St. Marys River Area of Concern: Coastal Wetland Habitat Assessment Report

August 2015

Environment Canada
Environnement Canada
Canadian Wildlife Service
Service canadien de la faune

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Executive Summary

The St. Marys River is a 112 km connecting channel between Lake Superior and Lake Huron. In 1985, the International Joint Commission (IJC) identified the St. Marys River as one of the 43 Areas of Concern (AOC) on the Great Lakes. The condition of wildlife populations, a subcomponent under Beneficial Use Impairment (BUI) #3 (*Degradation of Fish and Wildlife Populations*), is currently listed as "requires further assessment" while BUI #14 (*Loss of Fish and Wildlife Habitat*) is currently listed as "impaired". Given that coastal wetlands provide a number of functions as well as wildlife habitat, it is important to gain a better understanding of their current state within the AOC and surrounding area. Building upon work started in 2012 (see Environment Canada, 2013), a subset of coastal wetlands in the St. Marys River, both within and outside the AOC, were visited and surveyed for water quality, submerged aquatic vegetation, aquatic macroinvertebrates, amphibians, and marsh breeding birds in 2014 to assess the condition of coastal wetland habitat and biotic communities.

Using the Water Quality Index (WQI), water quality within St. Marys River coastal wetlands ranged from very degraded to very good, with the majority of sites ranked in good condition. Water quality in AOC versus non-AOC wetlands was similar. The degradation of water quality appears to be primarily a result of increased turbidity. An Index of Biotic Integrity (IBI), which is a multimetric index indicating the ability of a habitat to support and maintain a balanced, integrated, adaptive biological system having the full range of elements expected in a region's natural habitat, is being developed for each of submerged aquatic vegetation (SAV), macroinvertebrates, marsh birds and amphibians. The potential SAV IBIs developed for the St. Marys River showed variation among sites, although a difference in AOC versus non-AOC sites was observed. Sites in the AOC ranged from poor to excellent, having both the highest and lowest scores recorded in 2014, while non-AOC sites ranged from fair to excellent. The potential aquatic macroinvertebrate IBI showed variation in AOC versus non-AOC sites, with sites in the non-AOC ranking in the good category while AOC sites ranged from poor to excellent. Marsh breeding bird communities had area-sensitive marsh-nesting obligate species at only two sites: Echo Bay and Lake George. The potential IBIs developed for the marsh bird community rank these two AOC sites in the best condition while non-AOC sites are ranked as poor or fair. The amphibian community in the St. Marys River did not respond well to the disturbance gradients assessed for development of an IBI, and therefore more monitoring is required before a suitable IBI can be established. The IBIs used in this report require validation before they can be used to report on the status of BUI # 14. Nonetheless, progress is being made to aid in providing empirical information to support the assessment of the Loss of First and Wildlife Habitat BUI for the St. Marys River AOC.

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Acknowledgements

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Cover Photo: Environment Canada – Canadian Wildlife Service

1. Introduction

The St. Marys River is a 112 km connecting channel between Lake Superior and Lake Huron. In 1985, the International Joint Commission (IJC) identified the St. Marys River as one of the 43 Areas of Concern (AOC) on the Great Lakes. On the Canadian side, the AOC extends from the head of the river at Whitefish Bay to Quebec Bay and includes the waters around St. Joseph Island (Figure 1). The area was listed because of historical problems associated with phosphorus, bacteria, oil and grease, heavy metals, trace organics, contaminated sediment, fish consumption advisories and impacted biota (St. Marys River Binational Public Advisory Committee 2002).

A standardized set of impairments called Beneficial Use Impairments (BUIs) were created by the IJC as a measure to assess the health of the Great Lakes. BUIs cover a wide range of environmental and ecological concerns. The Remedial Action Plan (RAP) process seeks to restore these beneficial uses through various remedial and monitoring actions recommended in the Stage 2 RAP report. In the St. Marys River AOC, nine of the fourteen beneficial uses defined in the Great Lakes Water Quality Agreement (GLWQA) are listed as impaired including degradation of fish and wildlife populations and loss of fish and wildlife habitat.

The condition of wildlife populations, a subcomponent under BUI #3 (*Degradation of Fish and Wildlife Populations*), is currently listed as “requires further assessment” while BUI #14 (*Loss of Fish and Wildlife Habitat*) is currently listed as “impaired”. Given that coastal wetlands provide a number of ecological functions as well as wildlife habitat, it is important to gain a better understanding of their current state within the AOC and surrounding area. Standardized methodologies for surveying in coastal wetlands have been developed (Environment Canada and Central Lake Ontario Conservation Authority (herein, EC and CLOCA) 2007). Using these methodologies, a subset of coastal wetlands in the St. Marys River, both within and outside the AOC, were surveyed from 2012 to 2014 to collect information on water quality, submerged aquatic vegetation, aquatic macroinvertebrates (2013-2014 only), marsh breeding birds, and amphibians (2013-2014 only). The results of these surveys can be used to provide components of information necessary for BUI assessments.

Cvetkovic and Midwood (2014, 2015a) developed disturbance gradients for the St. Marys River based on landscape variables and water quality parameters (see Appendix 1 for additional details). The relationship between these disturbance gradients and biotic data was used to identify metrics and develop potential Indices of Biotic Integrity (IBIs) specific to the St. Marys River to assess condition of marsh birds, aquatic macroinvertebrates, and submerged aquatic vegetation communities in the St. Marys River AOC. An independent dataset from an additional year of surveys will be required to validate the IBI options presented in this report. The validation will confirm if the IBIs are sensitive to change and can therefore be used to report on elements of BUI #3: *Degradation of Fish and Wildlife Populations* and BUI #14: *Loss of Fish and Wildlife Habitat*.

2. Purpose of Report

The purpose of this document is to briefly describe the sampling methodologies and report on the condition of coastal wetlands to compare the quality of coastal wetlands between survey years as well as between AOC and non-AOC coastal wetlands in the St. Marys River.

3. Surveyed Wetlands

Since all coastal wetlands within the St. Marys River cannot be surveyed, a subset of sites that collectively provide a geographic spread throughout the river and represent the geomorphic types and sizes of coastal wetlands present in the area was selected. More details on site selection and description of sites are provided in EC 2013. Six AOC and five non-AOC wetlands were surveyed in 2014 for water quality and biotic communities (Figure 1):

- AOC sites:
  - Carpin Beach
  - Echo Bay
  - Lake George
  - Maskinonge Bay
  - Pumpkin Point
  - West Shore, St. Joseph Island
- Non-AOC sites:
  - Anderson Creek (added in 2013)
  - Desbarats Wetland
  - Stobie Creek
  - Hay Bay Wetland
  - Joe Dollar Bay Wetland

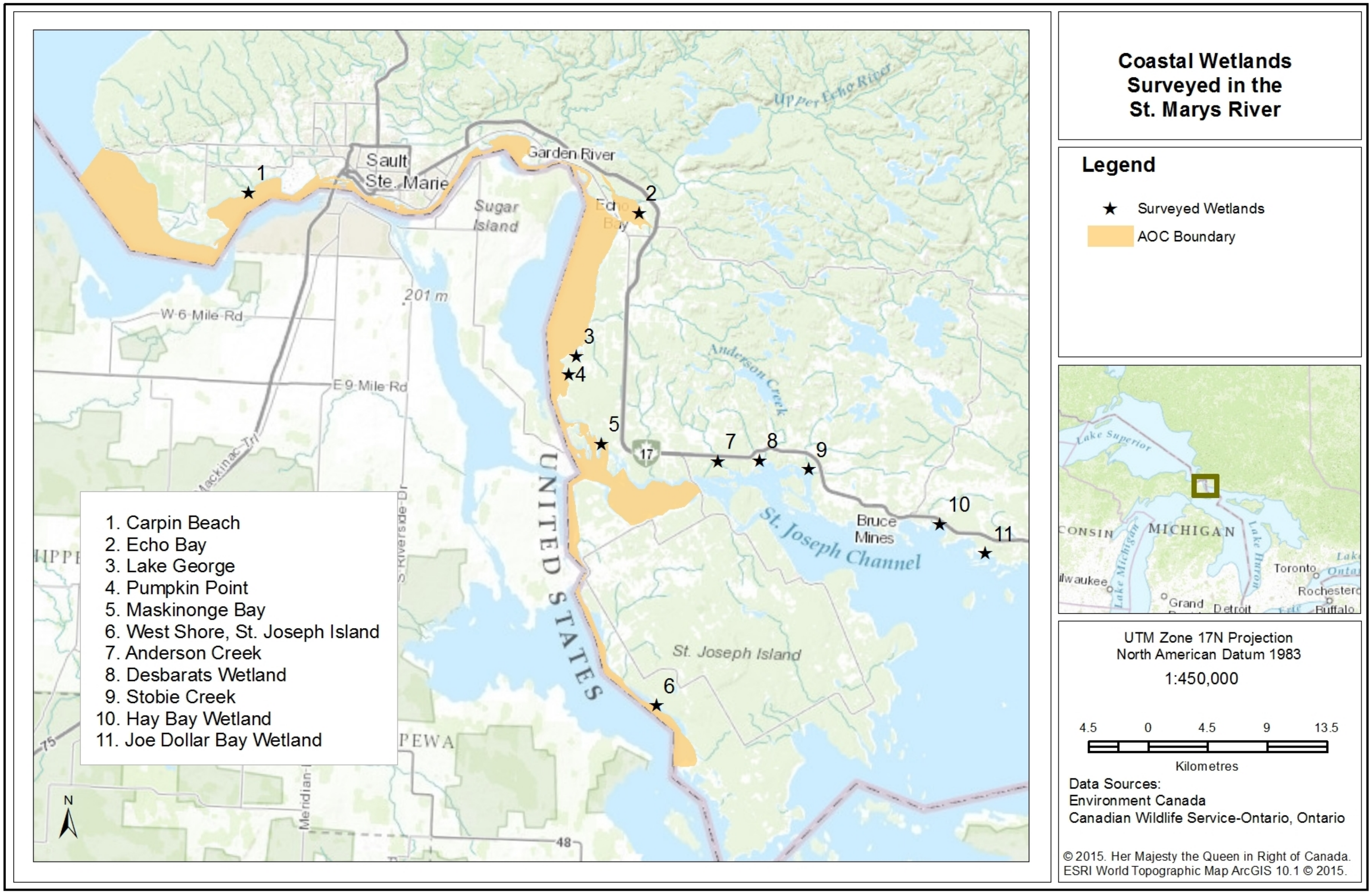

Figure 1: Location of coastal wetlands sampled in the St. Marys River in 2014.

