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

August 2016

Environment and Climate Change Canada   Environnement et Changement climatique Canada

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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 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. Building upon work started in 2012 (see Environment Canada 2013, 2014, 2015), a subset of coastal wetlands on the Canadian side of the St. Marys River, both within and outside the AOC, were visited and surveyed for water quality, submerged aquatic vegetation, aquatic macroinvertebrates, amphibians (frogs and toads), and marsh breeding birds in 2015 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 moderately degraded to very good, and indicated that water quality in AOC versus non-AOC wetlands was similar. The degradation of water quality appears to be primarily a result of increased turbidity which may be a result of natural processes or anthropogenic causes. An Index of Biotic Integrity (IBI), 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, was used to report on the condition of the submerged aquatic vegetation (SAV) community. The SAV IBI demonstrated variation among sites, with wetland condition ranging from poor to excellent. From 2015 data, it was determined that no suitable IBIs could be developed for macroinvertebrate, marsh bird, or amphibian communities due to the lack of a strong response to disturbance. The IBIs developed in previous work (Environment Canada 2014) did not respond well with 2015 data, and therefore cannot be used to report on the condition of these biotic communities. Biotic communities lacking a strong response to disturbance, combined with wetlands within the AOC and outside the AOC exhibiting comparable WQI values, suggest that the Canadian side of St. Marys River can be considered no longer impaired with respect to the status of the Loss of Fish and Wildlife Habitat BUI's first criterion regarding coastal wetland wildlife habitat conditions. Further, this also suggests the marsh bird and amphibian (frogs and toads) coastal wetland communities can be considered not impaired with respect to the status of the Degradation of Fish and Wildlife Populations BUI.

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Acknowledgements

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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) within the Great Lakes basin. On the Canadian side, the AOC extends from the head of the river at Whitefish Bay to Quebec Bay and includes the waters partway surrounding St. Joseph Island (Figure 1). The area was listed because of historical problems associated with pollution from industrial sources, partially treated municipal and private sewage, and physical alterations to the river and its shoreline (St. Marys River Binational Public Advisory Committee 2015).

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. The 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” and does not contain delisting criteria at the time of this report. BUI #14 (*Loss of Fish and Wildlife Habitat*) is currently listed as “impaired”, and the delisting criteria are as follows: i) coastal wetland wildlife habitat conditions within the Area of Concern are comparable to those of suitable reference sites, as assessed using an index of biotic integrity; ii) rapids habitat conditions are enhanced through feasible conservation and restoration measures identified in the Stage 2 Remedial Action Plan; and iii) the closely linked “Degradation of Fish Populations” BUI is no longer deemed impaired (St. Marys River Binational Public Advisory Council 2015).

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 2015 to collect information on water quality, submerged aquatic vegetation (SAV), aquatic macroinvertebrates (2013-2015 only), marsh breeding birds, and amphibians (2013-2015 only). The results of these surveys can be used to provide components of information necessary for BUI assessments.

Numerous attempts to develop disturbance gradients with multiple years of data (Cvetkovic and Midwood 2014, 2015a, 2015b) in the St. Marys River have had limited success. Compared to other AOCs in the Great Lakes, the St. Marys River demonstrates both a narrower range of disturbance and higher overall water quality. Indices of Biotic Integrity (IBIs) are ideally developed based on a wide continuum of disturbance that elicits a response in both degraded and pristine sites within a region. Most sites in the St. Marys River, however, exhibit relatively undisturbed condition. The absence of a broad range of disturbance necessary to capture change and variation in the St. Marys River results in the inability to create suitable IBIs for this area, in particular for the marsh breeding bird, aquatic macroinvertebrate, and amphibian biotic communities. The SAV community does show response to disturbance and may have limited use in reporting on wetland condition. The lack of wide and well-distributed disturbance and the subsequent difficulty in developing IBIs that are sensitive to change provide evidence of coastal wetland habitat and biotic communities in the Canadian side of the St. Marys River AOC being no longer impaired with respect to criterion (i) of BUI #14: *Loss of Fish and Wildlife Habitat* and provides information to support a not impaired assessment with respect to coastal wetland bird and amphibian (frogs and toads) populations in BUI #3: *Loss of Fish and Wildlife Populations*.

2. Purpose of Report

The purpose of this document is to briefly describe the sampling methodologies and report on the condition of coastal wetlands, where available. These assessments allow for comparisons of coastal wetland quality between survey years as well as between AOC and non-AOC coastal wetlands on the Canadian side of the St. Marys River. This report also suggests that there is a narrow range of relatively minimally disturbed coastal wetlands in the AOC, which supports the assertion that coastal wetlands are no longer impaired with respect to criterion (i) of BUI #14 and coastal wetland bird and amphibian (frogs and toads) populations in BUI #3.

3. Surveyed Wetlands

Since it was not feasible to survey all coastal wetlands within the St. Marys River, a subset of sites that collectively provide a geographic spread throughout the river and represent the geomorphic types and sizes of coastal wetlands present on the Canadian side was selected. More details on site selection and description of sites are provided in Environment Canada, 2013. Six AOC and five non-AOC wetlands (one added in 2013[1]) were surveyed from 2012 to 2015 for water quality and biotic communities (Figure 1) for a total of 43 site-years:

- AOC sites:
    - Carpin Beach
    - Echo Bay
    - Lake George
    - Maskinonge Bay
    - Pumpkin Point
    - West Shore, St. Joseph Island

[1] An addition non-AOC wetland was added in 2013 to improve AOC/non-AOC comparisons.

- Non-AOC sites:
  - Anderson Creek (added in 2013)
  - Desbarats Wetland
  - Stobie Creek
  - Hay Bay Wetland
  - Joe Dollar Bay Wetland

