# Monitoring and Assessing Marsh Habitat Health in the Niagara River Area of Concern

## Final Project Report

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MARSH MONITORING PROGRAM

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## 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. 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 Niagara River and its watersheds were designated as an AOC in 1987 mainly due to concerns around contaminants, although there were also concerns related to the loss of fish and wildlife habitat and impacts on their populations. However, at the time of designation there was little data to indicate the status of these BUIs (Ontario Ministry of Environment and Energy et al. 1993). In the Stage 1 RAP, the BUIs for degradation of wildlife populations and loss of fish and wildlife habitat were designated as Requiring Further Assessment, and Impaired, respectively (the terms Impaired and Requiring Further Assessment are defined in the Great Lakes Water Quality Agreement under Annex 2, revised 1987). In 2010, an updated Stage 2 RAP report was completed. The Stage 2 update revised the delisting criteria for the Niagara River AOC and included the following criterion for which this project was designed to assess:

***Delisting Criterion #4:***
*"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)

To inform the current status of this delisting criterion, BSC engaged in a two-year project in 2008 to assess AOC wetland quality and enhance long-term volunteer monitoring within the 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 the Niagara River AOC. A secondary goal was to increase MMP volunteer monitoring within the AOC. To increase volunteer monitoring in the AOC, BSC recruited a volunteer MMP regional coordinator to promote the program and assist staff with local volunteer training and coordination. Following two MMP orientation and training workshops that were held during the project period, 48 participants volunteered to monitor birds and/or amphibians at 38 marsh sites throughout the region, including 10 sites within the AOC and one within the reference watershed.

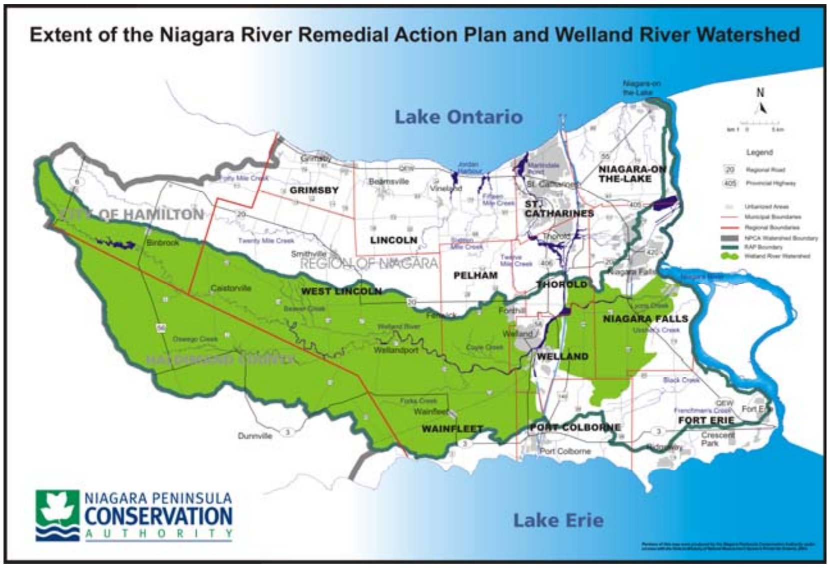


**Figure 1. Watershed-scale boundary (outlined in blue) of the Niagara River Area of Concern. Figure courtesy of the Niagara Peninsula Conservation Authority.**

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).

Recently, marsh bird, amphibian and macroinvertebrate IBIs were modified and used to evaluate wetland biotic condition in Great Lakes AOCs (Archer et al. 2006). Similarly, for this project we modified Great Lakes coastal wetland IBIs to make them suitable to report on Niagara River AOC wetlands. This was done by developing wetland disturbance gradients specific to AOC and reference watershed sites, and testing metrics for their response to those gradients. Through consultations with the Niagara River Remedial Action Plan Science Committee and the Niagara Peninsula Conservation Authority (NPCA), the Twenty Mile Creek watershed was chosen as a reference watershed due to its relative proximity and similarity of land use with the AOC watershed.

In 2009, we sampled aquatic macroinvertebrates and water quality at both AOC and reference watershed wetlands as part of a parallel wetland assessment project focusing on the Niagara River (Ontario), Niagara River (New York) and Buffalo River AOCs. Data from these surveys are reported here to complement surveys conducted in 2008 as part of this project.

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 the AOC and Twenty Mile Creek reference watershed.
2. Establish and work with an MMP regional coordinator for the Niagara River AOC to increase volunteer marsh bird and amphibian monitoring in the region.
3. Plan and host two MMP volunteer orientation and training workshops.
4. Develop bird, amphibian and macroinvertebrate IBIs that are specific to the Niagara River AOC.
5. Produce marsh bird, amphibian, macroinvertebrate and water quality data summaries.
6. Assess marsh bird and amphibian community diversity, within each monitored wetland and for the AOC as a whole, relative to non-AOC Great Lakes basin means.

This report provides an assessment of ecological integrity for several marshes within the Niagara River 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 Niagara River Remedial Action Plan (RAP) with respect to its progress to meet Degradation of Fish and Wildlife Populations delisting criterion #4, and to report a framework through which long-term monitoring to track wetland health recovery and response to remedial activities can be accomplished.

## METHODS

### MMP regional coordinator establishment

To identify potential volunteer MMP regional coordinators for the Niagara area, BSC staff conducted a review of long-term program participants and partners in the region. Kim Frohlich, ecologist with the NPCA, was selected due to her long history assisting program delivery in the region. For a complete description of the MMP regional coordinator duties and responsibilities, see Appendix A.

BSC staff provided Kim with coordinator information and resource materials (e.g., active participant lists, inactive route-station coordinates) and provided a half-day regional coordinator orientation and training meeting during September 2008 to clarify position duties and responsibilities and reinforce survey protocol knowledge.

### 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 anurans heard both inside and beyond the 100-m station boundary (i.e., within hearing distance).

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 twice 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 volunteers 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.

Table 1 lists the MMP routes monitored in 2008 and 2009, their respective marsh site names, the survey type, and survey date per visit.

### Water quality and aquatic macroinvertebrate sampling

Water quality and aquatic macroinvertebrate sampling was conducted by field staff primarily at marshes that were surveyed by volunteers, preferably for both marsh birds and amphibians. BSC staff consulted with the NPCA to identify priority sites for assessment and long-term monitoring. 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.

Water quality and macroinvertebrate sampling occurred from 18-22 Aug, 2008 and from 9-13 Aug, 2009. 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 by 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).

*Wetland water quality measurements*

Physical and chemical water quality measurements followed protocols developed by the Great Lakes Coastal Wetlands Consortium (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, total dissolved solids (2008 only), dissolved oxygen (concentration and 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.

**Table 1. Niagara River AOC and reference watershed marshes monitored for birds or amphibians in 2008 and 2009, with corresponding MMP route ID and survey visit dates.**

| | | | 2008 Survey Year | | 2009 Survey Year | |
|---|---|---|---|---|---|---|
| Wetland Site | Route ID | Survey Type | Visit | Survey | Visit | Survey Date |
| EC Brown Wetland | ON726 | Amphibians | 1 | April 21 | 1 | May 8 |
| | | | 2 | May 29 | 2 | June 2 |
| | | | 3 | June 21 | 3 | June 24 |
| | | Birds | | | 1 | June 15 |
| | | | | | 2 | July 6 |
| Humberstone Marsh | ON406 | Amphibians | 1 | April 8 | | |
| | | | 2 | April 20 | | |
| | | | 3 | June 14 | | |
| Lake Niapenco | ON199 | Birds | 1 | June 12 | 1 | June 16 |
| | | | 2 | July 4 | 2 | July 4 |
| Lower Lyons Creek-Beck | ON823b | Amphibians | | | 1 | March 17 |
| | | | | | 2 | April 10 |
| | | | | | 3 | June 4 |
| Lower Welland River-Grassy Brook | ON250b,c | Amphibians | 1 | April 16 | 1 | April 2 |
| | | | 2 | May 29 | 2 | April 26 |
| | | | 3 | June 25 | 3 | June 10 |
| Lower Welland River-Stanley | ON823a | Amphibians | | | 1 | March 17 |
| | | | | | 2 | April 10 |
| | | | | | 3 | June 4 |
| Lyons Creek-Cook's Mills | ON250a | Amphibians | 1 | April 16 | 1 | April 2 |
| | | | 2 | May 29 | 2 | April 26 |
| | | | 3 | June 21 | 3 | June 10 |
| Lyons Creek-Crowland | ON727a | Amphibians | 1 | April 21 | 1 | April 26, |
| | | | 2 | May 29 | 2 | June 14, |
| | | | 3 | June 21 | 3 | June 24 |
| | | Birds | | | 1 | May 23 |
| Lyons Creek-Schisler | ON727b | Amphibians | | | 1 | April 26 |
| | | | | | 2 | June 14 |
| | | Birds | | | 1 | May 23 |
| Mud Lake | ON740 | Amphibians | 1 | April 20 | | |
| | | | 2 | May 30 | | |
| | | | 3 | June 27 | | |
| | ON811 | Birds | | | 1 | May 21 |
| | | | | | 2 | June 5 |
| Niagara River at Baker's Creek | ON810 | Amphibians | | | 1 | April 12 |
| | | | | | 2 | May 11 |
| | | | | | 3 | May 22 |
| Twenty Mile Creek Mouth | ON808 | Birds | | | 1 | May 31 |
| | | | | | 2 | July 1 |
| Upper Draper's Creek-Foss | ON263a | Amphibians | 1 | May 25 | 1 | June 4 |
| | | | 2 | June 25 | 2 | June 21 |
| Upper Draper's Creek-Hoist | ON263b | Amphibians | 1 | May 25 | 1 | June 4 |
| | | | 2 | June 25 | 2 | June 21 |
| Wainfleet Bog | ON381 | Amphibians | 1 | May 8 | 1 | April 27 |
| | | | 2 | June 11 | 2 | May 23 |
| | | | 3 | June 26 | 3 | June 21 |
| | ON813 | Birds | | | 1 | May 25 |
| | | | | | 2 | June 5 |
| Welland River-Airport | ON276c | Amphibians | | | 1 | June 23 |
| Welland River at Big Forks Creek | ON276d | Amphibians | | | 1 | June 23 |

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.

*Aquatic macroinvertebrate community sampling*

Aquatic macroinvertebrates were sampled followed protocols developed by the Great Lakes Coastal Wetlands Consortium (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 min., 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 to at least the family taxonomic level. Macroinvertebrate identification was completed by NPCA staff in 2008, and by BSC staff in 2009. 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 workshop**

Two MMP volunteer orientation workshops were held on Feb. 28, 2009 and Mar. 6, 2010 at the Ball's Falls Centre for Conservation near Vineland, Ontario. Workshop advertisements, flyers and press releases were distributed to 19 newspapers, five nature clubs and organizations, one radio station, and to several other regional contacts. Information about each workshop was also distributed via Bird Studies Canada's electronic newsletter "Latest News", the Ontbirds birding listserv, the NPCA's website, and through correspondence with all existing MMP participants in the region.

Sixty-eight people attended the first workshop and 47 subsequently joined the MMP. 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. The 2010 workshop was a refresher workshop for existing participants and for those who attended the previous workshop but were unable to survey in 2009; 20 people were invited to attend the second workshop.

**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 was not collected for many 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 (Wood), crop land (Crop), and urban land use (Urban) 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 watershed-scale) 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 for southern Great Lakes coastal wetlands by Bird Studies Canada and Environment Canada (see methods in Grabas et al. 2008 (birds) and Timmermans et al. 2008 (amphibians)) were modified to test and incorporate metrics that responded to the Niagara-based wetland disturbance gradients. 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 twelve years of data (1998-2009). 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 five marsh bird or four amphibian survey stations, and recalculated the mean and standard deviation of each IBI through 1,000 iterations.

Wetland IBI scores were then plotted and ranked relative to scores of other AOC wetlands and to reference wetlands. For the purposes of IBI analyses, four Twenty Mile Creek watershed-based wetlands (Twenty Mile Creek Headwaters, Twenty Mile Creek-Westbrook, Twenty Mile Creek-Hodgkin, and Twenty Mile Creek Mouth) were identified as reference sites.

**Marsh bird and amphibian community assessments**

Species richness, scaled to sampling effort, was used in these summaries as a descriptor of amphibian and marsh bird communities. Four measures of species diversity were calculated:

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

See Table C1 for a list of bird and amphibian indicator species used in the community assessments.

Calculations of each richness measure were based on total number of species detected on each station within each year. Each measure was expressed as the average species richness per station per year. The AOC, and all MMP-monitored wetlands within it, was scored according to how species diversity compared to non-AOC MMP routes in the Great Lakes basin.

Variation due to effects of year and marsh size was taken into account prior to use of these measures for AOC scoring. This was done through use of both linear and quadratic (i.e., second-order polynomial) regression (PROC REG, SAS 8e 2001), whereby each of the four diversity measures were used in separate regression models as response variables and year, marsh size class, and their quadratic terms were considered simultaneously as predictor variables. Residuals from these models using AOC data were compared to residuals from these same regressions done using non-AOC MMP data.

A ranking system was developed that considered amphibian and marsh bird species richness (diversity) measures within the AOC relative to those recorded in other non-AOC routes in the Great Lakes basin. This ranking system required that survey data were statistically corrected for differences in estimated marsh size; therefore, MMP routes that did not have available marsh size data collected by volunteers were excluded from this ranking scheme. MMP-based evaluations reported herein are based on seven years of data (2003 through 2009) to provide an updated view of AOC status relative to an earlier assessment for the AOC reported in Timmermans et al. (2004).