4. Water Quality

Methodology

Water quality was measured using both *in situ* probes and chemical analyses. *In situ* water quality determination included four parameters (pH, conductivity [µS/cm], temperature [°C], and turbidity [NTU]) and was collected using a Hydrolab MS5™ multiprobe at mid depth of the water column adjacent to emergent vegetation.

Multiprobe sampling was conducted at all water quality stations. The four parameters measured are used to calculate the Water Quality Index (WQI; Equation 1), a tool for determining coastal wetland water quality in the Great Lakes (Chow-Fraser 2006).

Equation 1:

$$WQI = (-1.37 * \log TURB) - (1.58 * \log COND) - (1.63 * \log TEMP) - (2.37 * \log pH) + 9.27$$

where TURB = turbidity, COND = conductivity, and TEMP = temperature

Water samples for additional nutrient parameters (Table 1; Table 2) were collected in 2012 at four of the six stations at each wetland and include: Total Nitrate Nitrogen (TNN), Total Ammonia Nitrogen (TAN), and Total Phosphorus (TP). TNN and TAN were analyzed in a field lab within five hours of sampling using colorimetry (Hach DR890 Colorimeter); samples for TP were stabilized through acidification and later analyzed by Environment Canada's National Laboratory for Environmental Testing (NLET; Burlington, Ontario). From 2013 and onward, nitrate and ammonia values were analyzed at the site level using a composite water sample collected from each station at each wetland. Individual samples of TP in 2013-2014 were collected and analyzed using the same methodology as in 2012.

Table 1: Water quality parameters measured in coastal wetlands including parameter relationships with increased disturbance.

Parameter	Units	Relationship with Increased Disturbance
In Situ		
Turbidity	NTU	↑ turbidity from algae, suspended sediments, and bioturbation
Conductivity	µS/cm	↑ conductivity from agricultural, industrial, urban inputs (e.g., fertilizer salts and road salt)
Temperature	°C	↑ temperature from industrial/urban runoff and riparian vegetation removal
pH	pH	↑ in pH from photosynthesis affects nutrient availability
Nutrient		
Total Nitrate Nitrogen	mg/L	↑ nitrates from agricultural/urban runoff and wastewater and industrial discharge
Total Ammonia Nitrogen	mg/L	↑ ammonia from agricultural and industrial wastes; and sewage and septic leachate
Total Phosphorus	mg/L	↑ phosphorus from agricultural runoff, urban stormwater, and industrial discharge

Table 2: Descriptions of water quality parameters used to score and rank water quality.

Disturbance Variable	Description
Total Phosphorus	The concentration (mgL^{-1}) of all forms of phosphorus dissolved in the sample. This is an important indicator of enrichment in surface waters.
Ammonia	The concentration (mgL^{-1}) of ammonia nitrogen in the sample. Ammonia can be toxic to aquatic organisms and is released into waterways by many industries, primarily municipal wastewater treatment plants.
Nitrate	The concentration of nitrate nitrogen (mgL^{-1}) in the sample. The primary sources of nitrates in the environment are sewage, fertilizer, and manure.
Turbidity	A measure of the degree to which light traveling through a water column is scattered by the suspended organic (including algae) and inorganic particles measured in Nephelometric Turbidity Units (NTU).
Conductivity	A measure of the dissolved ions in water measured in microSiemens per centimetre (μScm^{-1}) or milliSiemens per centimetre ($mScm^{-1}$). Conductivity is a good indicator of urban run-off, especially from road salt.

Ranking Water Quality

The WQI was developed as a relative ranking tool to report on coastal wetland water quality in the Great Lakes Basin. WQI scores fit into six categories which correspond with values ranging from -3 to +3 (Table 3).

Table 3: Water Quality Index (WQI) score and associated category based on Chow-Fraser (2006).

WQI Score	Qualitative Descriptor
+3 to +2	Excellent
+2 to +1	Very good
+1 to 0	Good
0 to -1	Moderately degraded
-1 to -2	Very degraded
-2 to -3	Highly degraded

Results

In 2014, coastal wetland WQI qualitative descriptors (Table 3) varied from very degraded to very good with the majority of sites ranked in good condition (Table 5). Non-AOC wetlands varied from good to very good, while AOC wetlands demonstrated a broader range in condition from very degraded to very good. Impaired water quality from the WQI is typically the result of elevated turbidity. Wetlands considered moderately degraded or very degraded had turbidity values greater than 10 NTUs (Table 4).

Total phosphorus (TP) values in 2014 were below the Provincial Water Quality Objective (PWQO) limit of 0.03 mg/L (Table 6) for all wetlands except Maskinonge Bay, which had a total phosphorus level of 0.22 mg/L, and West Shore, St. Joseph Island's value of 0.04 mg/L, which is slightly over the limit. The extremely high level of TP at Maskinonge Bay is due to a single replicate at one water quality station, which has consistently been the source of high levels of phosphorus during all sampling years at this wetland. When the TP sample at this station is removed, the average of the TP samples in 2014 is 0.03 mg/L. Overall, total ammonia nitrogen values in 2014 were 0.08 mg/L or less, and total nitrate nitrogen values varied from 0.03 mg/L to 0.25 mg/L. As noted in the Methods section, these parameters were collected from a composite water sample in 2013-2014 compared to individual samples in 2012, which may account for the slight differences observed among years although several wetlands in 2014 had substantially higher values than in 2013.

Table 4: Mean water quality parameters for selected coastal wetlands in the St. Marys River Area of Concern (AOC) and non-AOC sites in the St. Marys River. Wetlands are ordered from west to east.

Wetland Name	Turbidity (NTU)			Conductivity (µS/cm)			Water Temp (°C)			pH		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
AOC sites												
Carpin Beach	6.3	7.2	5.7	130.5	125.5	110.0	23.4	18.6	18.0	7.33	7.16	7.32
Echo Bay	4.5	8.9	7.2	115.2	84.8	84.2	25.7	22.0	21.0	8.46	8.25	7.29
Lake George	50.6	38.7	14.3	150.0	129.1	111.8	23.5	21.7	19.0	7.82	7.68	7.29
Pumpkin Point	51.3	44.9	16.5	123.1	116.9	94.0	29.1	26.7	18.4	9.13	9.02	8.09
Maskinonge Bay	1.7	1.6	2.9	110.3	105.8	106.8	24.0	24.7	18.4	8.46	8.04	7.64
West Shore, St. Joseph Island	37.9	69.3	137.1	190.0	164.9	136.2	22.9	22.7	17.1	8.46	8.11	7.88
Non-AOC sites												
Anderson Creek	-	12.8	6.6	-	133.8	120.3	-	21.8	17.5	-	7.43	7.67
Desbarats Wetland	3.2	3.6	3.2	129.3	99.3	99.5	25.5	22.9	19.0	8.09	8.04	7.46
Stobie Creek	2.5	2.8	2.8	152.8	113.6	98.8	30.7	25.5	17.5	9.23	9.12	7.36
Hay Bay Wetland	31.9	19.2	12.2	195.1	135.0	129.5	24.3	25.6	16.2	8.19	8.58	7.73
Joe Dollar Bay Wetland	8.8	2.3	2.4	156.1	135.1	133.5	26.4	25.2	19.2	8.35	8.24	7.60

Table 5: Water Quality Index (WQI) score and descriptor for selected coastal wetlands in the St. Marys River Area of Concern (AOC) and non-AOC sites in the St. Marys River.

	WQI				
	2012	***2013***	***2014***	***Mean***	***Descriptor****
AOC sites					
Carpin Beach	0.55	0.69	0.92	**0.72**	Good
Echo Bay	0.63	0.56	0.86	**0.68**	Good
Lake George	-0.85	-0.51	0.33	**-0.34**	Moderately degraded
Pumpkin Point	-1.03	-0.84	0.28	**-0.53**	Moderately degraded
Maskinonge Bay	1.30	1.36	1.28	**1.31**	Very good
West Shore, St. Joseph Island	-0.90	-1.11	-1.15	**-1.05**	Very degraded
Non-AOC sites					
Anderson Creek	-	0.15	0.74	**0.45**	Good
Desbarats Wetland	0.79	0.99	1.26	**1.01**	Very good
Stobie Creek	0.56	0.85	1.42	**0.94**	Good
Hay Bay Wetland	-0.82	-0.36	0.38	**-0.27**	Moderately degraded
Joe Dollar Bay Wetland	0.01	0.97	1.22	**0.73**	Good

* based upon mean WQI value for years sampled

Table 6: Additional water quality collected for selected coastal wetlands in the St. Marys River Area of Concern (AOC) and non-AOC wetlands in the St. Marys River. TP=Total Phosphorus, NH_3-N=Total Ammonia Nitrogen, NO_3-N = Total Nitrate Nitrogen.

Wetland Name	NH_3-N (mg/L)			NO_3-N (mg/L)			TP (mg/L)		
	*2012**	*2013*	*2014*	*2012**	*2013*	*2014*	*2012*	*2013*	*2014*
AOC sites									
Carpin Beach	0.03	0.04	0.04	0.13	0.16	0.18	0.02	0.02	0.02
Echo Bay	0.00	0.02	0.01	0.15	0.02	0.03	0.02	0.03	0.02
Lake George	0.03	0.02	0.01	0.05	0.06	0.10	0.04	0.03	0.02
Pumpkin Point	0.06	0.02	0.01	0.03	0.05	0.25	0.03	0.03	0.02
Maskinonge Bay	0.02	0.01	0.04	0.10	0.01	0.06	0.18	0.17	0.22
West Shore, St. Joseph Island	0.01	0.03	0.01	0.10	0.03	0.18	0.03	0.04	0.04
Non-AOC sites									
Anderson Creek	-	0.03	0.01	-	0.05	0.20	-	0.05	0.02
Desbarats Wetland	0.00	0.02	0.01	0.16	0.05	0.08	0.04	0.03	0.02
Stobie Creek	0.00	0.02	0.08	0.15	0.03	0.13	0.04	0.03	0.01
Hay Bay Wetland	0.08	0.02	0.02	0.05	0.12	0.24	0.02	0.03	0.02
Joe Dollar Bay Wetland	0.00	0.02	0.03	0.18	0.04	0.09	0.02	0.02	0.01

*2012 levels of NH_3-N and NO_3-N were the mean of replicate samples collected at each wetland.