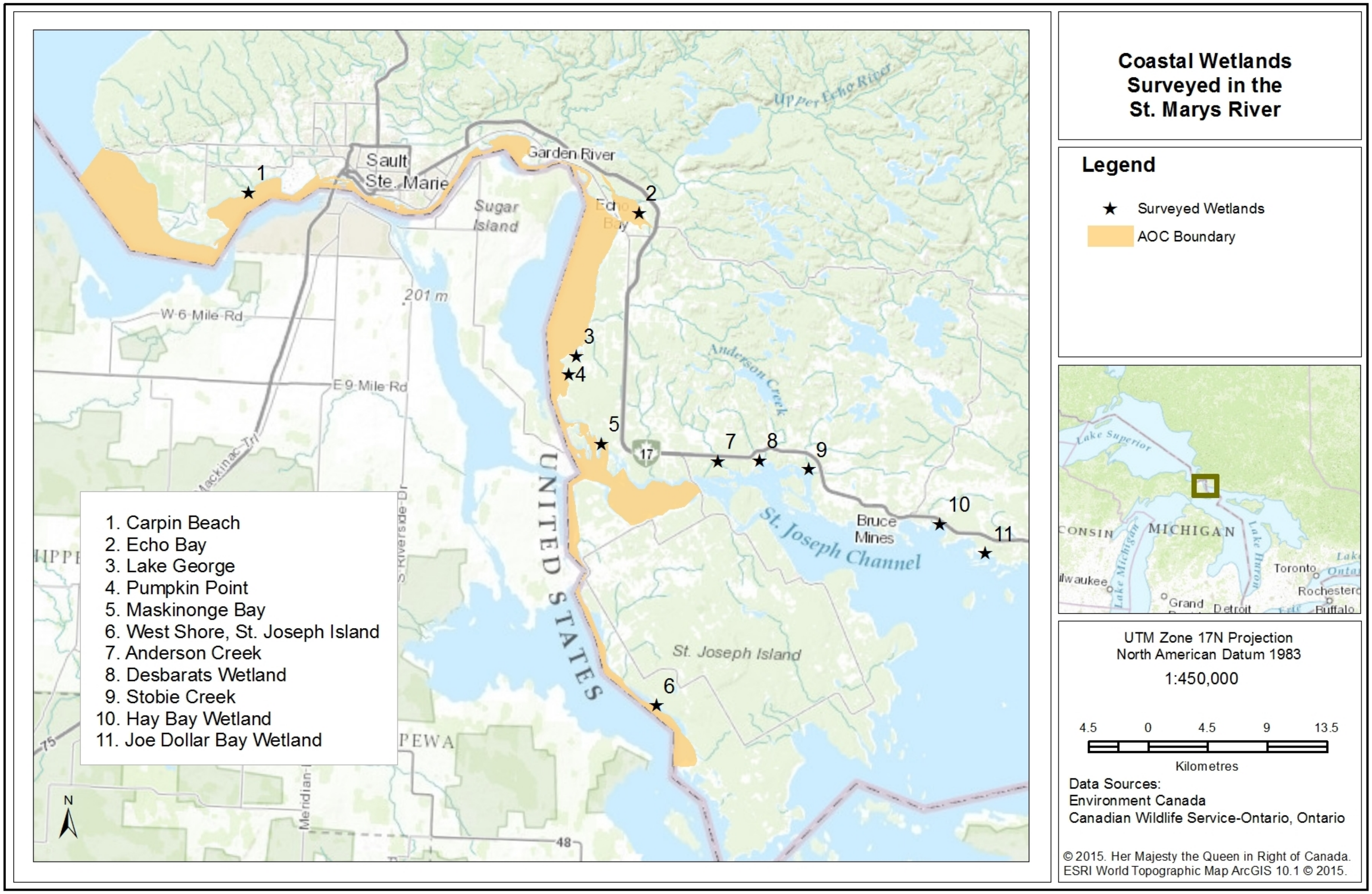

Figure 1: Location of coastal wetlands sampled in the St. Marys River from 2012-2015.

4. Disturbance and Wetland Condition in the St. Marys River

IBIs can be used to monitor the condition of coastal wetlands and have been used regionally (e.g., Durham Region's Coastal Wetland Monitoring Program) and in other AOCs (e.g., Bay of Quinte, Wheatley Harbour, Detroit River, St. Clair River, and Thunder Bay), as well as in lake-wide basin assessments (e.g., Environment Canada's Coastal Habitat Assessment and Monitoring Project). Previous efforts to develop IBIs specific to the St. Marys River (Cvetkovic and Midwood 2014, 2015a, 2015b) have had limited success, with only the SAV community showing a response to disturbance while marsh breeding birds, amphibians, and aquatic macroinvertebrates showed weak to no sensitivity to disturbance. The most common gradient of disturbance used in previous work is the Water Quality Index (WQI; Equation 1), a tool for determining coastal wetland water quality in the Great Lakes (Chow-Fraser 2006). The WQI was developed as a relative ranking tool to report on coastal wetland water quality in the Great Lakes Basin, further discussed in section 5. WQI scores fit into six categories which correspond with values ranging from -3 to +3, with lower scores indicating higher degradation, and are therefore useful in quantitatively determining the range of disturbance in an area.

Figure 2 highlights the distinct differences in the range of disturbance, as measured by the WQI, in the St. Marys River versus other Canadian areas in the lower Great Lakes (i.e., Lake Ontario, Lake Erie, the Huron-Erie Corridor), with the St. Marys River demonstrating a much narrower range of disturbance as well as overall better water quality.