Each AOC was scored relative to the average for non-AOCs in the same lake basin. Scoring was done with respect to each of a series of dependent variables: frequency of occurrence of each indicator species, and the four species richness measures described above. Multiple regressions that corrected for variation in marsh size among routes were run for non-AOCs in each basin. Expected values of the dependent variables based on these regressions (i.e., with non-AOCs) were compared to values of these dependent variables recorded in the AOC. Each AOC was then rated in terms of the difference between the expected values and the values observed in the AOC:

- *impaired* if the residual value was less than one standard error below the mean expected value (score =”-“),
- *apparently not impaired* if the residual value was within the range defined by plus or minus one standard error of the mean expected value (score =”0”), or
- *not impaired* if the residual value was greater than one standard error above the mean expected value (score = “+”).

The scoring procedures outlined above were used to derive an overall score for the AOC. 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 the 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

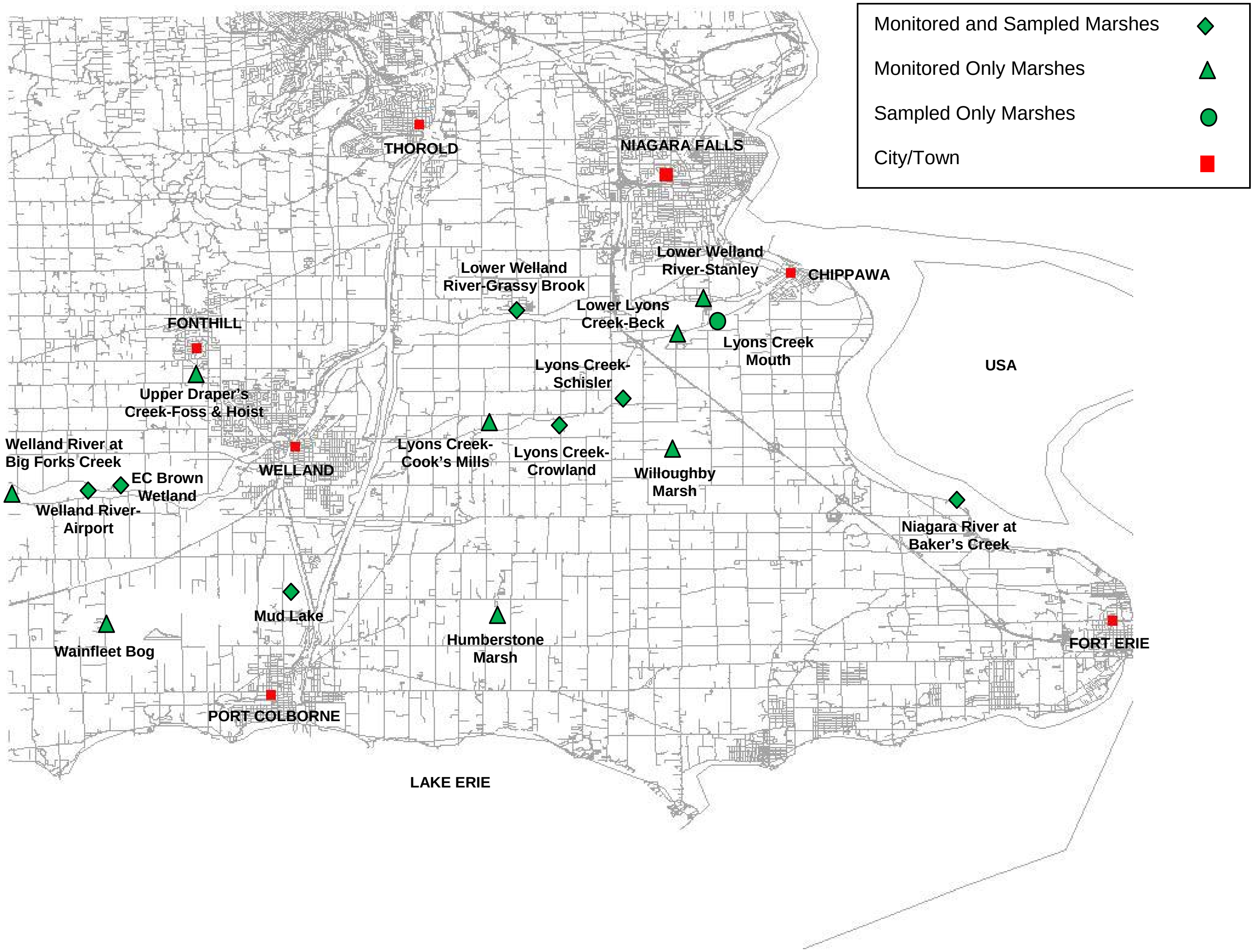


**Figure 2. Lower AOC watershed wetland sites monitored for birds and/or amphibians between 1995 and 2009, and/or sampled for water quality and macroinvertebrates in 2008 or 2009.**

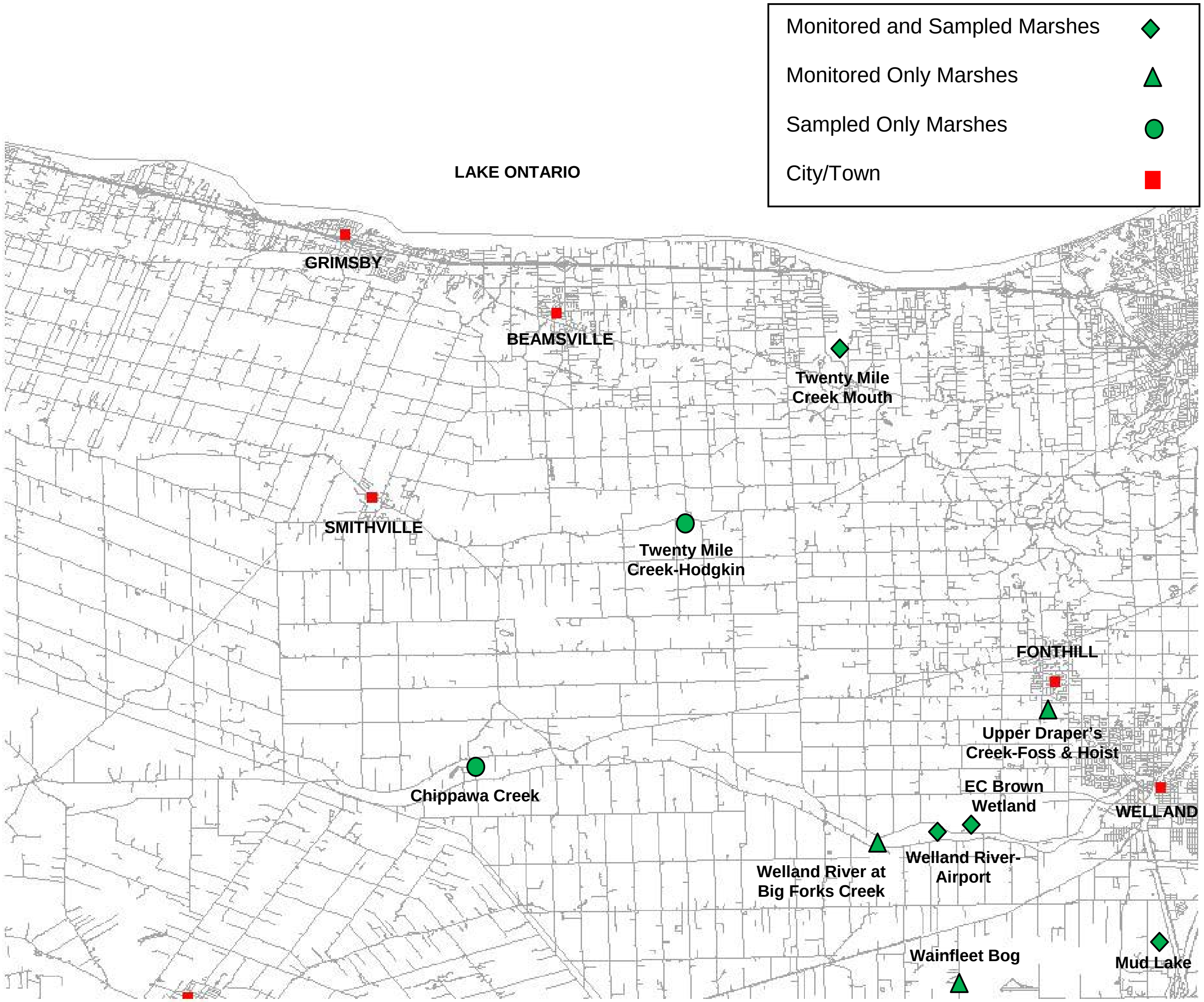


**Figure 3. Middle AOC/lower Twenty Mile Creek watershed wetland sites monitored for birds and/or amphibians between 1995 and 2009, and/or sampled for water quality and macroinvertebrates in 2008 or 2009.**

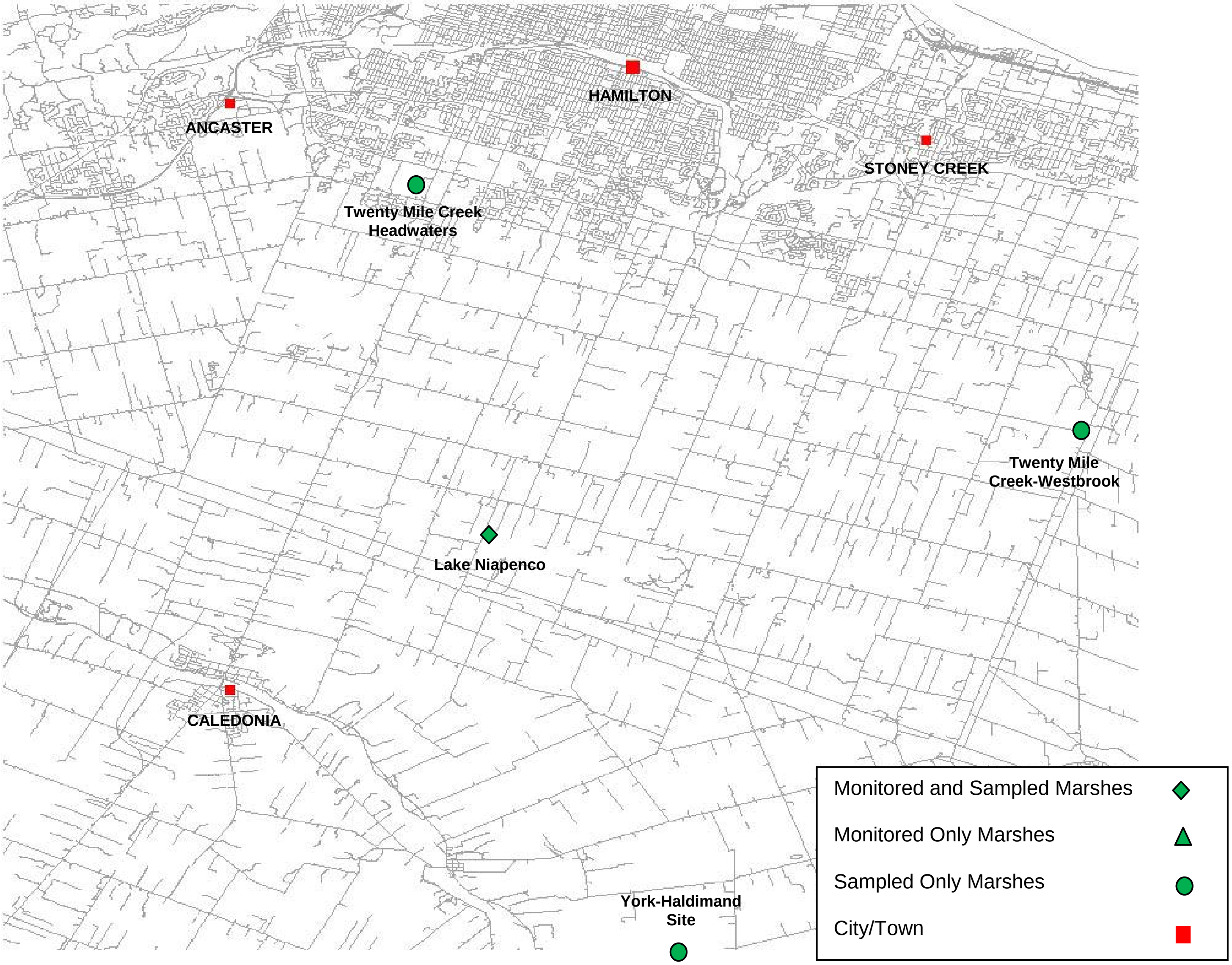


**Figure 4. Upper AOC/Twenty Mile Creek watershed wetland sites monitored for birds and/or amphibians between 1995 and 2009, and/or sampled for water quality and macroinvertebrates in 2008 or 2009**

Below are a brief descriptions of MMP-monitored and/or staff-sampled marsh sites. Twenty Mile Creek sites marked with an asterisk were identified as reference sites for water quality and Index of Biotic Integrity analyses.

| | |
|---|---|
| • Chippawa Creek | Fringing, riverine marsh along the Welland River near Chippawa Creek Conservation Area. Cattail-dominated; agricultural surroundings. |
| • 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-Hodgkin* | Fringing riverine marsh located at the creek's intersection with Hodgkin Rd. 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. |
| • Twenty Mile Creek-Westbrook* | Fringing riverine marsh located at the creek's intersection with Westbrook Rd. Surrounding agriculture with some housing. |
| • Upper Draper's Creek | Two pond-based marshes. Woodland and residential surroundings with nearby roads. |
| • 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 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. |
| • York-Haldimand Site | Palustrine marsh located on an agricultural property, containing a mix of open water and cattail/burreed vegetation. Agricultural surroundings. |

