St. Marys River Area of Concern
CANADIAN SECTION

# Status of the *Degradation of Fish and Wildlife Populations* Beneficial Use Impairment

October 2023

# Executive Summary

In 1987, Canada and the United States designated the St. Marys River as one of 43 Areas of Concern (AOC) in the Great Lakes basin, and both countries committed to restoring it under the Canada-U.S. Great Lakes Water Quality Agreement. The fish component of the *Degradation of Fish and Wildlife Populations* was identified as one of ten beneficial use impairments (BUI) in the St. Marys River Stage 1 Remedial Action Plan (RAP) in 1992 and again in the Stage 2 RAP (2002). The wildlife component was never deemed impaired, but instead was determined to "Require Further Assessment".

Since the river was designated as an AOC, vast improvements have been made to help restore water quality and ecosystem health. This report provides a summary on these improvements that have helped to support healthy fish and wildlife populations in the St. Marys River.

This document serves as an official record to account and recommend a change in status, on the Canadian side of the St. Marys River AOC, of the *Degradation of Fish and Wildlife Populations* BUI to "Not Impaired". The re-designation is supported by studies that address the Stage 2 RAP recommended actions on fish and wildlife and that showcase how the delisting criteria have been met. Specifically:

- Fisheries and Oceans Canada completed an overall assessment of the AOC fish community using the index of biotic integrity (IBI) approach in two separate studies. Both studies conclude the St. Marys River is home to a relatively healthy fish community that is complex, diverse, and dominated by native species (Appendix 1a, 1b).
- Results from the binational St. Marys River Fisheries Task Group's fish community gillnet survey and the river-wide Creel survey were used to confirm the status of managed[1] fish populations, with key findings revealing that managed fish populations appear to be stable or increasing (Appendix 2a, 2b).
- The wildlife component of the *Degradation of Fish and Wildlife Populations* BUI was designated as "Requires Further Assessment" in the Stage 1 and Stage 2 RAP reports (never deemed Impaired), and there were specific monitoring actions recommended in the Stage 2 RAP as the means to study the matter (i.e., Actions FFM-2, FFM-5, FFM-6, and FFM-8). These actions were completed, and an assessment of wildlife populations completed in September 2018 (Derickx, 2018) found wildlife to be in good condition and conclude it is not impaired (Appendix 3a-c).

A community review and engagement period on the assessment results and proposed re-designation was completed. Feedback and suggestions were taken into consideration and incorporated within this document as appropriate. At the end of the engagement period there were no objections to the recommendation to redesignate the *Degradation of Fish and Wildlife Populations* BUI to 'not impaired". A detailed account of the engagement process can be found in Appendix 4.

[1] These studies helped to assess the sport fisheries and to supplement the Index of Biotic Integrity approach that looks at nearshore fish communities. All the studies combined help to complement each other and showcase a picture of the fish populations in the St. Marys River as a whole.

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# 1.0 Introduction

## 1.1 The St. Marys River Area of Concern

The St. Marys River is a 112km binational waterway that connects Lake Superior to the North Channel of Lake Huron. The St. Marys River is one of the 43 Great Lakes Areas of Concern originally identified under *the Canada-United States Great Lakes Water Quality Agreement* (GLWQA). An Area of Concern (AOC) is a location with historically significant environmental impairment resulting from human activities at the local level. The St. Marys River, as a connecting channel, is one of five AOCs jointly shared by Canada and the United States.

The Canadian portion of the AOC extends from its head at Gros Cap in Whitefish Bay downstream to St. Joseph Island via Lake George to Quebec Bay in the St. Joseph Channel and downstream to Hay Point on the western shore of St. Joseph Island (Figure 1).

The St. Marys River AOC has a Remedial Action Plan that identifies the original beneficial use impairments and guides efforts to restore beneficial uses. Beneficial Use Impairments (BUIs) are reductions in the chemical, physical, or biological integrity of the area sufficient to cause environmental issues. These environmental problems were first identified in the Stage 1 RAP report (1992). In 2002, a number of remedial actions and monitoring initiatives to address the problems were identified, and restoration efforts have been underway since.

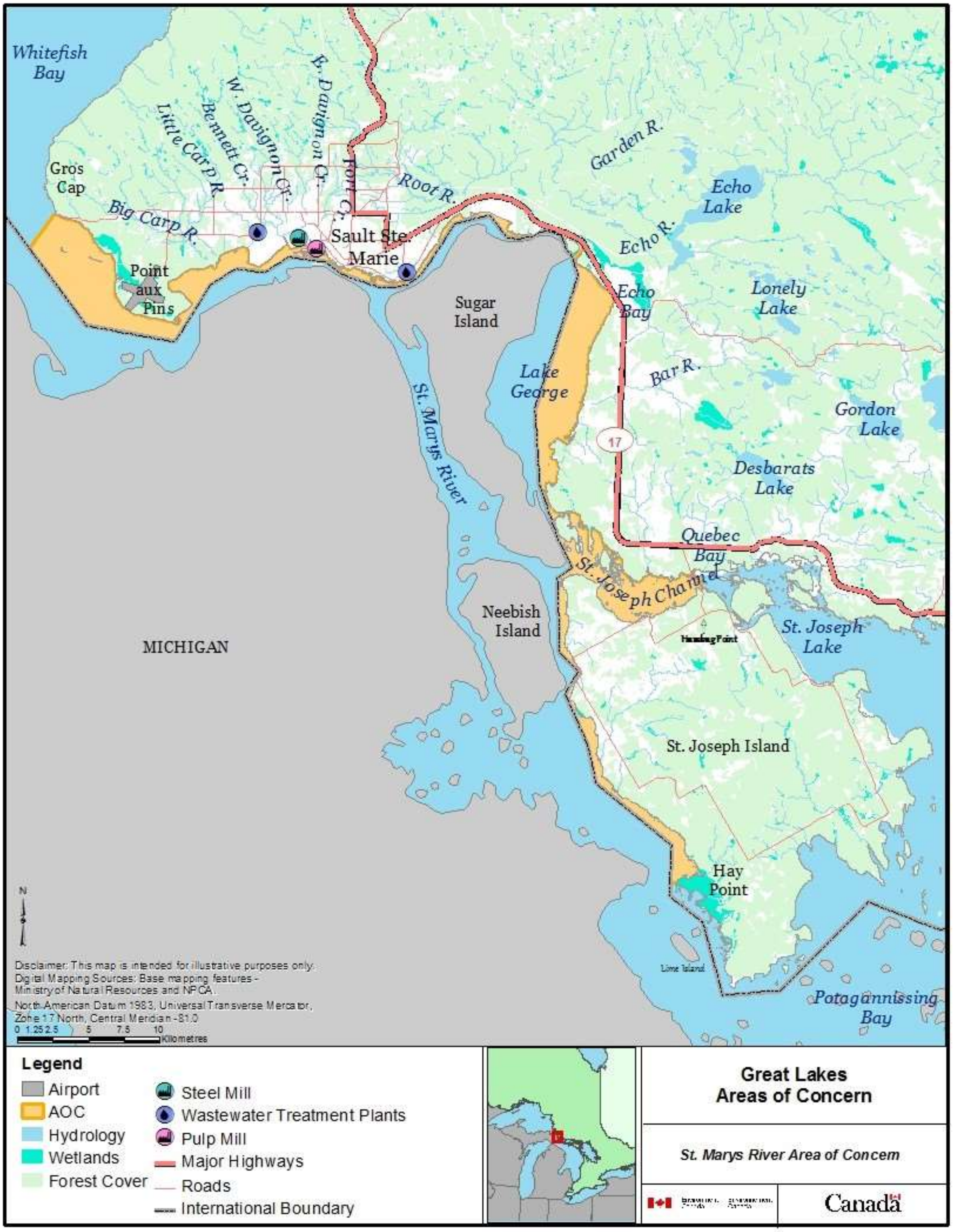


*Figure 1: St. Marys River Area of Concern Map (Canadian Section).*

## 1.2 Beneficial Use Impairment

The *Degradation of Fish and Wildlife Populations* BUI was listed as “Impaired” in the Stage 1 RAP report (1992) because native fish populations were being effected by habitat alteration, overfishing, pollution and invasive species. Although at the time wildlife populations appeared to be stable or increasing, it was noted that assessment criteria were needed to determine whether wildlife populations were impaired; and therefore further assessment was required.

The Stage 2 RAP report (2002) outlines a strategy to remediate the impaired beneficial uses identified in the St. Marys River AOC. It details 57 recommended actions to restore beneficial uses on both the Canadian and U.S. side of the AOC. The specific recommended actions for the *Degradation of Fish and Wildlife Populations* BUI on the Canadian side of the AOC are:

**Fish Populations**
Action FF-7: Develop a 10-year fisheries assessment program for the river
Action FF-8: Continued support for Sea Lamprey control efforts
Action FFM-3: The Fish Harvest Survey

**Wildlife populations**

Action FFM-2: Continued support for the Marsh Monitoring Program
Action FFM-5: Complete an assessment of Common and Black Tern populations for the area
Action FFM-6: Analyze contaminant levels in eggs from Herring Gull, Black Tern, and Common Tern nests in the AOC
Action FFM-8: Assessments of Herring Gulls, Black Terns and Common Terns within the AOC

## 1.3 Additional Actions

In addition to the actions outlined in the Stage 2 RAP report, other actions have been implemented that have helped to improve conditions for fish and wildlife populations. These actions are outlined below and are documented in the St. Marys River Interactive Map[2]. The online map highlights projects and progress made since the St. Marys River was first designated as an Area of Concern under the Great Lakes Water Quality Agreement.

- Fort Creek Clean-up:
  - In 2009, the Sault Ste. Marie Region Conservation Authority (SSMRCA) completed improvements to Fort Creek south of Second Line by planting trees, improving flow through sediment and garbage removal, and by establishing a pond to attract wildlife.

[2] The interactive map can be accessed here: http://bpac.algomau.ca/?page_id=76

- Bar River Restoration Project:
    - The community-driven Bar River Habitat Project improved stream bank and riparian zone conditions through the planting of trees and the restriction of livestock to the St. Marys River. The project was formed in 1999 by a local chapter of Scouts Canada as well as teachers and students from Central Algoma Secondary School, who worked with Environment and Climate Change Canada and the Ministry of Natural Resources and Forestry to plant spruce, cedar and hardwood species along three areas in the upper reaches of the Bar River while reinforcing banks against erosion (CWS, 2013).
- Improvements to Water Quality:
    - The East End Waste Water Treatment Plant was upgraded in 2006, which has improved water quality by reducing suspended solids, phosphorus levels, biological oxygen demand, and significantly reducing nitrogen and ammonia levels in water discharged. These upgrades allowed for secondary treatment of water, including Ontario's first biological nutrient removal and ultraviolet light disinfection, which prevents chlorine from being released into the St. Marys River.
    - A study conducted by Algoma University from 2013-2015 found no large algal blooms or high concentrations of microscopic algae. There was also no evidence of unnatural colour, odour, or turbidity indicating resolved problems associated with degraded aesthetics (Ginou, 2016).
    - Starting the early 1980s, Algoma Steel has worked to improve its operations and to reduce the impact it has on the quality of the river and the surrounding environment. Algoma Steel has worked to improve sources of water pollution in many ways such as the creation of a main water filtration plant, decommissioning of settling ponds, installation of a biological treatment facility and toxicity control system, as well as improving overall water re-use efficiency.
    - Once a source of historical pollution for the river, the St. Marys Paper Mill was decommissioned in 2012. The site was dismantled, removing it as a pollution source for the river.

## 1.4 Delisting Criteria

In 2015, the suite of BUI delisting criteria were finalized for the Canadian side of the AOC, including that for the *Degradation of Fish and Wildlife Populations* BUI to account for local circumstances, link to relevant regulations or guidelines, and to be specific, measurable, achievable, relevant, and time-oriented ("SMART"). The delisting criteria for fish component of the *Degradation of Fish and Wildlife Populations* states that the BUI will no longer be impaired when:

> *The overall fish community health within the AOC is comparable to that of a suitable reference site, as assessed using an index of biotic*

*integrity through a minimum of two consecutive studies.*

At the time, it was decided that other information/data sources would be used to supplement the IBI approach. Specifically, results from the binational St. Marys River Fisheries Task Group's fish surveys would be used to confirm the status of "managed" fish populations.

In the Stage 1 and 2 RAP reports, the wildlife portion of the BUI was never deemed "Impaired" but instead "Required Further Assessment" because assessment criteria were absent to help determine the status. Delisting criteria are only appropriate for when a beneficial use is impaired, but the assessment of the wildlife component follows established methods for evaluating wildlife health and ecosystem conditions so as to conclude if there is impairment. These studies are summarized in section 3.2 and included in full in Appendix 3a-c.

# 2.0 Degradation of Fish Populations

## 2.1 Summary of Impairment

At the time of the Stage 1 RAP report in the early 1990s, reductions in fish populations in the St. Marys River was suspected due to alteration of fish spawning habitat, overfishing, exotic species and decreases in benthos populations. In 2002, the Stage 2 RAP report recommended looking at fish population dynamics in order to assess whether local environmental conditions support healthy, self-sustaining communities of fish. This was not to be limited to population levels, but overall fish community health. Similar to concerns raised during in the Stage 1 RAP report, the Stage 2 RAP report also noted that native fish populations were being stressed by habitat alteration, over-fishing, pollution, and invasive species. Concerns with fish body burdens were also identified in the Stage 2 RAP report linked to polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and resin acids. Since the impact of these contaminants on fish are addressed in other BUIs, namely *Restrictions on Fish Consumption* and *Fish Tumours and Other Deformities*, the focus of this BUI was kept to fish population dynamics when the delisting criteria were revised in 2015.

## 2.2 Stage 2 Recommended Remedial Actions Specific to Fish Population Dynamics

### *2.2.1 Develop a 10 year fisheries assessment program for the river (Action FF-7)*

In 2002, the St. Marys River Fisheries Task Group completed a Fisheries Assessment Plan. This plan provides a standardized approach for regular assessment of the river's fishery and aquatic resources. Included are approaches for fish community assessment, fish harvest estimates and reporting, lower trophic level monitoring, and habitat mapping and data collection. The plan serves as a mutual and coordinated approach to assessment and ensures coordination of management actions for the St. Marys River Fishery through the Great Lakes Fishery Commission's Lake Huron Committee (Gerbhardt et al. 2002).

As part of the Fisheries Assessment Plan, the St. Marys Fishery Task Group has ongoing fish community surveys that occur every 3-5 years. These surveys provide managers with the necessary information and data to make informed decisions about the management of fish communities within the river. Fish community objectives for the St. Marys River are currently being developed (Godby et al. 2019).

This action is considered addressed because fisheries resource management is led by the binational St. Marys River Fishery Task Group under the Great Lakes Fisheries Commission, which functions independently of the RAP.

### *2.2.2 Continued support for Sea Lamprey control efforts (Action FF-8)*

Although the production of Sea Lamprey from the St. Marys River has been a serious problem for salmonine management in the Great Lakes, the overall presence of migrating adults in the river is not believed to be a significant factor affecting the rest of the river's fish community (Gerbhardt et al. 2002).

Overall, Sea Lamprey wounding rates remain low in the St. Marys River with 0.2% of the total fish collected during a 2017 fish community survey exhibiting a Sea Lamprey wound. Sea Lamprey management within the St. Marys River encompasses both the assessment of adult and larval populations within the river as well as targeted treatment of larval populations. Sea Lamprey assessment and control within the St. Marys River is an ongoing priority operation of DFO's Sea Lamprey Control Centre in Sault Ste. Marie, Ontario (O'Connor et al. 2019).

This action is considered addressed because aquatic invasive species are a lake- and basin-wide management issue, and not a local AOC-specific issue. And as noted above, there are dedicated programs led by the Sea Lamprey Control Centre under DFO, which functions independently of the RAP.

### *2.2.3 The Fish Harvest Survey (Action FFM-3)*

In order to quantify the sport fisheries, the Michigan Department of Natural resources (MDNR) and the Ontario Ministry of Natural Resources and Forestry (MNRF) undertook an open water access creel survey of sport anglers (Godby et al 2019). This was accompanied by a fish community gillnet survey of the river by the St. Marys River Fisheries Task Group and its member agencies. The general conclusion is that managed fish populations are stable or increasing, with key findings from Godby et al. that include:

- Northern Pike harvest and harvest rate are still lower than they were historically but are trending upwards.
- Smallmouth Bass are plentiful in the river and angler harvest and harvest rate remain substantially higher than in 1999.
- Walleye continue to be an important sport fish in the St. Marys River. Overall harvest and harvest rate of Walleye have declined since 2007, but both are higher than they were in 1999.
- Yellow Perch support a popular fishery in the river. Although overall harvest of Yellow Perch is down in 2017 compared to previous years, harvest rate has remained stable over the survey series (Godby et al. 2019).

And the key findings from the 2017 fish community gillnet survey (O'Connor et al. 2019) include:

- Walleye catch per unit effort (CPUE) has remained stable from 2006-2017, after increasing from a survey low in 2002. Overall in 2017, Walleye appear to be well distributed throughout the St. Marys River.
- In 2017, Northern Pike CPUE continued to improve, reversing the downward trend that began in 2002. Although the CPUE has not returned to pre-2002 levels, it has rebounded to more than double that of its lowest point, measured in 2009.
- Yellow Perch abundance decreased in 2017 but the mean CPUE is just below the survey average and the overall trend remains positive since the first survey in 1975.
- Cisco appear to be less abundant in recent years although the overall trends in gillnet CPUE were not significantly different (O'Connor et al. 2019).

#### *2.2.4 Assessment of Fish Populations using Index of Biotic Integrity*

In 2009, DFO (Pratt & O'Connor, 2011) compared the status of communities from four distinct areas of the river including the upper river above the compensating works, the main river, Lake George and the lower river. They provided an overall assessment of the fish community using an index of biotic integrity (IBI) approach. An IBI is a scientific tool used to identify and classify faunal communities. Several matrices are used to provide an overall assessment of fish community including mortality rates, age-class structure, survival to spawning age, reproductive success, total biomass, productivity, richness, assemblage, and abundance. The study concluded that the overall health of the St. Marys River fish community compared favourably with healthy reference sites from Lake Huron.

In 2014, DFO (O'Connor & Pratt, 2017) initiated a follow-up 2-year survey that again used the IBI approach called for in the BUI delisting criteria, and relied on the Mississagi River near the North Channel as the reference site. Key findings from this study include:

- Using the Great Lakes scoring system, the overall IBI score for the St. Marys River AOC is 60.3 which borders between fair (>41 -60) and good (>61-80).

- A small decline in IBI was observed between 2006-2009 and 2014-2015. The lower IBI scores can be attributed to more generalist species, lower percent piscivourous community, and lower biomass. However, these are expected and reflective of a cold-water, lower productivity, riverine environment such as the St. Marys River.
- The St. Marys River maintains a native fish community that is complex, diverse, and healthy.

Together, these studies directly answer the BUI delisting criteria and present a case for not impaired status, because: fish community health was assessed using an index of biotic integrity approach and in these two consecutive studies the health of the AOC fish community was found to be comparable to suitable reference sites.

### 2.3 Conclusions for Fish Populations

The delisting criteria for the *Degradation of Fish and Wildlife Populations* states that the BUI will no longer be impaired when *the overall fish community health within the AOC is comparable to that of a suitable reference site, as assessed using an index of biotic integrity through a minimum of two consecutive studies*. The two fish community studies by DFO that use an IBI approach show AOC fish populations "compare relatively well" to reference areas and the IBI score for the St. Marys River fish community borders between fair and good. In addition, supplemental assessments and work completed under Actions FF-7, FF-8, and FFM-3 (described above) all show that the St. Marys River is home to a relatively healthy fish community that is complex, diverse and dominated by native species, and has managed fish populations that are stable or increasing. It is therefore recommended a change in status from Impaired to Not Impaired.

## 3.0 Degradation of Wildlife Populations

### 3.1 Summary of Impairment

In the Stage RAP reports, the wildlife portion of the *Degradation of Fish and Wildlife Populations* BUI was designated as "Requires Further Assessment". Although wildlife populations appeared to be stable or increasing, it was noted assessment criteria were needed to evaluate their status. In the early 1990s, Common Tern (*Sterna hirundo*) populations were declining while Ring-billed Gull (*Larus delawarensis*) numbers were increasing. As stated in the Stage 1 RAP report, habitat loss and alteration were causing a reduction in nesting habitat and the larger, earlier nesting Ring-billed Gulls were displacing Common Terns along with other smaller species from nesting sites. In addition, both the Stage 1 and 2 RAP reports noted chemical contaminants within the tissues of waterfowl, particularly mercury and polychlorinated biphenyls (PCBs).

In response to this, the Stage 2 RAP report recommended an assessment of wildlife habitat conditions (Action FFM-2), an assessment of Common Tern and Black Tern (*Chlidonias niger*) populations for the entire St. Marys River (Action FFM-5) and a reproductive assessment of

Herring Gulls and Black and Common Terns (Action FFM-8, which fell under the *Bird and Animal Deformities or Reproductive Problems* BUI). The Stage 2 RAP report also recommended a full analysis of contaminant levels in the eggs of Herring Gulls and Black and Common Terns within the AOC (Action FFM-6). These actions and the associated studies are discussed below, because they serve to evaluate the health of wildlife populations in the AOC.

## 3.2 Stage 2 Recommended Remedial Actions Specific to Wildlife Populations

### *3.2.1 Continued Support for the Marsh Monitoring Program (Action FFM-2)*

In 2011, the Canadian RAP agencies and Binational Public Advisory Council (BPAC) discussed the need for a comprehensive assessment of wildlife habitat conditions (specifically coastal wetlands) and associated wildlife populations, and to evaluate the degree of impairment, if any. A multi-year study by Environment and Climate Change Canada's (ECCC) Canadian Wildlife Service (Darwin, 2016) started in 2012, and in August 2016, the 5-year monitoring effort was completed. The study assessed baseline wildlife habitat conditions and evaluated coastal wetland water quality, and breeding bird, amphibian, aquatic macroinvertebrate and submerged vegetation communities within the AOC, concluding the wildlife habitat and populations are not impaired. The full report is provided in Appendix 3a, but key findings included:

- Water quality within the AOC's coastal wetlands is comparable to non-AOC reference sites; suggesting overall water quality can be considered not impaired. Algoma University's water quality survey (2013-15) supports this (Ginou 2016).
- Breeding marsh birds in the AOC are in relatively undisturbed condition, and sites inside and outside the AOC are in comparable condition; suggesting there is no impairment.
- There is no clear response disturbance within the amphibian and aquatic macroinvertebrate communities, suggesting those populations are not impaired.
- There are some differences between submerged aquatic vegetation communities in the AOC versus non-AOC reference sites, but the overall area is not impaired for this community type.

### *3.2.2 Complete an Assessment of Common and Black Tern Populations for the Area (Action FFM-5)*

The Canadian RAP agencies and BPAC discussed the need to assess the populations of Common Terns and Black Terns within the AOC as per the recommendation in the Stage

2 RAP report. In 2014, ECCC completed the population assessment based on nest count surveys conducted between 2010 and 2013, which was supplemented with historical breeding data from 1978-80, 1989, 1999-00, and 2007-08 (Hughes et al. 2014b, see Appendix 3b). Population trends for colonial waterbirds breeding on the North Channel of Lake Huron were included to provide a broader context of trends in diversity and abundance within the AOC. The study concluded Commons Terns and Black Terns are breeding within the AOC, and that there is no evidence that breeding status within the AOC differs from that outside of AOC. Also, nesting and population patterns are influenced by life history strategies of the species and factors that are regional or basin-wide in nature, and not specific to influences within the AOC. The full report is provided in Appendix 3b, but key findings include:

- Despite natural fluctuations, Common Tern populations have had no significant change over the past 30 years, with 70 nests found in 1978-80 versus 78 in 2007-08.
- Evidence from nest count surveys between 1980 and 2013 suggest trends in populations of nesting Common Terns in the AOC are likely related to factors consistent with the life history strategies of the species, and are not specific to influences in the AOC.
- Black Terns seem to be limited on the Ontario side of the river, with a breeding colony found only at Echo Bay. It is not possible to report on temporal trends in abundance of Black Terns in the AOC due to limited data. However, based on the data that is available, there is no evidence to suggest that breeding status of Black Terns nesting within the AOC differs from those nesting at sites downstream in the North Channel.
- The relative low population of nesting Black Terns is likely reflective of low densities reported throughout the region, Ontario and the Great Lakes basin and not due to AOC-specific conditions.
- Overall, the total number of colonial waterbird nests on the Ontario side of the St. Marys River increased by almost 23% between 1999 and 2008; largely driven by dramatic increases in Ring-billed Gulls.

#### *3.2.3 Analyze Contaminant Levels in Eggs from Herring Gull, Black Tern, and Common Tern Nests in the AOC (Action FFM-6) and complete Reproductive Assessments of Herring Gulls, Black Terns and Common Terns within the AOC (Action FFM-8)*

In parallel to the above-mentioned assessment of Common Tern and Black Tern populations within the AOC, in 2014, ECCC also completed a three-year Common Tern and Herring Gull study based on fieldwork and laboratory analysis to assess deformities, reproductive health, and chemical contamination in eggs of these indicator species (under the *Bird and Animal Deformities or Reproductive Problems BUI*) . The study report (Hughes et al. 2014a) concludes that there is no evidence of impaired reproduction or deformities in colonial waterbirds attributable to local contamination effects within the AOC, and the reproductive success for birds studied within the AOC is similar to that from outside the AOC. The full report is provided in Appendix 3c, but the key findings include:

- Contaminant levels are low overall and not sufficiently elevated to have an adverse impact on reproductive success and development (which is an impact related to polychlorinated biphenyls (PCBs) and other organochlorines, dioxins/furans, heavy metals like mercury, and polybrominated diphenyl ethers (PBDEs)).
- No physical deformities have been detected within gull or tern chicks (the original issue identified by the RAP). There is a low incidence of embryonic deformities that cannot be linked to contaminant burdens or geographical area (i.e., there is no significant difference between AOC and non-AOC bird colonies); and the reproductive success for Herring Gulls within the AOC is high, and that of Common Terns is similar to the rest of the region.

The report supported the official re-designation of the *Bird and Animal Deformities or Reproductive Problems* BUI from "Requires Further Assessment", as identified under the Stage 2 RAP report (2002), to "Not Impaired" in January 2016 via a notification letter to the International Joint Commission. This is consistent with the same change in BUI status by the United States Environmental Protection Agency in 2014.

### 3.3 Conclusions for Wildlife Populations

All recommended remedial and monitoring actions pertaining to the wildlife component of the *Degradation of Fish and Wildlife* Populations BUI have been completed. The assessments and work completed under Actions FFM-2, FFM-5, and FFM-8 described above show that the overall health of wildlife in the St. Marys River is comparable to non-AOC areas. It is therefore recommended a change in status from Requires Further Assessment to Not Impaired.

## 4.0 Status of the Degradation of Fish and Wildlife Populations BUI in Sault Ste. Marie, Michigan

The *Degradation of Fish and Wildlife Populations* BUI removal on the U.S. side of the St. Marys River AOC became final on September 23, 2019. Subsequent to engaging BPAC on findings relating to both the *Degradation of Fish and Wildlife Populations* and *Loss of Fish and Wildlife Habitat BUIs*, the U.S. Environmental Protection Agency re-designated both BUIs to "Not Impaired" on the U.S. side of the AOC upon the recommendation of the Michigan Department of Environment, Great Lakes, and Energy. Michigan's delisting criteria for both BUIs state:

> *"The two fish and wildlife BUIs will be considered restored in the Michigan portion of the St. Marys River AOC upon completion of the Little Rapids project at Sugar Island, which would restore approximately 50 to 70 acres of fish and wildlife habitat."*

The Little Rapids restoration project was carried out between 2015 and 2016. More than 50 acres were positively impacted by the change in flow regime resulting from the removal of a causeway and construction of a bridge with 600 feet of free-flowing water beneath it. The project successfully achieved the target of restored habitat area acreage and the two BUIs were deemed “Not Impaired” in 2019 (Riley, 2019).

# 5.0 Conclusions and Recommendations Regarding Re-designation

The fish component of the *Degradation of Fish and Wildlife Populations* BUI was identified as “Impaired” in both the Stage 1 and Stage 2 RAP reports. The delisting criteria states that the BUI will no longer be impaired when: *the overall fish community health within the AOC is comparable to that of a suitable reference site, as assessed using an index of biotic integrity through a minimum of two consecutive studies*. Fisheries and Oceans Canada completed an assessment of the AOC fish community using the index of biotic integrity (IBI) approach in two separate studies, encompassing fieldwork and data analysis in 2006-08 and 2014-15. Both studies conclude the St. Marys River is home to a relatively healthy fish community that is complex, diverse, and dominated by native species. These results were shared and discussed with BPAC in October 2017. Other information and data sources have been used to supplement the IBI approach. Specifically, results from the binational St. Marys River Fisheries Task Group’s fish community gillnet survey and the river-wide Creel survey was used to confirm the status of “managed” fish populations and show they are stable or increasing.

The wildlife component of the *Degradation of Fish and Wildlife Populations* BUI was designated as “Requires Further Assessment” in the Stage 2 RAP report, and wildlife populations have since been assessed through the completion of Actions FFM-2, FFM-5, FFM-6, and FFM-8 and three studies as discussed above. Wildlife populations are found to be in good condition.

Based on the lines-of-evidence presented in this report, it is recommended that the *Degradation of Fish and Wildlife Populations* BUI for the Canadian side of the St. Marys River AOC be re-designated to “Not Impaired” since the BUI delisting criteria, as endorsed by BPAC, has been fulfilled.

# 6.0 References

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# Appendix 1a: An assessment of the nearshore fish community of the St. Marys River, Ontario (O'Connor & Pratt, 2017)

# An Assessment of the Nearshore Fish Community of the St. Marys River, Ontario

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# An Assessment of the Nearshore Fish Community of the St. Marys River, Ontario

by

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ABSTRACT

The health of the nearshore fish community in the St. Marys River, a binational Area of Concern, was assessed via night boat electrofishing over six sampling seasons, in 2006-2009, and again in 2014-15. Our objectives were to (1) determine if changes had occurred in the fish community from the previous five years; (2) assess and contrast the status of the fish community within each of the four sampling areas; (3) compare the fish community of the St. Marys River with that of the Mississagi River, a relatively undisturbed river used as a reference site; and (4) assess the current overall health of the fish community in the St. Marys River. The St. Marys River contains a diverse and complex native fish community, with consistent differences in fish communities observed among broad habitat types. There have been recently declines in the fish community coincident with higher water levels and colder water temperatures. Invasive fishes are not yet impacting the community despite being present in low numbers. The overall health of the St. Marys River fish community is considered fair, and is poorer than relatively un-impacted sites assessed from Lake Huron primarily due to the low number of piscivores captured and low overall biomass.

## INTRODUCTION

The St. Marys River, the connecting channel between Lake Superior and Lake Huron, is a 112 km long river bounded by Canada and the United States that encompasses a wide diversity of fish habitats (Bray 1996) and fish species (Duffy et al. 1987). Duffy et al. (1987) identified 75 fishes from 22 families. The greatest physical changes to the river occurred roughly between 1850 and 1930, which reduced the area of the St. Marys rapids to less than 20% of its original size through the construction of shipping locks and the development of multiple hydroelectric generating facilities (Duffy et al. 1987, Bray 1996, Ripley et al. 2011). Additional changes have included the building of a compensating works to control the outflow of Lake Superior, and ongoing dredging to support the commercial shipping industry.

The river was declared an Area of Concern (AOC) in 1987 by the International Joint Commission (IJC) as an amendment to the Great Lakes Water Quality Agreement (GLWQA 1987). The fish community was described as impaired due to the abundance of sea lamprey (*Petromyzon marinus*), the supporting of recreational and commercial fisheries through the use of stocked non-native salmonids, declining native species due to over-harvesting, the loss of fish habitat within the river, and concerns over aquatic invasive species (OMOE and MDNR 1992). As part of the AOC rehabilitation process, a Remedial Action Plan was developed for the St. Marys River which included actions to rehabilitate the fish community. The health of recreationally valuable sport fishes are determined tri-annually (since 1976) by the bi-national St. Marys River Fisheries Task Group using data from a graded mesh gillnet survey (Schaeffer et al. 2011). A baseline assessment of the broader fish community was undertaken by Liston et al. (1980; 1983) and Liston and McNabb (1986) using bottom trawls, and these data were used in conjunction with data from a recent standardized boat electrofishing survey using data from 2006-2008 to assess the health of the nearshore fish community (Pratt and O'Connor 2011).

A further update of the status of the Degradation of Fish and Wildlife Populations Beneficial Use Impairment was requested five years after the completion of the initial nearshore fish community surveys of Pratt and O'Connor (2011). Four distinct areas of the St. Marys River were sampled to: (1) determine if changes had occurred in the fish community from the previous five years; (2) assess and contrast the status of the fish community within each of the four sampling areas; (3) compare the fish community of the St. Marys River with that of the Mississagi River, a relatively undisturbed river used as a reference site for the St. Marys River fish community; and (4) assess the current overall health of the fish community in the St. Marys River. All objectives were addressed using an index of biotic integrity approach (Minns et al. 1994).

## METHODS

### STUDY SITE

The St. Marys River is the connecting channel between lakes Superior and Huron (Figure 1a). It is bounded on the upper end by Whitefish Bay (46°31'N; 84°36'W) and at the southeastern end below St. Joseph's Island (46°12'N; 83°40'W). Historically, the rapids at Sault Ste. Marie were the main feature of this river. However, modifications to the rapids area to provide for shipping through the construction of the locks, the construction of compensation gates to regulate the river flow and the development hydroelectric generating facilities drastically reduced the rapids to about 7% of its original flow (Duffy et al. 1987; Edsall and Gannon 1993). The four survey sections of the river outlined in Pratt and O’Connor (2011) corresponded with the three distinct areas of the river described in Duffy et al. (1987); the upper river, the rapids, and the lower river. We sampled the Canadian nearshore habitats of the St. Marys River, with the exception of the main rapids area where the current was too strong and the river too shallow to sample safely in our 4.4 m electrofishing boat. In 2014 and 2015, we also sampled the lower reach of the Mississagi River, located approximately 50 km east of the outflow of the St. Marys River, as a non-AOC reference site (Figure 1b). While the size, flow and habitat complexity available in the St. Marys River means that there are no perfect candidate rivers for comparison, the Mississagi River is largest river on the north shore of Lake Huron without an AOC designation and was selected a reference site for this study. Both study sites are described in detail below and the sampling dates, the number of transects completed in each section and habitat descriptions are found in Table 1.

## SITE DESCRIPTIONS

### Upper river

The transect locations in the upper river were approximately 5 km above the compensating gates, in Marks Bay and Leigh Bay (46°29’N; 84°27’W). There is little structural habitat in the area, with predominantly sand substrates. The majority of the available structural habitat is provided by sunken logs, remaining from the days of holding log booms in the western edge of Marks Bay. Sparse aquatic vegetation (primarily quillwort (*Isoetes riparia*)) provided the only macrophyte cover. Water temperatures were cool in this section of the river, consistent with its proximity to Lake Superior (Table 1).

### Main river

The main river extended from below the rapids (46° 30’N 84° 20’ W) to Bells Point (46° 32’N 84° 13’ W), a distance of approximately 12 km. This area of the river contained the greatest variation of habitat and the most flow of any of the sampled transects. The habitat below the main rapids and to Topsail Island is mainly cobble and boulder with some sand, and from east of Topsail Island to Bells Point the substrate is silt/sand and macrophytes (mainly *Potamogeton* spp. and quillwort). The area represented the open water main stem and embayment fish habitat described by Duffy et al. (1987). Water temperatures were coldest most years in this section of the river.

### Lake George

Lake George is large, shallow embayment with low flow and sandy substrate area with little in the way of macrophytes or structure for fish habitat. This area represented the sand beach fish habitat described by Duffy et al. (1987). Transects in this section were concentrated in the Bar River mouth area (46° 26’N 84° 06’ W). Water temperatures were warmer and conductivity higher in this section of the river.

