Bi-national Assessments of Marsh Habitat Quality for the Niagara River and Buffalo River Areas of Concern

Produced for:

The National Fish and Wildlife Foundation

Project 2009-0059-014

January, 2011

Ryan W. Archer and Robert William Rankin

Bird Studies Canada / Études D'Oiseaux Canada P.O. Box/B.P. 160, 115 Front St., Port Rowan, ON Canada N0E 1M0 www.birdscanada.org

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This project was made possible through funding from the National Fish and Wildlife Foundation's Sustain Our Great Lakes program in partnership with ArcelorMittal. This funding program is supported by the U.S. Environmental Protection Agency and ArcelorMittal.

We would like to acknowledge the partnership of Buffalo Niagara Riverkeeper and the Niagara Peninsula Conservation Authority, and support and assistance provided by the New York State Department of Environmental Conservation, Environment Canada, New York State Parks, and the City of Buffalo in the implementation of this project. Litwin's Consulting and Buffalo Niagara Riverkeeper provided contracted marsh bird and amphibian survey services. Bird Studies Canada's Ellen Kempmann assisted with marsh water quality and aquatic macroinvertebrate sampling field work, and Chris Lorenz performed laboratory-based macroinvertebrate identifications.

Finally, we would like to specially thank the dedicated efforts of our Niagara- and Buffalo-area Marsh Monitoring Program volunteer participants, and our volunteer Marsh Monitoring Program regional coordinators, without which these assessments would not be possible.

INTRODUCTION

Several marsh-dependent bird and anuran (frog and toad) species may be sensitive to anthropogenic disturbances that affect the integrity of their wetland habitats. Habitat loss and degradation are believed to be primary causes of their well-documented population declines over the past several decades (Gibbs et al. 1992, Conway 1995, Melvin and Gibbs 1996, Stuart et al. 2004). Monitoring relative population status and community structure of marsh birds and amphibians within the Great Lakes basin can thus help us evaluate how well marshes are functioning to maintain ecological integrity.

The Marsh Monitoring Program (MMP) is a binational marsh bird and amphibian monitoring program, coordinated by Bird Studies Canada (BSC) in partnership with Environment Canada and the U.S. Environmental Protection Agency. The MMP uses volunteer "Citizen Scientists" to collect data that are used to monitor the status and trends of wetland-dependent birds and amphibians. The MMP provides valuable information about the health and ecological integrity of Great Lakes coastal and inland wetlands. Since the program's inception in 1995, one of its primary objectives has been to contribute to the assessment and long-term monitoring of Great Lakes Areas of Concern (AOCs).

Wetland habitats are one of the most important habitat types within AOCs because of their ability to sustain water quality and quantity between terrestrial and aquatic environments. Wetlands are also capable of supporting a high diversity and abundance of wildlife.

Many AOC Beneficial Use Impairments (BUIs) are related in part to degraded marsh habitats. Conducting point-in-time assessments and long-term monitoring of wetland health indicators are important methods used to evaluate the ecological condition of an AOC region, and report on the status of relevant BUIs with respect to wetland quality.

The Buffalo River, Niagara River (New York) and Niagara River (Ontario) AOCs (Figure 1, a-c, respectively) occur in relatively close proximity and were all designated in large part due to the effects of toxic contamination of water and sediments. However, there have also been concerns in each region related to the loss of fish and wildlife habitat and impacts on their populations. Consequently, delisting criteria have been developed to address Degradation of Fish and Wildlife Populations Beneficial Use Impairments for each AOC:

Niagara River (ON) AOC: *"Maintenance of wetland-dwelling wildlife populations and diversity at or above suitable non-AOC reference sites (as determined by indicators such as Indices of Biotic Integrity and/or community status assessments derived from Bird Studies Canada's Marsh Monitoring Program)"* (Niagara River Remedial Action Plan 2009).

Niagara River (NY) and Buffalo River AOC: *"Wildlife surveys find that diversity and abundance of birds, mammals, reptiles, and amphibians in the AOC is comparable to a suitable reference site"* (New York State Department of Environmental Conservation 2008, Wooster and Matthies 2008).

To contribute to these information needs, BSC engaged in a two-year project in 2009 to assess wetland quality within each AOC and across the bi-national Buffalo/Niagara project region as a whole, and to enhance long-term volunteer monitoring within this broad region. The primary goal of this project was to integrate MMP bird and amphibian data with limnological and aquatic macroinvertebrate data to provide a multi-parameter assessment of wetland health for each

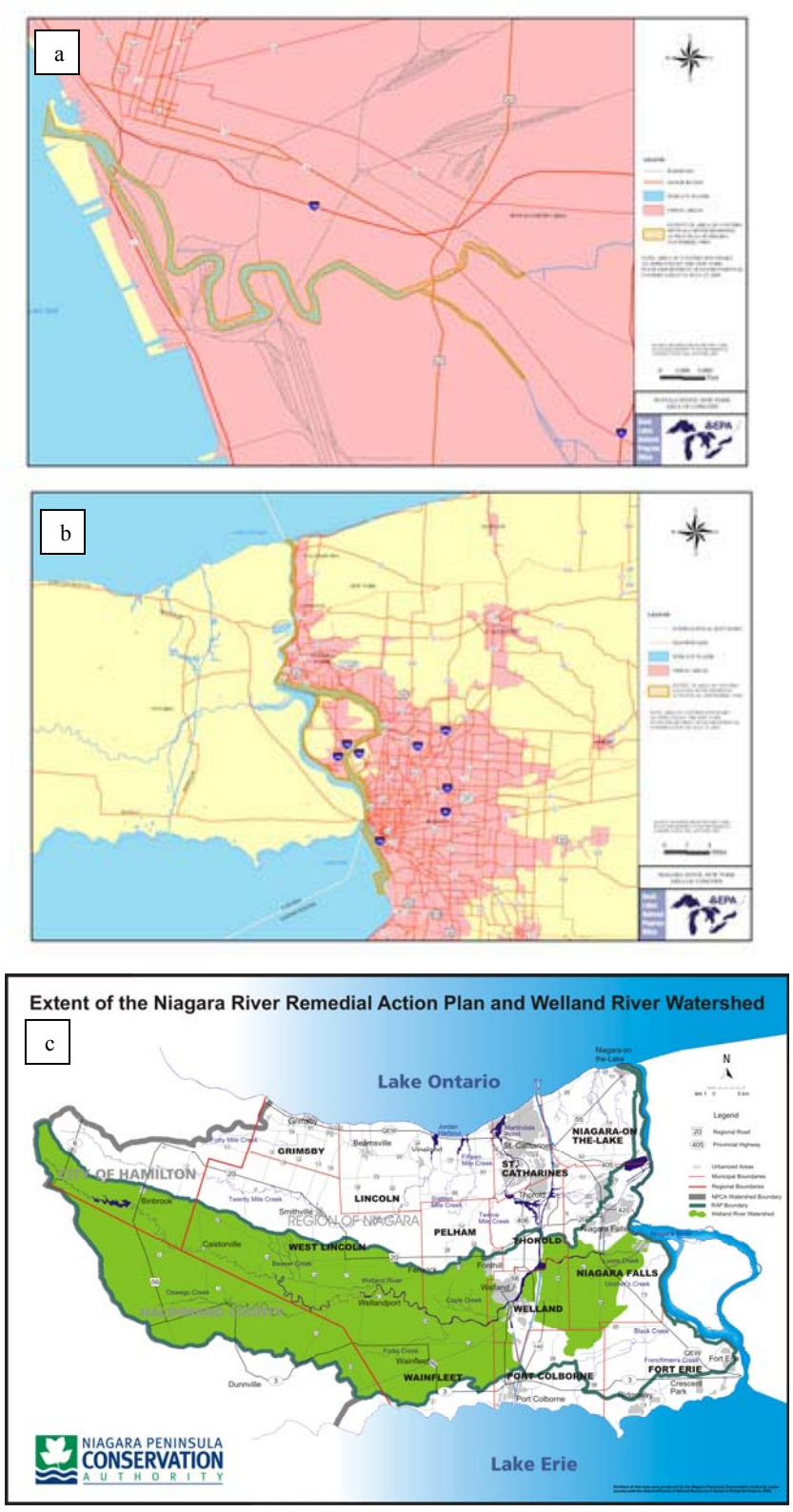

Figure 1. Boundaries of (a) Buffalo River and (b) Niagara River (NY) AOCs (outlined in yellow), and (c) watershed-scale boundary (outlined in blue) of the Niagara River (ON) AOC.

AOC. This project also offered a unique opportunity to apply standardized methods to assess wetland condition bi-nationally across the broad region, including across the two Niagara River AOCs. This aspect addressed a desire of several Canadian and U.S. Niagara River stakeholders to improve bi-national coordination of habitat restoration and monitoring.

A secondary goal was to increase MMP volunteer monitoring within and surrounding each AOC. To increase volunteer monitoring in each AOC region, BSC worked with volunteer MMP regional coordinators to promote the program and assist staff with local volunteer training and coordination. One new regional coordinator was recruited for the Buffalo area during the project period, in addition to two existing regional coordinators working within each of the Niagara, Ontario and Buffalo regions. Following an MMP volunteer orientation/training workshop held in Buffalo in February, 2009, and parallel workshops held in the Niagara, Ontario region as part of a separate MMP project, over 60 program registrants were assigned to survey 10 marshes in the Niagara River (ON), and four marshes in each of the Niagara River (NY) and Buffalo River AOCs.

In recent years, Indices of Biotic Integrity (IBIs) have been developed and used by researchers and managers to evaluate the relative health of coastal wetland habitats. Wetlands are evaluated based on data that describe various attributes of wetland biotic communities (e.g. fish, invertebrate, amphibian and bird populations, vegetation composition), which are known to be responsive to, and signal changes in, physical, chemical and/or biological attributes of wetlands and/or their surrounding landscapes. Marsh bird, amphibian and macroinvertebrate population metrics as indicators of coastal wetland condition have been used to measure coastal wetland health relative to other surveyed coastal wetland sites (Crewe and Timmermans 2005, Uzarski et al. 2004). To develop robust indicators of anthropogenic disturbance, the biological condition of communities must be sampled across a wide range of wetlands from most to least disturbed (reference condition).

Marsh bird, amphibian and macroinvertebrate IBIs have previously been modified and used to evaluate wetland biotic condition in Great Lakes AOCs (Archer et al. 2006). More recently, IBIs for these biotic communities were developed specifically to measure marsh habitat health in the Niagara River (ON) AOC and a reference watershed (Archer et al. 2010). Similarly, for this project we modified existing IBIs developed for Great Lakes coastal wetlands and the Niagara River (ON) AOC to make them suitable to report on wetlands across the bi-national project region. This was done by developing wetland disturbance gradients specific to AOC and reference watershed sites, and testing metrics for their response to those gradients.

For the Niagara River (ON) AOC, the Twenty Mile Creek watershed to the north of the AOC was retained as a reference watershed following consultations held with the Niagara River Remedial Action Plan Science Committee and the Niagara Peninsula Conservation Authority (NPCA) during the separate Niagara-Ontario project (Archer et al. 2010). This watershed was selected due to its relative proximity and similarity of land use with the AOC watershed. Reference sites for the U.S. AOCs were chosen following communication with regional wildlife/habitat biologists and Remedial Action Plan representatives. For the Niagara River (NY) AOC, the Buckhorn Marsh sites and Sunken Island were chosen as reference sites *a priori* due to previous assessments that had characterized them as being relatively less disturbed. Although the West Seneca Oxbow Wetland and Reinstein Woods are associated with the Buffalo River AOC through an expanded Habitat Opportunity Area (Wooster and Matthies 2008), they also effectively serve as references for lower Buffalo River-area sites. Tifft Nature Preserve can also serve as a regional reference site due to its protected and managed habitat. Finally, Sinking Ponds was selected for reference conditions given its upper watershed location. Reference site results are reported with their associated AOC sites, unless stated otherwise.

This report describes the activities and results of this two-year project. Specifically, the major objectives were to:

1. Conduct wetland water quality and aquatic macroinvertebrate sampling at priority wetlands within AOC and reference wetland sites.
2. Establish and work with MMP regional coordinators for each AOC region to increase volunteer marsh bird and amphibian monitoring.
3. Plan and host MMP volunteer orientation/training workshops in both Ontario and New York State.
4. Develop bird, amphibian and macroinvertebrate IBIs that are specific to the broad bi-national Buffalo/Niagara region, and rank wetland health according to biotic community condition for each AOC separately and across the broad Buffalo/Niagara region collectively.
5. Assess marsh bird and amphibian community diversity, within each monitored wetland, for each AOC as a whole, and bi-nationally for the Niagara River AOCs, relative to non-AOC Great Lakes basin means.

This report provides an assessment of ecological integrity for several marshes within each AOC, based on their bird, amphibian and macroinvertebrate communities, relative to each other and to non-AOC reference conditions. Its purpose is to inform the respective Remedial Action Plans (RAPs) with respect to their progress to meet designated Degradation of Fish and Wildlife Populations delisting criteria, and to report a framework through which long-term monitoring to track wetland health recovery and response to remedial activities can be accomplished. Project results and their interpretations are reported individually for each AOC to maximize usefulness to inform individual Remedial Action Plans; however, selected results are also presented at a broad regional scale to provide larger landscape-level context and certain findings are discussed that apply to the Buffalo/Niagara region as a whole.

METHODS

MMP regional coordinator establishment

Two volunteer MMP regional coordinators established prior to this project period (Kim Frohlich, ecologist with the Niagara Peninsula Conservation Authority [Niagara River (ON) AOC and surrounding region] and Jeff Santiago, a Buffalo-area youth outdoor educator [Buffalo River AOC and surrounding area]) agreed to continue their roles through this project period. To help develop an MMP volunteer network in the Buffalo area, a second regional coordinator for that area was sought and identified (David Spiering, ecologist for the Tifft Nature Preserve). David has monitored for the MMP for several years, and is a strong supporter of the program. Given his prior experience and public education/outreach role with the nature preserve, he was identified as an ideal local coordinator to work with Jeff in the Buffalo area. For a complete description of the MMP regional coordinator duties and responsibilities, see Appendix A.

MMP monitoring

Route selection and characteristics of MMP routes and stations

Upon registering with the MMP, volunteers received training kits that included detailed protocol instructions, field and summary data forms, instructional CDs with examples of songs and calls of common marsh birds and amphibians, and a CD used to elicit calls from secretive wetland bird species. Survey routes were established in marsh sites that were at least 1 ha in size. Each route consisted of one to eight monitoring stations depending on factors such as available time

and marsh habitat size. Each marsh bird survey station was separated by at least 250 m to minimize duplicate counts of individuals. For amphibians, this distance was extended to 500 m because observers record all amphibians heard both inside and beyond the 100-m station boundary (i.e., within hearing distance).

Volunteer-surveyed MMP routes were predominantly selected by the volunteers themselves, often with distance from home and ease of access in mind, although MMP staff encouraged volunteers to adopt existing inactive MMP routes where possible. In 2010, following volunteer route assignments, survey contractors were hired to ensure that certain priority marshes in both Ontario and New York, that volunteers did not select, were surveyed for birds, amphibians and habitat characteristics. The contractors followed the same survey protocols as all other volunteer participants.

An MMP station was defined as a 100-m radius semi-circle with marsh habitat covering greater than 50% of the semi-circular area. Marsh habitat was defined as habitat regularly or periodically wet or flooded to a depth of up to two metres where cattail, bulrush, burreed and other non-woody vegetation predominated. Counts were conducted from a focal point at each station – the surveyor stood at the midpoint of the 200-m semi-circular base and faced the arc of the station perimeter.

Using standard MMP forms, surveyors completed descriptions of habitat characteristics (e.g., proportion of emergent vegetation, open water, trees, shrubs) and emergent vegetation composition (e.g., proportion of cattails, reeds, bulrushes) within each station once during the survey season. For a description of the MMP habitat description protocol, see Bird Studies Canada (2008).

Bird survey protocol

Survey visits for birds were conducted two or three times between 20 May and 5 July, with at least 10 days occurring between visits. Morning visits occurred between sunrise and four hours after sunrise; evening visits occurred between four hours before sunset and the onset of darkness. Once a route was established as either a morning or evening route, it remained as such permanently. Bird surveys were conducted under appropriate survey conditions (i.e., warm, dry weather and little wind). The 15-minute survey consisted of a five-minute passive listening period, followed by a five-minute call broadcast period, and a final five-minute passive listening period. The broadcast CD contained calls of the normally secretive Least Bittern, Sora, Virginia Rail, Common Moorhen, American Coot and Pied-billed Grebe and was used to elicit call responses from those species.

During the count period, observations (seen or heard) of species listed among a defined list of “focal” (marsh obligate indicator) species were recorded on the survey form in one-minute intervals during the first ten minutes of the survey, and during the final five-minute period as a whole (no sub-intervals). Focal species individuals were tracked separately, and were observed within the semi-circular sample area at unlimited distance. All other observed bird species were recorded onto a survey station map if they occurred within the 100-m semi-circular station boundary. Aerial foragers were also counted and were defined as those species foraging within the station area to a height of 100 m. Non-focal bird species flying through or detected outside the station were tallied separately.

Amphibian survey protocol

MMP participants surveyed marshes for calling frogs and toads that typically depend on marsh habitat during spring and summer breeding periods. MMP amphibian routes were surveyed during three separate nights each year, between the beginning of April and the end of July, with at least 15 days between visits. Because peak amphibian calling periods are more strongly

associated with temperature and precipitation than with date, visits were scheduled to occur during three separate evenings according to minimum night air temperatures of 5°C, 10°C, and 17°C, 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 (i.e., full chorus); a count estimate is impossible for Call Level Code 3 and thus is not required by the protocol.

MMP participants were asked to use their best judgment to distinguish whether each species detected was calling from inside the station boundary only, from outside the station boundary only, or from both inside and outside the station boundary.

Tables 1-3 list the wetland sites monitored using the MMP in 2009 and 2010, the survey type used, and survey date per visit, for the Niagara River (ON), Niagara River (NY) and Buffalo River AOC, respectively.

Water quality and aquatic macroinvertebrate sampling

Water quality and aquatic macroinvertebrate sampling was conducted by field staff primarily at marshes that were surveyed for the MMP, preferably for both marsh birds and amphibians. BSC staff consulted with regional partners (NPCA in Ontario, Buffalo Niagara Riverkeeper in New York) to identify priority sites for assessment and long-term monitoring. In Ontario, efforts were made to representatively select lower, middle, and upper watershed sites; riverine, palustrine and coastal marshes; and sites predominantly influenced by industrial, urban, and agricultural pressures. In New York, sites were primarily selected from among state-protected wetlands located along the Niagara River, and within and upstream of the Buffalo River AOC; sites were selected with an aim to capture both relatively more and less degraded conditions.

Water quality and macroinvertebrate sampling occurred from 27-31 July, 2009 in New York and 9-13 August, 2009 in Ontario. Water and macroinvertebrate samples were paired and sampled within all major flooded vegetation zones when possible. Sampled habitat types typically consisted of flooded emergent vegetation zones (primarily consisting of reeds, cattails, etc.), and flooded submergent vegetation (consisting primarily of floating and submerged aquatic vegetation). When only one sample per site was possible, it was taken from the emergent/submergent interface. Replicate samples of water and macroinvertebrates were collected for each sampling site; typically at least two samples were obtained from each habitat zone where possible. For larger marshes, replicates of two or more were obtained within each habitat zone. At each sampling station, we recorded the time and geographic coordinates. Sites were accessed on foot or by canoe, depending on water depth. At each sampling location, we made a detailed description of the surrounding habitat. This included a description of the herbaceous emergent, floating aquatic and/or submergent vegetation present, to at least the genus level. Details about significant site characteristics were also noted (e.g., general marsh health, proximity to or influence from anthropogenic disturbances such as roads, residential areas and other surrounding land uses).

Table 1. Niagara River (ON) AOC and reference watershed marshes monitored for birds or amphibians in 2009 and 2010, with corresponding survey visit date.

Wetland Site	Survey Type	Visit Number	2009 Survey Date	2010 Survey Date
Chippawa Creek Pond	Amphibians	1		April 28
		2		May 20
		3		June 10
	Birds	1		May 28
		2		June 10
		3		July 9
EC Brown Wetland	Amphibians	1	May 8	
		2	June 2	
		3	June 24	
	Birds	1	June 15	June 21
		2	July 6	July 4
Lake Niapenco	Birds	1	June 16	
		2	July 4	
	Amphibians	1		May 20
Lower Lyons Creek-Beck	Amphibians	1	March 17	
		2	April 10	
		3	June 4	
	Birds	1		May 31
		2		June 22
		3		July 4
Lower Welland River-Grassy Brook	Amphibians	1	April 2	April 12
		2	April 26	May 17
		3	June 10	June 14
	Birds	1		June 25
		2		July 5
Lower Welland River-Stanley	Amphibians	1	March 17	
		2	April 10	
		3	June 4	
Lyons Creek-Cook's Mills	Amphibians	1	April 2	April 12
		2	April 26	May 17
		3	June 10	June 14
Lyons Creek-Crowland	Amphibians	1	April 26, May 8	
		2	June 14, June 2	
		3	June 24	
	Birds	1	May 23	
Lyons Creek-Schisler	Amphibians	1	April 26	
		2	June 14	
	Birds	1	May 23	
Mud Lake	Amphibians	1		April 28
		2		May 27
		3		June 18
	Birds	1	May 21	May 23
		2	June 5	June 10
Niagara River at Baker's Creek	Amphibians	1	April 12	April 14
		2	May 11	May 10
		3	May 22	June 4
	Birds	1		May 31
		2		June 22
		3		July 4

Table 1 (cont.)

Wetland Site	Survey Type	Visit Number	2009 Survey Date	2010 Survey Date
Twenty Mile Creek Headwaters	Amphibians	1		May 11
		2		May 27
		3		June 12
	Birds	1		May 27
		2		June 12, June 20
		3		June 23, July 3
Twenty Mile Creek Mouth	Amphibians	1		May 10
		2		June 4
		3		June 25
	Birds	1	May 31	May 23
		2	July 1	June 25
Upper Draper's Creek	Amphibians	1	June 4	May 6
		2	June 21	May 25
		3		June 30
Ussher's Creek	Birds	1		July 4
Wainfleet Bog	Amphibians	1	April 27	April 5
		2	May 23	May 16
		3	June 21	June 13
	Birds	1	May 25	May 20
		2	June 5	June 1
		3		June 14
Welland River-Airport	Amphibians	1	June 23	
Welland River-Chippawa Creek	Amphibians	1		April 28
		2		May 20
		3		June 10
Welland River at Big Forks Creek	Amphibians	1	June 23	
Willoughby Marsh	Amphibians	1		May 14

Table 2. Niagara River (NY) AOC marshes monitored for birds or amphibians in 2009 and 2010, with corresponding survey visit date.