## RESULTS

### Wetland Physical/Chemical Water Quality

Table 2 shows 2008 and 2009 mean values for selected physical and chemical water quality parameters. These parameters were selected because they were measured in both years and 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 2. Summary of selected mean physical and chemical limnological measurements.**

| Site Name | Sample Year | Conductivity (uS/cm) | pH | $NH_3$ (ppm) | $NO_3$ (ppm) | Cl (ppm) | Turbidity (FTU) |
|---|---|---|---|---|---|---|---|
| Chippawa Creek | 2008 | 323.3 | 7.46 | 0.24 | 0.00 | 3.70 | 194 |
| EC Brown Wetland | 2009 | 371.0 | 8.32 | 0.41 | 0.05 | 14.60 | 34 |
| Lake Niapenco | 2008 | 698.7 | 7.38 | 0.60 | 0.19 | 32.23 | 140 |
| | 2009 | 384.0 | 7.67 | 0.32 | 0.04 | 8.53 | 72 |
| Lower Welland River-Grassy Brook | 2008 | 395.0 | 8.15 | 0.32 | 0.33 | 8.43 | 18 |
| | 2009 | 311.3 | 7.79 | 0.27 | 0.30 | 11.40 | 41 |
| Lyons Creek-Crowland | 2008 | 381.0 | 7.44 | 0.44 | 0.00 | 6.00 | 53 |
| | 2009 | 179.0 | 7.41 | 0.51 | 0.26 | 3.65 | 107 |
| Lyons Creek-Schisler | 2009 | 227.0 | 7.34 | 0.28 | 0.12 | 3.00 | 31 |
| Lyons Creek Mouth | 2008 | 328.0 | 8.54 | 0.29 | 0.10 | 5.60 | 38 |
| | 2009 | 293.0 | 7.77 | 0.44 | 0.06 | 4.35 | 41 |
| Mud Lake | 2008 | 370.5 | 7.46 | 0.52 | 0.16 | 1.70 | 38 |
| | 2009 | 481.0 | 6.95 | 0.44 | 0.14 | 1.35 | 23 |
| Niagara River at Baker's Creek | 2008 | 348.5 | 7.62 | 0.36 | 0.25 | 81.60 | 75 |
| | 2009 | 256.5 | 7.73 | 0.43 | 0.25 | 4.70 | 53 |
| Twenty Mile Creek-Hodgkin | 2008 | 554.0 | 7.06 | 0.42 | 0.53 | 13.50 | 70 |
| Twenty Mile Creek-Westbrook | 2008 | 654.0 | 7.11 | 0.46 | 0.35 | 23.00 | 91 |
| Twenty Mile Creek Headwaters | 2008 | 580.0 | 7.62 | 0.39 | 0.08 | 39.27 | 20 |
| | 2009 | 455.3 | 7.63 | 0.48 | 0.17 | 43.37 | 18 |
| Twenty Mile Creek Mouth | 2008 | 559.0 | 7.74 | 0.52 | 0.15 | 21.18 | 46 |
| | 2009 | 717.5 | 8.25 | | 0.55 | | 12 |
| Welland River-Airport | 2009 | 400.0 | 7.77 | 0.54 | 0.12 | 4.80 | 54 |
| York-Haldimand Site | 2008 | 192.0 | 6.62 | 0.31 | 0.00 | 2.60 | 57 |
| | 2009 | 229.0 | 7.40 | 0.17 | 0.03 | 7.60 | 63 |

Water quality values were relatively consistent between years at most sites. The Twenty Mile Creek sites, as well as Lake Niapenco, Lower Welland River-Grassy Brook and Welland River-Airport tended to have high water conductivity and moderate-to-high chloride concentration. In contrast, Lyons Creek-Crowland, Lyons-Creek Schisler, Mud Lake, and the York-Haldimand Site had low values for these parameters. Ammonia- and nitrate-nitrogen concentrations were both relatively high at Twenty Mile Creek-Westbrook, Twenty Mile Creek Mouth and Lyons Creek-Crowland, while several other sites had relatively high levels of ammonia or nitrate. Chippawa Creek and the York-Haldimand Site had relatively low concentrations of both ammonia and nitrate. Relatively high pH values were measured at Lyons Creek Mouth, EC Brown Wetland, Lower Welland River-Grassy Brook and Twenty Mile Creek Mouth.

**Wetland Macroinvertebrate Communities**

Between years, the highest macroinvertebrate richness (mean number of families per sample) was found at Lyons Creek-Schisler, Twenty Mile Creek-Westbrook and the York-Haldimand Site (Figure 5). High numbers also occurred at Lyons Creek Mouth in 2008 and Twenty Mile Creek Mouth in 2009. By contrast, Lower Welland River-Grassy Brook, Welland River-Airport and Chippawa Creek had low numbers. Between years, total number of families per sample was higher for the reference watershed (10.3 and 6.5 for 2008 and 2009, respectively) than for AOC wetlands (8.7 and 2.6 for 2008 and 2009, respectively). See Table E1 for proportions of selected pollution-sensitive and tolerant taxa among sites, and Table E2 for number of specimens for each family collected per sample, by site.

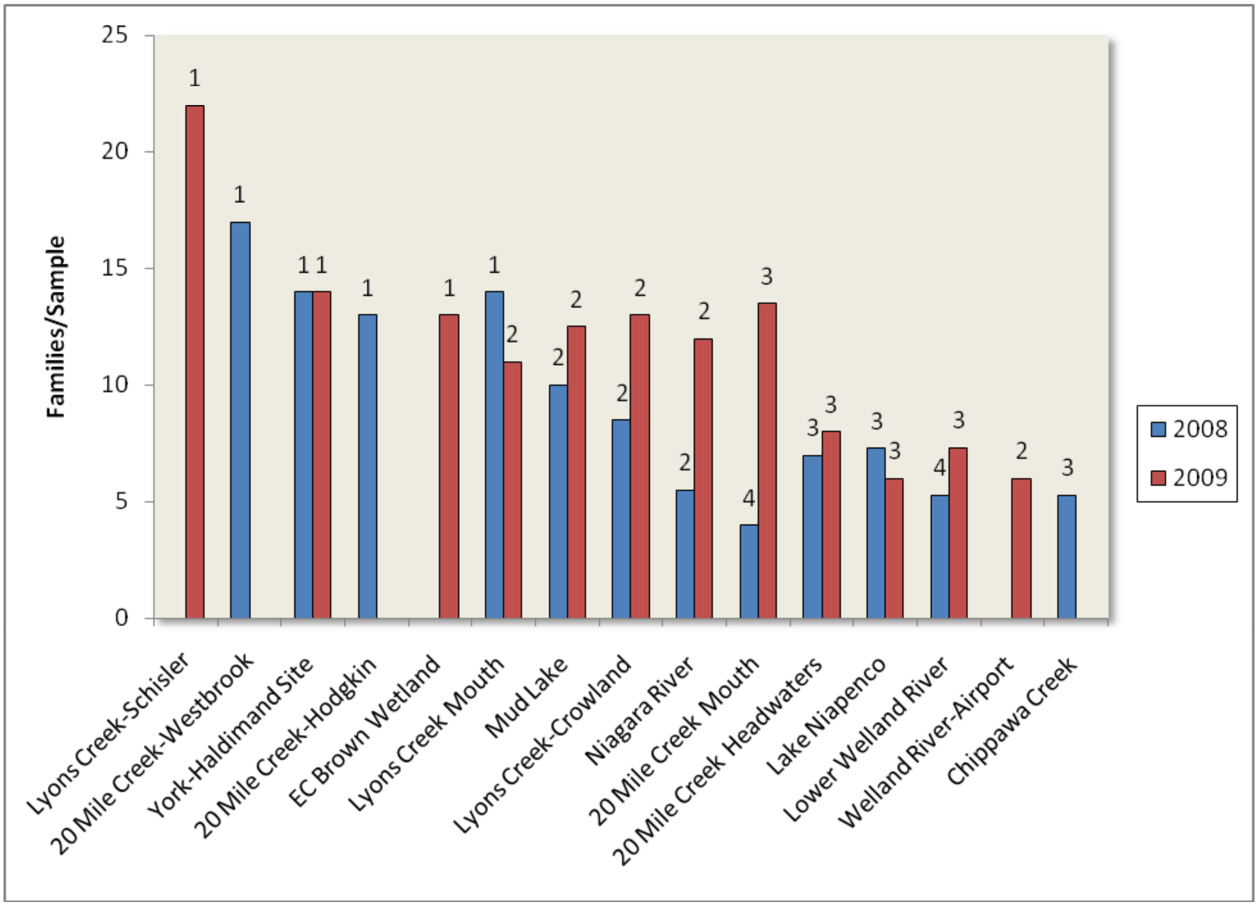


**Figure 5. Number of macroinvertebrate families per sample by sampling site for 2008 and 2009 sampling years. Sample size is indicated above each bar.**

*Index of Biotic Integrity*

Aquatic macroinvertebrate community attributes identified in Environment Canada and Central Lake Ontario Conservation Authority (2004) 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:

- Number of Trichoptera genera
- Number of Ephemeroptera and Trichoptera genera
- Total number of families
- Percent Gastropoda
- Number of Ephemeroptera genera
- Total number of genera
- Percent Trichoptera

Figure 6 shows macroinvertebrate IBI scores for sites that were sampled in 2009. Niagara River-Baker's Creek, Lyons Creek-Crowland and Mud Lake ranked highest among sites; these results corresponded with relatively high proportions of pollution-intolerant taxa (Table E1) and/or relatively high taxonomic richness values at these sites (Fig. 5). Lower Welland River-Grassy Brook and the York-Haldimand Site scored lowest for this IBI. Two reference watershed sites – Twenty Mile Creek Headwaters and Mouth – ranked low to moderate among AOC sites.

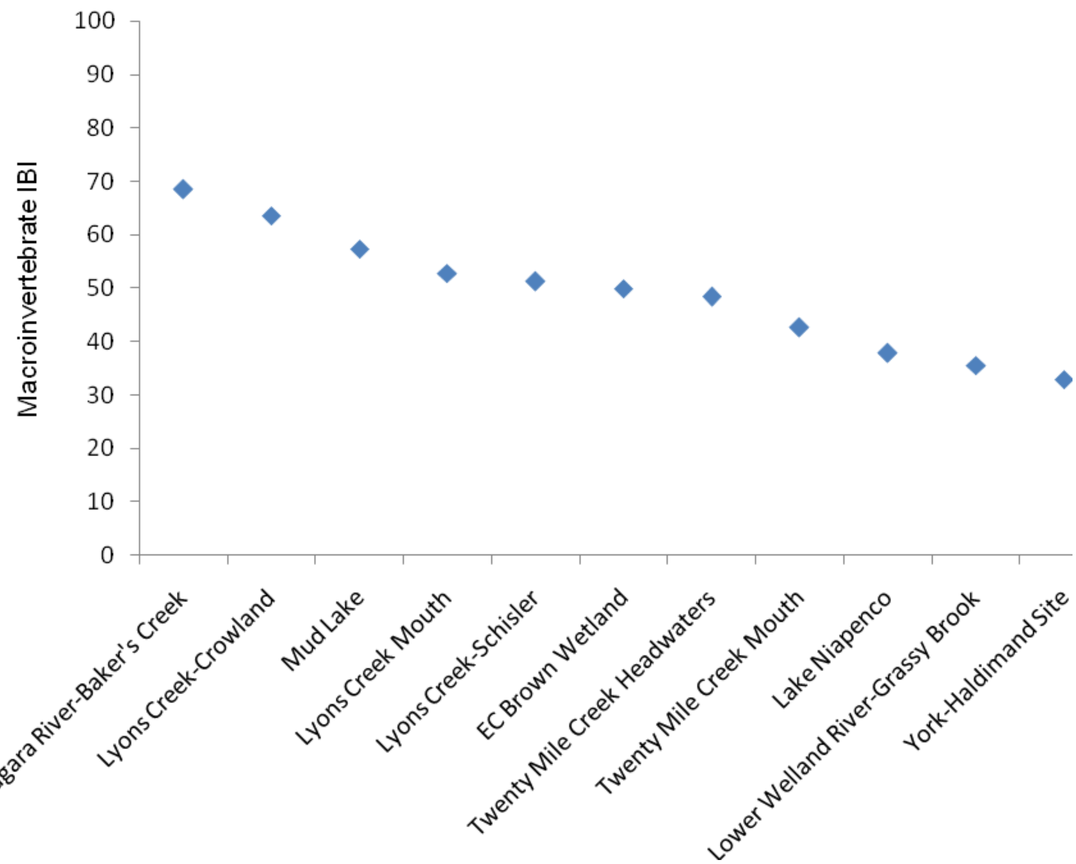


**Figure 6. Macroinvertebrate IBI scores for AOC and reference watershed sites.**

### Wetland Amphibian Communities

A total of seven species were detected across all sites between 2008 and 2009 (Table 3). The highest number of species (six) were recorded at Humberstone Marsh, Lyons Creek-Cook's Mills and Wainfleet Bog; five species were detected at EC Brown Wetland, Lyons Creek-Crowland and Lyons Creek-Schisler. Only one species was detected at Niagara River-Baker's

Creek, while two species were detected at six other sites. However, certain sites, (e.g., Upper Draper's Creek, Welland River-Airport) were not surveyed three times (see Table 1); therefore, some species may have been missed.