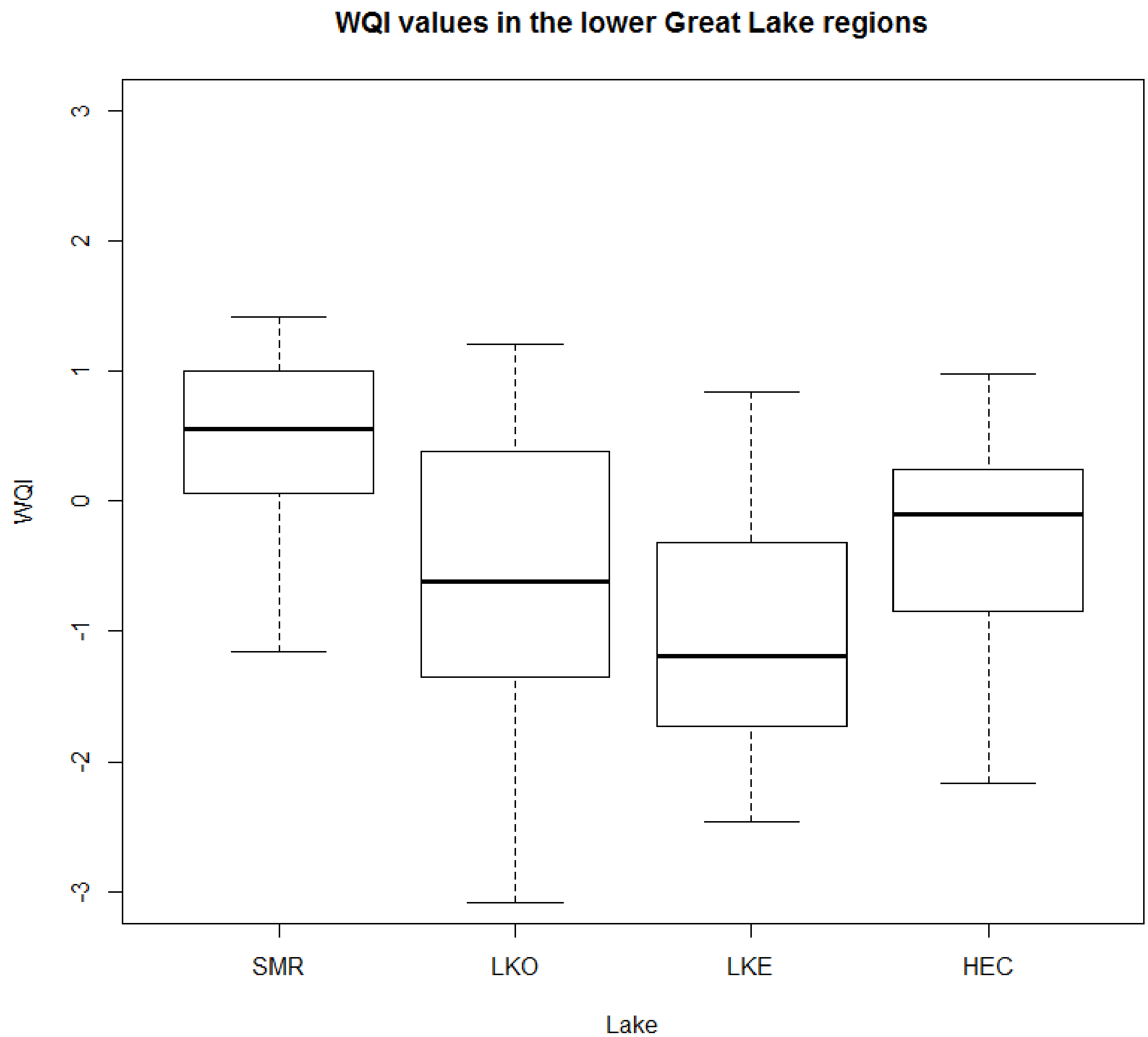

Figure 2: Boxplots of the mean WQI values corresponding to each lake/region, where SMR = St. Marys River, LKO = Lake Ontario, LKE = Lake Erie, and HEC = Huron-Erie Corridor. Boxplot "whiskers" indicate the maximum/minimum values, and the top and bottom of the boxplot indicate the 25^{th} and 75^{th} percentiles, respectively.

The development of IBIs includes, in part, examining the response of biotic community attributes over a continuum of disturbance. As site disturbance increases, the likelihood of observing sensitive taxa (e.g., species) decreases. For example, in lower Great Lakes, it is well known that as disturbance increases, overall coverage of SAV decreases. In the St. Marys River region, the disturbance continuum is truncated, wherein most sites experience relatively little disturbance. Without more highly disturbed sites (such as in the lower Great Lakes), associations between disturbance and biotic attribute cannot be statistically discerned. While there has been success in developing IBIs in the lower Great Lakes, the limited range of disturbance in the St. Marys River has resulted in the inability to develop suitable IBIs for this geographic area. Although several potential IBIs have been developed in the recent past (Cvetkovic and Midwood 2014, 2015a, 2015b), attempts at validation with 2015 data resulted in strong indication that these potential IBIs did not respond well to disturbance as predictors of wetland condition. Consequently, it was determined that IBIs as indicators of change in biotic communities, with the exception of the SAV community, cannot be developed for the St. Marys River. Although this may be frustrating from an IBI development standpoint, it is very encouraging from an impaired beneficial use perspective.

5. 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 2013-2015 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 2015, coastal wetland WQI qualitative descriptors (Table 3) varied from moderately degraded to very good with the majority of sites ranked in either good or very good condition (Table 5). Non-AOC wetlands varied from moderately degraded to very good, while AOC wetland condition was good or very good. Impaired water quality from the WQI is typically the result of elevated turbidity such as seen at Hay Bay Wetland, with a turbidity value greater than 15 NTUs and a WQI descriptor of moderately degraded (Table 4).

Total phosphorus (TP) values in 2015 were at or below the Provincial Water Quality Objective limit of 0.03 mg/L (Table 6) for all wetlands except Maskinonge Bay, which had a total phosphorus level of 0.07 mg/L. The higher level of TP at Maskinonge Bay is likely due to an output source in the vicinity of the wetland, which has consistently been the source of high levels of phosphorus during all sampling years at this wetland. Overall, total ammonia nitrogen values in 2015 were 0.03 mg/L or less, and total nitrate nitrogen values varied from 0.02 mg/L to 0.22 mg/L. As noted in the Methods section, these parameters were collected from a composite water sample in 2013-2015 compared to individual samples in 2012, which may account for the slight differences observed among years; values from 2014 to 2015 appear to be comparable among the same wetlands.

Statistical comparisons (paired t-tests) of the WQI and each water quality parameter were performed for AOC versus non-AOC wetlands for each sampling year, and then for the mean of all sampling years. No statistical difference was observed between wetlands located in the AOC versus outside the AOC for the WQI or any water quality parameter for any year.

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	2015	2012	2013	2014	2015	2012	2013	2014	2015	2012	2013	2014	2015
AOC sites																
Carpin Beach	6.3	7.2	5.7	13.5	130.5	125.5	110.0	107.8	23.4	18.6	18.0	21.1	7.3	7.2	7.3	7.2
Echo Bay	4.5	8.9	7.2	6.1	115.2	84.8	84.2	78.1	25.7	22.0	21.0	21.4	8.5	8.3	7.3	7.1
Lake George	50.6	38.7	14.3	7.6	150.0	129.1	111.8	103.7	23.5	21.7	19.0	19.8	7.8	7.7	7.3	7.5
Pumpkin Point	51.3	44.9	16.5	12.1	123.1	116.9	94.0	101.6	29.1	26.7	18.4	20.0	9.1	9.0	8.1	8.2
Maskinonge Bay	1.7	1.6	2.9	1.9	110.3	105.8	106.8	104.0	24.0	24.7	18.4	22.9	8.5	8.0	7.6	7.7
West Shore, St. Joseph Island	37.9	69.3	137.1	14.5	190.0	164.9	136.2	114.8	22.9	22.7	17.1	23.0	8.5	8.1	7.9	7.6
Non-AOC sites																
Anderson Creek	-	12.8	6.6	4.3	-	133.8	120.3	103.5	-	21.8	17.5	21.2	-	7.4	7.7	7.4
Desbarats Wetland	3.2	3.6	3.2	2.8	129.3	99.3	99.5	102.3	25.5	22.9	19.0	19.9	8.1	8.0	7.5	7.3
Stobie Creek	2.5	2.8	2.8	2.7	152.8	113.6	98.8	106.4	30.7	25.5	17.5	21.3	9.2	9.1	7.4	7.5
Hay Bay Wetland	31.9	19.2	12.2	17.3	195.1	135.0	129.5	136.9	24.3	25.6	16.2	21.2	8.2	8.6	7.7	7.9
Joe Dollar Bay Wetland	8.8	2.3	2.4	2.3	156.1	135.1	133.5	145.0	26.4	25.2	19.2	21.6	8.4	8.2	7.6	7.7