Wetland Site	Survey Type	Visit Number	2009 Survey Date	2010 Survey Date
Beaver Island	Amphibians	1		April 15
		2		May 25
		3		June 29
	Birds	1		June 4
		2		June 30
Buckhorn Marsh East	Amphibians	1		April 7
		2		May 6
Buckhorn Marsh West	Amphibians	1		April 7
		2		May 6
	Birds	1		June 17
		2		July 9
East River	Amphibians	1		March 31
		2		April 20
		3		May 24
Republic Steel	Amphibians	1		April 12
		2		May 26
		3		June 21
	Birds	1		May 25
		2		June 24
		3		July 5
Strawberry Island	Amphibians	1		April 26
		2		May 25
		3		June 17
	Birds	1		June 21
		2		July 2
		3		July 11
Sunken Island	Amphibians	1		April 30
		2		June 1
		3		June 24
	Birds	1		June 1
		2		July 1
		3		July 12
Tifft Nature Preserve	Amphibians	1	May 5	April 6
		2	June 10	May 21
		3		June 28
	Birds	1	June 5	May 21
		2	June 24	June 28
Times Beach	Amphibians	1		April 12
		2		May 20
		3		June 13
	Birds	1		June 13
		2		July 3

Table 3. Buffalo River AOC marshes monitored for birds or amphibians in 2009 and 2010, with corresponding survey visit date

Wetland Site	Survey Type	Visit Number	2009 Survey Date	2010 Survey Date
Meyer Rd. Wetland	Amphibians	1		April 12, April 30
		2		May 26, May 12
		3		June 21
	Birds	1		June 4, May 12
		2		June 30
West Seneca Oxbow Wetland	Amphibians	1		April 20
		2		May 27
		3		June 16

Wetland water quality measurements

Physical and chemical water quality measurements followed protocols described in the Great Lakes Coastal Wetlands Monitoring Plan (Uzarski et al. 2008a). A YSI 600 QS multi-probe Environmental Monitoring System (EMS), with a portable data logger and sonde, was used to measure water temperature, conductivity, dissolved oxygen (percent saturation), and pH. The multi-probe EMS was properly calibrated for each sampled parameter prior to use in the field, as directed by YSI's operations manual. Readings were obtained by placing the sonde within the water to a depth mid-way through the water column if possible, or in shallow water to a depth where all sensors were immersed.

A portable LaMotte Smart 2 colorimeter, with required chemical reagents, was used to measure chemical water quality parameters, such as ammonia, nitrate and chloride concentrations, and turbidity. Water samples for later chemical analysis were collected in 500 mL plastic bottles. Prior to collecting water samples, the bottles were rinsed twice with sample water. The bottles were then submerged open end-down into the water to a depth several centimetres below the surface, at which point the bottle was inverted and allowed to fill with water. Each bottle was filled completely, tightly sealed with a leak-proof cap and stored in an iced cooler. Water chemical measurements were conducted each day following field sampling activities.

Parameters were measured as directed by the colorimeter's operator's manual. For ammonia and nitrate analyses, high-range or low-range reagents were used depending on the concentrations of each sample, as directed by the operator's manual. Prior to analysis, reagent blanks were measured using sample water in order to account for any contribution to the test result by the reagent.

On-site, a handheld Turner Designs Aquafluor fluorometer/turbidimeter was used to measure *in vivo* chlorophyll *a* fluorescence. At least two replicate readings of chlorophyll *a* fluorescence were recorded at a given sampling station. Air temperature was measured using a mercury thermometer, and water depth was measured with a graduated depth bamboo stick. The weather conditions for the sampling day and pertinent recent weather events were also noted. Water quality data for the Twenty Mile Creek Mouth site were provided by the Canadian Wildlife Service following similar sampling protocols.

Aquatic macroinvertebrate community sampling

Aquatic macroinvertebrates were sampled following protocols described in the Great Lakes Coastal Wetlands Monitoring Plan (Uzarski et al. 2008b). Macroinvertebrate samples were collected by sweeping a D-frame dip net through the water at the surface, middle, and just above the sediment and water column interface, to ensure that an array of microhabitats were sampled. When sampling among emergent vegetation, the dip nets were swept up along the sides of the vegetation from the base to the water surface and back, while shaking and agitating

the vegetation sufficiently to dislodge attached macroinvertebrates. Any sediment collected in the net was sieved and rinsed out. Net contents were then emptied into a bucket for sorting. Each sample and subsample was thoroughly searched and sorted for 30 minutes or until approximately 100 organisms had been located and preserved. Using forceps, we searched the submergent and emergent plant material for attached and unattached macroinvertebrates. Field staff searched all contents of the sweep net sample and collected every specimen. Specimens were placed into a labelled 150 mL plastic bottle containing 70% ethanol preservative solution. Care was taken to ensure that smaller organisms were not missed, as there is a bias toward larger, more mobile individuals using this technique. Bottles were then stored in a dark container and refrigerated for later laboratory identification and enumeration.

Macroinvertebrate samples were sorted and identified by BSC staff to the genus taxonomic level. Identification was carried out using a dissecting microscope and various macroinvertebrate identification keys specific to Northeastern North America and the Great Lakes region.

All data were entered into a database, and for quality control and assurance, all digitized data were cross-referenced and proofed with original raw field data to minimize transfer error. Marsh sampling site locations were recorded on-site using GPS and electronically plotted using a mapping software program.

MMP volunteer orientation workshops

An MMP volunteer orientation workshop was held on Feb. 20, 2010 at the Reinstein Woods Nature Preserve in Depew, New York, a suburb of Buffalo. Workshop advertisements, flyers and press releases were distributed to several newspapers (including the large-circulation daily The Buffalo News), nature clubs and organizations, radio stations, and several other regional contacts. Information about the workshop was also distributed via Bird Studies Canada's electronic newsletter "Latest News", a state-wide birding internet listserv, and through correspondence with all existing MMP participants in the region.

Fourteen people attended the workshop. This workshop consisted of three major elements: 1) an in-house program orientation that described the program and its protocols, 2) volunteer route assignment and registration, and 3) an in-field practical demonstration and protocol training period. Wherever possible, volunteers were assigned to priority AOC investment sites for monitoring. Workshop attendees were assigned to monitor 11 marshes, four of which occur within each of the Niagara River (NY) and Buffalo River AOCs.

Another workshop was held in the Niagara, Ontario region on March 6, 2010, as part of a parallel project that focused on the Niagara River (ON) AOC. This event was primarily considered a refresher meeting for participants that attended an MMP workshop at that location one year earlier, and at which over 40 program registrants were assigned to marsh locations. Twenty people attended the 2010 Ontario workshop.

A follow-up outdoor MMP training workshop was planned for Buffalo-area participants to occur during May, 2010, but was ultimately cancelled due to lack of confirmed workshop registrations despite thorough advertisement to all area participants and nature clubs.

Index of Biotic Integrity development

Disturbance gradient quantification

Two separate disturbance gradients were created; one for the aquatic macroinvertebrate IBI, which included a combination of surrounding land cover quantification and within-site water quality; the other for the marsh bird and amphibian IBIs, which included only surrounding land

cover data. Two separate disturbance gradients were created because within-site water quality data were not collected for some sites where bird and amphibian surveys occurred, whereas both macroinvertebrate and water quality were always collected from each site.

To assess the land cover adjacent to a wetland, we digitized the sampled or monitored wetlands using a Geographic Information System (GIS; ArcView 3.2 1999). Spatial buffers were then created at 0.5 km, 1 km, 1.5 km, 2 km and watershed-scale distances around each polygon and the quantities of land use areas within these buffers were extracted. Percent cover of woodland, crop land, and urban land use were found to be predictive of wetland quality and were retained for use in the disturbance gradient (Crewe and Timmermans 2005). For each wetland scale of measurement, habitat ranks were summed across the three habitat types to develop a rank sum of disturbance by scale. Each disturbance gradient (0.5 km, 1 km, 1.5 km, 2 km and watershed-scale) was tested for its applicability and suitability to the IBIs.

Water quality data were included in the disturbance gradient for the aquatic macroinvertebrate IBI to create a robust disturbance gradient that more accurately reflected site condition. The following water quality parameters were used to create the disturbance gradient with land cover data: conductivity, turbidity, nitrate concentration, and pH.

Separate disturbance gradients were created for each buffer scale (0.5 km, 1 km, 1.5 km, 2 km and overall (summed across scales)) by using a rank sum analysis based on the amount of each land cover type within the buffer and the water quality at that site. Adjacent woodland was considered to be a positive landscape variable and was therefore ranked so that lower values represented higher disturbance. Higher values for urban, crop, conductivity, pH, turbidity and nitrate represented higher disturbance. Therefore, a high overall disturbance score was given to poor quality sites and a low overall disturbance score was given to high quality sites.

IBI calculation

The marsh bird and amphibian IBIs developed to report specifically on Niagara River (ON) AOC and reference marshes (Archer et al. 2010) were modified to test and incorporate metrics that responded to wetland disturbance gradients based on the bi-national project region. These IBIs were in turn modified from IBIs developed by Bird Studies Canada and Environment Canada for southern Great Lakes coastal wetlands (see methods in Grabas et al. 2008 (birds) and Timmermans et al. 2008 (amphibians)). Candidate marsh bird and amphibian metrics were selected from Crewe and Timmermans (2005) and tested for correlation against the disturbance gradient at each buffer scale. Metrics that showed significant correlation ($p<0.20$) to the disturbance gradient following the expected response (positive or negative) were incorporated into their respective IBI. The buffer scale(s) that yielded the highest number of metrics that exhibited significant responses to disturbance were retained for IBI reporting.

The marsh bird, amphibian and macroinvertebrate IBIs were developed to report at the wetland site-level. In cases where wetlands contained more than one MMP route, maximum values of biotic response variables (e.g., species richness) were calculated across all stations within the wetland.

Metrics for all three IBIs were summarized by calculating the mean metric value for each wetland across thirteen years of data (1998-2010). 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 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 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 marsh bird or amphibian IBI were in better biological condition than wetlands with a low IBI score.

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; R 2.9.2 2009). The applied method randomly chose three stations from wetlands with at least four marsh bird or four amphibian survey stations, and recalculated IBI scores for 1,000 iterations. The bootstrap standard deviation was calculated from the 1,000 IBI results.

IBI classes were then established by dividing the range of IBI scores by an estimate of the Minimum Detectable Effect. The Minimum Detectable Effect is the minimum difference between IBI scores for which one can be confident that the IBI scores are meaningfully different. The Minimum Detectable Effect was estimated by calculating the Power (alpha = 0.05) of all pairwise comparisons of routes' IBI scores for which standard deviations could be estimated from the bootstrap method described above. The difference in pairwise IBI scores and the calculated power were then plotted and fitted with a logistic curve (CITE R software), and a Minimum Detectable Effect was estimated as the difference in IBI scores where the curve equalled a Power of 0.8. This step was not completed for AOC-specific IBIs or any of the wetland macroinvertebrate IBIs due to lack of adequate sample sizes to calculate meaningful IBI classes. For the Buffalo/Niagara region-wide macroinvertebrate IBI, however, we conservatively assigned rating classes for the among-site IBI gradient. Wetland IBI scores were then plotted and ranked relative to scores of other AOC wetlands and to reference wetlands.

Marsh bird and amphibian community assessments

The community assessment method classifies wetlands as being impaired or not, by looking at deficiencies in the community structure of marsh birds and amphibians which cannot otherwise be explained by environmental conditions. Communities are large, complex networks of species, and difficult to describe quantitatively. Therefore, the assessment utilized a few emergent properties of the marsh communities which are indicative of the community structure, and possible to analyze in conventional ways. Species richness, scaled to sampling effort, was used in these summaries as a descriptor of amphibian and marsh bird communities. Four measures of species richness were calculated:

- all marsh-nesting birds
- marsh bird indicator species only
- all amphibian species
- amphibian indicator species only

See Table B1 for a list of bird and amphibian indicator species used in the community assessments.

Each species richness measure was modelled as a function of various environmental covariates, including marsh size, proportion of various vegetation classes, and annual trends in

population measures. Each richness measure was the response variable in a separate multivariate regression using quadratic polynomial transformations of the environmental covariates. The analysis used Great Lakes basin non-AOC sites as reference sites to build "idealized" relationships between each richness measure and environmental covariates, and were then used to predict the “expected” richness at each AOC site, based on their own environmental covariates.

For each richness measure, a difference between the observed richness and the expected richness was assumed indicative of some unexplained and anthropogenic impairment. The difference in observed and expected richness was summarized by mean and standard deviations for each route, using each visit-per-station-per-year as independent measures. For each richness measure, if the mean and standard deviation of the differences included zero, then the route was considered “apparently not impaired” and scored as "0" for that richness measure. If the mean and standard deviations were below zero, then the route was described as “impaired” and was scored as "-". If the mean and standard deviations were above zero, then the route was described as “not impaired” and was scored as "+".

The scoring procedures outlined above were used to derive an overall score for each AOC and the bi-national Niagara River AOCs collectively. The overall score was based on the four components of species richness: marsh-nesting bird species, marsh bird indicator richness, total amphibian richness, and amphibian indicator richness. The maximum score for each of the four components was two, and the maximum possible overall score for the AOC was eight. In our overall assessment of each AOC, scores of 0 – 2 suggested that the site was *impaired*; scores of 3 – 5 suggested that there was *no apparent impairment*; and scores of 6 – 8 indicated that site was *not impaired* and deemed healthy.

SURVEY SITES

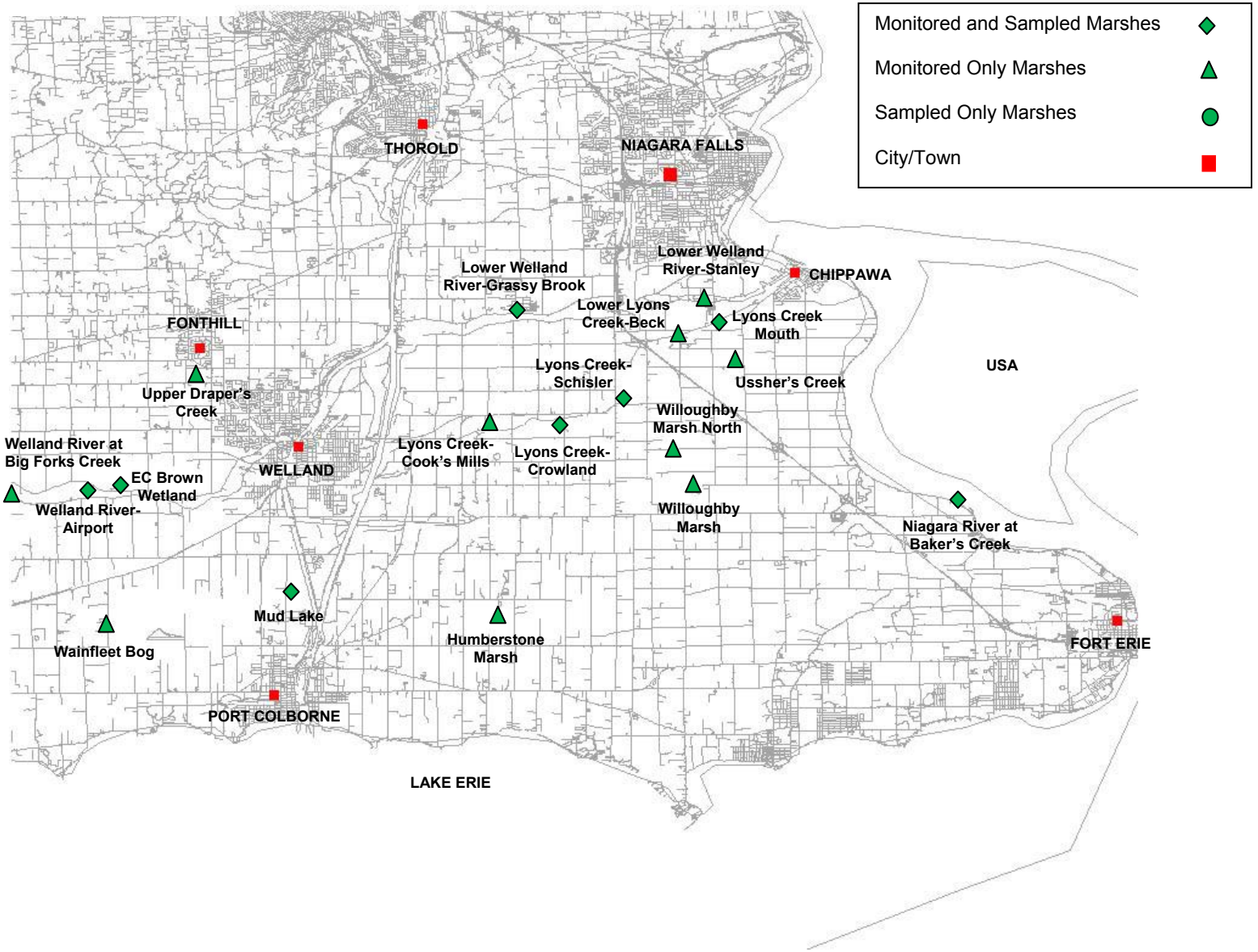

Figure 2. Lower Niagara River (ON) AOC watershed wetland sites monitored for birds and/or amphibians between 1998 and 2010, and/or sampled for water quality and macroinvertebrates in 2009.

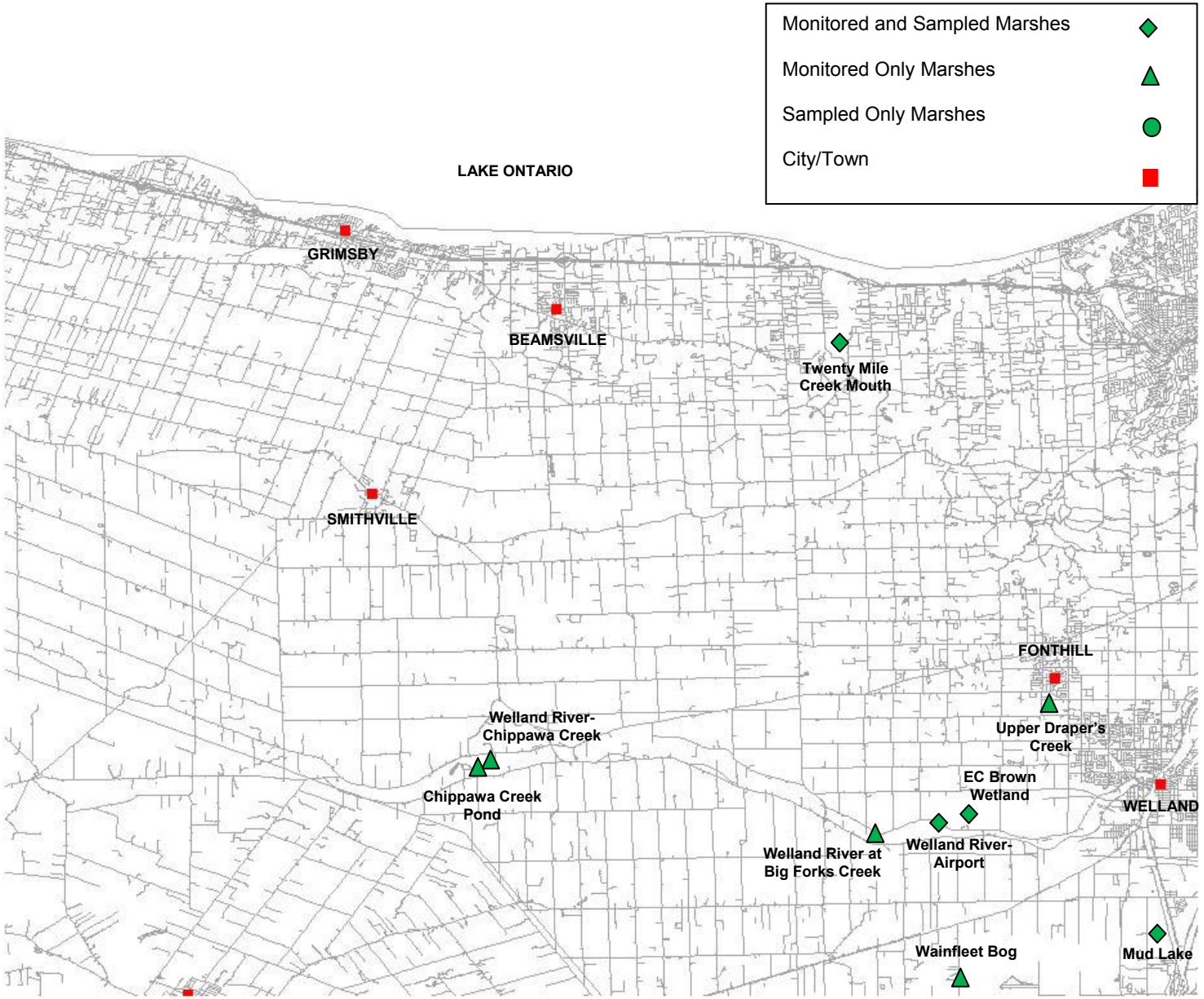

Figure 3. Middle Niagara River (ON) AOC/lower Twenty Mile Creek watershed wetland sites monitored for birds and/or amphibians between 1998 and 2010, and/or sampled for water quality and macroinvertebrates in 2009.

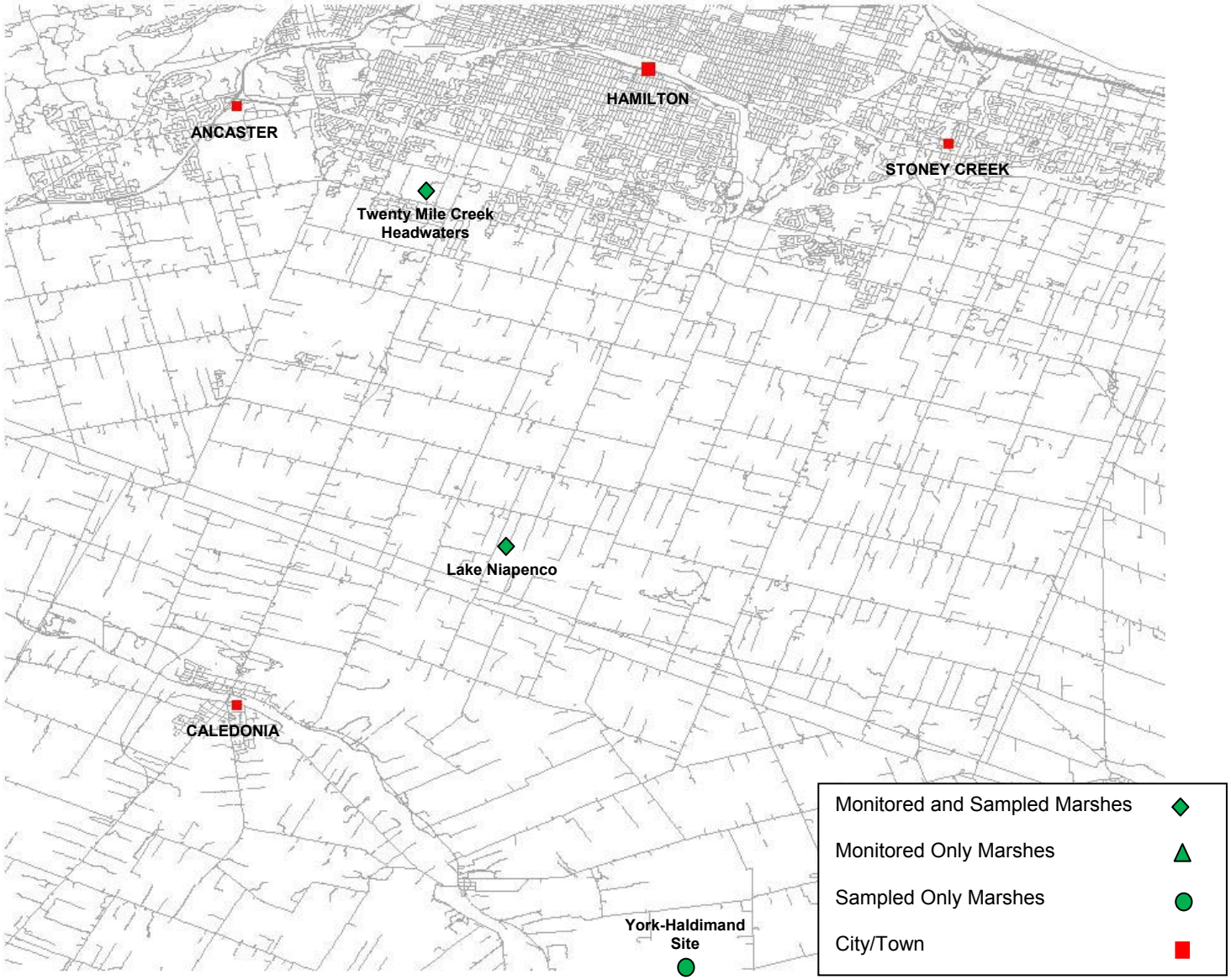

Figure 4. Upper Niagara River (ON) AOC/Twenty Mile Creek watershed wetland sites monitored for birds and/or amphibians between 1998 and 2010, and/or sampled for water quality and macroinvertebrates in 2009.