**Table 3. Maximum calling code detected across survey visits for each species, and number of stations surveyed, by marsh site.**

| Marsh Site | Maximum Calling Code | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | AMTO | BULL | CHFR | GRTR | GRFR | NLFR | SPPE | No. Stations Surveyed | No. Species Detected |
| EC Brown Conservation Area | 1 | | 1 | 3 | 1 | | 3 | 2 | 5 |
| Humberstone Marsh | 3 | 1 | 3 | | 1 | 1 | 3 | 1 | 6 |
| Lower Lyons Creek-Beck | 2 | 1 | | | | | | 1 | 2 |
| Lower Welland River-Grassy Brook | | 1 | | 1 | 1 | | | 4 | 3 |
| Lower Welland River-Stanley | 2 | 1 | | | | | | 1 | 2 |
| Lyons Creek-Cook's Mills | | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 6 |
| Lyons Creek-Crowland | 1 | 2 | 3 | | 3 | | 2 | 2 | 5 |
| Lyons Creek-Schisler | 1 | 2 | 2 | | 3 | | 2 | 1 | 5 |
| Mud Lake | 3 | 1 | | | 1 | 1 | 2 | 1 | 5 |
| Niagara River at Baker's Creek | | | 1 | | | | | 1 | 1 |
| Upper Draper's Creek-Foss | | 1 | | | 1 | | | 2 | 2 |
| Upper Draper's Creek-Hoist | | 1 | | | 1 | | | 2 | 2 |
| Wainfleet Bog | 1 | 1 | 1 | | 2 | 1 | 3 | 10 | 6 |
| Welland River-Airport | | 1 | | | 1 | | | 1 | 2 |
| Welland River at Big Forks Creek | | 1 | | | 1 | | | 1 | 2 |

Green Frog was the most widespread species, occurring at 46% of monitored stations, followed by Bullfrog and Spring Peeper, with 27% and 22% station occurrence, respectively (Table 4). Gray Treefrog was the most uncommon species, occurring at only 2% 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.

**Table 4. Maximum calling code for each species across all marsh complexes, number of stations at which each species was detected, and each species' percentage occurrence among all monitored stations.**

| Species Name | Maximum Calling Code | Number of stations with species detected | Percent occurrence among all stations |
|---|---|---|---|
| American Toad | 3 | 17 | 19.1 |
| Bullfrog | 2 | 24 | 27.0 |
| Western Chorus Frog | 3 | 13 | 14.6 |
| Gray Treefrog | 3 | 41 | 2.2 |
| Green Frog | 3 | 2 | 46.1 |
| Northern Leopard Frog | 1 | 8 | 9.0 |
| Spring Peeper | 3 | 20 | 22.5 |
| No anurans recorded | - | 12 | 13.5 |

*Index of Biotic Integrity*

Amphibian 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. Five metrics responded significantly at one or both of 500 m and 1000 m buffer distances ($p<0.20$), and were included in the IBI:

- Presence of Great Lakes basin-wide species
- Presence of disturbance-intolerant species
- Richness of disturbance-intolerant species
- Richness of Great Lakes basin-wide species
- Total species richness

Figure 7 shows amphibian IBI scores for AOC and reference watershed surveyed sites for the years 1998-2009. Humberstone Marsh scored significantly higher than all other sites (97.38), followed by Mud Lake (72.98) and Wainfleet Bog (70.53). By contrast, Twenty Mile Creek Mouth, the only reference watershed site ranked, scored lowest with 14.17.

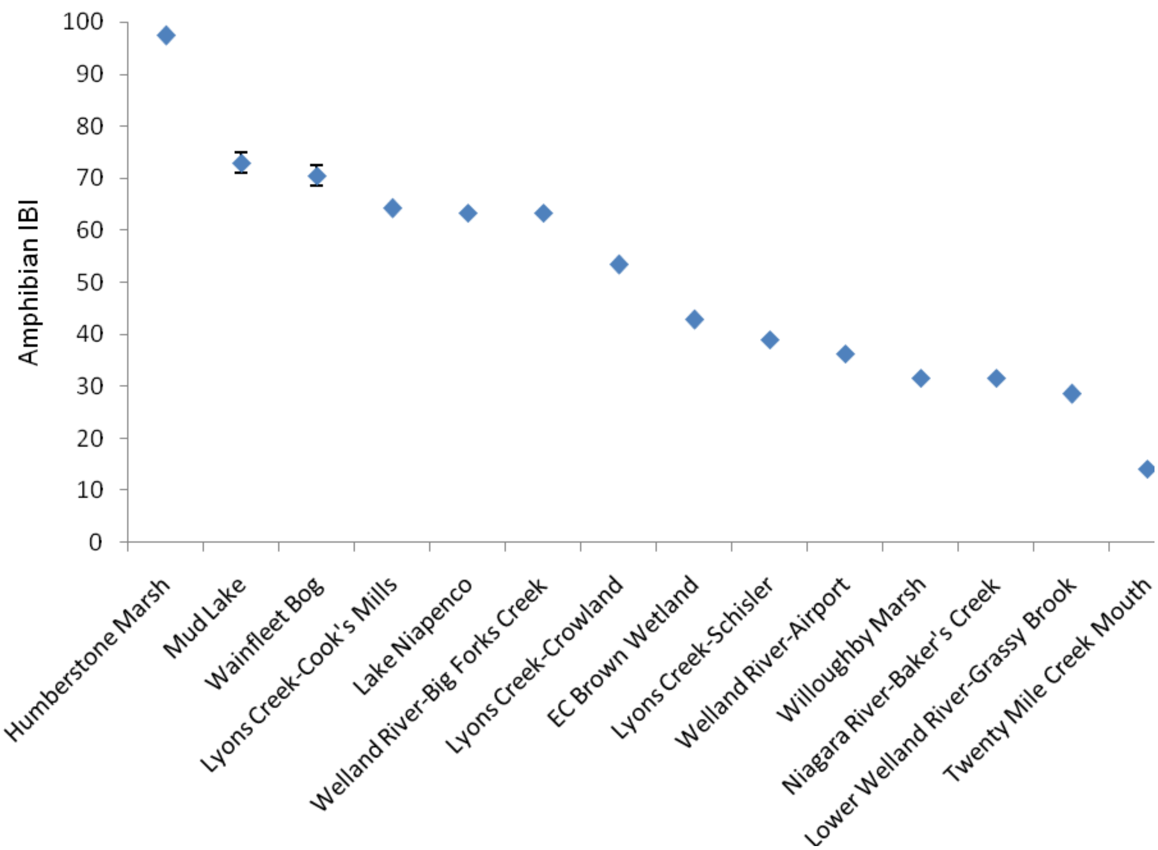


**Figure 7. Amphibian IBI scores for AOC and reference watershed sites, based on MMP data collected from 1998-2003.**

**Wetland Bird Communities**

In general, Red-winged Blackbird, Tree Swallow and Common Grackle were most abundant at monitored sites in 2008 and 2009 (Table 5). Only two (Lake Niapenco, Lyons Creek-Crowland) out of six AOC sites had indicator species; of these, only Swamp Sparrow was detected at each. Five indicator species (Least Bittern, Marsh Wren, Sora, Swamp Sparrow and Virginia Rail) were detected at the Twenty Mile Creek Mouth reference site. Despite relatively high species richness values at Mud Lake and Wainfleet Bog, no indicator species were detected at these sites. American Bittern, American Coot, Black Tern, and Common Moorhen were not recorded at any site.

*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. Two metrics (abundance of generalist species and richness of generalist species) responded significantly at all buffer distances ($p<0.20$), while one metric (abundance of non-aerial foragers) responded significantly at the 1000 m and 1500 m buffer scales. These metrics were included in the IBI; all other metrics did not respond to disturbance significantly in the expected fashion (i.e., positively or negatively to disturbance). Because this IBI was based on few metrics, including none based on marsh-obligate species responses, its results should be interpreted with some caution.

Figure 8 shows marsh bird IBI scores for AOC and reference watershed surveyed sites for the years 1998-2009. Lyons Creek-Crowland scored significantly higher than all other sites (93.60), followed by Mud Lake (63.18) and the Twenty Mile Creek Mouth reference site (58.43). EC Brown Wetland scored lowest with 15.50.

**Marsh Bird and Amphibian Community Assessments**

Table 6 presents scored assessments of marsh bird and amphibian community richness at AOC sites relative to Great Lakes basin non-AOC mean values, for 2003-2009. Total amphibian species richness and amphibian indicator species richness in the AOC both scored as average relative to Great Lakes basin non-AOC mean values. Based on limited data, marsh-nesting bird species richness and marsh bird indicator species richness in the AOC scored below average relative to Great Lakes basin non-AOC mean values. Two MMP routes/sites, Humberstone Marsh and Wainfleet Bog, were scored as being above-average in terms of their capacity to support a diverse assemblage of amphibian species. Three routes (EC Brown Wetland, Lyons Creek-Crowland/Schisler, and Mud Lake 2) showed no apparent impairment. Seven routes (Lake Niapenco, Lower Lyons Creek, Lyons Creek/Lower Welland River, Mud Lake 1, Niagara River-Baker’s Creek, Upper Draper’s Creek, and Upper Welland River (Airport/Big Forks Creek)) were classified as impaired in terms of their marsh bird or amphibian species richness. Overall, the Niagara River AOC was designated as impaired in its ability to support marsh-dependent species.

*Note that the term “impaired” in the context of this analysis strictly refers to the inability of a marsh habitat to support 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.*

**Table 5. Abundance per 10 stations for bird species detected across survey visits, by marsh site. Indicator species are identified by bolded and italicized font.**

| Species Code | Marsh Site | | | | | | |
|---|---|---|---|---|---|---|---|
| | Mud Lake | Twenty Mile Cr. Mouth | Lake Niapenco | Lyons Cr.- Crowland | Lyons Cr.- Schisler | Wainfleet Bog | EC Brown Wetland |
| ***AMBI*** | | | | | | | |
| ***AMCO*** | | | | | | | |
| ALFL | | | | | | 2.5 | |
| AMCR | | P | | 20.0 | | P | |
| AMGO | 5.0 | P | 1.4 | | | 1.0 | |
| AMRO | 6.7 | | 5.0 | | | 4.5 | |
| BANS | | | 25.7 | | | | |
| BAOR | 1.7 | P | 1.4 | | | 1.0 | |
| BARS | 6.7 | 14.2 | P | | | 0.5 | |
| BCCH | | | | | | 0.5 | |
| BEKI | | P | | | | | |
| BHCO | 6.7 | | P | | 20.0 | | |
| BLJA | | 0.8 | P | | | 1.0 | |
| ***BLTE*** | | | | | | | |
| CAGO | P | | P | | | | |
| CEDW | 5.0 | P | P | | | 7.0 | 13.3 |
| CHSP | | | 8.6 | | | | |
| CHSW | | 0.8 | | | | | |
| CLSW | | 4.2 | | | | | |
| COGR | 15.0 | 0.8 | 43.6 | | 10.0 | 5.5 | |
| ***COMO*** | | | | | | | |
| COTE | | 1.7 | | | | | |
| COYE | 1.7 | 2.5 | 3.6 | | | 1.5 | |
| DOWO | | | P | | | | |
| EAKI | 1.7 | P | | | | | |
| EATO | | | | | | 0.5 | |
| EAWP | | | | | | 0.5 | |
| EUST | P | P | 1.4 | | | P | |
| GBHE | P | P | P | | | | |
| GCFL | | P | | | | | |
| GRCA | | | 2.9 | | | 1.0 | |
| GRHE | | | P | 10.0 | | P | |
| KILL | | P | P | | | | |
| HETH | | | | | | 0.5 | |
| HOWR | 5.0 | | 0.7 | | | | |
| ***LEBI*** | | ***0.8*** | | | | | |
| MALL | 1.7 | | P | | | P | |
| ***MAWR*** | | ***20.8*** | | | | | |
| MODO | 1.7 | P | 0.7 | | | 2.5 | |
| NOCA | | | 0.7 | | | 1.0 | |
| NOFL | 3.3 | | | | | 1.5 | |
| NRWS | | P | P | | | P | |
| OSPR | | P | | | | | |
| ***PBGR*** | | | | | | | |
| PUMA | | 2.5 | | | | | |
| RBGU | P | P | P | | | P | |
| ROPI | | P | | | | | |
| RBGR | 1.7 | | P | | | 0.5 | |
| RTHA | | 2.5 | | | | | |
| RTHU | | | | | | 0.5 | |
| RWBL | 45.0 | 67.5 | 50.0 | 80.0 | 60.0 | 6.0 | 36.7 |
| SAVS | | | P | | | | |
| ***SORA*** | | ***2.5*** | | | | | |
| SOSP | 3.3 | 7.5 | 3.6 | | | 3.5 | P |

**Table 5. (cont.)**

| Species Code | Mud Lake | Twenty Mile Cr. Mouth | Lake Niapenco | Lyons Cr.-Crowland | Lyons Cr.-Schisler | Wainfleet Bog | EC Brown Wetland |
|---|---|---|---|---|---|---|---|
| | Marsh Site | | | | | | |
| SPSA | | | | | | | P |
| ***SWSP*** | | ***8.3*** | ***1.43*** | ***10.0*** | | | |
| TRES | 63.3 | 9.2 | 34.29 | | | 1.5 | 66.7 |
| ***VIRA*** | | ***3.3*** | | | | | |
| WAVI | | | 2.14 | | | | |
| WIFL | | | P | | | | |
| WODU | | | P | | | P | |
| WOTH | | | | | | 0.5 | |
| YBCU | | | | | | P | |
| YWAR | 8.3 | 1.7 | 7.1 | | | 10.5 | |
| No. Station-Visits | 6 | 12 | 14 | 1 | 1 | 20 | 3 |