### Lower river

The lower river was sampled along of the northwest edge of St. Joseph’s Island, in the Richards Landing area (46° 17’N 84° 02’ W). Bottom substrate varied, ranging from sand and silt to

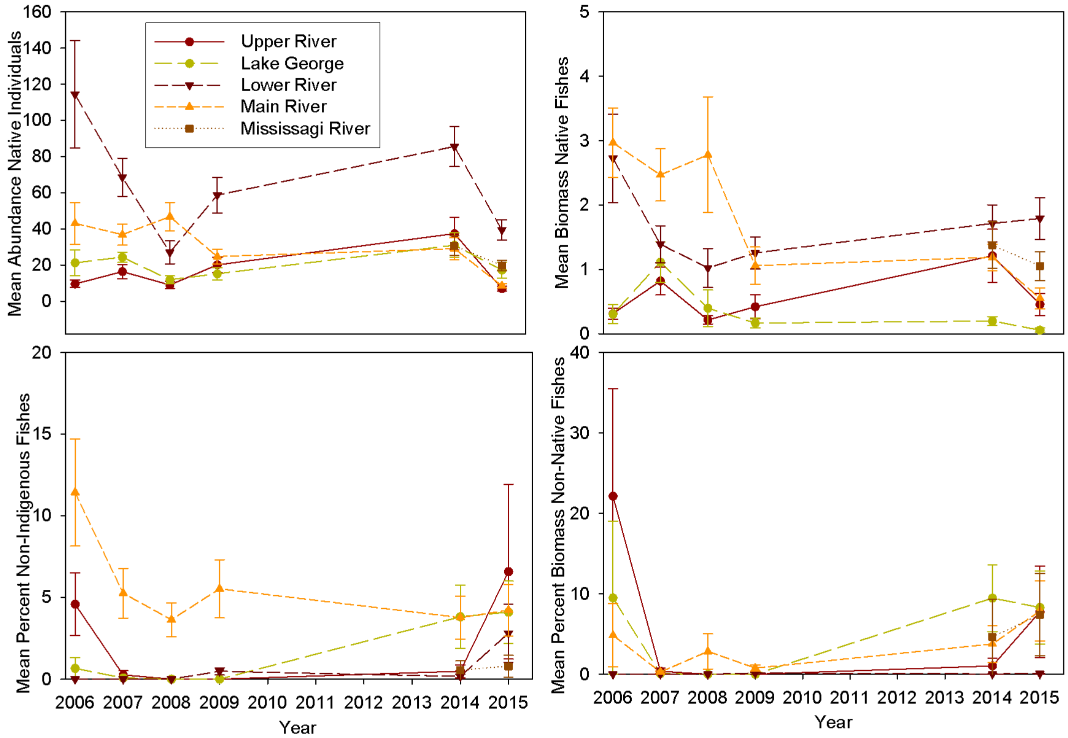


Figure 6: (a) mean abundance of native fishes, (b) mean biomass of native fishes, (c) mean percent non-native fish abundance, (d) mean percent non-native biomass by year for each of the four study areas in the St. Marys River and the Mississagi River. Data for 2006-2008 from Pratt and O'Connor (2011).

cobble and a wide range of macrophyte densities (sparse to dense). This area represented the emergent wetlands and protected reaches described by Duffy et al. (1987). Water temperatures and conductivity were similar to those of Lake George in this section of the river, and dissolved oxygen concentrations were lower than the upper and main river locations.

**Mississagi River**

The lower section of the Mississagi River (46° 11'N 83° 01 W) covers a delta area approximately 7 km in length. Bottom substrate in this stretch of river is similar to the Lake George and the lower St. Marys River areas; mainly sand, silt and sparse to moderate macrophytes. Water temperatures were warmer in the Mississagi River, likely as a consequence of later temporal sampling, and dissolved oxygen concentrations in the Mississagi River were the lowest of any location fished.

## SAMPLING METHODS

The nearshore fish community was sampled using a boat electrofisher. The technique for sampling the nearshore community was developed Fisheries and Oceans Canada for use in the Laurentian Great Lakes (Valere 1996, Brousseau et al. 2005) and described in Pratt and O'Connor (2011). Surveys were conducted in late spring, with the earliest survey beginning May 25th and the latest June 20th in the St. Marys River (Table 1). Surveys in the Mississagi River were conducted after those in the St. Marys River, starting as early as June 26th and ending as late as July 19th (Table 1). The same sites were visited during each sampling period where possible; changing water depths or turbidity levels periodically resulted a slight shift in transect location.

Detailed descriptions of the sampling procedure are available (Valere 1996, Brousseau et al. 2005, Pratt and O'Connor 2011), but are further summarized here. In 2006 – 2009, 100 m transects were laid out prior to dusk using floats with reflective tape and marked with a GPS. Transects were placed along the 1.5 m depth contour. The physical habitat was sampled prior to dark; at mid-transect, dissolved oxygen (mg/L), conductivity (µS/cm) and water temperature were taken, and bottom substrate was sampled using an Ekman dredge at each transect marker. Substrate was classified as silt, sand or gravel texturally, while areas of larger substrate, cobble or boulder, were classified visually. Organic and woody debris were also identified as well as the dominant (>50%), sub-dominant (10 to 50%), and trace (<10%) amounts for each component. Macrophyte abundance was determined visually and assigned to one of 4 categories: none (0%), sparse (1 to 19% cover), moderate (20 to 70% cover) or dense (>70% cover). The dominant macrophytes were identified to genus. For the 2014 and 2015 surveys, a change occurred and the 100 m transects were laid out using GPS coordinates along the 1.5 m contour and habitat data was collected after the completion of the transect. Dredge sampling was no longer used to collect bottom substrate for classification purposes; bottom samples were taken via net probing or anchor drops, and followed the previous classification system. Collected water sampling parameters remained the same and were assessed mid-transect. We found we were able to sample significantly more transects over the same time period by adjusting the transect marking and habitat collection techniques as the crew did not start until dark, which allowed for more time to be devoted to the electrofishing survey effort.

Electrofishing surveys were conducted in a Smith-Root SR -14H electrofishing boat (4.4 m long, 2.0 m wide). Electrofishing was conducted parallel to shore along the 100 m transect after dark. The target electrofishing time was 300 sec per transect. All fish were targeted for collection, brought on board and held in an aerated live well until the transect was completed. All fish were identified to species by the crew and 20 of each species were measured (± 1 mm) and weighed (± 1 g) in the field. If over 20 individuals of a given species were collected, the remainder was counted and batch weighed. Fish were then returned to the water, close to their location of capture. For species that could not be identified in the field, a subsample were preserved in 10% formalin and returned to the lab for individual identification and length (± 1 mm) and weight (± 0.01 g) measures.

In 2014 and 2015 we also added an additional fish collection sampling method, the Herzog-Armadillo (Modified Missouri) trawl net (Herzog et al. 2009). We added the trawl net to determine if bottom fishes beyond the 1.5 m depth contour were not being sampled due to depth limitations of the boat electrofisher. The net (2.4 m x 0.6 m) was towed along 100 m transects in generally the same areas where boat electrofishing occurred, but beyond the 2 m depth contour. All trawling surveys were conducted during the day. Captured fishes were processed the same as those collected during the electrofishing surveys, with all fishes identified to species, 20 individuals of each species measured for length (± 1 mm) and weight (± 1 g), and the remainder counted and bulk weighed.

## INDEX OF BIOTIC INTEGRITY (IBI) CALCULATION

All collected habitat and fish data were entered into a database developed specifically for Great Lakes nearshore fish communities (Moore et al. 1998). The database was developed for the comparison of the nearshore fish community, species richness and biomass with the habitat attributes of the surveyed transects. The database also calculates a Great Lakes nearshore index of biotic integrity (IBI) (Minns et al. 1994). Minns et al. (1994) developed the IBI specifically for the littoral habitats in the Great Lakes to provide a quantitative measure of impairment within an ecosystem and restoration measures for the fish community. The IBI uses 12 separate metrics based on the diversity and trophic metrics of the fish community to provide a score from 0 to 100 to determine the condition of the fish community, based on four broad classes of factors: non-native species, water quality, physical habitat, and piscivore abundance (Minns et al. 1994). Positive metrics include species richness (native, centrarchid, intolerant (intolerant of high turbidity) and native cyprinids), trophic structure (percent piscivore, specialist biomass), and abundance and condition (number and biomass of native species; Table 2). Negative metrics include non-native species richness, percent generalist biomass, percent number and percent biomass of non-native species (Randall and Minns 2002, Brousseau et al. 2005).

We also calculated a habitat-productivity index (HPI) (Randall and Minns 2002). The habitat productivity index Randall and Minns (2002). developed is a measure of habitat productive capacity for a given fish assemblage. For each sample, HPI was calculated as the product of fish biomass and the production to biomass ratio (P/B) for all species captured from a given transect. This index was used as an estimate of fish production. As detailed in Pratt and O'Connor (2011) for the St. Marys River, our total fish biomass from each transect was converted to kg/ha by multiplying the biomass by 40, as we estimated our electrofishing boat was effective over a 2.5

m strip along the 100 m transect. We also assumed our capture efficiency was 100% (Pratt and O'Connor 2011). Together, the IBI and the HPI provide indices of fish production and diversity (Randall and Minns 2002) and were used to examine the nearshore fish community in the St. Marys River.

## DATA ANALYSIS

All data analysis completed using SPSS 18 (SPSS 18). One-way analysis of variance (ANOVA) was used to test macrophyte density among years at the five individual fishing locations (lower river, Lake George, main river, upper river, and Mississagi River), followed by Tukey highly significant difference (HSD) post-hoc analyses to separate locations after a significant ANOVA was identified. IBI, HPI and IBI metrics were compared among years at the five locations with a one-way ANOVA, with Tukey HSD post-hoc comparisons completed as required. Two-way ANOVAs were used to contrast among year and site comparisons, with Tukey HSD post-hoc comparisons completed when required; when the site*year interactions were significant, MANOVAs were used to compare the individual factors, with Tukey HSD post-hoc analysis used to separate factors after significant tests were identified.

## RESULTS

### HABITAT

Mean water temperature varied among years across all locations in the St. Marys River with the highest mean temperatures occurring in 2007 (range 14.2 – 22.3$^{o}$C) and the lowest temperatures occurring in the 2015 (range 6.4 – 12.1$^{o}$C; Table 1). In the Mississagi River, the highest mean water temperature during sampling occurred in 2014 (mean 19.4$^{o}$C).

Mean dissolved oxygen (mg/L) levels varied among years at individual sites in the St. Marys River, ranging from 9.45 – 12.64 mg/L over the six years of sampling. Mean dissolved oxygen levels are inversely related to water temperature, as the lowest oxygen levels were observed in 2007 when the water temperatures in the St. Marys locations were the warmest. Mean dissolved oxygen levels were also lower in the Mississagi River, ranging from 9.10 to 9.26 mg/L, where the water was also relatively warmer than most years on the St. Marys River (Table 1).

In the St. Marys River, mean conductivity ranged from 70.8 – 141.75 µS in the five fishing locations and six years of sampling. Conductivity was lower in all fishing locations in 2015. Conductivity showed unusually high annual variation in the Mississagi River, with an average of 141 µS in 2014 and an average of 71.8 µS in 2015.

Bottom substrate in most transects consisted of sand and some silt with macrophytes ranging from zero to sparse in most locations. Lake George transects contained the least amount of macrophytes overall, while the main river had the most sites with sparse to moderate macrophytes (Figure 2). Macrophyte density among the years was not significantly different in either the main (ANOVA $F_{5,121} = 1.915$, $p=0.097$) or upper river (ANOVA $F_{5, 89} = 0.203$, $p = 0.961$) survey locations. In the lower river sites macrophyte density was significantly different among years (ANOVA $F_{5, 83} = 6.864$, $p< 0.001$), with the sites with the most macrophytes (moderate) sampled in 2008 and the presence of macrophytes diminishing in transects sampled after 2009 (Figure 2). Macrophyte density was also significantly different in Lake George (ANOVA $F_{5, 73} = 4.612$, p=0.001), with the majority of the macrophytes (sparse) sampled in 2008 compared to all other years, which were none to sparse. In the Mississagi River, the majority of sites contained zero to sparse macrophytes, with significantly fewer sites with macrophytes in the 2015 sampling (t test, p =0.010).

**FISH COLLECTION**

In total, 410 sites were electrofished in the St. Marys River over the six years and 45 sites were surveyed in two years of electrofishing in the Mississagi River (Table 3). The number of transects fished per year varied with weather conditions and available fishing time, though in general fewer transects were fished earlier in the time series. Fifty-two species were collected in the St. Marys River electrofishing surveys over the six years of sampling, and an additional three species were collected in the Mississagi River. In 2014, a daytime small boat trawl was added to the fish collection methods to supplement sampling in waters deeper than 1.5 m. A total of 86 trawls were completed over the two years, with the majority of trawl surveys occurring in the St. Marys River (Table 3). Only one additional species, lake sturgeon (*Acipenser fulvescens*) in the Mississagi River, was collected in with the addition of the trawl surveys. The cumulative number of species collected across all years in both sampling locations with the two gear types was 56 (Table 4).

On average, 33.5 species were collected per year across all four sampling sites in the St. Marys River. The highest species richness (36 species) was observed in 2006 and 2014, while the fewest species (29) were collected in 2015. The greatest number of species collected in a given sampling site was in the main river in 2007, with 30 different species captured, and the fewest species were observed in Lake George in 2008 with 8 (Table 3). The number of species/transect collected in lower river and the upper river were not significantly different among years (Table 5). In the lower river, the mean number of species collected was 7.2 per transect, with a range of 17 – 24 total species per year (Table 3). The upper river was less diverse with a mean of 3.5 species per transect collected and a range of 12-16 total species per year (Table 3). In Lake George and the main river, the number of species captured was significantly different among years (Table 5). In Lake George, an average of 4.3 species/transect, ranging from 8 to 19 total species per year (Table 3). Species captured/transect in 2015 (2.6 species/transect) and 2008 (4.0 species/transect) were significantly lower than all other years, with a peak of 5.4 species/transect in 2006 (Table 5). In the main river, a mean of 6.6 per species per transect were collected, with a range of 20 to 30 total species per year (Table 3). Capture rates in 2015 (3.8 species/transect), 2014 (5.7 species/transect) and 2009 (6.8 species/transect) were significantly lower than all other years (Table 5). There was no significant difference in species richness in the Mississagi River between years, with 25 species sampled in 2014 and 20 in 2015 (Table 5). On average, 6.4 species were collected per transect in the Mississagi River.

A total of 13,180 individual fish were sampled from the St. Marys River electrofishing transects (n=410), while 1,110 fish were sampled from the Mississagi River transects (n=45). An additional 4,095 fishes were collected in the trawl nets, with 3,850 captured in the St. Marys River and 245 caught in the Mississagi River. Abundance/transect in the Mississagi River and in

Lake George was not significantly different among years (Table 5). Abundance/transect was significantly different among years in the lower, main and upper river sections of the St. Marys River (Table 5). In the lower river, catch/transect was not significantly different in years 2008 (27.0 fish/transect) and 2015 (39.9 fish/transect), however, these were significantly lower than catch rates in 2006 (114.4 fish/transect) and 2014 (85.7 fish/transect). In the main river, catch/transect rates were lowest in 2015 (9.1 fish/transect) and 2009 (26.1 fish/transect) compared catch rates in all other years, with the peak catch/transect observed in 2008 (48.2 fish/transect; Table 5). In the upper river, catch/transect was significantly higher in 2014 (37.5 fish/transect) than all other years, which ranged from 7.0 (2015) to 20.1 (2009) fish/transect. Surveys in 2014 coincided with peak yellow perch spawning temperatures, as there was an average yellow perch catch of 31.3 fish/transect collected in 2014, 3 times higher than the previous peak collection rate of 10.7 fish/transect in 2009.

Patterns in mean biomass/transect followed the patterns observed in species richness (Table 4). In the lower and upper St. Marys River and in the Mississagi River, biomass was not significantly different among years (Table 4). In Lake George biomass/transect was highest in 2007 (1112.4 grams/transect) and significantly higher than both 2009 (165.4 grams/transect) 2014 (204.1 grams/transect). In the main river, biomass/transect was lowest in 2015 (458.9 grams/transect) compared to all other years fished (Table 5).

Of the 56 species that were collected during the surveys (Tables 6 and 7), some were ubiquitous throughout the study locations including rainbow smelt (*Osmerus mordax*), white sucker (*Catostomus commersoni*), emerald shiner (*Notropis atherinoides*), spottail shiner (*N. hudsonius*), mimic shiner (*N. volucellus*), bluntnose minnow (*Pimephales notatus*), rock bass (*Ambloplites rupestris*), yellow perch (*Perca flavescens*) and Johnny darter (*Etheostoma exile*). Others such as pink salmon (*Oncorhynchus gorbuscha*), cisco (*Coregonus artedi*), central mudminnow (*Umbra limi*) longnose dace (*Rhinichthys cataractae*), silver shiner (*Notropis photogenis*), and white bass (*Morone chrysops*) were rare and captured only once or within a single sampling year. Some fishes were localized and captured multiple years but only in certain sections of the river; for example, lake whitefish (*Coregonus clupeaformis*) and round whitefish (*Prosopium cylindraceum*) were only captured in the upper river, sea lamprey (*Petromyzon marinus*), Atlantic salmon (*Salmo salar*), longnose sucker (*Catostomus catostomus*), blacknose shiner (*Notropis heterolepis*) and brook stickleback (*Culaea inconstans*) were only observed in the main river, alewife (*Alosa pseudoharengus*) was only captured in Lake George, and silver redhorse (*Moxostoma anisurum*) was only seen in the lower river. Three additional species were collected in the Mississagi River electrofishing surveys; longnose gar (*Lepisosteus osseus*), bowfin (*Amia calva*) and common carp (*Cyprinus carpio*). The invasive fish white bass (*Morone chrysops*) and alewife were captured in the early sampling years and reported on by Pratt and O'Connor (2011); however, they were not collected in any gear or location sampled in 2014 or 2015. Another invasive fish, the threespine stickleback (*Gasterosteus aculeatus*), was captured the main river in the early survey years (Pratt and O'Connor 2011). In 2014 and 2015, the threespine stickleback was again collected in the main river, but its range had expanded to include capture in Lake George and the lower river. The threespine stickleback was not observed in the Mississagi River.

The diversity of fishes captured in the trawl transects was low, and with the exception of the age-0 lake sturgeon captured in the Mississagi River, no additional species were added via trawling (Table 7). However, the trawl sampled several species better than boat electrofishing. Brook stickleback, Iowa darter (*Etheostoma exile*), Johnny darter and mottled sculpin (*Cottus bairdi*) were all caught in higher numbers in the trawl.

**<u>Historical Comparison</u>**

The species catches were ranked and the top ten catches for each fishing area and gear type were contrasted with the rankings of species catch from previous surveys (Table 8). The rankings were compared with the electrofishing surveys of 2006-2009 (Pratt and O'Connor 2011) and the trawl surveys of Liston et al. (1980, 1983) and Liston and McNabb (1986). Similar to the findings of Pratt and O'Connor (2011), trout-perch (*Percopsis omiscomaycus*) catches continued to rank lower than previous surveys, while the ranking of mimic shiner and bluntnose minnow remained higher than in the historic trawling data. Emerald shiner continued to rank strongly in Lake George and the lower river. The addition of the trawl net did improve the catch ranking for Iowa and Johnny darters, bringing the rankings similar to those of the historic trawl surveys. The invasive threespine stickleback was consistently collected in the main river and ranked fifth in abundance in the Lake George trawl survey.

**WITHIN SITE COMPARISONS**

**<u>Index of Biotic Integrity</u>**

An IBI was calculated for the Mississagi River, and each of the four sections of the St. Marys River. In the upper river and the Mississagi River, the IBI was not significantly different among years. In the upper river, the mean IBI ranged from 41.8 through 53.2 over the six sampling periods while in the Mississagi River, the mean IBI was 65.9 and 65.6 in 2014 and 2015, respectively. In the lower river, Lake George and the main river, significant differences among years were noted, with the lowest IBI score in all three locations in occurring in 2015 (Tables 9 and 10; Figure 3). The 2015 lower river IBI score (59.4) was significantly lower than in 2006 (78.8) and in 2014 (71.8). The overall mean IBI score for the lower river was 67.5. In Lake George, the 2015 IBI score, 43.9, was significantly lower than in 2007 (54.9) and 2009 (56.7), with a mean IBI score of 52.3 for all years (Table 10, Figure 3). In the main river, the 2015 IBI score, 41.5, was significantly lower than in 2008 (58.4), 2009 (49.3), and 2014 (52.8) with an overall mean IBI score of 50.9 for all years (Table 10, Figure 3).

An assessment of the individual metrics of the IBI was completed for each of the river sections; the upper, main and lower St. Marys River along with Lake George, as well as the Mississagi River (Table 9). Five of the metrics deal with species richness, with four of the metrics, including native species, centrarchid, (turbidity) intolerant, native cyprinid species richness having a positive influence on the IBI score and one, non-native species richness, a negative influence (Table 2). In the Mississagi River, there was no significant difference in any of the species richness factors between the two survey years (Tables 9 and 10, Figures 4 and 5). In the lower river, four of the five metrics were not significantly different over the years, with only the turbidity intolerant species showing significant changes over time (Table 9). 2006 had the highest number of intolerant species, while the fewest occurred in 2008 (Tables 9 and 10, Figure 4). In Lake George, all five of the species richness metrics were significantly different during the sampling period. Native species richness was lowest in 2015 and highest in 2006 (Tables 9 and 10, Figure 4). Centrarchids were not commonly captured in Lake George; however significantly higher catches occurred in 2007, 2008, 2009, when compared to the other survey years (Tables 9 and 10, Figure 4). Peak captures of turbidity intolerant species occurred in 2006, with the lowest capture rates in 2015 (Tables 9 and 10, Figure 4). Native cyprinid richness was lowest in 2015 compared will all other fishing years and non-native species richness was highest in 2014 (Tables 9 and 10, Figure 5). In the main river section, centrarchid species richness did not change over the sampling period, however, the other four species richness measures differed significantly (Table 9). 2015 had the lowest native species richness and the lowest native cyprinid species richness in the main river and the highest number of non-native species sampled (Tables 9 and 10, Figures 4 and 5). The greatest number of turbidity intolerant species was collected in 2007 (Tables 9 and 10, Figure 4). In the upper river section, there was no difference among years for either the native species or the number of native cyprinids collected during the sampling period (Table 9). Centrarchid species richness was significantly lower in 2014 compared to 2009 (Tables 9 and 10, Figure 4). Intolerant species richness was significantly lower in 2006 and 2014 than in 2009 (Table 9). Non-native species richness was significantly higher in 2006 compared to all other years (Tables 9 and 10, Figure 4).

The biomass metrics, including percent piscivore, percent generalist, and percent specialist fishes, were relatively stable at the individual survey locations among the years with a few exceptions. The percentage of specialists was significantly lower in lower river section in 2015 when compared to 2009, and the percentage of generalists was significantly higher in 2015, compared to 2007 and 2008 (Tables 9 and 10, Figure 5). In the main river, the percentage of generalists was significantly lower in 2015 compared to the survey competed in 2006 (Tables 9 and 10, Figure 5). None of the metrics were significantly different in the Mississagi River over the two sampling periods.

The final four metrics deal with the number of native individual fishes, their biomass, and the percent of non-native species by number and their biomass. The percent of non-natives by number was not significantly different in any of the fishing locations among the years (Table 9, Figure 6). When looking at the percent of non-natives by biomass, only the upper river had a significant difference in capture over the years (Table 9). In 2006 the percent biomass of non-native fishes was higher than any other year (Tables 9 and 10, Figure 6). The highest catches of native fishes the occurred in 2014 in three of the river sections; the upper, main and lower river (Tables 9 and 10, Figure 6); however, a significantly larger biomass of natives was collected in the 2007 surveys in main and Lake George collection sites (Tables 9 and 10, Figure 6). In the Mississagi River, none of the abundance or biomass metrics were significantly different between years.

## HABITAT PRODUCTIVITY INDEX

The Habitat Productivity Index (HPI) was calculated for each section of the river over the 6 years of sampling. Across all four study sections of the St. Marys River, the HPI was significantly different among years (Table 9). In the lower river, the HPI in 2006 was not significantly different than in 2014, but it was significantly higher than all other years surveyed (Tables 9 and 10, Figure 3). In Lake George, the HPI in 2007 was significantly higher than any other year surveyed (Tables 9 and 10, Figure 3). In the main river, the HPIs calculated in 2006-2008 were significantly higher than those in 2009 and 2014-15 (Tables 9 and 10, Figure 3). In the upper river, the HPI for 2014 was higher than all other years, but was only significantly greater (than the 2015 survey (Tables 9 and 10, Figure 3). The HPI was not significantly different between years in the Mississagi River, with a mean HPI of 16.7.

## SITE COMPARISON

The fish community sampled at each location in 2014 and 2015 was compared with the results of Pratt and O'Connor (2011) for four metrics, including biomass, species richness, IBI and HPI (Table 9). Like the results from the initial survey years, the upper river and Lake George were significantly lower in biomass and species richness in comparison with the main and lower river areas. The Mississagi River was similar in biomass and species richness to the lower St. Marys River. In 2014, there was large increase in biomass observed in the upper river. However, this was a one year increase as biomass in 2015 was similar to the 2006-2009 catches. When taking into account the 2014 and 2015 data, the lower river had the highest HPI, IBI, and species richness of the four St. Marys River sites sampled, and the Mississagi River values were not significantly different from those of the lower river (Table 9, Figure 3).

## ASSESSMENT OF COMMUNITY HEALTH

The St. Marys River fish community was compared to the Mississagi River (control river) in 2014 and 2015 and with the previous St. Marys River surveys (Pratt and O'Connor 2011) as well as with the Penetang Harbour and Hog Bay, two additional Lake Huron locations. These locations were also used as control areas in Pratt and O'Connor (2011; Table 10). Similar to the findings of Pratt and O'Connor (2011), in 2014 and 2015, the St. Marys River still had the highest proportion of native species richness, native cyprinid species richness and the lowest percentage of non-native species when compared with the Lake Huron sites. The Mississagi River had the highest native and native cyprinid species richness and the lowest non-native species of any of the sites fished. Percent piscivore biomass remains low in the St. Marys River, compared with both the Lake Huron and Mississagi River sites while the percent generalist species remain high within the river. The percent specialist species observed was similar at all locations fished. The IBI in the St. Marys River averaged 54 for all years fished, lower than either the Mississagi River (65) and Lake Huron sites (65 and 66), but still within the range of fair (40 – 60) for the fish community.

## DISCUSSION

The nearshore electrofishing surveys performed in 2014 and 2015 were completed to complement the surveys accomplished in 2006-2008 and reported on in Pratt and O'Connor (2011), along with an unpublished year of data (2009), as part of the revisiting of the Beneficial Use Impairments (BUIs) for the St. Marys River Area of Concern. These extra sampling years were added to allow an assessment of the temporal stability of the nearshore fish community, and coincided with a change in habitat conditions (increasing flow, lower water temperatures) that are critical components of fish habitat. Our initial study identified a native fish community that was complex, diverse and healthy, with few apparent impacts of invasive fishes (Pratt and O'Connor 2011). While the additional survey years did not change our overall interpretation, there have been some declines in key measures, including declines in the IBI, species richness and HPI measures.

Habitat conditions in the river might explain some of the apparent decreases observed through time in our surveys. Water temperatures in the last three surveys (2009, 2014 and 2015) were all colder than in the initial 2006-2008 surveys. The winter of 2013-14 had the second highest level of ice coverage in 40 years, and some ice cover was maintained into early June, the longest ever recorded for Lake Superior (Clites et al. 2014). This led to cooler water temperatures in the St. Marys River in 2014, and the cool air temperatures that summer and heavy ice cover again in the winter of 2014-15 helped reduce water temperatures in 2015 to the lowest during any of our surveys. Water temperature impacts electrofishing efficiency by changing the distribution of fishes, fish metabolism and water conductivity (Reynolds and Kolz 2012), resulting in lower electrofishing catches for many fishes under in colder water (e.g., Hall 1986, Borkholder and Parsons 2001). While macrophyte density was not different among the years in either the upper river or main river transects, density was reduced in the lower river transects after 2009 and macrophyte density peaked in Lake George in 2008. In the Mississagi River, macrophyte density was significantly lower in 2015. The reduction in macrophyte density in the last two years of sampling is also likely due to the colder water temperatures as macrophyte production is strongly influenced by water temperature (Barko and Smart 1981). The temperatures in the river in both 2014 and 2015 are reflective of cold water outflow of Lake Superior (Duffy et al. 1987) and the longer ice coverage of both winters.

Another significant change in environmental conditions over the length of the electrofishing surveys were increased water levels increased water levels in the St. Marys River. After 15 years of water level declines, water levels rose rapidly in Lake Superior and Lake Huron and reached their historic average levels in mid-2013 (Gronewold et al. 2016). As a result, the International Joint Commission's International Lake Superior Board of Control adjusted the flow in the St. Marys River to increase to 2980 $m^3/s$ through the compensation works, and though reduced to 2650 $m^3/s$ for 2014 and 2015, the resulting flows have resulted in higher water levels in later survey years (IJC 2016). This resulted in more wetted bank area, and areas that were unfishable due to shallow depths in earlier survey years were now accessible. The area most affected by the increase in flow was the St. Marys Rapids (which we are unable to sample due to dangerous flows) and the main river section.

The original Degradation of Fish and Wildlife Populations BUI for the St. Marys River fish community stated that the issues were a) trends of lower cisco abundance; b) status of walleye (*Sander vitreum*) spawning stocks within the river; c) potential for exotic, invasive species to invade the fish community, and d) decline northern pike (*Esox lucius*) populations (EC and OME 2011). Our nearshore surveys do not generally sample the larger sport and game fishes due the shallow habitats fished via electrofishing. However, electrofishing can be used to target potential juvenile habitats of these species as well as address the issues of invasive fish species and their effects on the fish community. While our nearshore electrofishing survey is not able to address all of the identified issues alone, additional fisheries surveys, including gill netting and trawling, have been completed that complement our survey and allow a more comprehensive assessment of the fish community (e.g., Schaeffer et al. 2011, 2017).

The gill netting survey reported on by Schaeffer et al. (2011) addressed the open water fish community trends within the river, and noted that both northern pike and cisco continued to decline between 1975 and 2006, while walleye populations were stable. However, it was noted that the walleye population in the St. Marys River is supported by stocking, as an average ~30% of the fish sampled are of hatchery origin (Schaeffer et al. 2011). Remaining cisco populations in Lake Huron are generally considered to be small, localized, remnant populations and rehabilitation efforts continue (Riley 2010). In Lake Superior, where larger cisco populations support an important commercial fishery, recruitment has been poor and variable over the past two decades and populations are much reduced (Stockwell et al. 2009, Myers et al. 2015). Northern pike populations are declining throughout Lake Huron, and it is hypothesized that populations were negatively influenced by the period of low water levels (Riley 2010). Despite a declining population, the St. Marys River maintains the highest recreational harvest in the Michigan waters of Lake Huron (Riley 2010). It is unlikely that habitat conditions specific to the St. Marys River are responsible for the declines observed in cisco and northern pike, given that the same trends are observed at a broader spatial scale.

It is unlikely that any large bodies of water have been shaped by aquatic invasive species as much as the Great Lakes. There are now over 185 invaders documented in the lakes, and these species have completely reshaped (and continue to reshape) Great Lake's ecosystems (Pagnucco et al. 2015). It is therefore surprising that invasive fishes, while present in the St. Marys River, remain at low levels. Threespine stickleback continued to be caught in the main river, and have moved into both the Lake George and lower river locations. The expansion of this species was also noted in the recent trawl survey (Schaeffer et al. 2017). Rainbow smelt was the most common invasive fish encountered in our surveys, and it continued to be captured in all sections of the river. In our early survey years white bass and alewife were also collected (Pratt and O'Connor 2011), however these species were not collected in the 2009, 2014 and 2015 surveys although a few alewife were captured in the Schaeffer et al. (2017) trawl survey so they remain present in low numbers.

One invasive fish of particular concern to fisheries managers on the St. Marys River is the round goby (*Neogobius melanostomus*), a species that has been sampled in the river and has displaced native fishes in other Great Lakes locations (Kornis et al. 2012). Round goby had just been located at the lowest reaches of the St. Marys River when Pratt and O'Connor (2011) was published, and since then has been captured in low numbers in trawls in the river (Schaeffer et al. 2017). Our inability to sample the round goby is likely due to its continued low abundance in the river, as electrofishing is identified as the most effective tool for sampling this species (Brandner et al. 2013). The migration of Eurasian ruffe (*Gymnocephalus cernua*), another invasive fish, from western areas in Lake Superior appears to have stalled in the Whitefish Bay area (above the entrance to the St. Marys River), as a limited population has been found at the Tahquamenon River. However, annual trawl surveys have not located any within the St. Marys River boundary (Schaeffer et al. 2017) and none were collected in our nearshore surveys.

While some invasive species are located within the river, they do not appear to be displacing the native nearshore fish community from their existing habitats, with the potential exception of the reduction in the number of native sticklebacks compared to the invasive threespine stickleback. While this may change over time, if the offshore shore population of exotic species changes or as potential new invaders move into the nearshore community, at this point the change to the nearshore community from invasive species appears to be very limited. The inability of round goby and other invasive to proliferate in the river as they have in other locations may indicate that the abiotic conditions within the river, as the outflow of Lake Superior, is less prone to successful establishment. It is hypothesized that Lake Superior itself has fewer invasive species than the other Great Lakes due to the inhospitable nature of the lake (Grigorovich et al. 2003). Schaeffer et al. (2017) also hypothesize that the diverse, healthy nature of the St. Marys River fish community has also played a role in resisting the establishment of invasive fishes.

Pratt and O'Connor (2011) noted the differences in the species and abundances collected between the boat electrofishing surveys of 2006-2008 and the previous Liston et al. (1980, 1983) and Liston and McNabb (1986) surveys, and suggested that gear bias could play a role although they argued that there were likely some changes in the existing fish community as well. These suppositions were supported both with the addition of the small Hergog-Armadillo (modified Missouri) trawl net for our 2014 and 2015 surveys, and the trawl survey of Schaeffer et al. (2017). As one would expect, the catches of small bottom-oriented fishes such as Johnny and Iowa darter were higher when using the trawl net; in our trawl survey the ranked catches of Johnny and Iowa darter were again similar to those of the Liston et al. (1980, 1983) and Liston and McNabb (1986) trawl surveys, indicating that multiple gears may be needed to target the full nearshore fish community.

There have been changes within the community between the historic sampling in the 1980s and the more recent sampling, even when taking into account gear differences. The higher abundance of emerald shiner (more tolerant of turbid conditions), bluntnose minnow and mimic shiner, and the reduction in abundance of species such as trout-perch many not be adequately captured in the IBI. While the St. Marys River had fewer non-native species than the other Lake Huron locations, the increase in threespine stickleback in the main river and its movement into Lake George and the lower river may continue to affect the abundance of the native stickleback community. The percent of specialist species collected in the St. Marys River remain high, and Schaeffer et al. (2017) argue that the presence of species such as blacknose shiner is indicative of a healthy community.  However, the percent of pisciverous fishes are low and the number of generalist species is high in the river. While it is possible that the number of generalist species indicates a lower quality fish community, it is equally possible that the number of generalists indicates species that are more adapted to a riverine environment with its varied habitats such as the St. Marys River, as the Great Lakes IBI was originally developed for non-riverine species (Minns et al. 1994).

The average IBI score calculated for the St. Marys River across all years fished was 54, indicative of a fish community that is in fair condition (Minns et al. 1994). Across all sampling years, the IBI in the lower river was higher, ranging from a low of ~60 to a high of ~80. The lower river IBI was not different from the was average score in the Mississagi River (65) or the other Lake Huron locations, Penetang Harbour (65) and Hog Bay (66). This may be due to its proximity to the main Lake Huron nearshore fish community, or the more complex and productive habitats available to fishes in that area. The IBI scores in the other three river sections are lower, likely due to low habitat complexity, cool water temperatures and low productivity in those areas. The ability of an IBI to pinpoint individual species and site changes and their effect on the community compared with broad community changes over time can be challenging. For example, Granados (2010) determined that species replacement within the IBI guilds in the Detroit River had hidden changes to the fish community that were not expressed in the IBI. Trebitz et al. (2003) noted that IBIs may detect broad assemblage changes, but may miss the within-site and individual species changes within the IBI area. Gammon and Simon (2000) noted that natural variation and hydrological factors, including temperature and flow, and gear type used all affect the IBI calculation. Similarly, we noted that the water temperatures in 2014 and 2015 were lower than previous years and flow conditions were higher, and that the addition of data from the trawl net returned species rankings for bottom-oriented species (Johnny and Iowa darters) that were missing from our electrofishing surveys. Angermeier and Karr (1986) found that IBI scores increased with the length of stream sampled, due to increased species richness, and that scores also decreased as young-of the year fish were excluded. We did not exclude any fish from our surveys based on age, so this is not an explanation for the lower than expected scores in the St. Marys River. As outlined in Pratt and O'Connor (2011), two factors that are reducing the IBI score in the St. Marys River are low biomass and the low percentage of piscivores. Both of these metrics will be difficult to improve, as low biomass is reflective of low productivity in the river, and the stability of the open water fish community (Schaeffer et al. 2011) means increasing the number of predatory fishes will be difficult. The the index of biotic integrity is sensitive to both of these parameters; in particular, low piscivore abundance is considered evidence of poor conditions (Minns et al. 1994).