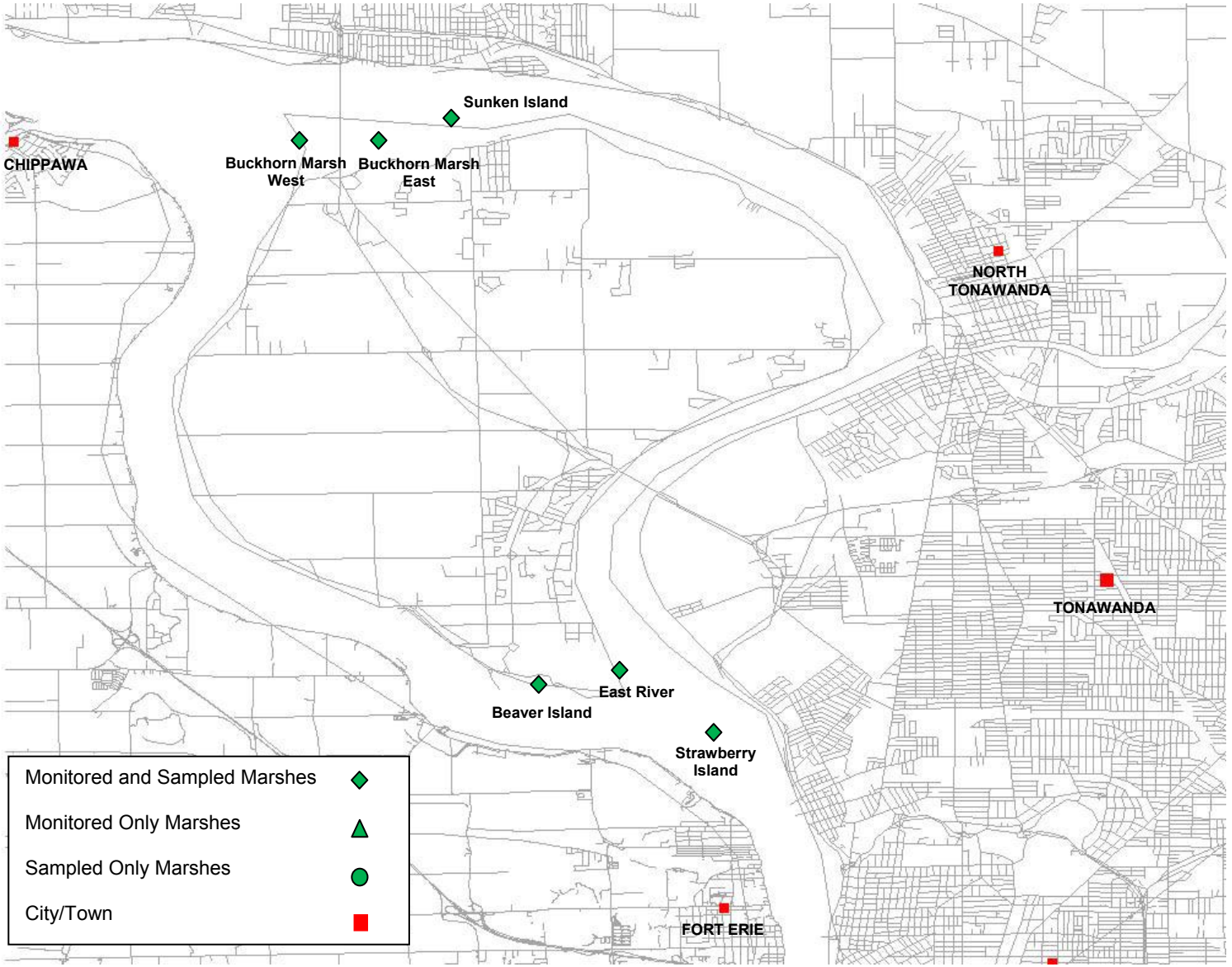

Figure 5. Northern Niagara River (NY) AOC wetland sites monitored for birds and/or amphibians between 1998 and 2010, and/or sampled for water quality and macroinvertebrates in 2009.

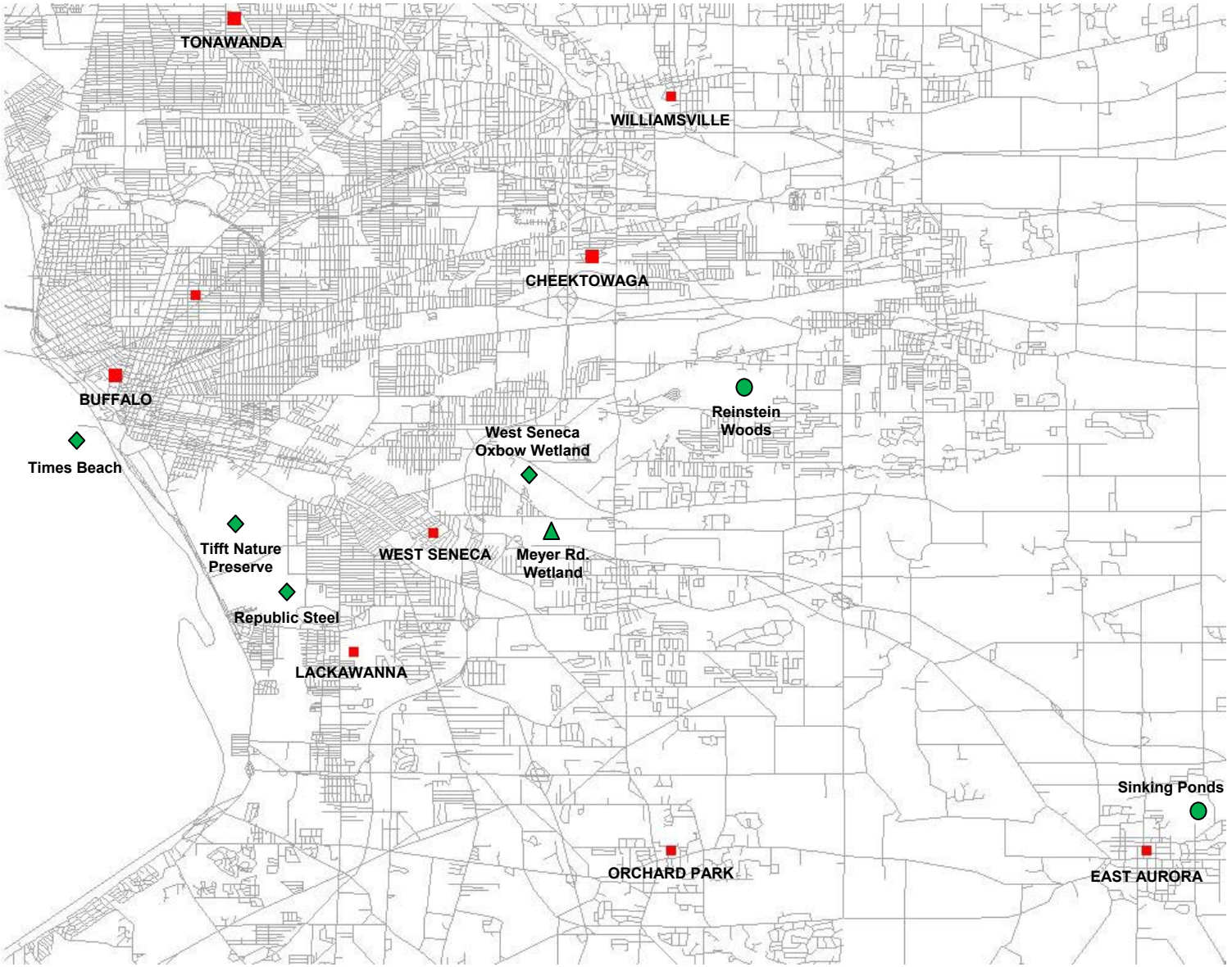

Figure 6. Southern Niagara River (NY) AOC, and Buffalo River AOC and upper watershed reference wetland sites monitored for birds and/or amphibians between 1998 and 2010, and/or sampled for water quality and macroinvertebrates in 2009.

Below are brief descriptions of MMP-monitored and/or staff-sampled marsh sites in the Niagara River (ON) AOC and Twenty Mile Creek reference watershed.

• Chippawa Creek Pond	Small conservation area pond. Surrounded by woodland.
• EC Brown Wetland	A recently-restored wetland with a young vegetation community planted by NPCA. A public education/demonstration site; agricultural surroundings.
• Humberstone Marsh	A restored marsh, initiated in 2000. Features include a mix of open water, planted cattails and surrounding planted trees and shrubs to buffer the marsh from a house and roadway. Not the NPCA conservation area.
• Lake Niapenco	Cattail-dominated marsh located at the western end of Lake Niapenco. Agricultural surroundings; adjacent to road on west end.
• Lower Lyons Creek-Beck	Marsh habitat at the creek's intersection with Beck Rd. Agricultural and residential surroundings.
• Lower Welland River-Grassy Brook	Riverine marsh located between Grassy Brook and Chippawa Creek roads. Adjacent to industrial/utility facilities and a well-travelled road.
• Lower Welland River-Stanley	Fringing marsh habitat at the river's intersection with Stanley Ave. Adjacent golf course, nearby industry and housing.
• Lyons Creek-Cook's Mills	Riverine marsh with surrounding agriculture, woodlands, and some housing.
• Lyons Creek-Crowland	Part of a semi-continuous riverine marsh along the creek at its intersection with Crowland Ave., with a relatively diverse plant community.
• Lyons Creek Mouth	Eastern end of the Lyons Creek riverine marsh complex near its mouth with the Welland River. Adjacent road; nearby golf course, housing and agriculture.
• Lyons Creek-Schisler	Part of a semi-continuous riverine marsh along the creek at its intersection with Schisler Rd., with a relatively diverse plant community.
• Mud Lake	Relatively large open water-cattail-dominated marsh complex, surrounded by terrestrial woodland within a conservation area.
• Niagara River at Baker's Creek	Fringing cattail marsh on the Niagara River near the mouth of Baker's Creek.
• Twenty Mile Creek Headwaters	Headwaters wetland located adjacent to a busy urban/suburban intersection. Residential and agricultural surroundings.
• Twenty Mile Creek Mouth	Large cattail-dominated marsh at the creek's mouth, opening into Jordan Harbour. Surrounded by agriculture on the west and housing on the east.
• Upper Draper's Creek	Two pond-based marshes. Woodland and residential surroundings with nearby roads.
• Ussher's Creek	Riparian marsh with nearby woodland. Agricultural surroundings.
• Wainfleet Bog	Disconnected marsh or wet meadow patches along Wilson Rd. at the western end of the large wetland complex. Surveyed stations do not include the significant bog ecosystem. Surrounding swamp/woodland.
• Welland River-Airport	Fringing riverine marsh; cattail and grass-dominated. Located opposite the Welland Airport. Agricultural surroundings
• Welland River-Chippawa Creek	Small wet meadow adjacent to the Welland River, part of a conservation area. Nearby woodland and campsites.
• Welland River at Big Forks Creek	Riverine marsh, located at the mouth of Big Forks Creek. Agricultural surroundings.
• Willoughby Marsh	Marsh patches located within a larger swamp wetland complex. Located within a conservation area. Agricultural surroundings.
• Willoughby Marsh North	Marsh patch located within a larger swamp wetland complex. Located within a conservation area. Agricultural surroundings.
• York-Haldimand Site	Palustrine marsh located on an agricultural property, containing a mix of open water and cattail/burreed vegetation. Agricultural surroundings.

Below are brief descriptions of MMP-monitored and staff-sampled marsh sites in the Niagara River (NY) AOC.

- Beaver Island — A small woody wetland within Beaver Island State Park at the southern tip of Grand Island, located between an open water lagoon and a parking lot/small road. Surrounding mowed parkland.
- Buckhorn Marsh East — Large managed emergent marsh located within Buckhorn Island State Park, east of the I-190. Managed as a nature preserve. Public canoe/kayak access. State wetland code TW-20.
- Buckhorn Marsh West — Large managed emergent marsh located within Buckhorn Island State Park, west of the I-190. Managed as a nature preserve. Public canoe/kayak access. State wetland code TW-19.
- East River — Emergent marsh on the southeast shore of Grand Island, the focus of a wetland enhancement project in the 2000s to limit wave action, increase biodiversity, and increase public access and appreciation. State wetland code BW-2.
- Republic Steel — Long, linear remnant wetlands located within or adjacent to old industrial lands and a landfill site, and along rail lines, south of the lower Buffalo River. 2010 MMP monitoring occurred at small marshy ponds along it southern terminus, north of South Park in Lackawanna. State wetland code BU-1.
- Strawberry Island — State-protected fringing wetland located on Strawberry Island in the Niagara River. Habitat was restored to maintain biodiversity, limit erosion, and to attract aquatic birds.
- Sunken Island — Cattail-dominated, small marshy island in the Niagara River, just off the north end of Grand Island. Also known as Grass Island, is a popular location for boaters in the summer. State wetland code TW-18.
- Tifft Nature Preserve — Large restored marsh located within the 264-acre nature preserve, south of the lower Buffalo River. Habitat is managed to enhance biodiversity and allow for public access and wildlife viewing. State wetland code BU-15.
- Times Beach — A former dredging disposal site in the Buffalo Harbor, consists of a restored wetland with enhanced public access and was designated a Buffalo nature preserve. Adjacent woodland; berms separate it from the open harbour. State wetland code BU-3.

Below are brief descriptions of MMP-monitored and/or staff-sampled marsh sites in the Buffalo River AOC (expanded habitat opportunity area) and the upper watershed.

- Meyer Rd. Wetland — Palustrine marsh located in West Seneca, surrounded by industrial land uses and crossed by rail lines. State wetland coded BU-13.
- Reinstein Woods — Riparian marsh located within the 292-acre wooded nature preserve, within the Cayuga Creek watershed in Depew. Residential areas occur around the preserve and upstream of the sampled marsh area. State wetland coded LA-6.
- Sinking Ponds — Part of a palustrine marsh complex in the upper Cazenovia Creek watershed; part of the Sinking Ponds Wildlife Sanctuary in East Aurora. Connected to an open water pond and surrounded by additional marsh, woodland, and some residential.
- West Seneca Oxbow Wetland — A woody oxbow wetland, hydrologically disconnected from adjacent Buffalo Creek in recent years, undergoing restoration to improve hydrologic connectivity, remove invasive species, improve biodiversity and to allow public access and awareness. Mixed urban and agricultural surroundings, from which a small inflowing creek derives. State wetland coded BU-17.

RESULTS

Note that Appendix B provides a legend for four-letter species bird and amphibian species codes used below, as well as their marsh-user guild used in data analyses. Also, see Appendix C for summarized habitat and vegetation composition estimates for monitored marsh sites, as collected by MMP surveyors.

Niagara River (ON) AOC

Wetland Physical/Chemical Water Quality

Table 4 shows mean values for selected physical and chemical water quality parameters. These parameters were selected because they are indicative of potential anthropogenic disturbance. Dissolved oxygen was not included because values for this parameter can range widely depending on several sampling factors (e.g., time of day, windiness). See Table D1 for all physical/chemical water quality results.

Table 4. Summary of selected mean physical and chemical water quality measurements for Niagara River (ON) AOC and reference marsh sites.

Site Name	Conductivity (uS/cm)	pH	NH_3 (ppm)	NO_3 (ppm)	Cl (ppm)	Turbidity (FTU)
EC Brown Wetland	371.0	8.32	0.41	0.05	14.60	34
Lake Niapenco	384.0	7.67	0.32	0.04	8.53	72
Lower Welland River-Grassy Brook	395.0	8.15	0.32	0.33	8.43	18
Lyons Creek-Crowland	179.0	7.41	0.51	0.26	3.65	107
Lyons Creek-Schisler	227.0	7.34	0.28	0.12	3.00	31
Lyons Creek Mouth	293.0	7.77	0.44	0.06	4.35	41
Mud Lake	481.0	6.95	0.44	0.14	1.35	23
Niagara River at Baker's Creek	256.5	7.73	0.43	0.25	4.70	53
Twenty Mile Creek Headwaters	455.3	7.63	0.48	0.17	43.37	18
Twenty Mile Creek Mouth	717.5	8.25	N/A	0.55	N/A	12
Welland River-Airport	400.0	7.77	0.54	0.12	4.80	54
York-Haldimand Site	229.0	7.40	0.17	0.03	7.60	63

The Twenty Mile Creek sites, as well as Lake Niapenco, Lower Welland River-Grassy Brook and Welland River-Airport tended to have moderate-to-high water conductivity or chloride concentration. In contrast, Lyons Creek-Crowland and Lyons-Creek Schisler had low values for these parameters. Values were not consistently high or low between these parameters for Mud Lake and the York-Haldimand Site. Ammonia- and/or nitrate-nitrogen concentrations were relatively high at the Twenty Mile Creek sites, Lyons Creek-Crowland, Welland River-Airport, and Lower Welland River-Grassy Brook. Several sites had relatively moderate-to-high ammonia concentrations. Concentrations of both nitrogenous compounds were relatively low at the York-Haldimand Site and Lyons Creek-Schisler. Turbidity was highest at Lyons Creek-Crowland, although sampling at this site followed a heavy rainstorm, which may have also temporarily elevated the recorded nutrient concentrations. pH recordings were relatively neutral but more alkaline readings were measured at Twenty Mile Creek Mouth, EC Brown Wetland and Lower Welland River-Grassy Brook.

Wetland Macroinvertebrate Communities

Mean taxonomic richness (no. taxa/sample) was evaluated among sites with the same number of sample replicates because number of taxa does not increase linearly with number of replicates at a marsh. Lyons Creek-Schisler contained a greater number of macroinvertebrate

orders and families than other sites at which one sample was collected (Fig. 7). Among sites with two sample replicates, Twenty Mile Creek Mouth featured the largest number of families, although Niagara River-Baker's Creek and Lyons Creek Mouth had more orders represented. Welland River-Airport featured the fewest orders and families among this group. Number of orders was similar among sites with three sample replicates, although Twenty Mile Creek Headwaters contained the largest number of families while Lake Niapenco contained the fewest. On average, 7.6 orders and 11.9 families were collected per sample among Niagara River (ON) AOC sites, while 5.7 orders and 11.0 families were collected between the two Twenty Mile Creek reference sites.

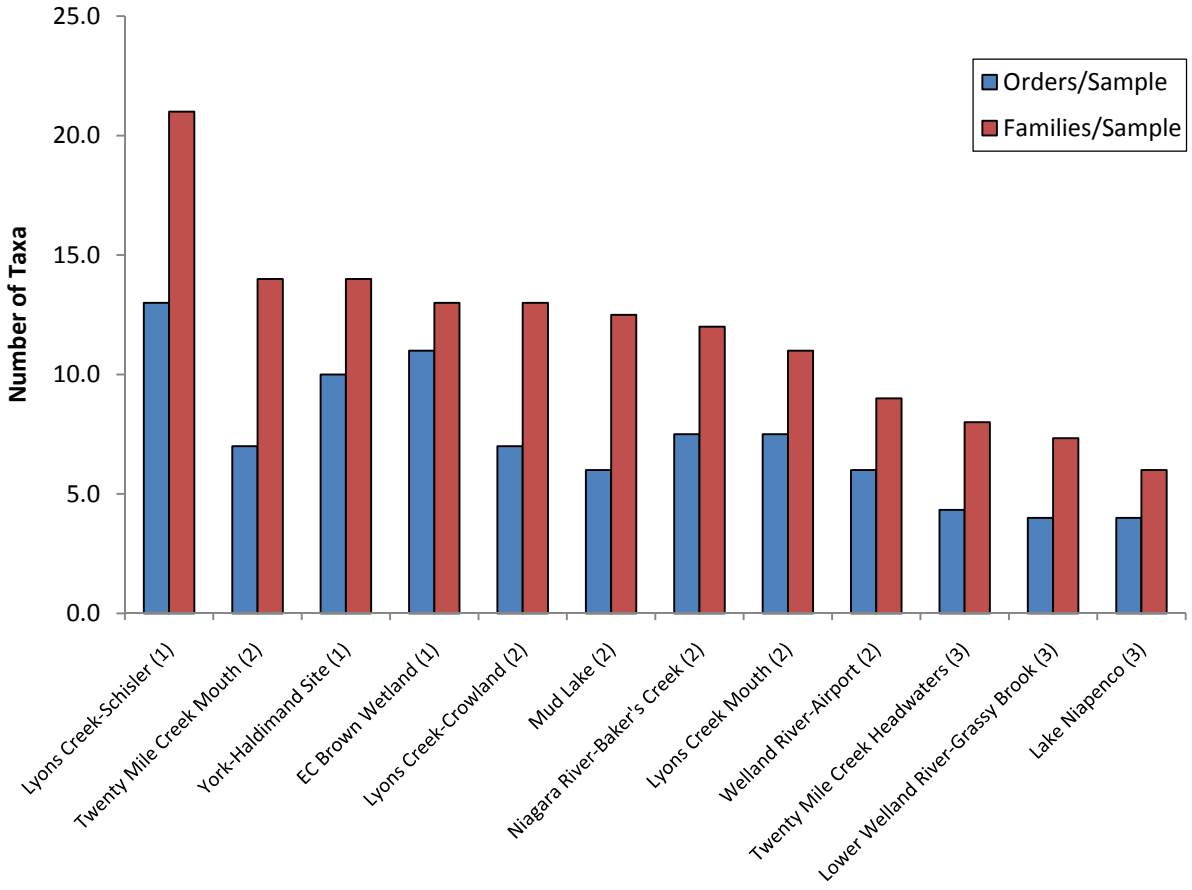

Figure 7. Number of macroinvertebrate orders and families per sample by site for Niagara River (ON) AOC and reference marshes. Sample size is indicated in brackets.

Index of Biotic Integrity

Aquatic macroinvertebrate community attributes were identified in Environment Canada and Central Lake Ontario Conservation Authority (2004) and, using data collected from all project region sites, were correlated against the macroinvertebrate IBI wetland site disturbance gradient (see Methods) to test for statistically-significant, expected responses to disturbance. Seven metrics responded significantly at all buffer distances ($p<0.20$), and were included in the IBI:

- Total number of genera
- Number of Ephemeroptera and Trichoptera genera
- Number of Crustacea and Mollusca genera
- Number of Ephemeroptera genera

- Number of Trichoptera genera
- Percent Trichoptera
- Percent Chironomidae

Niagara River-Baker's Creek, Lyons Creek-Crowland and Lyons Creek Mouth ranked highest among sites (Fig. 8); these results corresponded with relatively high taxonomic richness values (number of orders or families per sample) at these sites among other sites with the same number of sample replicates (Fig. 7). The EC Brown Wetland and the York-Haldimand Site scored lowest for this IBI among AOC sites. The Twenty Mile Creek watershed reference sites varied widely in IBI score, where the headwaters site was ranked fourth overall while the mouth site was scored lowest overall.