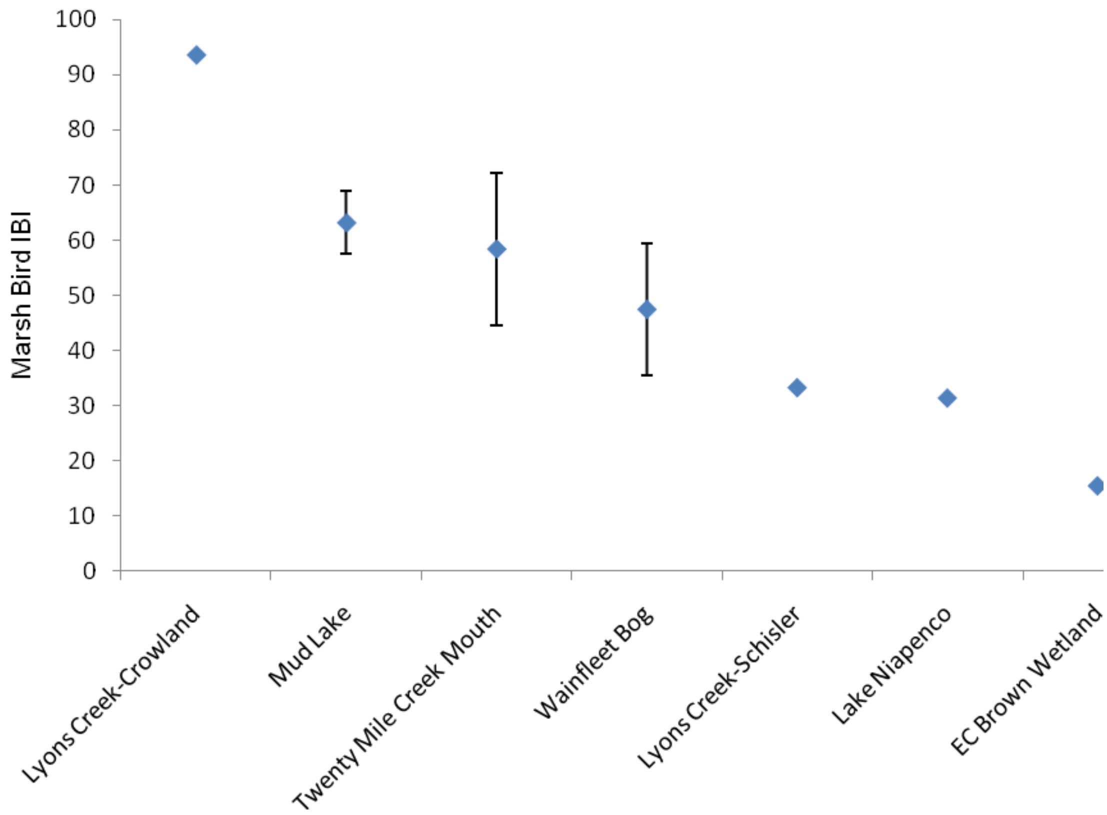


**Figure 8. Marsh bird IBI scores for AOC and reference watershed sites, based on MMP data collected from 1998-2009.**

**Table 6. Status of Niagara River AOC marshes from 2003 through 2009. "-" denotes values below the Great Lakes basin non-AOC average. "0" denotes values within the Great Lakes basin non-AOC average. "+" denotes values above the Great Lakes non-AOC average.**

| | | | | 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] |
| EC Brown Wetland | Amphibian | 2007-2009 | 1 | | | 0 | 0 | 2 |
| Humberstone Marsh | Amphibian | 2003-2008 | 1 | | | + | + | 4 |
| Lake Niapenco | Bird | 2007-2009 | 2 | 0 | - | | | 1 |
| Lower Lyons Creek | Amphibian | 2009 | 2 | | | - | - | 0 |
| Lyons Creek/Lower Welland River | Amphibian | 2003-2009 | 3 | | | - | - | 0 |
| Lyons Creek-Crowland/Schisler | Amphibian | 2007-2009 | 2 | | | 0 | 0 | 2 |
| Mud Lake 1 | Amphibian | 2003-2004 | 1 | | | - | - | 0 |
| Mud Lake 2 | Amphibian | 2008 | 1 | | | 0 | 0 | 2 |
| Niagara River-Baker's Creek | Amphibian | 2003-2006, 2009 | 1 | | | - | 0 | 1 |
| Upper Draper's Creek | Amphibian | 2003-2009 | 2 | | | - | - | 0 |
| Upper Welland River | Amphibian | 2009 | 2 | | | 0 | - | 1 |
| Wainfleet Bog | Bird, Amphibian | 2003-2009 | 5 | - | - | + | + | 4 |
| **Niagara River 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.**

## DISCUSSION

Using MMP data collected from 1995-2002, Timmermans et al. (2004) concluded that the Niagara River AOC was impaired[1] in its ability to support a diverse assemblage of wetland-associated bird and amphibian species. While the report authors grouped Niagara River (New York) AOC wetland sites with Ontario AOC sites, the majority of assessed sites were located in the Ontario AOC. **This report, which focuses specifically on the Ontario AOC, using data from 2003-2009, demonstrates that when marsh bird and amphibian data are considered collectively, the AOC remains impaired in its overall ability to support wetland-dependent bird and amphibian species.** However, amphibian and marsh bird communities exhibited different levels of ecological condition within the AOC, and considering these groups separately may provide more benefit for RAP wildlife population and/or habitat restoration planning.

Amphibian species diversity (richness) increased across all monitored wetland sites between these two assessment periods, from being classified as below-average during 1995-2002 to being within the Great Lakes basin non-AOC average during 2003-2009. Marsh bird survey coverage has been minimal within the AOC during the past several years, but based on limited information during the current assessment period, the AOC remains impaired in its ability to support marsh-nesting or marsh bird indicator species, unchanged from the 1995-2002 review period. Recent increases in MMP volunteer interest to conduct marsh bird surveys may improve understanding of the status of these communities across Niagara marshes in the future. Thus, the overall assessment describing the AOC as impaired in terms of its ability to collectively support wetland-dependent bird and amphibian communities may have been largely driven by the relatively poor marsh bird community results. Note that these assessments are based solely on the species richness-based analyses of MMP marsh bird and amphibian data summarized in Table 6; the results of water quality, macroinvertebrate, and other bird and amphibian summaries and analyses are discussed below.

Much variation existed among marsh sites in terms of their limnological water quality, and macroinvertebrate, amphibian and bird communities that did not always reflect simple gradients in watershed location (upper to lower) or land use/land cover context (surrounding rural vs. urban/industrial). In general, marsh sites that were better buffered from anthropogenic disturbances, had greater surrounding upland vegetation and greater habitat heterogeneity, supported a greater number of species, and presumably, healthier wetland-associated biotic communities. Examples of these sites include the Mud Lake marsh (located within a conservation area), Wainfleet Bog and Humberstone Marsh (a wetland restoration site). All of these marsh sites lie adjacent to surrounding woodland habitat.

Researchers and conservationists are increasingly recognizing the importance of woodland proximity to wetland breeding sites, and amphibians' accessibility between these habitat types, to species occurrence in a wetland (Guery and Hunter 2002). Given amphibians' unique terrestrial and 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. It should also be emphasized that this project only focused on marsh habitats and did not account for other amphibian breeding habitats within the AOC. Community series mapping conducted as part of the Natural Areas Inventory for the Niagara Region classified three-quarters of all identified wetlands within Niagara as swamps, which are important amphibian breeding habitats, particularly for woodland species. Therefore, our results that suggest amphibian community diversity is within average of Great Lakes basin non-AOC values may even be conservative, although surveys of other appropriate breeding habitats

[1] 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.

would be required to confirm this. Habitat classification and mapping information collected from the ongoing Natural Areas Inventory in Niagara may be useful in developing future amphibian population or habitat studies.

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 bird generalist species (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).

Other sites that had relatively healthy amphibian and macroinvertebrate communities included the EC Brown Wetland (a wetland restoration site), and the Lyons Creek-Cook's Mills, Crowland and Schisler sites, located along the upper-to-middle-course of that subwatershed. Conversely, sites such as Lake Niapenco, Lower Lyons Creek-Beck, Lower Welland River-Stanley, Lower Welland River-Grassy Brook, Welland River-Airport, Welland River-Big Forks Creek, Welland River-Chippawa Creek Conservation Area and Twenty Mile Creek Headwaters were classified as impaired in terms of their marsh bird or amphibian communities, had low IBI scores, had relatively low macroinvertebrate taxonomic richness, or had lower proportions of pollution-intolerant macroinvertebrate taxa. Common among these are marshes associated with the Welland River system, representing upper-, middle-, and lower-watershed reaches. However, sources of anthropogenic disturbance may vary greatly among these sites given differences in surrounding land use and road density. Results of limnological measurements may suggest possible stressors, and might explain some variation in biotic community condition among sites.

Sites with relatively poorer biotic community condition as measured during 2008-09, such as Lake Niapenco, Twenty Mile Creek Headwaters, Lower Welland River-Grassy Brook, and Welland River-Airport, tended to have high water conductivity/chloride concentration and high concentrations of either ammonia- or nitrate-nitrogen. High nitrate concentrations may be derived from non-point source inputs of fertilizers from surrounding agricultural or urban landscapes (Uzarski et al. 2004), while high conductivity and chloride values are commonly associated with contamination by de-icing salts from surrounding road networks. Many of these sites are located in rural areas immediately adjacent to roads. These marshes also had little or no surrounding woodland vegetation buffer, providing decreased connectivity to terrestrial amphibian habitat, and which may have exposed these sites to more direct non-point source inputs. Anthropogenic chemicals, such as nitrates, are known to negatively affect amphibian populations (Hecnar 1995, de Solla et al. 2002), and research has shown that woodlands tend to intercept nitrate in groundwater (Phillips 1993). Studies have demonstrated that road salts can have lethal effects on Wood Frog larvae (Sanzo and Hecnar 2006) and can negatively impact occurrence and survival of amphipod and larval chironomid macroinvertebrates, respectively, in wetlands (Uzarski et al. 2004, Silver et al. 2009).

Uzarski et al. (2004) found that relative abundance of isopods tended to decrease with higher pH. However, pH values measured across the project period did not consistently coincide with attributes of bird, amphibian or macroinvertebrate community condition, suggesting that other causative factors may have been more important.

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 contributed to differences in biotic community condition among sites. For example, both the Lyons Creek-Crowland and Schisler sites, at which amphibian and macroinvertebrate taxonomic richness was relatively high, had low conductivity and chloride levels. However, high ammonia and nitrate concentrations were measured at Lyons Creek-Crowland during both years. Therefore, other factors may have offset these stressors, such as the relatively long, contiguous riverine marsh habitat that exists along much of Lyons Creek. Another factor specific 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. While many of the influences described above may be beyond the scope of the RAP to address (i.e., not specific to the 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 most AOC marshes during breeding season 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, although they were not detected within the AOC during the project period. In general, lack of suitable habitat and anthropogenic disturbance within the AOC appear to be limiting factors toward occurrence and abundance of area-sensitive breeding marsh-dependent bird species (i.e., American Bittern, Virginia Rail, Sora, Swamp Sparrow, Black Tern, Pied-billed Grebe, Least Bittern).

*AOC Index of Biotic Integrity Development*

Based on comparative assessments of surrounding land cover and water quality among sites, it became apparent that Twenty Mile Creek watershed marsh sites altogether do not provide ideal reference conditions for AOC marsh bird, amphibian and macroinvertebrate community IBI analyses. In particular, most of these sites (Twenty Mile Creek Headwaters, Westbrook and Hodgkin) appeared to be similarly vulnerable to anthropogenic disturbances as several AOC sites, due to their landscape context directly adjacent to busy roadways, residential housing or agricultural fields. Rather, certain AOC sites, such as Humberstone Marsh and Wainfleet Bog, provided more of what may be considered reference conditions. Future studies assessing these biotic communities should select alternate reference sites that better represent less-disturbed habitat, even if those sites are most distant from the AOC. Doing so would improve wetland disturbance gradients against which to test metric responses as part of periodic IBI refinements.

Amphibian and macroinvertebrate community attributes were well represented as selected metrics for those IBIs, providing more confidence in their application and interpretation. However, most marsh bird community attributes, including all relating to marsh-obligate species, failed to respond significantly to disturbance in the expected manner, resulting in an IBI that may have less power to detect differences in community integrity. Continued increases in marsh bird survey coverage within the AOC may help refine this IBI by providing more data with which to test metrics.

We had insufficient time to derive IBI condition categories, whereby IBI score ranges, as determined by power analyses, would indicate marsh biotic integrity conditions (e.g., poor, fair, good). Performing subsequent power analyses may improve the usefulness of these indicators to provide site-based “status” conditions. Regardless, existing site rankings provide indications of relative wetland biotic integrity within the AOC. As well, assessments of temporal trends in AOC wetland IBI scores, if updated periodically, can provide valuable information about biotic responses to wildlife population and habitat restoration initiatives over time.