Overall, the St. Marys River does support a diverse, species rich community. A total of 52 different species were sampled using boat electrofishing in the river over a period of seven years. The addition of a trawl net in 2014 and 2015 supplemented the abundance of bottom-dwelling species that were otherwise difficult to sample and demonstrated that multiple gear types may be necessary to adequately sample such a diverse nearshore fish community. To obtain an overall picture of the health of the St. Marys River, the nearshore and open water fish community needs to be combined. The continuation of the work completed by the multi-national St. Marys River Task Force, with the large net gillnet survey (Schaeffer et al. 2011), provides an important complement to the work performed herein.

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Table 1. Sampling dates, effort, and mean water surface temperature, oxygen and conductivity from electrofishing transects in the St. Marys and Mississagi Rivers. Values in brackets represent standard deviations.

| Location | Year | Dates | Number of Transects | Mean Temperature | Mean oxygen | Mean conductivity |
|---|---|---|---|---|---|---|
| Upper river | 2006 | May 30 - June 1 | 9 | 11.23 (1.46) | 11.97 (0.70) | 98.89 (6.01) |
| | 2007 | May 28 - 30 | 17 | 14.29 (1.43) | 12.00 (0.84) | 105.88 (6.18) |
| | 2008 | June 1-2 | 15 | 11.15 (0.73) | 11.64 (0.31) | 106.67 (4.88) |
| | 2009 | May 25 - 26 | 16 | 10.78 (1.77) | 11.80 (0.41) | 108.67 (7.43) |
| | 2014 | June 2 - 17 | 20 | 11.19 (1.74) | 12.70 (0.69) | 97.50 (11.18) |
| | 2015 | June 4 - 5 | 19 | 10.15 (1.38) | 11.88 (0.50) | 77.39 (24.29) |
| Main river | 2006 | June 5-6 | 12 | 12.63 (1.42) | 12.64 (0.29) | 98.33 (7.12) |
| | 2007 | June 5-12 | 19 | 16.53 (3.23) | 10.84 (1.64) | 102.78 (6.69) |
| | 2008 | June 3-9 | 15 | 10.65 (0.99) | 12.32 (0.27) | 102.00 (4.14) |
| | 2009 | May 27 - 31 | 17 | 7.39 (0.55) | 12.89 (0.40) | 103.53 (6.06) |
| | 2014 | May 28 - June 10 | 33 | 7.07 (1.31) | 12.75 (0.25) | 102.73 (8.76) |
| | 2015 | May 31 - June 1 | 33 | 6.41 (1.06) | 12.67 (0.70) | 75.58 (14.49) |
| Lake George | 2006 | June 2-3 | 8 | 16.11 (0.67) | 11.41 (0.23) | 103.75 (5.18) |
| | 2007 | June 13-15 | 22 | 21.55 (2.59) | 9.83 (0.62) | 107.14 (5.61) |
| | 2008 | June 11 | 6 | 15.42 (0.59) | 10.14 (0.45) | 106.67 (5.16) |
| | 2009 | June 12 -13 | 15 | 16.01 (0.80) | 11.06 (0.39) | 102.00 (6.76) |
| | 2014 | June 5 - 6 | 20 | 13.43 (1.70) | 11.80 (0.83) | 103.00 (17.2) |
| | 2015 | June 2 | 20 | 11.93 (2.34) | 11.72 (0.34) | 90.74 (5.32) |
| Lower River | 2006 | June 4 | 5 | 17.06 (0.37) | 11.45 (0.27) | 108.00 (4.47) |
| | 2007 | June 17 - 20 | 13 | 22.30 (1.19) | 9.46 (0.29) | 111.54 (5.55) |
| | 2008 | June 13 - 18 | 11 | 14.75 (0.83) | 10.40 (0.40) | 108.89 (9.28) |
| | 2009 | June 2- 11 | 25 | 13.14 (1.95) | 11.79 (0.41) | 106.80 (5.57) |
| | 2014 | June 7 - 9 | 20 | 14.38 (1.45) | 11.82 (0.30) | 104.50 (13.17) |
| | 2015 | June 3- 8 | 20 | 12.11 (0.90) | 11.25 (0.57) | 88.31 (14.11) |
| Mississagi River | 2014 | July 8 - 19 | 20 | 16.35 (0.08) | 9.26 (0.05) | 141.75 (1.12) |
| | 2015 | June 26 - 29 | 25 | 19.38 (1.04) | 9.10 (0.53) | 70.80 (12.83) |

Table 2. Index of Biotic Integrity (IBI) metrics and their influence on the overall IBI score (positive or negative).

| Metric Name | Metric Class | Influence on IBI |
|---|---|---|
| Native species richness | richness | Positive |
| Centrarchid species richness | richness | Positive |
| Intolerant species richness | richness | Positive |
| Non-native species richness | richness | Negative |
| Native cyprinid species richness | richness | Positive |
| Percent piscivore biomass | trophic | Positive |
| Percent generalist biomass | trophic | Negative |
| Percent specialist biomass | trophic | Positive |
| Number of native individuals | number/biomass | Positive |
| Biomass of natives (kg) | number/biomass | Positive |
| Percent non-native species by number | number/biomass | Negative |
| Percent non-native species by biomass | number/biomass | Negative |

Table 3. Sampling dates, effort, total species, total catch, and mean catch per transect from electrofishing and trawl transects in the St. Marys and Mississagi Rivers.

| Location | Year | Number of Transects | Total Species | Mean Species/ Transect | Total Catch | Mean Catch/ Transect |
|---|---|---|---|---|---|---|
| Upper river | 2006 | 9 | 13 | 2.8 | 90 | 10.0 |
| | 2007 | 17 | 16 | 1.7 | 279 | 16.4 |
| | 2008 | 15 | 14 | 2.5 | 135 | 9.0 |
| | 2009 | 16 | 16 | 2.9 | 321 | 20.1 |
| | 2014 | 20 | 12 | 1.8 | 749 | 37.5 |
| | 2015 | 19 | 14 | 1.3 | 133 | 7.0 |
| Main river | 2006 | 12 | 27 | 9.5 | 573 | 47.8 |
| | 2007 | 19 | 30 | 9.5 | 725 | 38.2 |
| | 2008 | 15 | 25 | 8.6 | 723 | 48.2 |
| | 2009 | 17 | 24 | 6.8 | 443 | 27.7 |
| | 2014 | 33 | 25 | 5.7 | 978 | 29.6 |
| | 2015 | 33 | 20 | 3.8 | 300 | 9.1 |
| Lake George | 2006 | 8 | 14 | 5.4 | 171 | 21.4 |
| | 2007 | 22 | 19 | 4.8 | 535 | 24.3 |
| | 2008 | 6 | 8 | 4.0 | 71 | 11.8 |
| | 2009 | 15 | 13 | 4.7 | 227 | 15.1 |
| | 2014 | 20 | 15 | 4.8 | 628 | 31.4 |
| | 2015 | 20 | 14 | 2.6 | 355 | 17.8 |
| Lower River | 2006 | 5 | 17 | 9.8 | 572 | 114.4 |
| | 2007 | 13 | 17 | 6.2 | 891 | 68.5 |
| | 2008 | 11 | 17 | 6.6 | 297 | 25.1 |
| | 2009 | 25 | 23 | 7.7 | 1473 | 58.9 |
| | 2014 | 20 | 24 | 7.2 | 1713 | 85.6 |
| | 2015 | 20 | 23 | 7.0 | 798 | 39.9 |
| Trawl | 2014 | 35 | 14 | | 1357 | 38.8 |
| | 2015 | 36 | 13 | | 2493 | 69.3 |
| Mississagi River | 2014 | 20 | 25 | 6.8 | 614 | 30.7 |
| | 2015 | 25 | 20 | 6.1 | 496 | 19.8 |
| Trawl | 2014 | 6 | 9 | | 228 | 38.0 |
| | 2015 | 9 | 2 | | 17 | 1.9 |

Table 4. Cumulative species catch for the St. Marys and Mississagi rivers, including boat electrofishing and small boat trawl catch.

| | St Marys River Boat Electrofishing | | | | | | Mississagi River Boat Electrofishing | | Mississagi River Trawl | | St. Marys River Trawl | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2009 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| Total species | 36 | 35 | 31 | 34 | 36 | 29 | 25 | 20 | 9 | 2 | 14 | 13 |
| New species | 36 | 8 | 1 | 4 | 3 | 0 | 3 | 0 | 1 | 0 | 0 | 0 |
| Cumulative Total | 36 | 44 | 45 | 49 | 52 | 52 | 55 | 55 | 56 | 56 | 56 | 56 |

Table 5. Analysis of variance results for species richness, abundance, and biomass per transect by sites over years from the four locations on the St. Marys River and the Mississagi River. Sites included the upper river (Upper), main river (Main), Lake George (George), lower river (Lower), and Mississagi River (Mississagi).

| Parameter | Years | Factor | F | df | p | Tukey HSD |
|---|---|---|---|---|---|---|
| Species/ | 2006-2015 | Upper | 1.438 | 5, 90 | 0.218 | |
| Transect | | Main | 16.835 | 5, 123 | 0.000 | 2015, 2014<=2009<2006-2008 |
| | | George | 3.863 | 5, 85 | 0.003 | 2015<=2008<=2006-2014 |
| | | Lower | 1.244 | 5, 88 | 0.296 | |
| | | Mississagi | 0.721 | 1, 43 | 0.401 | |
| Abundance/ | 2006-2015 | Upper | 5.191 | 5, 90 | 0.000 | 2014>2006-2015 |
| Transect | | Main | 6.772 | 5, 123 | 0.000 | 2015<=2009<2006-2014 |
| | | George | 1.768 | 5, 85 | 0.128 | |
| | | Lower | 5.497 | 5, 88 | 0.000 | 2008, 2015<2006, 2014 |
| | | Mississagi | 3.552 | 1, 43 | 0.066 | |
| Biomass/ | 2006-2015 | Upper | 1.793 | 5, 90 | 0.122 | |
| Transect | | Main | 8.224 | 5, 123 | 0.000 | 2015<2006-2014 |
| | | George | 4.807 | 5, 85 | 0.001 | 2007>2009, 2014 |
| | | Lower | 1.756 | 5, 88 | 0.130 | |
| | | Mississagi | 0.376 | 1, 43 | 0.543 | |

Table 6. Scientific and common names of the 56 species collected via electrofishing in the St. Marys and Mississagi rivers 2006-2015. Values are the mean number of fish captured per 100 m transect. Total catch and total species included; (*) marked fishes are considered invasive.

| | | *Scientific name* Common name | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling location | Year | *Lampetra appendix* American brook lamprey | *Petromyzon marinus** sea lamprey | *Acipenser fulvescens* lake sturgeon | *Lepisosteus osseus* longnose gar | *Amia calva* bowfin | *Alosa pseudoharengus** alewife | *Oncorhynchus gorbuscha* pink salmon | *Oncorhynchus kisutch* coho salmon | *Oncorhynchus tshawytscha* Chinook salmon | *Oncorhynchus mykiss* rainbow trout | *Salmo salar* Atlantic salmon | *Coregonus clupeaformis* lake whitefish | *Prosopium cylindraceum* round whitefish | *Coregonus artedi* cisco | *Osmerus mordax** rainbow smelt | *Esox lucius* northern pike | *Umbra limi* central mudminnow | *Catostomus catostomus* longnose sucker | *Catostomus commersoni* white sucker |
| St. Marys; Upper river | 2006 | | | | | | | | | 0.22 | 0.22 | | 0.33 | 0.11 | | 0.89 | | | | |
| | 2007 | | | | | | | | | | 0.06 | | 0.47 | | | 0.53 | | | | 1.00 |
| | 2008 | 0.13 | | | | | | | | | | | | | | 0.13 | | | | 0.53 |
| | 2009 | | | | | | | | | | | | 0.06 | 0.06 | 1.25 | 0.75 | | | | 3.63 |
| | 2014 | | | | | | | | 0.10 | | | | 0.05 | | | 0.15 | | | | 1.55 |
| | 2015 | 0.05 | | | | | | | 0.05 | 0.05 | | | | 0.05 | | 0.16 | | | | 0.68 |
| St. Marys; Main river | 2006 | 0.42 | 0.42 | | | | | | | 2.08 | 0.08 | 0.25 | | | | 4.17 | | | 0.5 | 11.2 |
| | 2007 | | 0.16 | | | | | | | 0.11 | 0.11 | | | | | 0.53 | 0.05 | | | 8.32 |
| | 2008 | | 0.07 | | | | | | | 0.33 | 0.07 | | | | | 2.33 | 0.20 | | 0.5 | 9.30 |
| | 2009 | | | | | | | 0.12 | 0.06 | 0.41 | | | | | | 2.71 | 0.06 | | 0.1 | 4.53 |
| | 2014 | | | | | | | | | 0.24 | 0.12 | 0.15 | | | | 1.64 | | | | 3.91 |
| | 2015 | | | | | | | | 0.06 | 0.06 | 0.45 | 0.18 | | | | 1.33 | | | | 1.70 |
| St. Marys; Lake George | 2006 | | | | | | 0.13 | | | | | | | | | 10.6 | | | | 0.25 |
| | 2007 | | | | | | 0.07 | | | | | | | | | 0.27 | 0.06 | | | 0.82 |
| | 2008 | | | | | | | | | | | | | | | | | | | 0.83 |
| | 2009 | | | | | | | | | | | | | | | 0.80 | | | | 0.33 |
| | 2014 | | | | | | | | 0.15 | | 0.05 | | | | | 13.8 | | | | 0.10 |
| | 2015 | | | | | | | | 0.30 | 0.05 | 0.05 | | | | | 12.9 | | | | 0.05 |
| St. Marys; Lower river | 2006 | | | | | | | | | | | | | | | 4.80 | 0.80 | | | 2.60 |
| | 2007 | | | | | | | | | | | | | | | | 0.15 | 0.08 | | 0.54 |
| | 2008 | | | | | | | | | | | | | | | 0.91 | 0.18 | | | 0.36 |
| | 2009 | | | | | | | 0.16 | | 0.04 | | | | | | 5.04 | 0.28 | | | 0.60 |
| | 2014 | | | | | | | | | | | | | | | 0.15 | 0.20 | | | 0.70 |
| | 2015 | | | | | | | | | 0.15 | 0.15 | | | | | 0.85 | 0.40 | | | 1.30 |
| Mississagi River | 2014 | | | | 0.05 | 0.05 | | | | | | | | | | 0.10 | 0.95 | | | 0.90 |
| | 2015 | | | | | | | | | | | | | | | | 0.56 | | | 0.48 |

Table 6 continued…

| Sampling location | Year | *Moxostoma anisurum* silver redhorse | *Moxostoma macrolepidotum* shorthead redhorse | *Moxostoma* spp. redhorse sp. | *Couesius plumbeus* lake chub | *Cyprinus carpio* common carp | *Luxilus cornutus* common shiner | *Notemigonus crysoleucas* golden shiner | *Notropis atherinoides* emerald shiner | *Notropis heterolepis* blacknose shiner | *Notropis hudsonius* spottail shiner | *Notropis stramineus* sand shiner | *Notropis volucellus* mimic shiner | *Pimephales notatus* bluntnose minnow | *Rhinichthys atratulus* blacknose dace | *Rhinichthys cataractae* longnose dace | *Semotilus atromaculatus* creek chub | *Notropis photogenis* silver shiner | *Notropis* spp. Notropis species | *Ameiurus nebulosus* brown bullhead |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Scientific name* Common name | | | | | | | | | | | | | | | | | | |
| St. Marys; Upper river | 2006 | | | | | | | | | | | | | 1.67 | | | | | | |
| | 2007 | | | | | | | | 0.41 | | 0.35 | 0.06 | 0.35 | 3.41 | | | | | | |
| | 2008 | | | | | | 0.13 | | 0.13 | | 0.19 | | 0.47 | 1.33 | | | 0.07 | | | |
| | 2009 | | | | | | | | | | 0.31 | 0.38 | 1.38 | 1.44 | | | | | | |
| | 2014 | | | | | | | | 0.2 | | | | 4.9 | 2.9 | | | | | | |
| | 2015 | | | | | | | | 0.05 | | | | 0.89 | 1.68 | | | | | | |
| St. Marys; Main river | 2006 | | | | 0.58 | | | | 0.08 | | 0.25 | | 5 | 1.92 | 0.08 | 0.08 | | | | |
| | 2007 | | | 0.26 | 0.42 | | 1.05 | | 0.42 | 0.05 | 0.74 | 0.11 | 1.47 | 5.63 | | | | | | 0.0 |
| | 2008 | | | | 0.13 | | 0.13 | | 1.33 | | | | 1.73 | 5.6 | | | 0.07 | | | |
| | 2009 | | | | 0.35 | | | | 0.06 | | 0.06 | 0.12 | 3.24 | 3.06 | | | | | | |
| | 2014 | | | | 0.06 | | | | 0.09 | 0.06 | 0.09 | | 6.91 | 4.27 | | | | | | |
| | 2015 | | | | 0.18 | | | 0.03 | | | 0.03 | | 0.09 | 0.67 | | | | | | |
| St. Marys; Lake George | 2006 | | 0.25 | | | | | | 1.88 | | 2.38 | | 2.5 | 0.5 | | | | | | 0.1 |
| | 2007 | | 0.41 | | | | | | 12.1 | | 0.27 | | 1.73 | 0.32 | | | | | | 0.0 |
| | 2008 | | | | | | 1 | | 2.67 | | | | 2.17 | | | | | | | 0.1 |
| | 2009 | | | | | | | | 1.8 | | 1.6 | 1.93 | 5.8 | 0.13 | | | | | | |
| | 2014 | | | | | | | | 7.3 | | 2 | 0.1 | 4.6 | 1.4 | | | | 0.15 | | |
| | 2015 | | | | | | | | 0.9 | | 0.5 | | | 2.35 | 0.15 | | | | | |
| St. Marys; Lower river | 2006 | | 0.8 | | | | | 0.2 | 0.4 | | 8.2 | | 16.4 | 52.4 | | | 1.8 | | | |
| | 2007 | | 0.08 | | | | 0.15 | 0.15 | 24.6 | | 2 | | 7.46 | 15.8 | | | | | | 0.3 |
| | 2008 | | 0.18 | | | | 0.18 | | 10.9 | | 0.27 | | 3.36 | 5.18 | | | | | | |
| | 2009 | 0.12 | 0.44 | | | | 0.76 | | 3.12 | | 1.8 | 1.16 | 34.3 | 2.44 | | | | | | |
| | 2014 | | 0.1 | | | | | 0.05 | 2.35 | | 1 | 0.05 | 45.7 | 20.8 | | | | | 0.2 | |
| | 2015 | 0.05 | | | 0.05 | | | 6.55 | | | 0.65 | | 10.3 | 13.1 | | | | | | |
| Mississagi River | 2014 | 0.25 | 0.15 | | | 0.05 | | 0.3 | 4.05 | 0.2 | 0.45 | 0.15 | 8 | 0.35 | | | | | | |
| | 2015 | 0.12 | | | | 0.08 | 0.04 | | 1.08 | 0.6 | 0.88 | | 3.88 | | | | | | | |

Table 6 continued…

| Sampling location | Year | *Lota lota* burbot | *Culaea inconstans* brook stickleback | *Gasterosteus aculeatus** threespine stickleback | *Pungitius pungitius* ninespine stickleback | *Percopsis omiscomaycus* trout-perch | *Morone chrysops** white bass | *Ambloplites rupestris* rock bass | *Lepomis gibbosus* pumpkinseed | *Micropterus dolomieu* smallmouth bass | *Micropterus salmoides* largemouth bass | *Perca flavescens* yellow perch | *Sander vitreum* walleye | *Etheostoma exile* Iowa darter | *Etheostoma nigrum* Johnny darter | *Percina caprodes* logperch | *Etheostoma* spp. darter species | *Cottus bairdi* mottled sculpin | Total Catch | Total Species |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Scientific name* Common name | | | | | | | | | | | | | | | | | | |
| St. Marys; Upper river | 2006 | 0.22 | | | 0.67 | 0.33 | | 0.22 | | 0.67 | | 4.33 | | | 0.11 | | | | 90 | 13 |
| | 2007 | 0.12 | | | 0.06 | 0.18 | | 0.76 | | | | 8.53 | | 0.06 | | | | 0.06 | 279 | 16 |
| | 2008 | | | | 0.06 | | | 0.13 | | | | 4.93 | | | 0.33 | | | 0.4 | 135 | 14 |
| | 2009 | | | | 0.13 | | | 1.06 | | 0.06 | | 6.69 | | 0.25 | 1.38 | | | 1.25 | 321 | 16 |
| | 2014 | | | | 0.05 | | | 0.75 | | | | 26.6 | | | 0.1 | | | 0.1 | 749 | 12 |
| | 2015 | | | | | | | 0.58 | | | | 1.79 | | | 0.68 | 0.11 | | 0.16 | 133 | 14 |
| St. Marys; Main river | 2006 | 0.25 | 1.08 | 2.17 | 0.75 | 4.25 | | 2.08 | 0.08 | 0.83 | | 3.33 | | | 0.17 | 2.92 | | 2.67 | 573 | 27 |
| | 2007 | 0.11 | 0.47 | 1 | 0.11 | 1.16 | | 1.05 | 1.37 | 0.32 | | 9.42 | 0.32 | 0.16 | 0.11 | 2.11 | | 1 | 725 | 30 |
| | 2008 | | 0.4 | 1 | 0.2 | 0.2 | | 5.2 | 0.87 | | | 12.1 | 0.13 | 0.13 | 0.93 | 3.6 | | 1.67 | 723 | 25 |
| | 2009 | | 0.06 | 0.82 | 0.35 | 0.06 | | 3.24 | 0.06 | 0.12 | | 2.12 | | | 1.35 | 1.24 | | 1.76 | 443 | 24 |
| | 2014 | | 0.09 | 0.24 | 0.06 | | | 2.39 | 0.12 | 0.18 | | 5.55 | 0.06 | 0.06 | 0.45 | 2.09 | 0.03 | 0.73 | 978 | 25 |
| | 2015 | | | 0.03 | | | | 0.97 | | 0.12 | | 1 | 0.06 | | 0.73 | 0.73 | | 0.64 | 300 | 20 |
| St. Marys; Lake George | 2006 | | | | | 0.25 | | | | | | 1.25 | | | 0.13 | 1 | | | 171 | 14 |
| | 2007 | | | | | 0.27 | 0.05 | 0.23 | 0.05 | 0.05 | | 5.5 | 0.05 | | 0.14 | 1.86 | | | 535 | 19 |
| | 2008 | | | | | 0.5 | | 0.83 | | | | 2.83 | | | | | | | 71 | 8 |
| | 2009 | | | | | 0.73 | | 0.2 | | 0.07 | 0.07 | 0.93 | | | 0.27 | 0.47 | | | 227 | 14 |
| | 2014 | | | 0.25 | | 0.2 | | | | | | 0.35 | 0.05 | | 0.4 | 0.45 | | | 628 | 16 |
| | 2015 | | | 0.1 | | | | | | | | 0.05 | | | 0.25 | 0.05 | | | 355 | 14 |
| St. Marys; Lower river | 2006 | | | | | 1 | | 14.8 | 0.2 | 2.4 | | 7 | | | 0.2 | 0.4 | | | 572 | 17 |
| | 2007 | | | | | | | 6.92 | 3.46 | 1.38 | | 5.08 | | | 0.08 | | | 0.15 | 891 | 17 |
| | 2008 | | | | | 0.64 | | 0.64 | 0.27 | 0.82 | 0.09 | 2.73 | 0.09 | | | 0.09 | | | 297 | 17 |
| | 2009 | | | 0.04 | | 1.84 | | 1.92 | 0.84 | 0.48 | | 2.08 | 0.04 | | 0.56 | 0.76 | | 0.04 | 147 | 23 |
| | 2014 | | | 0.15 | 0.05 | 1.05 | | 5.75 | 0.7 | 1.45 | 0.05 | 3.55 | | 0.1 | 0.25 | 0.8 | | 0.1 | 171 | 24 |
| | 2015 | | | 0.2 | | 0.35 | | 2.2 | 0.1 | 0.5 | | 1.4 | 0.2 | 0.05 | 0.45 | 0.65 | | 0.1 | 798 | 23 |
| Mississagi River | 2014 | | | | | 0.6 | | 1.75 | | 0.8 | 0.05 | 6.35 | 0.55 | | 1.1 | 1.4 | | 0.05 | 614 | 25 |
| | 2015 | 0.16 | | | | 1.24 | | 2.88 | | 0.88 | | 3.68 | 0.2 | | 1 | 1.08 | 0.04 | 0.16 | 496 | 20 |

Table 7. Scientific and common names of the 19 species collected in the St. Marys and Mississagi rivers in 2014-2015 via trawling. Values are the mean number of fish captured per 100 m transect. Total catch and total species included.

| Scientific name | Common name | St Marys R. Trawl | | Mississagi R. Trawl | |
|---|---|---|---|---|---|
| | | 2014 | 2015 | 2014 | 2015 |
| *Acipenser fulvescens* | lake sturgeon | | | 1.5 | |
| *Oncorhynchus tshawytscha* | Chinook salmon | 0.06 | | | |
| *Esox lucius* | northern pike | 0.09 | | | |
| *Catostomus commersoni* | white sucker | 0.03 | | 0.33 | |
| *Notropis hudsonius* | spottail shiner | | 0.03 | | |
| *Notropis volucellus* | mimic shiner | 0.34 | 0.39 | | |
| *Pimephales notatus* | bluntnose minnow | 1.26 | 0.25 | | |
| *Culaea inconstans* | brook stickleback | 2.71 | 9.31 | | |
| *Gasterosteus aculeatus** | threespine stickleback | 0.2 | 0.11 | | |
| *Pungitius pungitius* | ninespine stickleback | 0.03 | 0.08 | | |
| *Percopsis omiscomaycus* | trout-perch | | | 3.83 | |
| *Ambloplites rupestris* | rock bass | 0.17 | 0.06 | | |
| *Lepomis gibbosus* | pumpkinseed | 0.94 | 0.03 | | |
| *Micropterus dolomieu* | smallmouth bass | | | 4.83 | |
| *Perca flavescens* | yellow perch | 0.58 | 0.22 | 1.67 | |
| *Etheostoma exile* | Iowa darter | 10.37 | 15.03 | 0.83 | |
| *Etheostoma nigrum* | Johnny darter | 18.03 | 32.36 | 23.5 | 1.33 |
| *Percina caprodes* | logperch | 0.23 | 0.11 | 0.17 | |
| *Cottus bairdi* | mottled sculpin | 3.71 | 11.28 | 1.33 | 0.56 |
| | Total Catch | 1357 | 2493 | 228 | 17 |
| | Total Species | 15 | 13 | 9 | 2 |

Table 8. The rank of the ten most abundant species collected in the sampled areas of the St. Marys River with boat electrofishing (this survey: efish 2006-2009 and efish 2014-2015) and trawling (this survey: trawl 2014-2015; past survey; Liston et al. 1980, 1983, and Liston and McNabb 1986) and the Mississagi River (this survey: efish and trawl 2014-2015).

| Sampling location | Year | lake sturgeon | coho salmon | rainbow trout | lake whitefish | cisco | rainbow smelt | northern pike | white sucker | common shiner | emerald shiner | spottail shiner | rosyface shiner | sand shiner | mimic shiner | bluntnose minnow | silver shiner | brook stickleback | threespine stickleback | ninespine stickleback | trout-perch | rock bass | pumpkinseed | smallmouth bass | black crappie | yellow perch | Iowa darter | Johnny darter | logperch | mottled sculpin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| St. Marys; Upper river | efish 2006-2009 | | | | | 9 | 6 | | 3 | | | 10 | | | 4 | 2 | | | | | | 5 | | | | 1 | | 7 | | 8 |
| | efish 2014-2015 | | 10 | | | | 7 | | 4 | | 8 | | | | 2 | 3 | | | | | | 5 | | | | 1 | | 6 | | 8 |
| | trawl 2014-2015 | | | | | | | | | | | | | | | | | 4 | | | | | | | | 5 | 1 | 2 | | 3 |
| | trawl 1979-1983 | | | | 10 | | 7 | 8 | 5 | | | | | | 4 | | | 6 | | 2 | 10 | | | | | 3 | 10 | 1 | | |
| St. Marys; Main river | efish 2006-2009 | | | | | | 7 | | 1 | | | | | | 5 | 3 | | | 10 | | 9 | 4 | | | | 2 | | | 6 | 8 |
| | efish 2014-2015 | | | 10 | | | 6 | | 3 | | | | | | 1 | 4 | | | | | | 5 | | | | 2 | | 9 | 7 | 8 |
| | trawl 2014-2015 | | | | | | | | | | | | | | | 5 | 7 | 2 | 8 | | | | 6 | | | 10 | 4 | 1 | 8 | 3 |
| | trawl 1979-1983 | | | | | | | | 6 | | | 5 | | | 3 | | | 10 | | 9 | 2 | | | | | 7 | | 4 | 8 | 1 |
| St. Marys; Lake George | efish 2006-2009 | | | | | | 4 | | 7 | | 1 | 6 | | 8 | 3 | | | | | | 9 | 10 | | | | 2 | | | 5 | |
| | efish 2014-2015 | | 8 | | | | 1 | | | | 2 | 4 | | | 3 | 5 | | | | | | | | | | 9 | | 6 | 7 | |
| | trawl 2014-2015 | | | | | | | | | | | | | | | | | 2 | 5 | 6 | | | | | | | 4 | 1 | | 3 |
| | trawl 1979-1983 | | | | | | 8 | | 6 | 5 | | 2 | | | | | | | | 9 | 1 | 10 | | | | 3 | | 4 | 7 | |
| St. Marys; Lower river | efish 2006-2009 | | | | | | 6 | | | | 3 | 7 | | | 1 | 2 | | | | | 9 | 4 | 8 | 10 | | 5 | | | | |
| | efish 2014-2015 | | | | | | | | 6 | | 3 | 8 | | | 1 | 2 | | | | | 10 | 4 | | 7 | | 5 | | | 9 | |
| | trawl 2014-2015 | | | | | | | 8 | | | | | | | | 5 | | 8 | | | | 7 | 3 | | | 6 | 2 | 1 | | 4 |
| | trawl 1979-1983 | | | | | | 8 | | 7 | | 6 | 2 | | | 3 | | | | | | 1 | 9 | | | 10 | 4 | | 5 | | |
| Mississagi River | efish 2014-2015 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | trawl 2014-2015 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table 9. Analysis of variance results for Index of Biotic Integrity (IBI) metrics: IBI (complete), native, centrarchid, turbidity intolerant, non-native, and native cyprinid species richness; percent piscivore, generalist, and specialist biomass, number of native individuals, biomass of natives (kg); percent non-native species by number and biomass by sites by years and the Habitat Productivity Index (HPI) from the four locations on the St. Marys River and the Mississagi River. Sites included the upper river (Upper), main river (Main), Lake George (George), lower river (Lower), and Mississagi River (Mississagi).

| Parameter | Years | Factor | F | df | p | Tukey HSD |
|---|---|---|---|---|---|---|
| IBI | 2006-2015 | Upper | 1.031 | 5, 90 | 0.405 | |
| | | Main | 6.043 | 5, 123 | 0.000 | 2015<2008, 2009, 2014 |
| | | George | 2.820 | 5, 85 | 0.021 | 2015<2007, 2009 |
| | | Lower | 2.965 | 5, 88 | 0.016 | 2015< 2006, 2014 |
| | | Mississagi | 0.004 | 1, 43 | 0.950 | |
| Native Species Richness | 2006-2015 | Upper | 1.701 | 5, 90 | 0.142 | |
| | | Main | 16.066 | 5, 123 | 0.000 | 2015<2014<=2009<2006, 2007, 2008 |
| | | George | 4.876 | 5, 85 | 0.001 | 2015<=2008<2006-2014 |
| | | Lower | 1.251 | 5, 88 | 0.292 | |
| | | Mississagi | 0.780 | 1, 43 | 0.382 | |
| Centrarchid Species Richness | 2006-2015 | Upper | 2.933 | 5, 90 | 0.017 | 2014<2009 |
| | | Main | 1.639 | 5, 123 | 0.155 | |
| | | George | 5.143 | 5, 85 | 0.000 | 2006, 2014, 2015<2007, 2008, 2009 |
| | | Lower | 1.487 | 5, 88 | 0.202 | |
| | | Mississagi | 1.626 | 1, 43 | 0.209 | |
| Turbidity Intolerant Species Richness | 2006-2015 | Upper | 4.855 | 5, 90 | 0.001 | 2015, 2006, 2014<=2007<=2009 |
| | | Main | 3.598 | 5, 123 | 0.005 | 2007>2009, 2015 |
| | | George | 2.503 | 5, 85 | 0.037 | 2006>2015 |
| | | Lower | 2.651 | 5, 88 | 0.028 | 2006>2008 |
| | | Mississagi | 1.062 | 1, 43 | 0.309 | |
| Non-native Species Richness | 2006-2015 | Upper | 3.741 | 5, 90 | 0.004 | 2006>2007-2015 |
| | | Main | 3.809 | 5, 123 | 0.003 | 2014, 2015<2006 |
| | | George | 3.228 | 5, 85 | 0.010 | 2014>2009, 2007 |
| | | Lower | 1.692 | 5, 88 | 0.145 | |
| | | Mississagi | 0.154 | 1, 43 | 0.697 | |

Table 9 continued…

| Parameter | Years | Factor | F | df | p | Tukey HSD |
|---|---|---|---|---|---|---|
| Native | 2006- | Upper | 1.410 | 5, 90 | 0.228 | |
| Cyprinid | 2015 | Main | 16.15 | 5, 123 | 0.000 | 2015< 2006, 2008, 2009, 2014< 2007 |
| Species | | George | 4.527 | 5, 85 | 0.0012 | 2015< 2006, 2009,2014 |
| Richness | | Lower | 0.420 | 5, 88 | 0.834 | |
| | | Mississagi | 4.200 | 1, 43 | 0.047 | |
| Percent | | | | | | |
| Piscivore | 2006- | Upper | 1.102 | 5, 90 | 0.365 | |
| Biomass | 2015 | Main | 0.837 | 5, 123 | 0.526 | |
| | | George | 0.432 | 5, 85 | 0.825 | |
| | | Lower | 1.250 | 5, 88 | 0.293 | |
| | | Mississagi | 0.247 | 1, 43 | 0.622 | |
| Percent | | | | | | |
| Generalist | 2006- | Upper | 1.407 | 5, 90 | 0.229 | |
| Biomass | 2015 | Main | 2.957 | 5, 123 | 0.015 | 2015<2006 |
| | | George | 0.672 | 5, 85 | 0.646 | |
| | | Lower | 3.146 | 5, 88 | 0.012 | 2015>2007, 2008 |
| | | Mississagi | 0.004 | 1, 43 | 0.947 | |
| Percent | | | | | | |
| Specialist | 2006- | Upper | 0.650 | 5, 90 | 0.662 | |
| Biomass | 2015 | Main | 2.064 | 5, 123 | 0.074 | |
| | | George | 0.204 | 5, 85 | 0.944 | |
| | | Lower | 2.553 | 5, 88 | 0.033 | 2015<2009 |
| | | Mississagi | 0.205 | 1, 43 | 0.653 | |
| Number of | 2006- | Upper | 5.201 | 5, 90 | 0.000 | 2006-2009, 2015<2014 |
| Native | 2015 | Main | 6.315 | 5, 123 | 0.000 | 2015<=2009<2006, 2007, 2008, 2014 |
| Individuals | | George | 1.734 | 5, 85 | 0.136 | |
| | | Lower | 5.531 | 5, 88 | 0.000 | 2008, 2015<2006<=2014 |
| | | Mississagi | 3.562 | 1, 43 | 0.066 | |

Table 9 continued….

