatial scales (500 m, 1 km, 20 km, watershed). Within each scale, relations were examined separately during a period of relatively higher Great Lakes water levels and during a period of relatively lower Great Lakes water levels. More marsh bird and amphibian population attributes responded consistently and significantly ($p < 0.20$) to disturbance at smaller (500 m, 1 km) than larger spatial scales, and during high as compared with low water level years. Consequently, marsh bird and amphibian IBIs were developed for all spatial scales during high water levels; during low water levels, a marsh bird IBI was developed for the 20 km scale only, and amphibian IBIs were developed for the 1 km and overall (rank sum of disturbance at all scales combined) disturbance gradients only. All IBIs were significantly correlated with their respective disturbance gradients, except for the 20 km marsh bird IBI for low water levels. Resampling and power analysis for the small scale marsh bird IBI during high water levels confirmed three wetland condition classifications. For amphibians, resampling and power analysis confirmed four wetland condition classification categories for the small spatial scales during both high and low water levels. Possible factors contributing to poor metric response during low water levels and at larger spatial scales, and differences between marsh bird and amphibian metric response to disturbance are discussed. Recommendations to improve marsh bird and amphibian IBI development are also included.

INTRODUCTION

BACKGROUND

The Laurentian Great Lakes system is one of the most prominent pro-glacial features of the North American landscape and provides immeasurable functions and beneficial services that extend far beyond the basin's boundary, despite impacts associated with expansion of intensive urban, agricultural, and industrial development over the last century. During the 1990s, scientists, policy makers, managers, and other stakeholders who are committed to monitoring Great Lakes environmental status and to conserving and restoring Great Lakes ecosystem functions, convened to participate in State of the Lakes Ecosystem Conference (SOLEC). SOLEC provides an inlet and outlet of information sharing and cooperation among its participants who share the common goal to improve the state of life in the Great Lakes region. Initiatives such as Lakewide Management Plans (LaMPs) and Remedial Action Plans (RAPs) are helping to coordinate protection, restoration, management and stewardship of a wide range of ecosystems and their inhabitants.

SOLEC's roots are embedded in the Great Lakes Water Quality Agreement, which has an overall purpose to "…*restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem*" (Anonymous 1987). Goals and objectives of SOLEC are outlined in detail in its bi-annual reports, the most recent one being *State of the Lakes 2003*. Over the years, SOLEC has evolved to recognize various 'State of the Lakes' (SOL) indicator categories, which are biological, chemical, physical, and societal in nature. One recognized SOLEC SOL indicator category is Coastal Wetlands, and during SOLEC 1998, several candidate indicators for coastal wetlands were identified and proposed for further development by a wetlands science working group. Two of these coastal wetland indicators, *4504 - Amphibian Diversity and Abundance* and *4507 - Wetland-Dependent Bird Diversity and Abundance*, are reported to SOLEC by Bird Studies Canada's (BSC) Marsh Monitoring Program (MMP).

To build upon SOLEC indicator development and SOL reporting capacity for coastal wetlands, the Great Lakes Coastal Wetlands Consortium (GLCWC) was established through a partnership between the Great Lakes Commission and the United States Environmental Protection Agency – Great Lakes National Program Office. The GLCWC is a coalition of scientific and policy experts that represents over two-dozen agencies, organizations and institutions who have various responsibilities for U.S. and Canadian Great Lakes coastal wetlands monitoring (http://www.glc.org/monitoring/). These participating members are working together to achieve the following:

A) Work with team members and colleagues to coordinate data collection and analytical methods across sampling sites;

B) Test the variability of indicators within wetland classes across all the Great Lakes;

C) Test the comparability and usefulness of indicators within the wetland classes and eliminate redundant indicators;

D) Test the feasibility of applying indicators in a monitoring plan, including an analysis across six criteria developed by the Consortium:

1) Cost
2) Measurability
3) Basin-wide applicability or sampling by wetland type
4) Availability of complementary existing research or data
5) Indicator sensitivity to wetland condition changes
6) Ability to set endpoint or attainment levels
7) Statistical approach

In 2001, BSC proposed to work with GLCWC research partners to collect wetland-dependent bird (hereafter marsh bird) and amphibian data at various coastal wetland sites throughout the Great Lakes basin, in an effort to advance development of SOL indicators 4504 and 4507 for reporting on biological integrity of Great Lakes coastal wetlands. This document reports on these activities and focuses on BSC's primary goals to examine current MMP data and seek meaningful marsh bird and amphibian population attributes with which to develop Indices of Biotic Integrity (Karr 1981) specific to marsh birds and anurans (frogs and toads) that occupy coastal wetland habitats of the Great Lakes basin.

COASTAL WETLAND HEALTH AND INTEGRITY

Introduction

Wetlands are important and highly productive natural systems of the Great Lakes basin. These physical, hydrological, chemical and biological zones of transition between aquatic and upland habitats are critical to sustaining and rehabilitating both open lake and terrestrial systems. Floodwater storage (Thibodeau and Ostro 1981), groundwater filtering and recharge, nutrient uptake (Johnston 1991, Mitsch et al. 1979, Whigham et al. 1988) and shoreline stabilization (Wang et al. 1997) are but a few physical and chemical functions provided by healthy wetlands. As host to a wide array of both common and rare plants and animals, wetlands also serve as important repositories of Great Lakes biodiversity, and provide breeding habitat for invertebrates (Batzer et al.1999), fish (Feierabend and Zelazny 1987), amphibians, birds (Wharton et al. 1982, Gibbs 1993) and mammals (Gibbs 1993).

Unfortunately, values of healthy wetlands have not always been recognized. Obvious impacts to wetlands such as draining and filling, and more subtle degradations due to water level stabilization, sedimentation, eutrophication, and exotic species invasions have combined to dramatically reduce area and function of Great Lakes wetlands. The biological '*integrity'* of a wetland, i.e., its ability to support and maintain a balanced community comparable to that of undisturbed habitats (Karr and Dudley 1981 in U.S. EPA 2002a), can become impaired when such stressors surpass a wetland's threshold of natural self-sustainability. However, ecological functions of '*healthy'* wetlands are formed by healthy interactions among biotic communities and their geophysical (i.e., chemical, hydrological, geological, physiographical and climactic) environment, such that healthy wetlands remain resilient to sources of natural variation, and can recover from stresses with minimal outside care, despite deviating somewhat from natural integrity (Figure 1).

When anthropogenic perturbations that disrupt the physical, chemical and/or biological functions of wetlands become severe, loss of biological integrity can occur, and the biotic condition of a wetland can diverge beyond self-sustainable thresholds such that the wetland is not able to recover naturally. In such cases, outside remediation activities must be under taken to reduce the sources of ecological degradation.

Evaluating Coastal Wetland Health in the Great Lakes Basin

In some jurisdictions of the United States and Canada, environmental policy developers are attempting to improve how policy benefits environmental protection (e.g., measuring biological integrity; Karr 1996). Some policies are being based on the use of Indices of Biotic Integrity (IBIs) to evaluate biotic and functional condition of environments such as wetlands. To evaluate wetland biological integrity, five key suites of information about a wetland must be acquired: 1) present biological condition; 2) reference biological condition; 3) present geophysical condition; 4) reference geophysical condition; and 5) anthropogenic disturbance(s) that alter either or both biological and geophysical conditions (Karr and Chu 1999).

To monitor ecological health and integrity of Great Lakes coastal wetlands, Karr and Chu's (1999) model for detecting anthropogenic sources of stream fish population changes can be adapted (Figure 2). Researchers, managers and policymakers are currently seeking useful attributes of various biological assemblages to measure the ecological condition of wetlands in relation to surrounding human-related activities, and to determine if the biotic changes imposed by those activities are acceptable or not. This requires sampling the biological condition of communities that reliably indicate wetland conditions across a range of wetlands from highly disturbed to least disturbed (reference condition).

Marsh Bird and Amphibian Communities as Indicators of Wetland Condition

Due to anthropogenic land use alterations that have occurred over the last century (e.g., dredging, filling, damming, river straightening, hydrologic alteration, purposeful or accidental dumping of pollutants, agricultural runoff, deforestation, urbanization and industrialization), degradation of the water quality and aquatic vegetation communities within many coastal wetlands has occurred in the Great Lakes basin (Chow-Fraser 1999; Karr and Chu 1999, Mitsch and Gosselink 2000). Such land use alterations adjacent to coastal wetlands can affect the amount of water, sediment, pesticide, chloride and nutrient loading of wetlands, and thus directly affect the composition of a wetland's fish, plant, reptilian, amphibian and avian communities (Chow-Fraser 1999; U.S. EPA 2002b).

The use of marsh bird and amphibian communities to develop IBIs has received more attention in recent years, but they are still considerably less developed than are those for other wetland taxa, because few studies have successfully developed and validated IBIs using bird and/or amphibian biotic communities (e.g., Brazner, unpubl. data, *but see* DeLuca et al. 2004, Micacchion 2002). However, both marsh bird and amphibian communities have shown promise as indicators of wetland health. In a review by Adamus (2001), for example, the use of wetland bird species composition as an indicator of land cover alteration, habitat fragmentation, and anthropogenic influences at several spatial scales was supported by a number of studies.

Wetlands and surrounding habitats provide marsh birds with food resources and breeding sites, which generally help support the completion of species' annual life history requirements (Fairbairn and Dinsmore 2001). Land cover alteration can therefore impede (or sometimes improve) these functions and thereby affect wetland bird species composition (Triquet et al. 1990, Richter and Azous 2000). For example, wetland bird community integrity was compromised as a result of increasing urbanization within 1 kilometer of a wetland (DeLuca et al. 2004). Nest predation can increase in areas where dikes or trails are built on fill within a wetland, because they provide previously unavailable access routes for terrestrial predators (Peterson and Cooper 1991). In addition, human land development in the surrounding landscape generally results in a greater frequency of human disturbance to wetlands, and during breeding periods this can adversely affect some wetland bird species, especially when such disturbances occur in close proximity to colonial nesting marsh birds (Dahlgren and Korschgen 1992, Erwin et al. 1993, Klein 1993, Knight and Gutzwiller 1995, Klein et al. 1995, Rogers and Smith 1997). Such disruption can reduce foraging efficiency (Skagen et al. 1991) and courtship activity, which are vital to reproductive success (Gutzwiller et al. 1994). Ultimately, these disturbances can lead to temporary or permanent shifts in species richness and abundance (Riffell et al. 1996). Foraging efficiency can also be reduced by excessive nutrient and nitrate enrichment, which often accompanies land cover change (Perry and Deller 1996).

Amphibian assemblages have also been used to indicate ecological condition of wetlands (e.g., Richter and Azous 2000), and documented declines in several amphibian populations over the last decade (Phillips 1990, Wyman 1990, Wake 1991, Crump et al. 1992, Blaustein and Wake 1995, Timmermans and Craigie 2002) have been attributed to multiple factors, including disease, parasites (Carey and Cohen 1999), aquatic acidification, a variety of chemical contaminants (Beattie and Tyler-Jones 1992, Rowe et al. 1992, Rowe and Dunson 1992), and forest cover removal (Findlay and Houlahan 1997). Because amphibians require aquatic habitats, they are especially vulnerable to wetland alteration and contamination (Dodd and Cade 1998, Stebbins and Cohen 1995, Lannoo 1998, Pough et al. 1998, Richter and Azous 1995, 2000). In particular, amphibian richness has been positively correlated with proximity (Richter and Azous 2000) and connectivity to forested areas, because loss of upland forest connecting wetland habitats can cause population declines (Blaustein et al. 1994, Lehtinen et al. 1999) by suppressing population recovery from drought (Pound and Crump 1994), disease, low productivity (Sinsch 1992), and wetland alteration (Dodd and Cade 1998). Greater population stochasticity and local extinction (Skelly et al. 1999) among certain amphibian species can result from those declines. This effect is exaggerated in areas with high road density, which can lead to lower species richness (Lehtinen et al. 1999) through direct mortality (Fahrig et al. 1995, Gibbs 1998), increased exposure to predators (Ashley and Robinson 1996), or road-avoidance, which inhibits migration and inter-population gene flow (Reh 1989).

PROJECT OBJECTIVES

Tools developed for basin-wide monitoring must provide information about wetland functions in an efficient, comprehensible and geographically extensive manner. With IBI development, the relative functional condition of wetlands can be measured by monitoring biological components that are known to be responsive to, and signal changes in, physical, chemical, and/or biological attributes of wetlands and their surrounding landscapes. Essentially, IBIs can serve as tools for assessing health of Great Lakes coastal wetlands. Thus, IBIs can be used to monitor restoration progress and to identify gaps in restoration efforts.

The main purpose of this report was to document research activities that Bird Studies Canada conducted to utilize existing MMP and land cover data across Great Lakes coastal wetlands to develop marsh bird and amphibian IBIs for monitoring coastal wetland health and integrity. This research project was carried out as a follow-up to the GLCWC MMP-based pilot studies that were conducted throughout Great Lakes coastal wetlands during 2002, in an effort to advance coastal wetland indicator development for wetland bird and amphibian communities (Timmermans and Craigie 2002). To achieve this, 5 steps were completed:

1. Identification of various categories of land use with which to rank relative disturbance (condition) of Great Lakes coastal wetlands;
2. Utilization of existing marsh bird and amphibian MMP data from 1995-2003 to identify attributes of those communities that consistently and reliably indicated wetland condition;
3. Standardization of those attributes and corresponding development of marsh bird and amphibian IBIs for Great Lakes coastal wetlands;
4. Determination of the power to detect differences in marsh bird and amphibian IBIs, such that wetlands can be classified into relative condition categories;
5. Recommendations made regarding strategies that can help refine and improve the ability to build robust coastal wetland bird and amphibian IBIs.

The intention of this study, then, was to determine if viable IBIs can be developed using bird and/or amphibian community attribute data, and if so, to rank sites from least to most degraded based on the performance of those biotic communities. These research objectives were carried out separately for temporal periods of relatively higher and lower Great Lakes water levels, and for each of these periods, at several spatial scales. Thus, temporal, spatial and hydrological variation in marsh bird and amphibian IBIs were considered and examined.

Theoretically, the endpoint or attainment level of this process is achieved when/if the wetland disturbance gradient can be divided into multiple condition categories for one or both of the bird and amphibian biotic communities. Local citizen committees, and provincial, state and federal agencies can then use those rankings to evaluate efforts to restore damaged wetland habitats and to reduce impacts to those few high quality wetlands that still remain.

METHODS

BIOTIC DATA COLLECTION

Every year since 1995, MMP volunteer participants have gathered bird and amphibian population data at approximately 240 survey routes at inland and coastal wetlands throughout the Great Lakes basin. Most MMP routes were established by these volunteers, occurred in marshes at least 1-ha in size, and consisted of one to eight monitoring stations, the latter depending on factors such as available time and marsh habitat size. Each marsh bird survey station was separated by at least 250 m (275 yd) to minimize duplicate counts of individuals. For amphibians, this distance was extended to 500 m (550 yd) because observers recorded all anurans heard inside and beyond the 100 m station boundary (i.e., within average hearing distance).

An MMP station was defined as a 100 m (110 yd) radius semicircle with marsh habitat covering greater than 50% of the semicircular area. Marsh habitat is habitat regularly or periodically wet or flooded to a depth of up to two meters (six feet) where cattail, bulrush, burreed and other herbaceous non-woody marsh vegetation is predominant. Counts were conducted from a focal point at each station – the surveyor stood at the midpoint of the 200 m (220 yd) semi-circular base and faced the arc of the station perimeter. Each focal point was permanently marked with a stake and metal tag to facilitate relocation within and among years.

Bird Survey Protocol

Survey visits for birds were conducted twice each year between May 20 and July 5, with at least 10 days occurring between visits. Visits began after 18:00 h under appropriate survey conditions (i.e., warm, dry weather and little wind). A five-minute broadcast tape (or CD) was played at each station during the first half of each 10-minute survey visit. The broadcast tapes/CDs contained calls of normally visually secretive Virginia rail, sora, least bittern, common moorhen, American coot and pied-billed grebe, and were used to elicit call responses from those species. During the count period, observers recorded all birds heard and/or seen within the survey station area onto a field map and data form. Aerial foragers were also counted and were defined as those species foraging within the station area to a height of 100 m (110 yd). Bird species flying through or detected outside the station were tallied separately. Additional details on MMP marsh bird survey protocols can be found in Anonymous (2001).

Amphibian Survey Protocol

Amphibians surveyed by MMP volunteer participants were calling frogs and toads that typically depend in marsh habitats during spring and summer breeding periods. MMP routes were surveyed for calling amphibians on three nights each year, between the beginning of April and the end of July, with at least 15 days occurring between visits. Because peak amphibian calling periods are more strongly associated with temperature and precipitation than with date, visits were scheduled to occur on three separate evenings according to minimum night air temperatures of 5 °C (41 °F), 10 °C, (50 °F), and 17 °C (63 °F), respectively.

Amphibian surveys began one-half hour after sunset and ended before or at midnight. Visits were conducted during evenings with little wind, preferably in moist conditions with one of the above corresponding temperatures. During three-minute survey visits, observers assigned a Call Level Code to each species detected; for two of these levels, estimated numbers of individuals were also recorded. Call Level Code 1 was assigned if calls did not overlap and calling individuals could be discretely counted. Call Level Code 2 was assigned if calls of individuals sometimes overlapped, but numbers of individuals could still reasonably be estimated. Call Level Code 3 was assigned if so many individuals of a species were calling that overlap among calls seemed continuous; a count estimate is impossible for Call Level Code 3 and was not required by the protocol. Additional information on MMP amphibian survey protocols can be found in Anonymous (2001).

COASTAL WETLAND SELECTION

In addition to providing biotic data, MMP volunteers provided the location of each survey route, and often of individual survey stations, using standardized maps. From those maps, station and/or route coordinates were derived with the help of MMP staff. A Geographic Information System (GIS; ArcView 3.2 1999) was used to plot the location of all bird and amphibian routes that had, as a minimum, one amphibian or bird route surveyed for at least one year since 1995. Routes that were located within 150 m of coastal wetlands classified by the Great Lakes Coastal Wetlands Database (Environment Canada et al. 2004) were included in analyses. We allowed a 150 m buffer because the route coordinates are often calculated as the average of coordinates across stations, which can be misleading for non-linear placement of stations within routes.

To ensure data quality, all routes that were surveyed less than the required number of times per year (twice for marsh birds, 3 times for amphibians), or that were not surveyed during appropriate weather conditions or time of day and year were also excluded from analyses. Overall, 88 and 87 Great Lakes coastal wetlands surveyed for marsh birds and amphibians, respectively, met the combined data quality criteria (Figure 3 a,b). Of those wetlands, 11 (bird) and 8 (amphibian) wetlands were located within Canadian Shield eco-regions, and were not included in the present analyses because of the inherent geological and biological differences between shield and non-shield wetlands, and the lack of sample size to analyze shield wetlands separately.

STRESSOR QUANTIFICATION

Characterization of a wetland's adjacent land use is essential for the evaluation and interpretation of wetland health and integrity (Karr and Chu 1999). Land use in this study was determined by constructing 500 m, 1 km and 20 km spatial buffers around each coastal wetland shapefile (Environment Canada et al. 2004; for example, see Figure 4) using GIS (ArcView 3.2 1999), and measuring percent cover of woodland, marsh, urban development and agriculture within each buffer. Percent cover of habitat variables was measured using Ontario and U.S. land cover vector files (in Canada: Ontario Ministry of Natural Resources 1998; in U.S.: United States Geological Survey 1999), which were comparable in resolution and in categorical land cover delineations. Spatial land use data were used as a proxy for wetland condition because proportion of forested, agricultural and urban lands in a watershed determines its water and sediment qualities (Crosbie and Chow-Fraser 1999). These same disturbance variables were also measured within the watershed of each wetland surveyed using watershed boundary shapefiles (Great Lakes Information Network 2005).

Disturbance data were incorporated into bird and amphibian wetland disturbance gradients for each buffer size and watershed using rank sums (following Uzarski et al., in press). This was accomplished by ranking all bird or amphibian wetlands surveyed from 1995-2003 according to the amount of woodland, marsh, urban development and agriculture within each spatial buffer category and watershed separately. Woodland and marsh were ranked such that large values represented minimally disturbed sites, whereas urban development and crop were ranked directly, such that large values represented highly disturbed sites. For each wetland and scale of measurement, habitat ranks were summed across the four habitat types to develop a rank sum of disturbance by scale. The rank sums of the buffer and watershed scales were then combined into an overall rank-sum of disturbance for each wetland. Thus, five disturbance gradients (500 m, 1 km, 20 km, watershed and overall rank sum) were tested for their applicability to marsh bird and amphibian IBI development.

METRIC DEVELOPMENT

Marsh Birds

To develop marsh bird IBI's, potential population attributes to include in the index were first identified. The attributes identified were species richness and abundance of aerial foragers, non-aerial foragers, water foragers (excluding marsh nesters), general nesters, non-area sensitive marsh obligate nesters, area-sensitive marsh obligate nesters, and total species richness or abundance (Table 1). Abundance of Black Terns, Least Bitterns and Virginia Rails were also tested for their response to disturbance because these species have shown significant basin-wide population declines (Crewe et al. 2005). Area-sensitive obligate nesters were identified by Riffell et al. (2001: American Bittern, Virginia Rail, Sora, Swamp Sparrow) and Brown and Dinsmore (1986: Black Tern, Swamp Sparrow, Pied-Billed Grebe, American Bittern and Least Bittern). Species were classified into the remaining guilds using the Birds of North America (Poole and Gill 1992 – ongoing) and expert opinion as primary references (Table A1).

Species richness of each marsh bird guild at a wetland was calculated by first determining the overall richness at a station across visits each year. Because bird richness varies with latitude/longitude (i.e., spatially across the Great Lakes basin), a direct comparison of bird richness among the different regions of the Great Lakes basin was not possible. To account for those differences, degree blocks and digital species range maps (Ridgely et al. 2003; ArcView 3.2 1999) were used to assign a maximum potential richness value to each wetland. At each survey station, the ratio of observed richness to maximum potential richness for each guild was used as a standardized richness value. Values tested against disturbance were wetland means (i.e., sum of standardized richness values across stations divided by the number of stations).

To estimate the abundance of each marsh bird guild at a survey station by year, the maximum observed abundance at a station between the two site visits was used. As with guild richness estimates, values tested against disturbance were wetland means (i.e., sum of abundance across stations divided by the total number of stations).

Amphibians

Nine amphibian species guilds were identified, and species richness and maximum calling code of each guild were considered for inclusion in the amphibian IBI. The guilds identified were: species that commonly occur in species-poor habitats, species associated with woodland habitats, species with basin-wide distributions, disturbance tolerant species, disturbance intolerant species, rare species (see review by Shirose 2003), declining species (those species that showed significant negative declines in the analysis of MMP data; Crewe et al. 2005), and MMP marsh indicator species (Table 2; Table A2). Maximum calling codes of American Toads, Northern Leopard Frogs and Wood Frogs were also tested because of their tolerance (American Toads) and intolerance (Leopard Frogs, Wood Frogs) to one or more forms of disturbance.

Richness of amphibian guilds was developed with the same method as described above for marsh bird richness. However, instead of digital range maps, Harding (1997) was used as a reference for the range of species that were not basin-wide in distribution. For those species, GIS was used to determine which routes were encompassed by each species' range map. A value for 'potential' species richness at a site was thereby generated and used to standardize observed richness at a station. Wetland means were tested for their response to each disturbance gradient (sum of standardized richness across stations, divided by total number of stations).

A station-level maximum calling code estimate for amphibian guilds was obtained by first determining the observed maximum calling code of each species across site visits, and then summing those values for all species in a guild. However, the 'potential' maximum calling code at a station will vary with amphibian richness as a consequence of latitudinal/longitudinal differences in species ranges. Maximum calling code estimates were therefore standardized by dividing the observed maximum calling code for a guild by the 'potential' maximum calling code, which was calculated by multiplying the 'potential' species richness at a site (obtained using Harding (1997) as described above) by three (i.e., the highest call code possible for each species). Wetland means were tested for their response to disturbance.

STATISTICAL ANALYSIS

Wilcox et al. (2002) suggested that water levels can have large impacts on faunal population estimates, and therefore on wetland IBIs, because of the association between water levels and faunal habitat quality and quantity. Data were therefore categorized by water level according to the delineation of Timmermans et al. (unpubl. data), which classifies 1995-1998 as years of high average Great Lakes water levels, and 1999-2003 as years of low average Great Lakes water levels.

Metric Suitability

Because Timmermans and Craigie (2002) found effects of wetland size and sampling effort on overall bird species richness and abundance in Great Lakes coastal wetlands, the correlation (Proc Corr; SAS 8e 2001) between bird or amphibian metrics and both wetland size and effort were tested before determining metric suitability.

Following this, marsh bird and amphibian metric suitability was analyzed, by year and disturbance gradient, using Spearman Rank Correlation (SAS 8e 2001). Metrics that were correlated with the disturbance gradient at $p \leq 0.20$ during at least three of the four high-water level years or four of the five low-water level years, and that showed a consistent positive or negative response to disturbance over all high or low water level years, were considered suitable for inclusion in marsh bird or amphibian IBI development. This conservative method avoided inclusion of metrics with strong but mixed signals, and thus included only those metrics that reliably and consistently responded to disturbance across years.

IBI development

Although the probability value used to select metrics required only 80% certainty ($p = 0.20$) of detecting a trend, incorporation of multiple metrics into an IBI increases the accuracy with which the data can describe the biological condition of a site. For this report, IBIs were developed for each wetland and disturbance scale when three or more metrics responded consistently to disturbance across the high or low Great Lakes water level year group.

Metrics that were found to be suitable for marsh bird or amphibian IBI development were summarized by calculating the mean metric value for each wetland across years for a water level period. Metrics were then transformed into a measure of biological integrity according to the method of Minns et al. (1994) and Hughes et al. (1998), which standardizes metrics from 0 to 10 using the equation:

$$M_S = A + BM_R$$

where $M_S = M_{min}$ if $M_S < M_{min}$, $M_S = M_{max}$ if $M_S > M_{max}$, B = slope between standardized metric (M_S) and the raw metric (M_R), and A = intercept. For metrics that decrease with increasing disturbance, a lower limit (M_{min}) of zero was used, and the upper limit (M_{max}) was based on the 97.5 percentile of raw metric values. Thus, $M_S = 10$ was assigned to wetlands with $M_R \geq 97.5$ percentile. For metrics that increased with increasing disturbance, the slope of this relationship was negative, and a value of $M_S = 0$ was assigned to those wetlands with $M_R \geq 97.5$ percentile, while a value of $M_S = 10$ was assigned when $M_R = 0$.

After metrics were standardized, an IBI score of 0-100 was calculated for each wetland and disturbance scale by adding the standardized values of each metric, multiplying those values by 10, and dividing by the total number of metrics. Thus, wetlands with a high bird or amphibian IBI were in better biological condition than wetlands with a low IBI score. The correlation (Proc Corr (Spearman); SAS 8e 2001) between marsh bird and amphibian IBIs and their respective disturbance gradients was then tested to confirm that the IBIs developed were a good measure of wetland disturbance.

The standard deviation of each wetland's marsh bird or amphibian IBI was calculated by bootstrapping raw metric values according to the methods of Environment Canada (2004; SAS 8e 2001). The applied method randomly chose three stations from wetlands with at least 5 survey stations, and recalculated the mean and standard deviation of each IBI through 1000 iterations. IBI classes were then established by determining the power of all pairwise comparisons at $\alpha = 0.05$ using the mean and standard deviation (SAS 8e 2001), and plotting the power of each pairwise comparison against the difference in IBI means.

RESULTS

The non-shield wetlands included in analysis varied in their distribution among lake basins and hydro-geomorphic classifications (Tables B1, B2), although the majority of routes fell within the

Lake Erie and Ontario basins. Among years, the number of wetlands included in analysis varied from 27-46 wetlands for marsh birds, and 24-45 wetlands for amphibians. Wetlands sampled for marsh birds ranged from 8.83 ha – 1807.34 ha in size (Table B1), with a mean of 401.54 ha. Wetlands sampled for amphibians ranged from 4.79 ha – 5528.80 ha in size (Table B2), with a mean of 431.10 ha. Despite the observed range in marsh size, an effect of marsh size or sampling effort (# stations/marsh) on mean abundance and richness attributes was not supported ($p > 0.05$), and correction of these effects in further analyses was therefore not required.

MARSH BIRDS

Disturbance Gradient

Percent cover of marsh, woodland, urban development and agriculture surrounding wetlands at five scales (500 m, 1 km, 20 km, watershed, overall) were incorporated into disturbance gradients (Tables C1.a-e). Wetlands with a high amount of disturbance within 500 m and within 1 km tended to be ranked as highly disturbed at all spatial scales. However, some wetlands, such as Long Point 4 and Rondeau Provincial Park 1, which were ranked as least disturbed at the smaller 500 m and 1 km scales, were mid-ranked between disturbed and undisturbed at the larger watershed and 20 km scales, respectively. Thus, the disturbance gradients tested were reflecting differences in local versus larger scale landscape disturbances.

Metric suitability

High Great Lakes Water Levels

Over the high water level year group, a greater number of marsh bird richness and abundance metrics responded to small-scale disturbance gradients (500 m, 1 km) than to large scales of measurement (20 km, watershed, overall rank sum; Table 3). At the 500 m and 1 km scales, eight metrics were considered suitable for IBI development: richness and abundance of water foragers, obligate area-sensitive species and indicator species, and abundance of Least Bitterns and Black Terns (Table 3). Water forager metrics consistently increased with disturbance, while the others consistently declined with an increase in disturbance across all high-water years (Tables D1.a-e, D2.a-e).

For the 20 km and watershed disturbance scales, four metrics were found to be suitable for IBI development: richness and abundance of water foragers, and abundance of obligate area-sensitive and indicator species (Table 3). Water forager richness and abundance tended to increase with disturbance, while abundance of obligate area-sensitive and indicator species declined as surrounding landscape disturbance increased (Tables D1.a-e, D2.a-e).

Finally, five metrics were suitable for IBI development at the overall disturbance scale: richness and abundance of both water foragers and obligate area-sensitive species, and abundance of indicator species (Table 3). As with the other scales of measurement, water forager metrics were positively correlated with disturbance, and obligate area-sensitive and indicator species metrics were negatively correlated with disturbance (Tables D1.a-e, D2.a-e).

Low Great Lakes Water Levels

Few marsh bird metrics responded to the measured disturbance gradients during low-water level years. In fact, of the five disturbance scales measured, four scales (500 m, 1 km, watershed, overall) resulted in only one metric that consistently and significantly ($p < 0.02$ in at least 4 of 5 years) responded to disturbance across all low-water years (Table 3; Tables D1.a-e, D2.a-e). However, at the 20 km disturbance scale, five metrics were suitable for IBI development. These were richness of water foragers, and abundance of aerial foragers, obligate area-sensitive species, indicator species and Black Terns (Table 3). Each showed the expected response across all low-water years (Tables D1.a-e, D2.a-e).

IBI Development and Response to Disturbance

Although both obligate area-sensitive and indicator species metrics were individually tested for their response to the five measured disturbance gradients, both marsh bird guilds consisted of similar species assemblages. Thus, although indicator species richness and abundance metrics significantly responded to disturbance at several scales during high and low Great Lakes water levels, this guild was excluded from the calculation of marsh bird IBIs to avoid redundancy between the two metrics.