## CONCLUSIONS AND RECOMMENDATIONS

In general, wetland-associated amphibian communities in the AOC do not appear to show signs of impairment in relation to non-AOC Great Lakes basin conditions. Several surveyed marshes contained most amphibian species expected to occur in the region. Unfortunately, limited data were available to assess AOC marsh bird communities. However, marshes that were surveyed for birds yielded few indicator species detections and were dominated by passerines and other generalist marsh-user species. Generally, sites that featured relatively good aquatic macroinvertebrate integrity had above average amphibian species richness among AOC sites.

Overall, marsh sites that featured surrounding/adjacent woodlands (e.g., Humberstone Marsh, Wainfleet Bog), or were connected as part of a larger marsh complex (e.g., Lyons Creek-Cook’s Mills, Crowland, Schisler sites) seemed adequate to support breeding amphibian, and (where they were sampled) aquatic macroinvertebrate, communities. In contrast, sites associated with the Welland River system tended to show signs of degradation in terms of water quality and species composition and diversity, although these results were not consistent across all measured parameters.

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

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. Connectivity between marshes and with other natural habitats should be conserved and restored to facilitate wildlife population movements among sites, increase habitat availability, and sustain local population integrity.
3. Continue to monitor natural development of habitat restoration sites (EC Brown Wetland, Humberstone Marsh) and make changes to site management where necessary to meet ecosystem functional objectives.
4. Continue efforts to encourage use of agricultural Best Management Practices to minimize non-point source pollution of aquatic systems.
5. Perform comprehensive wetland health assessments approximately every five years to track wildlife population and habitat recovery, interspersed with annual volunteer-based monitoring activity.
6. Investigate other factors that influence habitat suitability for wetland-breeding wildlife (particularly wetland-obligate breeding birds), such as effects caused by flow-reversal in the Welland River and 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 as less-frequent intensive habitat assessments. The Niagara-based IBIs should be continually evaluated and revised where needed to maximize their accuracy and usefulness. This includes calculation of biotic condition categories attributed to IBI score ranges. Future IBI use should consider re-evaluation of reference sites to improve power to detect differences in IBI values among sites.

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## 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

**Table B1. Percent cover of habitat features and emergent vegetation within monitored marshes, based on 2009 MMP data.**

| Habitat Characteristic | Marsh Site | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Habitat Composition (% Cover) | | | | | | | | | | | | | | | | |
| Emergent Vegetation | 77.5 | 81.3 | 82.5 | 18.8 | 67.5 | 60.0 | 32.0 | 4.0 | 40.0 | 50.0 | 29.5 | 55.0 | 66.5 | 60.0 | 32.0 | 20.0 |
| Open Water | 8.3 | 3.3 | 6.5 | 43.8 | 20.0 | 20.0 | 60.0 | 77.5 | 50.0 | 30.0 | 18.7 | 30.0 | 12.5 | 20.0 | 42.0 | 60.0 |
| Exposed Substrate | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 5.0 | 0.0 | 0.0 | 0.0 | 10.0 | 0.7 | 5.0 | 2.5 | 5.0 | 7.0 | 10.0 |
| Trees | 10.3 | 5.0 | 2.5 | 17.5 | 5.0 | 10.0 | 5.0 | 8.5 | 5.0 | 5.0 | 24.3 | 5.0 | 10.0 | 10.0 | 12.0 | 5.0 |
| Shrubs | 4.0 | 10.5 | 8.5 | 20.0 | 5.0 | 5.0 | 3.0 | 10.0 | 5.0 | 5.0 | 26.8 | 5.0 | 8.5 | 5.0 | 7.0 | 5.0 |
| Emergent Vegetation Composition (% Cover) | | | | | | | | | | | | | | | | |
| Cattail | 76.3 | 72.5 | 76.5 | 46.3 | 62.5 | 75.0 | 0.0 | 0.0 | 10.0 | 5.0 | 49.0 | 80.0 | 47.5 | 97.0 | 0.0 | 10.0 |
| Reeds | 11.3 | 0.0 | 6.5 | 3.3 | 0.0 | 0.0 | 29.0 | 40.0 | 0.0 | 0.0 | 12.0 | 0.0 | 5.0 | 0.0 | 0.0 | 0.0 |
| Grasses and Sedges | 0.0 | 22.5 | 15.0 | 41.0 | 5.0 | 15.0 | 69.0 | 45.0 | 80.0 | 80.0 | 18.1 | 20.0 | 17.5 | 0.0 | 50.0 | 60.0 |
| Rushes and Bulrushes | 5.0 | 5.0 | 0.0 | 0.0 | 0.0 | 5.0 | 0.0 | 0.0 | 0.0 | 10.0 | 0.0 | 0.0 | 2.5 | 0.0 | 0.0 | 10.0 |
| Water Willow | 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 | 10.0 |
| 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 |
| Arrowhead | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 50.0 | 0.0 |
| Smartweed | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Burreed | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 0.0 | 0.0 | 0.0 |
| Purple Loosestrife | 0.0 | 0.0 | 0.0 | 0.0 | 17.5 | 5.0 | 0.0 | 0.0 | 0.0 | 5.0 | 0.3 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 |
| 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 |
| Other | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 |
| Number of Stations Surveyed | 4 | 4 | 2 | 4 | 2 | 1 | 2 | 2 | 1 | 1 | 15 | 1 | 2 | 1 | 1 | 1 |

1=Mud Lake
2=Lake Niapenco
3=Lyons Creek-Cook's Mills
4=Lower Welland River-Grassy Brook
5=Lyons Creek
6=Lyons Creek
7=Upper Draper's Creek
8=Upper Draper's Creek
9=Welland River-Airport
10=Welland River at Big Forks Creek
11=Wainfleet Bog
12=Humberstone Marsh
13=EC Brown Conservation Area
14=Niagara River at Baker's Creek
15=Lower Welland River-Stanley
16=Lower Lyons Creek-Beck

## APPENDIX C

**Table C1. List of marsh bird and amphibian indicator species used in community assessment analyses.**

| Marsh Bird Indicator Species | Amphibian Indicator Species |
|---|---|
| American Bittern | Bullfrog |
| American Coot | Western Chorus Frog |
| Black Tern | Northern Leopard Frog |
| Blue-winged Teal | Spring Peeper |
| Common Moorhen | |
| Least Bittern | |
| Marsh Wren | |
| Undifferentiated Common Moorhen/American Coot | |
| Pied-billed Grebe | |
| Sora | |
| Virginia Rail | |
| Wilson's Snipe | |

## APPENDIX D

**Table D1. Summary of physical and chemical limnological parameters by sampling site for 2008 and 2009 sampling years. Sample size is indicated in brackets. "*" indicates data collected by Canadian Wildlife Service.**

| Site Name | Year | Depth (cm) | Air Temp (°C) | Water Temp (°C) | DO (%) | DO (mg/L) | Turb. (FTU) | Cond. (uS/cm) | pH | TDS (g/L) | NO3 (ppm) | NH3 (ppm) | Cl (ppm) | Chlor. a (fluoresc.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 Mile Creek-Hodgkin | 2008 | 55 (1) | 25.0 (1) | 21.2 (1) | 93.7 (1) | 8.35 (1) | 70 (1) | 554.0 (1) | 7.06 (1) | 0.360 (1) | 0.53 (1) | 0.42 (1) | 13.50 (1) | 3.323 (2) |
| 20 Mile Creek-Westbrook | 2008 | 85 (1) | 22.0 (1) | 18.6 (1) | 130.7 (1) | 12.09 (1) | 91 (1) | 654 .0 (1) | 7.11 (1) | 0.425 (1) | 0.35 (1) | 0.46 (1) | 23.00 (1) | 45.410 (3) |
| 20 Mile Creek Headwaters | 2008 | 22 (3) | 23.0 (3) | 24.5 (3) | 203.6 (3) | 17.13 (3) | 20 (3) | 580.0 (3) | 7.63 (3) | 0.378 (3) | 0.08 (3) | 0.39 (3) | 39.30 (3) | 5.956 (9) |
| | 2009 | 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) |
| 20 Mile Creek Mouth | 2008 | 66 (4) | 26.3 (4) | 23.4 (4) | 171.0 (4) | 14.54 (4) | 46 (4) | 559.0 (4) | 7.74 (4) | 0.363 (4) | 0.15 (4) | 0.52 (4) | 21.20 (4) | 7.298 (10) |
| | 2009* | 67 (2) | - | 22.8 (2) | - | 8.41 (2) | 12 (2) | 718.0 (2) | 8.25 (2) | - | 0.55 (2) | - | - | - |
| Chippawa Creek | 2008 | 33 (3) | 27.7 (3) | 27.2 (3) | 105.0 (3) | 8.45 (3) | 194 (3) | 323.0 (3) | 7.46 (3) | 0.268 (3) | 0.00 (3) | 0.24 (3) | 3.70 (3) | 19.294 (8) |
| EC Brown Wetland | 2009 | 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 | 2008 | 38 (3) | 23.0 (3) | 24.1 (3) | 140.4 (3) | 11.73 (3) | 140 (3) | 699.0 (3) | 7.38 (3) | 0.454 (3) | 0.19 (3) | 0.60 (3) | 32.20 (3) | 2.264 (5) |
| | 2009 | 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 | 2008 | 53 (4) | 23.8 (4) | 25.9 (4) | 241.2 (4) | 18.36 (4) | 18 (4) | 395.0 (4) | 8.15 (4) | 0.256 (4) | 0.33 (4) | 0.32 (4) | 8.40 (4) | 1.020 (4) |
| | 2009 | 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 | 2008 | 50 (2) | 19.5 (2) | 23.8 (2) | 167.0 (2) | 14.09 (2) | 53 (2) | 381.0 (2) | 7.44 (2) | 0.248 (2) | 0.00 (2) | 0.44 (2) | 6.00 (2) | 4.124 (2) |
| | 2009 | 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 | 2008 | 25 (1) | 18.0 (1) | 23.4 (1) | 210.3 (1) | 17.95 (1) | 38 (1) | 328.0 (1) | 8.54 (1) | 0.213 (1) | 0.10 (1) | 0.29 (1) | 5.60 (1) | 2.122 (1) |
| | 2009 | 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 | 2009 | 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 | 2008 | 20 (2) | 22.0 (2) | 20.0 (2) | 61.1 (2) | 5.58 (2) | 23 (2) | 481.0 (2) | 6.95 (2) | 0.314 (2) | 0.14 (2) | 0.44 (2) | 1.40 (2) | 4.663 (6) |
| | 2009 | 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 | 2008 | 15 (2) | 16.0 (2) | 20.2 2) | 127.6 (2) | 11.46 (2) | 75 (2) | 349.0 (2) | 7.62 2) | 0.237 (2) | 0.25 (2) | 0.36 (2) | 81.80 (2) | 2.874 (2) |

**Table D1. (cont.)**

| Site Name | Year | Depth (cm) | Air Temp (°C) | Water Temp (°C) | DO (%) | DO (mg/L) | Turb. (FTU) | Cond. (uS/cm) | pH | TDS (g/L) | NO3 (ppm) | NH3 (ppm) | Cl (ppm) | Chlor. a (fluoresc.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Niagara River at Baker's Creek | 2009 | 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) |
| Welland River-Airport | 2009 | 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 | 2008 | 50 (1) | 14.0 (1) | 18.3 (1) | 36.7 1) | 3.46 (1) | 57 (1) | 192.0 (1) | 6.62 (1) | 0.125 (1) | 0.00 (1) | 0.31 (1) | 2.60 (1) | 2.480 (2) |
| | 2009 | 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) |

## APPENDIX E

**Table E1. Mean proportion per sample of collected pollution-sensitive and pollution-tolerant macroinvertebrate indicator taxa, by site.**

| Site | Indicator Taxon Proportion (%) | | | | | |
|---|---|---|---|---|---|---|
| | Pollution-Sensitive | | | Pollution-Tolerant | | |
| | Trichoptera | Ephemeroptera | Elmidae | Pulmonata | Rhynchobdellida | Haplotaxida |
| Twenty Mile Creek-Hodgkin | 0.00 | 15.15 | 0.00 | 18.18 | 0.00 | 0.00 |
| Twenty Mile Creek-Westbrook | 0.00 | 13.27 | 0.00 | 15.31 | 0.00 | 0.00 |
| Twenty Mile Creek Headwaters | 0.00 | 4.33 | 0.00 | 8.87 | 1.30 | 1.52 |
| Twenty Mile Creek Mouth | 0.00 | 1.24 | 0.14 | 11.07 | 0.00 | 0.00 |
| *Reference Watershed Average* | *0.00* | *3.85* | *0.07* | *10.97* | *0.44* | *1.26* |
| Chippawa Creek | 0.00 | 12.82 | 0.00 | 3.85 | 3.85 | 2.56 |
| Lake Niapenco | 0.16 | 8.23 | 0.32 | 2.37 | 2.53 | 3.16 |
| Lower Welland River | 0.46 | 4.89 | 0.00 | 15.27 | 5.19 | 9.62 |
| Lyons Creek-Crowland | 2.92 | 3.45 | 0.00 | 2.65 | 0.27 | 6.10 |
| Lyons Creek Mouth | 2.17 | 7.22 | 0.00 | 19.13 | 3.25 | 0.00 |
| Mud Lake | 0.00 | 10.90 | 0.00 | 17.76 | 0.00 | 1.32 |
| Niagara River | 0.69 | 10.70 | 0.35 | 14.88 | 7.96 | 7.61 |
| York-Haldimand Site | 0.00 | 14.52 | 0.00 | 0.00 | 0.00 | 2.15 |
| Lyons Creek-Schisler | 1.01 | 10.10 | 2.02 | 4.04 | 2.02 | 4.04 |
| Welland River-Airport | 0.55 | 5.52 | 0.56 | 7.18 | 0.55 | 0.00 |
| EC Brown Wetland | 1.05 | 33.68 | 0.00 | 8.42 | 0.00 | 0.00 |
| *AOC Average* | *0.82* | *8.51* | *0.19* | *9.55* | *2.80* | *4.48* |