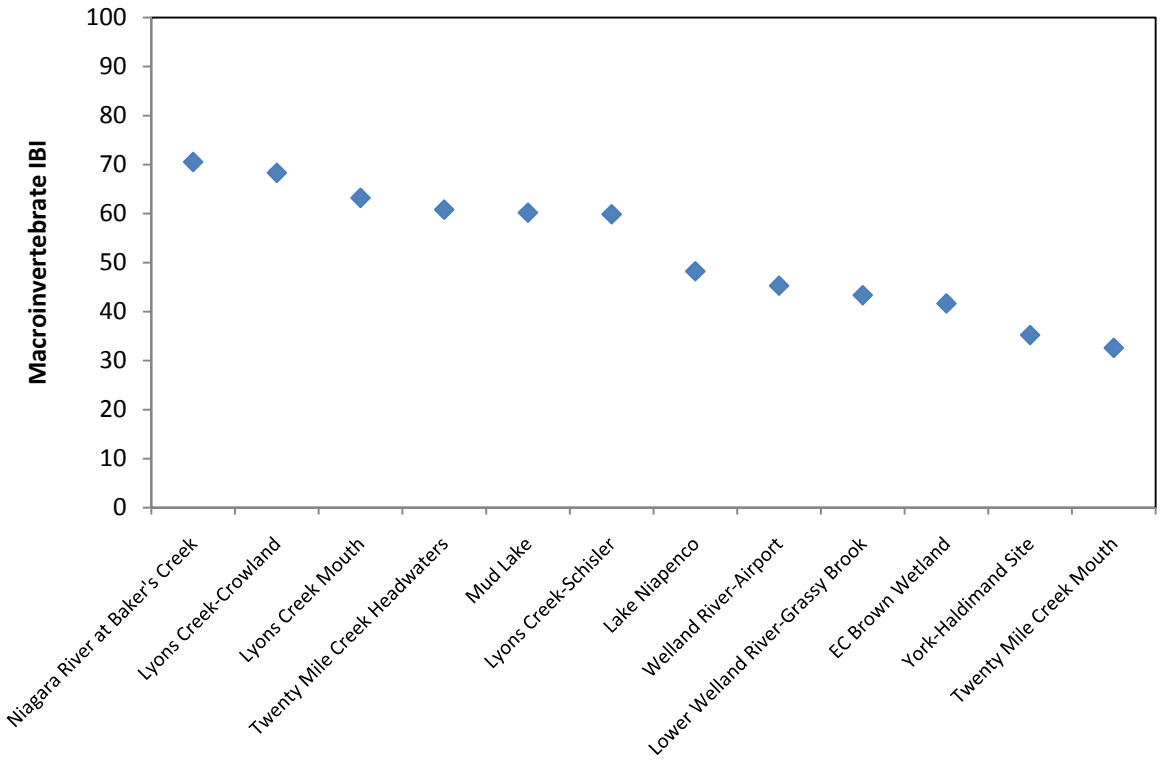

Figure 8. Macroinvertebrate IBI scores for Niagara River (ON) AOC and reference watershed sites.

Wetland Amphibian Communities

A total of seven species were detected across all sites between 2009 and 2010 (Table 5), including all four indicator species (Bullfrog, Western Chorus Frog, Northern Leopard Frog and Spring Peeper). All seven species were recorded at Lyons Creek-Cook's Mills, while six species were recorded at Chippawa Creek Pond and Wainfleet Bog. Only one species was detected at both Welland River-Airport and Welland River at Big Forks Creek, while only two species were recorded at four other AOC sites. However, these and certain other sites (e.g., Lake Niapenco, Willoughby Marsh) were not surveyed three times (see Table 1); therefore, some species may have been missed. Three and two species were recorded at the Twenty Mile Creek Headwaters and Mouth sites, respectively.

Species relative abundances tended to be high at sites such as Chippawa Creek Pond, Lyons Creek-Schisler and Willoughby Marsh, where a majority of species attained a maximum calling code of 2 or more (Table 6). Where they were recorded, Gray Treefrog mainly occurred at Code

Table 5. Maximum calling code detected across survey visits for each species, and number of station-visits, by Niagara River (ON) AOC and reference marsh site.

Marsh Site	Maximum calling code									
	AMTO	BULL	CHFR	GRTR	GRFR	NLFR	SPPE	WOFR	No. Station-Visits	No. Species Detected
Chippawa Creek Pond	1	2	1	3	3		3		3	6
EC Brown Wetland	1		1	3	1		3		3	5
Lake Niapenco					1		1		1	2
Lower Lyons Creek-Beck	2	1							3	2
Lower Welland River-Grassy Brook			2		1		1		12	3
Lower Welland River-Stanley	2	1							3	2
Lyons Creek-Cook's Mills	1	1	1	1	1	1	2		6	7
Lyons Creek-Crowland	1				3		2		5	3
Lyons Creek-Schisler		2	2		3		1		2	4
Mud Lake		2			2				6	2
Niagara River at Baker's Creek	1		1				1		6	3
Twenty Mile Creek Headwaters	1				1	1			6	3
Twenty Mile Creek Mouth		2			1				18	2
Upper Draper's Creek		2			2		2		12	3
Wainfleet Bog	1	1	1		2	1	3		30	6
Welland River-Airport		1							1	1
Welland River-Chippawa Creek									3	0
Welland River at Big Forks Creek		1							1	1
Willoughby Marsh	3		3		1		3		1	4

Table 6. Maximum calling code for each species across all marshes, number of stations at which each species was detected, and each species' percentage occurrence among all monitored stations, for Niagara River (ON) AOC marsh sites.

Species Name	Maximum Calling Code	Number of stations with species detected	Percent occurrence among all stations
American Toad	2	11	42.3
Bullfrog	2	13	50.0
Western Chorus Frog	3	12	46.1
Gray Treefrog	3	19	73.1
Green Frog	3	2	7.7
Northern Leopard Frog	1	4	15.4
Spring Peeper	3	16	61.5
Wood Frog	0	0	0.0
No anurans recorded	-	1	3.8

3; Spring Peeper relative abundance varied widely among sites, while other species mainly occurred at low relative abundances.

Green Frog was the most widespread species, occurring at 73% of monitored stations, followed by Spring Peeper and Bullfrog, with 62% and 50% station occurrence, respectively. Gray Treefrog was the most uncommon species, occurring at only 8% of monitored stations. Wood Frog, a species that occurs in the Niagara region, was not detected during either project year; this may be due to the difficulty inherent in timing surveys to capture their brief, early-season breeding period.

Index of Biotic Integrity

Amphibian community attributes were taken from Crewe and Timmermans (2005) and, using data collected from all project region sites, were correlated against the bird/amphibian IBI wetland site disturbance gradient (see Methods) to test for statistically-significant, expected responses to disturbance. Five metrics responded significantly at the 2000-m buffer distance ($p<0.20$), and were included in the IBI:

- Presence of woodland species
- Richness of woodland species
- Total species richness
- Presence of Great Lakes basin-wide species
- Richness of Great Lakes basin-wide species

Figure 9 shows a wide range of amphibian IBI scores across AOC and reference watershed surveyed sites. Chippawa Creek Pond and Humberstone Marsh scored highest among all sites (95.00 and 93.10, respectively), followed by Willoughby Marsh (81.67) and Wainfleet Bog (75.54). By contrast, Welland River-Chippawa Creek scored lowest among AOC sites (0.00) – a site at which no species were detected across 3 visits in 2010. Both Twenty Mile Creek sites scored next lowest (22.50 and 14.35 for the Headwaters and Mouth sites, respectively) among all scored sites.

Wetland Bird Communities

Table 7 shows mean abundance per 10 stations for marsh-nesters (including indicator species, shown in bold italics), water foragers and aerial foragers recorded at monitored sites. Only two indicator species were observed at AOC wetlands (Sora at Mud Lake and Swamp Sparrow at four Lyons Creek or Welland River riverine wetland sites). By contrast, five indicator species were detected at the Twenty Mile Creek Mouth reference site. Across all sites, the most marsh-nesters were detected at the two Twenty Mile Creek sites (10 species each), while Lower Welland River-Grassy Brook contained the most among AOC sites (9 species). Only three marsh-nesters were observed at the EC Brown Wetland, Lyons Creek-Crowland and Lyons Creek-Schisler. Across sites, Red-winged Blackbird had the highest mean abundance, followed by Tree Swallow and Common Grackle.

Index of Biotic Integrity

Bird community attributes were taken from Crewe and Timmermans (2005) and, using data collected from all project region sites, were correlated against the bird/amphibian IBI wetland site disturbance gradient (see Methods) to test for statistically-significant, expected responses to disturbance. Seven metrics responded significantly in the expected fashion at the 500-m buffer distance ($p<0.20$) and were included in the IBI:

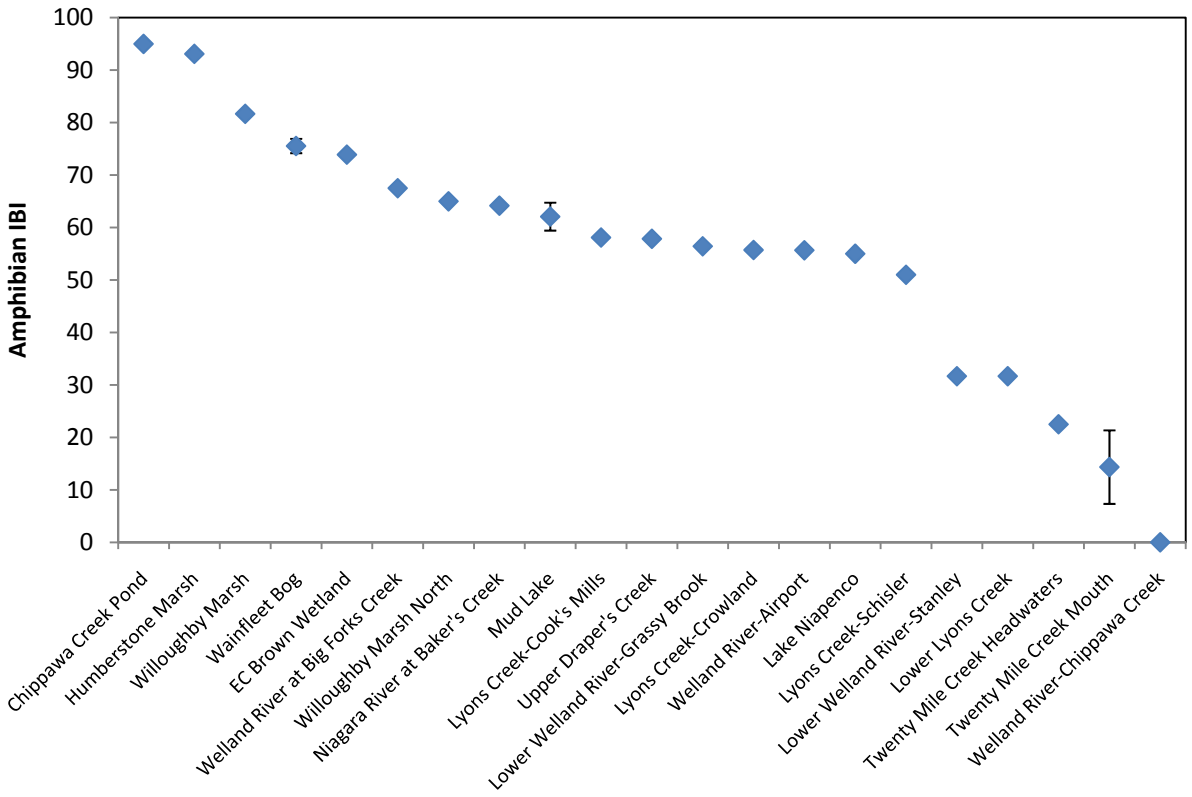

Figure 9. Amphibian IBI scores for Niagara River (ON) AOC and reference watershed sites, based on MMP data collected from 1998-2010.

Table 7. Mean abundance per 10 stations for bird species detected across survey visits, by Niagara River (ON) AOC and reference marsh site. Indicator species are identified by bold and italicized font.

Species Code	Marsh Site Number[1]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ALFL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0
AMBI	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***
AMCO	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***
AMWO	0.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	13.3
BANS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.0	0.0	0.4	0.0	0.0	0.0
BARS	0.0	6.7	1.7	10.0	0.0	0.0	3.3	16.7	0.0	53.3	20.4	20.0	0.4	6.7
BEKI	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BLRA	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***
BLTE	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***
CAGO	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	6.7
CHSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
CLSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.8	0.0	0.0	0.0
COGR	0.0	0.0	1.7	5.0	5.0	5.0	10.8	3.3	137.5	1.7	0.8	20.0	9.6	0.0
COMO	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***
COTE	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0
COYE	0.0	6.7	6.7	15.0	0.0	0.0	5.8	3.3	7.5	5.0	4.2	10.0	4.0	6.7
EAKI	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	1.7	0.0	0.0	0.0	0.0
GBHE	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	10.0	0.8	0.0
GCFL	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GRCA	0.0	3.3	5.0	15.0	0.0	0.0	0.0	6.7	10.0	3.3	0.0	0.0	4.4	3.3
GREG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
GRHE	0.0	0.0	0.0	0.0	5.0	5.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
LEBI	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.4***	***0.0***	***0.0***	***0.0***
MALL	0.0	0.0	0.0	0.0	0.0	0.0	0.8	3.3	0.0	5.0	0.0	0.0	0.4	0.0
MAWR	***5.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***20.0***	***0.0***	***0.0***	***0.0***
MOOT	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***
NOHA	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NRWS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0
PUMA	0.0	0.0	10.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0
PBGR	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***
RWBL	40.0	6.7	13.3	10.0	70.0	70.0	38.3	23.3	87.5	51.7	65.8	10.0	10.8	6.7
SORA	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.8***	***0.0***	***0.0***	***0.0***	***1.3***	***0.0***	***0.0***	***0.0***
SOSP	5.0	3.3	3.3	5.0			5.0	6.7	2.5	6.7	10.0	10.0	6.0	3.3
SWSP	***0.0***	***0.0***	***5.0***	***10.0***	***5.0***	***5.0***	***0.0***	***0.0***	***0.0***	***0.0***	***8.8***	***10.0***	***0.0***	***0.0***
TRES	62.5	0.0	6.7	50.0	0.0	0.0	72.5	0.0	85.0	18.3	6.3	0.0	6.0	0.0
VIRA	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***2.5***	***0.0***	***0.0***	***0.0***
WIFL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0
WODU	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	6.7
YWAR	0.0	13.3	15.0	5.0	0.0	0.0	6.7	16.7	12.5	30.0	2.5	0.0	16.0	13.3
No. Station-Visits	4	3	6	2	2	2	12	3	4	6	24	1	25	3

[1]Site/Route Name	Number	Site Name	Number	Site Name	Number
EC Brown Wetland	1	Lyons Creek-Schisler	6	Twenty Mile Creek Mouth	11
Chippawa Creek Pond	2	Mud Lake	7	Ussher's Creek	12
Lower Lyons Creek-Beck	3	Niagara River at Baker's Creek	8	Wainfleet Bog	13
Lower Welland River-Grassy Brook	4	Lake Niapenco	9	Welland River-Chippawa Creek	14
Lyons Creek-Crowland	5	Twenty Mile Creek Headwaters	10		

- Richness of marsh-nesting obligates
- Richness of area-sensitive marsh-nesting obligates
- Richness of emergent marsh-nesting obligates
- Richness of invasive bird species
- Abundance of marsh-nesting obligates
- Abundance of emergent marsh-nesting obligates
- Abundance of invasive bird species

Mud Lake had a significantly higher IBI score (58.55) than all other AOC sites, which were relatively low-scored (<40.00) (Fig. 10). Twenty Mile Creek Mouth scored second highest among all sites (51.67), although Twenty Mile Creek Mouth was second lowest (9.21). Niagara River at Baker's Creek scored the lowest overall (0.00).

Marsh Bird and Amphibian Community Assessments

Table 8 presents scored assessments of marsh bird and amphibian community richness at AOC sites relative to Great Lakes basin non-AOC mean values, for 2003-2010. This analysis was conducted at the MMP route-level; as such, "Chippawa Creek" comprises the Chippawa Creek Pond and Welland River-Chippawa Creek sites, "Lyons Creek/Lower Welland River" comprises Lower Welland River-Grassy Brook and Lyons Creek-Cook's Mills, "Lower Lyons Creek" comprises Lower Lyons Creek-Beck and Lyons Creek Mouth, and "Upper Welland River" comprises Welland River-Airport and Welland River at Big Forks Creek.

For the AOC as a whole, total amphibian species richness and amphibian indicator species richness were within the expected range of values calculated for Great Lakes basin non-AOC marshes based on measured environmental covariates (e.g., marsh size, proportional coverage of vegetation types). However, marsh-nester and indicator bird species richness values across AOC sites were below average relative to non-AOC values. Humberstone Marsh was scored as being above average in terms of its amphibian species richness. Five routes/sites (Chippawa Creek, EC Brown Wetland, Lake Niapenco, Mud Lake 2, and Wainfleet Bog) were characterized as exhibiting no apparent impairment in terms of their bird or amphibian species richness values. However, the majority of AOC routes/sites (Lower Lyons Creek, Lyons Creek/Lower Welland River, Lyons Creek-Crowland/Schisler, Lower Welland River-Grassy Brook, Mud Lake 1, Niagara River at Baker's Creek, Upper Draper's Creek and Upper Welland River) were classified as having lower than expected marsh bird and/or amphibian species richness values relative to non-AOC reference conditions. Overall, Niagara River (ON) AOC marsh habitats were classified as being impaired in terms of their ability to support marsh-dependent species richness levels that are expected given their measured physical and vegetation characteristics. This observed "deficit" in species richness values, unaccountable by latitudinal and temporal trends in species richness, nor environmental conditions at the site, may be assumed to be caused by anthropogenic disturbances originating from within or outside the AOC.

Note that the term "impaired" in the context of this analysis strictly refers to a marsh habitat featuring lower-than-expected marsh bird or amphibian species in relation to Great Lakes basin non-AOC reference conditions; it does not in any way relate to designations made as part of AOC Beneficial Use Impairment or delisting criteria evaluations.

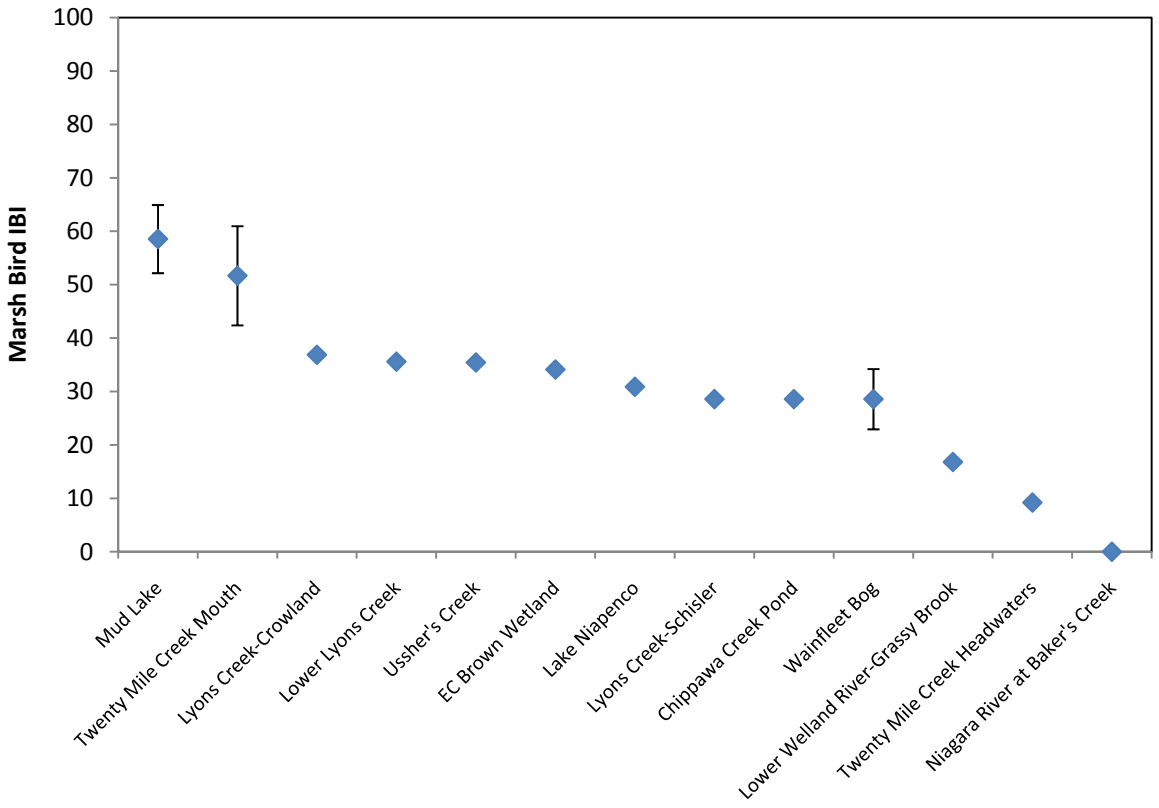

Figure 10. Marsh bird IBI scores for Niagara River (ON) AOC and reference watershed sites, based on MMP data collected from 1998-2010.

Table 8. Status of Niagara River (ON) AOC marshes from 2003 through 2010. "-" denotes lower than expected values based on Great Lakes basin non-AOC reference conditions. "0" denotes values within the expected range based on Great Lakes basin non-AOC reference conditions. "+" denotes higher than expected values based on Great Lakes basin non-AOC reference conditions.

				Assessment of Marsh Bird and Amphibian Species Richness				
Route Name	Survey Type	Years	Number of Stations	Marsh Nesting Bird Species Richness	Marsh Bird Indicator Species Richness	Amphibian Species Richness	Amphibian Indicator Species Richness	Overall Assessment[1,2,3]
Chippawa Creek	Bird, Amphibian	2010	1	-	-	+	0	3
EC Brown Wetland	Bird, Amphibian	2007-2010	1	-	-	+	0	3
Humberstone Marsh	Amphibian	2003-2008	1			+	+	4
Lake Niapenco	Bird, Amphibian	2007-2010	2	-	-	+	+	4
Lower Lyons Creek	Bird, Amphibian	2009-2010	2	-	-	-	-	0
Lyons Creek/Lower Welland River	Amphibian	2003-2010	3			-	0	1
Lyons Creek-Crowland/Schisler	Bird, Amphibian	2007-2009	2	-	-	-	-	0
Lower Welland R.-Grassy Brook (birds)	Bird	2010	1	-	-			0
Mud Lake 1	Amphibian	2003-2004	1			0	-	1
Mud Lake 2	Bird, Amphibian	2008, 2010	2	0	-	0	0	3
Niagara River at Baker's Creek	Bird, Amphibian	2003-2006, 2009-2010	1	-	-	-	0	1
Upper Draper's Creek	Amphibian	2003-2010	2			-	-	0
Upper Welland River	Amphibian	2009	2			0	-	1
Wainfleet Bog	Bird, Amphibian	2003-2010	5	0	-	+	+	5
Niagara River (ON) AOC Overall Assessment[1,2,3]				**-**	**-**	**0**	**0**	**2**

[1] A score of 0, 1 or 2 indicates impairment, a score of 3, 4 or 5 indicates no apparent impairment, and a score of 6, 7 or 8 indicates an above average marsh.
[2] For routes where only bird stations or only amphibian stations were surveyed, a score of 0 or 1 indicates impairment, a score of 2 or 3 indicates no apparent impairment, and a score of 4 indicates an above average marsh
[3] Classification of MMP routes or the AOC as impaired, or showing no apparent impairment, strictly relate to evaluations of capacity to support diverse marsh bird and/or amphibian communities relative to Great Lakes basin non-AOC reference conditions, and are not related in any way to designations applied as part of AOC Beneficial Use Impairment or delisting criteria evaluations by the Remedial Action Plan.

Niagara River (NY) AOC

Wetland Physical/Chemical Water Quality

Table 9 shows mean values for selected physical and chemical water quality parameters. These parameters were selected because they are indicative of potential anthropogenic disturbance. Dissolved oxygen was not included because values for this parameter can range widely depending on several sampling factors (e.g., time of day, windiness). See Table D2 for all physical/chemical water quality results.

Table 9. Summary of selected mean physical and chemical water quality measurements for Niagara River (NY) AOC marsh sites.