High Great Lakes Water Levels

During high Great Lakes water levels, the number of suitable metrics for IBI development differed with scale. Because similar metrics were considered suitable for IBI development at the 500 m and 1 km scales, and at the 20 km and watershed scales, three marsh bird IBIs were developed: a 500 m/1 km IBI, 20 km/watershed IBI and overall IBI (Tables D3.a-c). All three IBIs were significantly correlated ($p \leq 0.0002$) with their respective disturbance gradient(s) (Table 4; Figure 5.a-b). Figures are presented for the 500 m/1 km IBI only because a greater number of metrics responded to disturbance at those scales than at all other scales.

Low Great Lakes Water Levels

For low Great Lakes water levels, only the 20 km disturbance gradient resulted in the suitability of a sufficient number of metrics to warrant calculating an IBI (Table 3). Thus, one marsh bird IBI was developed for this year group (Table D3.d), and it did not show a significant response to the 20 km disturbance gradient ($p = 0.1958$; Table 4). Further development of this marsh bird IBI through re-sampling and power analysis (see below) was therefore not performed.

IBI Resampling and Power Analysis

High Great Lakes Water Levels

The minimum detectible difference in the 500 m/1 km IBI means at the statistical standard of 80% power was approximately 18 units (Figure 6). Thus, the number of classes into which the range in IBIs could be divided was three (Good, Fair, Poor; range in observed IBI = 61-11, divided by 18 units = 2.8). With this classification, no Great Lakes coastal wetlands were classified as good condition; the majority were fair condition, and a few were poor condition (Figure 7).

AMPHIBIANS

Disturbance Gradient

As with marsh bird wetlands, percent cover of marsh, woodland, urban development and agriculture surrounding wetlands sampled for amphibians were measured at 5 scales (500 m, 1 km, 20 km, watershed, overall) and incorporated into disturbance gradients using rank sums (Tables C2.a-e). Wetland ranks for amphibians differed somewhat from marsh bird wetland ranks because of differences in wetlands surveyed. However, the same trends were apparent: wetlands with a high amount of disturbance within 500 m-1 km tended to be ranked as highly disturbed at all scales, while wetlands such as Long Point 4 and Rondeau Provincial Park 2, which were ranked as least disturbed at the smaller 500 m and 1 km scales, tended to move toward a mid-rank between disturbed and undisturbed at the larger watershed and 20 km scales, respectively. Thus, disturbance gradients for amphibian wetlands reflected differences in local versus larger scale landscape disturbance.

Metric suitability

High Great Lakes Water Levels

Amphibian metrics were more responsive to disturbance at 500 m, 1 km, and 20 km spatial scales than at the watershed or overall scales during high Great Lakes water levels (Table 5). At the 500 m, 1 km and 20 km scales, nine metrics were considered suitable for IBI development according to the methods described above. The nine metrics were richness and maximum calling code of woodland species, disturbance tolerant species, indicator species; total species richness and abundance; and abundance of species with basin-wide distributions (Table 5). All metrics consistently declined with an increase in disturbance, which was the expected response for all metrics except disturbance tolerant species (Tables E1.a-e, E2.a-e; Table 2).

Four metrics, including richness of woodland and disturbance tolerant species, and maximum calling code of woodland and basin-wide species, were deemed suitable for development of a watershed-scale amphibian IBI (Table 5). Again, all metrics declined with an increase in surrounding landscape disturbance, including disturbance tolerant species (Tables E1.a-e, E2.a-e).

For the overall amphibian IBI, seven metrics were suitable: richness and maximum calling code of woodland and disturbance tolerant species; total species richness and maximum calling code; and maximum calling code of species with basin-wide distributions (Table 5). All metrics were negatively correlated with disturbance, as expected, except for disturbance tolerant species (Tables E1.a-e, E2.a-e).

Low Great Lakes Water Levels

During low average Great Lakes water levels, four metrics were considered suitable for IBI development at the 500 m scale (Table 5). The metrics were richness and maximum calling code of woodland and disturbance tolerant species. The same metrics, as well as basin-wide and total species maximum calling code, were regarded as suitable for amphibian IBI development at the 1 km scale. Five of those metrics were also deemed suitable at the overall scale: richness and maximum calling code of woodland and disturbance tolerant species, and total maximum calling code. Only two metrics, richness and maximum calling code of woodland species, were suitable for IBI development at the 20 km and watershed scales. At all scales, all metrics tended to decline with an increase in surrounding landscape disturbance (Tables E1.a-e, E2.a-e). This was the expected response for all metrics except disturbance tolerant species (Table 2).

IBI Development and Response to Disturbance

Although disturbance tolerant species metrics did respond consistently to disturbance at several scales for both high- and low-water level year groups, the response was not consistent with the expected metric response. Disturbance tolerant species metrics were therefore excluded from IBI development in all cases, but possible explanations for this discrepancy are discussed below (see Discussion).

High Great Lakes Water Levels

During high-water years, the 500 m, 1 km and 20 km scales all resulted in the same suite of suitable metrics, while the watershed and overall scales differed from each other and from the smaller spatial scales (Table 5). Three amphibian IBIs were therefore developed for the high water level year group (500 m/1 km/20 km IBI, watershed IBI, overall IBI; Tables E3.a-c), and all three IBIs declined significantly ($p \leq 0.0024$) with an increase in their respective disturbance gradient(s) (Table 6; Figure 8.a-c). Figures 8.a-c and results of bootstrapping and power analyses (below) are presented for the 500 m/1 km/ 20 km IBI only, because a greater number of metrics responded to disturbance and were used in IBI development at those scales than at the other scales of measurement.

Low Great Lakes Water Levels

With the exclusion of disturbance tolerant species metrics, only the 1 km and overall disturbance gradients resulted in the consistent response of greater than three amphibian metrics (Table 5). Thus, two amphibian IBIs (1 km IBI, overall IBI) were developed for the low water level year group (Tables E3.d-e), and both were significantly correlated with their respective disturbance gradient ($p \leq 0.01$), with lower IBI scores in wetlands with a higher amount of surrounding landscape disturbance (Table 6; Figure 9). Figure 9 and results of bootstrapping and power analyses (below) are presented for the 1 km IBI only because a greater number of metrics were compiled into the IBI at that scale.

IBI Resampling and Power Analysis

High Great Lakes Water Levels

For high Great Lakes water levels, the minimum detectible difference in IBI means at the statistical standard of 80% power was 22 (Figure 10). The range in IBI means was 94 units (95-1), which suggests that with the current data, four classes of wetland condition could be identified (Very Good, Good, Fair, Poor). With this classification, only Rattray Marsh was in very good condition, and the remaining marshes were divided almost equally between good, fair and poor classifications (Figure 11).

Low Great Lakes Water Levels

At the statistical standard of 80% power, the minimum detectable difference in low-water amphibian IBI means was 23 (Figure 12). Thus, with an IBI range of 94 (95-1), the wetlands analyzed were divided into four classes (Very Good, Good, Fair, Poor). This classification scheme resulted in wetlands occupying the full range of amphibian community condition classes, although a greater number of wetlands were classified in the Fair and Poor categories than in the Good and Very Good categories (Figure 13).

DISCUSSION

Overall, marsh bird and amphibian IBIs were strongly correlated with surrounding landscape disturbance at all scales during high water levels, which suggests that under those conditions, marsh bird and amphibian populations, as estimated by MMP protocols, are good indicators of the amount of marsh, woodland, urban development and agriculture in the landscape surrounding wetlands in eastern temperate (non-shield) Great Lakes wetlands.

Unlike results for high Great Lakes water levels, development of marsh bird and amphibian IBIs was less successful during low water levels. Although amphibian IBIs were strongly correlated with disturbance at the 1 km and overall disturbance scales, amphibian IBIs could not be developed at the other scales due to a lack of metric response. Those amphibian IBIs that were developed also tended to have a greater number of outliers when plotted against disturbance than did IBIs developed for high water levels (Figures 8.b,9). Similarly, marsh bird metric response to disturbance was also weak or lacking at all scales except the 20 km scale during low water levels, resulting in the development of only one marsh bird IBI, which in turn was not significantly correlated with disturbance. Thus, in general, both marsh bird and amphibian metrics were less responsive to the measured disturbance gradient during low average Great Lakes water levels.

WATER LEVELS

The difference in the strength and suite of metric responses to disturbance between high and low Great Lakes water levels exemplifies the importance of either statistically controlling for water levels in IBI development, or developing separate IBIs for discrete water level ranges. Several factors could contribute to observed differences in metric response to disturbance, and consequently in IBI development, between high and low Great Lakes water levels. Wilcox et al. (2002), for example, suggested that scoring ranges for wetland IBIs would not be valid across water level regimes because hydrologic variation can affect a wetland’s vegetative community and thereby its ability to support biotic populations. Delphey and Dinsmore (1993) also suggested that a lack of well-developed vegetation zones typical in natural wetlands likely leads to the lower occurrence of several marsh obligate bird species. The weaker response of marsh bird and amphibian metrics during low water levels observed here could therefore be a direct consequence of a reduced wetland carrying capacity for biotic communities, such that differences between wetlands were not as readily detected by MMP protocol.

In addition, Gibbs and Melvin (1993) suggest three marsh bird visits are necessary during the breeding season to achieve a detection rate of 90% certainty for pied billed grebe, American bittern, least bittern, Virginia rail and sora. Tozer (2002), Conway and Timmermans (2004) and Conway (2004) also recommend at least three survey visits are necessary to capture all secretive marsh bird species with reasonable accuracy. Current MMP protocol requires that stations are surveyed only twice for marsh birds during the breeding season. The probability therefore exists that MMP surveyors did not detect a secretive marsh bird species that was actually present. Adapting the MMP marsh bird monitoring protocol to include three survey visits within the breeding season would likely reduce some of the variation in the detection probabilities of marsh birds, especially during low water levels.

Variation in marsh bird and amphibian IBIs with Great Lakes hydrology might also result from the different assemblage of wetlands analyzed during the two periods. Of 52 and 61 wetlands surveyed for marsh birds during high and low water levels, respectively, and 57 and 61 wetlands surveyed for amphibians during high and low water levels, respectively, 41 wetlands were surveyed for marsh birds and 39 for amphibians throughout both hydrologic regimes. Despite differences in wetland assemblage between water levels, the disturbance rank sums were developed only once, using all wetlands sampled between 1995-2003. The relative difference in disturbance between wetlands with changing hydrology and changing land use was therefore not examined, even though differences may actually have occurred. Rather, only the strength of metric response to disturbance differed with hydrology in this study, because there was greater variation in both the response of marsh bird and amphibian metrics and, consequently, the response of amphibian IBIs to the disturbance gradient during low water levels. In fact, the majority of outliers in Figure 9 (ex. Wilm, SB1, Hay7, WSB1, EaL6, Hill, Butt2, PBrit, LP4, Saw7) were wetlands sampled only during low water levels. Analyzing the same wetlands across years and water levels would eliminate wetland assemblage as a source of variation in metric response. Ideally, a good IBI should be applicable across all wetlands at the scale measured – in this case the IBIs developed are considered applicable to the Lake Erie and Ontario basins, because the majority of wetlands included in analysis are situated in those basins.

Wetland classification into condition categories using amphibian IBIs also differed with Great Lakes hydrology. Of the 39 wetlands sampled during both high and low water levels, 19 were re-classified in the same category, 10 were classified in a better condition category, and 10 were classified in a poorer condition category during low water years as compared to high water years. These differences may reflect real changes in the biotic integrity of those wetlands over time. Alternatively, lower detection probabilities during low water levels combined with sampling bias (e.g. 2 visits as opposed to 3 visits for birds) probably contributed to differences in IBIs between water levels and years. Again, sampling protocols for marsh birds should be modified to include 3 survey visits.

DISTURBANCE GRADIENT

In this study, the disturbance gradient at each of the five scales was developed using landcover data developed from Landsat imagery from the early 1990's. Consequently, the full suite of wetlands surveyed between 1995-2003 was used to develop the disturbance rank sums because a measure of landcover change around each wetland across years was not available. The disturbance gradient at each scale was therefore static and similar for both high and low Great Lakes water levels.

Although the disturbance gradients did not reflect changes in landcover over time, they nevertheless resulted in the consistent response of several marsh bird and amphibian metrics, suggesting that spatial landcover data can be used to develop functional marsh bird and amphibian IBIs. However, in using a static measurement of disturbance such as that used here, there is a loss of information that may or may not be integral to successful IBI development. For example, because the Landsat imagery used to develop the landcover layers were from the early 1990s, the disturbance gradients developed were likely more appropriate for the 1995-1998 high Great Lakes water level period than the 1999-2003 low Great Lakes water level period. This may be another source of reduced number and strength of marsh bird and amphibian metric responses to disturbance during low water levels as compared to high water levels, as described above.

Ideally, habitat disturbance variables should be measured annually in conjunction with marsh bird and amphibian data. For large databases such as the Ontario and U.S. landcover datasets, this is not realistic. On the other hand, Karr and Chu (1999) suggest incorporating variables such as water quality (e.g., amount/type of effluent), wetland habitat composition (e.g., cover of emergents, wet meadow) and local disturbances (e.g., dams, levees) into disturbance gradients. These variables are more easily measured on a yearly basis, and are often strongly associated with marsh bird and/or amphibian communities. Habitat use by breeding Virginia Rails, Soras and Redheads, for example, was highly correlated with the availability of emergent cover (Johnson and Dinsmore 1986, Yerkes 2000).

In addition, when the correlations between the 500 m/1 km/ 20 km amphibian IBI and the 500 m, 1 km, and 20 km disturbance gradients were analyzed for high water levels, Rattray Marsh was an outlier in all three cases (Figure 8), because it had the highest observed amphibian IBI, despite a high proportion of urban development surrounding that marsh. Rattray Marsh was designated a Conservation Area in 1975, and it's wet meadow dominated wetland is surrounded by a relatively large buffer of forested land, resulting in ideal amphibian habitat. Rattray marsh also has boardwalks to prohibit visitors from disturbing local flora and fauna. Little Cataraqui Creek, another Conservation Area, also had a relatively high marsh bird IBI, despite a moderately high amount of surrounding landscape disturbance. Incorporating habitat composition variables and intensity of local disturbances (e.g., tourist/visitor density, water control structures) into disturbance gradients might therefore strengthen the relationship between population metrics and disturbance, and thereby provide greater confidence in developing marsh bird and amphibian IBIs.

Wetland hydrogeomorphic classification might also affect the relationship between marsh bird and amphibian metrics and, thus, marsh bird and amphibian IBIs and the measured disturbance gradients. In this study, disturbance gradients were not developed by hydrogeomorphic classification (i.e., lacustrine, riverine, barrier-protected), nor were the effects of hydrogeomorphic classification on metric response to disturbance examined. Although there are inherent biological differences between wetlands of different hydrogeomorphic classes, it was not taken into account because sample sizes were not large enough on a yearly basis.

MMP data were used post-hoc for this study: wetland selection by MMP volunteers was non-random and non-stratified, which resulted in an uneven distribution of surveyed wetlands across wetland types and locations in the Great Lakes basin. Regardless, the distribution of wetlands among lacustrine, riverine and barrier-protected wetland classifications was comparable during high and low water years for both marsh birds and amphibians. Consequently, hydrogeomorphology might explain some of the variation observed in the response of marsh bird and amphibian IBIs to disturbance, but was likely not a factor in the increased variance and poorer metric response during low water levels compared to high water levels. However, because IBIs were developed using wetlands that were distributed mostly throughout the Lake Erie and Ontario basins, the IBIs developed should not be applied at the individual Lake basin or Great Lake basin-wide scales until these are tested for adequacy at those scales (Keddy 2000).

Additionally, although the majority of marsh bird and amphibian metrics responded to the disturbance gradients in the expected directions, the responses of species richness and maximum calling code of disturbance tolerant amphibian species was opposite than expected. The species included in this guild were chosen based on their tolerance to one or more forms of disturbance (see review by Shirose 2003), and their populations were therefore expected to remain constant with an increase in disturbance, or increase as niches formerly occupied by disturbance intolerant species became available. However, the detection of tolerant species actually declined with an increase in disturbance, which suggests that either a threshold of disturbance was met, such that beyond that threshold, species were unable to maintain healthy, stable populations; or, these species may be misclassified and are actually sensitive to the type of disturbance measured in this study. Change point analysis (for example, see DeLuca et al. 2004) might be useful to determine if there was in fact a threshold disturbance beyond which tolerant species richness and maximum calling code declined.

DISTURBANCE SCALE

The high and low water marsh bird and amphibian IBIs developed tended to incorporate a greater number of population metrics at the smaller 500 m and 1 km scales than at the other scales of disturbance. This suggests that marsh bird and amphibian populations are affected to a greater degree by local as opposed to broader scale landscape disturbances. Findlay and Houlahan (1997), Findlay et al. (2001) and Vos and Stumpel (1995) also found that land-use within 1-2 km had the strongest relationship with species richness of wetland taxa.

While 1 km appears to be the most appropriate scale for amphibian IBI development, metric response during high water levels was similar for the 500 m, 1 km and 20 km scales, which suggests that broad landscape processes are also important to amphibian population integrity. Broader scale landscape disturbances might be important for amphibians because local populations can vary widely in abundance from year to year (Aubry 2000), and such stochasticity can lead to the local extinction of small populations (Skelly et al. 1999). Many local amphibian populations therefore depend on migration from neighboring wetlands and/or forested areas for recruitment and recolonization (Gill 1978). However, movement to and from these habitats depends on the distance between breeding wetlands and other supporting habitats, and also depends on the ability of individuals to move between these connecting habitats (Taylor et al. 1993). The degree of wetland connectivity, local habitat fragmentation, and the type of land use between wetlands might therefore be important variables to consider in determining a disturbance gradient for further amphibian IBI development. For example, high road density can result in a reduction in amphibian species richness (see review by Shirose 2003), thus density of roads between required habitats might be an important factor determining the biotic integrity of coastal wetlands.

In contrast, although the low water marsh bird IBI was not significantly correlated with disturbance, more marsh bird metrics responded to the larger 20 km scale of disturbance than to the other scales. This suggests that there may be a corresponding shift between hydrologic regimes and the scale at which marsh birds respond to disturbance, such that broad scale effects are more important during low water levels, and local disturbances are more important during high water levels. Further work is required to ascertain if this does occur, and if so to determine its cause.

MINIMUM DETECTABLE DIFFERENCE IN IBI MEANS

The resolution to detect differences in marsh bird IBI means (three classifications during high water levels) was relatively poor compared with amphibian IBIs, which were classified into four groups during both high and low water levels. Environment Canada and Central Lake Ontario Conservation Authority (2004), on the other hand, were able to resolve five classes for both marsh bird and amphibian IBIs for wetlands in the Durham region of Lake Ontario.

The poor resolution to classify marsh bird wetlands was in part the result of the small range (approximately 50 units; maximum IBI = 61.81) of IBIs observed at the 500m/1 km scale. Ideally, to calculate IBIs, a range of wetlands from unimpaired to very impaired should be chosen *a priori* to develop the gradient of disturbance. The wetland data used in this analysis, however, were not sampled for the purposes of IBI development. Consequently, the full range of wetland and surrounding site qualities may not have been sampled if, for example, volunteers avoided highly impaired wetlands because these lack the consistent calling of marsh birds and amphibians that occurs at more pristine wetlands. Despite this possibility, the range of wetlands included in the calculation of the marsh bird and amphibian IBIs did encompass both relatively undisturbed (Long Point) and highly disturbed localities (Detroit River/Lake St. Cair).

Including abundance of black terns and least bitterns in the IBI might also be a contributing factor to the low range in marsh bird IBI scores. The 97.5%ile of all stations surveyed was used to determine the upper limit for metric standardization. However, because black terns were absent from 63% of wetlands surveyed, and least bitterns were absent from 54% of wetlands surveyed, the 97.5%ile was probably too stringent a percentile for these metrics. By excluding black terns and least bitterns from the IBI, as was done for the overall high-water marsh bird IBI, the maximum observed IBI did increase from 61.81 (WhRi; Table D3.a) to 81.61 (Saw1; Table D3.c), which confirms that the inclusion of those two metrics was a factor in the low range in observed IBIs at the 500 m/1 km scale. This effect is likely compounded at that scale, as both species are also incorporated into the IBI through the obligate, area-sensitive marsh nester guild. A maximum IBI score of 100 is therefore misleading, as in this case, it is impossible for a wetland to receive such a high score. Rather, wetlands scoring in the high 50s and 60s likely have a relatively high biotic integrity. This effect might be avoided by using the 97.5%ile of wetland means, as this would reduce the effect of outliers, or by using a more liberal percentile (for example 75%ile) for those metrics that include many non-observations. Including a third survey visit for marsh birds in the MMP protocol, as described previously, could also reduce the number of non-observations.

The large deviation around the mean of several marsh bird and amphibian IBIs also contributed to the low resolution to detect differences between IBI scores. The standard deviation of a mean can be affected by the number of stations surveyed in a wetland within and across years. In theory, estimates of standard deviation based on several stations and years should provide a more accurate assessment of the actual variation in marsh bird and amphibian communities over time than should standard deviations that are based on few stations and few or one year. It might therefore be necessary to eliminate wetlands from analysis that do not have a minimum number of stations surveyed each year, and that are not surveyed over all years in a given hydrologic period. Alternatively, instead of excluding small wetlands from analysis by imposing a restriction on the minimum number of stations, sampling effort could be improved in small wetlands either by completing additional survey visits, or by using a separate protocol that is more appropriate for small wetlands.

The large deviation around the marsh bird and amphibian IBIs might also be a reflection of the degree of habitat heterogeneity within a wetland. In general, heterogeneous habitats should have a greater diversity of species among stations, as different species assemblages will occupy different habitat types. Homogeneous habitat, on the other hand, should be less diverse, and therefore have smaller among-station variation, than should heterogeneous habitat. The effect of wetland habitat composition and heterogeneity was not examined in this study, and stratification of IBIs according to habitat type will depend on specific management goals. If the goal is to compare all sites according to overall biodiversity, disregarding the lower natural diversity in some pristine wetland types as compared to others, then analysis should not be segregated by habitat type. Alternatively, if managers are interested in the biotic condition of wetlands of a certain composition, then wetland classification and/or local habitat composition should be incorporated into the development of IBIs. In either case, survey stations should be stratified such that habitat types are sampled proportional to the area that they cover within a wetland.

Variation in marsh bird and amphibian calling rates due to varying weather and natural temporal change are other factors that could affect the power to detect IBI differences by causing inflated estimates of standard deviation. Although MMP protocols suggest surveys be done only during appropriate weather and date ranges, *optimal* survey dates will vary annually with varying weather conditions; thus it is difficult to determine when optimal survey conditions will occur each year. This is especially true for explosive breeding amphibians, such as wood frogs, which breed for only a few days each year (Harding 1997). If surveyors miss that period of high intensity calling by chance, then the population index for such species used in analyses could be misleading.

It is also important to note that, based on the minimum detectible differences calculated for marsh bird and amphibian IBIs, some wetlands were classified differently with respect to marsh bird and amphibian community condition. For example, Rattray Marsh was classified as ‘Very Good’ condition using amphibian IBIs during both high and low water levels, but was classified as ‘Poor’ condition using marsh bird IBIs for high water levels. Because Rattray Marsh has an abundance of wet meadow and a large forested buffer, it is likely better habitat for amphibians than for marsh birds, many of which require an abundance of emergent wetland habitat (Johnson and Dinsmore 1986, Yerkes 2000). It might therefore be beneficial to develop an overall IBI (i.e., multi-taxon IBI) using marsh bird and amphibian community assemblages, as well as other appropriate wetland indicator species. Including more community assemblages will provide a better representation of the overall biotic condition at a wetland, and will provide sensitivity to a wider range of disturbance, thereby increasing confidence in management decisions based on IBIs (U.S. EPA 2002b).

RECOMMENDATIONS

Based on the results discussed above, several recommendations to improve MMP monitoring protocol and IBI development for marsh birds and amphibians in the Great Lakes basin are summarized below:

1. Hydrologically induced variability in marsh bird and amphibian community metrics is an important consideration, and methods to reduce or eliminate effects of water levels should be employed. This may involve developing IBIs specific to water level ranges that span the entire range of Great Lakes water levels. Alternatively, water level could be monitored within a wetland and among years, such that effects of water levels on the biotic community in question can be controlled for statistically.
2. The resolution to detect differences between mean wetland IBIs was lower for marsh birds than for amphibians.
    a. Resolution for both marsh birds and amphibians might be improved by pre-determining the disturbance gradient, and thus selecting sites spanning from reference to highly degraded conditions, *a priori* as opposed to *post hoc*, as done here.
    b. Variables included in the disturbance gradients should be as encompassing and representative as possible regarding factors deemed to affect marsh bird or amphibian biotic integrity. Such factors may be water quality, wetland habitat composition and habitat connectivity. Ideally, disturbance variables should be available on a yearly basis. It might be possible, for example, to interpret aerial photographs of a small number of sites on a yearly basis to obtain habitat cover data within and surrounding wetlands.
3. MMP marsh bird monitoring protocol should be amended to include three site visits per year to improve detection probability of secretive species. This might also improve the power to detect differences in mean IBIs.
4. Efforts should be made to improve the stratification of wetlands surveyed by MMP volunteers such that surveys are more equally distributed among the Great Lakes basins, hydrogeomophic wetland classifications, and among wetland habitat compositions (emergent/wet meadow). This will involve a greater degree of coordination among those individuals engaged in marsh bird and/or amphibian monitoring at Great Lake coastal wetlands.

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TABLES

Table 1. Description, code and expected response of marsh bird community metrics tested for response to surrounding landscape disturbances.

Metric	Metric Code	Expected Response
Bird Richness		
Aerial foragers	RAER	Decline
Non-aerial foragers	RNAER	Decline
Water foragers (marsh nesters excluded)	RWATER	Increase
General nesters	RGEN	Decline
Obligate nesters, non area-sensitive	RONS	Decline
Obligate nesters, area-sensitive	ROS	Decline
Indicator Species	RIND	Decline
Total species richness	RTOT	Decline
Bird Abundance		
Relative % aerial foragers	AAER	Decline
Relative % non-aerial foragers	ANAER	Decline
Relative % water foragers (marsh nesters excluded)	AWATER	Increase
Relative % general nesters	AGEN	Decline
Relative % obligate nesters, non area-sensitive	AONS	Decline
Relative % obligate nesters, area-sensitive	AOS	Decline
Relative % indicator species	AIND	Decline
Relative % Least Bittern	ABIT	Decline
Relative % Rails	ARAIL	Decline
Relative % Black Tern	ATERN	Decline
Total abundance	ATOT	Decline

Table 2. Description, code and expected response of amphibian community metrics tested for response to surrounding landscape disturbances.

Metric	Metric Code	Expected Response
Amphibian Richness		
Found in 'species-poor' sites	RPOOR	Decline
Woodland associated species	RWOOD	Decline
Disturbance tolerant species	RTOL	Increase
Disturbance intolerant species	RNTOL	Decline
Rare species	RRARE	Decline
Species showing a declining trend using MMP data	RDECLINE	Decline
MMP indicator species	RIND	Decline
Species with basin-wide distribution	RBASIN	Decline
Total species richness	RTOT	Decline
Amphibian Maximum Calling Code		
American Toad	MAMTO	Increase
Northern Leopard Frog	MNLFR	Decline
Wood Frog	MWOFR	Decline
Found in 'species-poor' sites	MPOOR	Decline
Woodland associated species	MWOOD	Decline
Disturbance tolerant species	MTOL	Increase
Disturbance intolerant species	MNTOL	Decline
Rare species	MRARE	Decline
Species showing a declining trend using MMP data	MDECLINE	Decline
MMP indicator species	MIND	Decline
Species with basin-wide distribution	MBASIN	Decline
Total species calling code	MTOT	Decline

Table 3. Summary of marsh bird metric responses to disturbance: metrics that were significantly correlated (p<0.20) with disturbance during at least three of four high water level years or four of five low water level years, and that showed a consistent reponse over all high or low water years, are depicted by + (positive response to disturbance) and - (negative response to disturbance).

		Richness Metrics								Relative % Abundance Metrics											
Water Level	Disturbance Scale	RAER	ANAER	RWATER	RGEN	RONS	ROS	RIND	RTOT	AAER	ANAER	AWATER	AGEN	AONS	AOS	AIND	ABIT	ARAIL	ATERN	ATOT	Total # Metrics
HIGH	500m			+			-	-				+			-	-	-		-		8
	1 km			+			-	-				+			-	-	-		-		8
	20 km			+								+			-	-					4
	Watershed			+								+			-	-					4
	Overall			+			-					+			-	-					5
LOW	500m																		-		1
	1 km																		-		1
	20 km			+						-					-	-			-		5
	Watershed																				0
	Overall														-						1

[1] See Table 1 for description of marsh bird metric codes.

Table 4. Spearman correlation coefficients and associated probability (*p*) values for the relationship between marsh bird IBIs and measured disturbance gradients.

Disturbance Scale	High Water			Low Water		
	# Metrics in IBI	*Corr*	*p*	# Metrics in IBI	*Corr*	*p*
500 m	6	-0.6582	**<0.0001**	-	-	-
1 km	6	-0.6170	**<0.0001**	-	-	-
20 km	3	-0.4767	**0.0002**	4	-0.1679	0.1958
Watershed	3	-0.4846	**0.0001**	-	-	-
Overall	4	-0.6588	**<0.0001**	-	-	-

Table 5. Summary of amphibian metric response to disturbance: metrics that were significantly correlated (p<0.20) with disturbance during at least three of four high water level years or four of five low water level years, and that showed a consistent reponse over all high or low water years, are depicted by + (positive response to disturbance) and - (negative response to disturbance).

		Richness Metrics									Maximum Calling Code Metrics												
Water Level	Disturbance Scale	RPOOR	RWOOD	RTOL	RNTOL	RRARE	RDECLINE	RIND	RBASIN	RTOT	MAMTO	MNLFR	MWOFR	MPOOR	MWOOD	MTOL	MNTOL	MRARE	MDECLINE	MIND	MBASIN	MTOT	Total # Metrics
	500m		-	-				-		-					-	-				-	-	-	9
	1 km		-	-				-		-					-	-				-	-	-	9
HIGH	20 km		-	-				-		-					-	-				-	-	-	9
	Watershed		-	-											-						-		4
	Overall		-	-						-					-	-					-	-	7
	500m		-	-											-	-							4
	1 km		-	-											-	-					-	-	6
LOW	20 km		-												-								2
	Watershed		-												-								2
	Overall		-	-											-	-						-	5

[1] See Table 2 for description of amphibian metric codes.

Table 6. Spearman correlation coefficients and associated probability (*p*) values for the relationship between amphibian IBIs and measured disturbance gradients.