**Table E2. Number of macroinvertebrate specimens per sample for each family and genus, by sampling site, collected in 2009. Twenty Mile Creek Mouth data were collected by Canadian Wildlife Service in 2009.**

| Site name | No. samples | Family | Genus | No. specimens | No. specimens per sample |
|---|---|---|---|---|---|
| Welland River-Airport | 2 | Hydracarina | - | 2 | 1 |
| Welland River-Airport | 2 | Talitridae | - | 1 | 0.5 |
| Welland River-Airport | 2 | Halaellidae | Hyalella | 60 | 30 |
| Welland River-Airport | 2 | Coenagrionidae | Enallagma | 4 | 2 |
| Welland River-Airport | 2 | Chironomidae | Tanypodinae | 2 | 1 |
| Welland River-Airport | 2 | Culicidae | Anopheles | 4 | 2 |
| Welland River-Airport | 2 | Caenidae | Caenis | 10 | 5 |
| Welland River-Airport | 2 | Pleidae | Neoplea | 1 | 0.5 |
| Welland River-Airport | 2 | Mesoveliidae | Mesovelia | 1 | 0.5 |
| Welland River-Airport | 2 | Aphididae | - | 2 | 1 |
| Welland River-Airport | 2 | Asellidae | Caecidotea | 74 | 37 |
| Welland River-Airport | 2 | Lymnaeidae | Pseudosuccinea | 4 | 2 |
| Welland River-Airport | 2 | Physidae | Physella | 9 | 4.5 |
| Welland River-Airport | 2 | Planariidae | - | 2 | 1 |
| Welland River-Airport | 2 | Elmidae | - | 1 | 0.5 |
| Welland River-Airport | 2 | Haliplidae | - | 2 | 1 |
| Welland River-Airport | 2 | Glossiphoniidae | - | 1 | 0.5 |
| Welland River-Airport | 2 | Polycentropodidae | Polycentropus | 1 | 0.5 |
| EC Brown Wetland | 1 | Hydracarina | - | 2 | 2 |
| EC Brown Wetland | 1 | Halaellidae | Hyalella | 37 | 37 |
| EC Brown Wetland | 1 | Coenagrionidae | Enallagma | 1 | 1 |
| EC Brown Wetland | 1 | Haliplidae | - | 1 | 1 |
| EC Brown Wetland | 1 | Ceratopogonidae | Bezzia | 1 | 1 |
| EC Brown Wetland | 1 | Chironomidae | Tanypodinae | 8 | 8 |
| EC Brown Wetland | 1 | Caenidae | Caenis | 32 | 32 |
| EC Brown Wetland | 1 | Pyralidae | Acentria | 1 | 1 |

**Table E2 (continued)**

| Site name | No. samples | Family | Genus | No. specimens | No. specimens per sample |
|---|---|---|---|---|---|
| EC Brown Wetland | 1 | Physidae | Physella | 5 | 5 |
| EC Brown Wetland | 1 | Planorbidae | Gyraulus | 3 | 3 |
| EC Brown Wetland | 1 | Planariidae | - | 1 | 1 |
| EC Brown Wetland | 1 | Leptoceridae | Oecetis | 1 | 1 |
| EC Brown Wetland | 1 | Dreissenidae | Dreissena | 2 | 2 |
| Lyons Creek Mouth | 2 | Hydracarina | - | 2 | 1 |
| Lyons Creek Mouth | 2 | Gammaridae | Gammarus | 21 | 10.5 |
| Lyons Creek Mouth | 2 | Halaellidae | Hyalella | 73 | 36.5 |
| Lyons Creek Mouth | 2 | Aeshnidae | Anax | 1 | 0.5 |
| Lyons Creek Mouth | 2 | Libellulidae | Sympetrum | 1 | 0.5 |
| Lyons Creek Mouth | 2 | | Leucorrhinia | 1 | 0.5 |
| Lyons Creek Mouth | 2 | Corduliidae | Somatochlora | 2 | 1 |
| Lyons Creek Mouth | 2 | Coenagrionidae | Enallagma | 19 | 9.5 |
| Lyons Creek Mouth | 2 | Cladocera | - | 2 | 1 |
| Lyons Creek Mouth | 2 | Hydrophilidae | - | 1 | 0.5 |
| Lyons Creek Mouth | 2 | Carabidae | - | 1 | 0.5 |
| Lyons Creek Mouth | 2 | Chironomidae | Tanypodinae | 2 | 1 |
| Lyons Creek Mouth | 2 | Caenidae | Caenis | 20 | 10 |
| Lyons Creek Mouth | 2 | Asellidae | Caecidotea | 7 | 3.5 |
| Lyons Creek Mouth | 2 | Pyralidae | Acentria | 1 | 0.5 |
| Lyons Creek Mouth | 2 | Lymnaeidae | Pseudosuccinea | 2 | 1 |
| Lyons Creek Mouth | 2 | Physidae | Physella | 22 | 11 |
| Lyons Creek Mouth | 2 | Planorbidae | Gyraulus | 3 | 1.5 |
| Lyons Creek Mouth | 2 | | Helisoma | 1 | 0.5 |
| Lyons Creek Mouth | 2 | | Promoretus | 2 | 1 |
| Lyons Creek Mouth | 2 | | Planorbella | 1 | 0.5 |
| Lyons Creek Mouth | 2 | Glossiphoniidae | - | 9 | 4.5 |
| Lyons Creek Mouth | 2 | Planariidae | - | 9 | 4.5 |
| Lyons Creek Mouth | 2 | | Leptocerus | 6 | 3 |
| Lyons Creek Mouth | 2 | Dreissenidae | Dreissena | 1 | 0.5 |
| Niagara R.-Baker's Cr. | 2 | Hydracarina | - | 20 | 10 |
| Niagara R.-Baker's Cr. | 2 | Gammaridae | Gammarus | 77 | 38.5 |

**Table E2 (continued)**

| Site name | No. samples | Order | Family | No. specimens | No. specimens per sample |
|---|---|---|---|---|---|
| Niagara R.-Baker's Cr. | 2 | Talitridae | - | 2 | 1 |
| Niagara R.-Baker's Cr. | 2 | Halaellidae | Hyalella | 7 | 3.5 |
| Niagara R.-Baker's Cr. | 2 | Libellulidae | Sympetrum | 1 | 0.5 |
| Niagara R.-Baker's Cr. | 2 | Coenagrionidae | Enallagma | 2 | 1 |
| Niagara R.-Baker's Cr. | 2 | Dytiscidae | - | 1 | 0.5 |
| Niagara R.-Baker's Cr. | 2 | Hydrophilidae | - | 1 | 0.5 |
| Niagara R.-Baker's Cr. | 2 | Chironomidae | Tanypodinae | 16 | 8 |
| Niagara R.-Baker's Cr. | 2 | Tipulidae | - | 1 | 0.5 |
| Niagara R.-Baker's Cr. | 2 | Baetidae | Procloean | 16 | 8 |
| Niagara R.-Baker's Cr. | 2 | Caenidae | Caenis | 4 | 2 |
| Niagara R.-Baker's Cr. | 2 | Tubificidae | - | 1 | 0.5 |
| Niagara R.-Baker's Cr. | 2 | Naididae | - | 12 | 6 |
| Niagara R.-Baker's Cr. | 2 | Pleidae | Neoplea | 1 | 0.5 |
| Niagara R.-Baker's Cr. | 2 | Belostomatidae | Belostoma | 1 | 0.5 |
| Niagara R.-Baker's Cr. | 2 | Asellidae | Caecidotea | 1 | 0.5 |
| Niagara R.-Baker's Cr. | 2 | Pyralidae | Acentria | 1 | 0.5 |
| Niagara R.-Baker's Cr. | 2 | Lymnaeidae | Pseudosuccinea | 1 | 0.5 |
| Niagara R.-Baker's Cr. | 2 | Physidae | Physella | 34 | 17 |
| Niagara R.-Baker's Cr. | 2 | Planorbidae | Gyraulus | 3 | 1.5 |
| Niagara R.-Baker's Cr. | 2 | | Ancylidae | 1 | 0.5 |
| Niagara R.-Baker's Cr. | 2 | | Leptocerus | 2 | 1 |
| Niagara R.-Baker's Cr. | 2 | | Cernotina | 1 | 0.5 |
| Lyons Creek Crowland | 2 | Hydracarina | - | 3 | 1.5 |
| Lyons Creek Crowland | 2 | Crangonyctidae | Crangonyx | 4 | 2 |
| Lyons Creek Crowland | 2 | Gammaridae | Gammarus | 15 | 7.5 |
| Lyons Creek Crowland | 2 | Talitridae | - | 2 | 1 |
| Lyons Creek Crowland | 2 | Halaellidae | Hyalella | 65 | 32.5 |
| Lyons Creek Crowland | 2 | Coenagrionidae | Enallagma | 22 | 11 |
| Lyons Creek Crowland | 2 | Cladocera | - | 4 | 2 |
| Lyons Creek Crowland | 2 | Dytiscidae | - | 1 | 0.5 |
| Lyons Creek Crowland | 2 | Haliplidae | - | 1 | 0.5 |
| Lyons Creek Crowland | 2 | Hydrophilidae | - | 1 | 0.5 |

**Table E2 (continued)**

| Site name | No. samples | Family | Genus | No. specimens | No. specimens per sample |
|---|---|---|---|---|---|
| Lyons Creek Crowland | 2 | Chironomidae | Tanypodinae | 20 | 10 |
| Lyons Creek Crowland | 2 | Sciomyzidae | Sepedon | 2 | 1 |
| Lyons Creek Crowland | 2 | Culicidae | Anopheles | 1 | 0.5 |
| Lyons Creek Crowland | 2 | Baetidae | Procloean | 3 | 1.5 |
| Lyons Creek Crowland | 2 | Caenidae | Caenis | 6 | 3 |
| Lyons Creek Crowland | 2 | Naididae | - | 20 | 10 |
| Lyons Creek Crowland | 2 | Pleidae | Neoplea | 4 | 2 |
| Lyons Creek Crowland | 2 | Belostomatidae | Belostoma | 3 | 1.5 |
| Lyons Creek Crowland | 2 | Aphididae | - | 1 | 0.5 |
| Lyons Creek Crowland | 2 | Naucoridae | - | 15 | 7.5 |
| Lyons Creek Crowland | 2 | Asellidae | Caecidotea | 14 | 7 |
| Lyons Creek Crowland | 2 | Physidae | Physella | 6 | 3 |
| Lyons Creek Crowland | 2 | Glossiphoniidae | - | 1 | 0.5 |
| Lyons Creek Crowland | 2 | Planariidae | - | 1 | 0.5 |
| Lyons Creek Crowland | 2 | | Cernotina | 4 | 2 |
| Lyons Creek Crowland | 2 | Hydropsychidae | - | 7 | 3.5 |
| Mud Lake | 2 | Hydracarina | - | 7 | 3.5 |
| Mud Lake | 2 | Crangonyctidae | Crangonyx | 5 | 2.5 |
| Mud Lake | 2 | Gammaridae | Gammarus | 6 | 3 |
| Mud Lake | 2 | | Echinogammarus | 0 | 0 |
| Mud Lake | 2 | Halaellidae | Hyalella | 16 | 8 |
| Mud Lake | 2 | Libellulidae | Sympetrum | 1 | 0.5 |
| Mud Lake | 2 | Coenagrionidae | Enallagma | 28 | 14 |
| Mud Lake | 2 | Cladocera | - | 6 | 3 |
| Mud Lake | 2 | Dytiscidae | - | 1 | 0.5 |
| Mud Lake | 2 | Hydrophilidae | - | 8 | 4 |
| Mud Lake | 2 | Gyrinidae | - | 1 | 0.5 |
| Mud Lake | 2 | Curculionidae | - | 1 | 0.5 |
| Mud Lake | 2 | Ceratopogonidae | Bezzia | 3 | 1.5 |
| Mud Lake | 2 | Chironomidae | Tanypodinae | 9 | 4.5 |
| Mud Lake | 2 | | Orthocladiinae | 1 | 0.5 |
| Mud Lake | 2 | Culicidae | Anopheles | 2 | 1 |