Site Name	Conductivity (uS/cm)	pH	NH_3 (ppm)	NO_3 (ppm)	Cl (ppm)	Turbidity (FTU)
Beaver Island	286.0	7.46	0.54	0.11	7.90	26
Buckhorn Marsh East	405.0	7.22	0.62	0.02	14.6	75
Buckhorn Marsh West	710.0	7.75	0.45	0.08	36.0	32
East River	291.5	7.61	0.31	0.14	4.5	17
Republic Steel	640.0	7.73	0.35	0.05	121.6	47
Strawberry Island	275.5	8.76	0.43	0.12	16.6	12
Sunken Island	276.5	8.23	0.44	0.24	10.6	10
Tifft Nature Preserve	266.0	7.26	0.40	0.09	6.8	41
Times Beach	270.3	8.53	0.26	0.04	7.0	39

Buckhorn Marsh West, Republic Steel and Buckhorn Marsh East (particularly at the sampling station near the I-190 overpass) all had high mean conductivity values relative to the other sampled marsh sites. Mean chloride concentration at Republic Steel was considerably higher than for all other sites. By contrast, chloride levels were relatively low at Times Beach, Tifft Nature Preserve, and East River. Sites with relatively high ammonia concentrations (Buckhorn Marsh East, Beaver Island, Buckhorn Marsh West) tended to have low-to-moderate nitrate concentrations; Times Beach yielded low levels for both of these parameters. Sites located on the Niagara River, such as Strawberry Island, Sunken Island, and Buckhorn Marsh West (samples taken near the marsh perimeter) had very alkaline pH levels. Most other sites had generally neutral pH values. Turbidity was highest at Buckhorn Marsh East, although these readings were taken following a heavy rainstorm. Turbidity was next highest at Republic Steel and Tifft Nature Preserve, while it was lowest at Strawberry Island and Sunken Island.

Wetland Macroinvertebrate Communities

Mean taxonomic richness (no. taxa/sample) was evaluated among sites with the same number of sample replicates because number of taxa does not increase linearly with number of replicates at a marsh. Overall, Beaver Island yielded the highest number of orders and families per sample, although it was the only site at which only one sample was collected (Fig. 11). East River, the Buckhorn Marsh sites and Strawberry Island generally had high taxonomic richness among sites, while Times Beach had notably lower numbers than all others. On average, 5.7 orders and 8.7 families were collected per sample among Niagara River (NY) AOC sites.

Index of Biotic Integrity

Aquatic macroinvertebrate community attributes were identified in Environment Canada and Central Lake Ontario Conservation Authority (2004) and, using data collected from all project region sites, were correlated against the macroinvertebrate IBI wetland site disturbance gradient

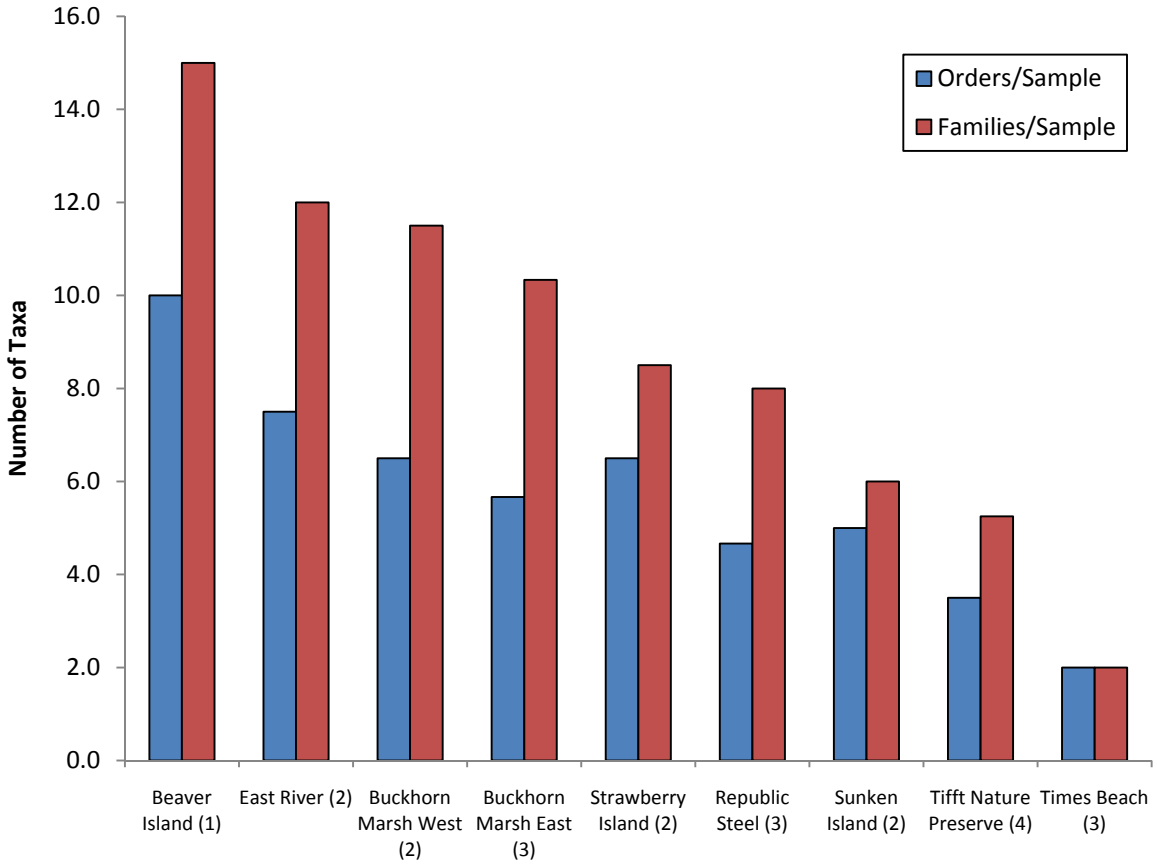

Figure 11. Number of macroinvertebrate orders and families per sample by site for Niagara River (NY) AOC marshes. Sample size is indicated in brackets.

(see Methods) to test for statistically-significant, expected responses to disturbance. Seven metrics responded significantly at all buffer distances ($p<0.20$), and were included in the IBI:

- Total number of genera
- Number of Ephemeroptera and Trichoptera genera
- Number of Trichoptera genera
- Percent Chironomidae
- Number of Crustacea and Mollusca genera
- Number of Ephemeroptera genera
- Percent Trichoptera

Buckhorn Marsh East ranked significantly higher in macroinvertebrate IBI score (87.58) than all other AOC sites (Fig. 12). By comparison, most other sites scored moderately along the IBI gradient (49.25-57.52). Beaver Island and Strawberry Island scored relatively lower, while Times Beach was lowest overall, achieving an IBI score of only 3.40.

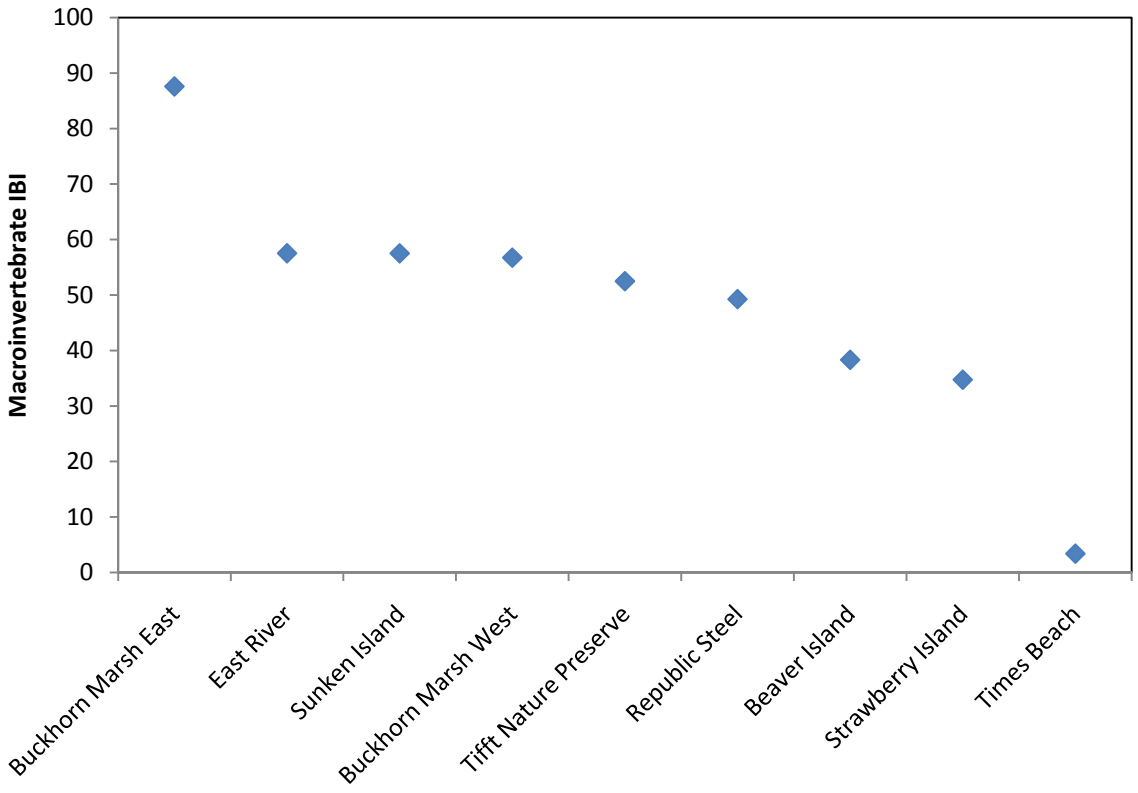

Figure 12. Macroinvertebrate IBI scores for Niagara River (NY) AOC marsh sites.

Wetland Amphibian Communities

A total of six species were detected across all sites between 2009 and 2010 (Table 10), including three of four indicator species (Bullfrog, Northern Leopard Frog and Spring Peeper). The highest number of species (five) were recorded at Beaver Island, East River, and Tifft Nature Preserve. No species were detected at Times Beach across nine station-visits in 2010, while only one species was recorded at Sunken Island following three survey visits in 2010.

Species relative abundances tended to be high at Strawberry Island, Tifft Nature Preserve and Sunken Island, where most or all recorded species attained a maximum calling code of 2 or more (Table 10). Among species, American Toad and Spring Peeper were recorded at the highest calling codes, while all other recorded species tended to occur at lower relative abundances.

Spring Peeper was the most widespread species, occurring at 60% of monitored stations, followed by Northern Leopard Frog and Green Frog, with 53% and 40% station occurrence, respectively (Table 11). All other species were detected much less frequently, occurring at less than 30% of stations. Wood Frog was the most uncommon species, occurring at only 7% of monitored stations. However, other occurrences of this species may have been missed due to its short breeding period during which peak calling activity occurs. The indicator species Western Chorus Frog, as well as Gray Treefrog, were not detected at any AOC site.

Index of Biotic Integrity

Amphibian community attributes were taken from Crewe and Timmermans (2005) and, using data collected from all project region sites, were correlated against the bird/amphibian IBI

Table 10. Maximum calling code detected across survey visits for each species, and number of station-visits, by Niagara River (NY) AOC marsh site.

Marsh Site	Maximum calling code								No. Station-Visits	No. Species Detected
	AMTO	BULL	CHFR	GRTR	GRFR	NLFR	SPPE	WOFR		
Beaver Island State Park		1			1	1	2	1	3	5
Buckhorn Marsh East						1	3		4	2
Buckhorn Marsh West						1	2		2	2
East River	2	1			1	1	3		6	5
Republic Steel					2	1			3	2
Strawberry Island	3					2	2		3	3
Sunken Island	3								3	1
Tifft Nature Preserve	2	2			2	1	3		20	5
Times Beach									9	0

Table 11. Maximum calling code for each species across all marshes, number of stations at which each species was detected, and each species' percentage occurrence among all monitored stations, for Niagara River (NY) AOC marsh sites.

Species Name	Maximum Calling Code	Number of stations with species detected	Percent occurrence among all stations
American Toad	3	4	26.7
Bullfrog	2	4	26.7
Western Chorus Frog	0	0	0.0
Gray Treefrog	0	0	0.0
Green Frog	2	6	40.0
Northern Leopard Frog	2	8	53.3
Spring Peeper	3	9	60.0
Wood Frog	1	1	6.7
No anurans recorded	-	4	26.7

wetland site disturbance gradient (see Methods) to test for statistically-significant, expected responses to disturbance. Five metrics responded significantly at the 2000-m buffer distance ($p<0.20$), and were included in the IBI:

- Presence of woodland species
- Richness of woodland species
- Total species richness
- Presence of Great Lakes basin-wide species
- Richness of Great Lakes basin-wide species

Figure 13 displays a clear gradation of amphibian IBI scores among Niagara River (NY) AOC sites. Beaver Island ranked clearly highest among all sites, with a score of 90.00, followed by East River and Strawberry Island, with scores of 72.78 and 71.67, respectively. In contrast,

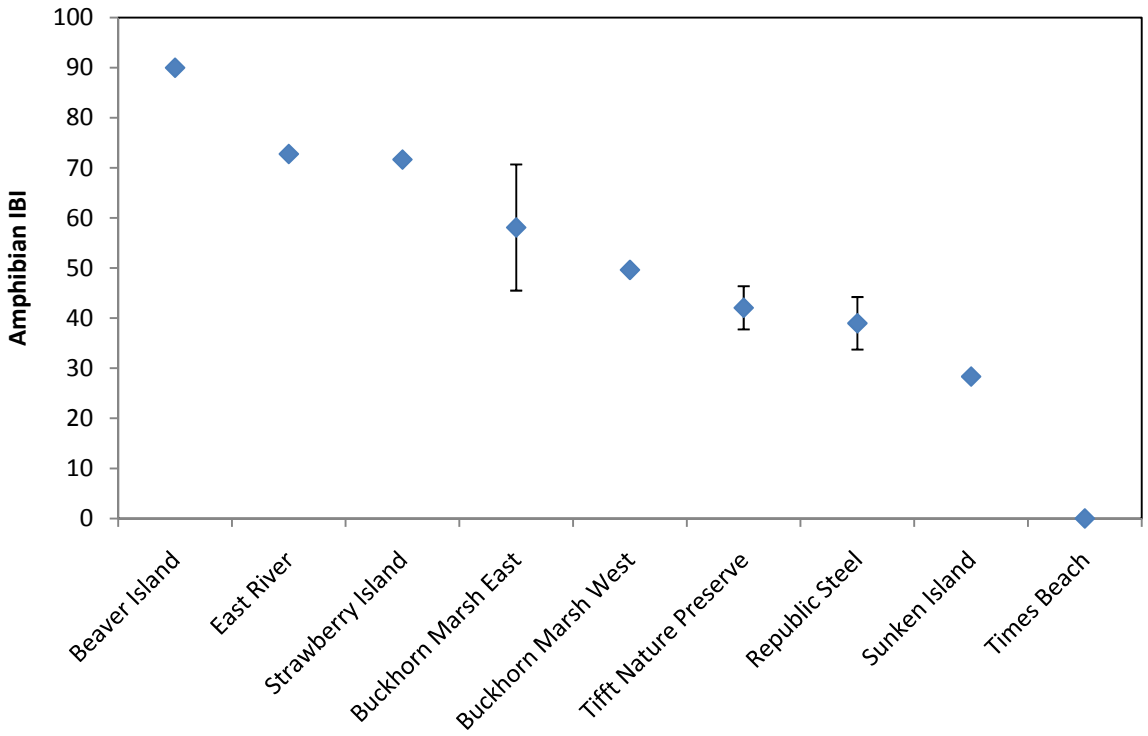

Figure 13. Amphibian IBI scores for Niagara River (NY) AOC sites, based on MMP data collected from 1998-2010.

Sunken Island received a score of only 28.33, while Times Beach received a score of 0.00 – a site at which no amphibians were detected across visits. Tifft Nature Preserve, informally considered to be a regional reference site, scored 6th of 9 sites, with a score of 42.07.

Wetland Bird Communities

Table 12 shows mean abundance per 10 stations for marsh-nesters (including indicator species, shown in bold italics), water foragers and aerial foragers recorded at monitored sites. Nine of a possible 12 indicator species were recorded across AOC marshes. Seven indicator species were recorded at Sunken Island, five at Tifft Nature Preserve, and two at Buckhorn Marsh West. No indicator species were observed at Times Beach while one species was recorded at the remaining sites. Among indicator species, Swamp Sparrow was the most widespread, occurring at four sites, while Marsh Wren was found at three sites. Observed indicator species included the state-wide endangered Black Rail at Sunken Island, the threatened Pied-billed Grebe at Sunken Island and Tifft Nature Preserve, the threatened Least Bittern at Tifft Nature Preserve, and the threatened Common Tern at Strawberry Island, Sunken Island, and Times Beach.

Across all sites, the most marsh nesters were detected at Tifft Nature Preserve (13), followed by Sunken Island and Buckhorn Marsh West with 13 and 8, respectively. Only two marsh-nesters were observed at Times Beach. Across sites, Common Tern had the highest mean abundance, followed by Red-winged Blackbird and Tree Swallow.

Index of Biotic Integrity

Bird community attributes were taken from Crewe and Timmermans (2005) and, using data collected from all project region sites, were correlated against the bird/amphibian IBI wetland site disturbance gradient (see Methods) to test for statistically-significant, expected responses to

Table 12. Mean abundance per 10 stations for bird species detected across survey visits, by Niagara River (NY) AOC marsh site. Indicator species are identified by bold and italicized font.

Species Code	Marsh Site						
	Beaver Island	Buckhorn Marsh West	Republic Steel	Strawberry Island	Sunken Island	Tifft Nature Preserve	Times Beach
AMBI	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***
AMCO	***0.0***	***0.0***	***0.0***	***0.0***	***13.3***	***0.0***	***0.0***
BANS	0.0	0.0	0.0	0.0	0.0	2.2	0.0
BARS	0.0	1.7	0.0	70.0	30.0	3.4	15.0
BCNH	0.0	0.0	3.3	0.0	0.0	0.3	0.0
BEKI	0.0	0.0	0.0	0.0	0.0	0.6	0.0
BLRA	***0.0***	***0.0***	***0.0***	***0.0***	***3.3***	***0.0***	***0.0***
BLTE	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***
CAGO	0.0	0.0	0.0	16.7	30.0	2.5	0.0
CATE	0.0	0.0	0.0	6.7	0.0	0.0	0.0
COGR	0.0	3.3	3.3	0.0	0.0	9.7	0.0
COMO	***0.0***	***0.0***	***0.0***	***3.3***	***10.0***	***0.0***	***0.0***
COTE	0.0	0.0	0.0	176.7	86.7	0.0	7.5
COYE	0.0	8.3	0.0	0.0	0.0	0.0	0.0
GADW	0.0	0.0	0.0	0.0	0.0	0.3	0.0
GBHE	0.0	0.0	0.0	10.0	0.0	0.0	2.5
GCFL	0.0	0.0	0.0	0.0	0.0	0.3	0.0
GRCA	5.0	3.3	5.0	0.0	0.0	2.5	0.0
GREG	0.0	0.0	0.0	3.3	0.0	0.3	2.5
GRHE	0.0	0.0	6.7	0.0	0.0	2.8	0.0
LEBI	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.3***	***0.0***
MALL	0.0	0.0	0.0	23.3	33.3	3.1	0.8
MAWR	***5.0***	***8.3***	***0.0***	***0.0***	***0.0***	***3.1***	***0.0***
MOOT	***0.0***	***0.0***	***0.0***	***0.0***	***13.3***	***0.3***	***0.0***
NRWS	25.0	0.0	0.0	0.0	0.0	0.6	45.0
PBGR	***0.0***	***0.0***	***0.0***	***0.0***	***20.0***	***2.5***	***0.0***
RWBL	40.0	6.7	13.3	10.0	70.0	70.0	38.3
SORA	***0.0***	***0.0***	***0.0***	***0.0***	***20.0***	***0.0***	***0.0***
SOSP	0.0	0.0	0.0	20.0	6.7	1.6	0.0
SWSP	***0.0***	***20.0***	***3.3***	***0.0***	***3.3***	***0.3***	***0.0***
TRES	0.0	0.0	26.7	6.7	0.0	48.4	12.5
VIRA	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***
WIFL	0.0	0.0	0.0	0.0	0.0	0.3	0.0
WODU	0.0	6.7	0.0	0.0	0.0	2.8	0.0
YCNH	0.0	0.0	0.0	0.0	3.3	0.0	0.0
YWAR	30.0	11.7	3.3	0.0	0.0	7.5	0.0
No. Station-Visits	2	6	3	3	3	32	4

disturbance. Seven metrics responded significantly in the expected fashion at the 500-m buffer distance ($p<0.20$) and were included in the IBI.

- Richness of marsh-nesting obligates
- Richness of emergent marsh-nesting obligates
- Abundance of marsh-nesting obligates
- Abundance of invasive bird species
- Richness of area-sensitive marsh-nesting obligates
- Richness of invasive bird species
- Abundance of emergent marsh-nesting obligates

Sunken Island scored clearly higher than all other AOC sites on the marsh bird IBI gradient (85.91) due to the richness and abundance of marsh-obligate species detected there (Fig. 14). Buckhorn Marsh West was scored next highest (63.06), followed by Tifft Nature Preserve (57.21). Republic Steel, East River and Times Beach scored relatively low among sites, with the latter two achieving a score of 28.57.

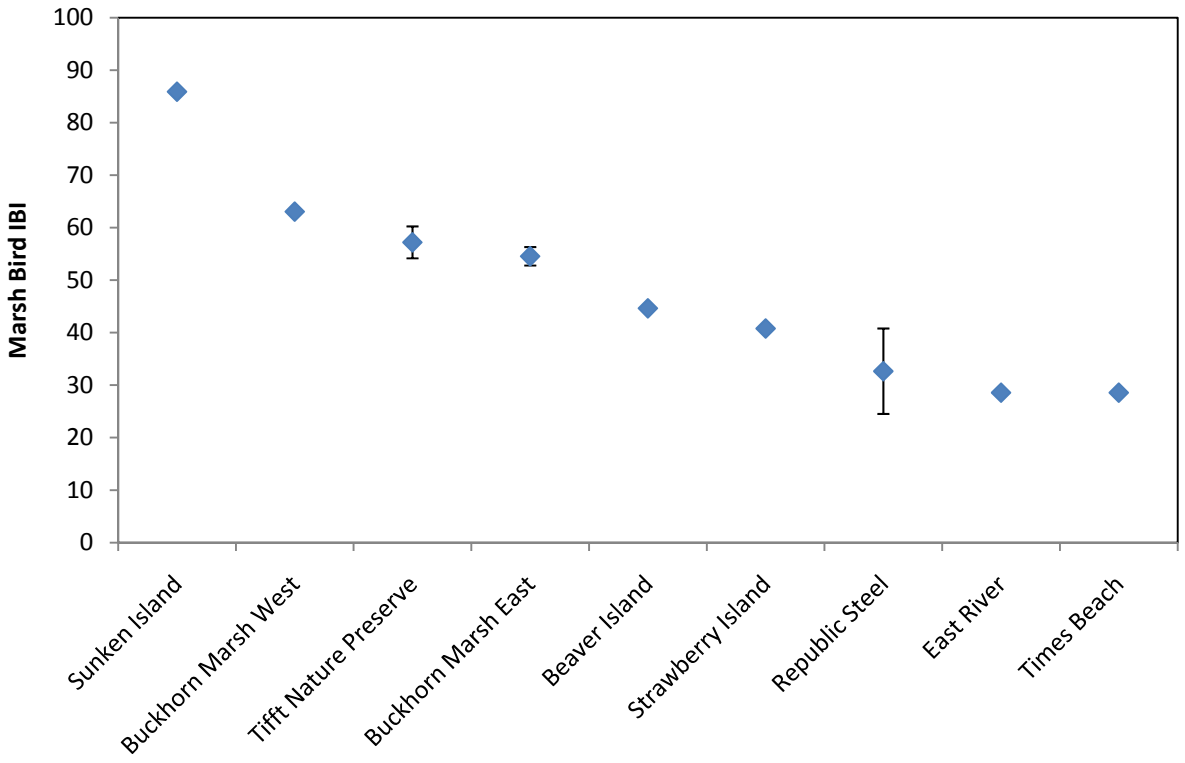

Figure 14. Marsh bird IBI scores for Niagara River (NY) AOC marsh sites, based on MMP data collected from 1998-2010.