Disturbance Scale	High Water			Low Water		
	# Metrics in IBI	*Corr*	*p*	# Metrics in IBI	*Corr*	*p*
500 m	7	-0.5171	**<0.0001**	-	-	**-**
1 km	7	-0.4677	**0.0004**	4	-0.327	**0.0101**
20 km	7	-0.4224	**0.0016**	-	-	**-**
Watershed	3	-0.4077	**0.0024**	-	-	**-**
Overall	5	-0.5789	**<0.0001**	3	-0.4241	**0.0007**

FIGURES

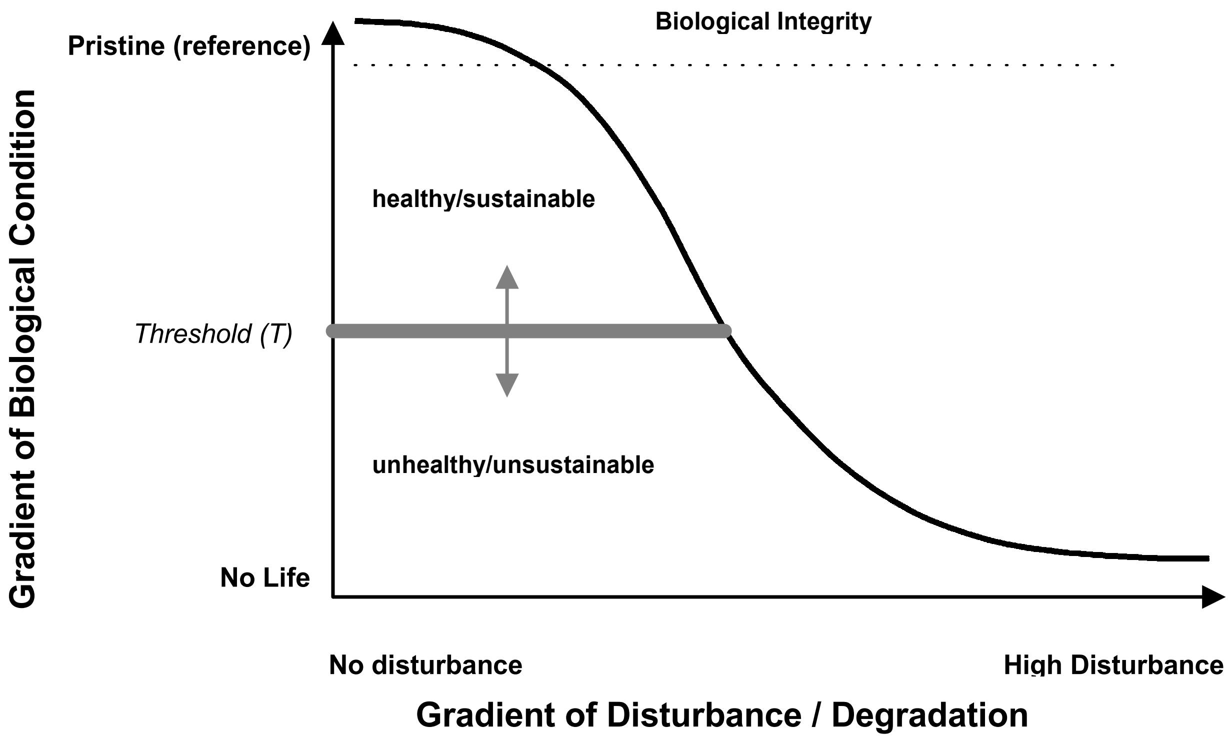


Figure 1. Hypothetical plot describing the relationship between gradients of biological condition and gradients of disturbances and degradation influencing ecosystems that support biotic communities (adapted from Karr and Chu 1999).

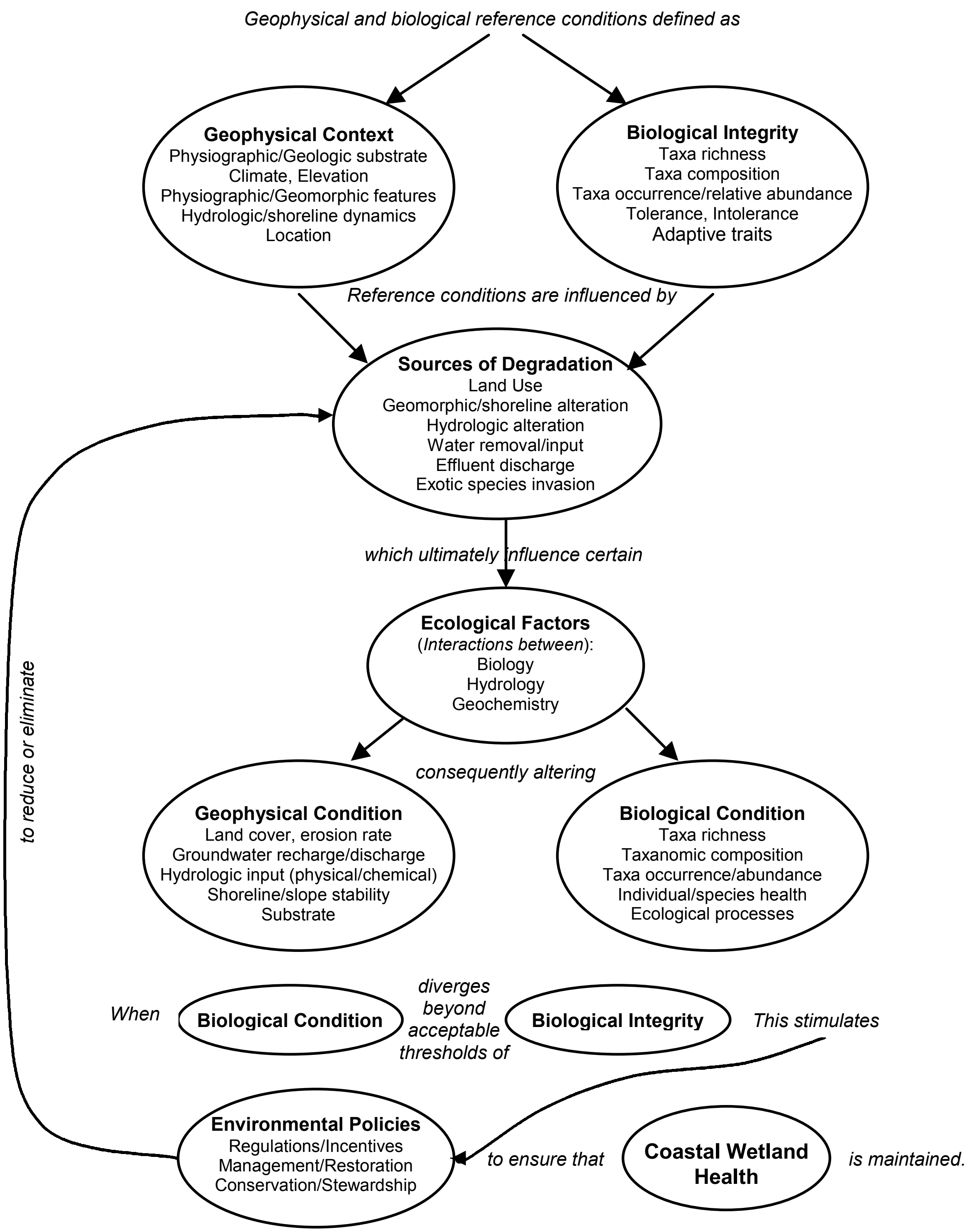
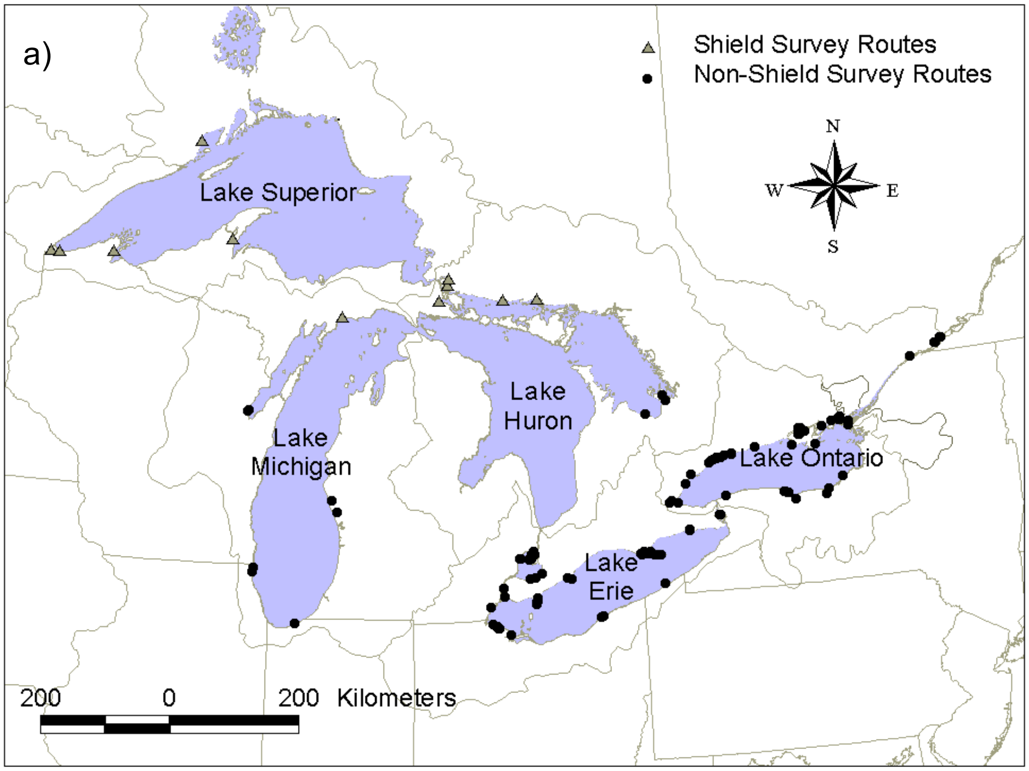


Figure 2. Relationship among potential biotic and stressor coastal wetland attributes to be measured and evaluated through biological monitoring. Biological condition is the endpoint of primary concern (Adapted from Karr and Chu 1999).



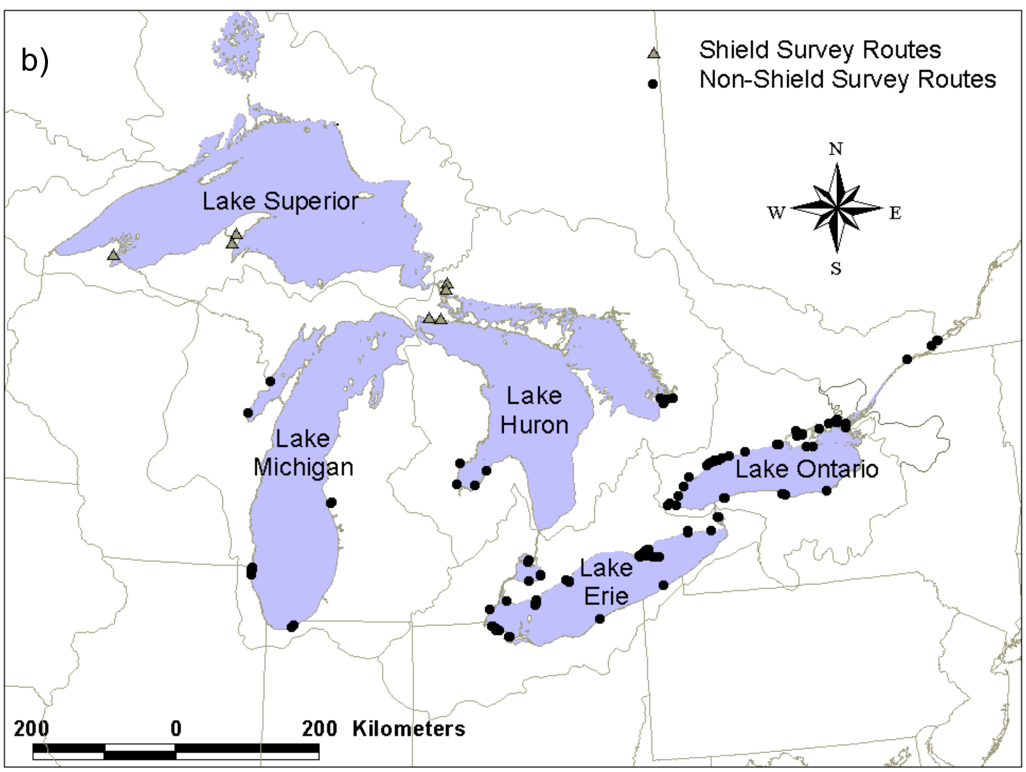


Figure 3. Distribution of MMP routes surveyed for a) marsh birds and b) amphibians throughout the Great Lakes Basin and St. Lawrence River from 1995-2003.

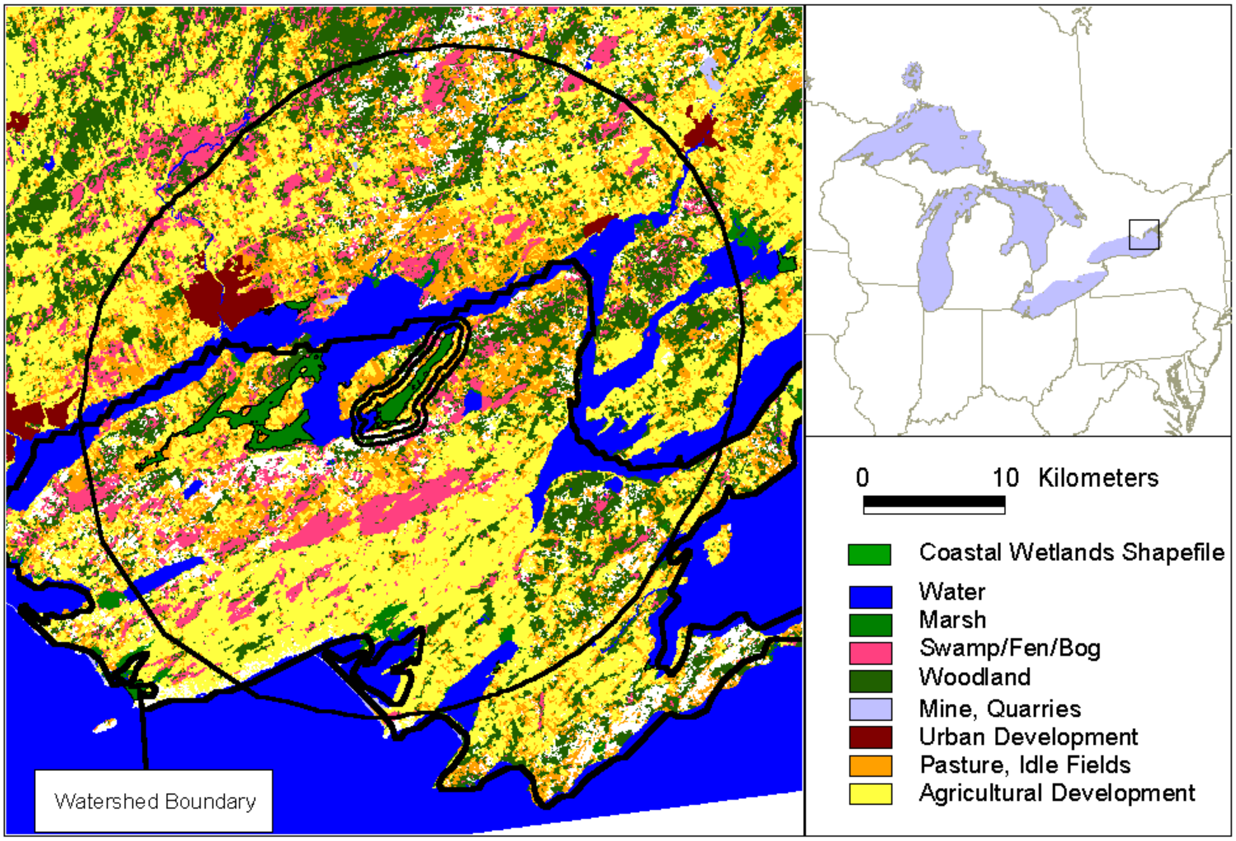
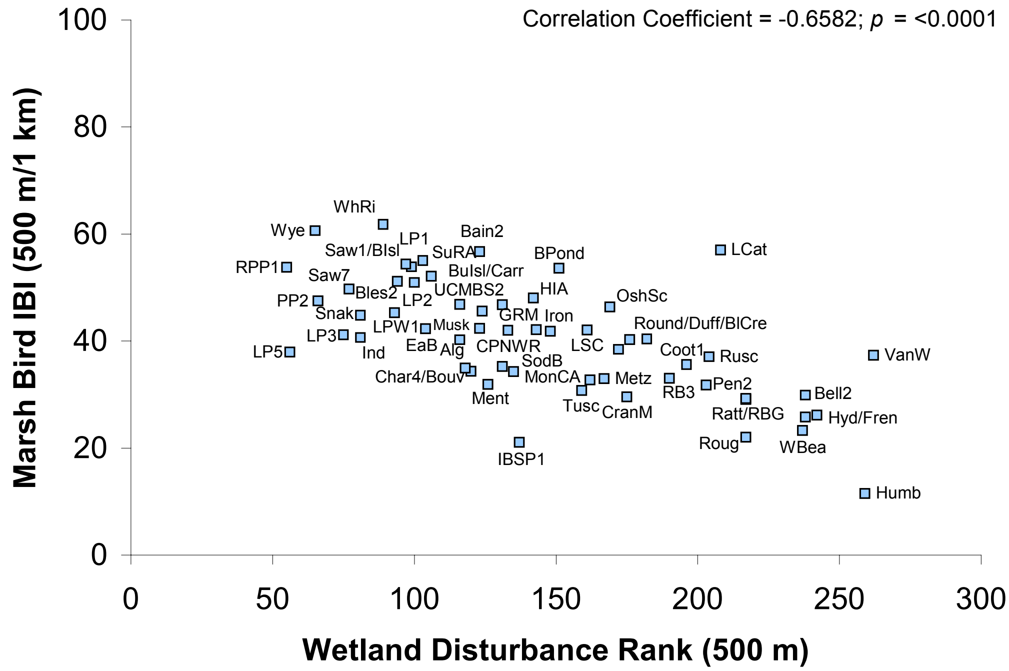


Figure 4. Example of a coastal wetland shapefile (Big Island Marsh) overlaid with Ontario landcover data. Outline of 500 m, 1 km and 20 km spatial buffers (black consecutive circles around wetland), and watershed boundary (irregular line) are shown.

a)



b)

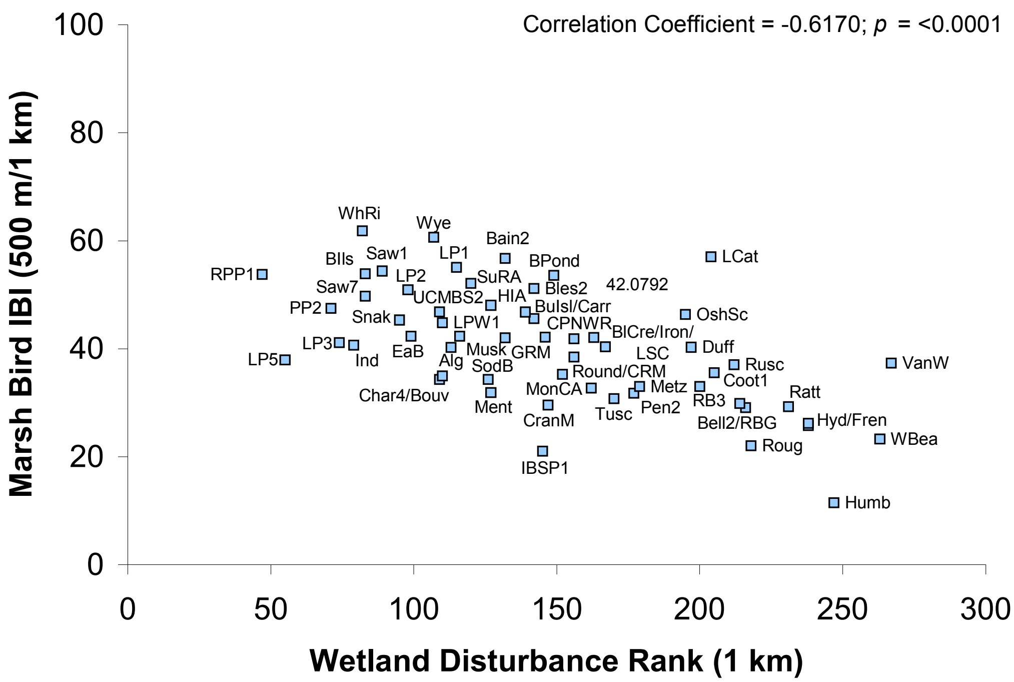


Figure 5. Correlation between the 500 m/1 km marsh bird IBIs and the a) 500m and b) 1 km disturbance gradients during high Great Lakes water levels.

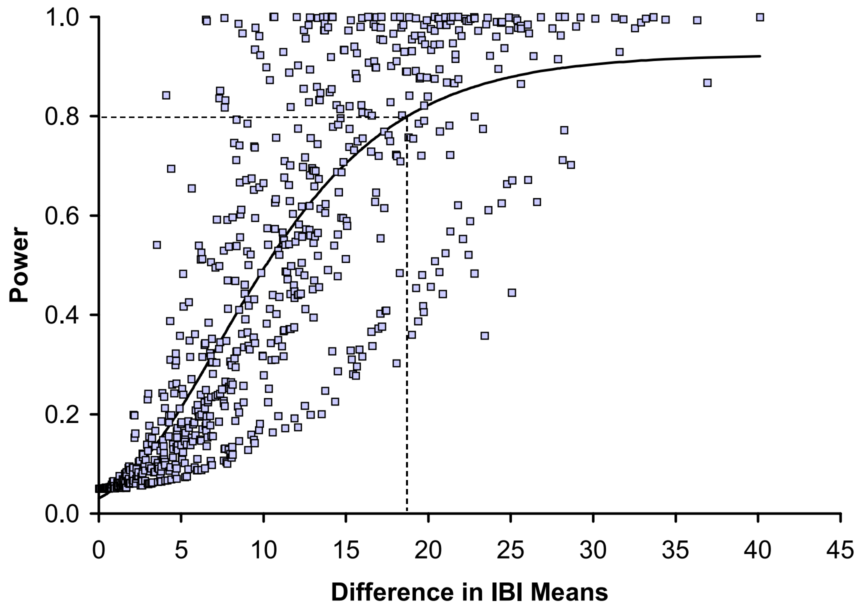


Figure 6. Power curve of 500 m/1 km-scale marsh bird IBIs, calculated for wetlands sampled during high Great Lakes water levels, and showing the minimum detectible difference between IBI means at 80% power. All points shown are for $\alpha = 0.05$.

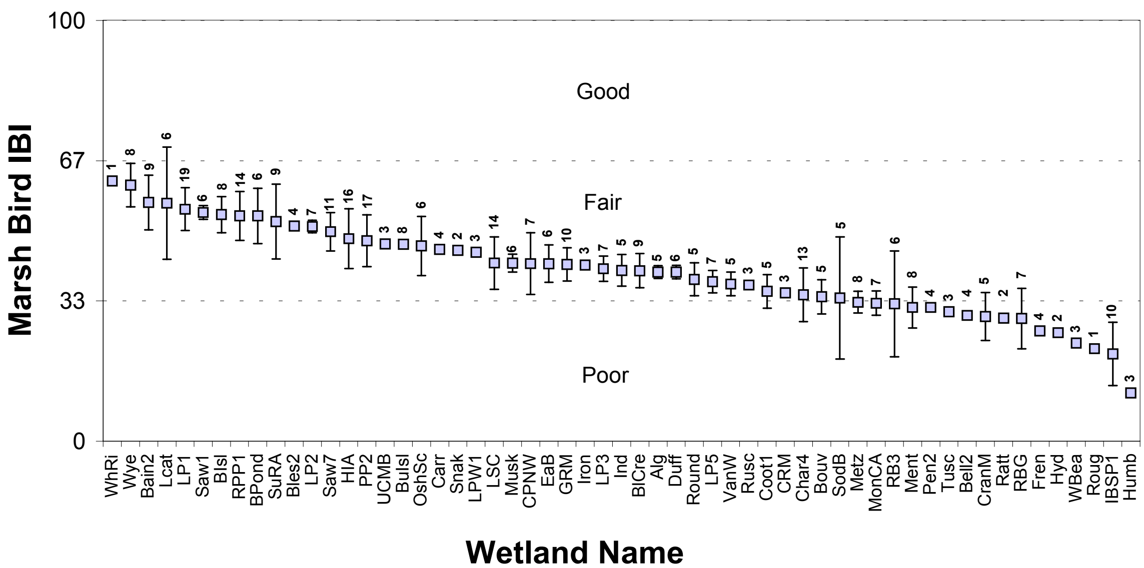


Figure 7. Mean marsh bird IBI (500 m/1 km-scale; ± standard deviation of resampled wetlands) of wetlands surveyed during high Great Lakes water levels. Three wetland category rankings, determined through power analysis, are shown. Number of stations surveyed per site is located above wetland markers.

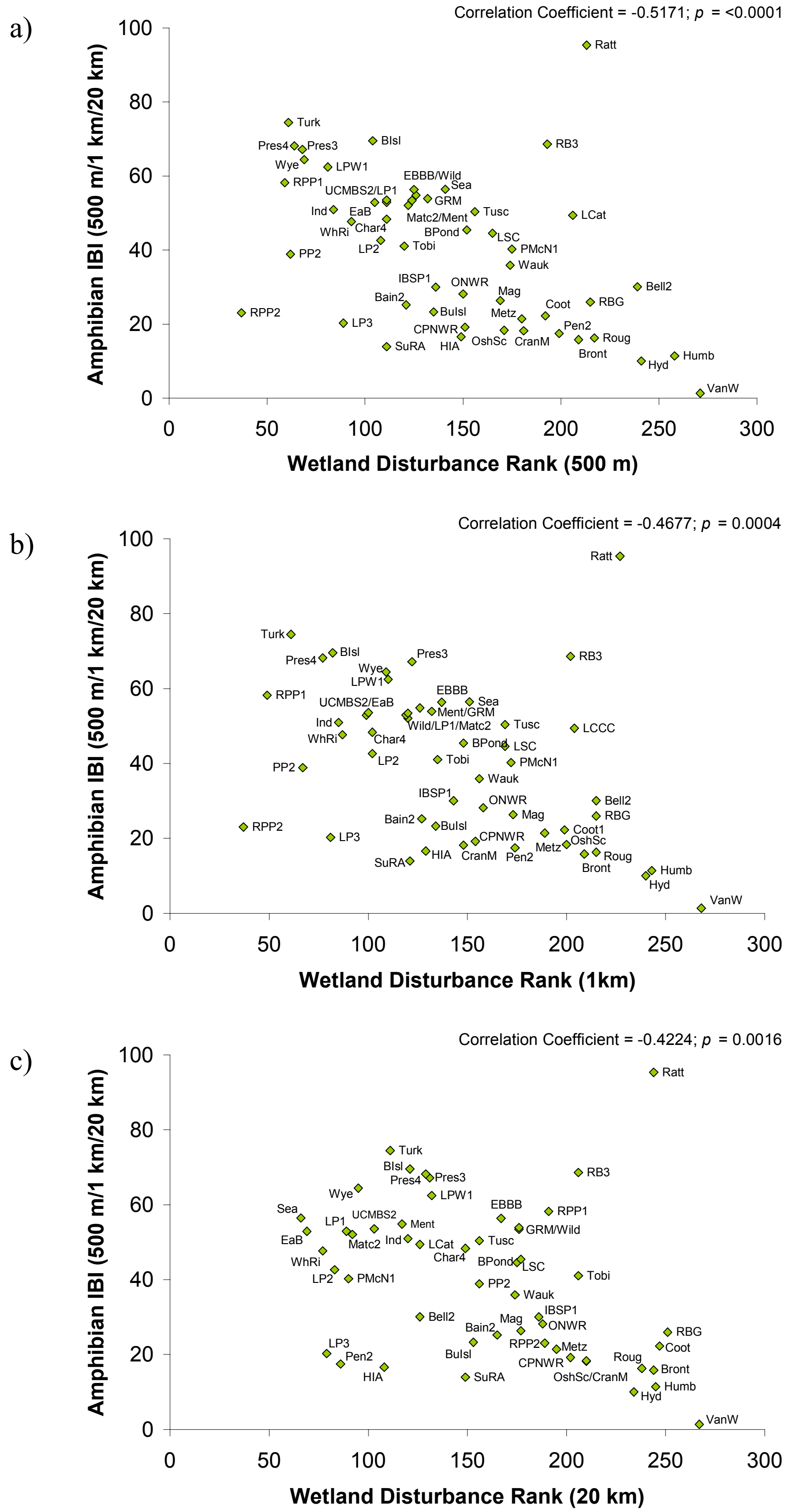


Figure 8. Correlation between the 500 m/1 km/20 km amphibian IBIs and the a) 500 m, b) 1 km, and c) 20 km disturbance gradients during high Great Lakes water levels.

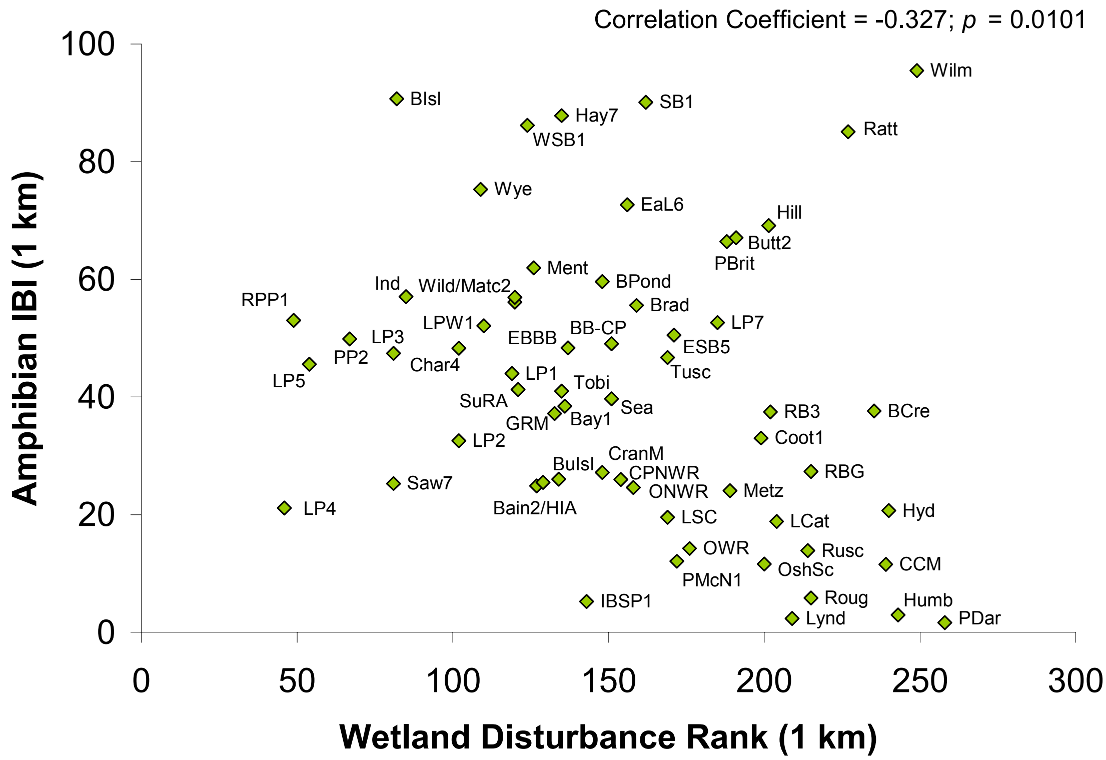


Figure 9. Correlation between amphibian IBIs and the 1 km disturbance gradient during low Great Lakes water levels.