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	2015	Mean	Descriptor*
AOC Sites						
Carpin Beach	0.55	0.69	0.92	0.33	**0.62**	Good
Echo Bay	0.63	0.56	0.86	1.02	**0.77**	Good
Lake George	-0.85	-0.51	0.33	0.70	**-0.08**	Moderately degraded
Pumpkin Point	-1.03	-0.84	0.28	0.34	**-0.31**	Moderately degraded
Maskinonge Bay	1.30	1.36	1.28	1.40	**1.34**	Very good
West Shore, St. Joseph Island	-0.90	-1.11	-1.15	0.13	**-0.76**	Moderately degraded
Non-AOC sites						
Anderson Creek	-	0.15	0.74	0.99	**0.63**	Good
Desbarats Wetland	0.79	0.99	1.26	1.33	**1.09**	Very good
Stobie Creek	0.56	0.85	1.42	1.24	**1.02**	Very good
Hay Bay Wetland	-0.82	-0.36	0.38	-0.08	**-0.22**	Moderately degraded
Joe Dollar Bay Wetland	0.01	0.97	1.22	1.09	**0.82**	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*	*2015*	*2012**	*2013*	*2014*	*2015*	*2012*	*2013*	*2014*	*2015*
AOC sites												
Carpin Beach	0.03	0.04	0.04	0.03	0.13	0.16	0.18	0.16	0.02	0.02	0.02	0.02
Echo Bay	0.00	0.02	0.01	0.01	0.15	0.02	0.03	0.02	0.02	0.03	0.02	0.02
Lake George	0.03	0.02	0.01	0.02	0.05	0.06	0.10	0.14	0.04	0.03	0.02	0.02
Pumpkin Point	0.06	0.02	0.01	0.01	0.03	0.05	0.25	0.22	0.03	0.03	0.02	0.02
Maskinonge Bay	0.02	0.01	0.04	0.03	0.10	0.01	0.06	0.05	0.18	0.17	0.22	0.07
West Shore, St. Joseph Island	0.01	0.03	0.01	0.03	0.10	0.03	0.18	0.13	0.03	0.04	0.04	0.02
Non-AOC sites												
Anderson Creek	-	0.03	0.01	0.02	-	0.05	0.20	0.07	-	0.05	0.02	0.03
Desbarats Wetland	0.00	0.02	0.01	0.02	0.16	0.05	0.08	0.08	0.04	0.03	0.02	0.02
Stobie Creek	0.00	0.02	0.08	0.03	0.15	0.03	0.13	0.14	0.04	0.03	0.01	0.02
Hay Bay Wetland	0.08	0.02	0.02	0.02	0.05	0.12	0.24	0.20	0.02	0.03	0.02	0.02
Joe Dollar Bay Wetland	0.00	0.02	0.03	0.01	0.18	0.04	0.09	0.11	0.02	0.02	0.01	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 four years, there is no apparent difference in coastal wetland AOC sites versus non-AOC sites: mean values ranged from moderately 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 2015. Exceptions include West Shore, St. Joseph Island, which experienced degradation in WQI from 2012-2014 but improvement in 2015, and Maskinonge Bay, which experienced relatively stable scores.

Sites with degraded water quality are typically wetlands 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 in 2015 and were the lowest recorded values measured during all sampling years for Pumpkin Point, Lake George, and West Shore, St. Joseph Island, turbidity at these sites remained high when compared to other wetlands. Carpin Beach's turbidity values in 2015 were slightly elevated compared to values measured in previous years. 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 (e.g., 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) increased slightly in 2015 from 2014 values. In most cases, 2015 temperatures remained lower than 2013 values. This drop in water temperature, combined with a drop in pH, likely contributed to the improved WQI scores seen in 2014 and 2015. Water depth per station was on average 92 cm in 2015, 71 cm in 2014, and 46 cm in 2013; these increased depths may have influenced the colder water temperatures seen in 2014 and 2015. 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, and combined with lower water temperatures, may have slowed SAV community growth, as discussed in Section 5.

Conductivity levels recorded in St. Marys River (average: 109 µS/cm) in 2015 are below levels observed through surveys conducted by Environment and Climate Change Canada – Canadian Wildlife Service in other Great Lakes coastal wetlands. 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 325 µS/cm in 2015 (Environment and Climate Change Canada, unpublished data). The average conductivity reading for St. Marys River AOC sites was 102 µS/cm and 119 µS/cm for non-AOC sites. This suggests that inputs from agricultural, industrial, and urban inputs in the St. Marys River are less than in other areas.

With the exception of Maskinonge Bay, total phosphorus levels were 0.03 mg/L or less. The 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 2015, nine of the eleven sites meet this objective, improving from only two of eleven sites meeting this objective in 2013.