Marsh Bird and Amphibian Community Assessments

Table 13 presents scored assessments of marsh bird and amphibian community richness at AOC sites relative to Great Lakes basin non-AOC mean values, for 2003-2010. For the AOC as a whole, total amphibian species richness and amphibian indicator species richness were greater than the expected range of values calculated for Great Lakes basin non-AOC marshes based on measured environmental covariates (e.g., marsh size, proportional coverage of vegetation types). However, marsh-nester and indicator bird species richness values across AOC sites were below average relative to non-AOC values. Strawberry Island was scored as

Table 13. Status of Niagara River (NY) AOC marshes from 2003 through 2010. "-" denotes lower than expected values based on Great Lakes basin non-AOC reference conditions. "0" denotes values within the expected range based on Great Lakes basin non-AOC reference conditions. "+" denotes higher than expected values based on Great Lakes basin non-AOC reference conditions.

				Assessment of Marsh Bird and Amphibian Species Richness				
Route Name	Survey Type	Years	Number of Stations	Marsh Nesting Bird Species Richness	Marsh Bird Indicator Species Richness	Amphibian Species Richness	Amphibian Indicator Species Richness	Overall Assessment[1,2,3]
Beaver Island	Bird, Amphibian	2010	1	-	0	0	0	3
Buckhorn Marsh East	Amphibian	2008, 2010	5			-	+	2
Buckhorn Marsh West	Bird, Amphibian	2008, 2010	3	0	0	0	+	5
East River	Bird, Amphibian	2005-2006, 2010	2	-	-	-	0	1
Republic Steel	Bird, Amphibian	2010	1	-	-	-	-	0
Strawberry Island	Bird, Amphibian	2010	1	-	+	+	+	6
Sunken Island	Bird, Amphibian	2010	1	+	+	-	-	4
Tifft Nature Preserve	Bird, Amphibian	2003-2010	8	-	-	+	+	4
Times Beach	Bird, Amphibian	2010	3	-	-	-	-	0
Niagara River (NY) AOC Overall Assessment[1,2,3]				**-**	**-**	**+**	**+**	**4**

[1] A score of 0, 1 or 2 indicates impairment, a score of 3, 4 or 5 indicates no apparent impairment, and a score of 6, 7 or 8 indicates an above average marsh.

[2] For routes where only bird stations or only amphibian stations were surveyed, a score of 0 or 1 indicates impairment, a score of 2 or 3 indicates no apparent impairment, and a score of 4 indicates an above average marsh

[3] **Classification of MMP routes or the AOC as impaired, or showing no apparent impairment, strictly relate to evaluations of capacity to support diverse marsh bird and/or amphibian communities relative to Great Lakes basin non-AOC reference conditions, and are not related in any way to designations applied as part of AOC Beneficial Use Impairment or delisting criteria evaluations by the Remedial Action Plan.**

being above average in terms of its total and indicator amphibian species richness and its marsh bird indicator species richness. In other words, given its habitat characteristics, it features greater species richness values for these measures than would be expected. The majority of AOC sites (Beaver Island, Buckhorn Marsh East, Buckhorn Marsh West, Sunken Island, and Tifft Nature Preserve) were characterized as exhibiting no apparent impairment in terms of their bird or amphibian species richness values. However, East River, Republic Steel and Times Beach were classified as having lower than expected marsh bird and/or amphibian species richness values relative to non-AOC reference conditions. Overall, Niagara River (NY) AOC marsh habitats were classified as showing no apparent impairment in terms of their ability to support marsh-dependent species richness levels that are expected given their measured physical and vegetation characteristics. However, these marshes generally appear better suited to support healthy amphibian communities than for marsh-nesting bird communities.

Note that the term "impaired" in the context of this analysis strictly refers to a marsh habitat featuring lower-than-expected marsh bird or amphibian species in relation to Great Lakes basin non-AOC reference conditions; it does not in any way relate to designations made as part of AOC Beneficial Use Impairment or delisting criteria evaluations.

Buffalo River AOC

Wetland Physical/Chemical Water Quality

Table 14 shows mean values for selected physical and chemical water quality parameters. These parameters were selected because they are indicative of potential anthropogenic disturbance. Dissolved oxygen was not included because values for this parameter can range widely depending on several sampling factors (e.g., time of day, windiness). See Table D3 for all physical/chemical water quality results.

Table 14. Summary of selected mean physical and chemical water quality measurements for Buffalo River AOC and reference marsh sites.

Site Name	Conductivity (uS/cm)	pH	NH_3 (ppm)	NO_3 (ppm)	Cl (ppm)	Turbidity (FTU)
Reinstein Woods	549.0	8.30	0.40	0.17	65.2	69
Sinking Ponds	964.0	8.25	0.58	0.16	58.6	530
West Seneca Oxbow Wetland	566.5	7.77	0.44	0.10	98.8	33

Water conductivity was very high at Sinking Ponds, while mean chloride concentration was very high at West Seneca Oxbow Wetland; however, all three sites had high conductivity and chloride levels when compared to average site values in the Niagara River ON and NY AOCs. Ammonia and nitrate concentrations did not vary substantially among sites, although ammonia concentration was highest at Sinking Ponds, while nitrate concentration was highest at Reinstein Woods. pH values across sites were somewhat alkaline, with the highest pH measured at Reinstein Woods. Turbidity was very high at Sinking Ponds, although this was based on a single sample.

Wetland Macroinvertebrate Communities

Mean taxonomic richness was generally highest at Sinking Ponds, the upper watershed reference site, although this assessment was based on a single sample, while two samples were collected at the other sites (Fig. 15). Reinstein Woods yielded the same number of families per sample as Sinking Ponds (12.0), while overall taxonomic richness at the West Seneca Oxbow Wetland was not appreciably lower than the other two sites. On average, 7.7 orders and

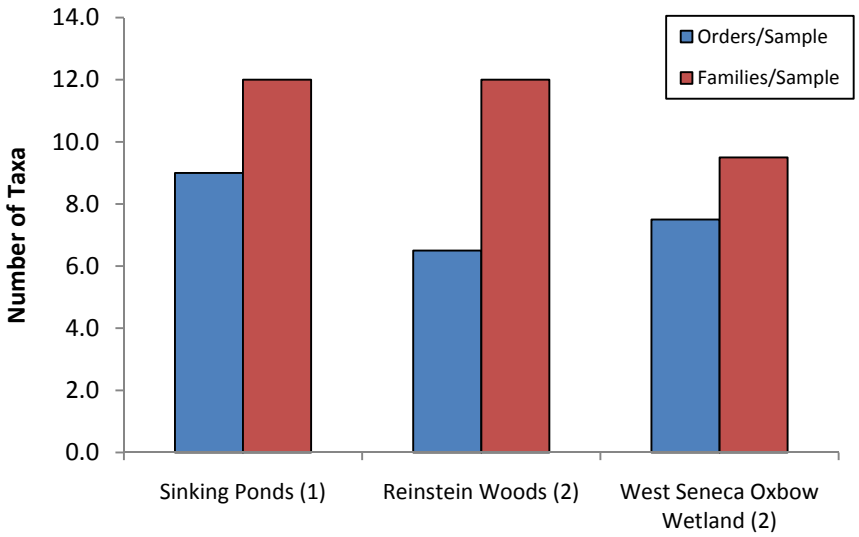

Figure 15. Number of macroinvertebrate orders and families per sample by site for Buffalo River AOC and reference marshes. Sample size is indicated in brackets.

11.2 families were collected per sample from Buffalo River AOC and upper watershed wetland sites.

Index of Biotic Integrity

Aquatic macroinvertebrate community attributes were identified in Environment Canada and Central Lake Ontario Conservation Authority (2004) and, using data collected from all project region sites, were correlated against the macroinvertebrate IBI wetland site disturbance gradient (see Methods) to test for statistically-significant, expected responses to disturbance. Seven metrics responded significantly at all buffer distances ($p<0.20$), and were included in the IBI:

- Total number of genera
- Number of Ephemeroptera and Trichoptera genera
- Number of Trichoptera genera
- Percent Chironomidae
- Number of Crustacea and Mollusca genera
- Number of Ephemeroptera genera
- Percent Trichoptera

Macroinvertebrate IBI scores for Buffalo River AOC/watershed sites were generally low-to-moderate on the IBI gradient (Fig. 16). Reinstein Woods was highest among these (48.23), while West Seneca Oxbow Wetland was the lowest (29.52). The Sinking Ponds reference site scored between these but still relatively low, with 35.14.

Wetland Amphibian Communities

A total of five species were detected between the two sites surveyed in 2010 (Table 15). Three of these five species included indicator species (Bullfrog, Western Chorus Frog, Northern Leopard Frog). Three species were detected at both the Meyer Rd. Wetland and the nearby West Seneca Oxbow Wetland. Of all recorded species, only Green Frog was recorded at full chorus (at each site); all other detected species were recorded at a calling code of 1.

Green Frog was also the most widespread species between sites, occurring at each of four discrete station locations (Table 16). Bullfrog was recorded at two stations while American Toad

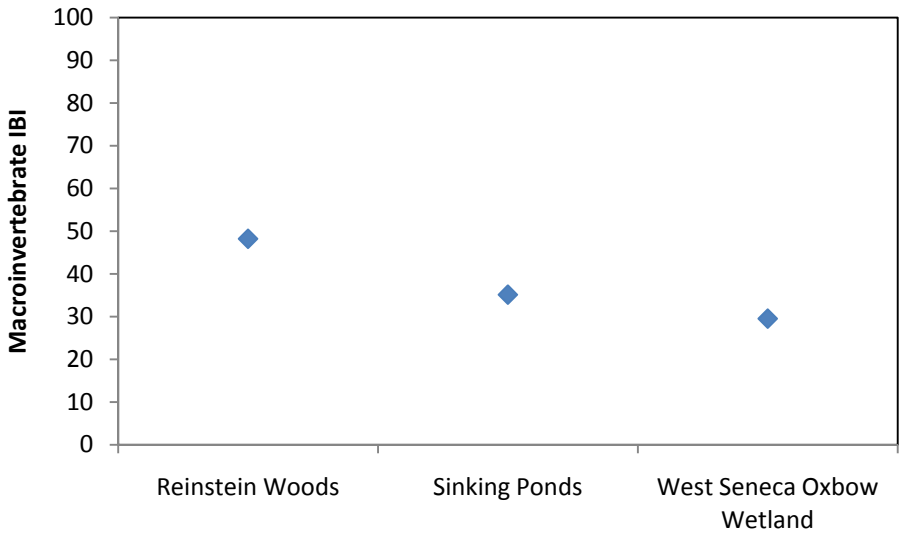

Figure 16. Macroinvertebrate IBI scores for Buffalo River AOC and reference marsh sites.

Table 15. Maximum calling code detected across survey visits for each species, and number of station-visits, by Buffalo River AOC marsh site.

Marsh Site	Maximum calling code									
	AMTO	BULL	CHFR	GRTR	GRFR	NLFR	SPPE	WOFR	No. Station-Visits	No. Species Detected
Meyer Rd. Wetland		1			3	1			5	3
West Seneca Oxbow Wetland	1		1		3				6	3

Table 16. Maximum calling code for each species across all marshes, number of stations at which each species was detected, and each species' percentage occurrence among all monitored stations, for Buffalo River AOC marsh sites.

Species Name	Maximum Calling Code	Number of stations with species detected	Percent occurrence among all stations
American Toad	1	1	25.0
Bullfrog	1	2	50.0
Western Chorus Frog	0	0	0.0
Gray Treefrog	0	0	0.0
Green Frog	3	4	100.0
Northern Leopard Frog	1	1	25.0
Spring Peeper	0	0	0.0
Wood Frog	0	0	0.0
No anurans recorded		0	0.0

and Northern Leopard Frog were each detected at one station. The indicator species Western Chorus Frog and Spring Peeper, as well as Gray Treefrog and Wood Frog, were not detected at AOC sites. An early-season visit to the West Seneca Oxbow Wetland site confirmed no Wood Frog calling activity despite what was perceived to be ideal weather/temperature conditions.

Index of Biotic Integrity

Amphibian community attributes were taken from Crewe and Timmermans (2005) and, using data collected from all project region sites, were correlated against the bird/amphibian IBI wetland site disturbance gradient (see Methods) to test for statistically-significant, expected responses to disturbance. Five metrics responded significantly at the 2000-m buffer distance ($p<0.20$), and were included in the IBI:

- Presence of woodland species
- Richness of woodland species
- Total species richness
- Presence of Great Lakes basin-wide species
- Richness of Great Lakes basin-wide species

Overall, both surveyed sites scored low-to-moderate on the amphibian IBI gradient. The West Seneca Oxbow Wetland was highest between sites, with an IBI score of 47.50. Conversely, the Meyer Rd. Wetland only scored 23.89.

Wetland Bird Communities

Table 17 shows mean abundance per 10 stations for marsh-nesters, water foragers and aerial foragers recorded at the Meyer Rd. Wetland – the only Buffalo River AOC or upper watershed site surveyed for birds during the project period. None of the 12 indicator species were recorded at the Meyer Rd. Wetland. In total, four marsh-nesters were detected within the marsh. Red-winged Blackbird had the highest mean abundance among species, followed by Canada Goose and Tree Swallow.

Table 17. **Mean abundance per 10 stations for bird species recorded at the Meyer Rd. Wetland, Buffalo River AOC.**

Species Code	Abundance/10 stations	Species Code	Abundance/10 stations	Species Code	Abundance/10 stations
BARS	10.0	EAKI	3.3	TRES	11.7
BEKI	1.7	MALL	3.3	WIFL	6.7
CAGO	16.7	RWBL	31.7	YWAR	5.0

Index of Biotic Integrity

Bird community attributes were taken from Crewe and Timmermans (2005) and correlated against the bird/amphibian IBI wetland site disturbance gradient (see Methods) to test for statistically-significant, expected responses to disturbance. Seven metrics responded significantly in the expected fashion at the 500-m buffer distance ($p<0.20$) and were included in the IBI.

- Richness of marsh-nesting obligates
- Richness of emergent marsh-nesting obligates
- Abundance of marsh-nesting obligates
- Abundance of invasive bird species
- Richness of area-sensitive marsh-nesting obligates
- Richness of invasive bird species
- Abundance of emergent marsh-nesting obligates

The sole bird-monitored site – Meyer Rd. Wetland – achieved an IBI score of 28.57, placing it relatively low on the marsh bird IBI score gradient.

Marsh Bird and Amphibian Community Assessments

Table 18 presents scored assessments of marsh bird and amphibian community richness at AOC sites relative to Great Lakes basin non-AOC mean values, for 2003-2010. The Buffalo River AOC assessment was based on results from only two sites; therefore, some caution is required when interpreting the results. Nonetheless, for each site and for the AOC overall, the biotic community measures for both marsh birds and amphibians were below the expected range of values calculated for Great Lakes basin non-AOC marshes. In other words, given their habitat characteristics (e.g., marsh size, proportional coverage of vegetation types), Buffalo River AOC sites featured lower species richness values than would be expected when compared to reference conditions. As such, each site individually, and the AOC as a whole, were classified as being impaired in terms of their ability to support marsh-dependent species richness values that are expected given their measured physical and vegetation characteristics. However, each of these sites has only been surveyed for one year and one site for amphibians only; additional long-term monitoring is required to more confidently draw conclusions. Regardless, this observed "deficit" in species richness values, unaccountable by latitudinal and temporal trends in species richness, nor environmental conditions at the site, may be assumed to be caused by anthropogenic disturbances originating from within or outside the AOC.

Broad Regional Assessments

Indices of Biotic Integrity

Wetland macroinvertebrate communities

Figure 17 shows macroinvertebrate IBI scores for all sampled sites within the broad project region. Overall, the majority of sampled sites were classified as "fair" in terms of their macroinvertebrate community assemblages, with three sites each falling within the "good" and "poor" categories. In general, Niagara River (ON) sites spanned a broad range of IBI scores, including two "good" sites (Niagara River at Baker's Creek, Lyons Creek-Crowland) and one "poor" site (Twenty Mile Creek Mouth). Niagara River (NY) sites tended to be classified as "fair" but included both a "good" site (Buckhorn Marsh East) and a "poor" site (Times Beach). Buffalo River sites were scored within the lower half of the IBI gradient and included two "fair" sites and one "poor" site (West Seneca Oxbow Wetland).

Wetland Amphibian Communities

Figure 18 shows mean amphibian IBI scores for all surveyed sites within the broad project region. A strong gradation from high to low mean amphibian IBI occurred across sites among all three AOC regions, with several sites attributed to all three wetland condition classes. Niagara River (ON) AOC sites constitute the majority of sites classified as "good" (five of eight) or "fair" (10 of 15) within the amphibian IBI. Five of eight "poor" sites are located in Ontario, although two of these are Twenty Mile Creek reference watershed sites. Niagara River (NY) sites are distributed widely across the amphibian IBI gradient, and comprise most New York sites deemed "good" or "fair". The two Buffalo River AOC sites occur within the lower half of the IBI gradient, with one site each considered "fair" and "poor".

Wetland Bird Communities

Figure 19 shows mean marsh bird IBI scores for all surveyed sites within the broad project region. Overall, the majority of sites were classified as "fair" or "poor" in terms of their marsh bird

Table 18. Status of Buffalo River AOC marshes from 2003 through 2010. "-" denotes lower than expected values based on Great Lakes basin non-AOC reference conditions. "0" denotes values within the expected range based on Great Lakes basin non-AOC reference conditions. "+" denotes higher than expected values based on Great Lakes basin non-AOC reference conditions.

				Assessment of Marsh Bird and Amphibian Species Richness				
Route Name	Survey Type	Years	Number of Stations	Marsh Nesting Bird Species Richness	Marsh Bird Indicator Species Richness	Amphibian Species Richness	Amphibian Indicator Species Richness	Overall Assessment[1,2,3]
Meyer Rd. Wetland	Bird, Amphibian	2010	2	-	-	-	-	0
West Seneca Oxbow Wetland	Amphibian	2010	2			-	-	0
Buffalo River AOC Overall Assessment[1,2,3]				**-**	**-**	**-**	**-**	**0**

[1] A score of 0, 1 or 2 indicates impairment, a score of 3, 4 or 5 indicates no apparent impairment, and a score of 6, 7 or 8 indicates an above average marsh.

[2] For routes where only bird stations or only amphibian stations were surveyed, a score of 0 or 1 indicates impairment, a score of 2 or 3 indicates no apparent impairment, and a score of 4 indicates an above average marsh

[3] **Classification of MMP routes or the AOC as impaired, or showing no apparent impairment, strictly relate to evaluations of capacity to support diverse marsh bird and/or amphibian communities relative to Great Lakes basin non-AOC reference conditions, and are not related in any way to designations applied as part of AOC Beneficial Use Impairment or delisting criteria evaluations by the Remedial Action Plan.**

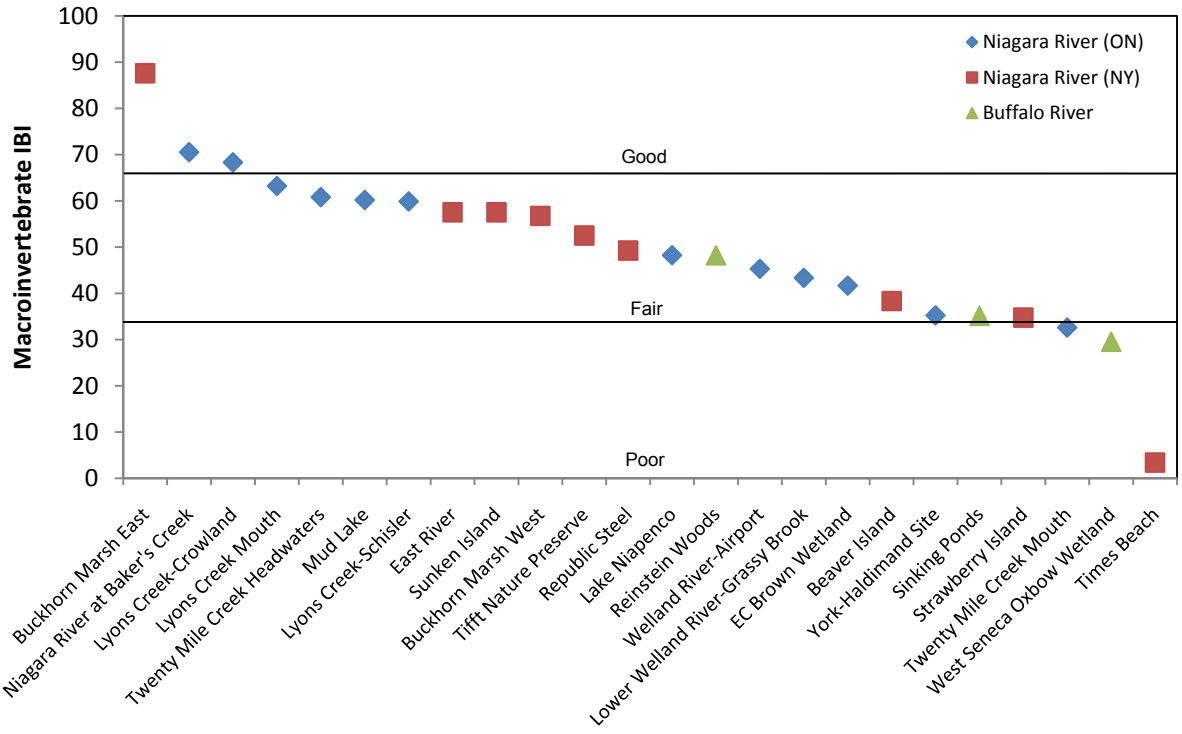

Figure 17. Macroinvertebrate IBI for all sampled project region marsh sites, based on data collected in 2009. Three wetland condition classes are shown.

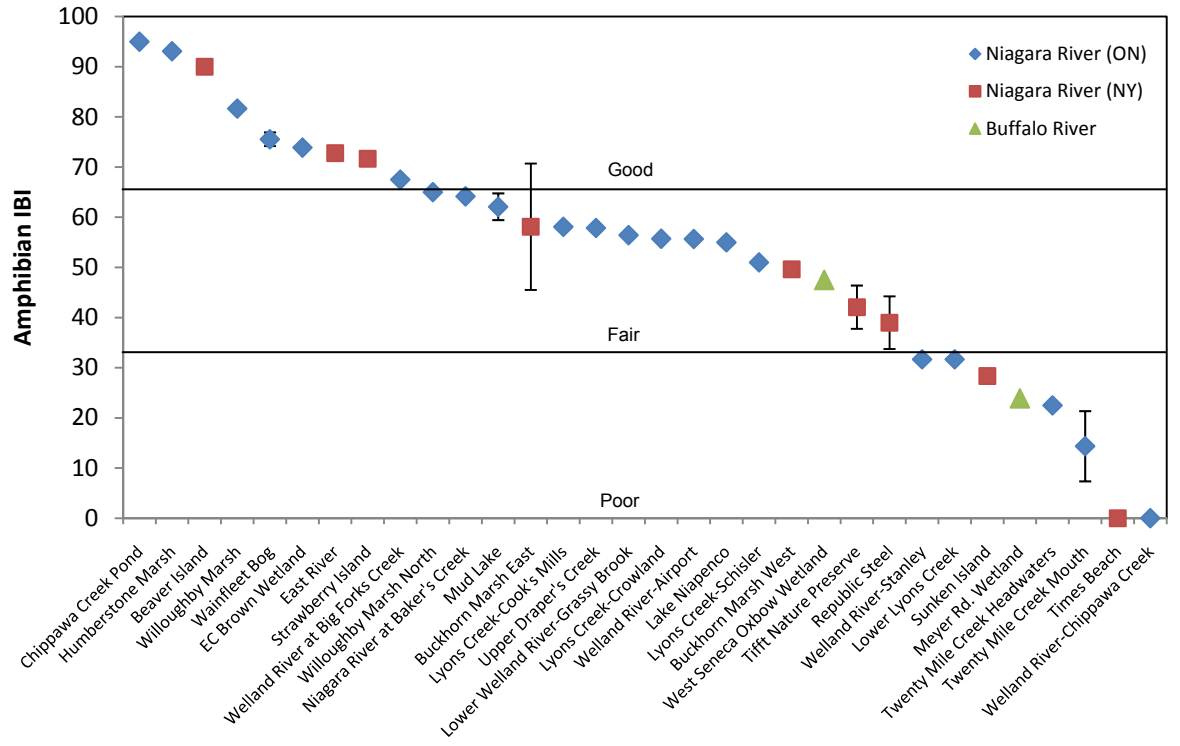

Figure 18. Mean amphibian IBI for all surveyed project region marsh sites, based on 1998-2010 MMP data. Three wetland condition classes are shown.