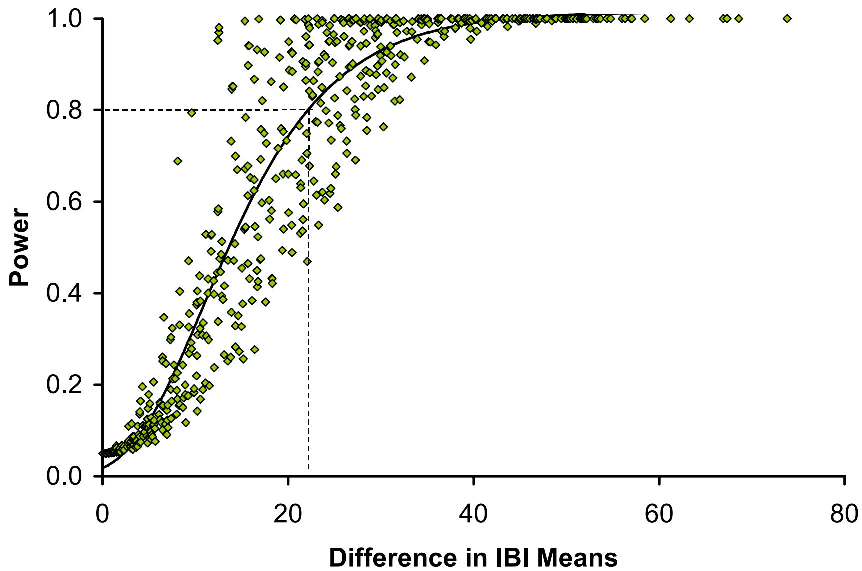


Figure 10. Power curve for 500 m/1 km/20 km-scale amphibian IBIs, calculated for wetlands sampled during high Great Lakes water levels, and showing the minimum detectible difference between IBI means at 80% power. All points shown are for $\alpha = 0.05$.

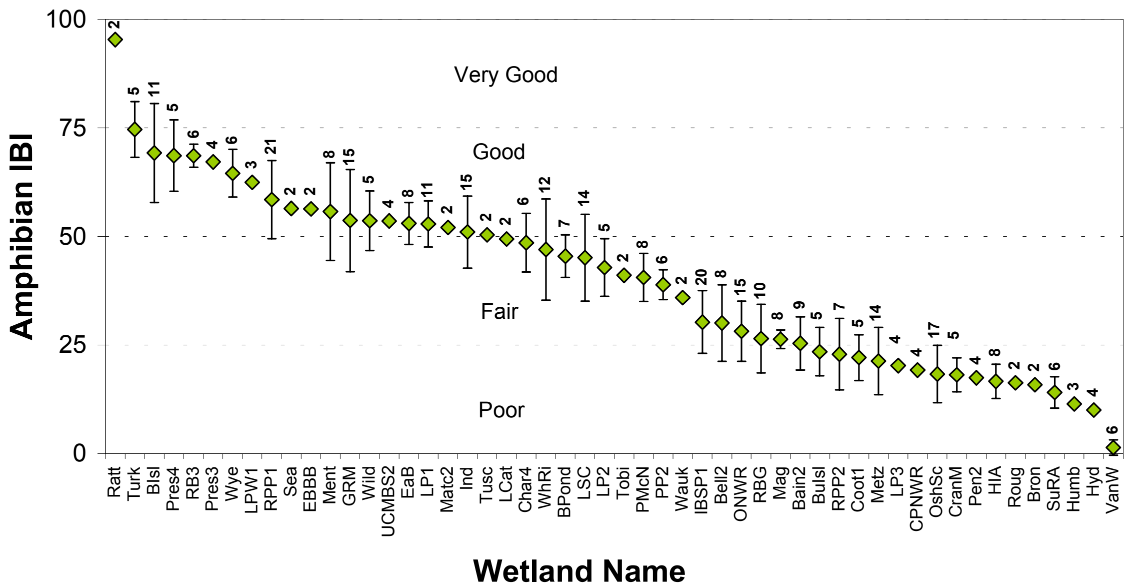


Figure 11. Mean amphibian IBI (500 m/1 km.20 km-scale; ± standard deviation of resampled wetlands) of wetlands surveyed during high Great Lakes water levels. Four wetland category rankings, determined through power analysis, are shown. Number of stations surveyed per site is located above wetland markers.

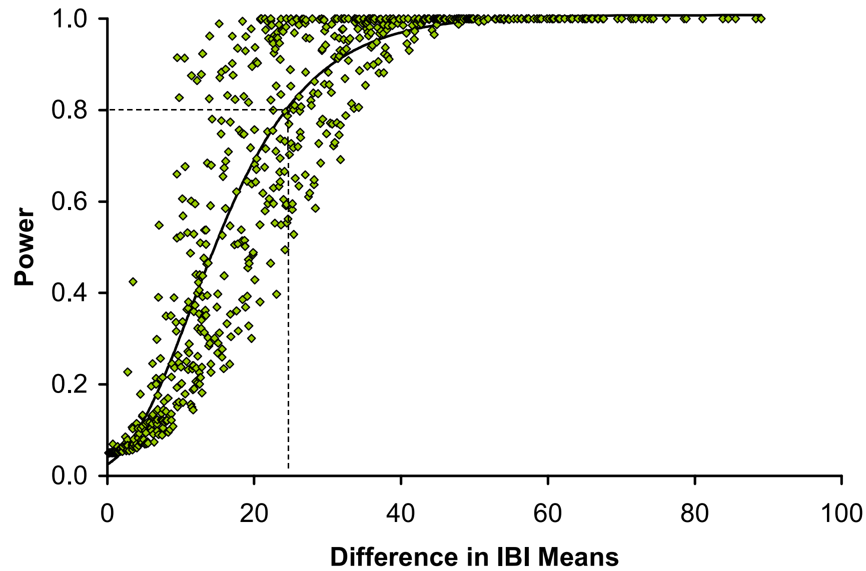


Figure 12. Power curve for 1 km-scale amphibian IBIs, calculated for wetlands sampled during low Great Lakes water levels, and showing the minimum detectible difference between IBI means at 80% power. All points shown are for $\alpha = 0.05$.

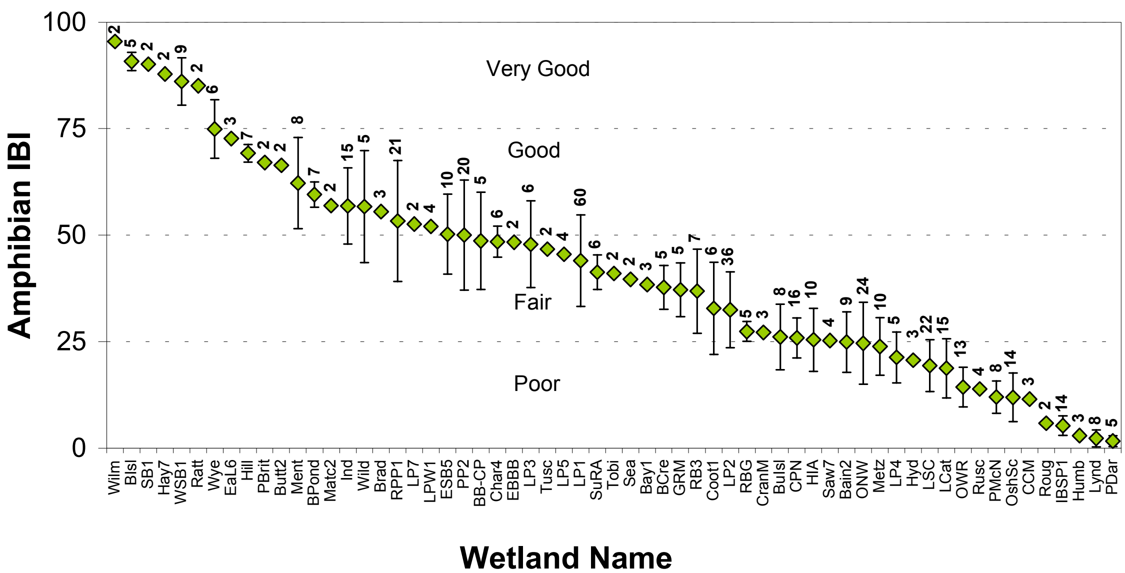


Figure 13. Mean amphibian IBI (1 km–scale; ± standard deviation of resampled wetlands), developed for wetlands surveyed during low Great Lakes water levels. Four wetland category rankings, determined through power analysis, are shown. Number of stations surveyed per site is located above wetland markers.

APPENDICES

APPENDIX A. SPECIES CLASSIFICATION

Table A1. Marsh bird species classification by guild[1]. Those species that are not classified in a guild were included in total species richness and abundance population metrics.

Common Name	CODE	AER	NAER	WATER	GEN	ONS	OS	IND
Alder Flycatcher	ALFL	X			X			
American Bittern	AMBI			X			X	X
American Black Duck	ABDU			X				
American Coot	AMCO			X		X		X
American Crow	AMCR		X					
American Goldfinch	AMGO		X					
American Redstart	AMRE		X					
American Robin	AMRO		X					
American Woodcock	AMWO		X					
Bald Eagle	BAEA							
Baltimore Oriole	BAOR		X					
Bank Swallow	BANS	X						
Barn Swallow	BARS	X						
Belted Kingfisher	BEKI							
Black Tern	BLTE						X	X
Black-billed Cuckoo	BBCU		X					
Black-capped Chickadee	BCCH		X					
Black-crowned Night-Heron	BCNH			X				
Blue Jay	BLJA		X					
Blue-gray Gnatcatcher	BGGN		X					
Blue-winged Teal	BWTE			X				X
Blue-winged Warbler	BWWA		X					
Bobolink	BOBO		X					
Brown Thrasher	BRTH		X					
Brown-headed Cowbird	BHCO		X					
Bufflehead	BUFF			X				
Canada Goose	CAGO		X		X			
Carolina Wren	CARW		X					
Caspian Tern	CATE							
Cedar Waxwing	CEDW		X					
Chestnut-sided Warbler	CSWA		X					
Chimney Swift	CHSW	X						
Chipping Sparrow	CHSP		X					
Clay-colored Sparrow	CCSP		X					
Cliff Swallow	CLSW	X						
Common Goldeneye	COGO			X				

[1] AER = aerial foragers, non-obligate marsh nesters; NAER = non-aerial foragers; WATER = water foragers; GEN = general nesters; ONS = Obligate nesters, non area-sensitive; OS = obligate nester, area-sensitive; IND = marsh indicator species.

Table A1. Continued...

Common Name	CODE	AER	NAER	WATER	GEN	ONS	OS	IND
Common Grackle	COGR		X		X			
Common Merganser	COME			X				
Common Moorhen	COMO			X		X		
Common Nighthawk	CONI	X						
Common Raven	CORA		X					
Common Tern	COTE							
Common Yellowthroat	COYE		X		X			
Cooper's Hawk	COHA							
Double-crested Cormorant	DCCO			X				
Downy Woodpecker	DOWO		X					
Eastern Bluebird	EABL		X					
Eastern Kingbird	EAKI	X			X			
Eastern Meadowlark	EAME		X					
Eastern Phoebe	EAPH	X						
Eastern Wood-Pewee	EAWP	X						
European Starling	EUST		X					
Field Sparrow	FISP		X					
Forster's Tern	FOTE					X		
Gadwall	GADW			X				
Grasshopper Sparrow	GRSP		X					
Gray Catbird	GRCA		X					
Great Blue Heron	GBHE			X	X			
Great Crested Flycatcher	GCFL	X						
Great Horned Owl	GHOW							
Green Heron	GRHE			X	X			
Hairy Woodpecker	HAWO		X					
Herring Gull	HERG							
House Finch	HOFI		X					
House Sparrow	HOSP		X					
House Wren	HOWR		X					
Indigo Bunting	INBU		X					
Killdeer	KILL		X					
King Rail	KIRA			X			X	X
Le Conte's Sparrow	LCSP		X		X			
Least Bittern	LEBI			X			X	X
Least Flycatcher	LEFL	X						
Lincoln's Sparrow	LISP		X					
Little Gull	LIGU				X			
Magnolia Warbler	MAWA		X					
Mallard	MALL			X				
Marsh Wren	MAWR		X			X		X
Moorhen/Coot	MOOT			X		X		
Mourning Dove	MODO		X					
Mourning Warbler	MOWA		X					
Mute Swan	MUSW			X		X		
Northern Cardinal	NOCA		X					
Northern Harrier	NOHA				X			
Northern Pintail	NOPI			X				
Northern Rough-winged Swallo	NRWS	X						

Table A1. Continued...

Common Name	CODE	AER	NAER	WATER	GEN	ONS	OS	IND
Northern Saw-whet Owl	NSWO							
Northern Shoveler	NSHO			X				
Northern Waterthrush	NOWA		X					
Olive-sided Flycatcher	OSFL	X						
Orchard Oriole	OROR		X					
Osprey	OSPR				X			
Ovenbird	OVEN		X					
Pied-billed Grebe	PBGR			X			X	X
Purple Martin	PUMA	X						
Red-bellied Woodpecker	RBWO		X					
Red-eyed Vireo	REVI		X					
Red-headed Woodpecker	RHWO		X					
Red-tailed Hawk	RTHA							
Red-winged Blackbird	RWBL		X		X			
Ring-billed Gull	RBGU							
Ring-necked Duck	RNDU			X	X			
Rock Pigeon	RODO		X					
Rose-Breasted Grosbeak	RBGR		X		X			
Ruby-throated Hummingbird	RTHU		X					
Sandhill Crane	SACR		X		X			
Savannah Sparrow	SAVS		X					
Sedge Wren	SEWR		X		X			
Solitary Sandpiper	SOSA		X					
Song Sparrow	SOSP		X		X			
Sora	SORA		X				X	X
Spotted Sandpiper	SPSA		X					
Swamp Sparrow	SWSP		X				X	
Tree Swallow	TRES	X						
Trumpeter Swan	TRUS			X		X		
Tufted Titmouse	TUTI		X					
Turkey Vulture	TUVU							
Veery	VEER		X					
Virginia Rail	VIRA		X				X	X
Warbling Vireo	WAVI		X					
White-breasted Nuthatch	WBNU		X					
White-eyed Vireo	WEVI		X					
White-throated Sparrow	WTSP		X					
Willow Flycatcher	WIFL	X			X			
Wilson's Phalarope	WIPH		X					
Wilson's Snipe	COSN		X			X		X
Wood Duck	WODU			X	X			
Wood Thrush	WOTH		X					
Yellow Warbler	YWAR		X		X			
Yellow-billed Cuckoo	YBCU		X					
Yellow-breasted Chat	YBCH		X					
Yellow-crowned Night-Heron	YCNH			X	X			
Yellow-headed Blackbird	YHBL		X			X		
Yellow-throated Vireo	YTVI		X					

Table A2. Amphibian species classification by guild[1]. Species that were not classified in either guild were included in the total species richness and maximum calling code metrics.

Common Name	Species Name	CODE	POOR	WOOD	TOL	NTOL	BASIN	RARE	DECLINE	IND
American Toad	*Bufo americanus*	AMTO	X		X		X		X	
Blanchard's Cricket Frog	*Acris crepitans blanchardi*	BCFR						X		
Bullfrog	*Rana catesbeiana*	BULL								X
Cope's (Diploid) Gray Treefrog	*Hyla chrysoscelis*	CGTR								
Chorus Frog	*Pseudacris triseriata & Pseudacris maculata*	CHFR			X				X	X
Fowler's Toad	*Bufo woohhousei fowleri*	FOTO								
Green Frog	*Rana clamitans melanota*	GRFR	X		X		X		X	
Gray (Tetraploid) Treefrog	*Hyla versicolor*	GRTR		X	X					
Mink Frog	*Rana septentrionalis*	MIFR								X
Northern Leopard Frog	*Rana pipiens*	NLFR	X			X	X	X	X	X
Pickerel Frog	*Rana palustris*	PIFR				X		X		
Spring Peeper	*Pseudacris crucifer*	SPPE		X	X		X			
Wood Frog	*Rana sylvatica*	WOFR		X		X	X			

[1] POOR = found in species-poor sites; WOOD = woodland associated; TOL = disturbance tolerant; NTOL = disturbance intolerant; BASIN = basinwide distribution; RARE = rare occurrence; DECLINE = MMP declining trend; IND = MMP indicator species.

APPENDIX B. WETLAND CLASSIFICATION

Table B1. Classification of Great Lakes coastal wetlands used in the development of marsh bird Indices of Biological Integrity.

Wetland Name	Wetland Acronym	Basin[1]	Hydro-geomorphic Classification[2]	Wetland Area (ha)
Long Point Wetland 4	LP4	E	B	249.91
Point Pelee Marsh 2	PP2	E	B	743.73
Tremblay Beach Marsh	Trem	E	L	17.77
Ruscom Shores Marsh	Rusc	E	L	27.18
Rondeau Bay Wetland 3	RB3	E	L	41.72
Metzger Marsh	Metz	E	L	77.84
Long Pond Wetland #1	LPW1	E	L	148.52
Rondeau Provincial Park Wetland 1	RPP1	E	L	756.26
Ottawa National Wildlife Refuge Wetland	ONWR	E	L	763.16
Cedar Point National Wildlife Refuge Wetland	CPNWR	E	L	838.41
Long Point Wetland 2	LP2	E	L	967.25
Long Point Wetland 5	LP5	E	L	1115.14
Long Point Wetland 1	LP1	E	L	1190.20
Long Point Wetland 3	LP3	E	L	1267.01
Lake St. Clair Marshes	LSC	E	L	1807.34
Buckthorn Island Wetland	BuIsl	E	R	111.39
Canard River Mouth Marsh	CRM	E	R	114.67
Hillman Marsh	Hill	E	R	153.11
Black Creek Area Wetland	BlCre	E	R	221.65
Ottawa Wildlife Refuge Wetland	OWR	E	R	285.56
Mentor Marsh	Ment	E	R	322.17
Monroe City Area Wetland	MonCA	E	R	520.12
Big Creek Marsh	BCre	E	R	675.52
Grand River Mouth Wetlands	GRM	E	R	944.52
Bouvier Bay Wetland	Bouv	E	R	1184.02
Harsens Island Area Wetland	HIA	E	R	1595.83
Penetang Marsh 2	Pen2	H	B	13.39
Collingwood Shores Wetland 4	Coll4	H	R	71.71
Wye Marsh	Wye	H	R	841.61
Suamico River Area Wetland	SuRA	M	B	116.23
Indiana Dunes Wetland	Ind	M	B	203.25
Illinois Beach State Park Wetland #1	IBSP1	M	B	1039.89
White River Wetland	WhRi	M	R	1167.38
Muskegon River Wetland	Musk	M	R	1463.21
Rattray Marsh	Ratt	O	B	11.41
Frenchman's Bay Marsh	Fren	O	B	32.35
Westside Beach Marsh	WBea	O	B	45.12

[1] E = Erie; H = Huron; M = Michigan; O = Ontario; S = Superior; SLR = St. Lawrence River

[2] B = Barrier; L = Lacustrine; R = Riverine

Table B1. Continued…

Wetland Name	Wetland Acronym	Basin[1]	Hydro-geomorphic Classification[2]	Wetland Area (ha)
Cranberry Marsh	CranM	O	B	47.29
Snake Creek Marsh	Snak	O	B	49.17
Carrs Marsh (Peters Rock Marsh)	Carr	O	B	70.63
Round Pond	Round	O	B	96.95
Oshawa Second Marsh	OshSc	O	B	112.80
Hucyks Bay 1	Huc1	O	B	155.57
Braddock Bay-Cranberry Pond Wetland	BB-CP	O	B	176.17
Buck Pond	BPond	O	B	297.71
Robinson Cove Marsh	Robi	O	L	8.83
Belleville Marsh 2	Bell2	O	L	16.04
South Bay Marsh 1	SB1	O	L	21.12
Parrott Bay Wetland 2	ParB2	O	L	28.59
Blessington Creek Marsh 2	Bles2	O	L	95.96
Hay Bay Marsh 7	Hay7	O	L	121.96
Sawguin Creek Marsh 7	Saw7	O	L	546.06
Big Island Marsh	BIsl	O	L	685.46
Tuscarora Bay Wetland	Tusc	O	R	15.82
Van Wagners Marsh	VanW	O	R	15.95
Corbett Creek Mouth Marsh	CCM	O	R	21.27
Hydro Marsh	Hyd	O	R	24.33
Humber River Marshes	Humb	O	R	25.10
RBG- Hendrie Valley (Lambs Holllow Wetland)	RBG	O	R	27.28
Port Darlington Marsh	PDar	O	R	28.70
Rouge River Marsh	Roug	O	R	67.60
Duffins Creek Lakeshore Marsh	Duff	O	R	71.99
Lynde Creek Marsh	Lynd	O	R	130.03
Cootes Paradise 1	Coot1	O	R	166.55
Braddock Bay Wetland	Brad	O	R	317.83
East Bay Wetland	EaB	O	R	326.55
Irondequoit Bay Wetland	Iron	O	R	800.92
Sawguin Creek Marsh 1	Saw1	O	R	1157.21
Sodus Bay Wetland	SodB	O	R	1494.22
Algonac Wetland	Alg	SLR	B	461.89
Upper Canada Migratory Bird Sanctuary (UCMBS) 2	UCMBS2	SLR	R	56.66
Button Bay 2	Butt2	SLR	R	100.56
Bainsville Bay Marsh 2	Bain2	SLR	R	102.44
Little Cataraqui Creek Complex	LCat	SLR	R	279.21
Bayfield Bay Wetland 1	Bay1	SLR	R	444.23
Charlottenburgh Marsh 4	Char4	SLR	R	705.09

[1] E = Erie; H = Huron; M = Michigan; O = Ontario; S = Superior; SLR = St. Lawrence River

[2] B = Barrier; L = Lacustrine; R = Riverine

Table B2. Classification of Great Lakes coastal wetlands used in the development of amphibian Indices of Biological Integrity.

Wetland Name	Wetland Acronym	Basin[1]	Hydro-geomorphic Classification[2]	Wetland Area (ha)
Empire Beach Backshore Basin Forest	EBBB	E	B	66.62
Rondeau Provincial Park Wetland 2	RPP2	E	B	80.76
Long Point Wetland 4	LP4	E	B	249.91
Point Pelee Marsh 2	PP2	E	B	743.73
Ruscom Shores Marsh	Rusc	E	L	27.18
Rondeau Bay Wetland 3	RB3	E	L	41.72
Long Point Wetland 7	LP7	E	L	45.36
Metzger Marsh	Metz	E	L	77.84
Long Pond Wetland #1	LPW1	E	L	148.52
Rondeau Provincial Park Wetland 1	RPP1	E	L	756.26
Ottawa National Wildlife Refuge Wetland	ONWR	E	L	763.16
Magee Marsh	Mag	E	L	832.54
Cedar Point National Wildlife Refuge Wetland	CPNWR	E	L	838.41
Long Point Wetland 2	LP2	E	L	967.25
Long Point Wetland 5	LP5	E	L	1115.14
Long Point Wetland 1	LP1	E	L	1190.20
Turkey Point Wetland	Turk	E	L	1211.38
Long Point Wetland 3	LP3	E	L	1267.01
Lake St. Clair Marshes	LSC	E	L	1807.34
Buckthorn Island Wetland	BuIsl	E	R	111.39
Hillman Marsh	Hill	E	R	153.11
Ottawa Wildlife Refuge Wetland	OWR	E	R	285.56
Mentor Marsh	Ment	E	R	322.17
Big Creek Marsh	BCre	E	R	675.52
Grand River Mouth Wetlands	GRM	E	R	944.52
Harsens Island Area Wetland	HIA	E	R	1595.83
Penetang Marsh 2	Pen2	H	B	13.39
Tobico Marsh Wetland	Tobi	H	B	454.26
Port McNicholl Marsh 1	PMcN1	H	L	20.79
Wildfowl Bay Wetland	Wild	H	L	209.10
Matchedash Bay Marsh 2	Matc2	H	L	502.32
East Saginaw Bay Coastal Wetland #5	ESB5	H	L	1424.32
Wye Marsh	Wye	H	R	841.61
West Saginaw Bay Wetland #1	WSB1	H	R	5528.80
Waukegan Area Wetland	Wauk	M	B	6.78

[1] E = Erie; H = Huron; M = Michigan; O = Ontario; S = Superior; SLR = St. Lawrence River

[2] B = Barrier; L = Lacustrine; R = Riverine

Table B2. Continued…

Wetland Name	Wetland Acronym	Basin[1]	Hydro-geomorphic Classification[2]	Wetland Area (ha)
Suamico River Area Wetland	SuRA	M	B	116.23
Indiana Dunes Wetland	Ind	M	B	203.25
Illinois Beach State Park Wetland #1	IBSP1	M	B	1039.89
Seagull Bar Area Wetland	Sea	M	L	36.07
White River Wetland	WhRi	M	R	1167.38
Rattray Marsh	Ratt	O	B	11.41
Port Britain Wetland	PBrit	O	B	20.45
Presquille Bay Marsh 3	Pres3	O	B	26.22
Cranberry Marsh	CranM	O	B	47.29
Oshawa Second Marsh	OshSc	O	B	112.80
Braddock Bay-Cranberry Pond Wetland	BB-CP	O	B	176.17
Buck Pond	BPond	O	B	297.71
East Lake Marsh 6	EaL6	O	L	8.52
Belleville Marsh 2	Bell2	O	L	16.04
South Bay Marsh 1	SB1	O	L	21.12
Presquille Bay Marsh 4	Pres4	O	L	112.95
Hay Bay Marsh 7	Hay7	O	L	121.96
Sawguin Creek Marsh 7	Saw7	O	L	546.06
Big Island Marsh	BIsl	O	L	685.46
Bronte Creek Marsh	Bron	O	R	4.79
Tuscarora Bay Wetland	Tusc	O	R	15.82
Van Wagners Marsh	VanW	O	R	15.95
Corbett Creek Mouth Marsh	CCM	O	R	21.27
Hydro Marsh	Hyd	O	R	24.33
Humber River Marshes	Humb	O	R	25.10
Wilmot Rivermouth Wetland	Wilm	O	R	25.87
RBG- Hendrie Valley (Lambs Holllow Wetland)	RBG	O	R	27.28
Port Darlington Marsh	PDar	O	R	28.70
Rouge River Marsh	Roug	O	R	67.60
Lynde Creek Marsh	Lynd	O	R	130.03
Cootes Paradise 1	Coot1	O	R	166.55
Braddock Bay Wetland	Brad	O	R	317.83
East Bay Wetland	EaB	O	R	326.55
Upper Canada Migratory Bird Sanctuary (UCMBS) 2	UCMBS2	SLR	R	56.66
Button Bay 2	Butt2	SLR	R	100.56
Bainsville Bay Marsh 2	Bain2	SLR	R	102.44
Little Cataraqui Creek Complex	LCat	SLR	R	279.21
Bayfield Bay Wetland 1	Bay1	SLR	R	444.23
Charlottenburgh Marsh 4	Char4	SLR	R	705.09

[1] E = Erie; H = Huron; M = Michigan; O = Ontario; S = Superior; SLR = St. Lawrence River

[2] B = Barrier; L = Lacustrine; R = Riverine

APPENDIX C. DISTURBANCE GRADIENTS

Table C1.a. Calculated rank sum of disturbance within 500 m of Great Lakes coastal wetlands surveyed for marsh birds.

Wetland Name	Rank Sum	Wetland Name	Rank Sum
Long Point Wetland 4	42	Irondequoit Bay Wetland	148
Rondeau Provincial Park Wetland 1	55	Buck Pond	151
Long Point Wetland 5	56	Braddock Bay-Cranberry Pond Wetland	158
Wye Marsh	65	Tuscarora Bay Wetland	159
Point Pelee Marsh 2	66	Lake St. Clair Marshes	161
Long Point Wetland 3	75	Hay Bay Marsh 7	162
Sawguin Creek Marsh 7	77	Monroe City Area Wetland	162
Indiana Dunes Wetland	81	South Bay Marsh 1	163
Long Pond Wetland #1	81	Metzger Marsh	167
Manistique City Area Wetland #3	89	Oshawa Second Marsh	169
White River Wetland	89	Braddock Bay Wetland	171
Parrott Bay Wetland 2	92	Round Pond	172
Snake Creek Marsh	93	Button Bay 2	174
Blessington Creek Marsh 2	94	Cranberry Marsh	175
Sawguin Creek Marsh 1	97	Duffins Creek Lakeshore Marsh	176
Big Island Marsh	99	Ottawa Wildlife Refuge Wetland	179
Long Point Wetland 2	100	Black Creek Area Wetland	182
Long Point Wetland 1	103	Robinson Cove Marsh	188
East Bay Wetland	104	Rondeau Bay Wetland 3	190
Suamico River Area Wetland	106	Tremblay Beach Marsh	192
Algonac Wetland	116	Lynde Creek Marsh	195
Upper Canada Migratory Bird Sanctuary 2	116	Cootes Paradise 1	196
Charlottenburgh Marsh 4	118	Hillman Marsh	198
Bouvier Bay Wetland	120	Penetang Marsh 2	203
Bainsville Bay Marsh 2	123	Ruscom Shores Marsh	204
Muskegon River Wetland	123	Little Cataraqui Creek Complex	208
Carrs Marsh (Peters Rock Marsh)	124	RBG- Hendrie Valley	217
Mentor Marsh	126	Rattray Marsh	217
Collingwood Shores Wetland 4	130	Rouge River Marsh	217
Buckthorn Island Wetland	131	Corbett Creek Mouth Marsh	218
Canard River Mouth Marsh	131	Big Creek Marsh	223
Grand River Mouth Wetlands	133	Westside Beach Marsh	237
Bayfield Bay Wetland 1	134	Belleville Marsh 2	238
Sodus Bay Wetland	135	Hydro Marsh	238
Illinois Beach State Park Wetland #1	137	Frenchman's Bay Marsh	242
Harsens Island Area Wetland	142	Port Darlington Marsh	248
Cedar Point National Wildlife Refuge	143	Humber River Marshes	259
Ottawa National Wildlife Refuge Wetland	143	Van Wagners Marsh	262
Hucyks Bay 1	146		

Table C1.b. Calculated rank sum of disturbance within 1 km of Great Lakes coastal wetlands surveyed for marsh birds.