Discussion

Based on the collected water quality data over the past three years, coastal wetlands in the St. Marys River, both in AOC and non-AOC sites, have good or degraded water quality. There is no apparent difference in AOC sites versus non-AOC sites: mean values ranged from very degraded to very good in the AOC and from moderately degraded to very good in non-AOC sites. Wetlands in the St. Marys River show a general improvement in WQI scores from 2012 to 2014. Exceptions include West Shore, St. Joseph Island, which experienced degradation in WQI over three years, and Maskinonge Bay, which experienced relatively stable scores.

Sites with degraded water quality are typically sites with higher turbidity which may be a result of natural processes (e.g., resuspension of fine sediments) or anthropogenic causes (e.g., inputs from the watershed) (Table 4). While turbidity values decreased for Pumpkin Point and Lake George in 2014, they remained high when compared to other wetlands. West Shore, St. Joseph Island experienced an increase in its turbidity value, although high turbidity values are consistent with previous surveys at this site. Higher turbidity values at Lake George, Pumpkin Point, and West Shore, St. Joseph Island may be a result of wave action from large vessels resuspending fine mineral (clay, silt) substrates into the water column. The high turbidity at Hay Bay Wetland may be a result of impacts from the aggregate quarry located to the north of the wetland. The passage of large vessels in the river increases wave action and the resulting turbidity may negatively affect emergent wetlands (Kauss 1991). Other wetlands along the shipping channel such as Echo Bay, Carpin Beach and Maskinonge Bay have, to some degree, a level of protection from wave action from the passage of large vessels. For example, Echo Bay is protected from wave action as it has an opening of approximately 30 metres at the base of the wetland into the river.

Mean water temperature (Table 4) decreased at all sites in 2014 from 2012 and 2013 temperatures, with the greatest drop at Stobie Creek from 2012's value of 30.7°C to 2014's value of 16.2°C. Water temperature was up to 9.5°C colder in 2014 and 2013. This drop in water temperature, combined with a drop in pH, likely contributed to the improved WQI scores seen in 2014. Water depth per station was on average 26 cm deeper in 2014 than 2013, which may have influenced the colder water temperatures. It should be noted that water depth is not measured at precisely the same points from year to year, but in most cases within the general vicinity of the same water station. Nonetheless, the increase in water depth was apparent at most sites; the combined effect with lower water temperatures may have slowed SAV community growth, as discussed in Section 5.

Conductivity levels recorded in St. Marys River (average: 111 µS/cm) in 2014 are below levels observed through surveyed by Environment Canada – Canadian Wildlife Service in other Great Lakes coastal wetlands (e.g., Environment Canada 2015). For example, surveys conducted as part of the Coastal Habitat Assessment and Monitoring Program in the Huron-Erie corridor, which includes the Detroit River and St. Clair River AOCs, showed an average conductivity value of 315 µS/cm in 2014. This suggests that inputs from agricultural, industrial and urban inputs are less than in other areas. The average conductivity reading for St. Marys River AOC sites was 107 µS/cm and 116 µS/cm for non-AOC sites.

With the exception of Maskinonge Bay, total phosphorus levels were 0.04 mg/L or less. As noted earlier, the high TP value observed for Maskinonge Bay is a result of water from one of the stations which has consistently shown high TP (0.53 to 0.80 mg/L) whereas other stations in the wetland range from 0.015 to 0.07 mg/L. Ministry of Environment and Energy (1999) presents an interim provincial water quality objective indicating that to avoid nuisance concentrations of algae in lakes, average total phosphorous concentrations should not exceed 0.02 mg/L. In 2014, nine of the eleven sites meet this objective, improving from only two of eleven sites meeting this objective in 2013.

5. Submerged Aquatic Vegetation Community

Methodology

The submerged aquatic vegetation (SAV) community was surveyed by sampling a one-metre square quadrat at 20 random locations in the open water basin of each wetland. Quadrat locations were randomly generated in a Geographic Information System (GIS) using ArcGIS 10.1 (ESRI 2012) prior to sampling. Within each quadrat, total areal coverage and species-specific coverages for submerged and floating-leaved species were recorded.

Submerged aquatic vegetation species were grouped into two plant guilds based on growing tolerance (i.e., turbidity tolerant and turbidity intolerant) and native designation (EC and CLOCA 2004; Grabas et al. 2012). Species were also assigned a coefficient of conservatism (Oldham et al. 1995); values range from 0 to 10 where higher scores are given to vegetation species having lower disturbance tolerance and greater fidelity to a certain habitat. Three disturbance gradients – a) the Water Quality Index (as described in Section 3) and PCA_{WQ} (Principal Component Analysis, Water Quality), which have the same metrics and are collectively referred to herein as WQ_{2015}-IBI; b) the $PCA_{Gradients}$; and c) the SAV WQ-IBI developed in 2014 (herein WQ_{2014}-IBI) which was recommended as a potential IBI due to changes in water quality observed during the field season of 2014 – were the three gradients found to have significant correlations with plant data. Thirteen metrics were tested to identify those that respond to the disturbance gradients developed by Cvetkovic and Midwood (2015a) and used to develop potential IBIs. The standardized metrics for all surveyed years and all three potential IBIs for the SAV community are displayed in Tables 8, 9, and 10.

Four metrics were shown to significantly respond to disturbance: SINT (number of turbidity-intolerant species), SNAT (number of native species), CC (Coefficient of conservatism), and PCOV (total coverage). Of these metrics, WQ_{2015}-IBI used four (SINT, CC, SNAT, PCOV), the $PCA_{Gradient}$ IBI used three (CC, SNAT, PCOV), and the WQ_{2014}-IBI used three (CC, SNAT, PCOV). Metrics were standardized into a range from 0 to 10 (EC and CLOCA 2004; Grabas et al. 2012). They were then added, multiplied by 10 and divided by the total number of metrics to create an IBI with scores between 0 and 100 which higher IBI scores representing better SAV community condition. EC and CLOCA (2004) identified five classes where identified in which minimum detectable differences could be distinguished and associated qualitative descriptor (Table 7).

Table 7: Index of biotic integrity (IBI) score and associated category based on EC and CLOCA (2004).

IBI Score	Qualitative Descriptor
81-100	Excellent
61-80	Very good
41-60	Good
21-40	Fair
0-20	Poor

Results

All surveyed wetlands in 2014 have one or more turbidity intolerant species present, as well as one or more native species present (see Appendix 2 for full list of plant species observed; Tables 8 and 9). Pumpkin Point and West Shore, St. Joseph Island scored zero in both the percent cover and coefficient of conservatism standardized metrics, although all other surveyed wetlands scored non-zero numbers. Total cumulative coverage ranged from 0.7% (West Shore, St. Joseph Island) to 85.9% (Maskinonge Bay).

In 2014, by percent cover and number of quadrats, Fern Pondweed (*Potamogeton robbinsii*), White Water Lily (*Nymphaea odorata*), Canada Waterweed (*Elodea canadensis*), Vasey's pondweed (*Potamogeton vaseyi*), and Richardson's Pondweed (*Potamogeton richardsonii*) were the five most common SAV species observed. Richardson's Pondweed was the most ubiquitous species, found at nine of the eleven wetlands surveyed. Fern Pondweed is turbidity intolerant, while Canada Waterweed is turbidity tolerant. All of the most common species are also native species.

When compared to data collected in previous years, all SAV IBIs showed a sharp drop in scores for the majority of sites in 2014 from previous years. The most drastic change was seen in Lake George, which dropped approximately 40 points from the 2013 value. Sites that had higher IBI scores in previous years (e.g., 80 or above) appeared to remain somewhat stable (e.g., Maskinonge Bay, Desbarat Wetlands, Stobie Creek). West Shore, St. Joseph Island and Pumpkin Point had the lowest IBI scores, with West Shore, St. Joseph Island consistently scoring the lowest in all three years surveyed.

Discussion

The metrics selected for inclusion in the SAV IBIs in the St. Marys River are the same as those metrics used to derive a SAV IBI for Lake Ontario (Grabas et al. 2012). The three potential IBIs appear to show differences between AOC and non-AOC sites in 2014. AOC sites ranged from poor to excellent (range in IBI scores from 2 to 97), with five of six sites ranked as fair or lower. West Shore, St. Joseph Island, Pumpkin Point, and Carpin Beach ranked in the poor category. Maskinonge Bay, however, ranked in the excellent category. In contrast, the non-AOC sites ranked from fair to excellent (range in IBI scores from 20 to 100), with no sites ranked as poor, although three of five sites ranked as fair.

Increased water depth and lower water temperatures in 2014 likely affected the wetland plant community. Increased depth at some quadrats may have limited the visibility to determine percent coverage, including species such as Stonewort (*Chara* sp.) or Slender Naiad (*Naja flexilis*) which may cover the bottom of the substrate. Both species were among the most common species found in 2013, but were not among the most common in 2014. Additionally, the wetland plant community may have experienced limited growth rates and abundance due to increased water depth. Zhu et al. (2012) studied the growth response of five SAV species to differing water depths, and found that increased water depth inhibited relative growth rate and biomass in all species, with Coontail (*Ceratophyllum demersum*) demonstrating the highest adaptive response to flooding. Furthermore, a decline in SAV at deep waters was suggested to be a result of root anchorage inhibition and subsequent facilitated uprooting in deep water conditions (Zhu et al. 2012).