**Table E2 (continued)**

| Site name | No. samples | Family | Genus | No. specimens | No. specimens per sample |
|---|---|---|---|---|---|
| Mud Lake | 2 | Tipulidae | - | 1 | 0.5 |
| Mud Lake | 2 | Baetidae | Procloean | 4 | 2 |
| Mud Lake | 2 | Caenidae | Caenis | 17 | 8.5 |
| Mud Lake | 2 | Naididae | - | 1 | 0.5 |
| Mud Lake | 2 | Notonectidae | Notonecta | 2 | 1 |
| Mud Lake | 2 | Aphididae | - | 1 | 0.5 |
| Mud Lake | 2 | Hydrobiidae | Amnicola | 1 | 0.5 |
| Mud Lake | 2 | Lymnaeidae | Pseudosuccinea | 1 | 0.5 |
| Mud Lake | 2 | | Stagnicola | 1 | 0.5 |
| Mud Lake | 2 | | Fossaria | 8 | 4 |
| Mud Lake | 2 | Physidae | Physella | 36 | 18 |
| Mud Lake | 2 | Planorbidae | Gyraulus | 4 | 2 |
| Mud Lake | 2 | | Planorbella | 1 | 0.5 |
| Mud Lake | 2 | Sphaeriidae | Musculium | 1 | 0.5 |
| Lower Welland R. Grassy B. | 3 | Hydracarina | - | 2 | 0.7 |
| Lower Welland R. Grassy B. | 3 | Crangonyctidae | Crangonyx | 6 | 2.0 |
| Lower Welland R. Grassy B. | 3 | Gammaridae | Gammarus | 63 | 21.0 |
| Lower Welland R. Grassy B. | 3 | Halaellidae | Hyalella | 30 | 10.0 |
| Lower Welland R. Grassy B. | 3 | Coenagrionidae | Enallagma | 14 | 4.7 |
| Lower Welland R. Grassy B. | 3 | - | - | 2 | 0.7 |
| Lower Welland R. Grassy B. | 3 | Haliplidae | - | 11 | 3.7 |
| Lower Welland R. Grassy B. | 3 | Hydrophilidae | - | 2 | 0.7 |
| Lower Welland R. Grassy B. | 3 | Coccinellidae | - | 1 | 0.3 |
| Lower Welland R. Grassy B. | 3 | Ceratopogonidae | Bezzia | 3 | 1.0 |
| Lower Welland R. Grassy B. | 3 | | Probezzia | 1 | 0.3 |
| Lower Welland R. Grassy B. | 3 | Chironomidae | Tanypodinae | 45 | 15.0 |
| Lower Welland R. Grassy B. | 3 | Caenidae | Caenis | 20 | 6.7 |
| Lower Welland R. Grassy B. | 3 | Tubificidae | - | 1 | 0.3 |
| Lower Welland R. Grassy B. | 3 | Naididae | - | 26 | 8.7 |
| Lower Welland R. Grassy B. | 3 | Asellidae | Caecidotea | 15 | 5.0 |
| Lower Welland R. Grassy B. | 3 | Hydrobiidae | Amnicola | 1 | 0.3 |
| Lower Welland R. Grassy B. | 3 | Lymnaeidae | Pseudosuccinea | 1 | 0.3 |

**Table E2 (continued)**

| Site name | No. samples | Family | Genus | No. specimens | No. specimens per sample |
|---|---|---|---|---|---|
| Lower Welland R. Grassy B. | 3 | | Fossaria | 1 | 0.3 |
| Lower Welland R. Grassy B. | 3 | Physidae | Physella | 29 | 9.7 |
| Lower Welland R. Grassy B. | 3 | Planorbidae | Gyraulus | 10 | 3.3 |
| Lower Welland R. Grassy B. | 3 | Glossiphoniidae | - | 33 | 11.0 |
| 20 Mile Cr. Headwaters | 3 | Gammaridae | Gammarus | 4 | 1.3 |
| 20 Mile Cr. Headwaters | 3 | Talitridae | - | 1 | 0.3 |
| 20 Mile Cr. Headwaters | 3 | Halaellidae | Hyalella | 20 | 6.7 |
| 20 Mile Cr. Headwaters | 3 | | Aeshna | 1 | 0.3 |
| 20 Mile Cr. Headwaters | 3 | Coenagrionidae | Enallagma | 20 | 6.7 |
| 20 Mile Cr. Headwaters | 3 | - | - | 5 | 1.7 |
| 20 Mile Cr. Headwaters | 3 | Hydrophilidae | - | 1 | 0.3 |
| 20 Mile Cr. Headwaters | 3 | Entomobryidae | - | 1 | 0.3 |
| 20 Mile Cr. Headwaters | 3 | Ceratopogonidae | Bezzia | 8 | 2.7 |
| 20 Mile Cr. Headwaters | 3 | | Probezzia | 2 | 0.7 |
| 20 Mile Cr. Headwaters | 3 | Chironomidae | Tanypodinae | 13 | 4.3 |
| 20 Mile Cr. Headwaters | 3 | Baetidae | Procloean | 4 | 1.3 |
| 20 Mile Cr. Headwaters | 3 | Caenidae | Caenis | 3 | 1.0 |
| 20 Mile Cr. Headwaters | 3 | Naididae | - | 6 | 2.0 |
| 20 Mile Cr. Headwaters | 3 | Corixidae | | 2 | 0.7 |
| 20 Mile Cr. Headwaters | 3 | Pleidae | Neoplea | 1 | 0.3 |
| 20 Mile Cr. Headwaters | 3 | Belostomatidae | Belostoma | 5 | 1.7 |
| 20 Mile Cr. Headwaters | 3 | Asellidae | Caecidotea | 78 | 26.0 |
| 20 Mile Cr. Headwaters | 3 | Hydrobiidae | Amnicola | 1 | 0.3 |
| 20 Mile Cr. Headwaters | 3 | | Stagnicola | 1 | 0.3 |
| 20 Mile Cr. Headwaters | 3 | | Fossaria | 13 | 4.3 |
| 20 Mile Cr. Headwaters | 3 | | Lymnaea | 1 | 0.3 |
| 20 Mile Cr. Headwaters | 3 | Physidae | Physella | 6 | 2.0 |
| 20 Mile Cr. Headwaters | 3 | Planorbidae | Gyraulus | 2 | 0.7 |
| 20 Mile Cr. Headwaters | 3 | | Planorbella | 2 | 0.7 |
| 20 Mile Cr. Headwaters | 3 | Bithyniidae | Bithynia | 1 | 0.3 |
| 20 Mile Cr. Headwaters | 3 | Glossiphoniidae | - | 6 | 2.0 |
| 20 Mile Cr. Headwaters | 3 | Planariidae | - | 80 | 26.7 |

**Table E2 (continued)**

| Site name | No. samples | Family | Genus | No. specimens | No. specimens per sample |
|---|---|---|---|---|---|
| Lake Niapenco | 3 | Hydracarina | - | 10 | 3.3 |
| Lake Niapenco | 3 | Crangonyctidae | Crangonyx | 7 | 2.3 |
| Lake Niapenco | 3 | Gammaridae | Gammarus | 3 | 1.0 |
| Lake Niapenco | 3 | Talitridae | - | 2 | 0.7 |
| Lake Niapenco | 3 | Halaellidae | Hyalella | 160 | 53.3 |
| Lake Niapenco | 3 | | Epitheca | 1 | 0.3 |
| Lake Niapenco | 3 | Coenagrionidae | Enallagma | 73 | 24.3 |
| Lake Niapenco | 3 | - | - | 9 | 3.0 |
| Lake Niapenco | 3 | Chironomidae | Tanypodinae | 30 | 10.0 |
| Lake Niapenco | 3 | | Orthocladiinae | 1 | 0.3 |
| Lake Niapenco | 3 | Culicidae | Anopheles | 1 | 0.3 |
| Lake Niapenco | 3 | Baetidae | Procloean | 1 | 0.3 |
| Lake Niapenco | 3 | Caenidae | Caenis | 10 | 3.3 |
| Lake Niapenco | 3 | Naididae | - | 19 | 6.3 |
| Lake Niapenco | 3 | Corixidae | | 0 | 0.0 |
| Lake Niapenco | 3 | Asellidae | Caecidotea | 2 | 0.7 |
| Lake Niapenco | 3 | Physidae | Physella | 1 | 0.3 |
| Lake Niapenco | 3 | Planorbidae | Gyraulus | 8 | 2.7 |
| Lake Niapenco | 3 | Glossiphoniidae | - | 18 | 6.0 |
| Lake Niapenco | 3 | Planariidae | - | 28 | 9.3 |
| York Haldimand Site | 1 | Hydracarina | - | 4 | 4 |
| York Haldimand Site | 1 | Gammaridae | Gammarus | 3 | 3 |
| York Haldimand Site | 1 | Halaellidae | Hyalella | 5 | 5 |
| York Haldimand Site | 1 | Libellulidae | Sympetrum | 12 | 12 |
| York Haldimand Site | 1 | Coenagrionidae | Enallagma | 27 | 27 |
| York Haldimand Site | 1 | Cladocera | - | 1 | 1 |
| York Haldimand Site | 1 | Dytiscidae | - | 1 | 1 |
| York Haldimand Site | 1 | Ceratopogonidae | Bezzia | 5 | 5 |
| York Haldimand Site | 1 | Chironomidae | Tanypodinae | 32 | 32 |
| York Haldimand Site | 1 | Baetidae | Procloean | 1 | 1 |
| York Haldimand Site | 1 | Caenidae | Caenis | 16 | 16 |
| York Haldimand Site | 1 | Naididae | - | 2 | 2 |

**Table E2 (continued)**

| Site name | No. samples | Family | Genus | No. specimens | No. specimens per sample |
|---|---|---|---|---|---|
| York Haldimand Site | 1 | Pleidae | Neoplea | 13 | 13 |
| York Haldimand Site | 1 | Belostomatidae | Belostoma | 1 | 1 |
| Lyons Creek Schisler | 1 | Hydracarina | - | 1 | 1 |
| Lyons Creek Schisler | 1 | Crangonyctidae | Crangonyx | 1 | 1 |
| Lyons Creek Schisler | 1 | Gammaridae | Gammarus | 10 | 10 |
| Lyons Creek Schisler | 1 | Halaellidae | Hyalella | 16 | 16 |
| Lyons Creek Schisler | 1 | Libellulidae | Sympetrum | 2 | 2 |
| Lyons Creek Schisler | 1 | | Epitheca | 1 | 1 |
| Lyons Creek Schisler | 1 | Coenagrionidae | Enallagma | 24 | 24 |
| Lyons Creek Schisler | 1 | - | - | 5 | 5 |
| Lyons Creek Schisler | 1 | Elmidae | - | 2 | 2 |
| Lyons Creek Schisler | 1 | Gyrinidae | - | 2 | 2 |
| Lyons Creek Schisler | 1 | Curculionidae | - | 1 | 1 |
| Lyons Creek Schisler | 1 | Chironomidae | Tanypodinae | 9 | 9 |
| Lyons Creek Schisler | 1 | Baetidae | Procloean | 1 | 1 |
| Lyons Creek Schisler | 1 | Caenidae | Caenis | 9 | 9 |
| Lyons Creek Schisler | 1 | Naididae | - | 4 | 4 |
| Lyons Creek Schisler | 1 | Asellidae | Caecidotea | 3 | 3 |
| 20 Mile Cr. Mouth | 3 | Hydracarina | - | 68 | 22.7 |
| 20 Mile Cr. Mouth | 3 | Gammaridae | Gammarus | 76 | 25.3 |
| 20 Mile Cr. Mouth | 3 | | Echinogammarus | 8 | 2.7 |
| 20 Mile Cr. Mouth | 3 | Halaellidae | Hyalella | 64 | 21.3 |
| 20 Mile Cr. Mouth | 3 | Aeshnidae | Anax | 2 | 0.7 |
| 20 Mile Cr. Mouth | 3 | Gomphidae | Arigomphus | 1 | 0.3 |
| 20 Mile Cr. Mouth | 3 | | Ischnura | 30 | 10.0 |
| 20 Mile Cr. Mouth | 3 | | - | 17 | 5.7 |
| 20 Mile Cr. Mouth | 3 | - | - | 3 | 1.0 |
| 20 Mile Cr. Mouth | 3 | | Tropisternus | 2 | 0.7 |
| 20 Mile Cr. Mouth | 3 | | Dineutus | 1 | 0.3 |
| 20 Mile Cr. Mouth | 3 | Helophoridae | Helophorus | 1 | 0.3 |
| 20 Mile Cr. Mouth | 3 | Ceratopogonidae | Bezzia | 1 | 0.3 |
| 20 Mile Cr. Mouth | 3 | | - | 111 | 37.0 |

**Table E2 (continued)**

| Site name | No. samples | Family | Genus | No. specimens | No. specimens per sample |
|---|---|---|---|---|---|
| 20 Mile Cr. Mouth | 3 | Caenidae | Caenis | 3 | 1.0 |
| 20 Mile Cr. Mouth | 3 | Pleidae | Neoplea | 1 | 0.3 |
| 20 Mile Cr. Mouth | 3 | Belostomatidae | Belostoma | 1 | 0.3 |
| 20 Mile Cr. Mouth | 3 | Mesoveliidae | Mesovelia | 1 | 0.3 |
| 20 Mile Cr. Mouth | 3 | Gerridae | Gerris | 7 | 2.3 |
| 20 Mile Cr. Mouth | 3 | | - | 2 | 0.7 |
| 20 Mile Cr. Mouth | 3 | Asellidae | Caecidotea | 2 | 0.7 |
| 20 Mile Cr. Mouth | 3 | | Stagnicola | 7 | 2.3 |
| 20 Mile Cr. Mouth | 3 | | Physa | 45 | 15.0 |
| 20 Mile Cr. Mouth | 3 | | Promoretus | 3 | 1.0 |
| 20 Mile Cr. Mouth | 3 | Bithyniidae | Bithynia | 1 | 0.3 |
| 20 Mile Cr. Mouth | 3 | Hydridae | Hydra | 1 | 0.3 |
| 20 Mile Cr. Mouth | 3 | Erpobdellidae | Erpobdella | 1 | 0.3 |
| 20 Mile Cr. Mouth | 3 | Valvatidae | Valvata | 1 | 0.3 |