Wetland Name	Rank Sum	Wetland Name	Rank Sum
Long Point Wetland 4	44	Buck Pond	149
Rondeau Provincial Park Wetland 1	47	Ottawa National Wildlife Refuge Wetland	150
Long Point Wetland 5	55	Braddock Bay-Cranberry Pond Wetland	152
Point Pelee Marsh 2	71	Canard River Mouth Marsh	152
Long Point Wetland 3	74	Irondequoit Bay Wetland	156
Indiana Dunes Wetland	79	Round Pond	156
White River Wetland	82	Robinson Cove Marsh	161
Big Island Marsh	83	Monroe City Area Wetland	162
Sawguin Creek Marsh 7	83	Braddock Bay Wetland	163
Manistique City Area Wetland #3	89	Lake St. Clair Marshes	163
Sawguin Creek Marsh 1	89	South Bay Marsh 1	164
Snake Creek Marsh	95	Black Creek Area Wetland	167
Long Point Wetland 2	98	Tuscarora Bay Wetland	170
East Bay Wetland	99	Ottawa Wildlife Refuge Wetland	175
Parrott Bay Wetland 2	106	Penetang Marsh 2	177
Wye Marsh	107	Metzger Marsh	179
Bouvier Bay Wetland	109	Button Bay 2	188
Upper Canada Migratory Bird Sanctuary 2	109	Oshawa Second Marsh	195
Charlottenburgh Marsh 4	110	Duffins Creek Lakeshore Marsh	197
Long Pond Wetland #1	110	Hillman Marsh	200
Algonac Wetland	113	Rondeau Bay Wetland 3	200
Long Point Wetland 1	115	Tremblay Beach Marsh	203
Muskegon River Wetland	116	Little Cataraqui Creek Complex	204
Suamico River Area Wetland	120	Lynde Creek Marsh	204
Sodus Bay Wetland	126	Cootes Paradise 1	205
Harsens Island Area Wetland	127	Ruscom Shores Marsh	212
Mentor Marsh	127	Belleville Marsh 2	214
Collingwood Shores Wetland 4	130	RBG- Hendrie Valley	216
Bainsville Bay Marsh 2	132	Rouge River Marsh	218
Grand River Mouth Wetlands	132	Corbett Creek Mouth Marsh	229
Hucyks Bay 1	135	Rattray Marsh	231
Bayfield Bay Wetland 1	136	Big Creek Marsh	232
Hay Bay Marsh 7	137	Frenchman's Bay Marsh	238
Buckthorn Island Wetland	139	Hydro Marsh	238
Blessington Creek Marsh 2	142	Humber River Marshes	247
Carrs Marsh (Peters Rock Marsh)	142	Port Darlington Marsh	255
Illinois Beach State Park Wetland #1	145	Westside Beach Marsh	263
Cedar Point National Wildlife Refuge	146	Van Wagners Marsh	267
Cranberry Marsh	147		

Table C1.c. Calculated rank sum of disturbance within 20 km of Great Lakes coastal wetlands surveyed for marsh birds.

Wetland Name	Rank Sum	Wetland Name	Rank Sum
Manistique City Area Wetland #3	33	Irondequoit Bay Wetland	161
East Bay Wetland	68	Collingwood Shores Wetland 4	165
White River Wetland	75	Carrs Marsh (Peters Rock Marsh)	167
Long Point Wetland 4	82	Ottawa Wildlife Refuge Wetland	167
Penetang Marsh 2	85	Bainsville Bay Marsh 2	168
Long Point Wetland 3	89	Grand River Mouth Wetlands	172
Long Point Wetland 5	89	Lake St. Clair Marshes	175
Algonac Wetland	90	Round Pond	176
Long Point Wetland 2	91	Braddock Bay-Cranberry Pond Wetland	177
Sodus Bay Wetland	92	Buck Pond	180
Snake Creek Marsh	93	Braddock Bay Wetland	183
Wye Marsh	93	Rondeau Provincial Park Wetland 1	184
Long Point Wetland 1	96	Hillman Marsh	187
Upper Canada Migratory Bird Sanctuary 2	96	Ottawa National Wildlife Refuge Wetland	187
Muskegon River Wetland	97	Illinois Beach State Park Wetland #1	188
Bouvier Bay Wetland	108	Metzger Marsh	189
South Bay Marsh 1	110	Monroe City Area Wetland	195
Harsens Island Area Wetland	116	Rondeau Bay Wetland 3	200
Hay Bay Marsh 7	117	Port Darlington Marsh	201
Mentor Marsh	118	Cedar Point National Wildlife Refuge	202
Bayfield Bay Wetland 1	123	Westside Beach Marsh	203
Blessington Creek Marsh 2	124	Corbett Creek Mouth Marsh	204
Parrott Bay Wetland 2	124	Oshawa Second Marsh	209
Big Island Marsh	125	Tremblay Beach Marsh	209
Indiana Dunes Wetland	129	Ruscom Shores Marsh	210
Little Cataraqui Creek Complex	129	Cranberry Marsh	211
Belleville Marsh 2	130	Big Creek Marsh	212
Hucyks Bay 1	131	Lynde Creek Marsh	212
Long Pond Wetland #1	132	Duffins Creek Lakeshore Marsh	223
Robinson Cove Marsh	134	Canard River Mouth Marsh	224
Sawguin Creek Marsh 1	135	Hydro Marsh	236
Sawguin Creek Marsh 7	142	Rouge River Marsh	240
Black Creek Area Wetland	143	Frenchman's Bay Marsh	242
Charlottenburgh Marsh 4	145	Cootes Paradise 1	245
Button Bay 2	146	Humber River Marshes	247
Buckthorn Island Wetland	153	Rattray Marsh	248
Suamico River Area Wetland	154	RBG- Hendrie Valley	249
Point Pelee Marsh 2	155	Van Wagners Marsh	266
Tuscarora Bay Wetland	160		

Table C1.d. Calculated rank sum of disturbance within the watershed of Great Lakes coastal wetlands surveyed for marsh birds.

Wetland Name	Rank Sum	Wetland Name	Rank Sum
Manistique City Area Wetland #3	35	Round Pond	152
White River Wetland	46	Tuscarora Bay Wetland	152
Muskegon River Wetland	59	Bayfield Bay Wetland 1	158
Belleville Marsh 2	61	Button Bay 2	158
Blessington Creek Marsh 2	61	Monroe City Area Wetland	162
Hay Bay Marsh 7	61	Cedar Point National Wildlife Refuge	179
Little Cataraqui Creek Complex	61	Metzger Marsh	179
Parrott Bay Wetland 2	61	Ottawa National Wildlife Refuge Wetland	179
Big Island Marsh	84	Ottawa Wildlife Refuge Wetland	179
Hucyks Bay 1	84	Rondeau Bay Wetland 3	179
Robinson Cove Marsh	84	Rondeau Provincial Park Wetland 1	179
Sawguin Creek Marsh 1	84	Carrs Marsh (Peters Rock Marsh)	180
Sawguin Creek Marsh 7	84	Corbett Creek Mouth Marsh	180
South Bay Marsh 1	84	Oshawa Second Marsh	180
Mentor Marsh	96	Port Darlington Marsh	180
Long Pond Wetland #1	106	Westside Beach Marsh	180
Bainsville Bay Marsh 2	119	Black Creek Area Wetland	187
Charlottenburgh Marsh 4	119	Grand River Mouth Wetlands	192
Upper Canada Migratory Bird Sanctuary 2	119	Algonac Wetland	194
East Bay Wetland	121	Illinois Beach State Park Wetland #1	209
Irondequoit Bay Wetland	121	Big Creek Marsh	215
Snake Creek Marsh	121	Canard River Mouth Marsh	215
Sodus Bay Wetland	121	Hillman Marsh	215
Bouvier Bay Wetland	124	Point Pelee Marsh 2	215
Indiana Dunes Wetland	124	Ruscom Shores Marsh	215
Collingwood Shores Wetland 4	126	Tremblay Beach Marsh	215
Penetang Marsh 2	126	Cootes Paradise 1	218
Wye Marsh	126	RBG- Hendrie Valley	218
Suamico River Area Wetland	128	Rattray Marsh	218
Buckthorn Island Wetland	130	Van Wagners Marsh	218
Harsens Island Area Wetland	135	Cranberry Marsh	231
Long Point Wetland 1	145	Duffins Creek Lakeshore Marsh	231
Long Point Wetland 2	145	Frenchman's Bay Marsh	231
Long Point Wetland 3	145	Humber River Marshes	231
Long Point Wetland 4	145	Hydro Marsh	231
Long Point Wetland 5	145	Lynde Creek Marsh	231
Braddock Bay Wetland	152	Rouge River Marsh	231
Braddock Bay-Cranberry Pond Wetland	152	Lake St. Clair Marshes	238
Buck Pond	152		

Table C1.e. Calculated overall rank sum of buffer and watershed disturbance gradients of Great Lakes coastal wetlands surveyed for marsh birds.

Wetland Name	Rank Sum	Wetland Name	Rank Sum
Manistique City Area Wetland #3	246	Carrs Marsh (Peters Rock Marsh)	613
White River Wetland	292	Grand River Mouth Wetlands	629
Long Point Wetland 4	313	Buck Pond	632
Long Point Wetland 5	345	Braddock Bay-Cranberry Pond Wetland	639
Long Point Wetland 3	383	Tuscarora Bay Wetland	641
Parrott Bay Wetland 2	383	Belleville Marsh 2	643
Sawguin Creek Marsh 7	386	Round Pond	656
Big Island Marsh	391	Ottawa National Wildlife Refuge Wetland	659
Wye Marsh	391	Button Bay 2	666
East Bay Wetland	392	Braddock Bay Wetland	669
Muskegon River Wetland	395	Cedar Point National Wildlife Refuge	670
Snake Creek Marsh	402	Black Creek Area Wetland	679
Sawguin Creek Marsh 1	405	Illinois Beach State Park Wetland #1	679
Indiana Dunes Wetland	413	Monroe City Area Wetland	681
Blessington Creek Marsh 2	421	Ottawa Wildlife Refuge Wetland	700
Long Pond Wetland #1	429	Metzger Marsh	714
Long Point Wetland 2	434	Canard River Mouth Marsh	722
Upper Canada Migratory Bird Sanctuary 2	440	Lake St. Clair Marshes	737
Long Point Wetland 1	459	Oshawa Second Marsh	753
Bouvier Bay Wetland	461	Cranberry Marsh	764
Rondeau Provincial Park Wetland 1	465	Rondeau Bay Wetland 3	769
Mentor Marsh	467	Hillman Marsh	800
Sodus Bay Wetland	474	Tremblay Beach Marsh	819
Hay Bay Marsh 7	477	Duffins Creek Lakeshore Marsh	827
Charlottenburgh Marsh 4	492	Corbett Creek Mouth Marsh	831
Hucyks Bay 1	496	Ruscom Shores Marsh	841
Point Pelee Marsh 2	507	Lynde Creek Marsh	842
Suamico River Area Wetland	508	Cootes Paradise 1	864
Algonac Wetland	513	Big Creek Marsh	882
Harsens Island Area Wetland	520	Westside Beach Marsh	883
South Bay Marsh 1	521	Port Darlington Marsh	884
Bainsville Bay Marsh 2	542	RBG- Hendrie Valley	900
Bayfield Bay Wetland 1	551	Rouge River Marsh	906
Collingwood Shores Wetland 4	551	Rattray Marsh	914
Buckthorn Island Wetland	553	Hydro Marsh	943
Robinson Cove Marsh	567	Frenchman's Bay Marsh	953
Irondequoit Bay Wetland	586	Humber River Marshes	984
Penetang Marsh 2	591	Van Wagners Marsh	1013
Little Cataraqui Creek Complex	602		

Table C2.a. Calculated rank sum of disturbance within 500 m of Great Lakes coastal wetlands surveyed for amphibians.

Wetland Name	Rank Sum	Wetland Name	Rank Sum
Rondeau Provincial Park Wetland 2	37	Braddock Bay-Cranberry Pond Wetland	154
Long Point Wetland 4	42	Tuscarora Bay Wetland	156
Long Point Wetland 5	55	East Saginaw Bay Coastal Wetland #5	160
Rondeau Provincial Park Wetland 1	59	Hay Bay Marsh 7	160
Turkey Point Wetland	61	Monroe City Area Wetland	160
Point Pelee Marsh 2	62	South Bay Marsh 1	161
Presquille Bay Marsh 4	64	Lake St. Clair Marshes	165
Presquille Bay Marsh 3	68	Magee Marsh	169
Wye Marsh	69	Button Bay 2	171
Sawguin Creek Marsh 7	75	Oshawa Second Marsh	171
Long Pond Wetland #1	81	Braddock Bay Wetland	173
Indiana Dunes Wetland	84	Waukegan Area Wetland	174
Long Point Wetland 3	89	Port McNicholl Marsh 1	175
Parrott Bay Wetland 2	89	Duffins Creek Lakeshore Marsh	177
White River Wetland	93	Long Point Wetland 7	178
Big Island Marsh	104	Metzger Marsh	180
East Bay Wetland	105	Cranberry Marsh	181
Long Point Wetland 2	108	Ottawa Wildlife Refuge Wetland	187
Charlottenburgh Marsh 4	111	Port Britain Wetland	191
Long Point Wetland 1	111	Cootes Paradise 1	192
Suamico River Area Wetland	111	Rondeau Bay Wetland 3	193
Upper Canada Migratory Bird Sanctuary 2	111	Lynde Creek Marsh	195
Tobico Marsh Wetland	120	Penetang Marsh 2	199
Bainsville Bay Marsh 2	121	Hillman Marsh	202
Matchedash Bay Marsh 2	122	Little Cataraqui Creek Complex	206
Wildfowl Bay Wetland	124	Ruscom Shores Marsh	208
Empire Beach Backshore Basin Forest	125	Bronte Creek Marsh	209
Mentor Marsh	126	Rattray Marsh	213
West Saginaw Bay Wetland #1	130	RBG- Hendrie Valley	215
Grand River Mouth Wetlands	132	Rouge River Marsh	217
Bayfield Bay Wetland 1	134	Big Creek Marsh	221
Buckthorn Island Wetland	135	Corbett Creek Mouth Marsh	223
Illinois Beach State Park Wetland #1	136	Belleville Marsh 2	239
Seagull Bar Area Wetland	141	Hydro Marsh	241
East Lake Marsh 6	147	Frenchman's Bay Marsh	246
Harsens Island Area Wetland	149	Port Darlington Marsh	253
Ottawa National Wildlife Refuge Wetland	150	Wilmot Rivermouth Wetland	256
Cedar Point National Wildlife Refuge	151	Humber River Marshes	258
Buck Pond	152	Van Wagners Marsh	271

Table C2.b. Calculated rank sum of disturbance within 1 km of Great Lakes coastal wetlands surveyed for amphibians.

Wetland Name	Rank Sum	Wetland Name	Rank Sum
Rondeau Provincial Park Wetland 2	37	Cedar Point National Wildlife Refuge	154
Long Point Wetland 4	46	East Lake Marsh 6	156
Rondeau Provincial Park Wetland 1	49	Waukegan Area Wetland	156
Long Point Wetland 5	54	Ottawa National Wildlife Refuge Wetland	158
Turkey Point Wetland	61	Braddock Bay Wetland	159
Point Pelee Marsh 2	67	Monroe City Area Wetland	159
Presquille Bay Marsh 4	77	South Bay Marsh 1	162
Long Point Wetland 3	81	Lake St. Clair Marshes	169
Sawguin Creek Marsh 7	81	Tuscarora Bay Wetland	169
Big Island Marsh	82	East Saginaw Bay Coastal Wetland #5	171
Indiana Dunes Wetland	85	Port McNicholl Marsh 1	172
White River Wetland	87	Magee Marsh	173
East Bay Wetland	99	Penetang Marsh 2	174
Parrott Bay Wetland 2	99	Ottawa Wildlife Refuge Wetland	176
Upper Canada Migratory Bird Sanctuary 2	100	Long Point Wetland 7	185
Charlottenburgh Marsh 4	102	Button Bay 2	188
Long Point Wetland 2	102	Metzger Marsh	189
Wye Marsh	109	Port Britain Wetland	191
Long Pond Wetland #1	110	Duffins Creek Lakeshore Marsh	196
Long Point Wetland 1	119	Cootes Paradise 1	199
Matchedash Bay Marsh 2	120	Oshawa Second Marsh	200
Wildfowl Bay Wetland	120	Hillman Marsh	202
Suamico River Area Wetland	121	Rondeau Bay Wetland 3	202
Presquille Bay Marsh 3	122	Little Cataraqui Creek Complex	204
West Saginaw Bay Wetland #1	124	Bronte Creek Marsh	209
Mentor Marsh	126	Lynde Creek Marsh	209
Bainsville Bay Marsh 2	127	Ruscom Shores Marsh	214
Harsens Island Area Wetland	129	Belleville Marsh 2	215
Grand River Mouth Wetlands	132	RBG- Hendrie Valley	215
Buckthorn Island Wetland	134	Rouge River Marsh	215
Hay Bay Marsh 7	135	Rattray Marsh	227
Tobico Marsh Wetland	135	Big Creek Marsh	235
Bayfield Bay Wetland 1	136	Corbett Creek Mouth Marsh	239
Empire Beach Backshore Basin Forest	137	Frenchman's Bay Marsh	240
Illinois Beach State Park Wetland #1	143	Hydro Marsh	240
Buck Pond	148	Humber River Marshes	243
Cranberry Marsh	148	Wilmot Rivermouth Wetland	249
Braddock Bay-Cranberry Pond Wetland	151	Port Darlington Marsh	258
Seagull Bar Area Wetland	151	Van Wagners Marsh	268

Table C2.c. Calculated rank sum of disturbance within 20 km of Great Lakes coastal wetlands surveyed for amphibians.

Wetland Name	Rank Sum	Wetland Name	Rank Sum
Seagull Bar Area Wetland	66	Empire Beach Backshore Basin Forest	167
East Bay Wetland	69	Port Britain Wetland	171
Long Point Wetland 4	76	Waukegan Area Wetland	174
White River Wetland	77	Braddock Bay-Cranberry Pond Wetland	175
Long Point Wetland 3	79	Lake St. Clair Marshes	175
Long Point Wetland 2	83	Grand River Mouth Wetlands	176
Penetang Marsh 2	86	Wildfowl Bay Wetland	176
Long Point Wetland 7	88	Buck Pond	177
Long Point Wetland 1	89	Magee Marsh	177
Long Point Wetland 5	90	Braddock Bay Wetland	180
Port McNicholl Marsh 1	90	Wilmot Rivermouth Wetland	182
Matchedash Bay Marsh 2	92	Illinois Beach State Park Wetland #1	186
Wye Marsh	95	Ottawa National Wildlife Refuge Wetland	188
South Bay Marsh 1	103	Rondeau Provincial Park Wetland 2	189
Upper Canada Migratory Bird Sanctuary 2	103	Hillman Marsh	190
Harsens Island Area Wetland	108	Rondeau Provincial Park Wetland 1	191
Hay Bay Marsh 7	109	Metzger Marsh	195
West Saginaw Bay Wetland #1	110	Monroe City Area Wetland	198
Turkey Point Wetland	111	Port Darlington Marsh	200
East Lake Marsh 6	112	Cedar Point National Wildlife Refuge	202
Mentor Marsh	117	Corbett Creek Mouth Marsh	206
Bayfield Bay Wetland 1	119	Rondeau Bay Wetland 3	206
Parrott Bay Wetland 2	119	Tobico Marsh Wetland	206
Indiana Dunes Wetland	120	Cranberry Marsh	210
Big Island Marsh	121	Oshawa Second Marsh	210
Belleville Marsh 2	126	East Saginaw Bay Coastal Wetland #5	213
Little Cataraqui Creek Complex	126	Lynde Creek Marsh	213
Presquille Bay Marsh 4	129	Big Creek Marsh	216
Presquille Bay Marsh 3	131	Ruscom Shores Marsh	219
Long Pond Wetland #1	132	Duffins Creek Lakeshore Marsh	223
Sawguin Creek Marsh 7	141	Hydro Marsh	234
Button Bay 2	145	Rouge River Marsh	238
Charlottenburgh Marsh 4	149	Frenchman's Bay Marsh	239
Suamico River Area Wetland	149	Bronte Creek Marsh	244
Buckthorn Island Wetland	153	Rattray Marsh	244
Point Pelee Marsh 2	156	Humber River Marshes	245
Tuscarora Bay Wetland	156	Cootes Paradise 1	247
Bainsville Bay Marsh 2	165	RBG- Hendrie Valley	251
Ottawa Wildlife Refuge Wetland	165	Van Wagners Marsh	267

Table C2.d. Calculated rank sum of disturbance within the watershed of Great Lakes coastal wetlands surveyed for amphibians.

Wetland Name	Rank Sum	Wetland Name	Rank Sum
Seagull Bar Area Wetland	22	Monroe City Area Wetland	160
White River Wetland	43	Corbett Creek Mouth Marsh	167
Belleville Marsh 2	59	Oshawa Second Marsh	167
Hay Bay Marsh 7	59	Port Britain Wetland	167
Little Cataraqui Creek Complex	59	Port Darlington Marsh	167
Parrott Bay Wetland 2	59	Presquille Bay Marsh 3	167
Big Island Marsh	78	Presquille Bay Marsh 4	167
East Lake Marsh 6	78	Wilmot Rivermouth Wetland	167
Sawguin Creek Marsh 7	78	Cedar Point National Wildlife Refuge	177
South Bay Marsh 1	78	Magee Marsh	177
Mentor Marsh	95	Metzger Marsh	177
Long Pond Wetland #1	106	Ottawa National Wildlife Refuge Wetland	177
Matchedash Bay Marsh 2	109	Ottawa Wildlife Refuge Wetland	177
Penetang Marsh 2	109	Rondeau Bay Wetland 3	177
Port McNicholl Marsh 1	109	Rondeau Provincial Park Wetland 1	177
Wye Marsh	109	Rondeau Provincial Park Wetland 2	177
Indiana Dunes Wetland	111	East Saginaw Bay Coastal Wetland #5	186
Bainsville Bay Marsh 2	114	Wildfowl Bay Wetland	186
Charlottenburgh Marsh 4	114	Grand River Mouth Wetlands	193
Upper Canada Migratory Bird Sanctuary 2	114	Illinois Beach State Park Wetland #1	200
Suamico River Area Wetland	116	Waukegan Area Wetland	200
East Bay Wetland	122	Bronte Creek Marsh	204
Buckthorn Island Wetland	126	Cootes Paradise 1	204
Harsens Island Area Wetland	128	RBG- Hendrie Valley	204
Tobico Marsh Wetland	142	Rattray Marsh	204
West Saginaw Bay Wetland #1	142	Van Wagners Marsh	204
Long Point Wetland 1	143	Cranberry Marsh	223
Long Point Wetland 2	143	Duffins Creek Lakeshore Marsh	223
Long Point Wetland 3	143	Frenchman's Bay Marsh	223
Long Point Wetland 4	143	Humber River Marshes	223
Long Point Wetland 5	143	Hydro Marsh	223
Long Point Wetland 7	143	Lynde Creek Marsh	223
Turkey Point Wetland	143	Rouge River Marsh	223
Braddock Bay Wetland	145	Big Creek Marsh	227
Braddock Bay-Cranberry Pond Wetland	145	Hillman Marsh	227
Buck Pond	145	Point Pelee Marsh 2	227
Tuscarora Bay Wetland	145	Ruscom Shores Marsh	227
Bayfield Bay Wetland 1	152	Empire Beach Backshore Basin Forest	231
Button Bay 2	152	Lake St. Clair Marshes	241

Table C2.e. Calculated overall rank sum of buffer and watershed disturbance gradients of Great Lakes coastal wetlands surveyed for amphibians.

Wetland Name	Rank Sum	Wetland Name	Rank Sum
White River Wetland	300	Buck Pond	622
Long Point Wetland 4	307	Braddock Bay-Cranberry Pond Wetland	625
Long Point Wetland 5	342	Tuscarora Bay Wetland	626
Parrott Bay Wetland 2	366	Grand River Mouth Wetlands	633
Sawguin Creek Marsh 7	375	Belleville Marsh 2	639
Turkey Point Wetland	376	Button Bay 2	656
Seagull Bar Area Wetland	380	Braddock Bay Wetland	657
Wye Marsh	382	Empire Beach Backshore Basin Forest	660
Big Island Marsh	385	Illinois Beach State Park Wetland #1	665
Long Point Wetland 3	392	Ottawa National Wildlife Refuge Wetland	673
East Bay Wetland	395	Monroe City Area Wetland	677
Indiana Dunes Wetland	400	Cedar Point National Wildlife Refuge	684
Upper Canada Migratory Bird Sanctuary 2	428	Magee Marsh	696
Long Pond Wetland #1	429	Waukegan Area Wetland	704
Long Point Wetland 2	436	Ottawa Wildlife Refuge Wetland	705
Presquille Bay Marsh 4	437	Port Britain Wetland	720
Rondeau Provincial Park Wetland 2	440	East Saginaw Bay Coastal Wetland #5	730
Matchedash Bay Marsh 2	443	Metzger Marsh	741
Long Point Wetland 1	462	Oshawa Second Marsh	748
Hay Bay Marsh 7	463	Lake St. Clair Marshes	750
Mentor Marsh	464	Cranberry Marsh	762
Charlottenburgh Marsh 4	476	Rondeau Bay Wetland 3	778
Rondeau Provincial Park Wetland 1	476	Duffins Creek Lakeshore Marsh	819
Presquille Bay Marsh 3	488	Hillman Marsh	821
East Lake Marsh 6	493	Corbett Creek Mouth Marsh	835
Suamico River Area Wetland	497	Lynde Creek Marsh	840
South Bay Marsh 1	504	Cootes Paradise 1	842
West Saginaw Bay Wetland #1	506	Wilmot Rivermouth Wetland	854
Point Pelee Marsh 2	512	Bronte Creek Marsh	866
Harsens Island Area Wetland	514	Ruscom Shores Marsh	868
Bainsville Bay Marsh 2	527	Port Darlington Marsh	878
Bayfield Bay Wetland 1	541	RBG- Hendrie Valley	885
Port McNicholl Marsh 1	546	Rattray Marsh	888
Buckthorn Island Wetland	548	Rouge River Marsh	893
Penetang Marsh 2	568	Big Creek Marsh	899
Long Point Wetland 7	594	Hydro Marsh	938
Little Cataraqui Creek Complex	595	Frenchman's Bay Marsh	948
Tobico Marsh Wetland	603	Humber River Marshes	969
Wildfowl Bay Wetland	606	Van Wagners Marsh	1010

APPENDIX D. SUPPLEMENTAL MARSH BIRD DATA

Table D1.a. Response of marsh bird richness, by guild, to the 500 m disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Value	RAER	RNAER	RWATER	RGEN	RONS	ROS	RIND	RTOT
High	1995	37	Corr	**0.24**	0.15	**0.36**	0.02	-0.11	**-0.41**	**-0.32**	0.17
		37	*p*	**0.1488**	0.3786	**0.0270**	0.9049	0.5162	**0.0108**	**0.0568**	0.3153
	1996	46	Corr	**-0.26**	**-0.27**	**0.31**	**-0.30**	-0.05	**-0.35**	**-0.23**	**-0.23**
		46	*p*	**0.0759**	**0.0651**	**0.0336**	**0.0451**	0.7579	**0.0168**	**0.1212**	**0.1184**
	1997	37	Corr	0.08	-0.20	**0.34**	-0.18	-0.01	**-0.49**	**-0.37**	-0.11
		37	*p*	0.6445	0.2389	**0.0420**	0.2895	0.9305	**0.0023**	**0.0262**	0.5091
	1998	32	Corr	-0.20	-0.10	**0.32**	-0.04	0.02	**-0.24**	-0.18	0.01
		32	*p*	0.2664	0.6022	**0.0718**	0.8074	0.9008	**0.1927**	0.3329	0.9365
Low	1999	38	Corr	-0.08	0.01	**0.41**	0.10	-0.07	-0.19	-0.21	0.08
		38	*p*	0.6390	0.9407	**0.0113**	0.5457	0.6687	0.2570	0.2116	0.6433
	2000	32	Corr	-0.22	**-0.29**	0.01	-0.16	-0.01	-0.20	-0.02	-0.21
		32	*p*	0.2334	**0.1120**	0.9654	0.3674	0.9440	0.2661	0.9245	0.2447
	2001	27	Corr	0.11	-0.22	**0.36**	-0.23	-0.09	-0.21	**-0.26**	-0.09
		27	*p*	0.5998	0.2733	**0.0646**	0.2551	0.6435	0.2995	**0.1864**	0.6672
	2002	39	Corr	**-0.22**	**-0.31**	0.16	**-0.22**	-0.07	**-0.25**	-0.13	**-0.30**
		39	*p*	**0.1720**	**0.0587**	0.3379	**0.1789**	0.6863	**0.1316**	0.4318	**0.0611**
	2003	30	Corr	**-0.32**	**-0.41**	**0.37**	**-0.39**	-0.07	**-0.37**	-0.13	**-0.32**
		30	*p*	**0.0876**	**0.0232**	**0.0415**	**0.0309**	0.7232	**0.0465**	0.4988	**0.0857**

[1] See Table 1 for description of metric codes.

Table D1.b. Response of marsh bird richness, by guild, to the 1 km disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Value	RAER	RNAER	RWATER	RGEN	RONS	ROS	RIND	RTOT
High	1995	37	Corr	**0.25**	0.08	**0.30**	-0.04	-0.11	**-0.38**	**-0.29**	0.13
		37	*p*	**0.1423**	0.6218	**0.0668**	0.8108	0.4980	**0.0212**	**0.0800**	0.4530
	1996	46	Corr	**-0.22**	**-0.27**	**0.30**	**-0.30**	-0.03	**-0.36**	**-0.21**	**-0.22**
		46	*p*	**0.1375**	**0.0689**	**0.0460**	**0.0447**	0.8317	**0.0155**	**0.1518**	**0.1355**
	1997	37	Corr	0.08	**-0.24**	**0.38**	-0.21	-0.04	**-0.46**	**-0.34**	-0.12
		37	*p*	0.6382	**0.1570**	**0.0199**	0.2064	0.8045	**0.0046**	**0.0405**	0.4883
	1998	32	Corr	-0.23	-0.13	**0.40**	-0.05	0.02	-0.19	-0.15	0.00
		32	*p*	0.2113	0.4790	**0.0239**	0.7733	0.9333	0.2922	0.4213	0.9976
Low	1999	38	Corr	-0.08	0.01	**0.42**	0.07	-0.05	-0.14	-0.16	0.08
		38	*p*	0.6392	0.9657	**0.0091**	0.6914	0.7730	0.4150	0.3342	0.6410
	2000	32	Corr	-0.21	**-0.28**	0.03	-0.16	0.00	-0.17	0.01	-0.19
		32	*p*	0.2381	**0.1194**	0.8711	0.3703	0.9909	0.3426	0.9706	0.3065
	2001	27	Corr	0.13	-0.22	**0.35**	**-0.26**	-0.06	-0.19	-0.23	-0.08
		27	*p*	0.5312	0.2782	**0.0768**	**0.1970**	0.7624	0.3497	0.2400	0.6827
	2002	39	Corr	**-0.23**	**-0.28**	0.14	**-0.22**	-0.05	**-0.21**	-0.12	**-0.28**
		39	*p*	**0.1646**	**0.0867**	0.3852	**0.1741**	0.7617	**0.1945**	0.4534	**0.0796**
	2003	30	Corr	**-0.31**	**-0.42**	**0.34**	**-0.43**	-0.04	**-0.33**	-0.10	**-0.34**
		30	*p*	**0.0958**	**0.0225**	**0.0683**	**0.0184**	0.8331	**0.0738**	0.6152	**0.0629**

[1] See Table 1 for description of metric codes.