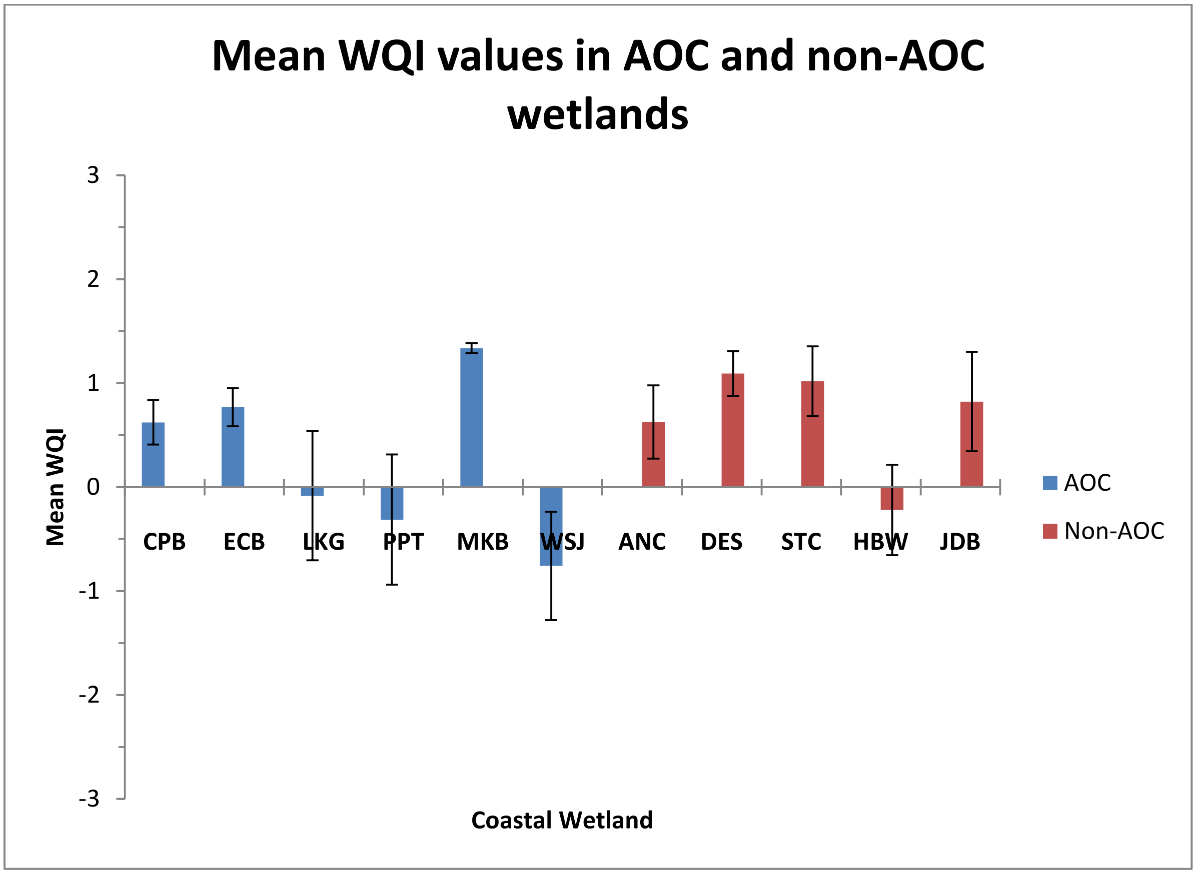

Figure 3: Mean WQI values for sampled wetlands during all years for comparisons between sites within the AOC and outside the AOC. CPB = Carpin Beach, ECB = Echo Bay, LKG = Lake George, PPT = Pumpkin Point, MKB = Maskinonge Bay, WSJ = West Shore, St. Joseph's Island, ANC = Anderson Creek, DES = Desbarats Wetlands, STC = Stobie Creek, HWB = Hay Bay Wetland, JDB = Joe Dollar Bay Wetland.

Figure 3 demonstrates the variation in mean WQI values over all sampled years, with wetlands both inside and outside the AOC demonstrating a range of values. In addition, the highest (best) scoring wetland, Maskinonge Bay, is within the AOC, and Hay Bay Wetland, which is outside of the AOC, scores below the majority of sites within the AOC. The WQI values of AOC sites showed no statistical difference from those of non-AOC sites, suggesting that values are comparable and overall water quality in the St. Marys River AOC can be considered not impaired with respect to criterion (i) of BUI #14.

6. 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 species having lower disturbance tolerance and greater fidelity to a certain habitat. Three metrics were shown to significantly respond to disturbance: SNAT (number of native species), CC (Coefficient of conservatism), and PCOV (total coverage).

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 with higher IBI scores representing better SAV community condition. EC and CLOCA (2004) identified five classes in which minimum detectable differences could be distinguished and associated with a 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 2015 had one or more native species present (see Appendix 2 for full list of plant species observed; Tables 8 and 9). Pumpkin Point, West Shore, St. Joseph Island, and Hay Bay Wetland scored zero in total cumulative cover. Carpin Beach scored zero in the coefficient of conservatism standardized metric. The average of total cumulative coverage ranged from 2.9% (Hay Bay Wetland) to 66.2% (Maskinonge Bay).

In 2015, by percent cover and number of quadrats, Fern Pondweed (*Potamogeton robbinsii*), Tape Grass (*Vallisineria americana*), Stonewort (*Chara* sp.), Canada Waterweed (*Elodea canadensis*), and Richardson's Pondweed (*Potamogeton richardsonii*) were the five most common SAV species observed. Tape Grass, Canada Waterweed, Stonewort, and Richardson's Pondweed were the most ubiquitous species, found at ten of the eleven wetlands surveyed. Fern Pondweed and Tape Grass are turbidity intolerant, while Canada Waterweed is turbidity tolerant. All of the most common species are also native species.

After experiencing a decline in IBI scores for the majority of sites in 2014, most wetlands remained stable or showed an increase in IBI score in 2015. Sites that had higher IBI scores in previous years (e.g., 80 or above) appeared to remain somewhat stable (e.g., Maskinonge Bay, Desbarats Wetland, Stobie Creek). Carpin Beach's IBI score was the lowest for all wetlands surveyed in 2015, while Stobie Creek's IBI score was the highest. Statistical comparisons (paired t-tests) of each SAV parameter were performed for AOC versus non-AOC wetlands for each sampling year, and then for the mean of all sampling years. The parameters of SNAT (number of native species) and FQI (floristic quality index, calculated by multiplying the mean coefficient of conservatism by the square root of native species per quadrat; Oldham et al., 1995) showed statistical differences in AOC versus non-AOC wetlands during 2013 and 2014, but not for other years or for the mean of all sampling years.

Discussion

The SAV IBI appeared to show differences between AOC and non-AOC sites in 2015 as well as in previous survey years. AOC sites ranged from poor to excellent (ranging in IBI scores from 5.5 to 88.9), with four of six sites ranked as fair or poor. West Shore, St. Joseph Island, Pumpkin Point, and Carpin Beach ranked in the poor category. Maskinonge Bay, however, ranked in the excellent category. Similarly, the non-AOC sites ranked from poor to excellent (ranging in IBI scores from 14.0 to 89.1), with one site ranked as poor and two of five sites ranked as excellent.

Increased water depth and lower water temperatures in 2015 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 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 only Stonewort was among the most common species found in 2015. 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 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 and 2015 surveys as one of the most common species, but was not one of the most common species in 2014 surveys during the lowest recorded temperatures, 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 four years of data, but fluctuations are apparent in the St. Marys River, likely as a result of variability in water levels. Statistical differences were observed in two SAV parameters in two years (2013 and 2014), during the aforementioned change in water levels and temperatures. However, these differences were not observed across all years or for the mean of all years, indicating that the overall area is not impaired with respect to the SAV community, but nonetheless that the SAV IBI may have limited use in detecting change. Sites are affected both inside and outside the AOC, which emphasizes the importance of delisting criteria that 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.