| Parameter | Years | Factor | F | df | p | Tukey HSD |
|---|---|---|---|---|---|---|
| Biomass of | 2006- | Upper | 2.257 | 5, 90 | 0.055 | |
| Natives (kg) | 2015 | Main | 7.142 | 5, 123 | 0.000 | 2009, 2014, 2015<2006, 2007, 2008 |
| | | George | 4.854 | 5, 85 | 0.001 | 2009, 2014, 2015<2007 |
| | | Lower | 1.773 | 5, 88 | 0.127 | |
| | | Mississagi | 6.33 | 1, 43 | 0.431 | |
| Percent of | 2006- | Upper | 1.205 | 5, 90 | 0.313 | |
| Non-natives/ | 2015 | Main | 1.909 | 5, 123 | 0.098 | |
| Number | | George | 1.984 | 5, 85 | 0.089 | |
| | | Lower | 1.542 | 5, 88 | 0.185 | |
| | | Mississagi | 0.064 | 1, 43 | 0.801 | |
| Percent of | 2006- | Upper | 3.046 | 5, 90 | 0.014 | 2006, 2015> 2007-2014 |
| Non-natives/ | 2015 | Main | 1.007 | 5, 123 | 0.416 | |
| Biomass | | George | 1.607 | 5, 85 | 0.167 | |
| | | Lower | 0.560 | 5, 88 | 0.730 | |
| | | Mississagi | 0.151 | 1, 43 | 0.700 | |
| HPI | 2006- | Upper | 3.435 | 5, 90 | 0.007 | |
| | 2015 | Main | 8.532 | 5, 123 | 0.000 | 2015, 2014, 2009<2008, 2007, 2006 |
| | | George | 8.418 | 5, 85 | 0.000 | 2007>2006-2015 |
| | | Lower | 5.034 | 5, 88 | 0.000 | 2006>=2006>2007-2015 |
| | | Mississagi | 0.042 | 1, 43 | 0.838 | |

Table 10. Two-way analysis of variance results for among site and year comparisons from the four locations on the St. Marys River. Data is separated into 2006-2008 (from Pratt and O'Connor 2011), 2009-2015 for the St. Marys River data only and 2006-2015 for the St. Marys River and 2006-2015 all data, which includes the Mississagi River data. Sites included the upper river (Upper), main river (Main), Lake George (George), lower river (Lower), and Mississagi River (Mississagi) for mean transect biomass, species richness, IBI and HPI indices.

| Parameter | Years | Factor | F | df | p | Tukey HSD |
|---|---|---|---|---|---|---|
| Biomass | 2006-2008 | site | 23.826 | 3, 140 | <0.001 | Upper, George<Main, Lower |
| | | year | 5.656 | 2, 140 | 0.004 | 2006, 2007>2008 |
| | | site*year | 1.409 | 6, 140 | 0.215 | |
| | 2009 -2015 | site | 22.358 | 3, 246 | <0.001 | George<Upper, Main<Lower |
| | data | year | 6.539 | 2, 246 | 0.002 | 2015<=2009<=2014 |
| | | site*year | 1.76 | 6, 246 | 0.108 | |
| | 2006-2015 | site | 24.952 | 3, 386 | <0.001 | George, Upper< Lower, Main[1] |
| | data | year | 5.154 | 5, 386 | <0.001 | 2015<2007, 2006[1] |
| | | site*year | 3.779 | 15, 386 | <0.001 | |
| | 2006-2015 | site | 17.509 | 4, 445 | <0.001 | George, Upper< Lower, Main, Mississagi[1] |
| | Including Mississagi | year | 4.566 | 5, 445 | <0.001 | 2015<2006[1] |
| | River | site*year | 3.029 | 16, 455 | <0.001 | |
| Species Richness | 2006-2008 | site | 48 | 3, 140 | <0.001 | Upper, George<Lower<Main |
| | | year | 3.456 | 2, 140 | 0.034 | 2007<=2006>2008 |
| | | site*year | 1.427 | 6, 140 | 0.208 | |
| | 2009 -2015 | site | 23.807 | 3, 246 | <0.001 | Upper, George<Main<Lower |
| | data | year | 9.959 | 2, 246 | <0.001 | 2015<2014<=2009 |
| | | site*year | 1.289 | 6, 246 | 0.263 | |
| | 2006-2015 | site | 53.529 | 3, 386 | <0.001 | Upper, George< Main, Lower[1] |
| | data | year | 9.22 | 5, 386 | <0.001 | 2015<2006-2014[1] |
| | | site*year | 3.907 | 15, 386 | <0.001 | |
| | 2006-2015 | site | 43.470 | 4, 445 | <0.001 | Upper, George< Main, Lower, Mississagi[1] |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Including | | | | | |
| | Mississagi | year | 9.257 | 5, 445 | <0.001 | 2015<2006, 2006, 2009[1] |
| | River | site*year | 3.666 | 16, 455 | <0.001 | |
| IBI | 2006-2008 | site | 21.54 | 3, 140 | <0.001 | Upper<George<Main<Lower |
| | | year | 1.124 | 2, 140 | 0.328 | |
| | | site*year | 1.581 | 6, 140 | 0.157 | |
| | 2009 -2015 | site | 23.295 | 3, 246 | <0.001 | Upper, Main, George< Lower |
| | data | year | 11.229 | 2, 246 | <0.001 | 2015<2009,2014 |
| | | site*year | 0.557 | 6, 246 | 0.764 | |
| | 2006-2015 | site | 36.925 | 3, 386 | <0.001 | Upper< George, Main < Lower |
| | data | year | 7.855 | 5, 386 | <0.001 | 2015<2006-2014 |
| | | site*year | 1.118 | 15, 386 | 0.338 | |
| | 2006-2015 | site | 37.907 | 4, 445 | <0.001 | Upper, Main, George<Mississagi<=Lower |
| | Including | | | | | |
| | Mississagi | year | 7.216 | 5, 445 | <0.001 | 2015<2009, 2006, 2008<= 2014, 2007 |
| | River | site*year | 1.345 | 16, 445 | 0.166 | |
| HPI | 2006-2008 | site | 21.683 | 3, 140 | <0.001 | Upper, George<Lower<Main |
| | | year | 1.977 | 2, 140 | 0.142 | |
| | | site*year | 1.8 | 6, 140 | 0.12 | |
| | 2009 -2015 | site | 12.32 | 3, 246 | <0.001 | George<Upper<=Main<Lower |
| | data | year | 11.527 | 2, 246 | <0.001 | 2015<=2009<2014 |
| | | site*year | 2 | 6, 246 | 0.066 | |
| | 2006-2015 | site | 28.463 | 3, 386 | <0.001 | George, Upper< Main, Lower[1] |
| | data | year | 8.427 | 5, 386 | <0.001 | 2015< 2014, 2007, 2006[1] |
| | | site*year | 4.305 | 15, 386 | <0.001 | |
| | 2006-2015 | site | 22.447 | 4, 445 | <0.001 | George, Upper< Main, Lower[1] |
| | Including | | | | | |
| | Mississagi | year | 8.174 | 5, 445 | <0.001 | 2015< 2014, 2007, 2006[1] |
| | River | site*year | 4.454 | 16, 455 | <0.001 | |

1. indicates two-factor ANOVA with interaction. MANOVA with Post Hoc Tukey analysis to determine effects.

Table 11. Mean values for 10 of the metrics used in the IBI calculation and the HPI for transects sampled in the St. Marys and Mississagi Rivers 2006 – 2015. The values from 2006-2008 are grouped, following Pratt and O'Connor (2011). Penetang Harbour and Hog Bay data from Brousseau et al. (2004) and are provided for comparison.

| | | Metric name | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Timeframe | Biomass (kg) | Number captured | Species richness | Native species richness | Native cyprinid species richness | Percent piscivore biomass | Percent generalist biomass | Percent specialist biomass | Percent non-native species by number | Percent non-native species by biomass | Index of biotic integrity | Habitat productivity index |
| St. Marys River Upper river | 2006-2008 | 0.6 | 12.3 | 3.6 | 3.5 | 1 | 3.0 | 14.5 | 75.1 | 1.1 | 5.0 | 48.0 | 9.5 |
| | 2009 | 0.4 | 20.1 | 4.6 | 4.6 | 1.3 | 0.17 | 22.8 | 64.6 | 0 | 0 | 50.3 | 9.3 |
| | 2014 | 1.2 | 37.5 | 3.2 | 3.1 | 1.2 | 1.0 | 24.6 | 69.4 | 0.5 | 1.0 | 49.2 | 28.8 |
| | 2015 | 0.5 | 7.0 | 2.9 | 2.8 | 0.8 | 7.8 | 29.8 | 57.1 | 6.6 | 7.8 | 43.8 | 5.7 |
| St. Marys River Main river | 2006-2008 | 2.7 | 43.9 | 9.2 | 8.3 | 2.2 | 8.1 | 64.6 | 27.4 | 6.3 | 2.3 | 56.9 | 37.1 |
| | 2009 | 1.1 | 26.1 | 6.8 | 6.0 | 1.8 | 0.5 | 54.1 | 39.6 | 5.5 | 0.8 | 49.3 | 16.8 |
| | 2014 | 1.0 | 29.6 | 5.7 | 5.2 | 1.5 | 3.0 | 53.2 | 43.8 | 3.8 | 3.8 | 52.8 | 19.3 |
| | 2015 | 0.5 | 9.1 | 3.8 | 3.4 | 0.5 | 8.0 | 36.5 | 46.4 | 4.2 | 7.9 | 41.5 | 8.2 |
| St. Marys River Lake George | 2006-2008 | 0.8 | 21.6 | 4.8 | 4.8 | 1.9 | 3.0 | 31.8 | 65.2 | 0.2 | 2.2 | 54.9 | 11.2 |
| | 2009 | 0.2 | 15.1 | 4.7 | 4.7 | 2.5 | 8.1 | 25.5 | 66.3 | 0 | 0 | 56.7 | 3.9 |
| | 2014 | 0.2 | 31.4 | 4.8 | 4.3 | 2.7 | 8.6 | 17.9 | 68.5 | 3.8 | 9.5 | 52.5 | 6.2 |
| | 2015 | 0.1 | 17.8 | 2.6 | 2.25 | 1.15 | 6.5 | 25.2 | 63.3 | 4.1 | 8.3 | 43.9 | 2.1 |
| St. Marys River Lower river | 2006-2008 | 1.5 | 60.7 | 7.0 | 7.0 | 3.1 | 28.6 | 21.9 | 49.5 | 0 | 0 | 70.9 | 27.3 |
| | 2009 | 1.3 | 60.0 | 7.3 | 7.5 | 3.0 | 15.6 | 31.5 | 52.8 | 0.2 | 0.1 | 66.7 | 17.7 |
| | 2014 | 1.5 | 66.8 | 7.3 | 7.1 | 2.9 | 26.3 | 35.2 | 38.4 | 0.2 | 0 | 71.8 | 28.0 |
| | 2015 | 1.8 | 39.9 | 7.0 | 6.8 | 2.9 | 21.4 | 55.9 | 22.7 | 2.8 | 0.1 | 59.4 | 21.1 |
| St. Marys River | 2006-2015 | 1.1 | 32.1 | 5.5 | 5.2 | 1.9 | 9.1 | 35.4 | 52.3 | 2.6 | 3.2 | 54.3 | 17.0 |
| Mississagi River | 2014 | 1.7 | 30.7 | 6.8 | 6.7 | 2.6 | 39.5 | 12.0 | 48.5 | 0.6 | 4.7 | 65.9 | 17.1 |
| | 2015 | 1.3 | 19.8 | 6.1 | 6.0 | 1.8 | 33.9 | 12.5 | 53.6 | 0.8 | 7.4 | 65.6 | 16.3 |
| Penetang Harbour | | 1.6 | 30.5 | 5.4 | 5.0 | 1.2 | 34.4 | 7.4 | 54.7 | 4.5 | 4.3 | 64.8 | N/A |
| Hog Bay | | 4.5 | 26.1 | 6.7 | 6.3 | 1.1 | 43.1 | 20.6 | 36.3 | 3.0 | 15.8 | 66.0 | N/A |

A)

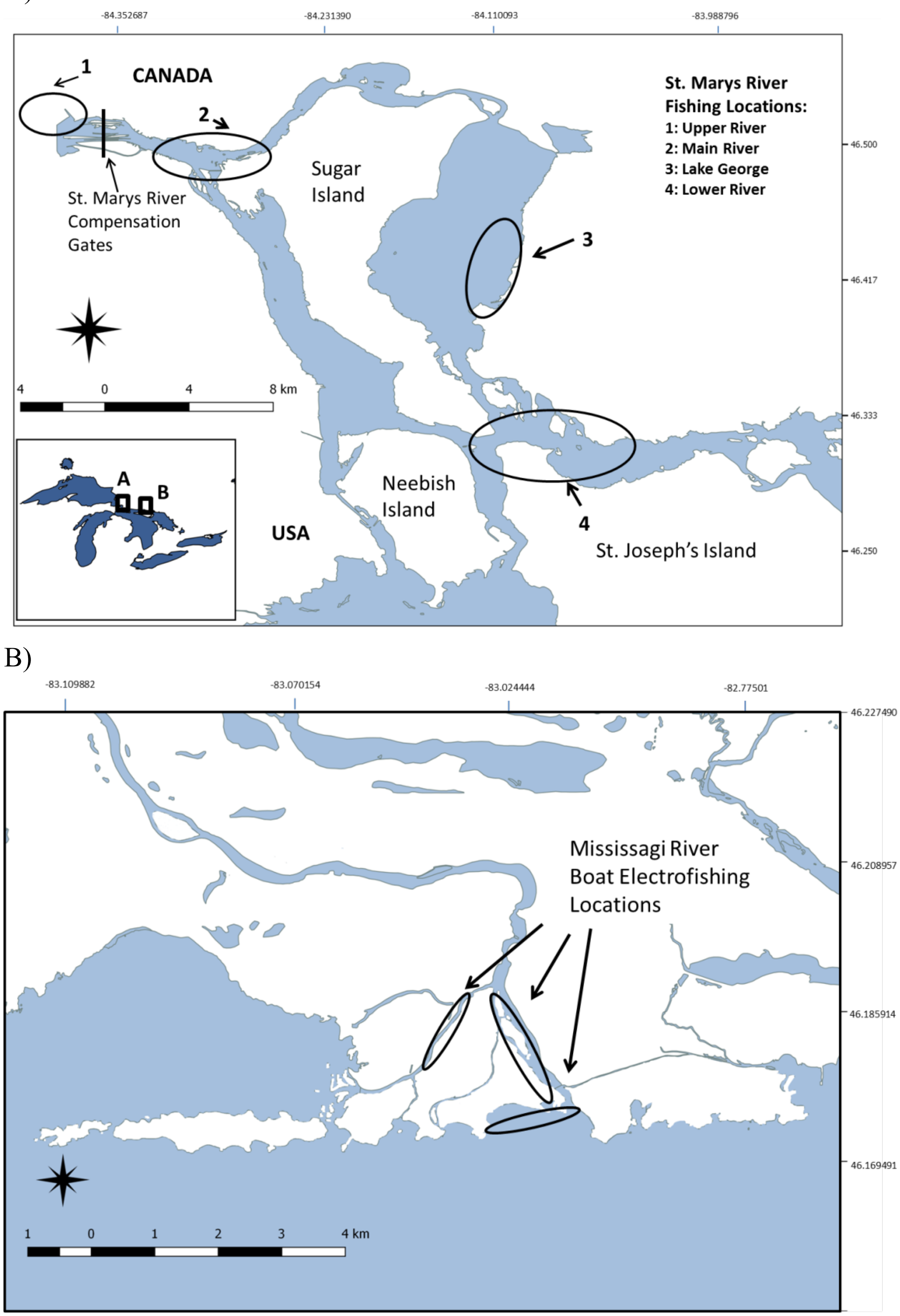


Figure 1: Map of the A) St. Marys River and B) Mississagi River, with survey locations indicated by ovals. The inset shows the location of the rivers in the broader Great Lakes.

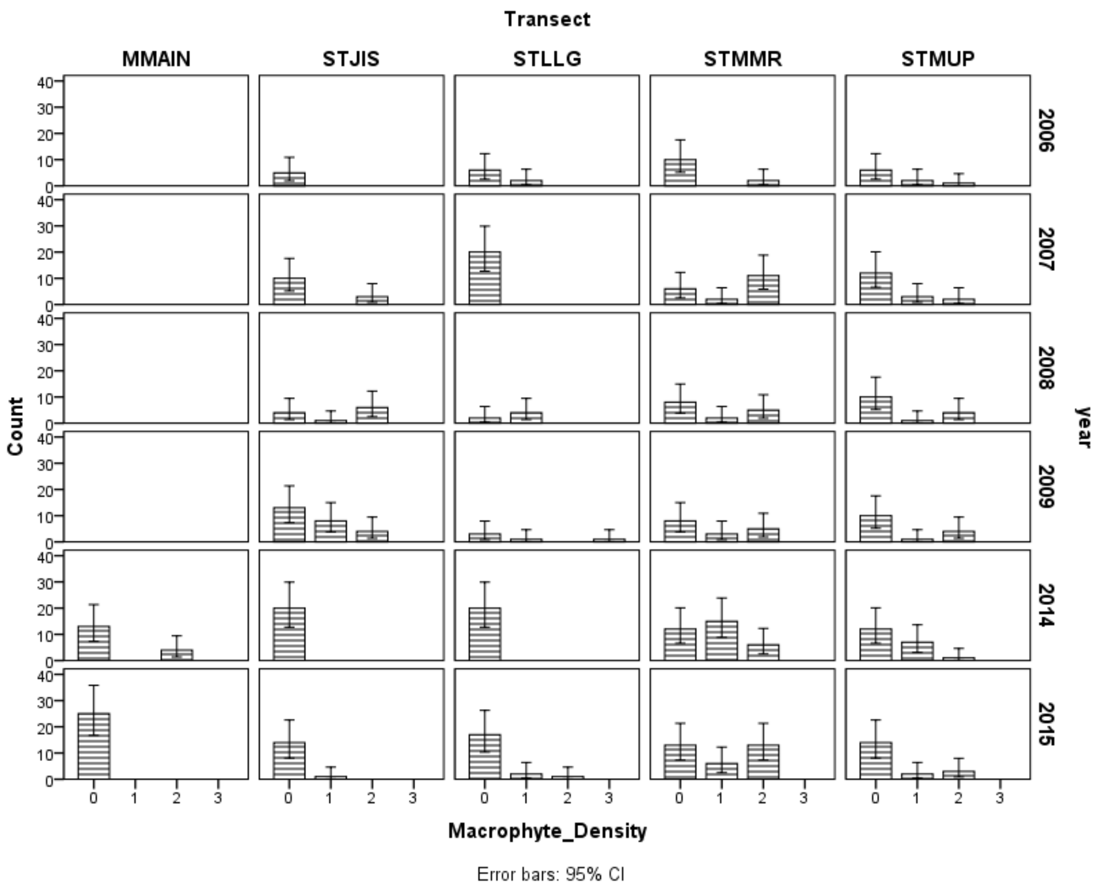


Figure 2: Macrophyte density location electrofished by year. MMain: Mississagi River; STJIS: lower St. Marys River; STLLG: Lake George; STMMR: St. Marys River, Main; STMUP: St. Marys River upper. Macrophyte densities are represented by 0 = none (0%), 1 = sparse (1 to 19% cover), 2 = moderate (20 to 70% cover), and 3 = dense (>70% cover). Error bars represent the 95% confidence limits.

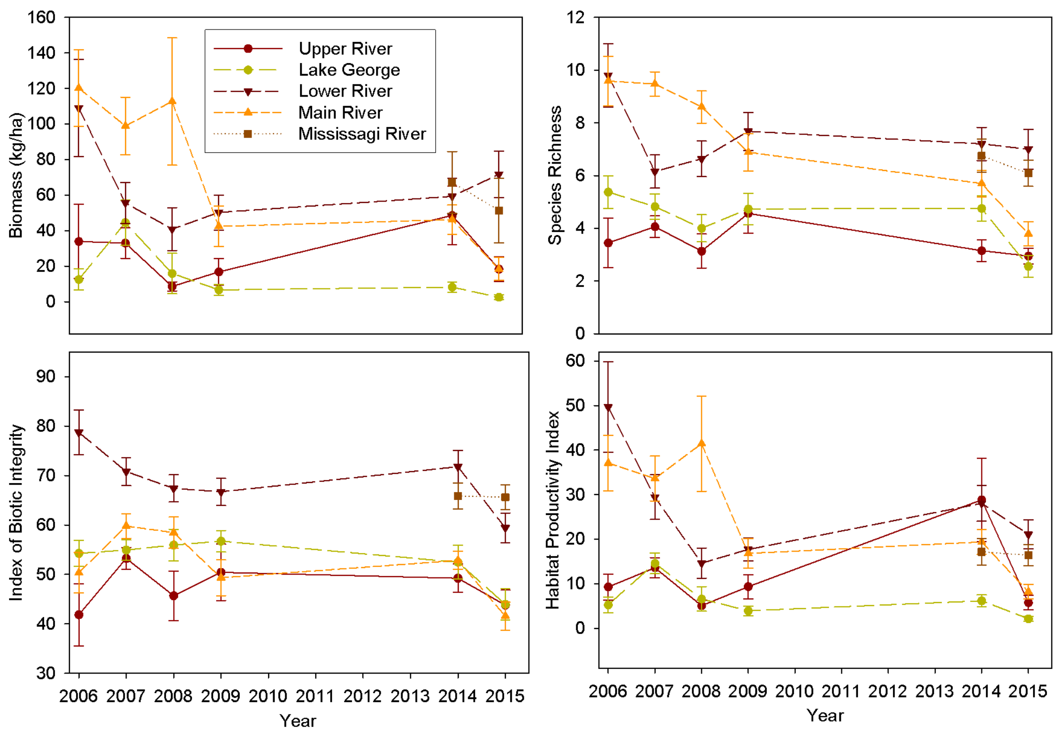


Figure 3: Mean biomass (top left panel), species richness (top right panel), Index of Biotic Integrity (bottom left panel), and Habitat Productivity Index (bottom right panel) by year for each of the four study areas in the St. Marys River and the Mississagi River.

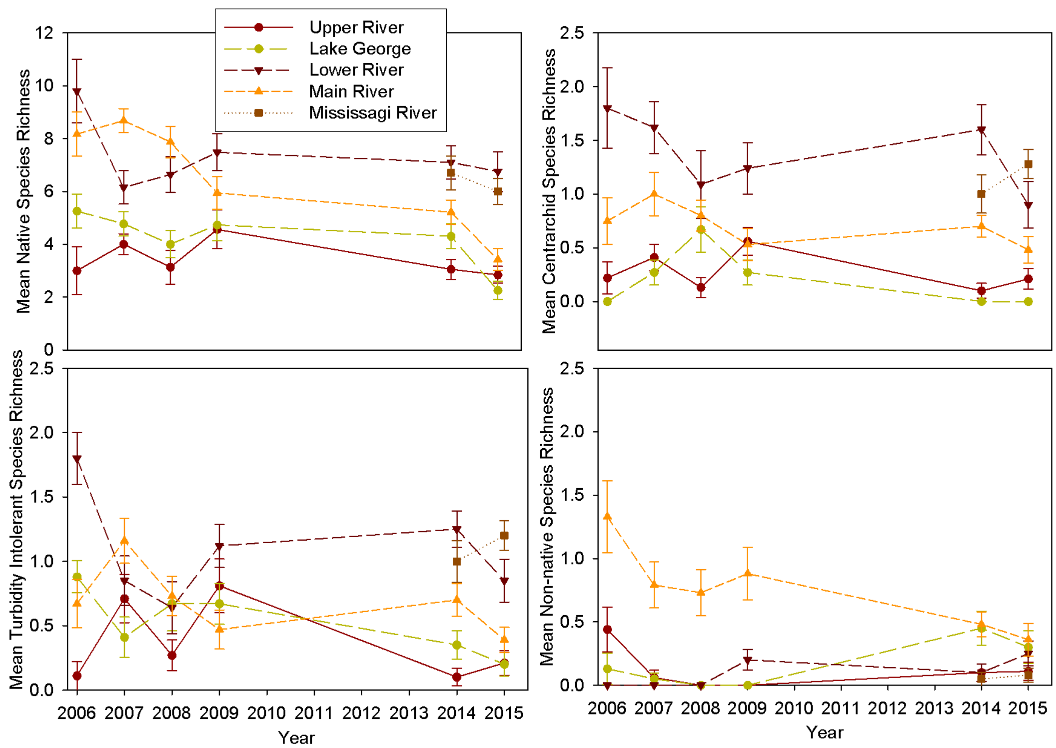


Figure 4: (a) mean native species richness, (b) mean centrarchid species, (c) mean turbidity intolerant species richness, (d) mean non-native species richness by year for each of the four study areas in the St. Marys River and the Mississagi River. Data for 2006-2008 from Pratt and O'Connor (2011).

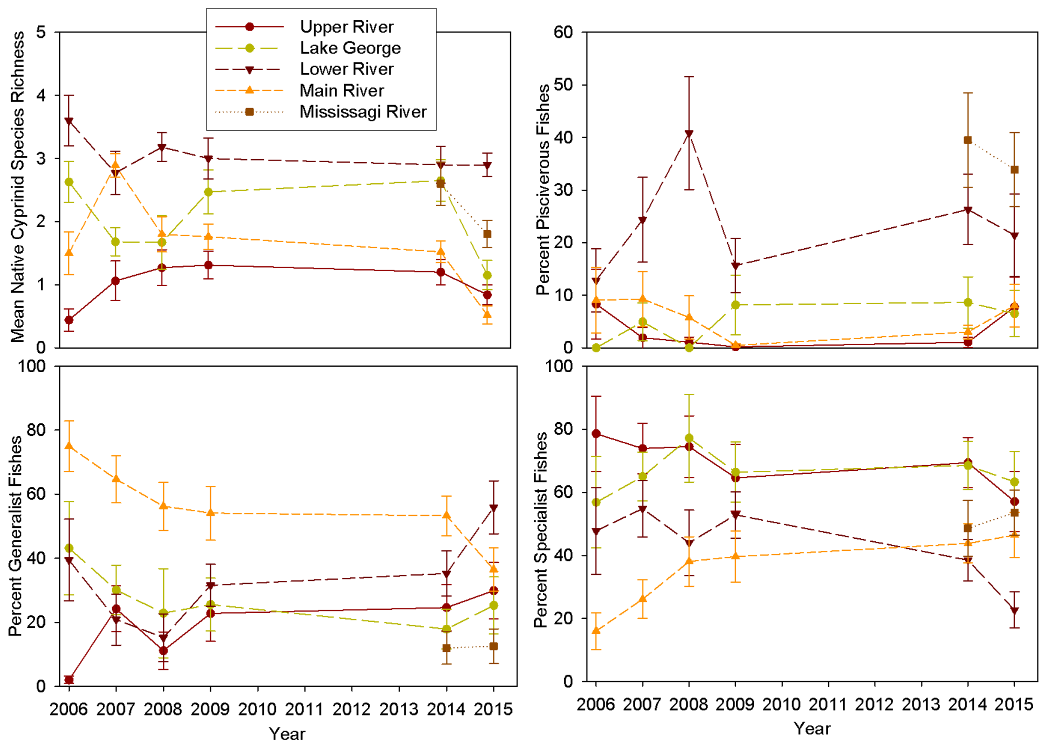


Figure 5: (a) mean native cyprinid species richness, (b) percent pisciverous fishes, (c) percent generalist, (d) percent specialist fishes by year for each of the four study areas in the St. Marys River and the Mississagi River. Data for 2006-2008 from Pratt and O’Connor (2011).

## Appendix 1b: An assessment of the health and historical changes of the nearshore fish community of the St. Marys River (Pratt & O'Connor, 2011)

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# An assessment of the health and historical changes of the nearshore fish community of the St. Marys River

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A B S T R A C T

We examined the nearshore fish community in the St. Marys River using a standardized boat electrofishing protocol to (1) compare the current nearshore fish community of the river to previous surveys, (2) compare the status of fish communities from four distinct areas of the river (the upper river above the compensating gates, the main river, Lake George, and the lower river), and (3) complete an overall assessment of the fish community using an index of biotic integrity approach. The St. Marys River contains a diverse and complex fish community, with dissimilar fish communities located in broad habitat types along the spatial extent of the river. We demonstrated that the nearshore fish community is relatively unaltered over the past 25 years, with many species that were common in the early 1980s remaining important community members today. More invasive fishes now inhabit the river, but unlike many other areas of the Great Lakes, invasives are not common and do not appear to be negatively affecting native species. The overall health of the St. Marys River fish community compared favorably with relatively un-impacted sites from Lake Huron.



## Introduction

The St. Marys River is a 112-km channel that connects Lake Superior with Lake Huron. The river, the only outlet from Lake Superior, is also the largest tributary to Lake Huron and contains a wide diversity of fish habitats (Bray, 1996). This high habitat heterogeneity has resulted in a widely diverse fish community, containing some 75 fishes from 22 families (Duffy et al., 1987). Despite this diversity, the fish community was listed as impaired as part of the Areas of Concern process due to high sea lamprey (*Petromyzon marinus*) abundance, reliance on stocked non-native salmonines to support recreational and commercial fisheries, declines in native species due to overfishing, and concerns about habitat loss and aquatic invasive species (OMOE and MDNR, 1992; Ripley et al., 2011).

Archaeological evidence suggests that lake whitefish (*Coregonus clupeaformis*) was historically the most important fish to First Nations peoples along the St. Marys River (Duffy et al., 1987), but now a mix of warm, cool and coldwater fishes are regularly captured by recreational and subsistence fishermen and assessed by fisheries management agencies active on the river (Schaeffer et al., 2011). While these ongoing efforts to manage harvestable fishes continue, there has been no published assessment of the status of the nearshore fish community in the St. Marys River. Liston et al. (1980, 1983), Liston and McNabb (1986) surveyed the nearshore fish community using bottom trawls to inform about potential dredging impacts with proposed improvements to the shipping/navigation channels, but these voluminous surveys were not synthesized and made available in the primary literature. An assessment of the nearshore fish community in the St. Marys River is recognized as an important but missing component of a comprehensive St. Marys River fisheries assessment plan (Gebhardt et al., 2002; Schaeffer et al., 2011) because the majority of fishes and the juveniles of managed species are too small to be sampled.

In this study, we examine the nearshore fish community in the St. Marys River using a standardized boat electrofishing protocol and use the resulting data to meet three main objectives. Four distinct areas of the river were sampled, and we (1) compared the current nearshore fish community from those areas of the St. Marys River to previous surveys, (2) compared the status of fish communities within each of those areas and (3) completed an overall assessment of the St. Marys River fish community using an index of biotic integrity (Minns et al., 1994) developed for nearshore areas of the Great Lakes.

## Methods

### *Study area*

The St. Marys River is an important corridor for aquatic species, and it has also played a significant role in the human develop of the area by providing hydroelectricity, potable water, a commercial shipping channel, and a food supply (Bray, 1996). The ability of

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organisms to move freely along the length of the river has been gradually reduced with increasing human development. The first locks were constructed in 1797, with the final significant modifications occurring in 1921 with the building of compensating gates at the head of the St. Marys River rapids to regulate water levels on the system, and the expansion of the commercial shipping locks in 1943 (Duffy et al., 1987). Cool, oxygenated water discharges from Lake Superior and provides good quality conditions for most fishes throughout the River. Duffy et al. (1987) identified three distinct areas in the St. Marys River; the upper river, the rapids area, and the lower river, and four primary fish habitats; the open water main stem and embayment reaches, emergent wetlands bordering protected reaches, sand beaches, and the rapids area. We sampled four nearshore areas and habitats in Canadian waters; the upper river, the main river (representing the open water main stem and embayment habitat), Lake George (representing the sand beach habitat), and the lower river (representing emergent wetlands and protected reaches) (Fig. 1). The rapids habitat was not sampled as it is too shallow and swift to sample with an electrofishing boat. Similar sites were fished in the last broad examination of the St. Marys River fish community completed by Liston et al. (1980, 1983), Liston and McNabb (1986). Each site is described in more detail below, and sampling dates and habitat descriptions for each of the areas when fishing occurred are available in Table 1.

*Site descriptions*

*Upper river*

Transects in the upper site were located in Marks and Leigh Bays, well above the compensating gates (Fig. 1). The substrate was predominately sand, and there was little structural cover with the exception of sparse aquatic macrophytes (primarily quillwort (*Isoetes riparia*)) and sunken logs leftover from historic logging operations located on the western side of Marks Bay. Water temperature was consistently colder in this part of the river, reflecting its closer proximity to and influence of Lake Superior (Table 1).

*Main river*

Transects were fished in this location from just below the rapids to above Bells Point (Fig. 1). The main stem of the river had the greatest habitat diversity and highest flows of any of the sampling locations. The substrate was largely cobble and boulders around Topsail Island, with silt and aquatic macrophytes (mostly *Potomogeton* spp. and quillwort) providing physical structure above Bells Point. Abiotic conditions were generally similar to those of the upper river (Table 1).

*Lake George*

Lake George transects were located off of the mouth of the Bar River. They were dominated by sand substrates and contained almost no

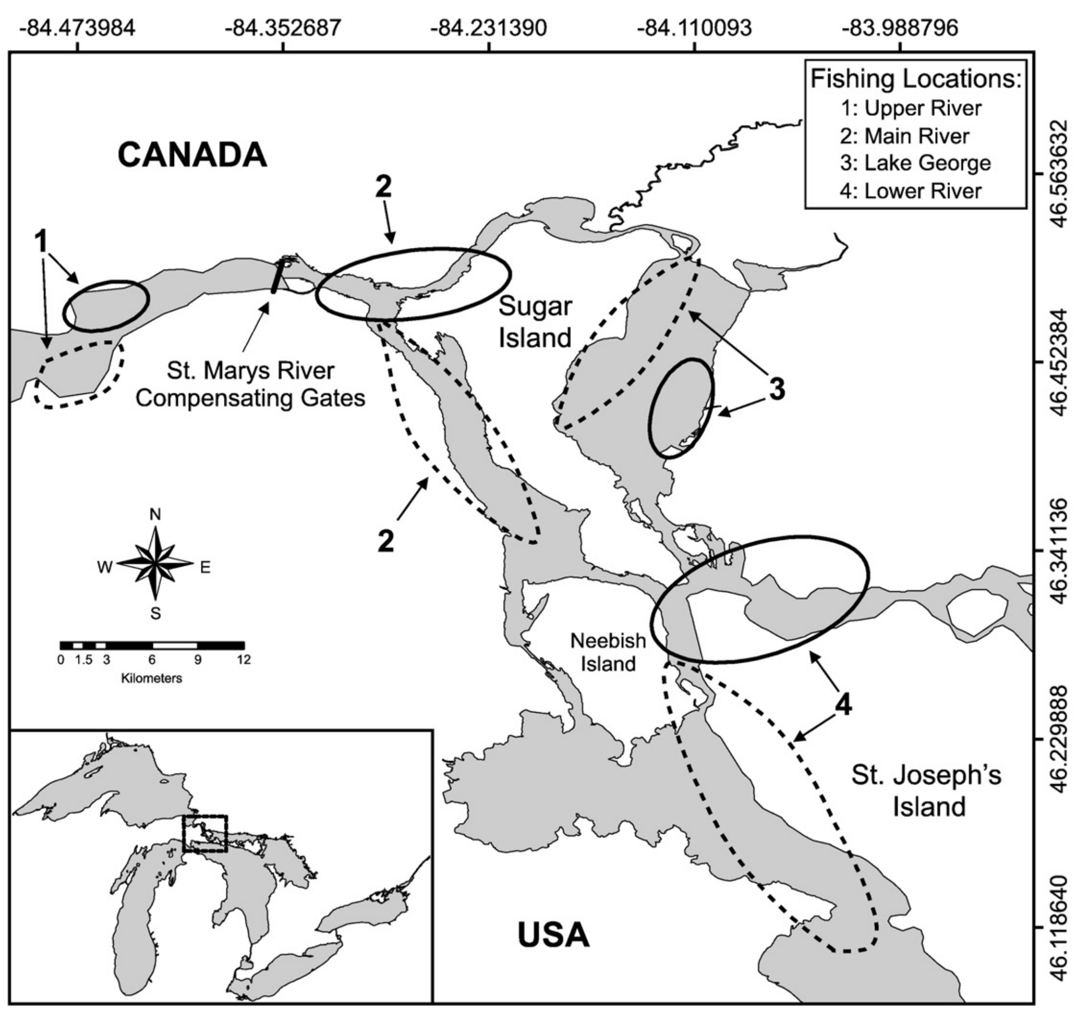


**Fig. 1.** Map of study area and general fishing locations. The solid ellipses represent the sampling areas from this study, while the hatched ellipses represent the trawling areas from the Liston et al. (1980, 1983) and Liston and McNabb (1986) reports.