Temperature has been shown to influence aquatic plant biomass, with 45-1160% more biomass produced in a warm year than a cool one (a difference of 1-6°C) in boreal lakes (Rooney and Kalff 2000). Bartleson et al. (2014) found Tape Grass (*Vallisneria americana*) had faster growing rates at high light and temperatures greater than 20°C, and slowest growth rates at 13°C, which may suggest a change in species dynamics due to cooler temperatures. Tape Grass was recorded in 2013 surveys as one of the most common species, but was not one of the most common species in 2014 surveys, although it remained abundant.

The numerous and different factors influencing wetland plant community appear to be nuanced; it is therefore difficult to observe a pattern in solely three years of data, but fluctuations are apparent in the St. Marys River, likely as a result of variability in water levels.

Sites are affected both inside and outside the AOC, which emphasizes the importance of delisting criteria that similarly accounts for natural variation.

Table 8: Submerged aquatic vegetation community standardized metrics (out of 10) for selected coastal wetlands in the St. Marys River Area of Concern (AOC) and non-AOC sites in the St. Marys River for potential IBIs using the WQ_{2015} and PCA_{Grad} disturbance gradients.

	SINT*			SNAT			CC			PCOV		
Wetland Name	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**
AOC sites												
Carpin Beach	0.25	1.00	0.25	2.50	3.38	1.63	5.08	6.69	0.38	2.26	2.92	0.25
Echo Bay	8.50	4.25	1.75	7.63	4.75	2.88	8.03	7.94	6.31	10.0	6.77	1.67
Lake George	3.75	5.50	1.00	4.38	4.25	2.00	4.99	7.46	1.17	5.58	4.03	1.25
Pumpkin Point	5.00	3.25	0.50	4.00	3.13	0.88	7.60	3.79	0.00	3.59	2.43	0.00
Maskinonge Bay	8.25	7.00	6.00	9.38	7.63	8.25	9.10	9.67	10.0	9.99	10.0	9.82
West Shore, St. Joseph Island	2.50	1.75	0.50	1.75	1.63	0.63	1.46	2.17	0.00	0.82	0.00	0.00
Non-AOC sites												
Anderson Creek	-	3.00	0.25	-	7.63	5.25	-	8.77	8.31	-	5.37	1.43
Desbarats Wetland	8.00	7.75	6.25	9.00	8.50	8.25	9.04	10.0	9.27	10.0	10.0	6.98
Stobie Creek	7.25	10.0	6.75	6.75	10.00	9.63	8.55	9.46	8.84	8.57	10.0	7.93
Hay Bay Wetland	2.25	3.00	2.50	4.00	3.75	3.25	3.50	5.19	2.31	3.82	1.60	0.53
Joe Dollar Bay Wetland	6.00	7.25	2.75	4.88	7.38	3.25	4.35	7.38	4.96	5.59	7.08	5.02

*SINT is used only in calculations for the WQ_{2015} IBI

SINT	Number of turbidity intolerant species
SNAT	Number of native species
CC	Coefficient of conservatism
PCOV	Total cumulative coverage

Table 9: Submerged aquatic vegetation community standardized metrics (out of 10) for selected coastal wetlands in the St. Marys River Area of Concern (AOC) and non-AOC sites in the St. Marys River for potential IBIs using the WQ_{2014} disturbance gradient.

	SNAT			CC			PCOV		
Wetland Name	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**
AOC sites									
Carpin Beach	3.33	4.50	2.16	5.08	6.69	0.38	1.86	2.46	0.02
Echo Bay	10.0	6.33	3.83	8.03	7.94	6.31	9.22	6.00	1.32
Lake George	5.83	5.66	2.66	4.99	7.46	1.17	4.91	3.49	0.93
Pumpkin Point	5.33	4.16	1.17	7.60	3.79	0.00	3.08	2.02	0.00
Maskinonge Bay	10.0	10.0	10.0	9.10	9.67	10.0	8.95	9.50	8.79
West Shore, St. Joseph Island	2.33	2.16	0.83	1.46	2.17	0.00	0.54	0.00	0.00
Non-AOC sites									
Anderson Creek	-	10.0	6.99	-	8.77	8.31	-	4.71	1.10
Desbarats Wetland	10.0	10.0	10.0	9.04	10.0	9.27	10.0	10.0	6.19
Stobie Creek	8.99	10.0	10.0	8.55	9.46	8.84	7.64	9.94	7.06
Hay Bay Wetland	5.33	5.00	4.33	3.50	5.19	2.31	3.29	1.25	0.28
Joe Dollar Bay Wetland	6.49	9.82	4.33	4.35	7.38	4.96	4.91	6.28	4.39

SNAT Number of native species
CC Coefficient of conservatism
PCOV Total cumulative coverage

Table 10: Water Quality and Water Quality Index and PCA-gradient IBI scores (out of 100) and means for the condition of the submerged aquatic vegetation (SAV) community for selected coastal wetlands in the St. Marys River Area of Concern (AOC) and non-AOC sites in the St. Marys River.

Wetland Name	WQ_{2015} IBI				PCA-IBI				WQ_{2014} IBI			
	2012	*2013*	*2014*	***Mean***	*2012*	*2013*	*2014*	***Mean***	*2012*	*2013*	*2014*	***Mean***
AOC sites												
Carpin Beach	25.2	35.0	6.3	**22.2**	32.8	43.3	7.5	**27.9**	34.3	45.5	8.5	**29.4**
Echo Bay	85.4	59.3	31.5	**58.7**	85.5	64.9	36.2	**62.2**	90.8	67.6	38.2	**65.5**
Lake George	46.8	53.1	13.5	**37.8**	49.8	52.5	14.7	**39.0**	52.4	55.4	15.9	**41.2**
Pumpkin Point	50.5	31.5	3.4	**28.5**	50.7	31.2	2.9	**28.3**	53.4	33.2	3.9	**30.2**
Maskinonge Bay	91.8	85.7	85.2	**87.6**	94.9	91.0	93.6	**93.2**	93.5	97.3	96.0	**95.6**
West Shore, St. Joseph Island	16.3	13.9	2.8	**11.0**	13.4	12.6	2.1	**9.4**	14.4	14.4	2.8	**10.6**
Non-AOC sites												
Anderson Creek	-	61.9	38.1	**50.0**	-	72.6	50.0	**61.3**	-	78.3	54.7	**66.5**
Desbarats Wetland	90.1	90.6	76.9	**85.9**	93.5	95.0	81.7	**90.1**	96.8	100.0	84.9	**93.9**
Stobie Creek	77.8	98.7	82.9	**86.4**	79.6	98.2	88.0	**88.6**	83.9	98.0	86.3	**89.4**
Hay Bay Wetland	33.9	33.8	21.5	**29.8**	37.7	35.1	20.3	**31.1**	40.4	38.1	23.1	**33.9**
Joe Dollar Bay Wetland	52.0	72.7	40.0	**54.9**	49.4	72.8	44.1	**55.4**	52.5	78.3	45.6	**58.8**

6. Aquatic Macroinvertebrates

Methodology

For each wetland, three replicate sub-samples of approximately 150 nektonic and epiphytic aquatic macroinvertebrates (≥ 500 µm) were taken by sweep-netting through the water column in the emergent communities. Macroinvertebrates were identified to the lowest taxonomic group possible. While the target number of aquatic macroinvertebrates in each sample is 150, in some instances (as described below) samples contain far fewer than 150.

Cvetkovic and Midwood (2015a) developed an invertebrate IBI based on the WQI. Three metrics were used to calculate the IBI: Percent of Crustacea and Mollusca (PCRM), Percent of Odonata genera (PODO), and Percent of Crustacea (PCRU). The PCRU metric is nested within the PCRM metric, but included in the development because it was determined that the level of variability within Mollusca warranted its inclusion.

Results

The candidate standardized metrics and potential IBIs show quite a bit of variation between wetlands as well as between years (Tables 11 and 12). Carpin Beach, Maskinonge Bay and Joe Dollar Bay saw substantial decreases in the PISO metric. For some wetlands, PCRU and/or PCRM metrics substantially increased while in other instances, there were substantial decreases. Comparisons of 2013 to 2014 show that many wetlands experience a sharp decline in aquatic macroinvertebrate IBI ranking. The sharpest declines were seen at Pumpkin Point (IBI score of 62.8 in 2013 to 11.8 in 2014) and Joe Dollar Bay Wetland (IBI score of 74.1 in 2013 to 26.4 in 2014). The majority of wetlands experienced a decline from 2013 to 2014, although three wetlands experienced improvements in their IBI scores, with Hay Bay experiencing approximately a 35 point increase from 28.0 in 2013 to 63.0 in 2014. All of the wetlands that increased in IBI scores were located outside of the AOC.

The macroinvertebrate community also exhibited changes in its composition from 2013 to 2014, which may have influenced interannual changes observed in the IBIs. For example, *Hyalella azteca*, an amphipod crustacean and important food source for waterfowl, was abundant in many wetlands. Although, as described below, sampling sizes were not always consistent among wetlands and among years, the proportion of *H. azteca* decreased in some wetlands, particularly in Pumpkin Point, to the extent that the PCRU and PCRM at the site dropped significantly and in turn lowered the IBI. Similar to the SAV community, the majority of the AOC sites ranked as fair or lower, while the majority of non-AOC sites ranked as good or better. This may be due to the association of macroinvertebrates and submerged aquatic vegetation, where SAV provides habitat for the invertebrates; the absence of high-quality SAV at some sites may therefore result in lower macroinvertebrate communities at these sampling points. A full list of aquatic macroinvertebrates can be found in Appendix 3.

Table 11: Aquatic macroinvertebrate standardized metrics (out of 10) for selected coastal wetlands in the St. Marys River Area of Concern (AOC) and non-AOC sites in the St. Marys River.