	SNAT				CC				PCOV			
Wetland Name	**2012**	**2013**	**2014**	**2015**	**2012**	**2013**	**2014**	**2015**	**2012**	**2013**	**2014**	**2015**
AOC sites												
Carpin Beach	3.33	4.50	2.16	1.50	5.08	6.69	0.38	0.00	1.86	2.46	0.02	0.14
Echo Bay	10.0	6.33	3.83	10.0	8.03	7.94	6.31	8.96	9.22	6.00	1.32	2.38
Lake George	5.83	5.66	2.66	4.00	4.99	7.46	1.17	3.03	4.91	3.49	0.93	0.15
Pumpkin Point	5.33	4.16	1.17	2.16	7.60	3.79	0.00	1.06	3.08	2.02	0.00	0.00
Maskinonge Bay	10.0	10.0	10.0	10.0	9.10	9.67	10.0	10.0	8.95	9.50	8.79	6.67
West Shore, St. Joseph Island	2.33	2.16	0.83	2.00	1.46	2.17	0.00	0.25	0.54	0.00	0.00	0.00
Non-AOC sites												
Anderson Creek	-	10.0	6.83	10.0	-	8.77	8.19	10.0	-	4.71	1.10	1.19
Desbarats Wetland	10.0	10.0	10.0	10.0	9.04	10.0	9.27	9.69	10.0	10.0	6.19	4.62
Stobie Creek	8.99	10.0	10.0	10.0	8.55	9.46	8.84	9.63	7.64	9.94	7.06	7.09
Hay Bay Wetland	5.33	5.00	4.33	2.50	3.50	5.19	2.31	1.69	3.29	1.25	0.28	0.00
Joe Dollar Bay Wetland	6.49	9.82	4.33	5.66	4.35	7.38	4.96	4.68	4.91	6.28	4.39	3.45

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

Table 9: 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.

	SAV IBI				
Wetland Name	*2012*	*2013*	*2014*	*2015*	***Mean***
AOC sites					
Carpin Beach	34.3	45.5	8.5	5.5	**23.4**
Echo Bay	90.8	67.6	38.2	71.1	**66.9**
Lake George	52.4	55.4	15.9	23.9	**36.9**
Pumpkin Point	53.4	33.2	3.9	10.8	**25.3**
Maskinonge Bay	93.5	97.3	96.0	88.9	**93.9**
West Shore, St. Joseph Island	14.4	14.4	2.8	7.5	**9.8**
Non-AOC sites					
Anderson Creek	-	78.3	53.7	70.6	**67.5**
Desbarats Wetland	96.8	100.0	84.9	81.0	**90.7**
Stobie Creek	83.9	98.0	86.3	89.1	**89.3**
Hay Bay Wetland	40.4	38.1	23.1	14.0	**28.9**
Joe Dollar Bay Wetland	52.5	78.3	45.6	46.0	**55.6**

7. 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 samples in previous years contained far fewer than 150 individuals.

A full list of aquatic macroinvertebrates can be found in Appendix 3.

Results

Although Cvetkovic and Midwood (2015a) developed an invertebrate IBI based on the WQI, it was later determined that none of the candidate metrics were suitable for creating an IBI, and also that there were no single metrics that could be used to assess the aquatic macroinvertebrate condition (Cvetkovic and Midwood 2015c).

Discussion

The difficulty in developing an aquatic macroinvertebrate IBI reiterates the fact that relatively little disturbance occurs in the St. Marys River. Without a large continuum of disturbance, the biotic communities, both inside and outside the AOC, are similarly in relatively undisturbed condition. Note that this does not imply that any IBIs developed would not able to differentiate the degraded sites from those in better condition; rather, there appears to be little difference in condition among sites, and consequently that severe degradation is no longer occurring in this AOC. This similarity in condition suggests that the aquatic macroinvertebrate biotic community can be considered no longer impaired.

8. 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% marsh habitat (i.e., non-woody emergent plants) within the sampling radius (100 m) were surveyed. Marsh bird surveys were conducted using a 15 minute point count as follows: 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.

Results

All 11 wetlands were surveyed for birds in 2015. Echo Bay and Lake George were the only sites that had area-sensitive marsh-nesting obligates present during the surveys. Specifically, Lake George had Black Tern (*Chlidonias niger*) and American Bittern (*Botaurus lentiginosus*) present, while Echo Bay had Black Tern present. A full list of species recorded during the survey within 100 metres of the station can be found in Appendix 3.

Discussion

Area sensitive marsh nesting obligates such as Black Tern and American 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 consistently 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.

Although Cvetkovic and Midwood (2015a) previously developed potential marsh breeding bird IBIs in the St. Marys River AOC, validation with 2015 data proved unsuccessful wherein the developed IBIs responded poorly to the disturbance gradient. Thus, the potential IBIs were considered unsuitable to determine sensitivity of the wetland sites to disturbance. Again, the lack of sensitivity to disturbance suggests that sites are in relatively undisturbed condition. As sites inside and outside the AOC are in comparable condition, the marsh bird biotic community can be considered not impaired.

9. 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 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 tested 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 unsuitable for IBI development. Furthermore, there were no clear relationships between amphibian metrics and disturbance gradients.

Results

Eleven wetlands were surveyed for amphibians in 2015, while ten (excluding Anderson Creek) were surveyed in 2013-2014. As described above, no amphibian IBI was developed due to insufficient response of metrics to disturbance.

Using combined 2013-2015 amphibian data, Green Frog (*Rana clamitans melanota*) and Spring Peeper (*Pseudacris crucifer*) were present in every site, followed by Wood Frog (*Lithobates sylvaticus*), Gray Treefrog (*Hyla versicolor*), American Toad (*Anaxyrus americanus*), and Northern Leopard Frog (*Lithobates pipiens*) at ten of eleven sites. Mink Frog (*Lithobates septentrionalis*) was recorded in eight sites and Bullfrog (*Lithobates catesbeianus*) was only recorded once, in Desbarats in 2013. Desbarats had the highest mean species richness (2013-15) of all sites, recording all eight species, while Carpin Beach and Stobie Creek had the fewest, recording only five species. Species richness for AOC wetlands ranged from five to seven species and six to eight for non-AOC wetlands. A full list of species recorded during 2015 surveys within 100 metres of the station can be found in Appendix 4.

Discussion

The continued difficulty in creating an amphibian IBI suggests that the disturbance gradients for the region are not sufficient to detect strong responses from the amphibian community attributes. Nonetheless, without a sharp delineation between sites inside and outside the AOC with respect to the disturbance gradients used here, the amphibian community in the St. Marys River may be considered not impaired.

In an additional caveat, the amphibian community metrics were based on expected (within species range) species at each wetland. The list of expected species was set the same for all surveyed wetlands to aid in IBI analysis given the relatively small geographic range and limited number of other amphibian surveys in the area. Although necessary for analysis, the standardization of expected species across all sites may have diminished any subtle species or guild differences found among wetlands, therefore reducing the ability to develop an IBI that accurately detects changes and responses in the amphibian community.

At this time, with no clear response of the amphibian community to different disturbance gradients, it is recommended that the St. Marys River be considered not impaired for this biotic community.