**Table 1**
Sampling dates, effort, and mean water surface temperature, oxygen and conductivity from electrofishing transect sites in the St. Marys River. Values in brackets represent standard deviations.

| Location | Year | Sampling dates | # transects | Mean temperature | Mean oxygen | Mean conductivity |
|---|---|---|---|---|---|---|
| Upper river | 2006 | May 30–June 1 | 9 | 11.2 (1.5) | 12.0 (0.7) | 98.9 (6.0) |
| | 2007 | May 28–30 | 17 | 14.3 (1.4) | 12.0 (0.8) | 105.9 (6.2) |
| | 2008 | June 1–2 | 16 | 11.2 (0.7) | 11.6 (0.3) | 106.7 (4.9) |
| Main river | 2006 | June 5–6 | 12 | 12.6 (1.4) | 12.6 (0.3) | 98.3 (7.2) |
| | 2007 | June 5–12 | 19 | 16.5 (3.2) | 10.8 (1.6) | 102.8 (6.7) |
| | 2008 | June 3–9 | 15 | 10.7 (1.0) | 12.3 (0.3) | 102.0 (4.1) |
| Lake George | 2006 | June 2–3 | 8 | 16.1 (0.7) | 11.4 (0.2) | 103.8 (5.2) |
| | 2007 | June 13–15 | 22 | 21.6 (2.6) | 9.8 (0.6) | 107.1 (5.6) |
| | 2008 | June 11 | 6 | 15.4 (0.6) | 10.1 (0.5) | 106.6 (5.2) |
| Lower river | 2006 | June 4 | 5 | 17.1 (0.4) | 11.5 (0.3) | 108.0 (4.5) |
| | 2007 | June 17–20 | 13 | 22.3 (1.2) | 9.5 (0.3) | 111.5 (5.6) |
| | 2008 | June 13–18 | 11 | 14.8 (0.8) | 10.4 (0.4) | 108.9 (9.3) |

structural cover (Fig. 1). Water temperatures were warmer, the conductivity higher, and dissolved oxygen levels lower for the Lake George sites in comparison to the upper and main river sites (Table 1).

*Lower river*

Sites in the lower river were fished primarily in the area of Richard's Landing. Habitat diversity was high at the lower river sites; transects in this location were fished over sand, silt and cobble substrates and a variety of aquatic macrophytes were detected growing on the silt substrates (Fig. 1). The lower river sites had abiotic condition similar to Lake George, with higher temperatures and conductivity, but lower dissolved oxygen concentrations than the upper and main river sites (Table 1).

*Electrofishing methods*

The electrofishing technique used in this survey was developed to assess nearshore fish communities in the Laurentian Great Lakes by Fisheries and Oceans Canada (Valere, 1996; Brousseau et al., 2005). A total of 153 transects were fished in late spring 2006 (34 transects), 2007 (71 transects) and 2008 (48 transects). The earliest and latest dates fished were in 2007, when sampling was initiated on May 28 and ceased on June 20 (Table 1).

Complete details on the sampling procedure are available in Valere (1996) and Brousseau et al. (2005), but a summary is presented below. Prior to the onset of dusk, floats adorned with reflective tape were placed and marked via GPS 100 m apart along a 1.5 m depth contour. Habitat data, including dissolved oxygen (mg/L), conductivity (*u*S/cm), and water temperature (°C) were taken at the middle of each transect. An Ekman dredge was used to sample substrate at each transect marker, except when the marker was over cobble or boulder substrates which were identified visually. Finer substrates were texturally classified as silt, sand, or gravel. Organic and woody debris were identified in the substrate sample, and dominant (>50%), subdominant (10 to 50%) and trace (<10%) components of the substrate were also recorded. Macrophytes were identified to genus, and macrophyte abundance was determined visually and assigned to one of four categories: none (0% cover), sparse (1% to 19% cover), moderate (20% to 70% cover) or dense (>70% cover).

Surveys were conducted using a Smith-Root SR-14H electrofishing boat (length = 4.4 m, width = 2.0 m). The electric current was regulated through a 5.0 gas-powered pulsator, and the output was kept to 4 A. Transects were 100 m in length, parallel to shore along the 1.5 m depth contour. All fishing occurred after dark, and our target electrofishing time transect was 300 sec per transect. Fishes captured over each transect were held onboard in an aerated live well. Collected fishes were identified to species by the field crew, individually measured (length in mm, weight in grams) and then returned to the water. When fish could not be identified onboard, they were fixed in 10% formalin and returned to the laboratory for later identification and processing. Fish were individually processed up to 20 per species for a given transect, at which point any remaining individuals of that species were counted and batch weighed.

Habitat and fish data from each transect were entered into a database developed specifically for Great Lakes nearshore fish communities (Moore et al., 1998). The database was developed to facilitate the comparison of fish communities, species richness and biomass in areas with different habitat attributes. In addition, the database calculates a nearshore Great Lakes index of biotic integrity (Minns et al., 1994) and a habitat-productivity index (Randall and Minns, 2002). Minns et al. (1994) developed the index of biotic integrity specifically for Great Lakes littoral habitats to quantitatively measure the level of impairment and degree of restoration of fish-related intrinsic uses of the ecosystem. It uses four classes of factors that determine the condition of Great Lakes littoral fish assemblages which are incorporated into the index of biotic integrity: non-native species, water quality, physical habitat, and piscivore abundance (Minns et al., 1994). Randall and Minns (2002) developed the habitat-productivity index as a measure of habitat productive capacity for fish assemblages (Randall and Minns, 2002). The habitat-productivity index, the product of fish biomass and the production to biomass ratio (P/B) summed for all species captured from a transect accounts for the size structure of the fish community and was used an index of fish production. Together, the habitat-productivity index and the index of biotic integrity provide indices of fish production and diversity (Randall and Minns, 2002). For our survey, total fish biomass from each transect was converted to kg/ha by multiplying the biomass by 40, assuming that the electrofishing boat was effective over a 2.5-m strip along the length of the 100 m transect and that our capture efficiency was 100%.

*Data analysis*

*Historical comparison*

While no previous studies allow for a direct comparison of current and past fish community conditions on the St. Marys River, we compared our abundance rankings with those of Liston et al. (1980, 1983), Liston and McNabb (1986) who sampled the nearshore fish community using a 4.9-m bottom trawl with a 3-mm cod end liner deployed for five minute intervals at night. Trawls were performed monthly at two depth intervals, 1.5 m and 3.0 m, from May-November, and the total catches from those trawls were combined in the Liston et al. (1983) and Liston and McNabb (1986) reports. The comprehensive data available from the Liston et al. (1980, 1983), Liston and McNabb (1986) surveys are the only data that have collected small fishes from nearshore areas, so despite the differences in gear (electrofishing versus trawling) we believe that the comparisons may still illustrate potential fish community changes over the past 25 years. Rank abundance data were compared between the current (catches from all three years combined) and Liston et al. (1983) and Liston and McNabb (1986) surveys using the nonparametric gamma correlation coefficient, which is preferable to Spearman *R* statistic when there are many tied observations (Siegel and Castellan, 1988). For the Liston and McNabb (1986) data, site I was compared with our upper site, sites II and III were combined and assessed against our main site, while sites IV through VII were combined and compared against our lower site (Fig. 1). The data from Liston et al. (1983) were used for the Lake George comparison. The electrofishing and Liston et al. (1983) and Liston and McNabb (1986) trawling sites were in similar areas and habitats but not in the same locations, as we were restricted to Canadian waters and Liston et al. (1983) and Liston and McNabb (1986) were restricted to American waters.

*Site comparison*

Total fish biomass and productivity, species richness and fish assemblage measures were compared among the four sites using two-factor (site by year) analysis of variance. Biomass values were ln $(x+1)$ transformed prior to analysis. When significant differences were detected, Tukey honest significant difference tests were used to separate factors (Zar, 1999).

Species and site relationships were also summarized using correspondence analysis, and presented graphically to demonstrate separation (Jackson and Harvey, 1989). Correspondence analysis was selected because it was developed for data where objects of interest are measured by abundance, as abundance and site values are based on an average of each other, giving an ordination of both abundance and sites at the same time (Manly, 1994). We used the type 2 eigenvector standardization recommended by Legendre and Legendre (1998) to maximize distances among species, plotting the mean ordination of each site for visual simplicity.

*Assessment of community health*

An index of biotic integrity used was developed to evaluate Great Lakes nearshore fish assemblages as an indicator of ecosystem health and habitat quality (Minns et al., 1994). The index was developed using fish data collected under the protocols described in Valere (1996). These standardized fish sampling protocols were followed in this study, making the data collected herein comparable with other published studies that have used the same protocols. Fish community health was assessed with individual index of biotic integrity metrics, and by comparing those metrics and the overall index of biotic integrity with other Great Lakes Area of Concern (Hamilton Harbour and Bay of Quinte, Lake Ontario) reference (West Lake, Lake Ontario) and delisted Area of Concern (Penetang Harbour and Hog Bay, Lake Huron) locations. West Lake, a coastal wetland connected to Lake Ontario near the Bay of Quinte, was selected as a reference area for the Bay of Quinte Area of Concern. Penetang Harbour and Hog Bay are both located in the former Severn Sound Area of Concern. Fish communities were last assessed in Penetang Harbour and Hog Bay in 2002, Hamilton Harbour in 2006, and the Bay of Quinte and West Lake in 2007 (Brousseau et al., 2004; Brousseau and Randall, 2008), and the data from these assessments were used in comparison with our data from the St. Marys River.

## Results

*Historical comparison*

A total of 46 species were captured during our St. Marys River surveys (Table 2). These represented a mix of primarily demersal cold, cool and warmwater fishes. A number of species, including rainbow smelt (*Osmerus mordax*), white sucker (*Catostomus commersoni*), emerald (*Notropis atherinoides*), spottail (*N. hudsonius*) and mimic (*N. volucellus*) shiner, bluntnose minnow (*Pimephales notatus*), trout-perch (*Percopsis omiscomaycus*), rock bass (*Ambloplites rupestris*), and yellow perch (*Perca flavescens*), were ubiquitous to all areas and abundant (Table 2). Many other species were rarely captured (e.g. central mudminnow (*Umbra limi*), rosyface shiner (*N. rubellus*), blacknose (*Rhinichthys atratulus*) and longnose dace (*R. cataractae*)), or only appeared in certain sections of the river (e.g. lake whitefish, lake chub (*Couesius plumbeus*), burbot (*Lota lota*); Table 2). Thirty-seven species were captured in the main river, more than the lower (25) and upper (23) river or Lake George (21).

There were significant differences in the species composition in the upper river and Lake George between the trawl data from Liston et al. (1983) and Liston and McNabb (1986) and the contemporary electrofishing survey (upper river $\gamma=0.16$, $P=0.29$, $n=26$; Lake George $\gamma=0.18$, $P=0.21$, $n=27$), but we found no significant changes in the main and lower river areas (main river $\gamma=0.44$, $P<0.001$, $n=41$; lower river $\gamma=0.36$, $P=0.004$, $n=35$). The few differences observed may be due to changes in fish community composition over the past three decades, or they may be attributable to the two gear types used in the studies. Species such as trout-perch and Johnny darter (*Etheostoma nigrum*) were among the most numerous fish in the early 1980s, but were less common in our electrofishing survey (Table 3). In contrast, bluntnose minnow was more readily observed. Emerald shiner was the most common species in Lake George in our survey, yet the species was not reported in Lake George by Liston et al. (1983). Many species including yellow perch, white sucker, rainbow smelt and spottail and mimic shiner were common in the Liston et al. (1983) and Liston and McNabb (1986) surveys and they remain important community members today. It is also apparent that more invasive fishes have appeared in the St. Marys River. Native sticklebacks (brook stickleback (*Culaea inconstans*) and ninespine stickleback (*Pungitius pungitius*)) that were abundant in the historic surveys are no longer as common, and the invasive threespine stickleback (*Gasterosteus aculeatus*) is becoming more abundant in the main river. Other invasive fishes such as white bass (*Morone chrysops*) and alewife (*Alosa pseudoharengus*) were captured in our sampling, but not in the early 1980s work.

*Site comparison*

There were differences in fish community composition along the downstream gradient of the St. Marys River, with significant differences detected among sites in all four parameters examined in this study (Table 4). The upper river and Lake George had significantly lower total biomass, species richness and indices of biotic integrity and productivity than the main and lower river sites (Fig. 2a–d). The main river had significantly higher species richness and greater productivity than any other site (Fig. 2b, d), while the lower river had the highest index of biotic integrity (Fig. 2c). 2008 collections had the lowest total biomass, richness and productivity of any year. Among-year patterns in total biomass, species richness and indices of biotic integrity and productivity were relatively consistent in three of the four areas (Fig. 2a–d). The exception was the lower river, which showed a sharp decrease in all four parameters after our initial assessment in 2006, and these declines accounted for the significant year affects in total biomass and species richness.

The among-site fish assemblage differences are reflected in the correspondence analysis, though the amount of variation in species and site relationships was low (Fig. 3). The two locations in the lowest part of the watershed, Lake George and lower river, are in close proximity along with the warm-water species that are mostly restricted to the warmer parts of the river including the main river, with its unique species assemblage composed of cool water species adapted to flowing waters, separates out on the right side of the Figure. Ubiquitous species, such as bluntnose minnow, spottail shiner and rock bass, are located in the middle of the plot, while species adapted to warmer or more turbid conditions (white bass, emerald shiner, largemouth bass (*Micropterus salmoides*)) are associated with the Lake George and lower river sites.

*Assessment of community health*

The fish community in the St. Marys River appears most similar to the Lake Huron locations, Penetang Harbour and Hog Bay, but there are unique qualities to the St. Marys River community that make it quite different than any of the other Great Lakes locations that were assessed by the same methods. The biomass and number of fish captured and species and native species richness from a given transect, and the overall index of biotic integrity, were all similar to the Lake Huron sites (Table 5). When compared across all sites, the St. Marys River had the highest proportion of native species observed, the highest cyprinid richness, the lowest percentage of non-indigenous

**Table 2**
The scientific and common names of the 46 species captured via boat electrofishing transects in four areas of the St. Marys River in 2006–2008. Values represent the mean number of fish captured per 100 m transect in a given year. The two letter codes in brackets after the common name represent the species abbreviations found in Fig. 3. Fishes marked with an asterisk (*) are considered invasive.

| Family | Scientific and common name | Upper river | | | Main river | | | Lake George | | | Lower river | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2006 | 2007 | 2008 | 2006 | 2007 | 2008 | 2006 | 2007 | 2008 | 2006 | 2007 | 2008 |
| Petromyzontidae | *Lampetra appendix* American brook lamprey (AL) | | | 0.13 | 0.42 | | | | | | | | |
| | **Petromyzon marinus* sea lamprey (SL) | | | | 0.42 | 0.16 | 0.07 | | | | | | |
| Clupeidae | **Alosa pseudoharengus* alewife (AW) | | | | | | | 0.13 | 0.07 | | | | |
| Cyprinidae | *Couesius plumbeus* lake chub (LC) | | | | 0.58 | 0.42 | 0.13 | | | | | | |
| | *Luxilus cornutus* common shiner (CS) | | | 0.13 | | 1.05 | 0.13 | | | 1.00 | | 0.15 | 0.18 |
| | *Notemigonus crysoleucas* golden shiner (GS) | | | | | | | | | | 0.20 | 0.15 | |
| | *Notropis atherinoides* emerald shiner (ES) | | 0.41 | 0.13 | 0.08 | 0.42 | 1.33 | 1.88 | 12.14 | 2.67 | 0.40 | 24.62 | 10.91 |
| | *Notropis heterolepis* blacknose shiner (BN) | | | | | 0.05 | | | | | | | |
| | *Notropis hudsonius* spottail shiner (ST) | | 0.35 | 0.19 | 0.25 | 0.74 | | 2.38 | 0.27 | | 8.20 | 2.00 | 0.27 |
| | *Notropis rubellus* rosyface shiner (RF) | | | | | | | 0.13 | | | | | |
| | *Notropis stramineus* sand shiner (SS) | | 0.06 | | | 0.11 | | | | | | | |
| | *Notropis volucellus* mimic shiner (MS) | | 0.35 | 0.19 | 5.00 | 1.47 | 1.60 | 2.50 | 1.73 | 2.17 | 16.40 | 7.46 | 3.36 |
| | *Pimephales notatus* bluntnose minnow (BM) | 1.67 | 3.41 | 1.25 | 1.92 | 5.63 | 5.67 | 0.50 | 0.32 | | 52.40 | 15.85 | 5.09 |
| | *Rhinichthys atratulus* blacknose dace (BD) | | | | 0.08 | | | | | | | | |
| | *Rhinichthys cataractae* longnose dace (LD) | | | | 0.08 | | | | | | | | |
| | *Semotilus atromaculatus* creek chub (CC) | | | 0.06 | | | 0.07 | | | | 1.80 | | |
| Catostomidae | *Catostomus catostomus* longnose sucker (LS) | | | | 0.50 | | 0.47 | | | | | | |
| | *Catostomus commersoni* white sucker (WS) | | 1.00 | 0.50 | 11.25 | 8.32 | 9.40 | 0.25 | 0.82 | 0.83 | 2.60 | 0.54 | 0.36 |
| | *Moxostoma macrolepidotum* shorthead redhorse (SR) | | | | | | | 0.25 | 0.41 | | 0.80 | 0.08 | 0.09 |
| | *Moxostoma anisurm* silver redhorse (SV) | | | | | 0.26 | | | | | | | 0.09 |
| Ictaluridae | *Ameiurus nebulosus* brown bullhead (BB) | | | | | 0.05 | | 0.13 | 0.09 | 0.17 | | 0.38 | |
| Esocidae | *Esox lucius* northern pike (NP) | | | | | 0.05 | 0.20 | | 0.06 | | 0.80 | 0.15 | 0.18 |
| Umbridae | *Umbra limi* central mudminnow (CM) | | | | | | | | | | | 0.08 | |
| Osmeridae | **Osmerus mordax* rainbow smelt (RS) | 0.89 | 0.53 | 0.19 | 4.17 | 0.53 | 2.33 | 10.63 | 0.27 | | 4.80 | | 0.91 |
| Salmonidae | *Coregonus clupeaformis* lake whitefish (LW) | 0.33 | 0.47 | | | | | | | | | | |
| | *Oncorhynchus tshawytscha* Chinook salmon (CH) | 0.22 | | | 2.08 | 0.11 | 0.33 | | | | | | |
| | *Oncorhynchus mykiss* rainbow trout (RT) | 0.22 | 0.06 | | 0.08 | 0.11 | 0.07 | | | | | | |
| | *Prosopium cylindraceum* round whitefish (RW) | 0.11 | | | | | | | | | | | |
| | *Salmo salar* Atlantic salmon (AS) | | | | 0.25 | | | | | | | | |
| Percopsidae | *Percopsis omiscomaycus* trout-perch (TP) | 0.33 | 0.18 | | 4.25 | 1.16 | 0.27 | 0.25 | 0.27 | 0.5 | 1.00 | | 0.64 |
| Gadidae | *Lota lota* burbot (BU) | 0.22 | 0.12 | | 0.25 | 0.11 | | | | | | | |
| Gasterosteidae | *Culaea inconstans* brook stickleback (BS) | | | | 1.08 | 0.47 | 0.40 | | | | | | |
| | **Gasterosteus aculeatus* threespine stickleback (TS) | | | | 2.17 | 1.00 | 1.00 | | | | | | |
| | *Pungitius pungitius* ninespine stickleback (NS) | 0.67 | 0.06 | 0.06 | 0.75 | 0.11 | 0.20 | | | | | | |
| Cottidae | *Cottus bairdi* mottled sculpin (MO) | | 0.06 | 0.38 | 1.25 | 1.00 | 1.67 | | | | | 0.08 | |
| | *Cottus cognatus* slimy sculpin (SC) | | | | | 1.42 | | | | | | 0.08 | |
| Percichthyidae | **Morone chrysops* white bass (WB) | | | | | | | | 0.05 | | | | |
| Centrarchidae | *Ambloplites rupestris* rock bass (RB) | 0.22 | 0.76 | 0.13 | 2.08 | 1.05 | 5.07 | | 0.23 | 0.83 | 14.80 | 6.92 | 0.64 |
| | *Lepomis gibbosus* pumpkinseed (PU) | | | | 0.08 | 1.37 | 0.87 | | 0.05 | | 0.20 | 3.46 | 0.27 |
| | *Micropterus dolomieu* smallmouth bass (SB) | 0.67 | | | 0.83 | 0.32 | | | 0.05 | | 2.40 | 1.38 | 0.82 |
| | *Micropterus salmoides* largemouth bass (LB) | | | | | | | | | | | | 0.09 |
| Percidae | *Etheostoma exile* Iowa darter (ID) | | 0.06 | | | 0.16 | 0.13 | | | | | | |
| | *Etheostoma nigrum* Johnny darter (JD) | 0.11 | | 0.31 | 0.17 | 0.11 | 0.93 | 0.13 | 0.14 | | 0.20 | 0.08 | |
| | *Perca flavescens* yellow perch (YP) | 4.33 | 8.53 | 4.63 | 3.33 | 9.42 | 12.00 | 1.25 | 5.50 | 2.83 | 7.00 | 5.08 | 2.64 |
| | *Percina caprodes* logperch (LP) | | | | 2.92 | 2.11 | 3.13 | 1.00 | 1.86 | | 0.40 | | 0.09 |
| | *Sander vitreum* walleye (WE) | | | | | 0.32 | 0.13 | | 0.05 | | | | 0.09 |

species observed, and the highest percent specialist biomass (Table 5). However, the high specialist biomass meant that there was a low piscivore and generalist biomass in St. Marys River. Only the Hamilton Harbour Area of Concern had a lower piscivore biomass, and the St. Marys River had the lowest percentage of generalists (Table 5). Three of the four locations fished in the St. Marys River had similar individual index of biotic integrity metrics, with the exception of the lower river sites which had greater piscivore biomass (Table 5).

## Discussion

Our examination of the nearshore fish community in the St. Marys River fulfills a long-standing desire of the agencies charged with managing the important fishery on this river to concurrently assess juvenile and forage fish status along with the status of the managed game fishes (Gebhardt et al., 2002; for results of managed fish assessment see Schaeffer et al., 2011). Our assessment highlighted a number of interesting findings about the nearshore fish community in the St. Marys River. First, we demonstrated that the nearshore fish community is relatively unaltered over the past 25 years, with many species that were common in the Liston et al. (1980, 1983), Liston and McNabb (1986) surveys remaining important community members today. Secondly, over the past 25 years, more invasive fishes, including threespine stickleback, white bass and alewife have moved into the St. Marys River, but unlike many other areas of the Great Lakes invasives are not common and do not appear to be negatively affecting resident native species. Thirdly, our assessment demonstrated that the high habitat heterogeneity available to fishes in, and large spatial area covered by, the St. Marys River have led to a diverse and complex fish community, with dissimilar fish communities located in broad habitat types along the spatial extent of the river. Lastly, the overall health of the St. Marys River fish community compared favorably with relatively unimpacted sites from Lake Huron.

We observed only limited changes in the St. Marys River fish community from the last time the community was surveyed in the early 1980s. Riverine biodiversity depends upon the interaction of natural and anthropomorphic disturbance patterns and environmental gradients, which produces the spatio-temporal habitat heterogeneity necessary for

**Table 3**
The rank of the ten most abundant fishes from nearshore boat electrofishing (this survey; Current) and trawling (Liston et al., 1983; Liston and McNabb (1986); Past) in four areas (upper river, main river, Lake George, lower river) of the St. Marys River.

| Species | Location | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Upper river | | Main river | | Lake George | | Lower river | |
| | Current | Past | Current | Past | Current | Past | Current | Past |
| Lake whitefish | 7 | 10 | | | | | | |
| Rainbow smelt | 4 | 7 | 7 | | 3 | 8 | 9 | 8 |
| Northern pike | | 8 | | | | | | |
| White sucker | 3 | 5 | 1 | 6 | 7 | 6 | 10 | 7 |
| Shorthead redhorse | | | | | 9 | | | |
| Common shiner | | | | | | 5 | | |
| Emerald shiner | 7 | | | | 1 | | 2 | 6 |
| Spottail shiner | 7 | | | 5 | 6 | 2 | 6 | 2 |
| Mimic shiner | 9 | 4 | 6 | 3 | 4 | | 3 | 3 |
| Bluntnose minnow | 2 | | 3 | | 9 | | 1 | |
| Brook stickleback | | 6 | | 10 | | | | |
| Threespine stickleback | | | 9 | | | | | |
| Ninespine stickleback | 10 | 2 | | 9 | | 9 | | |
| Trout-perch | | 10 | 8 | 2 | 9 | 1 | | 1 |
| Rock bass | 5 | | 5 | | | 10 | 4 | 9 |
| Pumpkinseed | | | | | | | 7 | |
| Smallmouth bass | | | | | | | 8 | |
| Black crappie | | | | | | | | 10 |
| Yellow perch | 1 | 3 | 2 | 7 | 2 | 3 | 5 | 4 |
| Iowa darter | | 10 | | | | | | |
| Johnny darter | | 1 | | 4 | | 4 | | 5 |
| Logperch | | | 4 | 8 | 5 | 7 | | |
| Mottled sculpin | | | 10 | 1 | | | | |

highly diverse fish communities (Ward, 1998; Allan, 2004). Fish communities can be transformed by physical or physio-chemical habitat alteration (e.g. Bain et al., 1988; Winston and Taylor, 1991; Wolter et al., 2000; Gehrke et al., 2002; Quinn and Kwak, 2003) or the introduction of invasive species (e.g. Crowl et al., 1992; Mills et al., 1994; Crivelli, 1995). As the majority of landscape-level habitat alterations in the St. Marys River area occurred over 100 years ago (Duffy et al., 1987; Bray, 1996), it may not be surprising large fish community alterations were not observed, even in a disturbed system such as the St. Marys River. Our results are consistent with the findings of Schaeffer et al. (2011) for managed fishes in the St. Marys River, as the community index netting program indicates relative stability in the managed fish community since that program's inception in 1975, and other studies have demonstrated long-term fish assemblage persistence in riverine communities (e.g. Ross et al., 1985;

**Table 4**
Two-way analysis of variance results for among-site and year comparisons from four locations on the St. Marys River. Mean transect biomass, species richness, Index of Biotic Integrity (IBI), and Habitat-Productivity Index (HPI) were assessed at the upper river (Upper), main river (Main), Lake George (George) and lower river (Lower) sites.

| Parameter | Factor | $F^*$ | $P$ | Tukey HSD |
|---|---|---|---|---|
| Biomass | Site | $23.8_{3,\ 140}$ | <0.001 | Upper, George<Main, Lower 2006, 2007>2008 |
| | Year | $5.7_{2,\ 140}$ | 0.004 | |
| | Site * Year | $1.4_{6,\ 140}$ | 0.21 | |
| Richness | Site | $48.3_{3,\ 140}$ | <0.001 | Upper, George<Lower<Main |
| | Year | $3.6_{2,\ 140}$ | 0.03 | 2007≤2006>2008 |
| | Site * Year | $1.4_{6,\ 140}$ | 0.21 | |
| IBI | Site | $40.1_{3,\ 137}$ | <0.001 | Upper<George<Main<Lower |
| | Year | $0.3_{2,\ 137}$ | 0.76 | |
| | Site * Year | $2.0_{6,\ 137}$ | 0.07 | |
| HPI | Site | $21.7_{3,\ 140}$ | <0.001 | Upper, George<Lower<Main |
| | Year | $2.0_{2,\ 140}$ | 0.14 | |
| | Site * Year | $1.8_{6,\ 140}$ | 0.12 | |

It is important to note that our fish community survey was based on boat electrofishing data, while the Liston et al. (1980,1983), Liston and McNabb (1986) surveys relied on 5 min bottom trawls. These two techniques are both capable of successfully characterizing nearshore fish communities (e.g. Yoder and Smith, 1999; Lyons et al., 2001; Bronte et al., 2003), and we believe that both techniques provided a reasonable representation of the relative abundance rankings used in our analysis. Obviously trying to compare more quantitative measures, such as catch-per-unit effort among gears, would not be understandable, but others have used relative rankings from different sampling techniques to assess temporal changes in fish communities (Quinn and Kwak, 2003). It is possible that some of the limited differences detected between the Liston et al. (1980, 1983), Liston and McNabb (1986) and our surveys are due to the differences in survey techniques; species that live on the bottom such as Johnny and Iowa darter (*Etheostoma exile*) may be more likely to be sampled by a trawl than boat electrofishing. However, gear differences are not able to explain the changes in other species, such as the decreases in trout-perch or increases in bluntnose minnow, which occupy a similar position in the water column.

Despite the presence of an increasing number of invasive fishes in the St. Marys River, there is little evidence that the invasive fishes are negatively impacting the fish community. There is concern that the recent invasion of threespine stickleback may result in the displacement of native brook stickleback, as appears to be occurring at other Lake Superior locations (Pratt et al., 2009), and brook stickleback was less commonly observed in comparison with the Liston et al. (1980, 1983), Liston and McNabb (1986) St. Marys River surveys. However, overall less than 1% of the fish captured, and just over 2% of total biomass in our surveys, were non-native despite most invasives being in the community for many years. This seems to indicate that the collapse of native fishes that occurred in the main basins of the Great Lakes (e.g. Vanderploeg et al., 2002; Mills et al., 2003; Dobiesz et al., 2005) has not transpired in the St. Marys River.

There are other examples of communities where invasive fishes have not resulted in large-scale changes in the fish community (Jowett et al., 1998; Eby et al., 2003), and there is a growing body of literature which contends that certain biotic and abiotic conditions make it less likely for invasive species to successfully invade a given community. These include unsuitable or harsh abiotic conditions (Eby et al., 2003), and the presence of a highly heterogeneous receiving community (García-Ramos and Rodríguez, 2002; Olden et al., 2004). Both factors may play a role in protecting the St. Marys River from invasive fishes. Abiotic conditions in the St. Marys River reflect the harsh conditions of Lake Superior, with primarily cold, clear, low productivity waters (Duffy et al., 1987). Grigorovich et al. (2003) observed that Lake Superior had few invasive species despite receiving a high proportion of ballast water discharges, and they attributed this to abiotic conditions that were unfavourable for the establishment and spread of most aquatic invasive species. Additionally, our fish community assessment identified that the St. Marys River fish community is healthy and diverse, containing cold, cool, and warmwater fishes. Together, the physical-chemical and biological conditions may have helped limit the establishment and spread of invasive fishes in the St. Marys River. The resilience of the St. Marys River fish community to invasive fishes will be severely tested in the near future, however, as first reports of the round goby, a fish that has radically altered ecosystems elsewhere in the Great Lakes (Vanderploeg et al., 2002), were just received from the lower river (Anjanette Bowen, USFWS, personal communication).

Our assessment supported the contention that the St. Marys River contains a diverse fish community, representing fishes from a number of thermal niches (Liston and McNabb, 1986; Duffy et al., 1987; Kauss, 1991). Others have characterized the St. Marys River as being a percid-dominated fish community due to the presence of walleye, yellow perch, northern pike, and white sucker (Duffy et al., 1987; Kauss, 1991), but we feel that this depiction is too simplistic and does

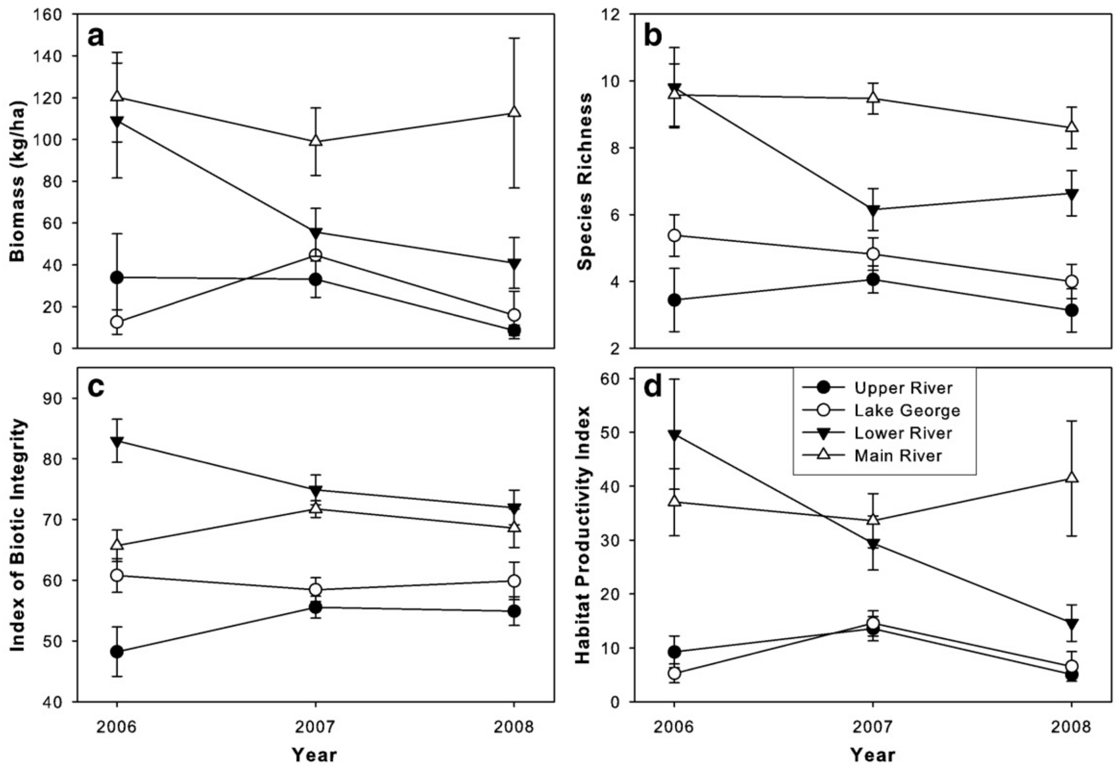


**Fig. 2.** (a) Mean biomass, (b) species richness, (c) Index of Biotic Integrity and (d) Habitat Productivity Index by year for each of the four study areas in the St. Marys River.

not capture the full complexity of the community. Two areas in the river, the upper river and Lake George sites, were relatively depauperate, had lower biomass and productivity, and were not percid-dominated. The biota of the upper river, closest to Lake Superior's outflow, is heavily influenced by the cold, oligotrophic water arising in Lake Superior (Liston and McNabb, 1986), which was reflected in the consistently lower water temperatures we observed. Consequently, the upper river contained some cold tolerant fishes that were not observed in other locations. In contrast, Lake George's depauperate fish community is comprised of fishes that are primarily large-lake oriented, tolerant of a wide-range of abiotic conditions or fluctuating turbidity (Lane et al., 1996; Scott and Crossman, 1998).

Both the main and lower river sections contained a more diverse fish fauna, as indicated by the high index of biotic integrity scores for those sections of the river. The main river fish community had cold, cool, and warm-water fish represented, likely indicative of the high habitat heterogeneity available in that part of the river (Copp, 1989; Bray, 1996). The lower river was more dominated by warm-water fishes such as cyprinids and centrarchids. This pattern reflects the lotic-to-lentic succession of fish communities that is commonly observed in large rivers, where geomorphic and hydrologic changes occur along the spatial extent of the system (e.g. Amoros et al., 1987; Copp, 1989; Ward, 1998). We observed a trend of decreasing fish community health measures in the lower river over the three years of our study, but the short study duration makes it difficult to know whether managers should be concerned about these decreases. High inter-annual variability in riviverine fish community composition is not uncommon (e.g. Godinho et al., 2000; Bernardo et al., 2003), and to date there is no apparent response from the managed fishes on the river (Schaeffer et al., 2011).

Our assessment indicates that the St. Marys River fish community is reasonably healthy. The index of biotic integrity used in our assessment was developed for nearshore fish assemblages in the Great Lakes, and has been used an indicator of ecosystem health (Minns et al., 1994) and habitat quality (Randall and Minns, 2002). The health of the St. Marys River fish community, based on the mean overall index of biotic integrity score, would be classified by Minns et al. (1994) as good. The overall score and many individual index of biotic integrity metrics were similar to those observed in two Lake Huron locations (Brousseau and Randall, 2008), though the St. Marys River had a number of unique community attributes that indicated a robust and healthy fish community. These included a high proportion of specialists in the community, a high number of cyprinids, and a small contribution of invasive fishes. It is possible that the highly heterogeneous habitats available in the river are providing opportunities for many of these specialized nearshore forage fishes to thrive (Bray, 1996). A score of 80 is required for a fish community to be assessed as excellent, and it is likely that the low overall biomass and low percentage of piscivores captured during our surveys prevented the St. Marys River fish community from scoring higher, as the index of biotic integrity is sensitive to these parameters (Minns et al., 1994). In particular, low piscivore abundance is considered evidence of poor conditions (Minns et al., 1994), so a better balance of specialists and piscivores would have improved the overall assessment.