Table D1.c.. Response of marsh bird richness, by guild, to the 20 km disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at p = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Value	RAER	RNAER	RWATER	RGEN	RONS	ROS	RIND	RTOT
High	1995	37	Corr	**0.39**	**0.30**	**0.44**	0.21	-0.15	-0.16	-0.14	**0.34**
		37	*p*	**0.0170**	**0.0672**	**0.0067**	0.2096	0.3725	0.3492	0.4163	**0.0420**
	1996	46	Corr	-0.18	-0.12	**0.25**	**-0.20**	0.03	**-0.25**	-0.10	-0.11
		46	*p*	0.2213	0.4109	**0.0988**	**0.1800**	0.8314	**0.0970**	0.5215	0.4762
	1997	37	Corr	0.08	-0.17	**0.43**	-0.10	-0.04	**-0.26**	-0.17	-0.02
		37	*p*	0.6365	0.3239	**0.0083**	0.5467	0.8105	**0.1266**	0.3234	0.9251
	1998	32	Corr	-0.16	0.08	**0.49**	0.18	-0.05	-0.10	-0.08	0.17
		32	*p*	0.3830	0.6659	**0.0046**	0.3141	0.8001	0.5888	0.6621	0.3631
Low	1999	38	Corr	-0.02	0.11	**0.35**	**0.25**	-0.16	-0.12	-0.21	0.16
		38	*p*	0.9249	0.5022	**0.0309**	**0.1238**	0.3422	0.4701	0.2162	0.3447
	2000	32	Corr	-0.16	-0.10	0.09	0.01	**-0.27**	-0.17	-0.19	-0.07
		32	*p*	0.3708	0.5824	0.6203	0.9706	**0.1391**	0.3524	0.2927	0.7211
	2001	27	Corr	0.10	-0.03	**0.47**	0.01	**-0.31**	**-0.26**	**-0.43**	0.03
		27	*p*	0.6259	0.8774	**0.0138**	0.9662	**0.1171**	**0.1951**	**0.0240**	0.8882
	2002	39	Corr	-0.16	-0.10	**0.28**	0.03	0.02	**-0.31**	-0.14	-0.12
		39	*p*	0.3243	0.5359	**0.0842**	0.8486	0.9256	**0.0536**	0.3788	0.4834
	2003	30	Corr	-0.12	-0.14	**0.44**	-0.14	-0.05	-0.20	-0.12	-0.05
		30	*p*	0.5315	0.4696	**0.0161**	0.4535	0.7745	0.2837	0.5129	0.7973

[1] See Table 1 for description of metric codes.

Table D1.d. Response of marsh bird richness, by guild, to the watershed scale disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at p = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Value	RAER	RNAER	RWATER	RGEN	RONS	ROS	RIND	RTOT
High	1995	37	Corr	**0.40**	**0.38**	**0.39**	**0.34**	-0.10	-0.18	-0.11	**0.41**
		37	*p*	**0.0155**	**0.0215**	**0.0164**	**0.0405**	0.5449	0.2902	0.5066	**0.0116**
	1996	46	Corr	0.01	-0.07	0.07	-0.15	0.10	-0.19	-0.08	-0.03
		46	*p*	0.9647	0.6457	0.6464	0.3190	0.5006	0.2104	0.6203	0.8235
	1997	37	Corr	-0.02	-0.22	**0.29**	-0.13	-0.19	**-0.31**	**-0.29**	-0.10
		37	*p*	0.8905	0.2008	**0.0774**	0.4605	0.2720	**0.0645**	**0.0843**	0.5596
	1998	32	Corr	-0.14	0.01	**0.40**	0.11	-0.14	**-0.41**	**-0.35**	0.03
		32	*p*	0.4396	0.9689	**0.0223**	0.5452	0.4506	**0.0198**	**0.0498**	0.8581
Low	1999	38	Corr	0.00	0.10	-0.01	0.18	**-0.22**	-0.14	-0.20	0.11
		38	*p*	0.9870	0.5416	0.9542	0.2751	**0.1939**	0.3921	0.2384	0.5291
	2000	32	Corr	-0.01	0.02	0.16	0.06	-0.22	-0.17	-0.22	0.10
		32	*p*	0.9557	0.8993	0.3681	0.7549	0.2293	0.3433	0.2224	0.5774
	2001	27	Corr	**0.26**	0.12	**0.32**	0.15	**-0.28**	-0.18	**-0.41**	0.19
		27	*p*	**0.1862**	0.5513	**0.1047**	0.4565	**0.1606**	0.3642	**0.0334**	0.3549
	2002	39	Corr	0.01	-0.02	0.16	0.07	**0.23**	**-0.40**	0.09	0.06
		39	*p*	0.9315	0.9183	0.3427	0.6876	**0.1672**	**0.0107**	0.5677	0.7193
	2003	30	Corr	0.10	-0.14	**0.46**	-0.12	-0.12	-0.04	-0.11	0.06
		30	*p*	0.5850	0.4598	**0.0106**	0.5216	0.5402	0.8511	0.5797	0.7637

[1] See Table 1 for description of metric codes.

Table D1.e. Response of marsh bird richness, by guild, to the overall rank sum disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Value	RAER	RNAER	RWATER	RGEN	RONS	ROS	RIND	RTOT
High	1995	37	Corr	**0.39**	**0.28**	**0.42**	0.18	-0.10	**-0.32**	**-0.22**	**0.32**
		37	*p*	**0.0164**	**0.0963**	**0.0091**	0.2980	0.5501	**0.0534**	**0.1977**	**0.0523**
	1996	46	Corr	-0.18	**-0.21**	**0.28**	**-0.26**	0.01	**-0.31**	-0.17	-0.16
		46	*p*	0.2243	**0.1717**	**0.0600**	**0.0800**	0.9466	**0.0383**	0.2571	0.2994
	1997	37	Corr	0.05	-0.20	**0.41**	-0.16	-0.06	**-0.42**	**-0.32**	-0.07
		37	*p*	0.7503	0.2465	**0.0123**	0.3424	0.7225	**0.0099**	**0.0500**	0.6685
	1998	32	Corr	-0.15	-0.02	**0.46**	0.05	-0.04	-0.22	-0.18	0.10
		32	*p*	0.4025	0.9151	**0.0084**	0.7825	0.8396	0.2288	0.3161	0.5934
Low	1999	38	Corr	-0.05	0.06	**0.35**	0.16	-0.14	-0.17	**-0.22**	0.12
		38	*p*	0.7677	0.7407	**0.0334**	0.3420	0.4019	0.3165	**0.1833**	0.4847
	2000	32	Corr	-0.18	-0.19	0.11	-0.07	-0.16	**-0.23**	-0.14	-0.10
		32	*p*	0.3222	0.2895	0.5654	0.7107	0.3967	**0.1979**	0.4558	0.5837
	2001	27	Corr	0.14	-0.12	**0.45**	-0.09	-0.20	-0.24	**-0.35**	0.01
		27	*p*	0.4894	0.5491	**0.0200**	0.6528	0.3254	0.2373	**0.0731**	0.9675
	2002	39	Corr	**-0.21**	**-0.22**	0.20	-0.14	0.08	**-0.29**	-0.04	-0.20
		39	*p*	**0.1991**	**0.1740**	0.2291	0.3882	0.6484	**0.0766**	0.7961	0.2298
	2003	30	Corr	-0.16	**-0.32**	**0.45**	**-0.31**	-0.03	**-0.25**	-0.09	-0.18
		30	*p*	0.4114	**0.0897**	**0.0128**	**0.0931**	0.8703	**0.1821**	0.6206	0.3491

[1] See Table 1 for description of metric codes.

Table D2.a. Response of marsh bird relative percent abundance, by guild, to the 500 m disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Scale	AAER	ANAER	AWATER	AGEN	AONS	AOS	AIND	ABIT	ARAIL	ATERN	ATOT
High	1995	37	Corr	0.13	-0.14	**0.39**	0.02	**-0.22**	**-0.65**	**-0.43**	**-0.26**	**-0.29**	**-0.41**	0.03
		37	*p*	0.4453	0.4160	**0.0168**	0.9074	**0.1997**	**<.0001**	**0.0080**	**0.1173**	**0.0825**	**0.0125**	0.8510
	1996	46	Corr	-0.08	-0.09	**0.32**	-0.04	-0.03	**-0.39**	**-0.27**	-0.11	-0.08	**-0.21**	**-0.20**
		46	*p*	0.6020	0.5741	**0.0278**	0.8131	0.8674	**0.0076**	**0.0680**	0.4797	0.5824	**0.1646**	**0.1906**
	1997	37	Corr	0.09	-0.14	**0.32**	-0.14	-0.10	**-0.56**	**-0.43**	**-0.50**	**-0.42**	**-0.31**	**0.25**
		37	*p*	0.6017	0.4089	**0.0502**	0.4001	0.5491	**0.0003**	**0.0087**	**0.0016**	**0.0097**	**0.0604**	**0.1436**
	1998	32	Corr	-0.20	0.01	**0.26**	0.10	-0.17	**-0.32**	**-0.29**	**-0.36**	-0.01	**-0.28**	-0.21
		32	*p*	0.2621	0.9452	**0.1436**	0.5773	0.3479	**0.0788**	**0.1039**	**0.0458**	0.9545	**0.1255**	0.2479
Low	1999	38	Corr	-0.09	-0.07	**0.40**	-0.03	-0.15	**-0.36**	**-0.28**	0.03	-0.07	**-0.44**	0.13
		38	*p*	0.5817	0.6636	**0.0117**	0.8741	0.3652	**0.0258**	**0.0943**	0.8746	0.6827	**0.0056**	0.4284
	2000	32	Corr	-0.16	0.07	0.00	0.21	-0.02	-0.23	-0.10	-0.12	0.02	**-0.31**	-0.23
		32	*p*	0.3938	0.7055	0.9786	0.2583	0.9048	0.2011	0.5947	0.4965	0.9261	**0.0803**	0.2071
	2001	27	Corr	0.09	-0.16	**0.32**	0.02	-0.12	**-0.27**	**-0.27**	-0.25	0.04	**-0.43**	0.00
		27	*p*	0.6716	0.4227	**0.1090**	0.9398	0.5515	**0.1730**	**0.1665**	0.2180	0.8457	**0.0257**	0.9855
	2002	39	Corr	0.07	-0.03	0.13	-0.03	-0.14	-0.19	**-0.22**	-0.18	0.02	**-0.31**	-0.11
		39	*p*	0.6655	0.8371	0.4161	0.8429	0.3909	0.2511	**0.1871**	0.2730	0.9018	**0.0559**	0.5180
	2003	30	Corr	**-0.30**	-0.15	**0.39**	0.04	-0.16	**-0.46**	-0.10	-0.19	0.15	-0.20	-0.17
		30	*p*	**0.1030**	0.4310	**0.0332**	0.8482	0.3860	**0.0107**	0.6092	0.3209	0.4442	0.2800	0.3761

[1] See Table 1 for description of metric codes.

Table D2.b. Response of marsh bird relative percent abundance, by guild, to the 1 km disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at p = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Scale	AAER	ANAER	AWATER	AGEN	AONS	AOS	AIND	ABIT	ARAIL	ATERN	ATOT
High	1995	37	Corr	0.18	-0.18	**0.32**	-0.03	**-0.22**	**-0.61**	**-0.42**	**-0.24**	**-0.23**	**-0.39**	0.02
		37	*p*	0.2813	0.2826	**0.0530**	0.8804	**0.1931**	**<.0001**	**0.0098**	**0.1472**	**0.1765**	**0.0165**	0.9281
	1996	46	Corr	-0.10	-0.07	**0.31**	-0.03	-0.01	**-0.41**	**-0.26**	-0.13	-0.08	-0.19	-0.19
		46	*p*	0.5090	0.6477	**0.0358**	0.8569	0.9225	**0.0047**	**0.0819**	0.3921	0.6159	0.2109	0.2059
	1997	37	Corr	0.13	-0.20	**0.36**	-0.21	-0.11	**-0.51**	**-0.38**	**-0.55**	**-0.37**	**-0.23**	**0.24**
		37	*p*	0.4526	0.2285	**0.0271**	0.2217	0.5218	**0.0011**	**0.0219**	**0.0004**	**0.0246**	**0.1718**	**0.1566**
	1998	32	Corr	-0.17	-0.03	**0.34**	0.08	-0.19	**-0.26**	**-0.29**	**-0.34**	0.08	**-0.29**	-0.21
		32	*p*	0.3504	0.8726	**0.0562**	0.6536	0.2911	**0.1587**	**0.1073**	**0.0535**	0.6526	**0.1077**	0.2506
Low	1999	38	Corr	-0.08	-0.08	**0.38**	-0.04	-0.15	**-0.31**	**-0.27**	0.10	-0.03	**-0.46**	0.15
		38	*p*	0.6391	0.6284	**0.0200**	0.7911	0.3791	**0.0550**	**0.1056**	0.5641	0.8682	**0.0037**	0.3764
	2000	32	Corr	-0.18	0.08	0.00	0.19	-0.02	-0.18	-0.07	-0.12	0.04	**-0.26**	-0.21
		32	*p*	0.3345	0.6564	0.9852	0.2875	0.9198	0.3369	0.7162	0.5217	0.8167	**0.1533**	0.2568
	2001	27	Corr	0.07	-0.13	**0.30**	-0.01	-0.09	-0.23	-0.24	**-0.26**	0.08	**-0.36**	-0.01
		27	*p*	0.7404	0.5061	**0.1248**	0.9506	0.6469	0.2524	0.2376	**0.1834**	0.7008	**0.0679**	0.9458
	2002	39	Corr	0.04	-0.02	0.12	-0.04	-0.11	-0.16	-0.20	-0.20	0.05	**-0.32**	-0.10
		39	*p*	0.8100	0.8954	0.4533	0.8300	0.5152	0.3204	0.2329	0.2191	0.7556	**0.0479**	0.5448
	2003	30	Corr	**-0.28**	-0.12	**0.35**	0.00	-0.13	**-0.42**	-0.07	-0.19	0.19	-0.18	-0.16
		30	*p*	**0.1383**	0.5217	**0.0552**	0.9823	0.4810	**0.0205**	0.7208	0.3277	0.3194	0.3347	0.4090

[1] See Table 1 for description of metric codes.

Table D2.c. Response of marsh bird relative percent abundance, by guild, to the 20 km disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at p = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Scale	AAER	ANAER	AWATER	AGEN	AONS	AOS	AIND	ABIT	ARAIL	ATERN	ATOT
High	1995	37	Corr	0.14	-0.20	**0.47**	0.01	**-0.26**	**-0.35**	**-0.26**	-0.03	0.03	-0.20	0.14
		37	*p*	0.4203	0.2283	**0.0033**	0.9434	**0.1167**	**0.0312**	**0.1150**	0.8435	0.8633	0.2310	0.4049
	1996	46	Corr	-0.14	-0.08	**0.25**	-0.06	0.04	**-0.26**	-0.19	-0.07	-0.08	-0.06	-0.17
		46	*p*	0.3590	0.6023	**0.0958**	0.6707	0.7711	**0.0760**	0.2091	0.6214	0.5885	0.6735	0.2621
	1997	37	Corr	0.02	-0.20	**0.41**	-0.14	-0.07	**-0.31**	**-0.24**	**-0.37**	-0.20	-0.04	0.09
		37	*p*	0.9185	0.2272	**0.0107**	0.4037	0.7011	**0.0654**	**0.1544**	**0.0249**	0.2353	0.8174	0.5813
	1998	32	Corr	-0.17	-0.01	**0.44**	**0.32**	**-0.26**	-0.20	**-0.34**	-0.22	0.15	**-0.25**	-0.13
		32	*p*	0.3583	0.9397	**0.0122**	**0.0759**	**0.1524**	0.2684	**0.0543**	0.2170	0.4085	**0.1723**	0.4659
Low	1999	38	Corr	**-0.22**	0.09	**0.27**	**0.26**	**-0.35**	**-0.27**	**-0.43**	0.17	-0.04	**-0.26**	0.18
		38	*p*	**0.1768**	0.5790	**0.0951**	**0.1081**	**0.0336**	**0.0954**	**0.0070**	0.3085	0.8199	**0.1083**	0.2828
	2000	32	Corr	**-0.28**	0.20	-0.01	**0.30**	**-0.29**	-0.17	**-0.32**	-0.14	-0.01	-0.13	-0.13
		32	*p*	**0.1274**	0.2750	0.9683	**0.0963**	**0.1100**	0.3516	**0.0763**	0.4591	0.9580	0.4744	0.4614
	2001	27	Corr	**-0.26**	0.20	**0.41**	**0.37**	**-0.32**	**-0.31**	**-0.40**	**-0.37**	0.00	**-0.36**	-0.02
		27	*p*	**0.1846**	0.3074	**0.0315**	**0.0596**	**0.0990**	**0.1190**	**0.0372**	**0.0595**	0.9885	**0.0654**	0.9373
	2002	39	Corr	-0.12	0.06	**0.26**	0.06	-0.01	**-0.28**	**-0.24**	**-0.34**	0.07	**-0.45**	-0.12
		39	*p*	0.4535	0.6979	**0.1089**	0.7378	0.9321	**0.0856**	**0.1416**	**0.0351**	0.6576	**0.0038**	0.4805
	2003	30	Corr	**-0.31**	-0.03	**0.44**	-0.01	-0.15	**-0.26**	-0.10	**-0.25**	**0.24**	**-0.25**	-0.07
		30	*p*	**0.0986**	0.8665	**0.0144**	0.9684	0.4324	**0.1588**	0.5877	**0.1907**	**0.1934**	**0.1887**	0.6941

[1] See Table 1 for description of metric codes.

Table D2.d. Response of marsh bird relative percent abundance, by guild, to the watershed scale disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Scale	AAER	ANAER	AWATER	AGEN	AONS	AOS	AIND	ABIT	ARAIL	ATERN	ATOT
High	1995	37	Corr	0.12	-0.17	**0.45**	0.12201	-0.16	**-0.35**	**-0.23**	0.00	-0.05	-0.07	**0.29**
		37	*p*	0.4833	0.3247	**0.0052**	0.4719	0.3391	**0.0320**	**0.1765**	0.9861	0.7884	0.6965	**0.0771**
	1996	46	Corr	-0.05	-0.03	0.12	-0.1582	0.16	**-0.20**	-0.14	-0.02	-0.14	0.06	-0.06
		46	*p*	0.7616	0.8245	0.4454	0.2937	0.2764	**0.1844**	0.3373	0.8760	0.3496	0.7105	0.6882
	1997	37	Corr	0.10	-0.17	**0.29**	-0.149	-0.14	**-0.28**	**-0.29**	**-0.29**	**-0.35**	-0.01	0.10
		37	*p*	0.5445	0.3079	**0.0824**	0.3788	0.4252	**0.0935**	**0.0773**	**0.0818**	**0.0333**	0.9350	0.5709
	1998	32	Corr	-0.06	-0.07	**0.37**	0.22569	**-0.24**	**-0.39**	**-0.38**	**-0.33**	-0.08	**-0.36**	-0.19
		32	*p*	0.7446	0.7220	**0.0377**	0.2142	**0.1905**	**0.0279**	**0.0309**	**0.0688**	0.6811	**0.0424**	0.2918
Low	1999	38	Corr	-0.17	0.16	-0.06	0.14	**-0.27**	**-0.28**	**-0.33**	-0.02	-0.09	**-0.29**	**0.22**
		38	*p*	0.3153	0.3441	0.7098	0.4116	**0.0994**	**0.0912**	**0.0463**	0.9227	0.5917	**0.0818**	**0.1797**
	2000	32	Corr	-0.12	0.10	0.04	0.05	**-0.28**	-0.15	**-0.31**	-0.22	-0.22	0.04	0.12
		32	*p*	0.4956	0.5829	0.8295	0.7987	**0.1268**	0.4101	**0.0881**	0.2349	0.2371	0.8257	0.5287
	2001	27	Corr	-0.16	0.14	0.25	0.15	**-0.34**	-0.20	**-0.32**	**-0.38**	0.00	-0.16	0.24
		27	*p*	0.4215	0.4732	0.2131	0.4534	**0.0837**	0.3053	**0.1073**	**0.0502**	0.9993	0.4275	0.2369
	2002	39	Corr	0.12	**-0.21**	0.11	**-0.29**	0.14	**-0.46**	-0.01	-0.19	0.03	**-0.34**	0.20
		39	*p*	0.4791	**0.1893**	0.4898	**0.0726**	0.3860	**0.0034**	0.9427	0.2390	0.8685	**0.0330**	0.2129
	2003	30	Corr	-0.03	**-0.31**	**0.45**	**-0.25**	-0.16	-0.13	-0.09	**-0.30**	**0.31**	-0.13	0.01
		30	*p*	0.8741	**0.0916**	**0.0133**	**0.1825**	0.3940	0.4801	0.6315	**0.1032**	**0.0923**	0.4953	0.9504

[1] See Table 1 for description of metric codes.

Table D2.e. Response of marsh bird relative percent abundance, by guild, to the overall rank sum disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Scale	AAER	ANAER	AWATER	AGEN	AONS	AOS	AIND	ABIT	ARAIL	ATERN	ATOT
High	1995	37	Corr	0.17	-0.20	**0.45**	0.04	**-0.22**	**-0.58**	**-0.36**	-0.17	-0.18	**-0.29**	0.18
		37	*p*	0.3207	0.2399	**0.0051**	0.8106	**0.1829**	**0.0002**	**0.0269**	0.3277	0.2925	**0.0859**	0.2982
	1996	46	Corr	-0.07	-0.11	**0.30**	-0.12	0.02	**-0.35**	**-0.26**	-0.08	-0.10	-0.13	-0.15
		46	*p*	0.6378	0.4786	**0.0415**	0.4305	0.8764	**0.0162**	**0.0859**	0.6189	0.5255	0.3784	0.3218
	1997	37	Corr	0.09	-0.21	**0.40**	-0.19	-0.11	**-0.46**	**-0.37**	**-0.51**	**-0.37**	-0.14	0.21
		37	*p*	0.6052	0.2169	**0.0144**	0.2701	0.5182	**0.0042**	**0.0254**	**0.0012**	**0.0238**	0.4142	0.2181
	1998	32	Corr	-0.18	-0.05	**0.41**	0.15	**-0.25**	**-0.26**	**-0.36**	**-0.37**	0.05	**-0.28**	-0.16
		32	*p*	0.3348	0.8033	**0.0207**	0.3973	**0.1726**	**0.1541**	**0.0445**	**0.0386**	0.7792	**0.1177**	0.3816
Low	1999	38	Corr	-0.17	0.04	**0.29**	0.10	**-0.27**	**-0.33**	**-0.37**	0.07	-0.06	**-0.41**	**0.19**
		38	*p*	0.2946	0.8047	**0.0748**	0.5467	**0.1037**	**0.0432**	**0.0226**	0.6677	0.7355	**0.0096**	**0.2516**
	2000	32	Corr	-0.20	0.10	0.03	0.21	-0.18	**-0.24**	**-0.23**	-0.18	-0.07	-0.18	-0.12
		32	*p*	0.2675	0.6038	0.8520	0.2494	0.3318	**0.1947**	**0.1975**	0.3164	0.7053	0.3245	0.5271
	2001	27	Corr	-0.10	-0.04	**0.40**	0.15	-0.24	**-0.28**	**-0.34**	**-0.34**	0.03	**-0.36**	0.06
		27	*p*	0.6343	0.8549	**0.0414**	0.4555	0.2365	**0.1522**	**0.0784**	**0.0848**	0.8840	**0.0628**	0.7588
	2002	39	Corr	-0.01	-0.05	0.18	-0.09	0.03	**-0.28**	-0.13	**-0.21**	0.07	**-0.40**	-0.04
		39	*p*	0.9434	0.7816	0.2842	0.5687	0.8781	**0.0824**	0.4152	**0.1955**	0.6667	**0.0121**	0.7988
	2003	30	Corr	-0.22	-0.19	**0.46**	-0.07	-0.14	**-0.34**	-0.07	**-0.26**	**0.25**	-0.20	-0.08
		30	*p*	0.2321	0.3227	**0.0108**	0.7120	0.4539	**0.0656**	0.7186	**0.1678**	**0.1911**	0.2800	0.6739

[1] See Table 1 for description of metric codes.

Table D3.a. Standardized marsh bird metrics and IBIs calculated for 500 m and 1 km buffers around Great Lakes coastal wetlands during high average water levels (1995-1998).

Wetland	Stations	RWATER	ROS	AWATER	AOS	ABIT	ATERN	IBI
WhRi	1	10.00	10.00	10.00	2.08	5.00	0.00	61.81
Wye	8	7.92	9.22	8.86	5.05	1.34	4.00	60.65
LCat	6	7.50	7.92	7.69	5.77	0.00	5.33	57.01
Allo	9	8.75	7.19	9.36	5.08	0.68	2.99	56.75
LP1	19	9.80	5.53	9.81	4.16	1.74	1.99	55.04
Saw1	6	10.00	3.75	10.00	8.89	0.00	0.00	54.40
BIsl	8	10.00	5.16	10.00	3.04	3.30	0.84	53.90
RPP1	14	8.84	6.82	9.09	3.13	2.81	1.58	53.78
BPond	6	9.51	5.83	9.68	2.88	1.83	2.43	53.61
SuRA	9	8.18	6.02	9.19	4.18	1.11	2.59	52.11
Bles2	4	10.00	4.69	10.00	6.00	0.00	0.00	51.14
LP2	7	10.00	4.92	10.00	2.20	3.18	0.27	50.95
Saw7	11	9.55	4.09	9.09	7.13	0.00	0.00	49.76
HIA	16	7.19	5.75	7.54	3.10	0.63	4.63	48.06
PP2	17	9.75	4.62	9.87	1.87	0.76	1.62	47.48
UCMBS2	3	10.00	5.00	10.00	3.11	0.00	0.00	46.85
BuIsl	8	10.00	3.49	10.00	4.60	0.00	0.00	46.81
OshSc	6	8.13	6.29	8.58	3.24	0.21	1.38	46.37
Carr	4	7.92	7.93	7.31	4.20	0.00	0.00	45.59
Snak	2	7.50	7.50	8.41	3.79	0.00	0.00	45.34
LPW1	3	9.58	3.28	9.84	1.80	2.40	0.00	44.84
Musk	6	10.00	3.01	10.00	1.09	1.02	0.29	42.36
EaB	6	9.17	4.38	9.74	1.15	0.96	0.00	42.33
CPNWR	7	7.86	6.09	7.88	1.67	1.80	0.00	42.16
LSC	14	9.17	3.85	8.26	2.82	0.00	1.15	42.08
GRM	10	9.25	3.12	9.19	2.80	0.85	0.00	42.01
Iron	3	8.61	5.00	8.57	2.92	0.00	0.00	41.84
LP3	7	9.76	2.66	9.85	1.57	0.84	0.00	41.13

[1] See Table 1 for description of marsh bird metrics.

Table D3.a. Continued…

Wetland	Stations	RWATER	ROS	AWATER	AOS	ABIT	ATERN	IBI
Ind	5	10.00	2.95	10.00	1.44	0.00	0.00	40.66
BlCre	9	8.33	4.74	9.49	1.54	0.00	0.14	40.40
Duff	6	9.58	3.14	9.80	1.64	0.00	0.00	40.27
Alg	5	10.00	2.84	10.00	1.31	0.00	0.00	40.25
Round	5	8.92	3.13	8.22	2.70	0.00	0.12	38.47
LP5	7	10.00	1.02	10.00	0.57	0.95	0.23	37.94
VanW	5	10.00	1.31	10.00	1.09	0.00	0.00	37.33
Rusc	3	10.00	1.09	10.00	1.16	0.00	0.00	37.09
Coot1	5	8.00	3.45	8.27	0.99	0.64	0.00	35.57
CRM	3	9.17	1.64	9.11	1.24	0.00	0.00	35.26
Char4	13	5.91	5.58	6.83	1.80	0.86	0.00	34.96
Bouv	5	9.00	1.31	9.72	0.57	0.00	0.00	34.33
SodB	5	7.00	3.50	5.87	2.21	2.00	0.00	34.31
RB3	6	5.83	3.28	6.23	0.85	3.33	0.29	33.04
Metz	8	9.38	0.41	9.83	0.18	0.00	0.00	33.00
MonCA	7	9.29	0.47	9.73	0.15	0.00	0.00	32.73
Ment	8	8.33	1.78	8.67	0.36	0.00	0.00	31.90
Pen2	4	8.75	0.94	9.09	0.29	0.00	0.00	31.77
Tusc	3	9.44	0.00	9.00	0.00	0.00	0.00	30.75
Bell2	4	8.75	0.00	9.19	0.00	0.00	0.00	29.90
CranM	5	6.00	3.28	6.33	1.44	0.00	0.70	29.59
Ratt	2	0.63	8.28	6.55	0.85	1.03	0.23	29.27
RBG	7	7.68	0.82	8.06	0.23	0.67	0.00	29.11
Fren	4	5.00	3.28	6.16	0.83	0.00	0.44	26.18
Hyd	2	6.25	2.46	6.11	0.64	0.00	0.00	25.77
WBea	3	7.22	0.36	6.36	0.03	0.00	0.00	23.30
Roug	1	5.00	3.28	3.08	1.85	0.00	0.00	22.02
IBSP1	10	5.44	0.98	5.42	0.18	0.61	0.00	21.04
Humb	3	3.33	0.55	2.86	0.16	0.00	0.00	11.50

Table D3.b. Standardized marsh bird metrics and IBIs calculated for the 20 km buffer and watershed of Great Lakes coastal wetlands during high average water levels (1995-1998).[1]

Wetland	Stations	RWATER	AWATER	AOS	IBI
Saw1	6	10.00	10.00	8.89	96.31
Bles2	4	10.00	10.00	6.00	86.66
Saw7	11	9.55	9.09	7.13	85.88
BuIsl	8	10.00	10.00	4.60	82.00
LP1	19	9.80	9.81	4.16	79.24
Allo	9	8.75	9.36	5.08	77.31
UCMBS2	3	10.00	10.00	3.11	77.03
BIsl	8	10.00	10.00	3.04	76.81
LP2	7	10.00	10.00	2.20	74.01
WhRi	1	10.00	10.00	2.08	73.61
BPond	6	9.51	9.68	2.88	73.60
Wye	8	7.92	8.86	5.05	72.75
SuRA	9	8.18	9.19	4.18	71.85
PP2	17	9.75	9.87	1.87	71.65
Ind	5	10.00	10.00	1.44	71.48
Alg	5	10.00	10.00	1.31	71.02
GRM	10	9.25	9.19	2.80	70.80
LPW1	3	9.58	9.84	1.80	70.73
LP3	7	9.76	9.85	1.57	70.61
Rusc	3	10.00	10.00	1.16	70.53
Musk	6	10.00	10.00	1.09	70.31
VanW	5	10.00	10.00	1.09	70.29
RPP1	14	8.84	9.09	3.13	70.18
Duff	6	9.58	9.80	1.64	70.06
LCat	6	7.50	7.69	5.77	69.86
LP5	7	10.00	10.00	0.57	68.56
LSC	14	9.17	8.26	2.82	67.49
Iron	3	8.61	8.57	2.92	67.00

[1] See Table 1 for description of marsh bird metrics.