10. Summary

Water Quality and Biotic Community

Based on data collected in the four surveyed 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 condition for water quality and biotic communities. Statistical comparisons showed no statistical difference between wetlands located in the AOC versus outside the AOC for any water quality parameter for any year, suggesting that the water quality in the St. Marys River is comparable and therefore not impaired. While the SAV parameters of SNAT and FQI showed statistical differences in AOC versus non-AOC wetlands during 2013 and 2014, statistical differences were not observed across all years, indicating that the overall area is not impaired with respect to the SAV community.

Development of IBIs

An IBI was developed for the SAV community, but IBIs could not be developed for marsh bird, aquatic macroinvertebrate, and amphibian communities in the St. Marys River. 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, and generally remained low in 2015. 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 if differences are mitigated by the multi-year data when averaged by wetland.

The increase in water levels observed in the St. Marys River from 2012 to 2013, 2013 to 2014, and 2014 to 2015 may have had significant impacts on the biotic communities measured here. 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 (Crewe and Timmermans 2005).

Wetlands were sampled in the St. Marys River from 2012 to 2015, totalling 43 site years. Despite this, development of an amphibian IBI has consistently proved unsuccessful, and other biotic communities generally showed weak to no response to disturbance. Validation of potential IBIs developed in 2014 proved successful with only the SAV community; potential IBIs for the marsh bird and invertebrate community did not show a strong response to disturbance, which rendered them unsuitable for reporting on community condition. Accordingly, IBIs cannot be used in the St. Marys River to assess wetland condition in most biotic communities.

The exception of the SAV IBI in responding to disturbance and its ability to detect change in wetland condition suggests that this IBI is tied strongly to the geophysical parameters of the WQI, although it represents only a portion of overall wetland condition. Therefore, using IBIs to assess overall wetland condition in the St. Marys River remains unsuitable, resulting in a strong indication that the area is not impaired with respect to the marsh breeding bird, aquatic macroinvertebrate, and amphibian biotic communities.

The narrow range of WQI values and overall high water quality in the area, combined with the fact that IBIs cannot be developed for several biotic communities, suggest that the range of disturbance in the St. Marys River is no longer strong enough to warrant a corresponding response in the biota. Therefore, with sites condition inside and outside the AOC being comparable, it is recommended that the St. Marys River be considered no longer impaired for criterion (i) of BUI #14: *Loss of Fish and Wildlife Habitat* as well as coastal wetland bird and amphibian (frogs and toads) populations in BUI #3: *Loss of Fish and Wildlife Populations*.

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Appendices

Appendix 1: List of taxa recorded on submerged aquatic vegetation surveys for 2015 showing nativeness, turbidity tolerance (√ = tolerant, X = intolerant) and coefficient of conservatism (for vascular species).

Common Name	Genus/Species	Native	Turbidity-Tolerant	Coefficient of Conservatism
Algae	Algae sp. (fil. underwater)	√		
Algae	Algae sp. (fil. surface)	√		
Bladderwort	*Utricularia* sp.	√		
Brittlewort	*Nitella* sp.	√		
Broad-leaved Arrowhead	*Sagittaria latifolia*	√		4
Canada Waterweed	*Elodea canadensis*	√	√	4
Claspingleaf pondweed	*Potamogeton perfoliatus*	√		7
Common Bladderwort	*Utricularia vulgaris*	√		4
Common burreed	*Sparganium eurycarpum*	√		3
Common Three-square	*Schoenoplectus pungens*	√		6
Coontail, Hornwort	*Ceratophyllum demersum*	√	√	4
Eurasian Water Milfoil	*Myriophyllum spicatum*		√	
Fern Pondweed	*Potamogeton robbinsii*	√	X	7
Flat-leaved Bladderwort	*Utricularia intermedia*	√		
Flat-stemmed Pondweed	*Potamogeton zosteriformis*	√	X	5
Floating-leaved Burreed	*Sparganium fluctuans*	√		9
Floating-leaved Pondweed	*Potamogeton natans*	√		5
Greater Duckweed	*Spirodela polyrhiza*	√		4
Hardstem Bulrush	*Schoenoplectus acutus*	√		6
Lakebank sedge	*Carex lacustris*	√		5
Leafy Pondweed	*Potamogeton foliosus*	√	√	4
Marsh St. John's Wort	*Triadenum virginicum*	√		
Narrow-leaved Cattail	*Typha angustifolia*	√		3
Needle Spikerush	*Eleocharis acicularis*	√		
Northern Water Milfoil	*Myriophyllum sibiricum*	√	X	6
Pickerelweed	*Pontederia cordata*	√		7
Purple Loosestrife	*Lythrum salicaria*			
Pygmy Water Lily	*Nymphaea tetragona*	√		
Richardson's, Clasping Leaved Pondweed	*Potamogeton richardsonii*	√		5
Seven-angled pipewort	*Eriocaulon aquaticum*	√		9
Slender Naiad	*Najas flexilis*	√	X	5
Slender Pondweed	*Potamogeton pusillus*	√	√	5
Softstem Bulrush	*Schoenoplectus tabernaemontani*	√		5
Spike-Rush	*Eleocharis smallii*	√		6
Star Duckweed	*Lemna trisulca*	√		4
Stonewort, Muskgrass	*Chara* sp.	√		
Tape Grass, Water Celery	*Vallisneria americana*	√	X	6
Threeway sedge	*Dulichium arundinaceum*	√		7
Variable-leaved Pondweed	*Potamogeton gramineus*	√		4
Vasey's pondweed	*Potamogeton vaseyi*	√		8

Common Name	Genus/Species	Native	Turbidity-Tolerant	Coefficient of Conservatism
Water horsetail	*Equisetum fluviatile*	√		7
Watershield	*Brasenia schreberi*	√		7
Water Smartweed	*Polygonum amphibium*	√		5
Water Star-grass	*Heteranthera dubia*	√	√	7
Water-Marigold	*Megalodonta beckii*	√	X	8
White Water Lily, Fragrant Water Lily	*Nymphaea odorata*	√		5
Whorl-leaf Water Milfoil, Bracted Water Milfoil	*Myriophyllum verticillatum*	√		7
Wild Rice	*Zizania palustris*	√		9
Yellow Pond Lily, Bullhead Lily	*Nuphar lutea* ssp. *variegata*	√		4

Appendix 2: List of aquatic macroinvertebrate species identified to the lowest taxonomic unit possible from 2015 samples.