	PCRM		PISO		PCRU	
Wetland Name	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
AOC sites						
Carpin Beach	8.01	10.0	9.54	4.37	4.39	1.61
Echo Bay	6.54	6.67	2.28	0.00	7.71	6.41
Lake George	3.42	0.16	2.47	0.00	2.64	0.07
Pumpkin Point	8.89	2.37	0.00	0.00	9.94	1.18
Maskinonge Bay	7.38	9.40	10.0	5.06	9.35	9.73
West Shore, St. Joseph Island	2.82	0.00	0.32	0.90	0.81	0.00
Non-AOC sites						
Anderson Creek	10.0	5.20	1.29	0.76	10.0	6.33
Desbarats Wetland	3.34	7.56	3.61	0.88	5.51	7.33
Stobie Creek	6.26	8.28	1.22	1.16	7.78	10.0
Hay Bay Wetland	3.30	8.54	0.22	0.37	4.87	10.0
Joe Dollar Bay Wetland	7.83	4.47	7.70	0.00	6.71	3.46

PCRM	% Crustacea + Mollusca
PISO	% Isopoda genera
PCRU	% Crustacea

Table 12: Index of Biotic Integrity (IBI) score (out of 100) and descriptor for the condition of the aquatic macroinvertebrate community for selected coastal wetlands in the St. Marys River Area of Concern (AOC) and non-AOC sites in the St. Marys River.

Wetland Name	2013	2014	Mean	Descriptor*
AOC sites				
Carpin Beach	73.1	53.3	**63.2**	Very good
Echo Bay	55.1	43.6	**49.4**	Good
Lake George	28.1	0.8	**14.5**	Poor
Pumpkin Point	62.8	11.8	**37.3**	Fair
Maskinonge Bay	89.1	80.6	**84.9**	Excellent
West Shore, St. Joseph Island	13.2	3.0	**8.1**	Poor
Non-AOC sites				
Anderson Creek	71.0	41.0	**56.0**	Good
Desbarats Wetland	41.5	52.6	**47.1**	Good
Stobie Creek	50.9	64.8	**57.9**	Good
Hay Bay Wetland	28.0	63.0	**45.5**	Good
Joe Dollar Bay Wetland	74.1	26.4	**50.3**	Good

** based upon mean IBI value for years sampled*

Discussion

The aquatic macroinvertebrate IBIs showed a potential difference in community condition in AOC sites versus non-AOC sites, similar to the difference observed in the SAV community. Specifically, the AOC wetlands of Lake George and West Shore, St. Joseph Island ranked in the poor category with 2014 IBI scores of 0.8 and 3.0, respectively. Joe Dollar Bay was the lowest scoring wetland in the non-AOC with a score of 26.4, which was well above the lowest scores of wetlands in the AOC. However, Maskinonge Bay, located within the AOC, had the highest invertebrate IBI score of 80.6, just under the excellent category and well above any other wetland surveyed. Non-AOC sites had less variation but higher scores overall.

There exist several caveats with using the invertebrate IBI as described above to assess community condition in the St. Marys River. The metrics of PCRU and PCRM both include the percent of Crustacea found in the aquatic macroinvertebrate community and may be redundant and further discussion is warranted to determine whether it is appropriate to include both metrics in the IBI. Further, it was not always possible to find 150 invertebrates in every sample or in some cases, a sample of 150 was collected but a portion of the sample was species that are not part of the protocol. The macroinvetebrate protocol specifies that microcrustacea (e.g., cladocerans, copepods) are not part of the protocol and should be ignored (Uzarski et al. 2014). As identification is completed at a later date, it is possible for many samples to contain a few (generally less than 10) of these individuals which can reduce the total number of macroinvetebrates in the sample to less than 150. However, in 2014 there were several samples where cladocerans ("water fleas") were abundant (more than 50) in a sample thus greatly reducing the overall sample size. This occurred at Lake George (2 of 3 samples) and Pumpkin Point (3 of 3 samples). At several other wetlands cladocerans were common (10-50). In 2014, the cladocerans in the samples were very large thus thought to be acceptable. It is presently unclear as to why these very large cladocernas were so abundant in 2014. As a result, in several wetlands, both in 2013 and 2014, replicate samples had less than 150 invertebrates, and in some cases less than 100 invertebrates. Although the metrics are based on percentages of certain groups of species in the sample, the reduction of number of individuals per sample may have an effect on these and other metrics that were testing during the development of the potential IBI. The small sample size further complicates efforts to identify metrics that respond to disturbance. Cvetkovic and Midwood (2015b) further investigated options on how to account for the differences in sampling numbers, but did not find a practical solution; as a result, the potential invertebrate IBI should be used with caution and requires additional surveys for validation.

7. Breeding Bird Community

Methodology

Breeding marsh bird communities were surveyed using a modification to the Marsh Monitoring Program (MMP) protocol (Meyer et al. 2006) to report on site-level or specific AOC wetland bird communities. The primary purpose of the MMP is to assess population trends of common marsh bird species across broad geographic scales and/or long timeframes. Bird survey stations were identified using aerial photographs and set up at least 250 metres apart. Only those that had at least 50% of marsh habitat (i.e., non-woody emergent plants) within the sampling radius (100 m) were surveyed. Marsh bird surveys were conducted using a 15-min point count: five minutes of passive surveying followed by five minutes of call broadcasting for secretive species (e.g., Yellow Rail (*Coturnicops noveboracensis*), Least Bittern (*Ixobrychus exilis*), Sora (*Porzana carolina*), Virginia Rail (*Rallus limicola*), Common Moorhen (*Gallinula chloropus)* / American Coot (*Fulica americana*), and Pied-billed Grebe (*Podilymbus podiceps*)) followed by five minutes of passive surveying. The protocol was modified slightly so that only marsh birds were recorded rather than all birds.

Cvetkovic and Midwood (2015a) used two data sets, one that excluded the large number of black terns (*Chlidonias niger*) observed in Echo Bay in 2012 and one that included all species, to develop potential bird IBIs specific to the St. Marys River. Both data sets were found to respond to $PCA_{WQ\text{-}landuse}$ disturbance gradient and used to develop potential IBIs. The dataset that excluded the black terns observed in 2012 was recommended as more suitable for IBI metric development and is what is presented here. Thirty five metrics were tested and four of these metrics were shown to respond to disturbance: AEMNO MaxAb (area-sensitive emergent marsh nesting obligate Maximum Abundance), MNO MaxAb (marsh-nesting obligate maximum abundance), AMNO MaxAb (area-sensitive marsh nesting obligate maximum abundance), and AMNO pMaxAb (area-sensitive marsh nesting obligate proportion of maximum abundance). As these four metrics are all nested within each other (i.e., all contributing metrics are related to marsh nesting obligates [MNO]; Figure 2), two of the metrics (AEMNO MaxAb and MNO MaxAb) were selected for development of a simplified IBI alongside the four-metric IBI.

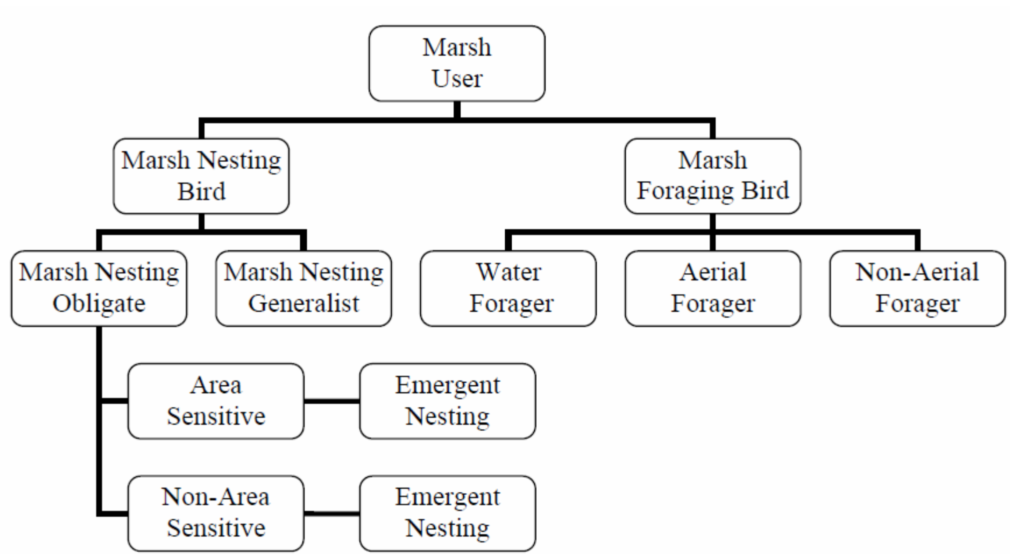

Figure 2: Illustration of marsh user categories for bird species based on marsh use (Grabas et al. 2008)

Results

All 11 wetlands were surveyed for birds in 2014. Echo Bay and Lake George were the only sites that had area-sensitive marsh-nesting obligates present during the surveys (Table 13). Lake George had Black Tern, American Bittern (*Botaurus lentiginosus*), and Least Bittern present while Echo Bay had Black Tern and Least Bittern. This was the first year Least Bittern was reported at any of the wetlands. These two sites scored in the excellent category, while the remaining sites scored in the poor or fair (four-metric) or good to fair (two-metric) categories (Table 14). The presence of area sensitive marsh nesting obligate species is the main driver of the four metric potential IBI as three of the metrics require this category of species. A full list of species recorded during the survey within 100 metres can be found in Appendix 4.

Discussion

Area sensitive marsh nesting obligates such as Black Tern, American Bittern, and Least Bittern are species that are known to prefer larger wetlands and are less likely to be found in smaller wetland sites. For example, MMP data suggests that Black Terns require permanent marshes of at least 50 hectares in size to reproduce successfully (McCracken, no date). Of the wetlands surveyed, the following are over 50 hectares: Echo Bay (587 ha), Lake George (155 ha) Maskinonge Bay (71.5 ha), Desbarats Wetland (89.7 ha), and Hay Bay Wetland (158.5 ha) although only a small portion (12 ha) of the wetland is accessible for surveys. To date, area sensitive marsh nesting obligate species have only been in Echo Bay and Lake George. Smaller wetlands may not be large enough to support populations of area-sensitive marsh nesting obligates, and in some cases, wetlands over the threshold limit still may not be able to support these species for various other reasons (e.g., ratio of vegetation to open water). Water level changes are also likely to impact the available suitable habitat within the wetlands.