It is important to recognize that the index of biotic integrity was developed for Lake Ontario (Bay of Quinte and Hamilton Harbour) and Lake Huron (Georgian Bay) locations (Minns et al., 1994), and there may be issues with extending the index outside of those areas (e.g. Schulz et al., 1999). In particular, the low productivity, depauperate nature of the upper river and Lake George sites may not be well-suited to the index as it was developed using more productive areas. That said, as (1) Minns et al. (1994) demonstrated that the index was robust across broad spatial areas and diverse fish assemblages, (2) our sampling locations, with the exception of the upper river location, are considered part of Lake Huron, which includes two sites from which the index was developed, and (3) the overall fish communities are similar among the Lake Huron locations (Brousseau et al., 2004), we are confident that the index provides a fair assessment of the St. Marys River fish community.

In summary, our evaluation of the St. Marys River nearshore fish community is the first spatially extensive assessment of the river in over

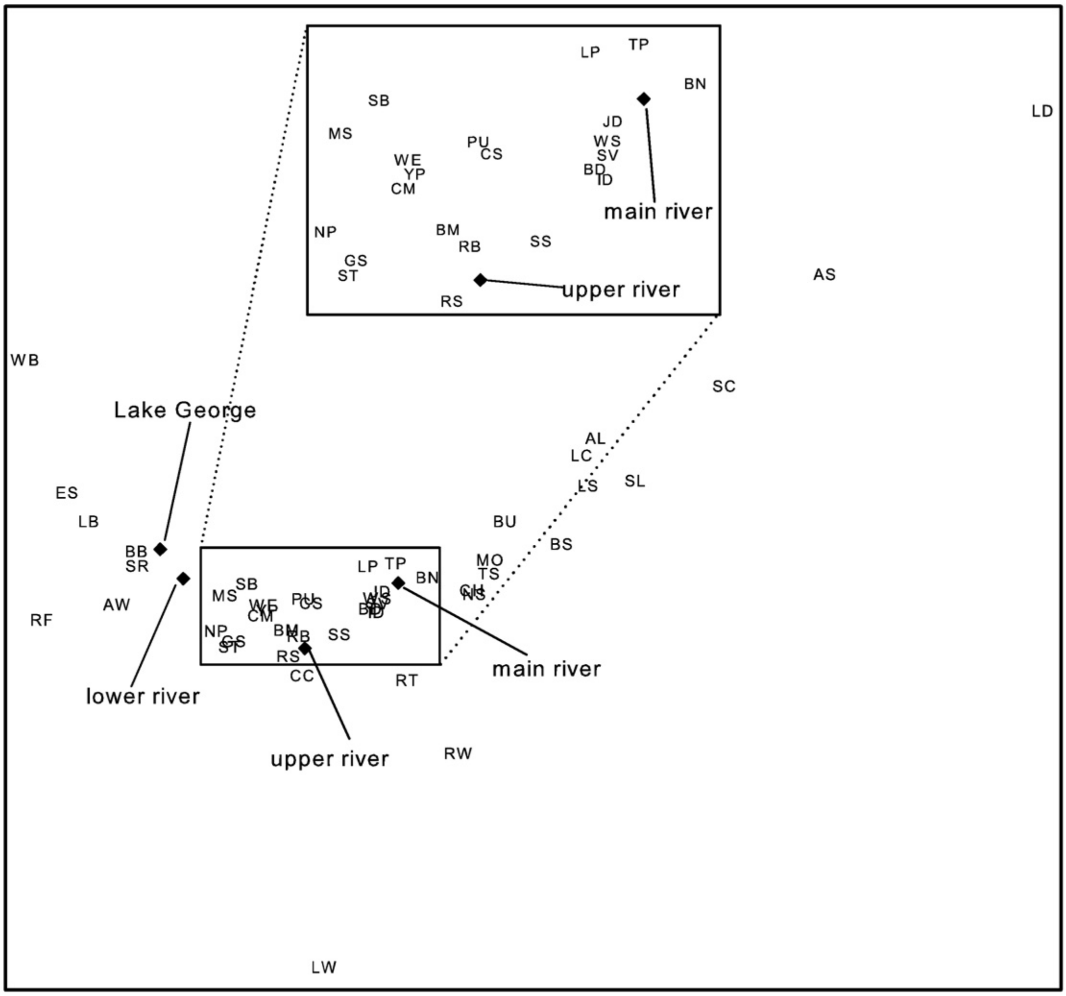


**Fig. 3.** Dimensions 1 and 2 from a correspondence analysis of fish captures by site ($n = 152$) from night boat electrofishing transects. Mean ordinations for sites ($n = 4$) are represented by black diamonds, while species ($n = 46$) are represented by 2 letter codes. The upper box is an enlarged insert to better display the ordination of the many species clustered near the center of the figure. Dimensions 1 and 2 explain 8.9% and 6.3%, of the variance in the species by St. Marys River location analysis, respectively. Species codes can be found in Table 2.

25 years. We demonstrated that the community has not altered appreciatively over that timeframe, and that it is diverse, robust, and relatively un-impacted by invasive fishes. The concerns that resulted in the fish community being listed as impaired as part of the Great Lakes Areas of Concern process appear to be mostly ameliorated. While sea lampreys continue to infest the river, recent efforts to reduce sea lamprey abundance with increasing trapping effort, targeted Bayluscide treatments, and a sterile male release program have been successful in

**Table 5**

The average biomass, catch in numbers, species richness per 100 m transect, and the average index of biotic integrity metrics, from the four St. Marys River sampling locations and five Great Lakes sites. Hamilton Harbour and the Bay of Quinte are both Areas of Concern in Lake Ontario, while West Lake (Lake Ontario), Penetang Harbour (Lake Huron) and Hog Bay (Lake Huron) are reference areas.

| St. Marys River | | | | | | Hamilton Harbour[a] | Bay of Quinte[b] | West Lake[c] | Penetang Harbour[c] | Hog Bay[c] |
|---|---|---|---|---|---|---|---|---|---|---|
| Metric name | Upper river | Main river | Lake George | Lower river | Overall | | | | | |
| Biomass (kg) | 0.6 | 2.7 | 0.8 | 1.5 | 1.5 | 7.5 | 5.9 | 2.4 | 1.6 | 4.5 |
| Number captured | 12.3 | 44.0 | 21.6 | 60.7 | 33.3 | 20.5 | 72.9 | 53.7 | 30.5 | 26.1 |
| Species richness | 3.6 | 9.2 | 4.8 | 7.0 | 6.2 | 5.6 | 8.8 | 11.1 | 5.4 | 6.7 |
| Native species richness | 3.5 | 8.7 | 4.8 | 7.0 | 6.0 | 4.0 | 8.1 | 10.4 | 5.0 | 6.3 |
| Native cyprinid species richness | 1.0 | 2.2 | 1.8 | 3.1 | 2.0 | 0.5 | 0.4 | 1.9 | 1.2 | 1.1 |
| Percent piscivore biomass | 2.6 | 8.0 | 3.0 | 28.6 | 9.3 | 5.0 | 35.7 | 44.8 | 34.4 | 43.1 |
| Percent generalist biomass | 2.2 | 2.2 | 7.7 | 4.3 | 3.9 | 55.6 | 11.6 | 21.7 | 7.4 | 20.6 |
| Percent specialist biomass | 87.9 | 89.7 | 89.3 | 67.1 | 84.8 | 39.4 | 52.6 | 33.6 | 54.7 | 36.3 |
| Percent non-indigenous species by number | 1.1 | 1.4 | 0.2 | 0.0 | 0.8 | 36.8 | 4.5 | 1.7 | 4.5 | 3.0 |
| Percent non-indigenous species by biomass | 5.0 | 0.8 | 2.2 | 0.0 | 2.1 | 21.2 | 5.0 | 0.6 | 4.3 | 15.8 |
| Index of biotic integrity | 50.2 | 69.8 | 59.2 | 75.2 | 63.0 | 40.1 | 73.5 | 79.9 | 64.8 | 66.0 |

[a] Brousseau and Randall 2008.
[b] Christine Brousseau, personal communication.
[c] Brousseau et al. 2004.

reducing larval sea lamprey abundance (Schleen et al., 2003), though the number of parasitic sea lampreys remains above target in Lake Huron. Additionally, while non-native salmonines continue to provide extensive angling opportunities in the river, and other invasive fishes have appeared in the community, there appears to be few impacts on native fishes in the St. Marys River from these invasives.

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# Appendix 2a: A synthesis of sport fishing activity in the St. Marys River (Godby et al. 2019)

# A synthesis of sport fishing activity
# In the St. Marys River

May through October 2017

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St. Marys River Fisheries Task Group
Lake Huron Technical Committee
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**Introduction**

The St. Marys River provides world-class fishing opportunities for a variety of species. The river is unique in the diversity of recreational sport fisheries and the magnitude of the fishery. In order to quantify the sport fisheries, the Michigan Department of Natural Resources (MDNR) and the Ontario Ministry of Natural Resources and Forestry (OMNRF) undertook an open water creel survey of sport anglers in 2017. The survey covered both Ontario and Michigan waters from the compensating works downstream to Lake Huron at DeTour. This is only the second whole-river creel study of the St. Marys River, with the first conducted in 1999-2000 (Fielder et al. 2002). Partial river creel surveys were conducted during a number of years, but extrapolation to whole-river estimates proved difficult (Greenwood et al. 2011). The 2017 creel survey was also accompanied by a fish community gillnet survey of the river that same year by the St. Marys River Fisheries Task Group (SMRFTG) and its member agencies (O'Connor et al. 2019).

This survey is intended to quantify angler harvest and effort in the St. Marys River and identify any trends in the river recreational sport fishery. This information will supplement other individual management agency data, and the joint river-wide fish community gillnet survey, and it will be used to help inform management of the river. Fish Community Objectives for the St. Marys River are being developed, and common sport fishing regulations for this binational waterbody remain a goal of the St. Marys River Fisheries Task Group. These surveys equip managers with data necessary to make informed decisions about the world-class fisheries the river supports.

The St. Marys River is the connecting channel between Lakes Superior and Huron (Figure 1). The river flows southeasterly from Lake Superior's Whitefish Bay for 112 km and empties into northern Lake Huron at DeTour, Michigan, and into the North Channel of Lake Huron in Ontario at St. Joseph Island. The river holds the international boundary line between Ontario, Canada and Michigan, United States of America. Although the fish community has been described as percid dominated (Duffy and Batterson 1987, Ryder and Kerr 1978), the river supports a diverse mix of migratory and resident warm, cool, and coldwater species (St. Marys River RAP Team 1992). Resident species of interest to anglers include Northern Pike (*Esox Lucius*), Smallmouth Bass (*Micropterus dolomieu*), Walleye (*Sander vitreus*), and Yellow Perch (*Perca flavescens*). These species are well distributed throughout the river and its numerous bays. These four species, along with Cisco (*Coregonus artedii*) will be highlighted throughout this report. The river, main rapids in Sault Ste. Marie, the Little Rapids adjacent to Sugar Island, and several St. Marys tributaries are also seasonally used by salmonid species, providing popular fisheries. Aquatic habitats vary throughout the river's length, often changing abruptly from one habitat type to another. Habitats are generally characterized as open water, embayments, sand and gravel beaches, rapids and emergent wetlands (Duffy and Batterson 1987). The lower reaches of the river, Potagannissing Bay, Raber Bay, and Lake Munuscong, are more lacustrine in form and at least seasonally contain feeding aggregations of Cisco or migrating Pacific salmons and Rainbow Trout (*Oncorhynchus mykiss*) resulting in short term, seasonal fisheries. Considerable shoreline and channel alteration and hardening, dredging, and flow control and flow redirection have occurred over the past two centuries. Both the distribution of habitat types and anthropogenic stresses influence the species angler target in the various river reaches and the intensity and seasonality of fishing effort.

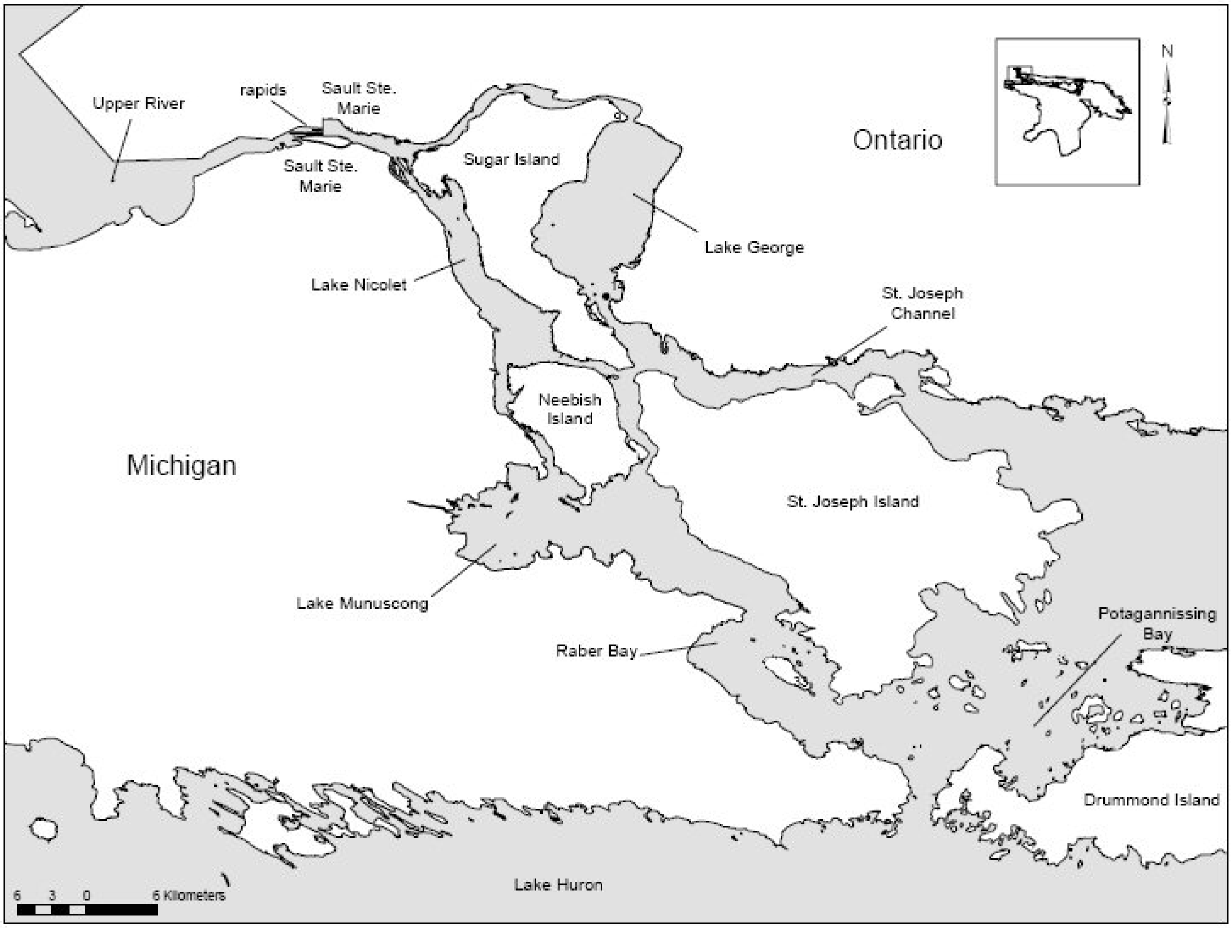


Figure 1. Map of the St. Marys River
Methods

**Creel Methodology**

In 2017 the MDNR, in conjunction with Ontario Ministry of Natural Resources and Forestry (OMNRF), the Environmental Protection Agency (EPA), and the United States Fish and Wildlife Service (USFWS) performed a river-wide survey of the St. Mary's River employing MDNR creel census methodology. The results in this report are derived from the survey performed during the open water season (May 1st - October 31st). Due to hiring delays creel census did not begin in Michigan until May10th.

The creel survey was based on a stratified design using three-stage sampling within the strata: i) days; ii) shifts; and iii) count times, and followed the methods detailed by Lockwood et al. (1999) and Su and Clapp (2013). Strata included 'sites' (Figure 2) fished by month, by day-type (weekday-weekend/holiday), and by mode of fishing (e.g, boat, pier/dock, shore). Catch and effort estimates were made for each stratum and then combined to give monthly and seasonal figures. The estimation sites were:

- Site 403; the northernmost sampling location. The area includes the St. Mary's River rapids on the Canadian side of the river, north of the Locks in Sault Ste. Marie, USA.
- Site 209; the river from the Locks in Sault Ste. Marie moving south to include Lake Nicolet and the middle Neebish Channel ending at Oak Point on Neebish Island and east to Harwood Point.
- Site 208; the river branch north of Sugar Island and all of Lake George, including Echo Bay and ending on a line north from Harwood Point to the Canadian mainland.
- Site 405; the river south of Lake George to the North Channel of Lake Huron, including the St. Joseph Channel.

- Site 207; the river south of Neebish Island and west of St. Joseph Island to the village of Detour, including Munuscong Lake and Raber Bay.
- Site 210; the river east of the village of Detour including Potagannissing Bay extending from Milford Haven on St. Joseph Island to Chippewa Point on Drummond Island.

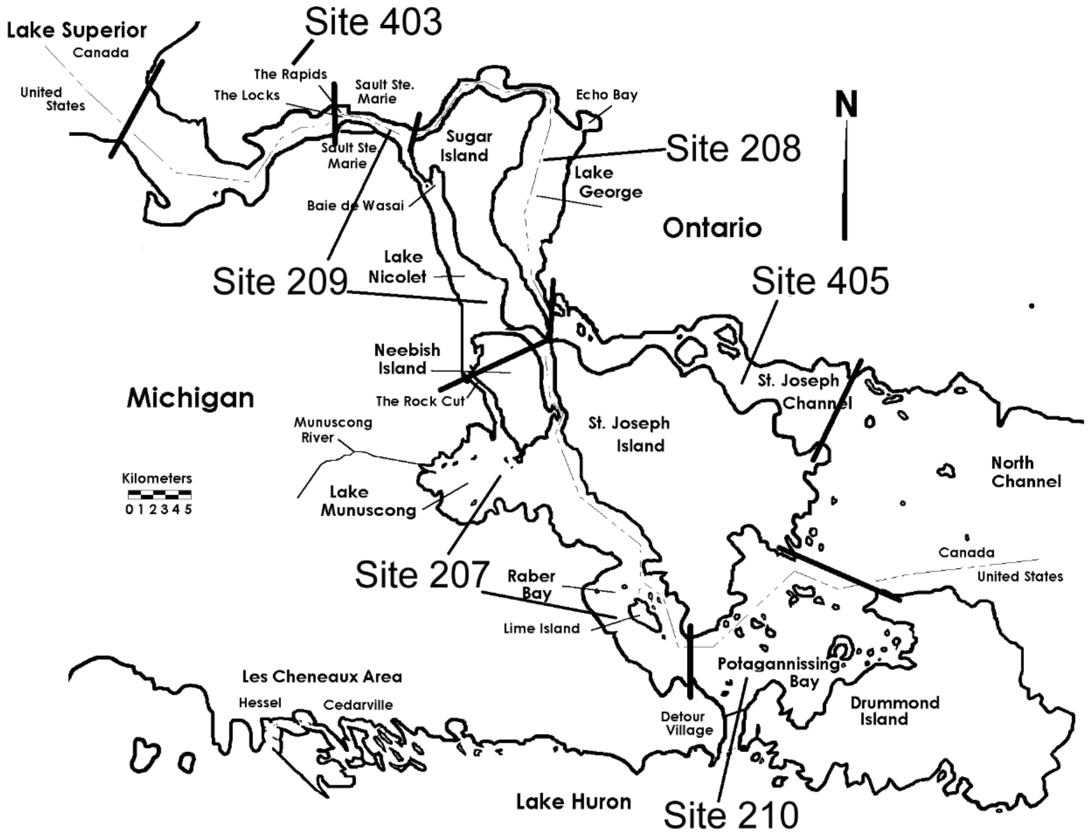


Figure 2. Creel Survey sites sampled in 2017.

Both weekend days and three randomly selected weekdays were sampled each week. The entire angling day from dawn to dusk was covered in each month. This was accomplished by breaking each day into two 8-hour work shifts, then randomly selecting one shift to be worked. The first shift began at daylight and ended in the afternoon; the second shift began in the afternoon and ended at sunset. Shift hours varied by month due to varying length of daylight among months. Each individual clerk was responsible for sampling more than one area, thus the interview site for each clerk was also randomly selected for each shift. Two types of data were collected for each area sampled: angler party interviews for catch rates and angler (boat, pier and shore) counts for effort. An angler party was defined as one or more anglers who fished together.

Two seasonal clerks were employed by the MDNR and two seasonal clerks were employed by the OMNR to perform the survey. All four clerks were trained by MDNR Fisheries personnel at the beginning of the field season to ensure the consistency of data collected. Data was submitted monthly by all clerks for review by the MDNR.

Clerks interviewed as many anglers as possible by encountering boats that returned to access sites or shore and pier anglers that fished during a scheduled shift. If the boater did not fish, that was recorded on the form as a non-fishing party and the interview was ended. If fishing did take place, anglers were queried as to their mode of fishing (i.e., boat, pier, shore), where they fished (site and grid number), how long they fished, what they fished for, the number of lines fished, how often they fished the area, the numbers (by species) of fish they caught and kept, the numbers (by species) of fish released, and the number of fishing trips they made or intended to make that day. Additional data were collected for one member of each party such as age and sex, zip code, and the types of angling method used (casting, still fishing, trolling, etc.).

Fishing effort was determined through instantaneous counts of boats and fishing piers made from airplanes. Five flights were made each week at randomly selected starting times; one each weekend day, and one on each of three randomly selected week days. Flights were also randomly started at the northern and southern end of the route. The proportion of boaters interviewed by creel clerks who indicated they were not fishing was used to adjust the aerial counts for non-fishing effort. Creel clerks also recorded a ratio of anglers to non-anglers that were present on fishing piers at randomly selected times of day. This angler ratio was applied to the airplane count of total people present on any piers. Shore anglers present at Site 403 (the Canadian rapids) were counted by the clerk twice daily at randomly assigned times on scheduled shifts.

Effort estimates were made for each site and mode by month. Harvest estimates were made for each site and mode by month for all fish species observed in the harvest by creel clerks. Catch estimates were made for each site and mode by month and included numbers harvested and numbers of legal-sized fish released for those selected species. Standard mathematical formulas for creel survey (Lockwood et al. 1999) were used to calculate all estimates. Three measures of fishing effort were calculated: angler hours, angler trips, and angler days. An angler trip is one completed fishing excursion and an angler day is composed of one or more fishing excursions during a 24-hour period. Uncertainty estimates for all catch and effort estimates in this report are defined as two standard errors of their mean estimates (2 times the square root of the variance for an estimate).

Creel clerks also collected biological data from harvested fish (total length and weight and fin clip information) encountered during on-site angler interviews. Dorsal fin spines or rays were also collected for certain species for age estimation. Monthly target sample sizes for age analysis were based on a minimum number needed to provide a reasonable representation of the age structure of the harvest each month, balanced with the logistical feasibility of the creel clerk to collect biological data samples without negatively impacting angler interview numbers.

## Results

### *Interview and Angling Effort*

A total of 3,558 anglers were interviewed on the St. Marys River by the creel clerks from May 1-October 31, 2017.

Total annual effort for the entire river was 232,921 angler hours in 2017 (Table 1). This does not include site 403 (the Rapids), since it was not surveyed in all years. This is the lowest value of the seven years for which we have estimated effort, down from a high of 565,095 angler hours in 2001. In 2017, site 210 (Potagannissing Bay) had the most effort, followed by site 207 (Munuscong and Raber Bays) and site 208 (Lake George). Anglers targeting walleye contributed a total of 118,484 hours of angling effort (Table 2), or approximately 51% of the effort on the river.

Table 1. Estimated recreational effort (in hours) for all species from open-water sport fisheries in the St. Marys River 1999-2001, 2005-2007, and 2017. Italics denotes data obtained through extrapolation methods described in the Methods section (Greenwood et al. 2011). Note that site 403 (Rapids) is not included, as it was not surveyed every year. Two standard errors are in parentheses.

| Year | 207 | 208 | 209 | 210 | 404 | 405 | Total |
|---|---|---|---|---|---|---|---|
| 1999 | 112,283 | 96,732 | 68,441 | 140,743 | 58,561 | 65,307 | 556,399 |
| | (19,570) | (16,256) | (11,010) | (27,674) | (11,454) | (12,611) | (42,820) |
| 2000 | 93, 301 | 60,816 | 60,564 | 131,107 | *55,616* | *61,572* | 462,976 |
| | (15,420) | (12,794) | (11,511) | (20,871) | *(46,434)* | *(76,874)* | (183,904) |
| 2001 | 124,823 | 97,111 | 76,694 | 123,878 | *67,671* | *74,918* | 565,095 |
| | (28,135) | (17,919) | (14,401) | (17,646) | *(64,802)* | *(106,689)* | (249,592) |
| 2005 | 68,289 | 51,245 | *54,378* | 131,887 | *47,410* | 74,105 | 427,314 |
| | (12,840) | (10,260) | (*232,480*) | (35,124) | *(60,886)* | (14,371) | (365,960) |
| 2006 | 93,025 | 70,944 | 84,845 | 152,254 | *58,378* | *52,984 | 512,430 |
| | (24,502) | (14,685) | (15,437) | (36,035) | *(72,178)* | *(9,645) | (172,483) |
| 2007 | 139,310 | 35,273 | *71,430* | 183,668 | *62,276* | 45,112 | 537,069 |
| | (34,103) | (8,859) | *(313,367)* | (60,215) | *(107,502)* | (11,057) | (535,103) |
| 2017 | 45,491 | 33,122 | 24,332 | 98,966 | *Not* | 31,010 | 232,921 |
| | (26,153) | (17,306) | (9,559) | (47,311) | *Surveyed* | (12,455) | (112,784) |

* In 2006, no interviews were conducted for Site 405, see Greenwood et al. (2011) for methods.
**In 2017, site 404 was not surveyed.

Table 2. Estimated targeted effort (in hours) for selected species for the open-water sport fisheries in the St. Marys River 1999-2001, 2005-2007, and 2017. Two standard errors are in parentheses.

| | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | **1999** | **2000** | **2001** | **2005** | **2006** | **2007** | **2017** |
| Walleye | 126,988 | 119,122 | 161,526 | 168,031 | 168,333 | 200,006 | 118,484 |
| | (25,083) | (24,654) | (28,699) | (53,463) | (37,817) | (63,957) | (16,713) |
| Yellow Perch | 89,238 | 60,607 | 78,869 | 32,414 | 58,191 | 65,326 | 39,885 |
| | (18,255) | (16,698) | (20,924) | (14,026) | (23,031) | (30,758) | (6,648) |
| Salmonids | 122,280 | 56,988 | 79,529 | 76,419 | 49,241 | 66,488 | 29,635 |
| | (20,238) | (14,007) | (21,306) | (43,360) | (14,674) | (44,801) | (3,985) |

*Harvest*

Twenty-four species were reported as caught during the 2017 St. Marys River creel survey. Harvest estimates for 16 of these species are presented in Table 3, with some rarely encountered species grouped together in the “other” category. White Bass (*Morone chrysops*) was reported as harvested in 2017 as it had been previously, but the invasive White Perch (*Morone Americana*) was not reported during this survey. Estimated harvest numbers and harvest rates by species for the survey series are reported in Appendix 1, Table 1.

Table 3. Estimated harvest per hour and total number harvested by species for each month. Angler effort (angler hours, trips, and days) for the St. Marys River system (Michigan and Ontario), for all sites including Site 403 (Rapids) and all non-charter modes of sportfishing, for each month in 2017. Two standard errors are in parentheses.

| All Sites | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Harvest per hour | May | June | July | August | September | October | Season |
| Atlantic Salmon | 0.0042 | 28 | 124 | 492 | 275 | 99 | 7 | 1,025 |
| | (0.0064) | (50) | (133) | (275) | (197) | (90) | (12) | (756) |
| Brown Trout | 0.0000 | 0 | 0 | 0 | 2 | 0 | 0 | 2 |
| | (0.0000) | (0) | (0) | (0) | (5) | (0) | (0) | (5) |
| Channel Catfish | 0.0003 | 0 | 38 | 0 | 0 | 31 | 0 | 69 |
| | (0.0012) | (0) | (76) | (0) | (0) | (60) | (0) | (136) |
| Chinook Salmon | 0.0006 | 0 | 16 | 9 | 18 | 73 | 22 | 138 |
| | (0.0018) | (0) | (32) | (18) | (36) | (87) | (36) | (209) |
| Coho Salmon | 0.0003 | 63 | 0 | 0 | 0 | 1 | 0 | 64 |
| | (0.0009) | (103) | (0) | (0) | (0) | (2) | (0) | (105) |
| Freshwater Drum | 0.0004 | 0 | 75 | 0 | 0 | 0 | 20 | 95 |
| | (0.0016) | (0) | (149) | (0) | (0) | (0) | (38) | (187) |
| Cisco | 0.1313 | 0 | 0 | 32,267 | 0 | 0 | 0 | 32,267 |
| | (0.1545) | (0) | (0) | (18,255) | (0) | (0) | (0) | (18,255) |
| Lake Trout | 0.0000 | 0 | 0 | 0 | 0 | 9 | 0 | 9 |
| | (0.0002) | (0) | (0) | (0) | (0) | (18) | (0) | (18) |
| Lake Whitefish | 0.0245 | 457 | 457 | 4,962 | 25 | 73 | 37 | 6,011 |
| | (0.0409) | (600) | (515) | (3,506) | (26) | (117) | (71) | (4,836) |
| Northern Pike | 0.0161 | 899 | 1,543 | 755 | 302 | 430 | 39 | 3,968 |
| | (0.0329) | (1,384) | (635) | (938) | (310) | (539) | (80) | (3,885) |
| Other | 0.0001 | 0 | 16 | 0 | 0 | 16 | 0 | 32 |
| | (0.0005) | (0) | (32) | (0) | (0) | (31) | (0) | (62) |
| Pink Salmon | 0.0005 | 0 | 0 | 0 | 30 | 93 | 0 | 123 |
| | (0.0013) | (0) | (0) | (0) | (44) | (114) | (0) | (158) |
| Pumpkinseed | 0.0009 | 0 | 161 | 0 | 59 | 0 | 0 | 220 |
| | (0.0027) | (0) | (244) | (0) | (76) | (0) | (0) | (320) |
| Rainbow Trout | 0.0033 | 241 | 190 | 218 | 49 | 80 | 29 | 807 |
| | (0.0074) | (267) | (193) | (210) | (67) | (74) | (58) | (870) |
| Smallmouth Bass | 0.0125 | 174 | 1,262 | 1,228 | 88 | 321 | 0 | 3,073 |
| | (0.0286) | (294) | (1,318) | (1,121) | (101) | (545) | (0) | (3,379) |
| Walleye | 0.0568 | 3,076 | 4,629 | 2,718 | 1,167 | 1,495 | 878 | 13,963 |
| | (0.1174) | (3,998) | (3,865) | (3,019) | (921) | (1,168) | (893) | (13,865) |
| Yellow Perch | 0.1597 | 942 | 2,220 | 2,963 | 2,043 | 18,145 | 12,928 | 39,241 |
| | (0.2510) | (1,388) | (2,252) | (2,515) | (2,518) | (10,492) | (10,492) | (29,657) |
| | | | | | | | | |
| Angler hours | | 23,718 | 55,467 | 82,113 | 29,882 | 40,604 | 13,991 | 245,775 |
| | | (17,400) | (30,830) | (34,796) | (11,805) | (14,857) | (8,445) | (118,134) |
| Angler trips | | 5,692 | 13,326 | 19,791 | 6,428 | 10,018 | 3,115 | 58,370 |
| | | (4,029) | (5,731) | (8,901) | (3,275) | (3,822) | (1,931) | (27,688) |
| Angler Days | | 5,293 | 12,838 | 18,353 | 6,146 | 9,714 | 3,060 | 55,404 |
| | | (3,740) | (5,546) | (8,368) | (3,163) | (3,738) | (1,902) | (26,456) |

Harvest numbers for the survey series are presented in Table 4 below for Cisco, Northern Pike, Smallmouth Bass, Walleye, and Yellow Perch. Site-specific harvest numbers for each species are detailed in Appendix 2. Total catch by species, including released fish, is listed in Appendix 3.

Table 4. Estimated harvest (numbers of fish) for Cisco, Northern Pike, Smallmouth Bass, Walleye, and Yellow Perch from open-water sport fisheries in the St. Marys River 1999-2001 and 2005-2007. Two standard errors are in parentheses.

| | Species | | | | |
|---|---|---|---|---|---|
| Year | Cisco | Northern Pike | Smallmouth Bass | Walleye | Yellow Perch |
| | | | | | |
| 1999 | 31,258 | 5,408 | 1,188 | 9,890 | 62,646 |
| | (40,040) | (5,170) | (1,797) | (8,255) | (32,274) |
| 2000 | 113,621 | 12,402 | 3,235 | 17,064 | 86,098 |
| | (182,114) | (17,744) | (9,001) | (17,768) | (100,284) |
| 2001 | 131,662 | 14,336 | 3,653 | 39,568 | 91,120 |
| | (199,643) | (22,768) | (10,371) | (30,643) | (96,696) |
| 2005 | 48,163 | 1,547 | 4,216 | 32,134 | 84,097 |
| | (92,339) | (3,516) | (10,329) | (24,882) | (96,889) |
| 2006 | 168,988 | 14,894 | 5,322 | 38,743 | 118,214 |
| | (211,690) | (18,288) | (10,567) | (46 ,952) | (150,617) |
| 2007 | 158,141 | 4,231 | 4,030 | 60,733 | 125,391 |
| | (372,281) | (5,322) | (7,691) | (56,668) | (180,500) |
| 2017 | 32,267<br>(18,255) | 3,968<br>(3,885) | 3,073<br>(3,379) | 13,963<br>(13,865) | 39,241<br>(29,657) |

*Harvest Rates*

River-wide, species-specific harvest rates (harvest per hour) based on total effort for all species, Cisco, Northern Pike, Smallmouth Bass, Walleye, and Yellow Perch - for the survey series are presented in Table 5. These rates are presented for all species by site specific locations in Appendix 2 (Tables 1-7).

Table 5. Mean annual harvest per hour for Cisco, Northern Pike, Smallmouth Bass, Walleye, and Yellow Perch (based on total effort) from open-water sport fisheries in the St. Marys River (from all sites including Potagannissing Bay), 1999-2001, 2005-2007, and 2017. Two standard errors are in parentheses.

| Year | Cisco | Northern Pike | Smallmouth Bass | Walleye | Yellow Perch |
|---|---|---|---|---|---|
| 1999 | 0.0562 | 0.0097 | 0.0021 | 0.0178 | 0.1126 |
| | (0.0721) | (0.0093) | (0.0032) | (0.0149) | (0.0586) |
| 2000 | 0.1631 | 0.0284 | 0.0069 | 0.0376 | 0.1314 |
| | (0.1688) | (0.1626) | (0.1167) | (0.1606) | (0.3123) |
| 2001 | 0.1790 | 0.0269 | 0.0055 | 0.0687 | 0.1462 |
| | (0.1766) | (0.1685) | (0.1568) | (0.1872) | (0.3438) |
| 2005 | 0.0708 | 0.0037 | 0.0072 | 0.0747 | 0.1297 |
| | (0.2116) | (0.1457) | (0.1302) | (0.2265) | (0.3742) |
| 2006 | 0.2303 | 0.0305 | 0.0108 | 0.0830 | 0.1705 |
| | (0.2176) | (0.1775) | (0.1794) | (0.2294) | (0.4210) |
| 2007 | 0.1587 | 0.0093 | 0.0080 | 0.0997 | 0.1686 |
| | (0.5180) | (0.1829) | (0.2191) | (0.3410) | (0.3787) |
| 2017 | 0.1313 | 0.0161 | 0.0125 | 0.0568 | 0.1597 |
| | (0.1545) | (0.0329) | (0.0286) | (0.1174) | (0.2510) |

*Biological Summary of Angler Harvest*

In 2017, a total of 745 fish were sampled by creel clerks. Biological data collected from those samples are summarized in Table 6. Aging structures (e.g., scales or fin spines) were not collected for all samples because a much larger sample size of fish were aged during the 2017 fish community gillnet survey. That companion survey was fishery-independent, and provides a much better view of the age and size structure of the population. See O'Connor et al. (2019) for the additional biological data.