Table D3.b. Continued…

Wetland	Stations	RWATER	AWATER	AOS	IBI
EaB	6	9.17	9.74	1.15	66.86
OshSc	6	8.13	8.58	3.24	66.46
Round	5	8.92	8.22	2.70	66.10
Snak	2	7.50	8.41	3.79	65.67
CRM	3	9.17	9.11	1.24	65.05
Carr	4	7.92	7.31	4.20	64.75
Metz	8	9.38	9.83	0.18	64.63
BlCre	9	8.33	9.49	1.54	64.54
Bouv	5	9.00	9.72	0.57	64.29
MonCA	7	9.29	9.73	0.15	63.90
Tusc	3	9.44	9.00	0.00	61.49
Pen2	4	8.75	9.09	0.29	60.42
Bell2	4	8.75	9.19	0.00	59.80
HIA	16	7.19	7.54	3.10	59.42
CPNWR	7	7.86	7.88	1.67	58.01
Ment	8	8.33	8.67	0.36	57.88
Coot1	5	8.00	8.27	0.99	57.53
RBG	7	7.68	8.06	0.23	53.23
SodB	5	7.00	5.87	2.21	50.30
Char4	13	5.91	6.83	1.80	48.47
CranM	5	6.00	6.33	1.44	45.90
WBea	3	7.22	6.36	0.03	45.37
Hyd	2	6.25	6.11	0.64	43.34
RB3	6	5.83	6.23	0.85	43.06
Fren	4	5.00	6.16	0.83	39.95
IBSP1	10	5.44	5.42	0.18	36.77
Roug	1	5.00	3.08	1.85	33.09
Ratt	2	0.63	6.55	0.85	26.75
Humb	3	3.33	2.86	0.16	21.18

Table D3.c. Standardized marsh bird metrics and IBIs calculated for overall rank sum of disturbance around Great Lakes coastal wetlands during high average water levels (1995-1998).[1]

Wetland	Stations	RWATER	ROS	AWATER	AOS	IBI
Saw1	6	10.00	3.75	10.00	8.89	81.61
WhRi	1	10.00	10.00	10.00	2.08	80.21
Wye	8	7.92	9.22	8.86	5.05	77.61
Bles2	4	10.00	4.69	10.00	6.00	76.71
Allo	9	8.75	7.19	9.36	5.08	75.95
Saw7	11	9.55	4.09	9.09	7.13	74.64
LP1	19	9.80	5.53	9.81	4.16	73.25
LCat	6	7.50	7.92	7.69	5.77	72.19
BIsl	8	10.00	5.16	10.00	3.04	70.50
UCMBS2	3	10.00	5.00	10.00	3.11	70.28
BuIsl	8	10.00	3.49	10.00	4.60	70.22
BPond	6	9.51	5.83	9.68	2.88	69.78
RPP1	14	8.84	6.82	9.09	3.13	69.68
SuRA	9	8.18	6.02	9.19	4.18	68.93
Carr	4	7.92	7.93	7.31	4.20	68.38
Snak	2	7.50	7.50	8.41	3.79	68.00
LP2	7	10.00	4.92	10.00	2.20	67.81
OshSc	6	8.13	6.29	8.58	3.24	65.57
PP2	17	9.75	4.62	9.87	1.87	65.28
Iron	3	8.61	5.00	8.57	2.92	62.75
LPW1	3	9.58	3.28	9.84	1.80	61.25
EaB	6	9.17	4.38	9.74	1.15	61.08
Ind	5	10.00	2.95	10.00	1.44	60.99
GRM	10	9.25	3.12	9.19	2.80	60.89
Duff	6	9.58	3.14	9.80	1.64	60.41
Alg	5	10.00	2.84	10.00	1.31	60.38
BlCre	9	8.33	4.74	9.49	1.54	60.26
Musk	6	10.00	3.01	10.00	1.09	60.25

[1] See Table 1 for description of marsh bird metrics.

Table D3.c. Continued...

Wetland	Stations	RWATER	ROS	AWATER	AOS	IBI
LSC	14	9.17	3.85	8.26	2.82	60.24
LP3	7	9.76	2.66	9.85	1.57	59.60
HIA	16	7.19	5.75	7.54	3.10	58.95
CPNWR	7	7.86	6.09	7.88	1.67	58.74
Round	5	8.92	3.13	8.22	2.70	57.39
VanW	5	10.00	1.31	10.00	1.09	56.00
Rusc	3	10.00	1.09	10.00	1.16	55.63
LP5	7	10.00	1.02	10.00	0.57	53.96
CRM	3	9.17	1.64	9.11	1.24	52.89
Coot1	5	8.00	3.45	8.27	0.99	51.76
Bouv	5	9.00	1.31	9.72	0.57	51.50
Char4	13	5.91	5.58	6.83	1.80	50.30
Metz	8	9.38	0.41	9.83	0.18	49.50
MonCA	7	9.29	0.47	9.73	0.15	49.10
Ment	8	8.33	1.78	8.67	0.36	47.85
Pen2	4	8.75	0.94	9.09	0.29	47.66
SodB	5	7.00	3.50	5.87	2.21	46.47
Tusc	3	9.44	0.00	9.00	0.00	46.12
Bell2	4	8.75	0.00	9.19	0.00	44.85
CranM	5	6.00	3.28	6.33	1.44	42.63
RBG	7	7.68	0.82	8.06	0.23	41.97
Ratt	2	0.63	8.28	6.55	0.85	40.76
RB3	6	5.83	3.28	6.23	0.85	40.50
Hyd	2	6.25	2.46	6.11	0.64	38.66
Fren	4	5.00	3.28	6.16	0.83	38.16
WBea	3	7.22	0.36	6.36	0.03	34.94
Roug	1	5.00	3.28	3.08	1.85	33.02
IBSP1	10	5.44	0.98	5.42	0.18	30.04
Humb	3	3.33	0.55	2.86	0.16	17.25

Table D3.d. Standardized marsh bird metrics and IBIs calculated for the 20 km buffer around Great Lakes coastal wetlands during low average water levels (1999-2003).[1]

Wetland	Stations	RWATER	AAER	AOS	ATERN	IBI
Ratt	2	15.00	10.00	1.99	0.00	67.47
ParB2	2	15.00	2.04	7.29	0.00	60.84
Hyd	2	10.00	8.65	0.00	0.00	46.64
CranM	7	11.43	4.44	2.73	0.00	46.48
Wye	8	1.56	4.02	7.62	4.51	44.27
SuRA	6	1.36	7.43	3.10	4.32	40.55
OshSc	7	6.71	2.89	6.21	0.00	39.54
RB3	7	5.71	9.10	0.99	0.00	39.51
Butt2	2	5.00	2.31	4.92	2.84	37.69
Carr	4	2.71	2.95	8.83	0.00	36.20
Bay1	3	6.67	4.11	3.37	0.00	35.36
Fren	5	5.33	6.31	1.23	0.00	32.19
PP2	7	0.00	3.47	4.96	4.39	32.06
Hill	7	3.29	8.21	1.31	0.00	32.01
Bain2	9	1.25	1.54	7.73	2.22	31.86
Round	2	5.00	4.54	3.16	0.00	31.77
LP1	72	0.51	5.08	5.32	1.73	31.60
Iron	3	2.00	6.41	4.05	0.00	31.13
LP4	7	0.00	6.48	2.52	2.86	29.63
BuIsl	8	1.25	2.16	8.31	0.00	29.30
Alg	2	1.00	8.59	2.02	0.00	29.03
SB1	2	0.00	8.67	2.78	0.00	28.62
BIsl	7	0.57	5.17	4.59	1.09	28.54
BCre	3	2.50	6.87	2.02	0.00	28.48
Ment	4	7.50	3.25	0.34	0.00	27.72
LPW1	3	4.00	5.01	1.99	0.00	27.52
CCM	4	2.50	4.49	3.66	0.00	26.62
CPNWR	16	5.63	4.40	0.50	0.00	26.33
Huc1	2	0.00	5.44	5.03	0.00	26.19
Brad	3	0.00	0.00	3.81	6.67	26.18
Roug	2	0.00	5.36	4.98	0.00	25.83
LCat	19	1.75	3.46	3.52	1.56	25.72
Wbea	8	0.00	6.45	3.35	0.00	24.51
HIA	8	4.38	3.46	1.78	0.00	24.02
LP2	49	0.00	5.09	3.74	0.54	23.41
LSC	7	2.14	2.41	1.89	2.88	23.28
LP5	14	0.71	7.48	1.07	0.00	23.18
RPP1	15	2.47	2.73	2.76	1.31	23.17
ONWR	15	5.67	0.91	2.51	0.00	22.72
BPond	6	1.67	2.97	3.66	0.66	22.38
CRM	3	0.00	8.47	0.00	0.00	21.18
OWR	8	3.75	3.08	1.52	0.00	20.89

[1] See Table 1 for description of marsh bird metrics.

Table D3.d. Continued…

Wetland	Stations	RWATER	AAER	AOS	ATERN	IBI
Rusc	3	0.00	5.70	2.58	0.00	20.70
Hay7	3	0.00	3.04	5.13	0.00	20.42
RBG	5	5.20	2.45	0.49	0.00	20.37
LP3	7	0.00	6.15	1.97	0.00	20.30
Robi	2	0.00	3.16	4.92	0.00	20.19
PDar	6	1.67	3.87	2.43	0.00	19.94
Humb	3	6.67	0.93	0.00	0.00	19.00
BB-CP	6	1.67	1.30	4.56	0.00	18.82
Duff	4	0.00	6.40	1.05	0.00	18.63
Musk	6	0.00	3.98	2.16	0.40	16.36
Metz	8	2.50	0.00	4.01	0.00	16.27
Ind	5	1.13	1.87	2.48	0.00	13.70
Coot1	5	1.20	2.14	1.05	0.00	10.97
Coll4	2	0.00	4.21	0.00	0.00	10.53
Lynd	12	0.42	1.31	2.12	0.00	9.60
IBSP1	4	0.00	3.64	0.00	0.00	9.10
GRM	4	0.00	0.91	2.55	0.00	8.65
VanW	5	0.00	1.87	1.56	0.00	8.56
Trem	5	0.00	0.00	0.00	0.00	0.00

APPENDIX E. SUPPLEMENTAL AMPHIBIAN DATA

Table E1.a. Observed response of amphibian richness population metrics to the 500 m buffer disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.

Water Level	Year	N	Scale	RPOOR	RWOOD	RTOL	RNTOL	RRARE	RDECLINE	RIND	RBASIN	RTOT
High	1995	28	Corr	-0.09	**-0.52**	**-0.43**	**-0.31**	-0.13	-0.15	**-0.27**	**-0.36**	**-0.48**
			p	0.6664	**0.0042**	**0.0222**	**0.1142**	0.4977	0.4559	**0.1657**	**0.0637**	**0.0092**
	1996	41	Corr	-0.07	**-0.48**	**-0.36**	**-0.29**	-0.12	-0.08	**-0.27**	-0.20	**-0.39**
			p	0.6416	**0.0015**	**0.0218**	**0.0678**	0.4386	0.5989	**0.0914**	0.2019	**0.0113**
	1997	32	Corr	-0.12	**-0.52**	**-0.52**	-0.05	-0.05	-0.21	**-0.38**	**-0.26**	**-0.49**
			p	0.4975	**0.0023**	**0.0023**	0.7943	0.8035	0.2409	**0.0342**	**0.1485**	**0.0045**
	1998	26	Corr	0.24	**-0.43**	-0.22	0.01	0.04	0.17	-0.12	0.03	-0.21
			p	0.2401	**0.0293**	0.2755	0.9708	0.8596	0.4132	0.5704	0.8891	0.2936
Low	1999	36	Corr	0.17	**-0.28**	-0.07	0.07	0.03	**0.26**	0.11	0.06	0.00
			p	0.3167	**0.0938**	0.6755	0.7037	0.8462	**0.1326**	0.5139	0.7129	0.9917
	2000	28	Corr	0.06	**-0.38**	**-0.26**	0.10	0.01	0.00	0.12	0.03	-0.10
			p	0.7732	**0.0480**	**0.1773**	0.6022	0.9619	0.9856	0.5457	0.8889	0.6138
	2001	27	Corr	**0.26**	**-0.60**	**-0.30**	0.20	0.06	0.22	0.23	-0.15	-0.03
			p	**0.1954**	**0.0010**	**0.1335**	0.3074	0.7747	0.2687	0.2415	0.4404	0.8697
	2002	45	Corr	0.01	**-0.46**	**-0.31**	**-0.25**	-0.07	-0.07	**-0.30**	-0.08	**-0.26**
			p	0.9472	**0.0014**	**0.0414**	**0.0989**	0.6670	0.6594	**0.0471**	0.6220	**0.0865**
	2003	24	Corr	0.02	**-0.56**	**-0.44**	0.07	0.03	-0.03	-0.04	-0.12	-0.16
			p	0.9244	**0.0048**	**0.0321**	0.7607	0.9019	0.8812	0.8425	0.5744	0.4520

[1] See Table 2 for description of metric codes.

Table E1.b. Observed response of amphibian richness population metrics to the 1 km buffer disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.

Water Level	Year	N	Scale	RPOOR	RWOOD	RTOL	RNTOL	RRARE	RDECLINE	RIND	RBASIN	RTOT
High	1995	28	Corr	-0.13	**-0.48**	**-0.40**	**-0.33**	-0.13	-0.16	**-0.29**	**-0.39**	**-0.48**
			p	0.5040	**0.0102**	**0.0366**	**0.0908**	0.5050	0.4144	**0.1338**	**0.0405**	**0.0092**
	1996	40	Corr	-0.05	**-0.43**	**-0.32**	**-0.23**	-0.06	-0.06	**-0.22**	-0.16	**-0.33**
			p	0.7410	**0.0050**	**0.0433**	**0.1429**	0.7019	0.7201	**0.1674**	0.3104	**0.0324**
	1997	32	Corr	-0.11	**-0.53**	**-0.52**	-0.06	-0.05	-0.22	**-0.39**	**-0.25**	**-0.50**
			p	0.5593	**0.0019**	**0.0023**	0.7597	0.7972	0.2204	**0.0279**	**0.1642**	**0.0036**
	1998	26	Corr	0.20	**-0.46**	-0.25	-0.01	0.02	0.14	-0.17	-0.01	-0.26
			p	0.3167	**0.0184**	0.2104	0.9496	0.9359	0.5080	0.4134	0.9696	0.2054
Low	1999	36	Corr	0.13	**-0.29**	-0.09	0.01	-0.01	0.21	0.06	0.02	-0.06
			p	0.4326	**0.0900**	0.6073	0.9396	0.9692	0.2104	0.7386	0.8994	0.7453
	2000	28	Corr	0.03	**-0.42**	**-0.30**	0.06	0.01	-0.04	0.06	0.00	-0.16
			p	0.8724	**0.0270**	**0.1242**	0.7810	0.9720	0.8295	0.7448	0.9835	0.4222
	2001	27	Corr	0.16	**-0.59**	**-0.30**	0.10	**-0.05**	0.12	0.14	-0.24	-0.12
			p	0.4366	**0.0012**	**0.1245**	0.6145	**0.7988**	0.5416	0.4765	0.2292	0.5560
	2002	45	Corr	-0.05	**-0.44**	**-0.31**	**-0.27**	-0.12	**-0.10**	**-0.30**	-0.12	**-0.28**
			p	0.7623	**0.0027**	**0.0371**	**0.0718**	0.4437	**0.5133**	**0.0458**	0.4438	**0.0627**
	2003	24	Corr	-0.04	**-0.59**	**-0.45**	0.00	-0.01	-0.12	-0.08	-0.20	-0.19
			p	0.8399	**0.0025**	**0.0285**	0.9887	0.9569	0.5695	0.7186	0.3414	0.3708

[1] See Table 2 for description of metric codes.

Table E1.c. Observed response of amphibian richness population metrics to the 20 km buffer disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.

Water Level	Year	N	Scale	RPOOR	RWOOD	RTOL	RNTOL	RRARE	RDECLINE	RIND	RBASIN	RTOT
High	1995	28	Corr	-0.01	**-0.28**	-0.19	**-0.31**	-0.23	-0.14	**-0.29**	-0.22	**-0.30**
			p	0.9421	**0.1457**	0.3395	**0.1068**	0.2287	0.4910	**0.1355**	0.2578	**0.1151**
	1996	40	Corr	-0.06	**-0.34**	**-0.35**	**-0.26**	-0.01	-0.10	**-0.35**	-0.15	**-0.38**
			p	0.7179	**0.0277**	**0.0248**	**0.0949**	0.9339	0.5147	**0.0254**	0.3615	**0.0147**
	1997	32	Corr	**-0.23**	**-0.47**	**-0.55**	-0.09	0.05	**-0.35**	**-0.27**	**-0.36**	**-0.50**
			p	**0.1995**	**0.0069**	**0.0012**	0.6430	0.7856	**0.0499**	**0.1395**	**0.0451**	**0.0035**
	1998	26	Corr	0.01	**-0.51**	**-0.36**	-0.05	-0.01	-0.05	-0.11	-0.19	**-0.37**
			p	0.9709	**0.0077**	**0.0692**	0.8014	0.9579	0.7923	0.5836	0.3633	**0.0600**
Low	1999	36	Corr	0.22	**-0.35**	-0.18	0.19	**0.33**	0.21	0.19	0.02	-0.03
			p	0.2040	**0.0346**	0.2967	0.2738	**0.0494**	0.2104	0.2573	0.8988	0.8548
	2000	28	Corr	**0.35**	**-0.31**	-0.14	**0.44**	**0.42**	**0.33**	**0.46**	**0.30**	0.20
			p	**0.0711**	**0.1139**	0.4770	**0.0178**	**0.0275**	**0.0860**	**0.0131**	**0.1164**	0.3148
	2001	27	Corr	0.22	**-0.45**	-0.21	0.19	0.11	0.23	**0.29**	-0.01	0.03
			p	0.2601	**0.0171**	0.3030	0.3305	0.5703	0.2526	**0.1439**	0.9547	0.8858
	2002	45	Corr	-0.14	**-0.38**	**-0.42**	**-0.20**	**-0.12**	-0.19	**-0.35**	-0.19	**-0.32**
			p	0.3760	**0.0107**	**0.0043**	**0.1791**	**0.4173**	0.2049	**0.0201**	0.2051	**0.0321**
	2003	24	Corr	0.04	**-0.49**	**-0.41**	0.02	0.06	-0.04	-0.09	-0.06	-0.19
			p	0.8470	**0.0160**	**0.0490**	0.9160	0.7981	0.8581	0.6921	0.7834	0.3754

[1] See Table 2 for description of metric codes.

Table E1.d. Observed response of amphibian richness population metrics to the watershed scale disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.

Water Level	Year	N	Scale	RPOOR	RWOOD	RTOL	RNTOL	RRARE	RDECLINE	RIND	RBASIN	RTOT
High	1995	28	Corr	0.24	**-0.31**	-0.17	-0.07	0.13	0.15	-0.02	0.07	-0.12
			p	0.2254	**0.1119**	0.3895	0.7362	0.4945	0.4549	0.9043	0.7380	0.5416
	1996	40	Corr	0.02	**-0.46**	**-0.36**	-0.06	0.16	0.03	-0.08	-0.10	**-0.23**
			p	0.8771	**0.0023**	**0.0210**	0.7297	0.3249	0.8311	0.6082	0.5395	**0.1426**
	1997	32	Corr	-0.14	**-0.51**	**-0.56**	0.08	0.19	**-0.24**	-0.01	**-0.29**	**-0.41**
			p	0.4521	**0.0030**	**0.0009**	0.6682	0.2961	**0.1787**	0.9431	**0.1125**	**0.0189**
	1998	26	Corr	0.17	**-0.59**	**-0.35**	0.24	**0.32**	0.24	**0.32**	-0.08	-0.04
			p	0.4197	**0.0014**	**0.0752**	0.2378	**0.1125**	0.2344	**0.1126**	0.7092	0.8283
Low	1999	36	Corr	0.14	**-0.33**	-0.10	0.09	**0.27**	0.21	**0.25**	-0.05	-0.03
			p	0.4175	**0.0475**	0.5459	0.5961	**0.1130**	0.2164	**0.1370**	0.7718	0.8500
	2000	28	Corr	0.17	**-0.28**	-0.04	0.17	**0.28**	0.22	**0.26**	0.16	0.03
			p	0.3917	**0.1564**	0.8241	0.3998	**0.1468**	0.2647	**0.1861**	0.4238	0.8731
	2001	27	Corr	0.19	**-0.51**	-0.07	0.15	0.17	**0.42**	**0.45**	0.04	0.18
			p	0.3308	**0.0066**	0.7441	0.4604	0.3829	**0.0302**	**0.0180**	0.8334	0.3799
	2002	45	Corr	-0.08	**-0.54**	**-0.42**	-0.07	-0.10	-0.11	-0.10	**-0.21**	**-0.24**
			p	0.5998	**0.0001**	**0.0044**	0.6365	0.5224	0.4817	0.5177	**0.1668**	**0.1195**
	2003	24	Corr	0.07	**-0.49**	**-0.29**	0.08	0.12	0.07	0.20	-0.01	-0.07
			p	0.7342	**0.0151**	**0.1629**	0.7215	0.5695	0.7395	0.3486	0.9782	0.7526

[1] See Table 2 for description of metric codes.

Table E1.e. Observed response of amphibian richness population metrics to the overall rank sum disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.

Water Level	Year	N	Scale	RPOOR	RWOOD	RTOL	RNTOL	RRARE	RDECLINE	RIND	RBASIN	RTOT
High	1995	28	Corr	-0.04	**-0.49**	**-0.37**	**-0.32**	-0.13	-0.12	**-0.26**	**-0.31**	**-0.44**
			p	0.8345	**0.0085**	**0.0534**	**0.0953**	0.5218	0.5531	**0.1748**	**0.1096**	**0.0193**
	1996	40	Corr	-0.05	**-0.52**	**-0.40**	**-0.21**	0.00	-0.05	**-0.23**	-0.18	**-0.38**
			p	0.7797	**0.0005**	**0.0088**	**0.1836**	0.9978	0.7495	**0.1526**	0.2700	**0.0146**
	1997	32	Corr	**-0.24**	**-0.61**	**-0.64**	-0.05	0.01	**-0.34**	**-0.28**	**-0.40**	**-0.58**
			p	**0.1954**	**0.0002**	**<.0001**	0.7682	0.9647	**0.0540**	**0.1162**	**0.0228**	**0.0005**
	1998	26	Corr	0.10	**-0.61**	**-0.43**	0.05	0.06	0.05	0.00	-0.16	**-0.30**
			p	0.6431	**0.0010**	**0.0297**	0.8053	0.7659	0.8052	0.9967	0.4294	**0.1342**
Low	1999	36	Corr	0.16	**-0.41**	-0.17	0.11	0.16	**0.22**	0.18	-0.05	-0.08
			p	0.3573	**0.0135**	0.3106	0.5173	0.3608	**0.1956**	0.2895	0.7871	0.6356
	2000	28	Corr	0.14	**-0.46**	**-0.28**	0.24	0.23	0.10	**0.25**	0.09	-0.07
			p	0.4891	**0.0145**	**0.1563**	0.2177	0.2462	0.6102	**0.1912**	0.6400	0.7409
	2001	27	Corr	0.23	**-0.69**	**-0.34**	0.25	0.12	**0.28**	**0.38**	-0.13	0.02
			p	0.2525	**<.0001**	**0.0876**	0.2027	0.5541	**0.1556**	**0.0526**	0.5123	0.9223
	2002	45	Corr	-0.09	**-0.53**	**-0.43**	**-0.22**	-0.13	-0.15	**-0.28**	-0.19	**-0.31**
			p	0.5675	**0.0002**	**0.0028**	**0.1494**	0.3916	0.3367	**0.0597**	0.2145	**0.0374**
	2003	24	Corr	0.06	**-0.60**	**-0.44**	0.05	0.08	-0.02	-0.03	-0.09	-0.16
			p	0.7649	**0.0019**	**0.0333**	0.8123	0.7014	0.9116	0.8872	0.6887	0.4509

[1] See Table 2 for description of metric codes.

Table E2.a. Observed response of amphibian mean maximum calling code metrics to the 500 m buffer disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Scale	MAMTO	MNLFR	MWOFR	MPOOR	MWOOD	MTOL	MNTOL	MRARE	MDECLINE	MIND	MBASIN	MTOT
High	1995	28	Corr	**0.33**	-0.18	-0.07	0.01	**-0.53**	**-0.45**	**-0.30**	-0.17	-0.06	**-0.28**	**-0.41**	**-0.50**
			p	**0.0848**	0.3532	0.7050	0.9415	**0.0035**	**0.0169**	**0.1254**	0.3921	0.7681	**0.1446**	**0.0290**	**0.0069**
	1996	41	Corr	0.12	-0.17	0.04	-0.18	**-0.49**	**-0.44**	**-0.32**	-0.17	-0.15	**-0.28**	**-0.32**	**-0.48**
			p	0.4707	0.2846	0.8205	0.2567	**0.0013**	**0.0044**	**0.0413**	0.3001	0.3428	**0.0716**	**0.0400**	**0.0016**
	1997	32	Corr	-0.15	-0.14	0.18	**-0.27**	**-0.60**	**-0.63**	-0.16	-0.13	**-0.34**	**-0.37**	**-0.51**	**-0.63**
			p	0.4142	0.4369	0.3131	**0.1296**	**0.0003**	**0.0001**	0.3746	0.4667	**0.0556**	**0.0381**	**0.0030**	**0.0001**
	1998	26	Corr	0.18	0.02	0.12	0.13	**-0.52**	**-0.45**	-0.10	-0.01	0.05	-0.10	**-0.31**	**-0.45**
			p	0.3867	0.9093	0.5437	0.5401	**0.0071**	**0.0214**	0.6416	0.9583	0.8131	0.6161	**0.1211**	**0.0213**
Low	1999	36	Corr	0.22	0.03	0.22	0.07	**-0.32**	-0.18	-0.05	-0.02	0.15	0.04	-0.19	-0.21
			p	0.2045	0.8810	0.2004	0.6861	**0.0558**	0.2856	0.7541	0.8996	0.3738	0.7993	0.2784	0.2108
	2000	28	Corr	-0.08	0.05	-0.02	-0.04	**-0.48**	**-0.36**	0.04	-0.08	-0.09	0.09	-0.24	**-0.31**
			p	0.6685	0.8094	0.9204	0.8573	**0.0092**	**0.0613**	0.8582	0.7017	0.6481	0.6599	0.2202	**0.1144**
	2001	27	Corr	0.12	0.08	0.00	0.25	**-0.63**	**-0.33**	0.18	0.07	0.22	0.19	**-0.30**	**-0.28**
			p	0.5588	0.6892	1.0000	0.2047	**0.0004**	**0.0910**	0.3703	0.7267	0.2803	0.3413	**0.1328**	**0.1501**
	2002	45	Corr	**0.20**	-0.05	0.03	-0.05	**-0.41**	**-0.34**	**-0.29**	-0.07	-0.08	**-0.28**	**-0.21**	**-0.28**
			p	**0.1944**	0.7606	0.8446	0.7521	**0.0052**	**0.0216**	**0.0521**	0.6571	0.6138	**0.0622**	**0.1637**	**0.0618**
	2003	24	Corr	**0.29**	0.06	-0.03	0.02	**-0.54**	**-0.40**	0.13	0.03	0.07	0.10	-0.27	-0.22
			p	**0.1751**	0.7737	0.8998	0.9122	**0.0061**	**0.0524**	0.5469	0.8778	0.7511	0.6491	0.2012	0.2965

[1] See Table 2 for description of metric codes.

Table E2.b. Observed response of amphibian mean maximum calling code metrics to the 1 km buffer disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Scale	MAMTO	MNLFR	MWOFR	MPOOR	MWOOD	MTOL	MNTOL	MRARE	MDECLINE	MIND	MBASIN	MTOT
High	1995	28	Corr	**0.30**	-0.19	0.02	-0.04	**-0.45**	**-0.38**	**-0.31**	-0.18	-0.05	**-0.29**	**-0.38**	**-0.45**
			p	**0.1193**	0.3265	0.9290	0.8397	**0.0164**	**0.0477**	**0.1050**	0.3712	0.8096	**0.1414**	**0.0456**	**0.0168**
	1996	41	Corr	0.11	-0.10	0.02	-0.15	**-0.44**	**-0.38**	**-0.27**	-0.10	-0.12	**-0.23**	**-0.26**	**-0.40**
			p	0.4923	0.5253	0.9117	0.3461	**0.0043**	**0.0142**	**0.0923**	0.5454	0.4674	**0.1492**	**0.0979**	**0.0090**
	1997	32	Corr	-0.06	-0.16	**0.24**	**-0.26**	**-0.60**	**-0.62**	-0.19	-0.15	**-0.33**	**-0.38**	**-0.51**	**-0.63**
			p	0.7304	0.3806	**0.1901**	**0.1429**	**0.0003**	**0.0001**	0.3041	0.4106	**0.0666**	**0.0305**	**0.0030**	**<.0001**
	1998	26	Corr	0.23	-0.01	0.14	0.09	**-0.53**	**-0.47**	-0.14	-0.05	0.01	-0.17	**-0.32**	**-0.47**
			p	0.2643	0.9629	0.4991	0.6561	**0.0052**	**0.0145**	0.5052	0.8264	0.9432	0.4161	**0.1080**	**0.0142**
Low	1999	36	Corr	0.19	-0.02	0.21	0.04	**-0.32**	-0.17	-0.11	-0.06	0.14	0.01	-0.21	**-0.23**
			p	0.2780	0.9131	0.2109	0.8100	**0.0602**	0.3186	0.5248	0.7403	0.3999	0.9625	0.2278	**0.1811**
	2000	28	Corr	-0.04	0.04	0.03	-0.05	**-0.51**	**-0.39**	0.00	-0.07	-0.12	0.04	**-0.27**	**-0.36**
			p	0.8504	0.8210	0.8880	0.7964	**0.0057**	**0.0391**	0.9978	0.7396	0.5429	0.8408	**0.1682**	**0.0581**
	2001	27	Corr	0.10	-0.02	0.02	0.17	**-0.64**	**-0.34**	0.08	-0.04	0.14	0.11	**-0.34**	**-0.33**
			p	0.6309	0.9376	0.9338	0.3841	**0.0003**	**0.0791**	0.6954	0.8354	0.4753	0.5920	**0.0802**	**0.0941**
	2002	45	Corr	0.16	-0.08	0.09	-0.07	**-0.39**	**-0.32**	**-0.29**	-0.10	-0.07	**-0.27**	**-0.22**	**-0.26**
			p	0.2931	0.5875	0.5562	0.6300	**0.0087**	**0.0294**	**0.0538**	0.4975	0.6250	**0.0737**	**0.1445**	**0.0849**
	2003	24	Corr	0.25	0.01	-0.10	-0.03	**-0.58**	**-0.39**	0.04	0.00	0.01	0.05	**-0.34**	-0.25
			p	0.2377	0.9448	0.6485	0.9018	**0.0031**	**0.0583**	0.8697	0.9927	0.9799	0.8341	**0.1074**	0.2350

[1] See Table 2 for description of metric codes.