The potential four metric IBI contains nested metrics, of which three are based on the presence of area sensitive marsh nesting obligates. Without any of these species present, those wetlands can receive a maximum IBI score of 25. The two-metric IBI reduces redundancy in the nested metrics, but also reduces sensitivity. Superficially, it appears that the two-metric IBI improves the scores of lower-ranked IBIs, while the higher scoring wetlands remain high. Due to the reduced sensitivity in the two-metric IBI, changes may appear amplified. For example, Pumpkin Point has an IBI in the four-metric IBI of 9.4 in 2014 compared to 18.8 in the same year using the two-metric IBI, where the two-metric IBI score is essentially double the four-metric IBI. This pattern can be seen among the lower-ranking wetlands, although the higher-ranking wetlands remain high. The two-metric IBI may, however, be useful in detecting change, as well as simplifying the IBI; indeed, the option of a single-metric IBI was also suggested. Additionally, further discussion is warranted to determine whether the metrics presented here are suitable for reporting on the marsh bird community. It is recommended that additional surveys be completed in order to validate the potential two- and four-metric IBIs to determine their suitability in assessing the condition of marsh birds in the St. Marys River.

Table 13: Marsh breeding bird community standardized metrics (out of 10) for selected coastal wetlands in the St. Marys River Area of Concern (AOC) and non-AOC sites in the St. Marys River. Four-metric IBI uses all of the metrics while two-metric IBI uses AEMNO MaxAb and MNO MaxAb only.

	AMNO MaxAb			AEMNO MaxAb			AMNO pMaxAb			MNO MaxAb		
Wetland Name	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**
AOC sites												
Carpin Beach	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	2.50
Echo Bay	10.0	2.22	7.78	10.0	2.22	10.0	10.0	3.71	8.89	10.0	10.0	10.0
Lake George	0.00	2.50	10.0	0.00	2.50	10.0	0.00	3.93	10.0	8.13	10.0	10.0
Pumpkin Point	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	2.50	5.00
Maskinonge Bay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.25	6.25	8.75
West Shore, St. Joseph Island	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	4.17	5.00
Non-AOC sites												
Anderson Creek	-	-	0.00	-	-	0.00	-	-	0.00	-	-	6.25
Desbarats Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	4.38	6.88
Stobie Creek	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.75	3.75	5.00
Hay Bay Wetland	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	1.25	2.50
Joe Dollar Bay Wetland	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	7.08	5.83

AMNO MaxAb	Area-sensitive marsh nesting obligate maximum abundance
AEMNO MaxAb	Area-sensitive emergent marsh nesting obligate maximum abundance
AMNO pMaxAb	Area-sensitive marsh nesting obligate proportion of maximum abundance
MNO MaxAb	Marsh-nesting obligate maximum abundance

Table 14: Marsh breeding bird community IBIs (out of 100) and standardized metrics (out of 10) for selected coastal wetlands in the St. Marys River Area of Concern (AOC) and non-AOC sites in the St. Marys River.

Wetland Name	Four-metric IBI				Two-metric IBI			
	2012	*2013*	*2014*	***Mean***	*2012*	*2013*	*2014*	***Mean***
AOC sites								
Carpin Beach	-	0.0	6.3	**3.1**	-	0.0	12.5	**6.3**
Echo Bay	100.0	45.4	91.7	**79.0**	100.0	61.1	88.9	**83.3**
Lake George	20.3	47.3	100.0	**55.9**	40.6	62.5	100.0	**67.7**
Pumpkin Point	-	6.3	12.5	**9.4**	-	12.5	25.0	**18.8**
Maskinonge Bay	15.6	15.6	21.9	**17.7**	31.3	31.3	43.8	**35.4**
West Shore, St. Joseph Island	-	10.4	12.5	**11.5**	-	20.8	25.0	**22.9**
Non-AOC sites								
Anderson Creek	-	-	15.6	**15.6**	-	-	31.3	**31.3**
Desbarats Wetland	20.0	10.9	17.2	**16.0**	40.0	21.9	34.4	**32.1**
Stobie Creek	9.4	9.4	12.5	**10.4**	18.8	18.8	25.0	**20.8**
Hay Bay Wetland	-	3.1	6.3	**4.7**	-	6.3	12.5	**9.4**
Joe Dollar Bay Wetland	-	17.7	14.6	**16.2**	-	35.4	29.2	**32.3**

8. Amphibians

Methodology

Surveys for amphibians (frogs and toads) were conducted following the Marsh Monitoring Program (Bird Studies Canada, 2000). Amphibian survey stations are separated by at least 500 metres and visited at night on three separate surveys. Each amphibian station is surveyed for three minutes and one of three Call Level Codes is used to categorize the intensity of calling activity for each species.

Amphibian community condition may be determined using an Index of Biotic Integrity (IBI). However, at present no IBI has been developed for St. Marys River coastal wetlands. Cvetkovic and Midwood (2015a, 2015b) determined that none of the nine metrics test were potential candidates to develop a suitable IBI for this region. Although a potential metric was identified in previous work (Cvetkovic and Midwood, 2014), an additional year of data rendered the potential metric as unsuitable for IBI development. Furthermore, there were no clear relationships between amphibian metrics and disturbance gradients.

Results

Eleven wetlands were surveyed for amphibians in 2014, while ten (excluding Anderson Creek) were surveyed in 2013. As described above, no amphibian IBI was developed due to insufficient response of metrics to disturbance.

Using combined 2013 and 2014 amphibian data, Green Frog (*Rana clamitans melanota*) and Spring Peeper (*Pseudacris crucifer*) were present in every site, followed by Wood Frog (*Lithobates sylvaticus*) (10 sites) and American Toad (*Anaxyrus americanus*) and Northern Leopard Frog (*Lithobates pipiens*) (9 sites; Table 15). Gray Treefrog and Mink Frog (*Lithobates septentrionalis*) were recorded in six sites and Bullfrog (*Lithobates catesbeianus*) was only recorded once, in Desbarats in 2013. Desbarats had the highest mean species richness (2013-14) of all sites, recording all eight species, while Carpin Beach and Pumpkin Point had the fewest, recording only four species. Species richness for AOC wetlands ranged from three to seven species and four to eight for non-AOC wetlands. A full list of species recorded during surveys within 100 metres can be found in Appendix 5.

Discussion

Cvetkovic and Midwood (2015b) suggest that more amphibian surveys need to be completed for multiple years before an IBI can be developed. Recommendations include analyses at the station level (rather than at the wetland level), which may prove useful in identifying metric response to disturbance. The disturbance gradients in the region may not be sufficient to detect strong responses from the amphibian population; additional landscape variables, different landscape scales, water level information, predator/prey, competition, and/or further distinction into other types of guilds may aid in developing an IBI. Additionally, metrics are based on expected (within species range) species at each wetland. Given the relatively small geographic range and limited other amphibian surveys in the area, the list of expected species was the same for all surveyed wetlands.

At this time, it is recommended that additional surveys be completed in the St. Marys River to increase sample size to better define predictors of amphibian community. Increased surveys will aid in better understanding of the natural levels of variability in amphibian community conditions over time to develop an appropriate IBI.

Table 15: Summary of presence/absence of amphibians recorded during 2013 and 2014 surveys for selected coastal wetlands in the St. Marys River Area of Concern (AOC) and non-AOC sites in the St. Marys River.

Wetland	Year	American Toad	Bullfrog	Gray Treefrog	Green Frog	Mink Frog	Northern Leopard Frog	Spring Peeper	Wood Frog	Species Richness
AOC sites										
Carpin Beach	2013	0	0	1	0	0	0	1	1	3
	2014	0	0	0	1	0	0	1	1	3
	2013-2014	0	0	1	1	0	0	1	1	4
Echo Bay	2013	0	0	0	1	1	1	1	1	5
	2014	1	0	0	1	1	1	1	0	5
	2013-2014	1	0	0	1	1	1	1	1	6
Lake George	2013	1	0	0	1	1	1	1	1	6
	2014	1	0	0	1	1	1	1	1	6
	2013-2014	1	0	0	1	1	1	1	1	6
Pumpkin Point	2013	1	0	0	1	0	1	1	0	4
	2014	0	0	0	1	0	1	1	0	3
	2013-2014	1	0	0	1	0	1	1	0	4
Maskinonge Bay	2013	1	0	1	1	0	0	1	1	5
	2014	1	0	1	1	1	1	1	1	7
	2013-2014	1	0	1	1	1	1	1	1	7
West Shore, St. Joseph's Island	2013	1	0	0	1	1	1	1	1	6
	2014	1	0	0	1	1	1	1	1	6
	2013- 2014	1	0	0	1	1	1	1	1	6
Non-AOC sites										
Anderson Creek	2013	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	--
	2014	1	0	0	1	0	1	1	1	5
	2013-2014	1	0	0	1	0	1	1	1	5
Desbarats Wetland	2013	1	1	1	1	1	1	1	1	8
	2014	1	0	1	1	0	1	1	1	6
	2013-2014	1	1	1	1	1	1	1	1	8
Stobie Creek	2013	1	0	1	1	0	0	1	1	5
	2014	1	0	1	1	0	0	1	1	5
	2013-2014	1	0	1	1	0	0	1	1	5
Hay Bay Wetland	2013	0	0	0	1	0	1	1	1	4
	2014	0	0	1	1	0	1	1	1	5
	2013-2014	0	0	1	1	0	1	1	1	5
Joe Dollar Bay	2013	0	0	1	1	1	1	1	1	6
	2014	1	0	1	1	1	1	1	1	7
	2013-2014	1	0	1	1	1	1	1	1	7
No. of wetlands*		9	1	6	11	6	9	11	10	

** based on 2013-14 combined results*

9. Summary

Water Quality and Biotic Community

Based on data collected in the first three years, there is no clear pattern in water quality or the biotic community for AOC and non-AOC sites. Both areas show a range of conditions for water quality and biotic communities.

Development of IBIs

Potential IBIs were developed for the SAV, marsh bird, and aquatic macroinvertebrate community in the St. Marys River. At least another year of data is required to validate the potential IBIs to assess their suitability in detecting changes in the various biotic communities prior to using these IBIs to report on the Loss of Fish and Wildlife Habitat BUI for the St. Marys River AOC. Further, an amphibian IBI was not developed as none of the tested metrics show a significant response to disturbance based on the developed disturbance gradients; therefore, additional surveys are required to detect changes in this community. Small sampling sizes combined with the lack of a clear gradient of disturbance likely contribute to the difficulty in developing appropriate IBIs.