Table 6. Summary of biological data collected from the St. Marys River during the open water sport fishery of 2017, by capture sites. N = sample size and appears in parentheses if different than reported. Data for species with a sample size smaller than 5 were not included in this table. A complete list of biological data for 2017 and previous creel surveys can be found in Appendix 4.

| Species | Year | Capture sites | N | Mean Age | Mean Length (cm) | Mean Wt (g) |
|---|---|---|---|---|---|---|
| Atlantic Salmon | 2017 | 208, 209, 403 | 117 | 2.2 (41) | 56.6 | 2174 (116) |
| Chinook Salmon | 2017 | 208, 403 | 6 | 2.8 (5) | 78.1 | 5934 |
| Cisco | 2017 | 209, 210 | 92 | | 38.5 | 605 (91) |
| Northern Pike | 2017 | 207, 208, 209, 210 | 74 | 4.6 | 67.6 | 1876 |
| Pink Salmon | 2017 | 208, 209, 403 | 31 | 2 (7) | 50.5 | 1283 |
| Rainbow Trout | 2017 | 208, 209, 403 | 32 | 2.5 | 48.5 | 1549 |
| Smallmouth Bass | 2017 | 207, 208, 209, 210 | 57 | 4 (2) | 39.6 | 1012 (32) |
| Walleye | 2017 | 207, 208, 209, 210, 403 | 157 | 5.3 (21) | 46.3 | 1019 (116) |
| Yellow Perch | 2017 | 207, 208, 209, 210 | 170 | 5.3 (3) | 22.9 | 165 (155) |

*Angler Interview Summary*

Angler Origin – Although most anglers were from Michigan and Ontario, the St. Marys River draws anglers from throughout the continent (Figure 3). Approximately 26% of the anglers were considered "local", defined as those whose reported home zip code is within 40 or 80 kilometers of the river. In addition to Michigan and Ontario, anglers were from 17 other states and 3 other provinces. American anglers comprised 68% of the anglers interviewed. Anglers hailed from as far away as Hawaii, Washington, British Columbia, and the maritime provinces.

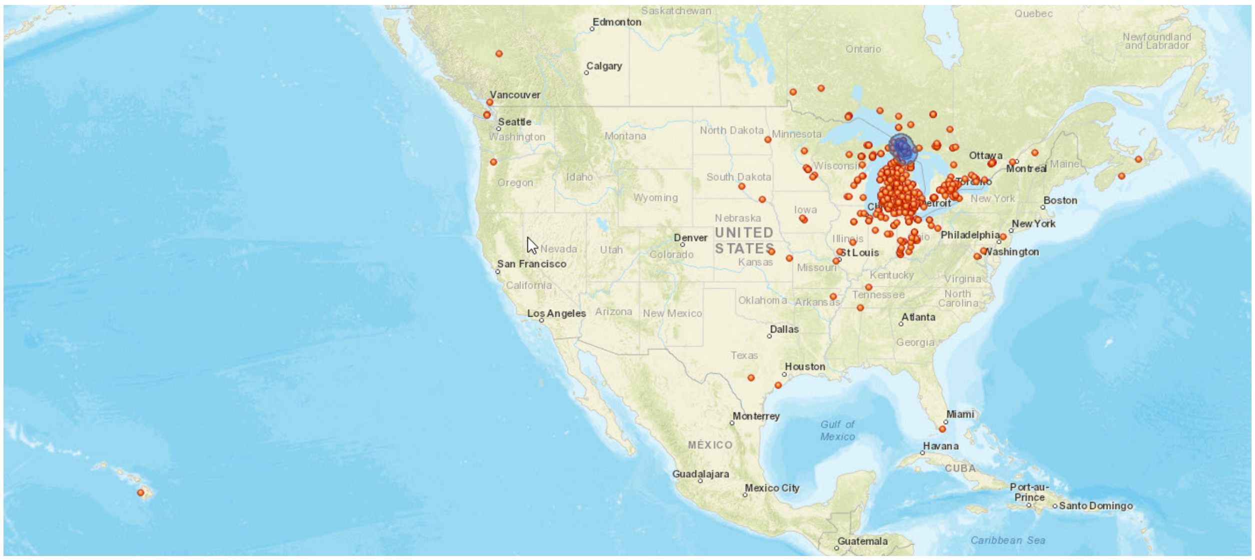


Figure 3. Map of angler origin for those fishing the St. Marys River in 2017, based on U.S. Zip/Canadian postal codes provided during the interviews.

*Angling target species, angling method, mode, and party size*

The St. Marys River presents diverse angling opportunities in terms of the species that can be targeted and the angling methods that can be used. Anglers targeted a variety of species throughout the season (Table 7). Walleye were the most frequently targeted species (28.2%), followed by general salmon and salmon or trout (totaling 11.5%), Rainbow Trout (11.0%) and Atlantic Salmon (10.9%). A fair percentage (14.2%) indicated they were fishing for anything.

Table 7. Percent of angling parties in the St. Marys River open water (May-Oct.) sport fishery reporting target species, by location as reported during angler interviews. N denotes number of respondents.

| TARGET | | 207 | 208 | 209 | 210 | 403 | 404 | 405 | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| ANY | | 15.9% | 12.3% | 11.3% | 17.0% | 9.2% | 0.0% | 64.6% | 14.2% |
| Atlantic Salmon | | 0.0% | 4.6% | 32.9% | 0.0% | 10.2% | 0.0% | 0.0% | 10.9% |
| Chinook Salmon | | 0.0% | 1.5% | 0.7% | 0.0% | 2.3% | 0.0% | 0.0% | 0.9% |
| Coho Salmon | | 0.0% | 0.3% | 0.0% | 0.0% | 0.5% | 0.0% | 0.0% | 0.2% |
| Cisco | | 1.4% | 0.0% | 0.0% | 3.7% | 0.0% | 0.0% | 0.0% | 0.9% |
| Largemouth Bass | | 0.0% | 0.0% | 0.0% | 0.0% | 0.3% | 0.0% | 0.0% | 0.1% |
| Muskellunge | | 0.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% |
| Northern Pike | | 6.1% | 13.8% | 5.3% | 8.0% | 0.0% | 50.0% | 12.5% | 6.5% |
| Other | | 2.4% | 0.0% | 1.8% | 6.2% | 4.1% | 0.0% | 0.0% | 2.8% |
| Pink Salmon | | 0.3% | 5.2% | 1.8% | 0.0% | 1.8% | 0.0% | 0.0% | 1.8% |
| Rainbow Trout | | 0.0% | 4.3% | 0.2% | 0.0% | 47.3% | 0.0% | 0.0% | 11.0% |
| Salmon | | 0.0% | 11.4% | 0.0% | 0.0% | 10.7% | 0.0% | 0.0% | 4.3% |
| Salmon or Trout | | 0.0% | 1.5% | 17.3% | 0.0% | 13.5% | 50.0% | 0.0% | 7.4% |
| Smallmouth Bass | | 2.4% | 0.9% | 0.5% | 6.5% | 0.0% | 0.0% | 4.2% | 1.9% |
| Walleye | | 65.1% | 33.8% | 19.8% | 35.9% | 0.3% | 0.0% | 18.8% | 28.2% |
| Walleye and Perch | | 0.3% | 0.3% | 0.0% | 0.6% | 0.0% | 0.0% | 0.0% | 0.2% |
| Yellow Perch | | 5.8% | 9.8% | 8.3% | 22.0% | 0.0% | 0.0% | 0.0% | 8.6% |
| N | | 295 | 325 | 434 | 323 | 393 | 2 | 48 | 1820 |

The St. Marys River Rapids (site 403) continues to be a popular fishing location, where the target species changes based on seasonal migration patterns (Table 8). Rainbow Trout (steelhead) are the most sought after species in May, June, and October, but Atlantic Salmon are the preferred target in July and August.

Table 8. Percent of angler parties reporting species targeted in the St. Marys River rapids sport fishery (Site 403) by month in 2017. N denotes sample size.

| | May | June | July | August | September | October |
|---|---|---|---|---|---|---|
| | | | | | | |
| ANY | 2% | 6% | 14% | 9% | 18% | 12% |
| Atlantic Salmon | | | 38% | 34% | 3% | |
| Chinook Salmon | | | | 5% | 8% | |
| Coho Salmon | | | | | 1% | 2% |
| Largemouth Bass | | | | | 1% | |
| Other | 2% | 11% | 6% | 2% | | 5% |
| Pink Salmon | | | | 2% | 8% | |
| Rainbow Trout | 95% | 73% | 14% | 11% | 10% | 41% |
| Salmon | 1% | 3% | 2% | 16% | 34% | 10% |
| Salmon and Trout | | 7% | 26% | 21% | 15% | 29% |
| Walleye | | | | | 1% | |
| N | 103 | 70 | 50 | 56 | 73 | 41 |

Additional, customized queries of the dataset may be run from the open data portal at: http://gis-midnr.opendata.arcgis.com/search?q=creel.

**Discussion**

*Fishing Effort*

Overall fishing effort in the St. Marys River was 232,921 angler hours in 2017. While this is approximately 50% less than it has been in previous creel surveys, the overall magnitude of the fishery remains substantial. Based on number of angler hours, the amount of fishing effort in the St. Marys River in 2017 was 34.5% as much as all the fishing effort in the Michigan waters of Lake Huron (Table 9). Although the amount of effort is down, that level of effort tracks consistent with the Michigan waters of Lake Huron.

The amount of fishing effort in the St. Marys River is even more impressive when examined based on surface acreage compared to other popular fisheries in the region. In 2017, the St. Marys River had more fishing effort per unit surface area than Big Bay de Noc and Saginaw Bay, and compared favorably with the fishing pressure per surface area in Little Bay de Noc (Figure 4).

Table 9. Comparison of fishing effort expressed as hours in the St. Marys River (excluding site 403 – the Rapids) to the lake wide fishery in the Michigan waters of Lake Huron and for Saginaw Bay. Site 403, the St. Marys rapids is excluded.

| Year | St. Marys River effort (Hours) | % as much of Lake Huron effort (Hours) | % as much of Saginaw Bay effort (hours) |
|---|---|---|---|
| 1999 | 542,067 | 27.7 | 60.0 |
| 2000 | 462,976 | 26.7 | 61.2 |
| 2001 | 565,095 | 31.4 | 70.0 |
| 2005 | 427,314 | 32.3 | 57.3 |
| 2006 | 512,430 | 44.8 | 79.7 |
| 2007 | 537,069 | 38.7 | 62.7 |
| 2017 | 232,921 | 34.5 | 53.2 |

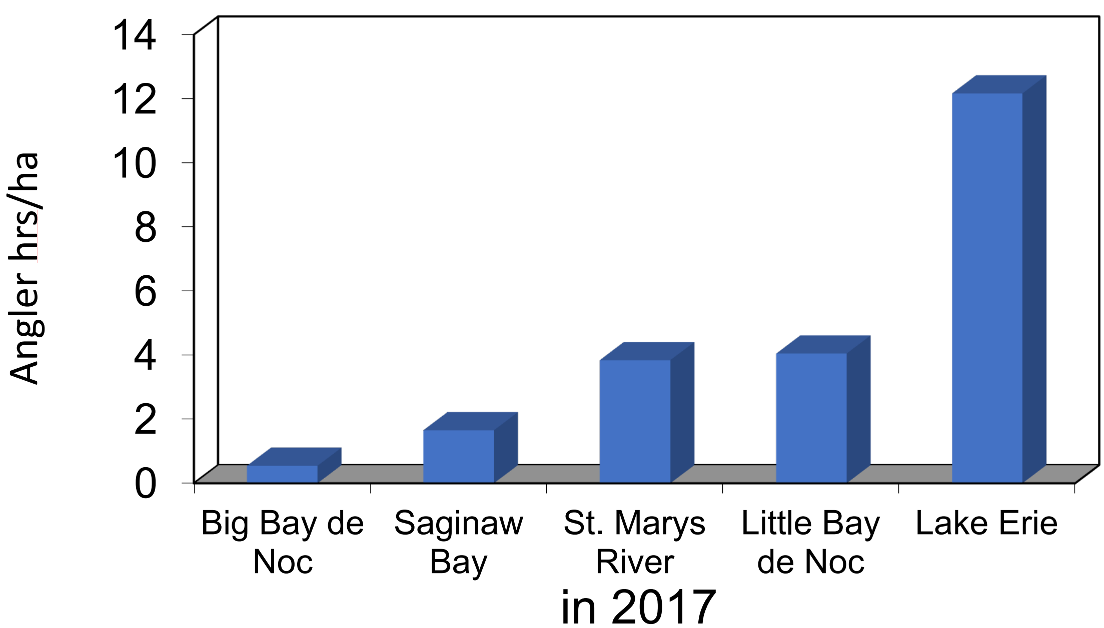


Figure 4. Angler hours per hectare in 2017 for a number of popular fishing locations in Michigan. Note that the Lake Erie estimate is for Michigan waters only.

*Harvest and Harvest Rates*

*Cisco*

Cisco harvest and harvest rates were down by approximately 80% in 2017 compared with previous years (2006, 2007), with harvest the lowest since 1999. Harvest rates were approximately the same as they were in 2005.

The Cisco fishery in the St. Marys River is often driven by an early summer feeding congregation of these fish in sites 207, 209, and 210. The feeding congregation of Cisco is keying in on emerging mayflies and can create substantial fishing effort in these areas of the river.

Cisco harvest is highly variable and is dependent upon factors such as weather conditions during the feeding congregation, as well as the timing and duration of that feeding congregation. Both harvest and harvest rate are within their historical range. The fish community gillnet survey also conducted in 2017 indicated cisco were at a low abundance for that time series (O'Connor et al. 2019). This suggests that cisco may genuinely be at a lower abundance that year and affecting the fishery.

The only notable change in fishing regulations for the river since the last creel survey were for Cisco. Ontario regulations for Cisco changed in 2008, when it went from no daily possession limit to a daily possession limit of 25 Cisco for a Sportfishing licnese or 12 Cisco for a Conservation license. Although Cisco harvest was down in 2017, it is likely not entirely attributable to the Ontario change in daily possession limit since harvest rate was also down. The SMRFTG is working towards developing common regulations between Ontario and Michigan for the remaining sport fisheries.

*Northern Pike and Muskellunge*

Northern Pike harvest and harvest rate are still much lower than they were historically, but are trending upwards. Coastal wetlands provide critical spawning and nursery habitat for Northern Pike. Great Lakes water levels, and therefore St. Marys River water levels, have increased since 2013. Lake Superior outflows, (St. Marys River flows) are partially controlled through the compensating gates at the head of the rapids. River flows in recent years have been higher than they've been in decades and these higher water levels have led to more spawning and nursery habitat resulting in improved pike numbers. Good numbers of Age-5 and younger pike captured in the companion survey (O'Connor et al. 2019) support the idea that the higher water levels since 2013 have helped the Northern Pike population. Higher water levels likely also improved survival of Northern Pike, as evidenced by the lowest total annual mortality rates seen in the survey series.

The mean age of Northern Pike captured in the sport fishery was 4.6, while the mean age in the fish community gillnet survey was 4.0. Mean length in the sport fishery was 676mm and was 552mm in the 2017 gillnet survey (O'Connor et al. 2019). These differences could point to gear selectivity; i.e., gill nets aren't effectively sampling older/larger Northern Pike, however it is also likely that the sport fishery selects for larger (older) pike. Northern Pike regulations differ between Michigan and Ontario. Michigan has a 610 mm (24 in) minimum size limit, while Ontario has no minimum size limit. In 2017, approximately 12% of the Northern Pike sampled during the creel survey were less than 610 mm. It is important to continue both the fishery-independent (gill net) survey and the creel survey of the sport fishery in order to get a complete picture of the fish community.

Muskellunge remain an important part of the fish community and provide a popular fishery. An estimated 214 muskies were caught in the St. Marys River during the open-water season in 2017.

*Smallmouth Bass*

Overall harvest of Smallmouth Bass is down slightly from the 2007 estimate, but is higher than the estimate from our last full-river creel in 1999. While harvest rate has increased by almost 67%, Smallmouth Bass are plentiful in the river and can provide a good fishery, though it remains an untapped resource. Only 1.9% of angling parties river-wide reported targeting Smallmouth Bass in 2017, with Potagannissing Bay, Site 210, having the highest percentage (6.5%) of angling parties reporting they were targeting Smallmouth Bass. Angler harvest and harvest rate remain substantially higher than in 1999, and harvest rate is above the mean 1999-2017harvest rate of 0.008.

*Walleye*

Walleye continue to be an important sport fish in the St. Marys River, and were the species most targeted by anglers. Overall harvest and harvest rate of Walleye in the river declined since 2007, but both are higher than they were in 1999 during our last full-river creel. The 2017 harvest rate (0.0568), however, is slightly lower than the mean harvest rate of 0.064 (1999-2017). Current estimates of harvest and harvest rate are within the historical range of this survey series.

Walleye were harvested from every creel site in 2017, but by far the most harvest (50%) came from site 207-Lake Munuscong and Raber Bay. That was followed by site 210-Potagannissing Bay (20.9%), site 208-Lake George (12.6%), and site 405-St. Joseph Channel (11.6%).

Walleye have been stocked in the St. Marys River since about 1985 at varying levels and by different entities. It is unknown, however, to what extent that stocking contributes to the fishery. To answer that question and others, a 10-year Walleye Stocking and Evaluation Plan was developed by the St. Marys River Fisheries Task Group and was implemented 2009-2018. The plan called for the annual stocking of 290,000 to 400,000 spring fingerling OTC-marked Walleye in different reaches and follow-up evaluations each fall. 2018 is the last year of evaluation under that plan, and results are expected soon to help inform the Walleye stocking strategy for the river.

*Yellow Perch*

Yellow Perch support a popular fishery in the St. Marys River, with 8.6% of angling parties targeting Yellow Perch river-wide throughout the open water season. They were the target species of 22% of the angling parties in site 210-Potagannissing Bay, second only to Walleye in popularity at that site. Although overall harvest of Yellow Perch is down in 2017 compared to previous years, harvest rate has remained relatively stable over the survey series.

*Economic Value*

The 2016 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, conducted by the U.S. Fish and Wildlife Service, estimated daily expenditures for hunters and anglers (USDI 2016). For Great Lakes anglers in 2016, USDI 2016 reports that Great Lakes anglers spend $153 per day on fishing trip-related expenses. The 2017 survey of the St. Marys River estimates 55,404 angler days of fishing effort were spent on the river, with a value of approximately $8.5 million US Dollars.

*Supplemental Questions*

MDNR was considering a change to the statewide regulations for Yellow Perch at the time of this survey. The daily possession limit for Yellow Perch at the time of the survey was 50; and the MDNR was considering changing the daily possession limit to 25 perch. In order to gage public opinion about the potential change, a supplement question was included in the creel survey. The following questions was asked: Would you support a decreased bag limit of 25 Yellow Perch?

Angler responses indicated support for the regulation change. In the Upper St. Marys River, 72% of those respondents with a definite opinion supported the change (28% did not support). In the Lower St. Marys River, 93% of those with a definite opinion supported the reduced bag limit. Overall, anglers in the St. Marys River supported going to a 25 fish bag limit for Yellow Perch. The reduced bag limit was subsequently approved and will be implemented on a statewide basis in 2019.

**Recommendations**

The river-wide creel survey should be conducted every five years in conjunction with the fish community gillnet survey on the same frequency. Recreational harvest regulations should be aligned between Ontario and Michigan waters of the river.

**Acknowledgements**

The authors would like to acknowledge the assistance provided by a number of people in the design, data gathering, analysis, and review of this survey. Dave Clapp of the MDNR administered the CSMI grant. Donna Wesander and co-authors Tracy Claramunt and Eric Morrow of the MDNR helped with the survey design and analysis. Creel clerks Cliff Pattinson and Matthias Bonzo interviewed anglers and collected survey information at Michigan access sites, while clerks Jillian Marquis and Cody Knight covered the Ontario access sites. Great Lakes Air provided the creel survey effort counts through a contract with the MDNR.

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The St. Marys River Fisheries Task Group is organized under the Great Lakes Fishery Commission's Lake Huron Committee, and coordinates fisheries management among the various agencies with jurisdiction over the St. Marys River (Fielder 2002).

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## Appendixes

Appendix 1, Table 1. Estimated species harvest numbers and harvest rate (in italics) from open-water sport fisheries in the St. Marys River, 1938 to 2017.

| Species | 1938 | 1987 | 1991 | 1999 | 2000 | 2001 | 2005 | 2006 | 2007 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|
| Atlantic Salmon | 0 | 6 | 64 | 509 | 95 | 787 | 0 | 716 | 2,039 | 1,025 |
| | *0* | *<0.0001* | *0.0001* | *0.0009* | *0.0002* | *0.0014* | *0* | *0.0014* | *0.0038* | *0.0042* |
| Bluegill | | | | 107 | 0 | 0 | 0 | 0 | 0 | |
| | | | | *0.0002* | *0* | *0* | *0* | *0* | *0* | |
| Brown Trout | | | | | | | | | | 2 |
| | | | | | | | | | | 0 |
| Channel Catfish | | | | 109 | 5 | 12 | 131 | 0 | 13 | 69 |
| | | | | *0.0002* | *0* | *0* | *0.0003* | *0* | *0* | *0.0003* |
| Chinook Salmon | 0 | 4,662 | 469 | 6 249 | 5,707 | 6,785 | 1,619 | 3,632 | 4,042 | 138 |
| | *0* | *0.0062* | *0.0008* | *0.0112* | *0.0123* | *0.012* | *0.0038* | *0.0071* | *0.0075* | *0.0006* |
| Cisco | 289 | 141,386 | 14,528 | 31,258 | 113,620 | 131,662 | 48,163 | 168,988 | 158,141 | 32,267 |
| | *0.15* | *0.1880* | *0.0244* | *0.0562* | *0.2454* | *0.233* | *0.1127* | *0.3298* | *0.2945* | *0.1313* |
| Coho Salmon | | | | 381 | 65 | 42 | 129 | 104 | 321 | 64 |
| | | | | *0.0007* | *0.0001* | *0.0001* | *0.0003* | *0.0002* | *0.0006* | *0.0003* |
| Freshwater Drum | | | | 0 | 19 | 0 | 1,180 | 1,729 | 1,168 | 95 |
| | | | | *0* | *0* | *0* | *0.0028* | *0.0034* | *0.0022* | *0.0004* |
| Lake Trout | | | | 1 | 0 | 0 | 162 | 0 | 454 | 9 |
| | | | | *0* | *0* | *0* | *0.0004* | *0* | *0.0008* | *0* |
| Lake whitefish | 16 | 25,187 | 204 | 19,769 | 13,154 | 16,594 | 17,877 | 37,880 | 50,973 | 6,011 |
| | *0.008* | *0.0335* | *0.0003* | *0.0355* | *0.0284* | *0.0294* | *0.0418* | *0.0739* | *0.0949* | *0.0245* |
| Largemouth Bass | | | | 114 | 202 | 51 | 0 | 0 | 0 | 0 |
| | | | | *0.0012* | *0.0004* | *0.0001* | *0* | *0* | *0* | *0* |

Appendix 1, Table 1.  Cont.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Muskellunge | | | | 34 | 8 | 56 | 110 | 0 | 0 | 0 |
| | | | | *0.0001* | *0* | *0.0016* | *0.0003* | *0* | *0* | *0* |
| Northern Pike | 184 | 20,965 | 26,116 | 5,408 | 12,402 | 14,336 | 1,547 | 14,894 | 4,231 | 3,968 |
| | *0.09* | *0.0279* | *0.0438* | *0.0097* | *0.0268* | *0.0254* | *0.0036* | *0.0291* | *0.0079* | *0.0161* |
| Other | | | | 1,124 | 995 | 2,427 | 138 | 338 | 4,832 | 32 |
| | | | | *0.002* | *0.0021* | *0.0043* | *0.0003* | *0.0007* | *0.009* | *0.0001* |
| Pink Salmon | 0 | 5.699 | 17,573 | 2,073 | 1,899 | 5,042 | 1,437 | 3,719 | 2,743 | 123 |
| | *0* | *0.0076* | *0.0295* | *0.0037* | *0.0041* | *0.0089* | *0.0034* | *0.0073* | *0.0051* | *0.0005* |
| Pumpkinseed | | | | 161 | 0 | 0 | 175 | 0 | 1 | 220 |
| | | | | *0.0003* | *0* | *0* | *0.0004* | *0* | *0* | *0.0009* |
| Rainbow Trout | 13 | 1,990 | 192 | 380 | 133 | 89 | 220 | 449 | 359 | 807 |
| | *0.007* | *0.0026* | *0.0003* | *0.0007* | *0.0003* | *0.0002* | *0.0005* | *0.0009* | *0.0007* | *0.0033* |
| Rock Bass | 166 | 13,708 | 19,718 | 70 | 105 | 0 | 720 | 428 | 448 | 0 |
| | *0.08* | *0.0182* | *0.0311* | *0.0003* | *0.0002* | *0* | *0.0017* | *0.0008* | *0.0008* | *0* |
| Round whitefish | | | | 516 | 1,651 | 0 | 1,348 | 1,416 | 1,603 | |
| | | | | *0.0009* | *0.0036* | *0* | *0.0032* | *0.0028* | *0.003* | |
| Smallmouth Bass | 3 | 2,779 | 9,497 | 1,188 | 3,235 | 3,653 | 4,216 | 5,322 | 4,030 | 3,073 |
| | *0.002* | *0.0036* | *0.0159* | *0.0032* | *0.007* | *0.0065* | *0.0099* | *0.0104* | *0.0075* | *0.0125* |
| Walleye | 102 | 25,602 | 26,435 | 9,898 | 17,064 | 39,568 | 32,134 | 38,743 | 60,733 | 13,963 |
| | *0.05* | *0.0340* | *0.0443* | *0.0178* | *0.0369* | *0.07* | *0.0752* | *0.0756* | *0.1131* | *0.0568* |
| White bass | | | | | 0 | 127 | 280 | 1,396 | 70 | |
| | | | | | *0* | *0.0002* | *0.0007* | *0.0027* | *0.0001* | |
| White perch | | | | | 0 | 229 | 0 | 0 | 578 | |
| | | | | | *0* | *0.0004* | *0* | *0* | *0.0011* | |
| Yellow Perch | 2,465 | 316,436 | 91,019 | 62,646 | 86,098 | 91,120 | 84,097 | 118,214 | 125,391 | 39,241 |
| | *1.25* | *0.4207* | *0.1526* | *0.1126* | *0.186* | *0.1612* | *0.1968* | *0.2307* | *0.2335* | *0.1597* |

Appendix 2, Table 1. Estimated harvest per hour, number harvested, and effort (angler hours, trips, and days) of sport fishing for all sites combined on the St. Marys River, by all modes (non-charter) in 2017. Area covered is from the compensating works at the head of the rapids to DeTour (including Potagannissing Bay). Two standard errors in parentheses.

| All Sites | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Harvest per hour | May | June | July | August | September | October | Season |
| Atlantic Salmon | 0.0042 | 28 | 124 | 492 | 275 | 99 | 7 | 1,025 |
| | (0.0064) | (50) | (133) | (275) | (197) | (90) | (12) | (756) |
| Brown Trout | 0.0000 | 0 | 0 | 0 | 2 | 0 | 0 | 2 |
| | (0.0000) | (0) | (0) | (0) | (5) | (0) | (0) | (5) |
| Channel Catfish | 0.0003 | 0 | 38 | 0 | 0 | 31 | 0 | 69 |
| | (0.0012) | (0) | (76) | (0) | (0) | (60) | (0) | (136) |
| Chinook Salmon | 0.0006 | 0 | 16 | 9 | 18 | 73 | 22 | 138 |
| | (0.0018) | (0) | (32) | (18) | (36) | (87) | (36) | (209) |
| Coho Salmon | 0.0003 | 63 | 0 | 0 | 0 | 1 | 0 | 64 |
| | (0.0009) | (103) | (0) | (0) | (0) | (2) | (0) | (105) |
| Freshwater Drum | 0.0004 | 0 | 75 | 0 | 0 | 0 | 20 | 95 |
| | (0.0016) | (0) | (149) | (0) | (0) | (0) | (38) | (187) |
| Cisco | 0.1313 | 0 | 0 | 32,267 | 0 | 0 | 0 | 32,267 |
| | (0.1545) | (0) | (0) | (18,255) | (0) | (0) | (0) | (18,255) |
| Lake Trout | 0.0000 | 0 | 0 | 0 | 0 | 9 | 0 | 9 |
| | (0.0002) | (0) | (0) | (0) | (0) | (18) | (0) | (18) |
| Lake Whitefish | 0.0245 | 457 | 457 | 4,962 | 25 | 73 | 37 | 6,011 |
| | (0.0409) | (600) | (515) | (3,506) | (26) | (117) | (71) | (4,836) |
| Northern Pike | 0.0161 | 899 | 1,543 | 755 | 302 | 430 | 39 | 3,968 |
| | (0.0329) | (1,384) | (635) | (938) | (310) | (539) | (80) | (3,885) |
| Other | 0.0001 | 0 | 16 | 0 | 0 | 16 | 0 | 32 |
| | (0.0005) | (0) | (32) | (0) | (0) | (31) | (0) | (62) |
| Pink Salmon | 0.0005 | 0 | 0 | 0 | 30 | 93 | 0 | 123 |
| | (0.0013) | (0) | (0) | (0) | (44) | (114) | (0) | (158) |
| Pumpkinseed | 0.0009 | 0 | 161 | 0 | 59 | 0 | 0 | 220 |
| | (0.0027) | (0) | (244) | (0) | (76) | (0) | (0) | (320) |
| Rainbow Trout | 0.0033 | 241 | 190 | 218 | 49 | 80 | 29 | 807 |
| | (0.0074) | (267) | (193) | (210) | (67) | (74) | (58) | (870) |
| Smallmouth Bass | 0.0125 | 174 | 1,262 | 1,228 | 88 | 321 | 0 | 3,073 |
| | (0.0286) | (294) | (1,318) | (1,121) | (101) | (545) | (0) | (3,379) |
| Walleye | 0.0568 | 3,076 | 4,629 | 2,718 | 1,167 | 1,495 | 878 | 13,963 |
| | (0.1174) | (3,998) | (3,865) | (3,019) | (921) | (1,168) | (893) | (13,865) |
| Yellow Perch | 0.1597 | 942 | 2,220 | 2,963 | 2,043 | 18,145 | 12,928 | 39,241 |
| | (0.2510) | (1,388) | (2,252) | (2,515) | (2,518) | (10,492) | (10,492) | (29,657) |
| | | | | | | | | |
| Angler hours | | 23,718 | 55,467 | 82,113 | 29,882 | 40,604 | 13,991 | 245,775 |
| | | (17,400) | (30,830) | (34,796) | (11,805) | (14,857) | (8,445) | (118,134) |
| Angler trips | | 5,692 | 13,326 | 19,791 | 6,428 | 10,018 | 3,115 | 58,370 |
| | | (4,029) | (5,731) | (8,901) | (3,275) | (3,822) | (1,931) | (27,688) |
| Angler Days | | 5,293 | 12,838 | 18,353 | 6,146 | 9,714 | 3,060 | 55,404 |
| | | (3,740) | (5,546) | (8,368) | (3,163) | (3,738) | (1,902) | (26,456) |

Appendix 2, Table 2. Estimated harvest per hour, number harvested, and effort (angler hours, trips, and days) of sport fishing for the area from Sweets Point to the Neebish Island Ferry (includes the Michigan and Ontario waters of Raber Bay, Munuscong Lake, and Neebish Channel), by all modes (non-charter) in 2017. Two standard errors in parentheses.

| Site 207 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Harvest per hour | May | June | July | August | September | October | Season |
| Channel Catfish | 0.0013 | 0 | 38 | 0 | 0 | 23 | 0 | 61 |
| | (0.0046) | (0) | (76) | (0) | (0) | (44) | (0) | (121) |
| Freshwater Drum | 0.0021 | 0 | 75 | 0 | 0 | 0 | 20 | 95 |
| | (0.0071) | (0) | (149) | (0) | (0) | (0) | (38) | (187) |
| Northern Pike | 0.0100 | 144 | 95 | 76 | 8 | 118 | 12 | 453 |
| | (0.0271) | (298) | (142) | (109) | (16) | (120) | (24) | (709) |
| Smallmouth Bass | 0.0015 | 0 | 0 | 68 | 0 | 0 | 0 | 68 |
| | (0.0041) | (0) | (0) | (107) | (0) | (0) | (0) | (107) |
| Walleye | 0.1543 | 2,482 | 2,402 | 1,091 | 348 | 572 | 123 | 7,018 |
| | (0.2493) | (3,261) | (1,905) | (628) | (204) | (373) | (150) | (6,520) |
| Yellow Perch | 0.1121 | 431 | 1,301 | 1,888 | 160 | 570 | 749 | 5,099 |
| | (0.1753) | (857) | (1,354) | (1,152) | (141) | (528) | (552) | (4,584) |
| | | | | | | | | |
| Angler hours | | 7,409 | 15,682 | 11,545 | 3,369 | 5,560 | 1,926 | 45,491 |
| | | (6,997) | (11,312) | (4,062) | (1,280) | (1,545) | (957) | (26,153) |
| Angler trips | | 1,852 | 3,634 | 2,860 | 664 | 1,532 | 461 | 11,003 |
| | | (1,599) | (2,538) | (1,110) | (266) | (460) | (258) | (6,230) |
| Angler Days | | 1,634 | 3,444 | 2,730 | 650 | 1,532 | 458 | 10,448 |
| | | (1,454) | (2,414) | (1,087) | (259) | (460) | (253) | (5,928) |

Appendix 2, Table 3. Estimated harvest per hour, number harvested, and effort (angler hours, trips, and days) of sport fishing for Lake George to Green Point (includes Little Lake George, and the area from Bellview Marina to Stribling Point in Ontario, Canada), by all modes (non-charter) in 2017. Two standard errors in parentheses.

| Site 208 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Harvest per hour | May | June | July | August | September | October | Season |
| Atlantic Salmon | 0.0010 | 10 | 0 | 11 | 11 | 0 | 0 | 32 |
| | (0.0038) | (22) | (0) | (23) | (21) | (0) | (0) | (66) |
| Chinook Salmon | 0.0009 | 0 | 0 | 0 | 8 | 21 | 0 | 29 |
| | (0.0027) | (0) | (0) | (0) | (17) | (30) | (0) | (47) |
| Coho Salmon | 0.0009 | 31 | 0 | 0 | 0 | 0 | 0 | 31 |
| | (0.0025) | (43) | (0) | (0) | (0) | (0) | (0) | (43) |
| Lake Whitefish | 0.0053 | 166 | 0 | 0 | 0 | 11 | 0 | 177 |
| | (0.0167) | (267) | (0) | (0) | (0) | (21) | (0) | (288) |
| Northern Pike | 0.0491 | 88 | 1,184 | 42 | 243 | 70 | 0 | 1,627 |
| | (0.0457) | (102) | (226) | (88) | (210) | (165) | (0) | (791) |
| Pink Salmon | 0.0002 | 0 | 0 | 0 | 8 | 0 | 0 | 8 |
| | (0.0010) | (0) | (0) | (0) | (17) | (0) | (0) | (17) |
| Rainbow Trout | 0.0040 | 36 | 0 | 65 | 8 | 0 | 23 | 132 |
| | (0.0110) | (46) | (0) | (76) | (17) | (0) | (51) | (190) |
| Smallmouth Bass | 0.0027 | 0 | 14 | 76 | 0 | 0 | 0 | 90 |
| | (0.0080) | (0) | (30) | (109) | (0) | (0) | (0) | (139) |
| Walleye | 0.0532 | 144 | 992 | 225 | 85 | 64 | 252 | 1,762 |
| | (0.0963) | (207) | (683) | (254) | (108) | (129) | (286) | (1,667) |
| Yellow Perch | 0.1504 | 511 | 499 | 610 | 913 | 230 | 2,218 | 4,981 |
| | (0.3252) | (532) | (485) | (628) | (1,362) | (447) | (2,175) | (5,629) |
| | | | | | | | | |
| Angler hours | | 2,321 | 9,441 | 6,898 | 5,789 | 5,567 | 3,106 | 33,122 |
| | | (1,752) | (5,699) | (2,755) | (2,813) | (2,415) | (1,870) | (17,306) |
| Angler trips | | 489 | 2,293 | 1,533 | 1,267 | 1,183 | 554 | 7,319 |
| | | (376) | (738) | (755) | (686) | (575) | (332) | (3,463) |
| Angler Days | | 458 | 2,293 | 1,511 | 1,228 | 1,183 | 554 | 7,227 |
| | | (356) | (738) | (752) | (670) | (575) | (332) | (3,423) |

Appendix 2, Table 4. Estimated harvest per hour, number harvested, and effort (angler hours, trips, and days) of sport fishing for the area from the Neebish Island Ferry to the rapids in Sault Ste. Marie (includes Lake Nicolet, the St. Marys River below the rapids and the area from the rapids to Bellview Marina in Ontario, Canada), by all modes (non-charter) in 2017. Two standard errors in parentheses.