Phylum	Class	Order	Family	Genus/Species
Annelida	Clitellata	Arhynchobdellida	Erpobdellidae	
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	*Alboglossiphonia heteroclita*
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	*Glossiphonia complanata*
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	*Helobdella sp.*
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	*Helobdella stagnalis*
Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae	*Helobdella triserialis*
Annelida	Oligochaeta			
Arthropoda	Arachnida	Hydracarina		
Arthropoda	Crustacea	Amphipoda		
Arthropoda	Crustacea	Amphipoda	Gammaridae	*Gammarus fasciatus*
Arthropoda	Crustacea	Amphipoda	Gammaridae	*Gammarus sp.*
Arthropoda	Crustacea	Amphipoda	Hyalellidae	*Hyalella azteca*
Arthropoda	Crustacea	Decapoda	Cambaridae	*Orconectes sp.*
Arthropoda	Crustacea	Isopoda	Asellidae	*Caecidotea sp.*
Arthropoda	Crustacea	Isopoda	Asellidae	*Lirceus 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	*Tropisternus sp.*
Arthropoda	Insecta	Collembola		
Arthropoda	Insecta	Diptera	Ceratopogonidae	
Arthropoda	Insecta	Diptera	Ceratopogonidae	*Bezzia/Palpomyia*
Arthropoda	Insecta	Diptera	Chironomidae	
Arthropoda	Insecta	Diptera	Chironomidae	*Tanypodinae sp.*
Arthropoda	Insecta	Diptera	Sciomyzidae	
Arthropoda	Insecta	Ephemeroptera	Baetidae	
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Callibaetis sp.*
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Cloeon dipterum*
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Procloeon/Centroptilum*
Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis sp.*
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	*Eurylophella 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.*
Arthropoda	Insecta	Hemiptera	Mesoveliidae	*Mesovelia sp.*
Arthropoda	Insecta	Hemiptera	Nepidae	*Ranatra sp.*
Arthropoda	Insecta	Hemiptera	Notonectidae	*Notonecta sp.*
Arthropoda	Insecta	Hemiptera	Pleidae	*Neoplea sp.*
Arthropoda	Insecta	Lepidoptera	Crambidae	*Acentria sp.*

Phylum	Class	Order	Family	Genus/Species
Arthropoda	Insecta	Lepidoptera	Crambidae	*Elophila sp.*
Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis 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	Calopterygidae	*Calopteryx 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	Corduliidae	
Arthropoda	Insecta	Odonata	Corduliidae	*Epitheca (Tetragoneuria)*
Arthropoda	Insecta	Odonata	Gomphidae	*Stylurus sp.*
Arthropoda	Insecta	Odonata	Lestidae	*Lestes sp.*
Arthropoda	Insecta	Odonata	Libellulidae	*Leucorrhinia sp.*
Arthropoda	Insecta	Odonata	Libellulidae	*Leucorrhinia/Sympetrum*
Arthropoda	Insecta	Odonata	Libellulidae/Corduliidae	
Arthropoda	Insecta	Trichoptera	Helicopsychidae	*Helicopsyche sp.*
Arthropoda	Insecta	Trichoptera	Hydroptilidae	*Agraylea sp.*
Arthropoda	Insecta	Trichoptera	Hydroptilidae	*Oxyethira sp.*
Arthropoda	Insecta	Trichoptera	Leptoceridae	
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.*
Mollusca	Bivalvia	Veneroida	Pisidiidae	
Mollusca	Bivalvia	Veneroida	Pisidiidae	*Musculium 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	*Pseudosuccinea sp.*
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	*Helisoma/Planorbella*
Mollusca	Gastropoda	Basommatophora	Planorbidae	*Promenetus sp.*
Mollusca	Gastropoda	Mesogastropoda	Valvatidae	*Valvata sp.*
Mollusca	Gastropoda	Mesogastropoda	Valvatidae	*Valvata tricarinata*
Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	
Platyhelminthes	Turbellaria	Tricladida		

Appendix 3: List of species recorded within 100 m on marsh breeding bird surveys in 2015.

Species Common Name	Scientific Name	Marsh User	Forager
Alder Flycatcher	*Empidonax alnorum*	NA	AF
American Bittern	*Botaurus lentiginosus*	AEMNO	WF
American Black Duck	*Anas rubripes*	MNG	WF
American Crow	*Corvus brachyrhynchos*	NA	NAF
American Goldfinch	*Carduelis tristis*	NA	NAF
American Redstart	*Setophaga ruticilla*	NA	NAF
American Robin	*Turdus migratorius*	NA	NAF
American Wigeon	*Anas americana*	NA	WF
Bald Eagle	*Haliaeetus leucocephalus*	NA	AF
Bank Swallow	*Riparia riparia*	NA	AF
Barn Swallow	*Hirundo rustica*	NA	AF
Belted Kingfisher	*Ceryle alcyon*	NA	AF
Black Tern	*Chlidonias niger*	AEMNO	AF
Black-capped Chickadee	*Parus atricapillus*	NA	NAF
Blue Jay	*Cyanocitta cristata*	NA	NAF
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
Common Goldeneye	*Bucephala clangula*	NA	WF
Common Grackle	*Quiscalus quiscula*	NA	NAF
Common Loon	*Gavia immer*	MNG	WF
Common Merganser	*Mergus merganser*	NA	WF
Common Moorhen	*Gallinula chloropus*	EMNO	WF
Common Raven	*Corvus corax*	NA	NAF
Common Tern	*Sterna hirundo*	NA	AF
Common Yellowthroat	*Geothlypis trichas*	MNG	NAF
Double-crested Cormorant	*Phalacrocorax auritus*	NA	WF
European Starling	*Sturnus vulgaris*	NA	NAF
Gadwall	*Anas strepera*	NA	WF
Great Blue Heron	*Ardea herodias*	NA	WF
Green-winged Teal	*Anas crecca*	NA	WF
Hairy Woodpecker	*Picoides villosus*	NA	NAF
Hermit Thrush	*Catharus guttatus*	NA	NAF
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
Mallard	*Anas platyrhynchos*	NA	WF
Marsh Wren	*Cistothorus palustris*	EMNO	NAF
Merlin	*Falco columbarius*	NA	AF
Northern Flicker	*Colaptes auratus*	NA	NAF
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	NA	AF
Northern Shoveler	*Anas clypeata*	NA	WF
Northern Waterthrush	*Seiurus noveboracensis*	NA	NAF
Osprey	*Pandion haliaetus*	NA	AF
Pied-billed Grebe	*Podilymbus podiceps*	EMNO	WF
Pine Warbler	*Dendroica pinus*	NA	NAF
Red-winged Blackbird	*Agelaius phoeniceus*	MNG	NAF

Species Common Name	Scientific Name	Marsh User	Forager
Ring-billed Gull	*Larus delawarensis*	NA	AF
Sandhill Crane	*Grus canadensis*	MNG	WF
Song Sparrow	*Melospiza melodia*	NA	NAF
Sora	*Porzana carolina*	EMNO	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
Wilson's Snipe	*Capella gallinago delicata*	MNG	NAF
Wood Duck	*Aix sponsa*	NA	WF
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 4: List of species recorded within 100 m on amphibian surveys in 2015.

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*