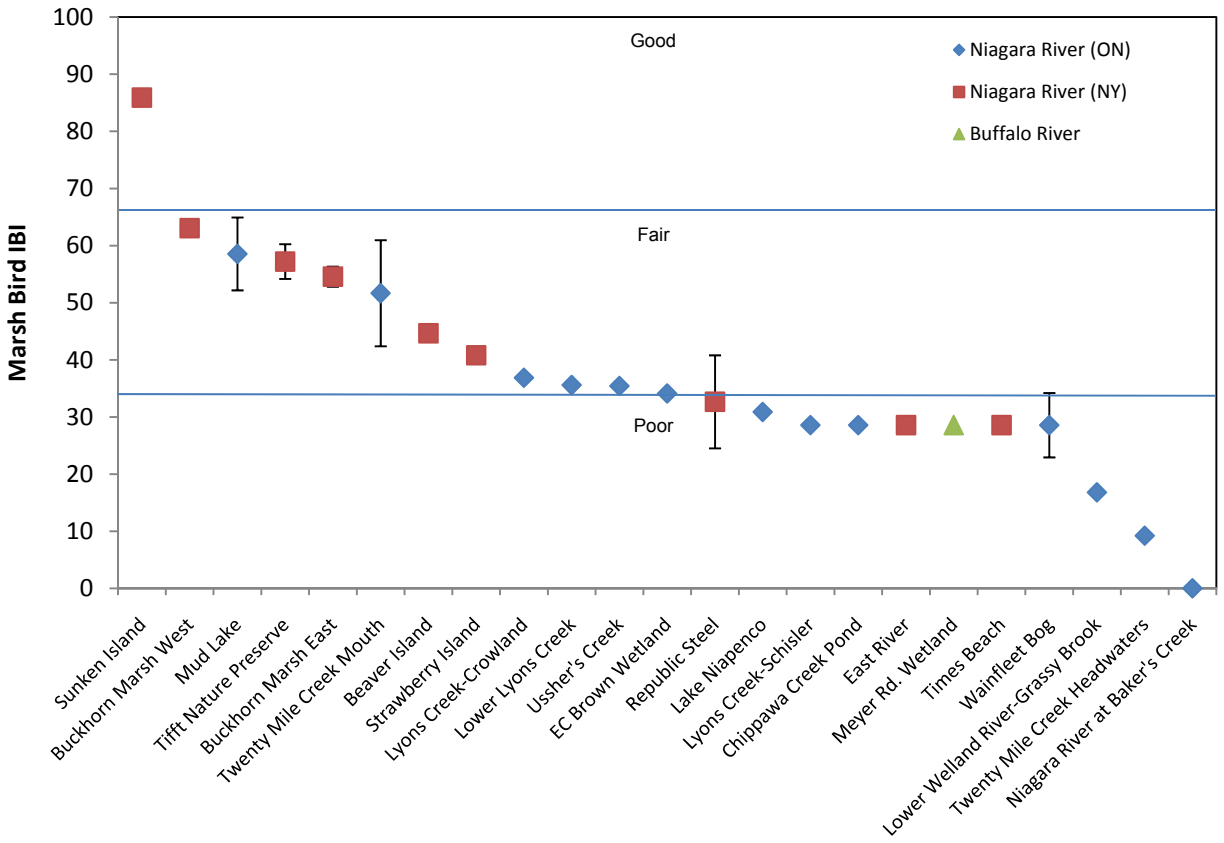

Figure 19. Mean marsh bird IBI for all surveyed project region marsh sites, based on 1998-2010 MMP data. Three wetland condition classes are shown.

community condition. One site (Sunken Island, of the Niagara River (NY) AOC) was classified as featuring a "good" marsh bird community condition. In general, Niagara River (ON) AOC sites occurred within the lower half of the IBI gradient and comprised several of the "poor" sites. Exceptions to this include Mud Lake and the Twenty Mile Creek Mouth reference site. In contrast, Niagara River (NY) sites comprised most of the highest scoring sites, and were mainly classified as having "fair" marsh bird community integrity. The single Buffalo River AOC site that was surveyed for birds (Meyer Rd. Wetland) was classified as poor with respect to its marsh bird community status.

Marsh Bird and Amphibian Community Assessments

Scored assessments of marsh bird and amphibian species richness values were calculated for all Niagara River (ON and NY) AOC marsh sites combined, and considering the two AOCs as a single, bi-national AOC. Overall, the combined AOC featured marsh-nesting and indicator bird species richness values that were lower than expected relative to Great Lakes basin non-AOC reference values. However, total amphibian species richness and amphibian indicator species richness values were above average for the combined AOC, relative to reference values. Following the standard scoring scheme, the combined AOC would be classified as showing no apparent impairment with respect to the condition of its measured wetland-dependent species, although the results clearly suggest that, in general, combined AOC marshes function better to support "healthy" amphibian communities than they do as habitat for large or diverse marsh bird communities.

DISCUSSION

Niagara River (ON) AOC

Results of this project reported for the Niagara River (ON) AOC and its individual surveyed wetland sites generally agree with a similar wetland assessment report completed specifically for this AOC as part of a separate 2008-2010 project (Archer et al. 2010). That project, which, in part, assessed AOC wetland bird and amphibian community condition based on 2003-2009 MMP data, was in turn intended to serve as a follow-up to a similar AOC wetland assessment conducted earlier using 1995-2002 MMP data (Timmermans et al. 2004). This current report in essence updates assessments made in Archer et al. (2010) with an additional year of MMP bird and amphibian data – a year in which several sites were surveyed for both marsh birds and amphibians through the participation of an expanded regional volunteer base and the involvement of an MMP survey contractor at certain priority marsh sites.

Based on species richness-based community assessment analyses, the Niagara River (ON) AOC is considered impaired in its ability to collectively support wetland-dependent bird and amphibian species richness levels that would be expected based on Great Lakes basin non-AOC reference conditions. However, this result was driven by below-average marsh bird species richness levels across AOC sites, while, in fact, overall amphibian community values were within the range that would be expected across sites in relation to reference conditions. These results are unchanged from Archer et al. (2010), which also reported a change in AOC amphibian community status from impaired in 1995-2002 to showing no apparent impairment based on data collected since 2003. However, AOC habitat functionality for marsh-dependent bird species is considered impaired based on 2003-2010 data, unchanged from the 1995-2002 assessment.

Individual sites often differed in terms of which taxonomic group they seemed to most optimally support. Mud Lake, though, appeared to represent a generally good site within the AOC with respect to its marsh bird, amphibian and macroinvertebrate communities. Several AOC marshes appear to support healthy amphibian communities, such as Chippawa Creek Pond, Humberstone Marsh, Willoughby Marsh and Wainfleet Bog. Most AOC sites ranked significantly higher than the reference marshes on the amphibian IBI. Aside from Mud Lake, most AOC marshes did not contain bird species indicative of healthy marsh conditions, but see below regarding caveats involving marsh size; most sites scored well below the large Twenty Mile Creek Mouth reference marsh in terms of marsh bird community status. Conversely, multiple AOC sites that were considered to be relatively poor, as represented by marsh bird and amphibian community status assessment classifications of “impaired”, low- or “poor”-ranking IBI scores, and/or low macroinvertebrate taxonomic richness, tended to be associated with the Welland River system and the lower Lyons Creek. However, some of these sites (e.g., Lyons Creek Mouth) contained relatively healthy macroinvertebrate communities in spite of varied bird and amphibian community integrity. This suggests that these sites may or do contain better bird and/or amphibian community assemblages than reported, which may be borne out through additional MMP surveys. However, macroinvertebrate results were based on limited data; some caution should be used when interpreting the results.

The Twenty Mile Creek watershed marshes generally did not perform well as references for AOC conditions, with the exception of Twenty Mile Creek Mouth for marsh bird community status. This conclusion was also reached in Archer et al. (2010), a project that partially occurred in parallel to this one. In particular, these sites appear to be similarly vulnerable to anthropogenic disturbances as several AOC sites, due to their landscape contexts directly adjacent to busy roadways, residential housing, or agricultural fields. Rather, certain AOC sites, such as Humberstone Marsh or Chippawa Creek Pond, provided more of what may be

considered reference conditions for amphibian community integrity. Future studies assessing these biotic communities should select alternate reference sites that better represent less-disturbed habitat, even if those sites are more distant from the AOC. Further, reference sites may need to be selected separately to compare discrete taxonomic groups. Doing so would improve wetland disturbance gradients against which to test metric responses as part of periodic IBI refinements.

Niagara River (NY) AOC

Based on species richness-based community assessment analyses, the Niagara River (NY) AOC does not show any apparent impairments in its ability to collectively support wetland-dependent bird and amphibian species richness levels that would be expected relative to Great Lakes basin non-AOC reference conditions. This result, though, was largely driven by robust amphibian communities observed across several AOC sites, whereby, collectively, the AOC was considered to have amphibian species richness values that exceeded the expected range for both community measures. While the overall AOC was considered to have below-average marsh bird species richness, certain individual sites met or exceeded expected values given their measured habitat parameters (e.g., Sunken Island, Strawberry Island).

In general, Buckhorn Marsh (East and West) and Tifft Nature Preserve exhibited healthy wetland-dependent biotic communities, based on species richness-based community analyses, IBI results and survey data summaries. These results appear to justify the *a priori* informal designation of these marshes as references for surrounding sites. However, species richness modelling suggested that Tifft Nature Preserve marsh bird community values were lower than they could be based on measured habitat parameters, suggesting that this site may be impacted to some degree by surrounding anthropogenic pressures. Other state-protected marshes on the Niagara River (Sunken Island, Strawberry Island, East River) appeared to contain healthy communities of one or more measured taxonomic groups, suggesting relatively good ecological condition of these sites as well. Conversely, Times Beach, and to a lesser extent, Republic Steel featured generally low-quality habitat condition according to measured parameters. Reasons for poor results at Times Beach are unclear; however, while it is a protected nature reserve, it is surrounded by intensive urban and harbour land/water uses, which may be impacting it to an unknown extent. Additional years of MMP surveys at this site will help to improve our knowledge of its bird and amphibian community integrity.

Buffalo River AOC

Relatively little data was collected within the AOC itself (specifically, the expanded Habitat Opportunity Area), necessitating some caution when interpreting the results at an AOC scale. However, species richness community assessment analyses suggest that the Buffalo River AOC is impaired in its ability to support wetland-dependent species richness values at reference condition levels. In particular, measures for both marsh bird and amphibian community integrity were below average relative to Great Lakes basin non-AOC conditions. These results suggest that surveyed sites are being impacted by certain anthropogenic stressors derived from the largely urban landscape surrounding these sites.

Site quality did not seem to vary noticeably according to watershed location (lower vs. upper). Direct comparisons are hampered by a lack of common survey types (MMP, water quality, macroinvertebrates) across all sites. Nonetheless, the upper-watershed Sinking Ponds, selected *a priori* as a reference site, ranked relatively low on the macroinvertebrate IBI and featured poor water quality values typical of sites heavily impacted by adjacent urban and/or agricultural land uses. Additionally, although the Reinstein Woods marsh occurs within a protected nature preserve, it yielded high conductivity, chloride and nitrate values, possibly resulting from a water

source derived from a heavily urbanized landscape. While the West Seneca Oxbow Wetland (currently undergoing habitat restoration) appears to contain a "fair" amphibian ecological condition, water quality measurements suggest that surrounding upland land uses may be having a negative effect on the site's aquatic ecosystem integrity.

Region-wide Results and Concepts

Generally, marsh sites that exhibited good ecological integrity of aquatic macroinvertebrate and amphibian and/or marsh bird communities tended to be those that are or were managed, protected or restored. Examples of these sites include Humberstone Marsh and the East River wetland (wetland restoration sites), Buckhorn Marsh and Tifft Nature Preserve (actively managed) and Chippawa Creek Pond, Willoughby Marsh and Mud Lake (located within conservation areas, state parks or nature preserves). There were some exceptions to this. Times Beach and Reinstein Woods are located within protected nature reserves, but the former rated poorly for all biotic parameters while the latter yielded only a moderate macroinvertebrate IBI score. Notwithstanding the need for additional long-term monitoring at these sites, this demonstrates how even protected marsh sites can be vulnerable to anthropogenic stressors derived from surrounding urban, industrial or agricultural land uses.

Most of these sites also tended to be located adjacent to or surrounded by upland woodlands and contained relatively healthy amphibian communities. Studies have demonstrated the importance of woodland proximity to wetland breeding sites, and amphibians' accessibility between these habitat types, to species occurrence in a wetland (Hecnar and M'Closkey 1998, Kolozsvary and Swihart 1999, Guery and Hunter 2002, Houlahan and Findlay 2003). Given amphibians' unique terrestrial and aquatic life history habitat requirements, efforts should be made to conserve aquatic and wetland environments, as well as adjacent wooded uplands, to increase the likelihood of a diverse amphibian population. Efforts to conserve surrounding woodland should particularly focus on the region immediately adjacent to wetland breeding sites (i.e., within 200 m) as land-use disturbances in this area most strongly impact breeding amphibian populations (Dinehart 2005). It should also be emphasized that this project only focused on marsh habitats and did not account for other amphibian breeding habitats within each AOC. Community series mapping conducted as part of the Natural Areas Inventory for Ontario's Niagara Region classified three-quarters of all identified wetlands within Niagara as swamps, which are important amphibian breeding habitats, particularly for woodlands species. Therefore, our amphibian community richness results may be conservative, although surveys of other appropriate breeding habitats would be required to confirm this.

Efforts to conserve or restore swamp or upland woodland habitats to surround or buffer marsh habitats from adjacent anthropogenic land uses or other stressors may also improve marsh bird community integrity or species richness. DeLuca et al. (2004) showed that relatively low levels of urban/suburban development (14%) within 500 m of a marsh can significantly reduce its bird community integrity. The general prevalence of marsh-nesting generalist species and other general marsh-users (e.g., Yellow Warbler, Common Grackle) across monitored sites rather than marsh-dependent species may have been due in part to disturbances originating in close proximity to the marsh sites (e.g., adjacent roads, agricultural fields) (Blair 1996). Indeed, IBI metrics that represented measures of obligate marsh-nesting bird species richness and abundance correlated most strongly to disturbance at the smallest spatial scales around target wetlands (e.g., 500 m).

AOC sites that were considered to be relatively poor, as represented by marsh bird and amphibian community status assessment classifications of "impaired", low- or "poor"-ranking IBI scores, and/or low macroinvertebrate taxonomic richness, were often associated with the Welland River system and the lower Lyons Creek in Ontario, and Buffalo River tributaries in

New York. As prominent waterways within each AOC, they are naturally subject to non-point source pollution inputs variously from agricultural, urban and industrial sources. High conductivity or chloride levels (associated with urban/road stormwater runoff) and relatively high concentrations of nitrogenous compounds (associated with urban and agricultural fertilizers) commonly measured at these sites are indicative of anthropogenic stressors on wetland biotic communities from surrounding land uses and may be contributing factors toward the poor ecological condition of wetland-dependent bird and amphibian communities observed at these sites. Field and laboratory studies have validated the deleterious effects of salts, nitrogenous compounds, and other water-borne pollutants on amphibian physiological development, survivorship, behaviour, and community structure (Sanzo and Hecnar 2006, de Solla et al. 2002). These sites also tend to be more directly exposed to surrounding intensive land uses through adjacent location to roadways or lack much natural woodland buffer, which is known to be able to intercept nitrates in groundwater (Phillips 1993).

Other unmeasured variables that were beyond the scope of this project, such as marsh size, connectivity, water and sediment metal concentrations, and wetland vegetation diversity likely also contributed to differences in biotic community condition among sites. Another factor unique to the upper Niagara River and the Welland River and its tributaries below the Port Davidson weir is the effect of in-river water-flow reversal caused by hydroelectric power facilities. One result of this local phenomenon is regular, daily fluctuation in river water level of two to three feet (D. McDonell, pers. Comm.). Such large fluctuations may inhibit nesting success of marsh-breeding species that build nests at or close to the water surface (e.g., Common Moorhen, Virginia Rail); Desgranges et al. (2006) found that frequent water level change during the breeding period can adversely affect the reproductive success of several marsh-breeding species. Further research is required to determine the relative influence of various local- and landscape-level stressor variables on biotic community condition at AOC wetlands, particularly for sites at or near which known historic or current contaminant point sources are known. While many of the influences described above may be beyond the score of RAPs to address (i.e., not specific to an AOC), it is nonetheless important to consider their effects as part of broader population or habitat conservation or management planning.

Certain marsh-nesting and indicator bird species may not be expected to occur at many of the monitored AOC marshes due to their relatively small size (< 5 ha) or fringing riverine nature. For example, species such as Common Moorhen, Least Bittern, Marsh Wren, American Bittern and Black Tern have <20% probability of occurring in marshes smaller than 25 ha (Timmermans and McCracken 2004). Marsh-nesting generalist species, such as Yellow Warbler, Common Yellowthroat and Eastern Kingbird, are more likely to breed in AOC marshes, particularly those that may be disturbed due to anthropogenic stressors (Blair 1996). However, Sora and Virginia Rail are known to occasionally breed in small marshes. Grabas et al. (2008) caution that the marsh bird IBI is most appropriately used for marshes at least 10 ha in size, since among-site differences in marsh size are currently not accounted for when evaluating site condition, which may be based, in part, on metrics associated with area-sensitive marsh-nesters. This methodological limitation must be considered when interpreting the marsh bird IBI results, particularly due to the small size of many AOC marshes. Nevertheless, within the Niagara River (ON) and Buffalo River AOCs, the collective results suggest that lack of suitable habitat and anthropogenic disturbance appear to be limiting factors toward occurrence and abundance of area-sensitive marsh-dependent bird species (i.e., American Bittern, Virginia Rail, Sora, Swamp Sparrow, Black Tern, Pied-billed Grebe, Least Bittern).

The Niagara River is an attractive location for many waterbird species across all life cycle stages, as recognized in its designation as a globally significant Important Bird Area. As such, remaining marsh habitats, even relatively small ones (Sunken Island, Strawberry Island) are

important habitats for certain recorded marsh bird species. However, these sites remain under pressure from human-induced disturbances, as indicated by biotic community condition models for certain sites, which suggest that species richness measures of marsh birds, and to a lesser extent, amphibians, are lower than what would be expected due to some unexplained impairment(s) originating within or outside of the AOC.

CONCLUSIONS AND RECOMMENDATIONS

Most marsh habitats within the two Niagara River AOCs contain wetland macroinvertebrate, amphibian and bird communities that are in at least "fair" condition as measured by IBIs, although Buffalo River AOC sites seem to be in generally poorer condition. Overall, the Niagara River AOCs contain amphibian communities that meet or exceed expected (non-AOC) values, but are both impaired in terms of their marsh bird community condition. Overall, Buffalo River AOC marshes are impaired in terms of their ability to support both marsh bird and amphibian species at expected richness levels.

In general, marshes that are protected and/or actively managed, and buffered from surrounding incompatible land uses with surrounding or adjacent woodland, tended to have higher ecological integrity of resident wetland-dependent species. Conversely, marshes that were exposed to intensive agricultural, urban or industrial activity, with little or no natural buffer, often featured poorer ecological condition. However, exceptions to this occurred, and certain sites seemed to feature good ecological condition for one taxonomic group while featuring poor condition for another. Continued, annual monitoring will help to better understand status and long-term trends of wetland biotic community health in these wetlands.

Based on our results the following recommendations can be made to inform future wildlife population and/or habitat management planning in the AOCs:

1. Natural land cover types, particularly woodlands, that surround or lie adjacent to marsh habitats should be conserved and maintained to optimize localized wildlife biodiversity.
2. Continue to monitor natural development of habitat restoration sites (e.g., EC Brown Wetland, East River wetland) and make changes to site management where necessary to meet ecosystem functional objectives.
3. Continue efforts to encourage use of agricultural Best Management Practices, and inform urban planning, to minimize non-point source pollution of aquatic systems.
4. Perform comprehensive wetland health assessments approximately every five years to track wildlife population and habitat recovery, interspersed with annual volunteer-based monitoring activity.
5. Investigate other factors that influence habitat suitability for wetland-breeding wildlife, such as effects caused by flow-reversal in the Welland River and its tributaries.

We also recommend regular, periodic updates of wetland-based IBI values for amphibians, birds, and if possible, macroinvertebrates, to track changes in AOC wetland community integrity. The local volunteer surveyor base should be maintained to provide adequate data to perform these analyses for birds and amphibians. Macroinvertebrate and water quality sampling can occur as part of less-frequent intensive habitat assessments. In conjunction with Environment Canada and with support from the U.S. Environmental Protection Agency-Great Lakes National Program Office and the Great Lakes Restoration Initiative, Bird Studies Canada plans to continually evaluate, and where needed, revise these IBIs to maximize their accuracy and usefulness in reporting wetland habitat condition. This includes methods to account for the effects of marsh size when evaluating marsh condition, such that, for example, small marshes are better recognized as being of good ecological quality

despite not containing certain area-sensitive marsh-breeding bird species. Future IBI use should also consider re-evaluation of reference site selection procedures to improve power to detect differences in IBI values among sites.

LITERATURE CITED

Archer, R.W., S.T.A. Timmermans and C.L. Robinson. 2006. Monitoring and assessing marsh habitats in Great Lakes Areas of Concern – Final Project Report. Unpublished Bird Studies Canada report for the U.S. Environmental Protection Agency – Great Lakes National Program Office. 301 pp.

Archer, R.W., P.C.J. Lorenz, and K.E. Jones. 2010. Monitoring and assessing marsh habitat health in the Niagara River Area of Concern. Unpublished Bird Studies Canada report for the Great Lakes Sustainability Fund, Environment Canada. 31 pp.

Bird Studies Canada. 2008. Marsh Monitoring Program Participant's Handbook – Getting Started. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. 13 pp.

Blair, R.B. 1996. Land use and avian species diversity along an urban gradient. Ecological Applications 6(2): 506-519.

Conway, C.J. 1995. Virginia Rail (*Rallus limicola*). In: The Birds of North America. No. 173 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelpia, and the American Ornithologists' Union, Washington, D.C.

Crewe, T.L. and S.T.A. Timmermans. 2005. Assessing biological integrity of Great Lakes coastal wetlands using marsh bird and amphibian communities. Unpublished Bird Studies Canada technical report for the U.S. Environmental Protection Agency. 88 pp.

de Solla, S.R., K.E. Pettit, C.A. Bishop, K.M. Cheng, and J.E. Elliott. 2002. Effects of agricultural runoff on native amphibians in the lower Fraser River Valley, British Columbia, Canada. Environmental Toxicology and Chemistry. 21(2): 353-360.