Water temperatures dropped drastically in the St. Marys River during 2014 when compared to 2012 and 2013. Lower conductivity and lower pH were also observed. Cvetkovic and Midwood (2015a) suggest that interannual variability may be greater than among-site variability, and therefore grouping data by wetland (as done in this report) may mask changes in water quality better observed when grouped by year. For example, the 2014 WQI values showed a higher range in values (Table 5) in 2014 than in previous years, but these differences are mitigated by the multi-year data when averaged by wetland. The WQI scores for wetlands sampled in the St. Marys River AOC ranged from very degraded to very good. Cvetkovic and Midwood (2015a) recommendations include evaluating response to stressors at different scales to produce a more complete gradient of disturbance.

The increase in water levels observed in the St. Marys River from 2012 to 2013 and 2013 to 2014 may have had significant impacts on the biotic communities measured here, and in turn affected development of the IBIs with the incorporation of 2014 data. Water levels in Lake Michigan-Huron increased approximately 1.0 metre from January 2013 to December 2014 (Gronewold et al. 2015). Comparing data gathered in the St. Marys River from a single year may be more effective at analyzing change than combining wetland data from several years, which may mask yearly effects. Further, amphibian and bird metric responses were found to be weaker during low water levels in IBI development in Lake Ontario and Lake Erie, such that broad-scale effects were more apparent during low water levels while local disturbances were more apparent during high water levels. Statistically controlling for water levels or developing separate IBIs for water level changes was suggested to account for these differences (Crewe and Timmermans 2005), which may be applicable to future St. Marys River work.

The results presented herein provide a snapshot of the condition of coastal wetlands in the St. Marys River. However, additional sampling and multi-year assessments are necessary to develop and/or validate IBIs that will provide a clear picture of the current condition of coastal wetland biotic communities.

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Appendices

Appendix 1: Development of Disturbance Gradients (from Cvetkovic and Midwood, 2015a)

In order to characterize each wetland along a gradient of disturbance, water quality, landscape, and land classification variables from 32 site-years sampled in the St. Marys River were used to develop 11 different gradients. Water quality metrics included temperature, conductivity, turbidity, and total phosphorus. An estimate of connectivity to the main river, the geomorphology index (GI) was calculated for each wetland.

Ecological Land Classification data (ELC; provided by CWS-ON) were used to identify the proportion of the area within 1000 m of the wetland that was swamp (total swamp/total area), marsh (marsh size/total area), or covered by floating or submerged aquatic vegetation (floating/submerged size/total area). These individual variables were used either independently or in combination. The ELC data were also used to calculate two landscape metrics: the proportion of natural and disturbed land use in the watershed.

For gradients comprised of a single variable (e.g., GI) or simple sums of variables (e.g., % Natural), their expected relationship with disturbance was converted to move from low to high (i.e., high values of the variable are associated with high disturbance and low values of the variable with low disturbance). Combined gradients (e.g., all PCAs) had no expected relationship with disturbance and therefore their relationship needed to be determined. Please see Table A1 for a more detailed description of each gradient and the variables that contributed to its development.

Table A1: A list of all gradients that were applied to the development of IBIs along with a brief description of how they were derived.

Gradient	Brief Description
Geomorphology Index (GI)	Calculated by dividing the width of the wetland opening by the perimeter of the wetland. These calculations were made using Google Earth. This is a measure of the degree of exposure to wind and wave action for a wetland based on its geomorphology, and thus is a measure of physical disturbance and not human disturbance. Values of the GI should range between 0 and 1, 0 being extremely protected (no opening) and 1 being extremely exposed (basically a straight shoreline).
% Disturbed	Sum of % industrial, % cultivated, % residential, and % constructed other (ELC variables).
% Natural	Sum of % wetland, % forest (ELC variables). % Natural values were multiplied by -1 to invert the directionality of the disturbance from low to high impact.
Water Quality Index (WQI)	Calculated by CWS using the 4-parameter formula in Chow-Fraser (2006).
$PCA_{Gradients}$	PCA was conducted with four input variables: Geomorphology Index, Water Quality Index, % Disturbed, and % Natural.
PCA_{WQ}	PCA was conducted with four water quality input variables: turbidity, conductivity, temperature and total phosphorus.
$PCA_{WQ\text{-}Landuse}$	PCA was conducted with four water quality input variables: turbidity, conductivity, temperature and total phosphorus and 5 landscape variables: % Disturbed, % Natural, % Marsh, % Swamp, and % Floating/SAV

Appendix 2: List of taxa recorded on submerged aquatic vegetation surveys for 2014 showing nativeness, turbidity tolerance and coefficient of conservatism (for vascular species).

Genus/Species	Common Name	Native	Turbidity-Tolerant	Coefficient of Conservatism
Algae sp. (fil. underwater)	Filamentous algae underwater	√		
Bidens sp.	beggartick	√		
Calamagrostis canadensis	Blue-Joint Grass	√		4
Carex lacustris	lakebank sedge	√		5
Carex sp.	Sedge sp.			
Ceratophyllum demersum	Coontail, Hornwort	√	√	4
Chara sp.	Stonewort, Muskgrass	√		
Dulichium arundinaceum	threeway sedge	√		7
Eleocharis smallii	Spike-Rush	√		6
Eleocharis sp.	Spikerush	√		
Elodea canadensis	Canada Waterweed	√	√	4
Equisetum fluviatile	Water horsetail	√		7
Heteranthera dubia	Water Star-grass	√	√	7
Isoetes tenella	spiny-spore quilwort	√		7
Leersia oryzoides	Rice Cut Grass	√		3
Lemna minor	Lesser Duckweed	√		2
Lemna trisulca	Star Duckweed	√		4
Lythrum salicaria	Purple Loosestrife			
Megalodonta beckii	Water-Marigold	√	X	8
Moss sp.	Moss sp.	√		
Myriophyllum sibiricum	Northern Water Milfoil	√	X	6
Myriophyllum spicatum	Eurasian Water Milfoil		√	
Najas flexilis	Slender Naiad	√	X	5
Nitella sp.	Brittlewort	√		
Nuphar lutea ssp. *variegata*	Yellow Pond Lily, Bullhead Lily, Spatterdock	√		4
Nymphaea odorata	White Water Lily, Fragrant Water Lily	√		5
Phalaris arundinacea	Reed canary grass	√		
Phragmites australis subsp *americanus*	Common Reed (native)	√		
Pontederia cordata	Pickerelweed	√		7
Potamogeton amplifolius	Large-leaved Pondweed	√	X	5
Potamogeton foliosus	Leafy Pondweed	√	√	4
Potamogeton gramineus	Variable-leaved Pondweed	√		4
Potamogeton obtusifolius	bluntleaf pondweed	√		8
Potamogeton pusillus	Slender Pondweed	√	√	5
Potamogeton richardsonii	Richardson's, Clasping Leaved Pondweed	√		5
Potamogeton robbinsii	Fern Pondweed	√	X	7
Potamogeton vaseyi	Vasey's pondweed	√		8
Potamogeton zosteriformis	Flat-stemmed Pondweed	√	X	5
Ranunculus longirostris	Curly White Water Crowfoot	√	√	
Riccia fluitans	Floating Slender Liverwort	√		
Ricciocarpos natans	Purple-fringed Liverwort	√		
Sagittaria graminea	grass-leafed arrowhead	√		8

Genus/Species	Common Name	Native	Turbidity-Tolerant	Coefficient of Conservatism
Sagittaria latifolia	Broad-leaved Arrowhead	√		4
Schoenoplectus acutus	Hardstem Bulrush	√		6
Schoenoplectus pungens	Common Three-square	√		6
Schoenoplectus tabernaemontani	Softstem Bulrush	√		5
Sparganium eurycarpum	Common burreed	√		3
Sparganium fluctuans	Floating-leaved Burreed	√		9
Spirodela polyrhiza	Greater Duckweed	√		4
Spongillidae	Freshwater Sponge			
Typha angustifolia	Narrow-leaved Cattail	√		3
Typha x *glauca*	Hybrid Cattail	√		3
Utricularia vulgaris	Common Bladderwort	√		4
Vallisneria americana	Tape Grass, Wild Celery, Water Celery	√	X	6
Zizania palustris	Wild Rice	√		9

Appendix 3: List of aquatic macroinvertebrate species identified to the lowest taxonomic unit possible from 2014 samples.

Phylum	Class	Order	Family	Genus/Species
Annelida	Clitellata	Arhynchobdellida	Erpobdellidae	
Annelida	Clitellata	Arhynchobdellida	Erpobdellidae	Erpobdella punctata
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	Helobdella sp.
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	Helobdella stagnalis
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	Theromyzon sp.
Annelida	Oligochaeta			
Arthropoda	Arachnida	Hydracarina		
Arthropoda	Crustacea	Amphipoda		
Arthropoda	Crustacea	Amphipoda	Crangonyctidae	Crangonyx sp.
Arthropoda	Crustacea	Amphipoda	Gammaridae	Gammarus fasciatus
Arthropoda	Crustacea	Amphipoda	Gammaridae	Gammarus sp.
Arthropoda	Crustacea	Amphipoda	Hyalellidae	Hyalella azteca
Arthropoda	Crustacea	Decapoda	Cambaridae	
Arthropoda	Crustacea	Isopoda	Asellidae	Caecidotea sp.
Arthropoda	Crustacea	Isopoda	Asellidae	Lirceus sp.
Arthropoda	Insecta	Coleoptera	Dytiscidae	
Arthropoda	Insecta	Coleoptera	Dytiscidae	Laccophilus sp.
Arthropoda	Insecta	Coleoptera	Dytiscidae	Neoporus sp.
Arthropoda	Insecta	Coleoptera	Gyrinidae	Dineutus sp.
Arthropoda	Insecta	Coleoptera	Gyrinidae	Gyrinus sp.
Arthropoda	Insecta	Coleoptera	Haliplidae	Haliplus sp.
Arthropoda	Insecta	Coleoptera	Haliplidae	Peltodytes sp.
Arthropoda	Insecta	Coleoptera	Hydrophilidae	
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Laccobius sp.
Arthropoda	Insecta	Coleoptera	Hydrophilidae	Tropisternus sp.
Arthropoda	Insecta	Diptera	Ceratopogonidae	
Arthropoda	Insecta	Diptera	Ceratopogonidae	Bezzia/Palpomyia
Arthropoda	Insecta	Diptera	Chironomidae	
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae sp.
Arthropoda	Insecta	Diptera	Dixidae	Dixella sp.
Arthropoda	Insecta	Ephemeroptera	Baetidae	
Arthropoda	Insecta	Ephemeroptera	Baetidae	Callibaetis sp.
Arthropoda	Insecta	Ephemeroptera	Baetidae	Paracloeodes sp.
Arthropoda	Insecta	Ephemeroptera	Baetidae	Procloeon/Centroptilum
Arthropoda	Insecta	Ephemeroptera	Baetidae	Procloeon/Centroptilum/Cloeon
Arthropoda	Insecta	Ephemeroptera	Caenidae	Caenis sp.
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Dannella sp.
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Eurylophella sp.
Arthropoda	Insecta	Ephemeroptera	Siphlonuridae	Siphlonurus sp.
Arthropoda	Insecta	Hemiptera	Belostomatidae	
Arthropoda	Insecta	Hemiptera	Corixidae	
Arthropoda	Insecta	Hemiptera	Corixidae	Hesperocorixa sp.
Arthropoda	Insecta	Hemiptera	Corixidae	Palmacorixa sp.
Arthropoda	Insecta	Hemiptera	Corixidae	Sigara sp.
Arthropoda	Insecta	Hemiptera	Corixidae	Trichocorixa sp.
Arthropoda	Insecta	Hemiptera	Gerridae	
Arthropoda	Insecta	Hemiptera	Gerridae	Gerris sp.