Table E2.c. Observed response of amphibian mean maximum calling code metrics to the 20 km buffer disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Scale	MAMTO	MNLFR	MWOFR	MPOOR	MWOOD	MTOL	MNTOL	MRARE	MDECLINE	MIND	MBASIN	MTOT
High	1995	28	Corr	0.23	**-0.28**	-0.01	-0.06	**-0.30**	**-0.29**	**-0.30**	**-0.28**	-0.16	**-0.29**	**-0.34**	**-0.35**
			p	0.2492	**0.1526**	0.9580	0.7706	**0.1163**	**0.1415**	**0.1181**	**0.1535**	0.4141	**0.1312**	**0.0802**	**0.0696**
	1996	41	Corr	0.19	-0.06	-0.05	-0.17	**-0.35**	**-0.35**	**-0.26**	-0.04	**-0.21**	**-0.31**	**-0.24**	**-0.37**
			p	0.2390	0.7012	0.7470	0.2844	**0.0261**	**0.0239**	**0.1008**	0.8196	**0.1832**	**0.0521**	**0.1250**	**0.0174**
	1997	32	Corr	**-0.25**	-0.08	0.01	**-0.30**	**-0.46**	**-0.60**	-0.14	-0.04	**-0.38**	**-0.26**	**-0.51**	**-0.58**
			p	**0.1607**	0.6782	0.9396	**0.1008**	**0.0087**	**0.0002**	0.4503	0.8098	**0.0340**	**0.1519**	**0.0031**	**0.0005**
	1998	26	Corr	0.22	0.00	0.13	0.03	**-0.49**	**-0.36**	-0.14	-0.01	-0.06	-0.07	**-0.34**	**-0.45**
			p	0.2872	0.9887	0.5282	0.8669	**0.0111**	**0.0697**	0.4838	0.9742	0.7651	0.7311	**0.0867**	**0.0208**
Low	1999	36	Corr	**0.26**	**0.30**	0.02	0.16	**-0.28**	-0.15	0.10	**0.26**	0.15	0.09	-0.07	-0.13
			p	**0.1271**	**0.0768**	0.9110	0.3636	**0.1044**	0.3728	0.5615	**0.1242**	0.3823	0.5995	0.6697	0.4412
	2000	28	Corr	0.19	**0.44**	0.24	**0.25**	**-0.41**	**-0.28**	**0.38**	**0.35**	0.24	**0.34**	-0.01	-0.08
			p	0.3294	**0.0192**	0.2283	**0.1905**	**0.0306**	**0.1427**	**0.0467**	**0.0677**	0.2245	**0.0759**	0.9581	0.6762
	2001	27	Corr	0.21	0.13	**0.41**	0.18	**-0.32**	-0.07	**0.26**	0.17	0.18	**0.29**	-0.06	-0.03
			p	0.2971	0.5162	**0.0344**	0.3637	**0.1029**	0.7203	**0.1858**	0.3937	0.3704	**0.1356**	0.7518	0.8917
	2002	45	Corr	0.07	-0.11	**0.41**	-0.16	**-0.32**	**-0.37**	**-0.21**	-0.11	-0.18	**-0.31**	**-0.29**	**-0.30**
			p	0.6494	0.4717	**0.0052**	0.2954	**0.0310**	**0.0127**	**0.1762**	0.4665	0.2367	**0.0382**	**0.0577**	**0.0462**
	2003	24	Corr	**0.53**	0.06	0.05	0.10	**-0.55**	**-0.52**	0.05	0.06	-0.02	-0.10	-0.24	**-0.33**
			p	**0.0083**	0.7705	0.8299	0.6258	**0.0057**	**0.0100**	0.8002	0.7951	0.9148	0.6454	0.2640	**0.1192**

[1] See Table 2 for description of metric codes.

Table E2.d. Observed response of amphibian mean maximum calling code metrics to the watershed scale disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Scale	MAMTO	MNLFR	MWOFR	MPOOR	MWOOD	MTOL	MNTOL	MRARE	MDECLINE	MIND	MBASIN	MTOT
High	1995	28	Corr	**0.35**	0.05	-0.03	0.14	**-0.25**	-0.17	-0.06	0.07	0.13	-0.03	-0.06	-0.16
			p	**0.0697**	0.8200	0.8883	0.4887	**0.2065**	0.3935	0.7787	0.7050	0.5058	0.8879	0.7435	0.4210
	1996	41	Corr	**0.28**	0.06	-0.11	-0.07	**-0.46**	**-0.35**	-0.07	0.10	-0.01	-0.05	**-0.23**	**-0.29**
			p	**0.0719**	0.6880	0.5074	0.6680	**0.0023**	**0.0270**	0.6626	0.5229	0.9392	0.7582	**0.1469**	**0.0660**
	1997	32	Corr	-0.23	0.09	0.00	-0.21	**-0.53**	**-0.58**	0.02	0.14	-0.19	0.01	**-0.49**	**-0.45**
			p	0.2044	0.6368	0.9985	0.2472	**0.0020**	**0.0005**	0.9319	0.4307	0.3033	0.9566	**0.0041**	**0.0091**
	1998	26	Corr	0.20	0.24	0.03	0.13	**-0.56**	-0.24	0.11	**0.27**	**0.28**	**0.34**	**-0.30**	-0.17
			p	0.3152	0.2282	0.8901	0.5382	**0.0026**	0.2360	0.5818	**0.1906**	**0.1605**	**0.0878**	**0.1352**	0.4187
Low	1999	36	Corr	0.15	**0.25**	-0.12	0.12	**-0.24**	-0.07	0.05	**0.24**	**0.26**	**0.26**	-0.05	-0.06
			p	0.3749	**0.1387**	0.4977	0.4852	**0.1534**	0.6781	0.7530	**0.1517**	**0.1185**	**0.1208**	0.7670	0.7389
	2000	28	Corr	**0.32**	0.22	0.07	0.11	**-0.31**	-0.16	0.11	**0.25**	0.16	0.16	0.00	-0.09
			p	**0.1022**	0.2640	0.7200	0.5680	**0.1129**	0.4269	0.5743	**0.1973**	0.4225	0.4251	0.9839	0.6411
	2001	27	Corr	0.18	0.20	0.09	0.16	**-0.31**	0.06	**0.26**	**0.26**	**0.35**	**0.52**	-0.03	0.16
			p	0.3810	0.3108	0.6719	0.4295	**0.1177**	0.7534	**0.1949**	**0.1897**	**0.0755**	**0.0053**	0.8950	0.4251
	2002	45	Corr	0.15	-0.07	**0.22**	-0.04	**-0.48**	**-0.38**	-0.11	-0.07	0.02	-0.10	**-0.27**	**-0.23**
			p	0.3309	0.6552	**0.1522**	0.7698	**0.0007**	**0.0092**	0.4561	0.6455	0.9000	0.5208	**0.0775**	**0.1222**
	2003	24	Corr	**0.42**	0.12	-0.19	0.05	**-0.55**	**-0.51**	0.13	0.14	-0.05	0.14	-0.25	**-0.32**
			p	**0.0424**	0.5770	0.3753	0.8179	**0.0051**	**0.0100**	0.5417	0.5230	0.8285	0.5258	0.2320	**0.1323**

[1] See Table 2 for description of metric codes.

Table E2.e. Observed response of amphibian mean maximum calling code metrics to the overall rank sum disturbance gradient. Values shown are Spearman correlation coefficients and associated probability value, with bold indicating statistical significance at *p* = 0.20, and shaded areas indicating metrics used in IBI development.[1]

Water Level	Year	N	Scale	MAMTO	MNLFR	MWOFR	MPOOR	MWOOD	MTOL	MNTOL	MRARE	MDECLINE	MIND	MBASIN	MTOT
High	1995	28	Corr	**0.35**	-0.20	-0.07	-0.01	**-0.46**	**-0.39**	**-0.31**	-0.18	-0.06	**-0.27**	**-0.39**	**-0.45**
			p	**0.0660**	0.3075	0.7268	0.9492	**0.0136**	**0.0416**	**0.1097**	0.3521	0.7702	**0.1700**	**0.0419**	**0.0154**
	1996	41	Corr	**0.22**	-0.07	-0.05	-0.16	**-0.52**	**-0.44**	**-0.24**	-0.04	-0.13	**-0.22**	**-0.30**	**-0.44**
			p	**0.1603**	0.6573	0.7539	0.3191	**0.0005**	**0.0040**	**0.1390**	0.7946	0.4220	**0.1711**	**0.0532**	**0.0044**
	1997	32	Corr	**-0.23**	-0.13	0.09	**-0.36**	**-0.65**	**-0.72**	-0.16	-0.09	**-0.38**	**-0.28**	**-0.63**	**-0.69**
			p	**0.1988**	0.4719	0.6254	**0.0432**	**<.0001**	**<.0001**	0.3735	0.6377	**0.0325**	**0.1147**	**<.0001**	**<.0001**
	1998	26	Corr	0.13	0.02	0.05	0.03	**-0.63**	**-0.43**	-0.11	0.01	0.01	0.02	**-0.43**	**-0.45**
			p	0.5111	0.9370	0.8104	0.8656	**0.0006**	**0.0278**	0.5922	0.9517	0.9557	0.9280	**0.0268**	**0.0197**
Low	1999	36	Corr	**0.23**	0.13	0.10	0.08	**-0.38**	-0.21	0.00	0.10	0.16	0.11	-0.20	**-0.23**
			p	**0.1871**	0.4365	0.5497	0.6523	**0.0236**	0.2117	0.9824	0.5541	0.3378	0.5356	0.2393	**0.1754**
	2000	28	Corr	0.09	0.20	0.08	0.04	**-0.55**	**-0.41**	0.17	0.15	0.00	0.17	-0.20	**-0.31**
			p	0.6670	0.2958	0.7016	0.8216	**0.0023**	**0.0299**	0.3968	0.4516	0.9978	0.3965	0.3145	**0.1145**
	2001	27	Corr	0.12	0.14	0.15	0.16	**-0.60**	**-0.29**	**0.28**	0.16	0.21	**0.38**	**-0.29**	-0.18
			p	0.5474	0.4887	0.4560	0.4331	**0.0010**	**0.1488**	**0.1590**	0.4178	0.2952	**0.0483**	**0.1439**	0.3594
	2002	45	Corr	0.15	-0.10	**0.20**	-0.11	**-0.48**	**-0.43**	**-0.26**	-0.11	-0.09	**-0.26**	**-0.30**	**-0.32**
			p	0.3318	0.5272	**0.1816**	0.4768	**0.0009**	**0.0035**	**0.0865**	0.4683	0.5377	**0.0808**	**0.0437**	**0.0332**
	2003	24	Corr	**0.50**	0.09	-0.10	0.06	**-0.65**	**-0.56**	0.09	0.08	-0.04	-0.02	**-0.32**	**-0.36**
			p	**0.0125**	0.6846	0.6438	0.7708	**0.0007**	**0.0040**	0.6837	0.6940	0.8543	0.9259	**0.1305**	**0.0876**

[1] See Table 2 for description of metric codes.

Table E3.a. Standardized amphibian metrics and IBIs calculated for the 500 m, 1 km and 20 km buffers of Great Lakes coastal wetlands during high average water levels (1995-1998). [1]

Wetland	Stations	RWOOD	RIND	RTOT	MWOOD	MBASIN	MIND	MTOT	IBI
Ratt	2	10.00	7.50	10.00	10.00	10.00	9.25	10.00	95.36
Turk	5	7.50	5.78	7.67	6.91	9.23	6.13	8.90	74.45
BIsl	11	8.71	5.91	7.70	6.03	6.62	6.33	7.36	69.53
RB3	6	5.00	9.63	9.75	2.12	6.92	7.56	7.04	68.60
Pres4	5	7.00	8.00	7.67	5.82	5.23	6.80	7.20	68.17
Pres3	4	8.75	4.17	5.83	8.86	6.15	5.00	8.25	67.17
Wye	6	9.17	2.50	6.81	8.26	8.78	1.92	7.67	64.42
LPW1	3	8.33	3.95	6.48	7.07	8.03	2.96	6.89	62.46
RPP1	21	5.00	7.83	6.55	3.95	5.38	5.94	6.08	58.19
Sea	2	5.00	4.44	6.94	2.27	9.23	4.67	6.94	56.43
EBBB	2	2.92	9.44	4.79	2.88	3.78	10.00	5.63	56.34
Ment	8	8.54	3.15	5.28	7.12	6.15	2.22	5.92	54.83
GRM	15	5.89	5.26	5.15	4.14	6.41	5.39	5.49	53.90
UCMBS2	4	7.50	4.17	4.58	6.14	6.35	3.50	5.25	53.55
Wild	5	7.00	3.56	6.48	4.91	5.54	3.73	6.17	53.41
LP1	11	2.65	7.34	6.29	1.29	6.50	7.17	5.79	52.91
EaB	8	6.25	4.44	6.02	5.91	4.23	2.67	7.50	52.89
Matc2	2	10.00	0.00	5.83	8.18	6.92	0.00	5.50	52.05
Ind	15	8.50	2.67	5.05	6.18	5.74	2.49	5.03	50.95
Tusc	2	5.00	8.33	6.02	2.27	3.46	6.00	4.17	50.36
LCat	2	5.00	5.00	5.83	3.64	4.62	5.00	5.50	49.41
Char4	6	6.11	4.44	5.74	4.75	5.13	2.78	4.89	48.34
WhRi	12	6.25	4.44	5.43	3.94	4.87	3.50	4.92	47.66
BPond	7	4.82	2.86	5.03	4.55	7.14	2.10	5.32	45.44
LSC	14	0.74	7.14	6.77	0.40	5.18	5.41	5.51	44.52
LP2	5	0.00	8.00	5.67	0.00	5.23	6.13	4.80	42.62
Tobi	2	7.50	0.56	3.94	6.36	5.19	0.33	4.86	41.06
PMcN1	8	7.08	1.11	5.24	4.24	5.67	0.67	4.15	40.24
PP2	6	5.00	0.74	4.44	5.15	6.92	0.44	4.50	38.86
Wauk	2	0.00	6.67	4.17	0.00	2.31	8.00	4.00	35.92
Bell2	8	1.46	5.14	4.69	0.61	2.02	3.75	3.40	30.08
IBSP1	20	0.71	5.98	3.25	0.77	1.87	5.38	3.07	30.04
ONWR	15	0.33	7.11	3.44	0.12	1.64	4.80	2.27	28.17
Mag	8	1.25	5.00	3.75	0.45	1.35	4.00	2.63	26.32
RBG	10	1.38	3.00	4.21	0.50	3.96	2.20	2.92	25.95
Bain2	9	1.48	3.06	3.18	1.13	3.52	2.44	2.82	25.19
BuIsl	5	4.00	1.48	2.10	2.91	2.77	0.89	2.15	23.28
RPP2	7	5.00	1.27	2.65	2.86	0.66	1.14	2.54	23.02
Coot1	5	1.00	2.22	4.17	0.36	3.69	1.47	2.67	22.25
Metz	14	0.71	5.08	2.62	0.26	1.43	3.24	1.64	21.40
LP3	4	2.50	3.33	2.92	0.91	0.77	2.00	1.75	20.25
CPNWR	4	0.00	4.44	1.67	0.00	0.00	5.33	2.00	19.21
OshSc	17	1.94	0.95	3.00	0.79	3.38	0.57	2.20	18.31
CranM	5	3.00	0.67	3.00	1.09	2.77	0.40	1.80	18.18
Pen2	4	2.50	0.83	1.67	2.27	2.69	0.50	1.75	17.45
HIA	8	0.00	3.89	2.78	0.00	0.96	2.33	1.67	16.61
Roug	2	2.50	1.67	1.94	0.91	2.05	1.00	1.33	16.29
Bron	2	0.00	1.67	3.33	0.00	3.08	1.00	2.00	15.82
SuRA	6	2.50	0.56	2.47	1.21	1.03	0.33	1.67	13.95
Humb	3	0.00	1.48	2.22	0.00	2.05	0.89	1.33	11.40
Hyd	4	0.42	0.56	1.94	0.15	2.18	0.33	1.42	10.00
VanW	6	0.42	0.00	0.15	0.15	0.13	0.00	0.09	1.35
Monroe	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[1] See Table 2 for description of amphibian metrics.

Table E3.b. Standardized amphibian metrics and IBIs calculated for the watershed of Great Lakes coastal wetlands during high average water levels (1995-1998). 1

Wetland	Stations	RWOOD	MWOOD	MBASIN	IBI
Ratt	2	10.00	10.00	10.00	100.00
Wye	6	9.17	8.26	8.78	87.35
Matc2	2	10.00	8.18	6.92	83.68
Pres3	4	8.75	8.86	6.15	79.22
Turk	5	7.50	6.91	9.23	78.80
LPW1	3	8.33	7.07	8.03	78.13
Ment	8	8.54	7.12	6.15	72.72
BIsl	11	8.71	6.03	6.62	71.22
Ind	15	8.50	6.18	5.74	68.08
UCMBS2	4	7.50	6.14	6.35	66.61
Tobi	2	7.50	6.36	5.19	63.52
Pres4	5	7.00	5.82	5.23	60.16
Wild	5	7.00	4.91	5.54	58.16
PP2	6	5.00	5.15	6.92	56.92
PMcN1	8	7.08	4.24	5.67	56.66
BPond	7	4.82	4.55	7.14	55.03
Sea	2	5.00	2.27	9.23	55.01
GRM	15	5.89	4.14	6.41	54.80
EaB	8	6.25	5.91	4.23	54.63
Char4	6	6.11	4.75	5.13	53.29
WhRi	12	6.25	3.94	4.87	50.20
RPP1	21	5.00	3.95	5.38	47.77
RB3	6	5.00	2.12	6.92	46.81
LCat	2	5.00	3.64	4.62	44.17
Tusc	2	5.00	2.27	3.46	35.78
LP1	11	2.65	1.29	6.50	34.83
BuIsl	5	4.00	2.91	2.77	32.26
EBBB	2	2.92	2.88	3.78	31.93
RPP2	7	5.00	2.86	0.66	28.39
Pen2	4	2.50	2.27	2.69	24.88
CranM	5	3.00	1.09	2.77	22.87
LSC	14	0.74	0.40	5.18	21.09
Bain2	9	1.48	1.13	3.52	20.43
OshSc	17	1.94	0.79	3.38	20.36
RBG	10	1.38	0.50	3.96	19.46
Roug	2	2.50	0.91	2.05	18.20
LP2	5	0.00	0.00	5.23	17.44
Coot1	5	1.00	0.36	3.69	16.85
SuRA	6	2.50	1.21	1.03	15.79
LP3	4	2.50	0.91	0.77	13.93
Bell2	8	1.46	0.61	2.02	13.61
IBSP1	20	0.71	0.77	1.87	11.18
Bron	2	0.00	0.00	3.08	10.26
Mag	8	1.25	0.45	1.35	10.17
Hyd	4	0.42	0.15	2.18	9.16
Metz	14	0.71	0.26	1.43	8.01
Wauk	2	0.00	0.00	2.31	7.69
ONWR	15	0.33	0.12	1.64	6.99
Humb	3	0.00	0.00	2.05	6.84
HIA	8	0.00	0.00	0.96	3.21
VanW	6	0.42	0.15	0.13	2.32
CPNWR	4	0.00	0.00	0.00	0.00
Monroe	5	0.00	0.00	0.00	0.00

[1] See Table 2 for description of amphibian metrics.

Table E3.c. Standardized amphibian metrics and IBIs calculated for the overall disturbance rank sum of Great Lakes coastal wetlands during high average water levels (1995-1998). 1

Wetland	Stations	RWOOD	RTOT	MWOOD	MBASIN	MTOT	IBI
Ratt	2	10.00	10.00	10.00	10.00	10.00	100.00
Wye	6	9.17	6.81	8.26	8.78	7.67	81.36
Turk	5	7.50	7.67	6.91	9.23	8.90	80.41
Pres3	4	8.75	5.83	8.86	6.15	8.25	75.70
LPW1	3	8.33	6.48	7.07	8.03	6.89	73.62
Matc2	2	10.00	5.83	8.18	6.92	5.50	72.88
BIsl	11	8.71	7.70	6.03	6.62	7.36	72.86
Ment	8	8.54	5.28	7.12	6.15	5.92	66.02
Pres4	5	7.00	7.67	5.82	5.23	7.20	65.83
RB3	6	5.00	9.75	2.12	6.92	7.04	61.67
Ind	15	8.50	5.05	6.18	5.74	5.03	61.01
Sea	2	5.00	6.94	2.27	9.23	6.94	60.78
Wild	5	7.00	6.48	4.91	5.54	6.17	60.19
EaB	8	6.25	6.02	5.91	4.23	7.50	59.82
UCMBS2	4	7.50	4.58	6.14	6.35	5.25	59.63
Tobi	2	7.50	3.94	6.36	5.19	4.86	55.70
GRM	15	5.89	5.15	4.14	6.41	5.49	54.16
RPP1	21	5.00	6.55	3.95	5.38	6.08	53.93
BPond	7	4.82	5.03	4.55	7.14	5.32	53.71
Char4	6	6.11	5.74	4.75	5.13	4.89	53.23
PMcN1	8	7.08	5.24	4.24	5.67	4.15	52.78
PP2	6	5.00	4.44	5.15	6.92	4.50	52.04
WhRi	12	6.25	5.43	3.94	4.87	4.92	50.83
LCat	2	5.00	5.83	3.64	4.62	5.50	49.17
LP1	11	2.65	6.29	1.29	6.50	5.79	45.05
Tusc	2	5.00	6.02	2.27	3.46	4.17	41.84
EBBB	2	2.92	4.79	2.88	3.78	5.63	39.99
LSC	14	0.74	6.77	0.40	5.18	5.51	37.21
LP2	5	0.00	5.67	0.00	5.23	4.80	31.39
BuIsl	5	4.00	2.10	2.91	2.77	2.15	27.85
RPP2	7	5.00	2.65	2.86	0.66	2.54	27.40
RBG	10	1.38	4.21	0.50	3.96	2.92	25.93
Bell2	8	1.46	4.69	0.61	2.02	3.40	24.33
Bain2	9	1.48	3.18	1.13	3.52	2.82	24.26
Coot1	5	1.00	4.17	0.36	3.69	2.67	23.78
CranM	5	3.00	3.00	1.09	2.77	1.80	23.32
OshSc	17	1.94	3.00	0.79	3.38	2.20	22.61
Pen2	4	2.50	1.67	2.27	2.69	1.75	21.76
Wauk	2	0.00	4.17	0.00	2.31	4.00	20.95
IBSP1	20	0.71	3.25	0.77	1.87	3.07	19.34
Mag	8	1.25	3.75	0.45	1.35	2.63	18.85
SuRA	6	2.50	2.47	1.21	1.03	1.67	17.75
LP3	4	2.50	2.92	0.91	0.77	1.75	17.69
Roug	2	2.50	1.94	0.91	2.05	1.33	17.48
Bron	2	0.00	3.33	0.00	3.08	2.00	16.82
ONWR	15	0.33	3.44	0.12	1.64	2.27	15.61
Metz	14	0.71	2.62	0.26	1.43	1.64	13.33
Hyd	4	0.42	1.94	0.15	2.18	1.42	12.22
Humb	3	0.00	2.22	0.00	2.05	1.33	11.21
HIA	8	0.00	2.78	0.00	0.96	1.67	10.81
CPNWR	4	0.00	1.67	0.00	0.00	2.00	7.33
VanW	6	0.42	0.15	0.15	0.13	0.09	1.89
Monroe	5	0.00	0.00	0.00	0.00	0.00	0.00

[1] See Table 2 for description of amphibian metrics.

Table E3.d. Standardized amphibian metrics and IBIs calculated for the 1 km buffer of Great Lakes coastal wetands during low average water levels (1999-2003).[1]

Wetland	Stations	RWOOD	MWOOD	MBASIN	MTOT	IBI
Wilm	2	10.00	9.09	10.00	9.09	95.45
BIsl	5	9.80	9.31	8.00	9.16	90.68
SB1	2	10.00	9.55	7.86	8.64	90.10
Hay7	2	10.00	8.18	7.86	9.09	87.82
WSB1	9	10.00	8.08	8.10	8.28	86.15
Ratt	2	10.00	7.27	8.57	8.18	85.06
Wye	6	9.08	7.61	7.38	6.05	75.29
EaL6	3	8.89	8.59	5.48	6.11	72.66
Hill	7	5.14	5.45	9.55	7.51	69.14
PBrit	2	5.00	5.45	10.00	6.36	67.05
Butt2	2	5.00	3.64	9.29	8.64	66.40
Ment	8	8.13	7.05	4.82	4.77	61.91
BPond	7	5.00	5.40	7.84	5.60	59.60
Ind	15	8.24	6.11	4.41	4.05	57.02
Matc2	2	6.67	6.06	5.95	4.09	56.93
Wild	5	8.00	6.45	3.50	4.49	56.12
Brad	3	5.00	5.05	6.67	5.50	55.54
RPP1	21	5.24	4.55	5.65	5.78	53.02
LP7	2	5.00	1.82	7.86	6.36	52.60
LPW1	4	6.56	5.57	4.55	4.15	52.08
ESB5	10	3.50	2.55	6.71	7.44	50.51
PP2	20	4.08	4.21	6.61	5.04	49.85
BB-CP	5	5.00	3.64	5.71	5.25	49.01
EBBB	2	5.00	5.09	4.14	5.09	48.31
Char4	6	5.56	4.24	5.32	4.19	48.27
LP3	6	6.67	4.55	3.81	3.94	47.40
Tusc	2	6.50	4.91	3.43	3.84	46.69
LP5	4	5.00	2.27	5.71	5.23	45.54
LP1	60	4.73	2.80	5.30	4.76	43.97
SuRA	6	6.39	3.13	3.73	3.25	41.26
Tobi	2	5.00	5.00	2.86	3.54	40.98
Sea	2	5.00	1.82	5.00	4.04	39.65
Bay1	3	3.33	1.21	4.76	6.06	38.42
BCre	5	2.33	0.85	5.86	6.00	37.60
RB3	7	2.86	1.56	5.51	5.05	37.44
GRM	5	5.00	2.55	3.14	4.18	37.18

[1] See Table 2 for description of amphibian metrics

Table E3.d. Continued…

Wetland	Stations	RWOOD	MWOOD	MBASIN	MTOT	IBI
Coot1	6	4.00	1.64	4.19	3.37	32.98
LP2	36	0.69	0.25	6.27	5.81	32.56
RBG	5	1.20	0.51	5.37	3.84	27.30
CranM	3	2.50	2.12	3.81	2.42	27.14
BuIsl	8	3.75	1.82	2.32	2.53	26.04
CPNWR	16	3.60	1.47	2.59	2.72	25.94
HIA	10	2.75	1.00	3.00	3.43	25.46
Saw7	4	2.50	1.82	2.50	3.30	25.28
Bain2	9	1.67	0.61	4.13	3.54	24.84
ONWR	24	2.24	0.97	3.02	3.61	24.59
Metz	10	3.25	1.18	2.50	2.68	24.03
LP4	5	3.00	1.09	2.00	2.36	21.14
Hyd	3	3.33	1.82	1.90	1.21	20.67
LSC	22	0.34	0.15	3.00	4.32	19.53
LCat	15	2.61	1.37	1.17	2.36	18.81
OWR	13	0.77	0.28	1.98	2.66	14.21
Rusc	4	1.25	0.45	2.14	1.70	13.88
PMcN	8	2.08	0.76	1.16	0.82	12.06
OshSc	14	1.00	0.47	1.94	1.23	11.60
CCM	3	1.67	0.61	1.43	0.91	11.53
Roug	2	0.00	0.00	1.43	0.91	5.84
IBSP1	14	0.00	0.00	0.59	1.49	5.20
Humb	3	0.00	0.00	0.71	0.45	2.92
Lynd	8	0.00	0.00	0.54	0.40	2.33
PDar	5	0.00	0.00	0.29	0.36	1.62

Table E3.e. Standardized amphibian metrics and IBIs calculated for the overall disturbance rank sum of Great Lakes coastal wetlands during low average water levels (1999-2003).[1]

Wetland	Stations	RWOOD	MWOOD	MTOT	IBI
BIsl	5	9.80	9.31	9.16	94.24
SB1	2	10.00	9.55	8.64	93.94
Wilm	2	10.00	9.09	9.09	93.94
Hay7	2	10.00	8.18	9.09	90.91
WSB1	9	10.00	8.08	8.28	87.88
Ratt	2	10.00	7.27	8.18	84.85
EaL6	3	8.89	8.59	6.11	78.62
Wye	6	9.08	7.61	6.05	75.78
Ment	8	8.13	7.05	4.77	66.48
Wild	5	8.00	6.45	4.49	63.17
Ind	15	8.24	6.11	4.05	61.34
Hill	7	5.14	5.45	7.51	60.35
Butt2	2	5.00	3.64	8.64	57.58
Matc2	2	6.67	6.06	4.09	56.06
PBrit	2	5.00	5.45	6.36	56.06
LPW1	4	6.56	5.57	4.15	54.26
BPond	7	5.00	5.40	5.60	53.34
RPP1	21	5.24	4.55	5.78	51.88
Brad	3	5.00	5.05	5.50	51.83
Tusc	2	6.50	4.91	3.84	50.82
EBBB	2	5.00	5.09	5.09	50.61
LP3	6	6.67	4.55	3.94	50.51
Char4	6	5.56	4.24	4.19	46.63
BB-CP	5	5.00	3.64	5.25	46.30
Tobi	2	5.00	5.00	3.54	45.12
ESB5	10	3.50	2.55	7.44	44.97
PP2	20	4.08	4.21	5.04	44.44
LP7	2	5.00	1.82	6.36	43.94
SuRA	6	6.39	3.13	3.25	42.58
LP5	4	5.00	2.27	5.23	41.67
LP1	60	4.73	2.80	4.76	40.96
GRM	5	5.00	2.55	4.18	39.09
Sea	2	5.00	1.82	4.04	36.20
Bay1	3	3.33	1.21	6.06	35.35
RB3	7	2.86	1.56	5.05	31.55
BCre	5	2.33	0.85	6.00	30.61
Coot1	6	4.00	1.64	3.37	30.01

[1] See Table 2 for description of amphibian metrics.

Table E3.e. Continued…

Wetland	Stations	RWOOD	MWOOD	MTOT	IBI
BuIsl	8	3.75	1.82	2.53	26.98
CPNWR	16	3.60	1.47	2.72	25.95
Saw7	4	2.50	1.82	3.30	25.38
HIA	10	2.75	1.00	3.43	23.95
Metz	10	3.25	1.18	2.68	23.71
CranM	3	2.50	2.12	2.42	23.48
ONWR	24	2.24	0.97	3.61	22.73
LP2	36	0.69	0.25	5.81	22.52
LP4	5	3.00	1.09	2.36	21.52
Hyd	3	3.33	1.82	1.21	21.21
LCat	15	2.61	1.37	2.36	21.16
Bain2	9	1.67	0.61	3.54	19.36
RBG	5	1.20	0.51	3.84	18.49
LSC	22	0.34	0.15	4.32	16.05
OWR	13	0.77	0.28	2.66	12.35
PMcN	8	2.08	0.76	0.82	12.22
Rusc	4	1.25	0.45	1.70	11.36
CCM	3	1.67	0.61	0.91	10.61
OshSc	14	1.00	0.47	1.23	9.00
IBSP1	14	0.00	0.00	1.49	4.98
Roug	2	0.00	0.00	0.91	3.03
Humb	3	0.00	0.00	0.45	1.52
Lynd	8	0.00	0.00	0.40	1.33
PDar	5	0.00	0.00	0.36	1.21