DeLuca, W.V., C.E. Studds, L.L. Rockwod, and P.P. Marra. 2004. Influence of land use on the integrity of marsh bird communities of Chesapeake Bay, USA. Wetlands 24(4): 837-847.

Desgranges, J., J. Ingram, B. Drolet, J. Morin, C. Savage, and D. Borcard. 2006. Modelling wetland bird response to water level changes in the Lake Ontario-St. Lawrence River Hydrosystem. Environmental Monitoring and Assessment 113: 329-365.

Dinehart, S.K. 2005. The effects of disturbance on aquatic breeding amphibians within the Cuyahoga Valley National Park. MSc thesis. University of Akron. 74 pp.

Environment Canada and Central Lake Ontario Conservation Authority. 2004. Durham Region Coastal Wetland Monitoring Project: Year 2 Technical Report. 177 pp.

Gibbs, J.P., F.A. Reid, and S.M. Melvin. 1992. Least Bittern (*Ixobrychus exilis*). In: The Birds of North America. No. 17 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Grabas, G.P., T.L. Crewe and S.T.A. Timmermans. 2008. Bird community indicators. In: Great Lakes Coastal Wetlands Monitoring Plan (T.M. Burton, J.C. Brazner, J.J.H. Cibrowski, G.P. Grabas, J. Hummer, J. Schneider, D.G. Uzarski, eds.). Unpublished Great Lakes Commission report for the U.S. Environmental Protection Agency – Great Lakes National Program Office. 292 pp.

Guerry, A.D. and Hunter Jr., M.L. 2002. Amphibian distributions in a landscape of forests and agriculture: An examination of landscape composition and configuration. Conservation Biology 16(3): 745-754.

Hecnar, S.J. and R.T. M'Closkey. 1996. Regional dynamics and the status of amphibians. Ecology 77(7): 2091-2097.

Houlahan, J.E. and C.S. Findlay. 2003. The effects of adjacent land use on wetland amphibian species richness and community composition. Canadian Journal of Aquatic Sciences 60: 1078-1094.

Hughes, C.E., P. Binning, and G.R. Wallgoose. 1998. Characterization of the hydrology of an estuarine wetland. Journal of Hydrology 211 (1-4): 34-49.

Kolozsvary and Swihart. 1999. Habitat fragmentation and the distribution of amphibians: Patch and landscape correlates in farmland. Canadian Journal of Zoology 77: 1288-1299.

Melvin, S.M. and J.P. Gibbs. 1996. Sora (*Porzana carolina*). In: The Birds of North America. No. 250 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Minns, C.K., V.W. Cairns, R.G. Randall and J.E. Moore. 1994. An index of biotic integrity (IBI) for fish assemblages in the littoral zone of Great Lakes' Areas of Concern. Canadian Journal of Fisheries and Aquatic Sciences 51: 1804-1822.

New York State Department of Environmental Conservation. 2008. Niagara River Area of Concern Delisting Targets. NYSDEC report for U.S. Environmental Protection Agency, Region 2. 10 pp.

Niagara River Remedial Action Plan. 2009. Niagara River Remedial Action Plan Stage 2 Update Draft. 198 pp.

Phillips, P.J. 1993. Effect of forested wetlands on nitrate concentration in ground water on the Delmarva peninsula. Wetlands 13(2): 75-83.

Sanzo, D. and S.J. Hecnar. 2006. Effects of road de-icing salt (NaCl) on larval Wood Frogs (Rana sylvatica). Environmental Pollution 140: 247-256.

Stuart, S.N., J.S. Chanson, N.A. Cox, B.E. Young, A.S.L. Rodrigues, D.L. Fischman and R.W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306(5702): 1783-1786.

Timmermans, S. and J. McCracken. 2004. Marsh Havens: Improving Marsh Habitats for Birds in the Great Lakes Basin. Published by Bird Studies Canada. 15 pp.

Timmermans, S.T.A., G.E. Craigie, and K. Jones. 2004. Marsh Monitoring Program: Areas of Concern Summary Reports 1995-2002. Unpublished Bird Studies Canada report for the Great Lakes Sustainability Fund and the Canadian Wildlife Service, Environmental Conservation Branch, Ontario Region – Environment Canada.

Timmermans, S.T.A., T.L. Crewe and G.P. Grabas. 2008. Amphibian community indicators. In: Great Lakes Coastal Wetlands Monitoring Plan (T.M. Burton, J.C. Brazner, J.J.H. Cibrowski, G.P. Grabas, J. Hummer, J. Schneider, D.G. Uzarski, eds.). Unpublished Great Lakes Commission report for the U.S. Environmental Protection Agency – Great Lakes National Program Office. 292 pp.

Uzarski, D.G., T.M. Burton, and J.A. Genet. 2004. Validation and performance of an invertebrate index of biotic integrity for Lakes Huron and Michigan fringing wetlands during a period of lake level decline. Aquatic Ecosystem Health and Management 7(2): 269-288.

Uzarski, D.G., T.M. Burton, and J.J.H. Ciborowski. 2008a. Chemical/physical and land use/cover measurements. In: Great Lakes Coastal Wetlands Monitoring Plan (T.M. Burton, J.C. Brazner, J.J.H. Cibrowski, G.P. Grabas, J. Hummer, J. Schneider, D.G. Uzarski, eds.). Unpublished Great Lakes Commission report for the U.S. Environmental Protection Agency – Great Lakes National Program Office. 292 pp.

Uzarski, D.G., T.M. Burton, J.C. Brazner, and J.J.H. Ciborowski. 2008b. Invertebrate community indicators. In: Great Lakes Coastal Wetlands Monitoring Plan (T.M. Burton, J.C. Brazner, J.J.H. Cibrowski, G.P. Grabas, J. Hummer, J. Schneider, D.G. Uzarski, eds.). Unpublished Great Lakes Commission report for the U.S. Environmental Protection Agency – Great Lakes National Program Office. 292 pp.

Wooster, M. and L. Matthies. 2008. Buffalo and Niagara Rivers habitat assessment and conservation framework. Unpublished Buffalo Niagara Riverkeeper report. 112 pp.

APPENDIX A: MMP Regional Coordinator Duties and Responsibilities

Each Marsh Monitoring Program (MMP) regional coordinator oversees MMP volunteer monitoring within their Great Lakes Area of Concern (AOC) region. These regions are identified by BSC staff. Coordinators ensure that their AOC region is monitored as consistently as possible, and become familiar with marshes within their region. The following list of duties and responsibilities help coordinators achieve this important goal:

- Promote the program locally to garner interest among community members. This is done by giving presentations to community organizations, such as watershed councils, nature clubs, and environmental education centres or other volunteer groups that might yield new MMP volunteer participants. This is also achieved by distributing MMP information materials to conservation organization and park offices, and at community events.

- Participate in a one to two day-long regional MMP coordinator orientation session, and a follow-up MMP coordinator outdoor training and certification session, prior to first-year coordinator activities. Travel, food and accommodation costs to these sessions are occasionally reimbursed by Bird Studies Canada to those individuals committed to carrying out coordinator activities (funding-dependent), and as much as the project budget allows.

- Locally advertise, arrange for, and lead one pre-field season MMP volunteer training session for new and returning MMP volunteers in your AOC region. This training session serves to formally register new MMP participants, provide them with the knowledge they need to conduct an MMP survey, equip them with MMP training/survey kits, and assign them to wetland monitoring sites. Coordinators have full assistance of Bird Studies Canada's MMP Volunteer Coordinator and any local partnering organizations to help advertise, arrange for and/or host these events. Alternatively, when larger-scale training sessions are not feasible or necessary, coordinators can provide one-on-one MMP protocol training for individual participants.

- Assist new MMP volunteers in their region with route set-up and to take GPS readings of their station locations. Visit with MMP volunteers, in-field or otherwise, at their request regarding any aspects of their wetland monitoring activities.

- Regularly contact local MMP volunteers by phone or email, to encourage their continued participation, to answer questions, and to remind them to submit their survey data.

- Periodically provide feedback to BSC staff with updates of wetland monitoring activity and volunteer information in their AOC region.

Coordinator activities are tailored to meet their individual time and work commitments, and focus on their personal strengths. Coordinators work closely with BSC MMP staff to carry out their tasks and responsibilities. This includes assistance to identify priority marshes of interest, provision of wetland habitat maps for the region, information on current MMP monitoring activity, assistance to advertise for and organize MMP volunteer orientation/training sessions, and periodic communication to track regional monitoring activity.

Upon acceptance for the position, BSC MMP staff provide successful applicants the MMP Coordinator's Guide, which describes all aspects of the position in detail, including suggested activity timelines and resources for further useful information.

APPENDIX B: Bird and Amphibian Species Codes and Marsh-User Classifications

Table B1. Species codes, marsh-user type, and indicator status for bird and amphibian species. "A.F." = aerial forager; "W.F." = water forager.

Bird Species Name	Code	Marsh-User Type	Indicator Status	Amphibian Species Name	Code	Indicator Status
Alder Flycatcher	ALFL	A.F.	No	American Toad	AMTO	No
American Bittern	AMBI	Nester	Yes	Bullfrog	BULL	Yes
American Coot	AMCO	Nester	Yes	Western Chorus Frog	CHFR	Yes
American Woodcock	AMWO	Nester	No	Green Frog	GRFR	No
Bank Swallow	BANS	A.F.	No	Gray Treefrog	GRTR	No
Barn Swallow	BARS	A.F.	No	Northern Leopard Frog	NLFR	Yes
Black-crowned Night Heron	BCNH	W.F.	No	Spring Peeper	SPPE	Yes
Belted Kingfisher	BEKI	W.F.	No	Wood Frog	WOFR	No
Black Rail	BLRA	Nester	Yes			
Black Tern	BLTE	Nester	Yes			
Canada Goose	CAGO	Nester	No			
Caspian Tern	CATE	W.F.	No			
Chimney Swift	CHSW	A.F.	No			
Cliff Swallow	CLSW	A.F.	No			
Common Grackle	COGR	Nester	No			
Common Moorhen	COMO	Nester	Yes			
Common Tern	COTE	W.F.	No			
Common Yellowthroat	COYE	Nester	No			
Gadwall	GADW	W.F.	No			
Eastern Kingbird	EAKI	Nester	No			
Great Blue Heron	GBHE	W.F.	No			
Great Crested Flycatcher	GCFL	A.F.	No			
Gray Catbird	GRCA	Nester	No			
Great Egret	GREG	W.F.	No			
Green Heron	GRHE	W.F.	No			
Least Bittern	LEBI	Nester	Yes			
Mallard	MALL	Nester	No			
Marsh Wren	MAWR	Nester	Yes			
Undifferentiated Common Moorhen/American Coot	MOOT	Nester	Yes			
Northern Harrier	NOHA	Nester	No			
Northern Rough-winged Swallow	NRWS	A.F.	No			
Purple Martin	PUMA	A.F.	No			
Pied-billed Grebe	PBGR	Nester	Yes			
Red-winged Blackbird	RWBL	Nester	No			
Sora	SORA	Nester	Yes			
Song Sparrow	SOSP	Nester	No			
Swamp Sparrow	SWSP	Nester	Yes			
Tree Swallow	TRES	A.F.	No			
Virginia Rail	VIRA	Nester	Yes			
Willow Flycatcher	WIFL	A.F.	No			
Wood Duck	WODU	Nester	No			
Yellow-crowned Night Heron	YCNH	W.F.	No			
Yellow Warbler	YWAR	Nester	No			

APPENDIX C: Marsh Habitat and Vegetation Characteristics

Table C1. Percent cover of habitat features and emergent vegetation within Niagara River (ON) AOC and reference marshes, based on 2009-2010 MMP data.

Habitat Characteristic	Marsh Site 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Habitat Composition (% Cover)																	
Emergent Vegetation	35.0	59.0	68.8	20.0	43.6	32.0	13.5	75.0	60.0	76.7	60.0	67.0	88.9	13.0	37.0	40.0	50.0
Open Water	35.0	29.5	21.8	60.0	37.4	42.0	45.0	5.0	20.0	5.0	20.0	7.5	4.6	83.5	24.8	50.0	30.0
Exposed Substrate	0.0	3.0	0.0	10.0	0.0	7.0	0.0	0.0	5.0	0.0	5.0	1.8	0.0	0.0	1.0	0.0	10.0
Trees	20.0	2.5	5.0	5.0	6.8	12.0	20.0	10.0	10.0	13.3	10.0	11.3	6.2	1.8	18.4	5.0	5.0
Shrubs	10.0	6.0	4.5	5.0	12.2	7.0	21.5	10.0	5.0	5.0	5.0	12.5	0.8	1.8	18.8	5.0	5.0
Emergent Vegetation Composition (% Cover)																	
Cattail	30.0	15.0	75.0	10.0	70.0	0.0	5.0	35.0	75.0	68.3	97.0	60.0	100.0	0.0	49.0	10.0	5.0
Reeds	40.0	7.5	2.5	0.0	6.0	0.0	0.0	0.0	0.0	15.0	0.0	38.8	0.0	25.0	4.0	0.0	0.0
Grasses and Sedges	0.0	40.0	13.8	60.0	7.0	50.0	80.0	10.0	15.0	0.0	0.0	0.0	0.0	43.3	30.7	80.0	80.0
Rushes and Bulrushes	20.0	7.5	6.3	10.0	0.0	0.0	0.0	0.0	5.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	10.0
Water Willow	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pickerelweed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arrowhead	0.0	0.0	0.0	0.0	0.0	50.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Smartweed	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Burreed	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Purple Loosestrife	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.5	5.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	5.0
Wild Rice	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Number of Station-Visits	1	2	4	1	5	1	2	1	1	6	1	4	12	4	10	1	1

1=Chippawa Creek Pond
2=EC Brown Wetland
3=Lake Niapenco
4=Lower Lyons Creek-Beck
5=Lower Welland River-Grassy Brook
6=Lower Welland River-Stanley
7=Lyons Creek-Cook's Mills
8=Lyons Creek-Crowland
9=Lyons Creek-Schisler
10=Mud Lake
11=Niagara River at Baker's Creek
12=Twenty Mile Creek Headwaters
13=Twenty Mile Creek Mouth
14=Upper Draper's Creek
15=Wainfleet Bog
16=Welland River-Airport
17=Welland River at Big Forks Creek

Table C2. Percent cover of habitat features and emergent vegetation within Niagara River (NY) AOC marshes, based on 2009-2010 MMP data.

Habitat Characteristic	Marsh Site						
	Beaver Island	Buckhorn Marsh West	Republic Steel	Strawberry Island	Sunken Island	Tifft Nature Preserve	Times Beach
Habitat Composition (% Cover)							
Emergent Vegetation	20.0	76.7	40.0	20.0	80.0	62.1	60.0
Open Water	5.0	6.7	40.0	60.0	20.0	17.8	35.0
Exposed Substrate	0.0	0.0	0.0	0.0	0.0	1.4	0.9
Trees	15.0	0.0	0.0	10.0	0.0	14.9	0.0
Shrubs	60.0	16.7	20.0	10.0	0.0	4.3	1.7
Emergent Vegetation Composition (% Cover)							
Cattail	0.0	75.0	5.0	20.0	80.0	58.9	56.7
Reeds	3.0	15.0	80.0	20.0	0.0	26.9	43.3
Grasses and Sedges	10.0	0.0	0.0	20.0	0.0	1.3	0.0
Rushes and Bulrushes	2.0	0.0	0.0	0.0	5.0	0.0	0.0
Water Willow	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pickerelweed	0.0	0.0	0.0	10.0	5.0	0.0	0.0
Arrowhead	0.0	0.0	0.0	18.0	5.0	0.0	0.0
Smartweed	0.0	0.0	0.0	10.0	0.0	0.1	0.0
Burreed	0.0	0.0	0.0	0.0	0.0	3.5	0.0
Purple Loosestrife	5.0	0.0	0.0	10.0	0.0	0.0	0.0
Wild Rice	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Number of Station-Visits	1	3	1	1	1	8	3

Table C3. Percent cover of habitat features and emergent vegetation within Buffalo River AOC marshes, based on 2010 MMP data.

Habitat Characteristic	Marsh Site	
	Meyer Rd. Wetland	West Seneca Oxbow Wetland
Habitat Composition (% Cover)		
Emergent Vegetation	35.0	5.0
Open Water	60.0	75.0
Exposed Substrate	0.0	2.5
Trees	0.0	15.0
Shrubs	5.0	5.0
Emergent Vegetation Composition (% Cover)		
Cattail	0.0	30.0
Reeds	100.0	30.0
Grasses and Sedges	0.0	30.0
Rushes and Bulrushes	0.0	2.0
Water Willow	0.0	0.0
Pickerelweed	0.0	0.0
Arrowhead	0.0	0.5
Smartweed	0.0	0.0
Burreed	0.0	3.0
Purple Loosestrife	0.0	0.0
Wild Rice	0.0	0.0
Number of Station-Visits	2	1

APPENDIX D: Physical/Chemical Water Quality Values for All Measured Parameters

Table D1. Summary of physical and chemical water quality parameters by sampling site for the Niagara River (ON) AOC and reference watershed sites. Sample size is indicated in brackets. "*" indicates data collected by the Canadian Wildlife Service.

Site Name	Depth (cm)	Air Temp (°C)	Water Temp (°C)	DO (%)	DO (mg/L)	Turb. (FTU)	Cond. (uS/cm)	pH	NO3 (ppm)	NH3 (ppm)	Cl (ppm)	Chlor. a (fluoresc.)
EC Brown Wetland	65 (1)	26.0 (1)	24.2 (1)	89.5 (1)	-	34 (1)	371.0 (1)	8.32 (1)	0.05 (1)	0.41 (1)	14.60 (1)	0.218 (3)
Lake Niapenco	61 (3)	28.7 (3)	28.3 (3)	37.0 (3)	-	72 (3)	384.0 (3)	7.67 (3)	0.04 (3)	0.32 (3)	8.53 (3)	0.344 (9)
Lower Welland River-Grassy Brook	59 (3)	27.0 (3)	24.9 (3)	52.6 (3)	-	41 (3)	311.3 (3)	7.79 (3)	0.30 (3)	0.27 (3)	11.40 (3)	0.194 (9)
Lyons Creek-Crowland	80 (2)	27.0 (2)	22.2 (2)	34.5 (2)	-	107 (2)	179.0 (2)	7.41 (2)	0.26 (2)	0.51 (2)	3.65 (2)	0.241 (6)
Lyons Creek Mouth	58 (2)	26.0 (2)	24.1 (2)	60.1 (2)	-	41 (2)	293.0 (2)	7.77 (2)	0.06 (2)	0.44 (2)	4.35 (2)	0.328 (6)
Lyons Creek-Schisler	75 (1)	24.0 (1)	22.1 (1)	11.3 (1)	-	31 (1)	227.0 (1)	7.34 (1)	0.12 (1)	0.28 (1)	3.00 (1)	0.274 (3)
Mud Lake	30 (2)	27.0 (2)	25.2 (2)	44.6 (2)	-	38 (2)	370.5 (2)	7.46 (2)	0.16 (2)	0.52 (2)	1.70 (2)	0.233 (6)
Niagara River at Baker's Creek	35 (2)	26.0 (2)	22.0 (2)	57.5 (2)	-	53 (2)	256.5 (2)	7.73 (2)	0.25 (2)	0.43 (2)	4.70 (2)	0.230 (6)
Twenty Mile Creek Headwaters	23 (3)	26.3 (3)	23.7 (3)	32.8 (3)	-	18 (3)	455.3 (3)	7.63 3)	0.17 (3)	0.48 (3)	43.37 (3)	0.220 (3)
Twenty Mile Creek Mouth*	67 (2)	-	22.8 (2)	-	8.41 (2)	12 (2)	718.0 (2)	8.25 (2)	0.55 (2)	-	-	-
Welland River-Airport	25 (2)	26.0 (2)	25.3 (2)	135.0 (2)	-	54 (2)	400.0 (2)	7.77 (2)	0.12 (2)	0.54 (2)	4.80 (2)	0.604 (6)
York-Haldimand Site	50 (1)	30.0 (1)	27.0 (1)	31.9 (1)	-	63 (1)	229.0 (1)	7.40 (1)	0.03 (1)	0.17 (1)	7.60 (1)	4.209 (3)

Table D2. Summary of physical and chemical water quality parameters by sampling site for the Niagara River (NY) AOC. Sample size is indicated in brackets.

Site Name	Depth (cm)	Air Temp (°C)	Water Temp (°C)	DO (%)	DO (mg/L)	Turb. (FTU)	Cond. (uS/cm)	pH	NO3 (ppm)	NH3 (ppm)	Cl (ppm)	Chlor. a (fluoresc.)
Beaver Island	34 (1)	20.0 (1)	19.9 (1)	70.9 (1)	-	26 (1)	286.0 (1)	7.46 (1)	0.11 (1)	0.54 (1)	7.90 (1)	0.289 (3)
Buckhorn Marsh East	50 (3)	22.0 (1)	22.5 (3)	34.0 (3)	-	75 (3)	405.0 (3)	7.22 (3)	0.02 (3)	0.62 (3)	14.60 (3)	0.944 (9)
Buckhorn Marsh West	32 (2)	20.0 (2)	22.2 (2)	59.5 (2)	-	32 (2)	710.0 (2)	7.75 (2)	0.08 (2)	0.45 (2)	36.00 (2)	0.426 (8)
East River	41 (2)	25.0 (2)	22.7 (2)	65.5 (2)	-	17 (2)	291.5 (2)	7.61 (2)	0.14 (2)	0.31 (2)	4.50 (2)	0.108 (6)
Republic Steel	27 (3)	28.3 (3)	25.6 (3)	53.5 (3)	-	47 (3)	640.0 (3)	7.73 (3)	0.05 (3)	0.35 (3)	121.60 (3)	0.357 (9)
Strawberry Island	30 (2)	24.0 (2)	23.7 (2)	117.6 (2)	-	12 (2)	275.5 (2)	8.76 (2)	0.12 (2)	0.43 (2)	16.60 (2)	0.096 (6)
Sunken Island	92 (2)	23.0 (2)	22.1 (2)	89.5 (2)	-	10 (2)	276.5 (2)	8.23 (2)	0.24 (2)	0.44 (2)	10.60 (2)	0.053 (6)
Tifft Nature Preserve	59 (4)	27.3 (4)	27.1 (4)	94.0 (4)	-	41 (4)	266.0 (4)	7.26 (4)	0.09 (4)	0.40 (4)	6.80 (4)	0.689 (12)
Times Beach	31 (2)	27.3 (3)	27.9 (3)	112.9 (3)	-	39 (3)	270.3 (3)	8.53 3)	0.04 (3)	0.26 (3)	7.00 (3)	1.333 (9)

Table D3. Summary of physical and chemical water quality parameters by sampling site for the Buffalo River AOC and reference sites. Sample size is indicated in brackets.

Site Name	Depth (cm)	Air Temp (°C)	Water Temp (°C)	DO (%)	DO (mg/L)	Turb. (FTU)	Cond. (uS/cm)	pH	NO3 (ppm)	NH3 (ppm)	Cl (ppm)	Chlor. a (fluoresc.)
Reinstein Woods	45 (2)	27.0 (1)	26.2 (2)	102.3 (2)	-	26 (2)	549.0 (2)	8.30 (2)	0.17 (2)	0.40 (2)	65.20 (2)	0.456 (8)
Sinking Ponds	30 (1)	26.0 (1)	28.0 (1)	106.9 (1)	-	75 (1)	964.0 (1)	8.25 (1)	0.16 (1)	0.58 (1)	58.60 (1)	2.738 (4)
West Seneca Oxbow Wetland	21 (2)	22.0 (2)	22.5 (2)	97.3 (2)	-	32 (2)	566.5 (2)	7.77 (2)	0.10 (2)	0.44 (2)	98.80 (2)	0.617 (8)