Phylum	Class	Order	Family	Genus/Species
Arthropoda	Insecta	Hemiptera	Hebridae	Merragata sp.
Arthropoda	Insecta	Hemiptera	Mesoveliidae	Mesovelia sp.
Arthropoda	Insecta	Hemiptera	Notonectidae	
Arthropoda	Insecta	Hemiptera	Notonectidae	Notonecta sp.
Arthropoda	Insecta	Hemiptera	Pleidae	Neoplea sp.
Arthropoda	Insecta	Hemiptera	Veliidae	Microvelia sp.
Arthropoda	Insecta	Lepidoptera	Crambidae	Acentria sp.
Arthropoda	Insecta	Odonata	Aeshnidae	
Arthropoda	Insecta	Odonata	Aeshnidae	Aeshna sp.
Arthropoda	Insecta	Odonata	Aeshnidae	Anax sp.
Arthropoda	Insecta	Odonata	Aeshnidae	Basiaeshna sp.
Arthropoda	Insecta	Odonata	Coenagrionidae	
Arthropoda	Insecta	Odonata	Coenagrionidae	Enallagma sp.
Arthropoda	Insecta	Odonata	Coenagrionidae	Enallagma/Coenagrion sp.
Arthropoda	Insecta	Odonata	Coenagrionidae	Ischnura sp.
Arthropoda	Insecta	Odonata	Lestidae	Lestes sp.
Arthropoda	Insecta	Odonata	Libellulidae	
Arthropoda	Insecta	Odonata	Libellulidae	Leucorrhinia sp.
Arthropoda	Insecta	Odonata	Libellulidae	Leucorrhinia/Sympetrum
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Agraylea sp.
Arthropoda	Insecta	Trichoptera	Leptoceridae	Ceraclea sp.
Arthropoda	Insecta	Trichoptera	Leptoceridae	Mystacides sp.
Arthropoda	Insecta	Trichoptera	Leptoceridae	Oecetis sp.
Arthropoda	Insecta	Trichoptera	Leptoceridae	Triaenodes sp.
Arthropoda	Insecta	Trichoptera	Limnephilidae	Anabolia sp.
Arthropoda	Insecta	Trichoptera	Limnephilidae	Limnephilus sp.
Arthropoda	Insecta	Trichoptera	Polycentropodidae	
Arthropoda	Insecta	Trichoptera	Polycentropodidae	Polycentropus sp.
Cnidaria	Hydrozoa	Hydroida	Hydridae	Hydra sp.
Mollusca	Bivalvia	Veneroida	Pisidiidae	
Mollusca	Bivalvia	Veneroida	Pisidiidae	Musculium sp.
Mollusca	Bivalvia	Veneroida	Pisidiidae	Pisidium sp.
Mollusca	Gastropoda	Basommatophora	Ancylidae	
Mollusca	Gastropoda	Basommatophora	Ancylidae	Ferrissia sp.
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	Lymnaea stagnalis
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	Stagnicola sp.
Mollusca	Gastropoda	Basommatophora	Physidae	Physa/Physella
Mollusca	Gastropoda	Basommatophora	Planorbidae	
Mollusca	Gastropoda	Basommatophora	Planorbidae	Gyraulus sp.
Mollusca	Gastropoda	Basommatophora	Planorbidae	Gyraulus/Promenetus
Mollusca	Gastropoda	Basommatophora	Planorbidae	Helisoma/Planorbella
Mollusca	Gastropoda	Basommatophora	Planorbidae	Menetus sp.
Mollusca	Gastropoda	Basommatophora	Planorbidae	Planorbula sp.
Mollusca	Gastropoda	Basommatophora	Planorbidae	Promenetus sp.
Mollusca	Gastropoda	Mesogastropoda	Valvatidae	Valvata tricarinata
Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	
Mollusca	Gastropoda	Stylommatophora	Succineidae	Succinea sp.
Platyhelminthes	Turbellaria	Tricladida		

Appendix 4: List of species recorded within 100 m on marsh breeding bird surveys in 2014.

Species Common Name	Scientific Name	Marsh User	Forager
American Black Duck	*Anas rubripes*	MNG	WF
Alder Flycatcher	*Empidonax alnorum*	NA	AF
American Bittern	*Botaurus lentiginosus*	AEMNO	WF
American Crow	*Corvus brachyrhynchos*	NA	NAF
American Goldfinch	*Carduelis tristis*	NA	NAF
American Robin	*Turdus migratorius*	NA	NAF
Bald Eagle	*Haliaeetus leucocephalus*	NA	AF
Barn Swallow	*Hirundo rustica*	NA	AF
Black-capped Chickadee	*Parus atricapillus*	NA	NAF
Belted Kingfisher	*Ceryle alcyon*	NA	AF
Black Tern	*Chlidonias niger*	AEMNO	AF
Blue-winged Teal	*Anas discors*	NA	WF
Canada Goose	*Branta canadensis*	MNG	WF
Caspian Tern	*Sterna caspia*	NA	AF
Cedar Waxwing	*Bombycilla cedrorum*	NA	NAF
Chipping Sparrow	*Spizella passerina*	NA	NAF
Common Goldeneye	*Bucephala clangula*	NA	WF
Common Grackle	*Quiscalus quiscula*	NA	NAF
Common Tern	*Sterna hirundo*	NA	AF
Common Yellowthroat	*Geothlypis trichas*	MNG	NAF
Double-crested Cormorant	*Phalacrocorax auritus*	NA	WF
Gadwall	*Anas strepera*	NA	WF
Great Blue Heron	*Ardea herodias*	NA	WF
Green-winged Teal	*Anas crecca*	NA	WF
Herring Gull	*Larus argentatus*	NA	AF
Hooded Merganser	*Lophodytes cucullatus*	NA	WF
Killdeer	*Charadrius vociferus*	NA	NAF
Le Conte's Sparrow	*Ammodramus leconteii*	MNG	NAF
Least Bittern	*Ixobrychus exilis*	AEMNO	WF
Marbled Godwit	*Limosa fedoa*	NA	NAF
Mallard	*Anas platyrhynchos*	NA	WF
Marsh Wren	*Cistothorus palustris*	EMNO	NAF
Northern Flicker	*Colaptes auratus*	NA	NAF
Northern Waterthrush	*Seiurus noveboracensis*	NA	NAF
Osprey	*Pandion haliaetus*	NA	AF
Pied-billed Grebe	*Podilymbus podiceps*	EMNO	WF
Purple Finch	*Carpodacus purpureus*	NA	NAF
Ring-billed Gull	*Larus delawarensis*	NA	AF
Red-winged Blackbird	*Agelaius phoeniceus*	MNG	NAF
Sandhill Crane	*Grus canadensis*	MNG	WF
Savannah Sparrow	*Passerculus sandwichensis*	NA	NAF
Sedge Wren	*Cistothorus platensis*	MNG	NAF
Sora	*Porzana carolina*	EMNO	NAF
Song Sparrow	*Melospiza melodia*	NA	NAF
Spotted Sandpiper	*Actitis macularia*	NA	NAF
Swamp Sparrow	*Melospiza georgiana*	MNO	NAF
Tree Swallow	*Tachycineta bicolor*	NA	AF
Turkey Vulture	*Cathartes aura*	NA	AF
Virginia Rail	*Rallus limicola*	EMNO	NAF

Species Common Name	Scientific Name	Marsh User	Forager
Wilson's Snipe	*Capella gallinago delicata*	MNG	NAF
Wild Turkey	*Meleagris gallopavo*	NA	NAF
Wood Duck	*Aix sponsa*	NA	WF
Yellow Rail	*Coturnicops noveboracensis*	AMNO	NAF
Yellow Warbler	*Dendroica petechia*	NA	NAF

AEMNO	Area Sensitive Emergent Marsh Nesting Obligate
AMNO	Area Sensitive Marsh Nesting Obligate
EMNO	Emergent Marsh Nesting Obligate
MNG	Marsh Nesting Generalist
MNO	Marsh Nesting Obligate
AF	Aerial Forager
NAF	Non-Aerial Forager
WF	Water Forager

Appendix 5: List of species recorded within 100 m on amphibian surveys in 2014.

Species Common Name	Scientific Name
American Toad	*Anaxyrus americanus*
Gray Treefrog	*Hyla versicolor*
Green Frog	*Rana clamitans melanota*
Mink Frog	*Lithobates septentrionalis*
Northern Leopard Frog	*Lithobates pipiens*
Spring Peeper	*Pseudacris crucifer*
Wood Frog	*Lithobates sylvaticus*