| Site 209 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Harvest per hour | May | June | July | August | September | October | Season |
| Atlantic Salmon | 0.0402 | 18 | 124 | 481 | 255 | 94 | 7 | 979 |
| | (0.0700) | (29) | (133) | (252) | (163) | (81) | (12) | (669) |
| Channel Catfish | 0.0003 | 0 | 0 | 0 | 0 | 8 | 0 | 8 |
| | (0.0016) | (0) | (0) | (0) | (0) | (15) | (0) | (15) |
| Chinook Salmon | 0.0028 | 0 | 16 | 9 | 0 | 43 | 0 | 68 |
| | (0.0099) | (0) | (32) | (18) | (0) | (45) | (0) | (95) |
| Coho Salmon | 0.0005 | 13 | 0 | 0 | 0 | 0 | 0 | 13 |
| | (0.0025) | (24) | (0) | (0) | (0) | (0) | (0) | (24) |
| Cisco | 0.0025 | 0 | 0 | 62 | 0 | 0 | 0 | 62 |
| | (0.0087) | (0) | (0) | (83) | (0) | (0) | (0) | (83) |
| Lake Trout | 0.0004 | 0 | 0 | 0 | 0 | 9 | 0 | 9 |
| | (0.0019) | (0) | (0) | (0) | (0) | (18) | (0) | (18) |
| Lake Whitefish | 0.0634 | 291 | 457 | 708 | 25 | 62 | 0 | 1,543 |
| | (0.1401) | (333) | (515) | (369) | (26) | (96) | (0) | (1,339) |
| Northern Pike | 0.0086 | 0 | 50 | 100 | 7 | 52 | 0 | 209 |
| | (0.0303) | (0) | (48) | (153) | (14) | (75) | (0) | (289) |
| Other | 0.0013 | 0 | 16 | 0 | 0 | 16 | 0 | 32 |
| | (0.0065) | (0) | (32) | (0) | (0) | (31) | (0) | (62) |
| Pink Salmon | 0.0028 | 0 | 0 | 0 | 22 | 47 | 0 | 69 |
| | (0.0083) | (0) | (0) | (0) | (27) | (52) | (0) | (79) |
| Rainbow Trout | 0.0149 | 98 | 117 | 113 | 0 | 35 | 0 | 363 |
| | (0.0433) | (144) | (141) | (93) | (0) | (35) | (0) | (414) |
| Smallmouth Bass | 0.0011 | 0 | 16 | 10 | 0 | 0 | 0 | 26 |
| | (0.0054) | (0) | (32) | (19) | (0) | (0) | (0) | (51) |
| Walleye | 0.0263 | 0 | 185 | 27 | 286 | 141 | 0 | 639 |
| | (0.0622) | (0) | (154) | (54) | (259) | (127) | (0) | (595) |
| Yellow Perch | 0.1032 | 0 | 278 | 135 | 334 | 1,418 | 347 | 2,512 |
| | (0.2841) | (0) | (245) | (273) | (361) | (1,242) | (595) | (2,716) |
| | | | | | | | | |
| Angler hours | | 1,357 | 4,718 | 8,166 | 4,009 | 5,729 | 353 | 24,332 |
| | | (1,071) | (1,931) | (2,828) | (1,352) | (2,104) | (274) | (9,559) |
| Angler trips | | 373 | 1,006 | 1,854 | 976 | 1,276 | 77 | 5,562 |
| | | (309) | (418) | (729) | (392) | (493) | (60) | (2,400) |
| Angler Days | | 356 | 984 | 1,565 | 850 | 1,230 | 77 | 5,062 |
| | | (295) | (411) | (628) | (361) | (475) | (60) | (2,229) |

Appendix 2, Table 5. Estimated harvest per hour, number harvested, and effort (angler hours, trips, and days) of sport fishing for Potagannissing Bay (Michigan and Ontario), by allmodes (non-charter), in 2017. Two standard errors in parentheses.

| Site 210 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Harvest per hour | May | June | July | August | September | October | Season |
| Cisco | 0.3254 | 0 | 0 | 32,205 | 0 | 0 | 0 | 32,205 |
| | (0.3841) | (0) | (0) | (18,172) | (0) | (0) | (0) | (18,172) |
| Lake Whitefish | 0.0430 | 0 | 0 | 4,254 | 0 | 0 | 0 | 4,254 |
| | (0.0663) | (0) | (0) | (3,138) | (0) | (0) | (0) | (3,138) |
| Northern Pike | 0.0140 | 372 | 214 | 537 | 44 | 190 | 27 | 1,384 |
| | (0.0356) | (570) | (220) | (588) | (70) | (179) | (56) | (1,682) |
| Pumpkinseed | 0.0022 | 0 | 161 | 0 | 59 | 0 | 0 | 220 |
| | (0.0068) | (0) | (244) | (0) | (76) | (0) | (0) | (320) |
| Smallmouth Bass | 0.0268 | 174 | 1,232 | 1,074 | 88 | 86 | 0 | 2,654 |
| | (0.0562) | (294) | (1,257) | (885) | (101) | (121) | (0) | (2,658) |
| Walleye | 0.0295 | 450 | 569 | 232 | 448 | 718 | 499 | 2,916 |
| | (0.0570) | (531) | (507) | (320) | (349) | (539) | (450) | (2,697) |
| Yellow Perch | 0.2636 | 0 | 142 | 58 | 636 | 15,637 | 9,614 | 26,087 |
| | (0.3301) | (0) | (169) | (118) | (654) | (7,506) | (7,170) | (15,616) |
| | | | | | | | | |
| Angler hours | | 6,754 | 17,346 | 43,507 | 8,756 | 16,342 | 6,261 | 98,966 |
| | | (6,172) | (10,342) | (18,686) | (2,556) | (5,801) | (3,755) | (47,311) |
| Angler trips | | 1,520 | 3,978 | 10,682 | 1,473 | 4,040 | 1,395 | 23,088 |
| | | (1,382) | (1,647) | (4,741) | (642) | (1,455) | (866) | (10,734) |
| Angler Days | | 1,409 | 3,805 | 9,727 | 1,378 | 3,791 | 1,350 | 21,460 |
| | | (1,278) | (1,593) | (4,358) | (587) | (1,392) | (845) | (10,054) |

Appendix 2, Table 6. Estimated harvest per hour, number harvested, and effort (angler hours, trips, and days) of sport fishing for the Rapids in Sault Ste. Marie, Ontario, by all modes (non-charter) in 2017. Two standard errors in parentheses.

| Site 403 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Harvest per hour | May | June | July | August | September | October | Season |
| Atlantic Salmon | 0.0011 | 0 | 0 | 0 | 9 | 5 | 0 | 14 |
| | (0.0040) | (0) | (0) | (0) | (12) | (9) | (0) | (21) |
| Brown Trout | 0.0002 | 0 | 0 | 0 | 2 | 0 | 0 | 2 |
| | (0.0009) | (0) | (0) | (0) | (5) | (0) | (0) | (5) |
| Chinook Salmon | 0.0032 | 0 | 0 | 0 | 10 | 9 | 22 | 41 |
| | (0.0125) | (0) | (0) | (0) | (19) | (12) | (36) | (67) |
| Coho Salmon | 0.0016 | 19 | 0 | 0 | 0 | 1 | 0 | 20 |
| | (0.0071) | (36) | (0) | (0) | (0) | (2) | (0) | (38) |
| Lake Whitefish | 0.0029 | 0 | 0 | 0 | 0 | 0 | 37 | 37 |
| | (0.0132) | (0) | (0) | (0) | (0) | (0) | (71) | (71) |
| Pink Salmon | 0.0036 | 0 | 0 | 0 | 0 | 46 | 0 | 46 |
| | (0.0116) | (0) | (0) | (0) | (0) | (62) | (0) | (62) |
| Rainbow Trout | 0.0243 | 107 | 73 | 40 | 41 | 45 | 6 | 312 |
| | (0.0498) | (77) | (52) | (41) | (50) | (39) | (7) | (266) |
| Walleye | 0.0003 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| | (0.0012) | (0) | (0) | (0) | (0) | (0) | (6) | (6) |
| | | | | | | | | |
| Angler hours | | 4,604 | 2,469 | 1,796 | 869 | 1,641 | 1,475 | 12,854 |
| | | (1,338) | (1,342) | (752) | (460) | (732) | (727) | (5,350) |
| Angler trips | | 1,164 | 700 | 573 | 302 | 544 | 434 | 3,717 |
| | | (363) | (390) | (258) | (164) | (251) | (226) | (1,653) |
| Angler Days | | 1,142 | 694 | 531 | 294 | 535 | 427 | 3,623 |
| | | (356) | (389) | (237) | (161) | (247) | (224) | (1,614) |

Appendix 2, Table 7. Estimated harvest per hour, number harvested, and effort (angler hours, trips, and days) of sport fishing for the St. Joseph Channel, Ontario, Canada, by all modes (non-charter) in 2017. Two standard errors in parentheses.

| Site 405 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Harvest per hour | May | June | July | August | September | October | Season |
| Northern Pike | 0.0095 | 295 | 0 | 0 | 0 | 0 | 0 | 295 |
| | (0.0332) | (414) | (0) | (0) | (0) | (0) | (0) | (414) |
| Smallmouth Bass | 0.0076 | 0 | 0 | 0 | 0 | 235 | 0 | 235 |
| | (0.0340) | (0) | (0) | (0) | (0) | (424) | (0) | (424) |
| Walleye | 0.0524 | 0 | 481 | 1,143 | 0 | 0 | 0 | 1,624 |
| | (0.1910) | (0) | (616) | (1,763) | (0) | (0) | (0) | (2,379) |
| Yellow Perch | 0.0181 | 0 | 0 | 272 | 0 | 290 | 0 | 562 |
| | (0.0893) | (0) | (0) | (344) | (0) | (769) | (0) | (1,112) |
| | | | | | | | | |
| Angler hours | | 1,273 | 5,811 | 10,201 | 7,090 | 5,765 | 870 | 31,010 |
| | | (70) | (204) | (5,714) | (3,344) | (2,261) | (862) | (12,455) |
| Angler trips | | 294 | 1,715 | 2,289 | 1,746 | 1,443 | 194 | 7,681 |
| | | (0) | (0) | (1,307) | (1,124) | (589) | (189) | (3,209) |
| Angler Days | | 294 | 1,618 | 2,289 | 1,746 | 1,443 | 194 | 7,584 |
| | | (0) | (0) | (1,307) | (1,124) | (589) | (189) | (3,209) |

Appendix 3, Table 1. Estimated catch including legal and nonlegal release plus harvest for all sites combined on the St. Marys River in 2017. Two standard errors are in parentheses.

| Site All Sites - 2017 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Catch per hour | May | June | July | August | September | October | Season |
| Atlantic Salmon | 0.0071 | 185 | 219 | 761 | 454 | 116 | 18 | 1,753 |
| | (0.0021) | (38) | (30) | (82) | (57) | (26) | (12) | (244) |
| Brown Trout | 0.0000 | 0 | 0 | 0 | 2 | 4 | 0 | 6 |
| | (0.0001) | (0) | (0) | (0) | (3) | (4) | (0) | (7) |
| Channel Catfish | 0.0031 | 91 | 353 | 201 | 13 | 89 | 23 | 770 |
| | (0.0014) | (19) | (51) | (48) | (10) | (24) | (10) | (162) |
| Chinook Salmon | 0.0013 | 0 | 16 | 28 | 21 | 94 | 165 | 324 |
| | (0.0008) | (0) | (8) | (11) | (13) | (32) | (26) | (89) |
| Coho Salmon | 0.0004 | 63 | 0 | 0 | 0 | 1 | 46 | 110 |
| | (0.0004) | (27) | (0) | (0) | (0) | (2) | (14) | (43) |
| Freshwater Drum | 0.0007 | 0 | 75 | 23 | 37 | 0 | 43 | 178 |
| | (0.0005) | (0) | (17) | (10) | (16) | (0) | (19) | (62) |
| Cisco | 0.1369 | 0 | 0 | 33,658 | 0 | 0 | 0 | 33,658 |
| | (0.0034) | (0) | (0) | (404) | (0) | (0) | (0) | (404) |
| Lake Trout | 0.0001 | 0 | 0 | 0 | 0 | 9 | 9 | 18 |
| | (0.0001) | (0) | (0) | (0) | (0) | (6) | (6) | (12) |
| Largemouth Bass | 0.0001 | 0 | 0 | 0 | 21 | 0 | 4 | 25 |
| | (0.0002) | (0) | (0) | (0) | (14) | (0) | (4) | (18) |
| Lake Whitefish | 0.0262 | 506 | 536 | 5,232 | 25 | 111 | 37 | 6,447 |
| | (0.0030) | (63) | (46) | (192) | (10) | (27) | (12) | (349) |
| Musky | 0.0009 | 48 | 116 | 0 | 0 | 15 | 35 | 214 |
| | (0.0006) | (14) | (32) | (0) | (0) | (8) | (12) | (66) |
| Northern Pike | 0.0963 | 3,395 | 7,832 | 6,088 | 2,809 | 2,794 | 754 | 23,672 |
| | (0.0133) | (238) | (414) | (354) | (225) | (225) | (114) | (1,569) |
| Other | 0.0110 | 175 | 874 | 1,102 | 185 | 343 | 27 | 2,706 |
| | (0.0029) | (37) | (110) | (87) | (41) | (51) | (10) | (338) |
| Pink Salmon | 0.0047 | 0 | 0 | 0 | 30 | 512 | 624 | 1,166 |
| | (0.0011) | (0) | (0) | (0) | (15) | (60) | (50) | (125) |
| Pumpkinseed | 0.0033 | 12 | 224 | 215 | 342 | 0 | 27 | 820 |
| | (0.0011) | (7) | (41) | (29) | (40) | (0) | (10) | (128) |
| Rainbow Trout | 0.0181 | 2,327 | 1,131 | 437 | 131 | 130 | 285 | 4,441 |
| | (0.0035) | (127) | (100) | (71) | (35) | (32) | (50) | (415) |
| Rock Bass | 0.0077 | 0 | 1,256 | 495 | 52 | 51 | 41 | 1,895 |
| | (0.0019) | (0) | (121) | (65) | (14) | (14) | (13) | (227) |
| Smallmouth Bass | 0.0691 | 1,048 | 8,037 | 5,889 | 498 | 1,414 | 104 | 16,990 |
| | (0.0083) | (93) | (350) | (283) | (79) | (147) | (32) | (985) |
| Walleye | 0.1583 | 10,563 | 16,121 | 5,063 | 3,712 | 2,220 | 1,218 | 38,897 |
| | (0.0134) | (272) | (472) | (286) | (269) | (171) | (120) | (1,589) |
| White Bass | 0.0001 | 0 | 0 | 0 | 31 | 0 | 0 | 31 |
| | (0.0001) | (0) | (0) | (0) | (11) | (0) | (0) | (11) |
| Yellow Perch | 0.4034 | 2,069 | 5,624 | 11,041 | 5,454 | 44,131 | 30,827 | 99,146 |
| | (0.0202) | (146) | (297) | (419) | (286) | (664) | (579) | (2,391) |

Appendix 3, Table 1. Cont.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Angler hours | | 23,718 | 55,467 | 82,113 | 29,882 | 40,604 | 13,991 | 245,775 |
| | | (17,400) | (30,830) | (34,796) | (11,805) | (14,857) | (8,445) | (118,134) |
| Angler trips | | 5,692 | 13,326 | 19,791 | 6,428 | 10,018 | 3,115 | 58,370 |
| | | (4,029) | (5,731) | (8,901) | (3,275) | (3,822) | (1,931) | (27,688) |
| Angler Days | | 5,293 | 12,838 | 18,353 | 6,146 | 9,714 | 3,060 | 55,404 |
| | | (3,740) | (5,546) | (8,368) | (3,163) | (3,738) | (1,902) | (26,456) |

Appendix 3, Table 2. Estimated catch including legal and nonlegal release plus harvest for Site 207. Two standard errors are in parentheses.

| Site 207-2017 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Catch per hour | May | June | July | August | September | October | Season |
| Channel Catfish | 0.0077 | 0 | 264 | 0 | 5 | 81 | 0 | 350 |
| | (0.0021) | (0) | (32) | (0) | (4) | (18) | (0) | (55) |
| Freshwater Drum | 0.0023 | 0 | 75 | 0 | 8 | 0 | 20 | 103 |
| | (0.0012) | (0) | (17) | (0) | (6) | (0) | (9) | (32) |
| Cisco | 0.0027 | 0 | 0 | 122 | 0 | 0 | 0 | 122 |
| | (0.0008) | (0) | (0) | (22) | (0) | (0) | (0) | (22) |
| Largemouth Bass | 0.0001 | 0 | 0 | 0 | 5 | 0 | 0 | 5 |
| | (0.0002) | (0) | (0) | (0) | (4) | (0) | (0) | (4) |
| Musky | 0.0042 | 48 | 95 | 0 | 0 | 15 | 35 | 193 |
| | (0.0020) | (14) | (19) | (0) | (0) | (8) | (12) | (53) |
| Northern Pike | 0.1493 | 1,046 | 2,377 | 1,756 | 401 | 841 | 371 | 6,792 |
| | (0.0146) | (65) | (98) | (84) | (40) | (58) | (39) | (383) |
| Other | 0.0046 | 0 | 152 | 43 | 13 | 0 | 0 | 208 |
| | (0.0017) | (0) | (25) | (13) | (7) | (0) | (0) | (45) |
| Rock Bass | 0.0155 | 0 | 623 | 43 | 0 | 0 | 41 | 707 |
| | (0.0029) | (0) | (50) | (13) | (0) | (0) | (13) | (76) |
| Smallmouth Bass | 0.0295 | 95 | 436 | 437 | 51 | 295 | 29 | 1,343 |
| | (0.0064) | (19) | (42) | (46) | (14) | (34) | (11) | (167) |
| Walleye | 0.5692 | 9,842 | 11,547 | 2,792 | 653 | 862 | 196 | 25,892 |
| | (0.0251) | (198) | (215) | (106) | (51) | (59) | (28) | (657) |
| Yellow Perch | 0.2256 | 526 | 3,171 | 3,518 | 470 | 1,012 | 1,565 | 10,262 |
| | (0.0182) | (46) | (113) | (123) | (43) | (64) | (86) | (475) |
| | | | | | | | | |
| Angler hours | | 7,409 | 15,682 | 11,545 | 3,369 | 5,560 | 1,926 | 45,491 |
| | | (6,997) | (11,312) | (4,062) | (1,280) | (1,545) | (957) | (26,153) |
| Angler trips | | 1,852 | 3,634 | 2,860 | 664 | 1,532 | 461 | 11,003 |
| | | (1,599) | (2,538) | (1,110) | (266) | (460) | (258) | (6,230) |
| Angler Days | | 1,634 | 3,444 | 2,730 | 650 | 1,532 | 458 | 10,448 |
| | | (1,454) | (2,414) | (1,087) | (259) | (460) | (253) | (5,928) |

Appendix 3, Table 3. Estimated catch including legal and nonlegal release plus harvest for Site 208. Two standard errors are in parentheses.

| Site 208 - 2017 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Catch per hour | May | June | July | August | September | October | Season |
| Atlantic Salmon | 0.0032 | 73 | 0 | 23 | 11 | 0 | 0 | 107 |
| | (0.0019) | (17) | (0) | (10) | (7) | (0) | (0) | (33) |
| Channel Catfish | 0.0055 | 91 | 0 | 67 | 0 | 0 | 23 | 181 |
| | (0.0026) | (19) | (0) | (16) | (0) | (0) | (10) | (45) |
| Chinook Salmon | 0.0009 | 0 | 0 | 0 | 8 | 21 | 0 | 29 |
| | (0.0009) | (0) | (0) | (0) | (6) | (9) | (0) | (15) |
| Coho Salmon | 0.0009 | 31 | 0 | 0 | 0 | 0 | 0 | 31 |
| | (0.0006) | (11) | (0) | (0) | (0) | (0) | (0) | (11) |
| Freshwater Drum | 0.0014 | 0 | 0 | 23 | 0 | 0 | 23 | 46 |
| | (0.0011) | (0) | (0) | (10) | (0) | (0) | (10) | (19) |
| Largemouth Bass | 0.0001 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| | (0.0002) | (0) | (0) | (0) | (0) | (0) | (4) | (4) |
| Lake Whitefish | 0.0053 | 166 | 0 | 0 | 0 | 11 | 0 | 177 |
| | (0.0019) | (26) | (0) | (0) | (0) | (7) | (0) | (32) |
| Musky | 0.0004 | 0 | 14 | 0 | 0 | 0 | 0 | 14 |
| | (0.0004) | (0) | (7) | (0) | (0) | (0) | (0) | (7) |
| Northern Pike | 0.2095 | 461 | 3,396 | 1,589 | 942 | 449 | 101 | 6,938 |
| | (0.0241) | (43) | (160) | (90) | (61) | (42) | (20) | (417) |
| Other | 0.0071 | 71 | 143 | 0 | 11 | 11 | 0 | 236 |
| | (0.0031) | (17) | (24) | (0) | (7) | (7) | (0) | (54) |
| Pink Salmon | 0.0002 | 0 | 0 | 0 | 8 | 0 | 0 | 8 |
| | (0.0003) | (0) | (0) | (0) | (6) | (0) | (0) | (6) |
| Rainbow Trout | 0.0056 | 43 | 28 | 65 | 25 | 0 | 23 | 184 |
| | (0.0034) | (13) | (11) | (16) | (10) | (0) | (10) | (59) |
| Smallmouth Bass | 0.0441 | 46 | 360 | 931 | 78 | 43 | 4 | 1,462 |
| | (0.0085) | (14) | (38) | (61) | (18) | (13) | (4) | (147) |
| Walleye | 0.1251 | 189 | 2,519 | 735 | 349 | 85 | 268 | 4,145 |
| | (0.0161) | (27) | (100) | (61) | (37) | (18) | (33) | (278) |
| Yellow Perch | 0.3309 | 1,377 | 885 | 1,239 | 1,876 | 925 | 4,659 | 10,961 |
| | (0.0282) | (74) | (59) | (70) | (87) | (61) | (137) | (488) |
| | | | | | | | | |
| Angler hours | | 2,321 | 9,441 | 6,898 | 5,789 | 5,567 | 3,106 | 33,122 |
| | | (1,752) | (5,699) | (2,755) | (2,813) | (2,415) | (1,870) | (17,306) |
| Angler trips | | 489 | 2,293 | 1,533 | 1,267 | 1,183 | 554 | 7,319 |
| | | (376) | (738) | (755) | (686) | (575) | (332) | (3,463) |
| Angler Days | | 458 | 2,293 | 1,511 | 1,228 | 1,183 | 554 | 7,227 |
| | | (356) | (738) | (752) | (670) | (575) | (332) | (3,423) |

Appendix 3, Table 4. Estimated catch including legal and nonlegal release plus harvest for Site 209. Two standard errors are in parentheses.

| Site 209 - 2017 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Catch per hour | May | June | July | August | September | October | Season |
| Atlantic Salmon | 0.0648 | 112 | 219 | 708 | 419 | 111 | 7 | 1,576 |
| | (0.0187) | (21) | (30) | (61) | (41) | (21) | (5) | (179) |
| Channel Catfish | 0.0007 | 0 | 0 | 0 | 8 | 8 | 0 | 16 |
| | (0.0012) | (0) | (0) | (0) | (6) | (6) | (0) | (11) |
| Chinook Salmon | 0.0042 | 0 | 16 | 28 | 0 | 59 | 0 | 103 |
| | (0.0036) | (0) | (8) | (11) | (0) | (15) | (0) | (34) |
| Coho Salmon | 0.0005 | 13 | 0 | 0 | 0 | 0 | 0 | 13 |
| | (0.0008) | (7) | (0) | (0) | (0) | (0) | (0) | (7) |
| Cisco | 0.0025 | 0 | 0 | 62 | 0 | 0 | 0 | 62 |
| | (0.0016) | (0) | (0) | (16) | (0) | (0) | (0) | (16) |
| Lake Trout | 0.0004 | 0 | 0 | 0 | 0 | 9 | 0 | 9 |
| | (0.0006) | (0) | (0) | (0) | (0) | (6) | (0) | (6) |
| Lake Whitefish | 0.0779 | 340 | 536 | 895 | 25 | 100 | 0 | 1,896 |
| | (0.0181) | (37) | (46) | (60) | (10) | (20) | (0) | (173) |
| Musky | 0.0003 | 0 | 7 | 0 | 0 | 0 | 0 | 7 |
| | (0.0006) | (0) | (5) | (0) | (0) | (0) | (0) | (5) |
| Northern Pike | 0.0434 | 27 | 521 | 191 | 70 | 195 | 53 | 1,057 |
| | (0.0161) | (10) | (46) | (39) | (17) | (28) | (15) | (154) |
| Other | 0.0020 | 0 | 16 | 9 | 0 | 23 | 0 | 48 |
| | (0.0025) | (0) | (8) | (6) | (0) | (10) | (0) | (24) |
| Pink Salmon | 0.0028 | 0 | 0 | 0 | 22 | 47 | 0 | 69 |
| | (0.0028) | (0) | (0) | (0) | (9) | (17) | (0) | (26) |
| Rainbow Trout | 0.0238 | 107 | 231 | 167 | 7 | 43 | 24 | 579 |
| | (0.0110) | (21) | (30) | (26) | (5) | (13) | (10) | (105) |
| Smallmouth Bass | 0.0159 | 0 | 336 | 10 | 26 | 16 | 0 | 388 |
| | (0.0064) | (0) | (37) | (6) | (10) | (8) | (0) | (61) |
| Walleye | 0.0502 | 0 | 532 | 46 | 443 | 201 | 0 | 1,222 |
| | (0.0142) | (0) | (46) | (14) | (48) | (28) | (0) | (136) |
| Yellow Perch | 0.2065 | 0 | 574 | 480 | 1,076 | 2,378 | 517 | 5,025 |
| | (0.0314) | (0) | (48) | (44) | (66) | (98) | (45) | (300) |
| | | | | | | | | |
| Angler hours | | 1,357 | 4,718 | 8,166 | 4,009 | 5,729 | 353 | 24,332 |
| | | (1,071) | (1,931) | (2,828) | (1,352) | (2,104) | (274) | (9,559) |
| Angler trips | | 373 | 1,006 | 1,854 | 976 | 1,276 | 77 | 5,562 |
| | | (309) | (418) | (729) | (392) | (493) | (60) | (2,400) |
| Angler Days | | 356 | 984 | 1,565 | 850 | 1,230 | 77 | 5,062 |
| | | (295) | (411) | (628) | (361) | (475) | (60) | (2,229) |

Appendix 3, Table 5. Estimated catch including legal and nonlegal release plus harvest for Site 210. Two standard errors are in parentheses.

| Site 210 - 2017 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Catch per hour | May | June | July | August | September | October | Season |
| Channel Catfish | 0.0004 | 0 | 0 | 41 | 0 | 0 | 0 | 41 |
| | (0.0003) | (0) | (0) | (13) | (0) | (0) | (0) | (13) |
| Freshwater Drum | 0.0003 | 0 | 0 | 0 | 29 | 0 | 0 | 29 |
| | (0.0002) | (0) | (0) | (0) | (11) | (0) | (0) | (11) |
| Cisco | 0.3382 | 0 | 0 | 33,474 | 0 | 0 | 0 | 33,474 |
| | (0.0077) | (0) | (0) | (366) | (0) | (0) | (0) | (366) |
| Largemouth Bass | 0.0002 | 0 | 0 | 0 | 16 | 0 | 0 | 16 |
| | (0.0002) | (0) | (0) | (0) | (10) | (0) | (0) | (10) |
| Lake Whitefish | 0.0438 | 0 | 0 | 4,337 | 0 | 0 | 0 | 4,337 |
| | (0.0028) | (0) | (0) | (132) | (0) | (0) | (0) | (132) |
| Northern Pike | 0.0559 | 1,271 | 851 | 1,635 | 523 | 1,074 | 180 | 5,534 |
| | (0.0074) | (71) | (58) | (81) | (48) | (66) | (27) | (351) |
| Other | 0.0222 | 104 | 552 | 1,047 | 161 | 309 | 27 | 2,200 |
| | (0.0043) | (20) | (47) | (65) | (27) | (35) | (10) | (205) |
| Pumpkinseed | 0.0076 | 12 | 161 | 215 | 342 | 0 | 27 | 757 |
| | (0.0024) | (7) | (25) | (29) | (40) | (0) | (10) | (112) |
| Rock Bass | 0.0120 | 0 | 633 | 452 | 52 | 51 | 0 | 1,188 |
| | (0.0032) | (0) | (71) | (52) | (14) | (14) | (0) | (152) |
| Smallmouth Bass | 0.1010 | 907 | 4,166 | 4,069 | 343 | 438 | 71 | 9,994 |
| | (0.0087) | (60) | (129) | (128) | (37) | (42) | (17) | (413) |
| Walleye | 0.0510 | 532 | 836 | 347 | 1,506 | 1,072 | 750 | 5,043 |
| | (0.0072) | (46) | (58) | (37) | (78) | (65) | (55) | (339) |
| White Bass | 0.0003 | 0 | 0 | 0 | 31 | 0 | 0 | 31 |
| | (0.0002) | (0) | (0) | (0) | (11) | (0) | (0) | (11) |
| Yellow Perch | 0.7278 | 166 | 925 | 5,532 | 2,032 | 39,291 | 24,086 | 72,032 |
| | (0.0218) | (26) | (61) | (149) | (90) | (396) | (310) | (1,032) |
| | | | | | | | | |
| Angler hours | | 6,754 | 17,346 | 43,507 | 8,756 | 16,342 | 6,261 | 98,966 |
| | | (6,172) | (10,342) | (18,686) | (2,556) | (5,801) | (3,755) | (47,311) |
| Angler trips | | 1,520 | 3,978 | 10,682 | 1,473 | 4,040 | 1,395 | 23,088 |
| | | (1,382) | (1,647) | (4,741) | (642) | (1,455) | (866) | (10,734) |
| Angler Days | | 1,409 | 3,805 | 9,727 | 1,378 | 3,791 | 1,350 | 21,460 |
| | | (1,278) | (1,593) | (4,358) | (587) | (1,392) | (845) | (10,054) |

Appendix 3, Table 6. Estimated catch including legal and nonlegal release plus harvest for Site 403. Two standard errors are in parentheses.

| Site 403-2017 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Catch per hour | May | June | July | August | September | October | Season |
| Atlantic Salmon | 0.0054 | 0 | 0 | 30 | 24 | 5 | 11 | 70 |
| | (0.0060) | (0) | (0) | (11) | (10) | (4) | (7) | (32) |
| Brown Trout | 0.0005 | 0 | 0 | 0 | 2 | 4 | 0 | 6 |
| | (0.0013) | (0) | (0) | (0) | (3) | (4) | (0) | (7) |
| Channel Catfish | 0.0142 | 0 | 89 | 93 | 0 | 0 | 0 | 182 |
| | (0.0071) | (0) | (19) | (19) | (0) | (0) | (0) | (38) |
| Chinook Salmon | 0.0149 | 0 | 0 | 0 | 13 | 14 | 165 | 192 |
| | (0.0075) | (0) | (0) | (0) | (7) | (7) | (26) | (40) |
| Coho Salmon | 0.0051 | 19 | 0 | 0 | 0 | 1 | 46 | 66 |
| | (0.0045) | (9) | (0) | (0) | (0) | (2) | (14) | (24) |
| Lake Trout | 0.0007 | 0 | 0 | 0 | 0 | 0 | 9 | 9 |
| | (0.0011) | (0) | (0) | (0) | (0) | (0) | (6) | (6) |
| Lake Whitefish | 0.0029 | 0 | 0 | 0 | 0 | 0 | 37 | 37 |
| | (0.0023) | (0) | (0) | (0) | (0) | (0) | (12) | (12) |
| Other | 0.0011 | 0 | 11 | 3 | 0 | 0 | 0 | 14 |
| | (0.0019) | (0) | (7) | (3) | (0) | (0) | (0) | (10) |
| Pink Salmon | 0.0847 | 0 | 0 | 0 | 0 | 465 | 624 | 1,089 |
| | (0.0174) | (0) | (0) | (0) | (0) | (43) | (50) | (93) |
| Pumpkinseed | 0.0049 | 0 | 63 | 0 | 0 | 0 | 0 | 63 |
| | (0.0030) | (0) | (16) | (0) | (0) | (0) | (0) | (16) |
| Rainbow Trout | 0.2861 | 2,177 | 872 | 205 | 99 | 87 | 238 | 3,678 |
| | (0.0468) | (93) | (59) | (29) | (20) | (19) | (31) | (250) |
| Walleye | 0.0003 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| | (0.0007) | (0) | (0) | (0) | (0) | (0) | (4) | (4) |
| | | | | | | | | |
| Angler hours | | 4,604 | 2,469 | 1,796 | 869 | 1,641 | 1,475 | 12,854 |
| | | (1,338) | (1,342) | (752) | (460) | (732) | (727) | (5,350) |
| Angler trips | | 1,164 | 700 | 573 | 302 | 544 | 434 | 3,717 |
| | | (363) | (390) | (258) | (164) | (251) | (226) | (1,653) |
| Angler Days | | 1,142 | 694 | 531 | 294 | 535 | 427 | 3,623 |
| | | (356) | (389) | (237) | (161) | (247) | (224) | (1,614) |

Appendix 3, Table 7. Estimated catch including legal and nonlegal release plus harvest for Site 405. Two standard errors are in parentheses.

| Site 405 - 2017 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | | | | |
| Species | Catch per hour | May | June | July | August | September | October | Season |
| Northern Pike | 0.1081 | 590 | 687 | 917 | 873 | 235 | 49 | 3,351 |
| | (0.0213) | (49) | (52) | (61) | (59) | (31) | (14) | (265) |
| Smallmouth Bass | 0.1226 | 0 | 2,739 | 442 | 0 | 622 | 0 | 3,803 |
| | (0.0158) | (0) | (105) | (42) | (0) | (50) | (0) | (197) |
| Walleye | 0.0836 | 0 | 687 | 1,143 | 761 | 0 | 0 | 2,591 |
| | (0.0141) | (0) | (52) | (68) | (55) | (0) | (0) | (175) |
| Yellow Perch | 0.0279 | 0 | 69 | 272 | 0 | 525 | 0 | 866 |
| | (0.0077) | (0) | (17) | (33) | (0) | (46) | (0) | (95) |
| | | | | | | | | |
| Angler hours | | 1,273 | 5,811 | 10,201 | 7,090 | 5,765 | 870 | 31,010 |
| | | (70) | (204) | (5,714) | (3,344) | (2,261) | (862) | (12,455) |
| Angler trips | | 294 | 1,715 | 2,289 | 1,746 | 1,443 | 194 | 7,681 |
| | | (0) | (0) | (1,307) | (1,124) | (589) | (189) | (3,209) |
| Angler Days | | 294 | 1,618 | 2,289 | 1,746 | 1,443 | 194 | 7,584 |
| | | (0) | (0) | (1,307) | (1,124) | (589) | (189) | (3,209) |

Appendix 4. Summary of biological data collected from the St. Marys River during the open water sport fishery for the years 1999-2000, 2005-2009 and 2017, by capture sites. N = sample size and appears in parentheses if different than reported.

| Species | Year | Capture sites | N | Mean Age | Mean Length (cm) | Mean Wt (g) |
|---|---|---|---|---|---|---|
| Atlantic Salmon | 1999 | 209, 210 | 15 | 3.2 (14) | 73.0 | 4 810 |
| | 2001 | 209 | 13 | 2.5 (13) | 65.7 | 3 148 |
| | 2006 | 209 | 11 | 3.5 (11) | 65.3 | 3 336 |
| | 2007 | 210 | 1 | 3.0 (1) | 59.7 | 2 041 |
| | 2008 | 208, 209 | 109 | 2.6 (95) | 65.8 | 3 247 |
| | 2009 | 403 | 6 | 2.8 (6) | 67.1 | 2 895 |
| | 2017 | 208, 209, 403 | 117 | 2.2 (41) | 56.6 | 2174 (116) |
| Brown Trout | 2017 | 403 | 1 | 3 | 46.0 | 1202 |
| Channel Catfish | 2017 | 207 | 2 | | 49.9 | 1429 |
| Chinook Salmon | 1999 | 208, 209 | 214 | 3.0 (205) | 84.0 | 6 698 |
| | 2000 | 208 | 14 | 3.1 | 86.0 | 7 355 |
| | 2001 | 208, 209, 210 | 14 | 2.9 | 81.0 | 5 621 |
| | 2006 | 208, 209, 210 | 56 | 3.5 (41) | 77.0 | 4 248 |
| | 2007 | 208, 210, 405 | 62 | 2.7 | 75.0 | 4 090 |
| | 2008 | 208, 209, 403 | 47 | 2.7 (36) | 75.4 | 4 611 |
| | 2009 | 207, 403 | 7 | 2.9 | 82.4 | 5 242 |
| | 2017 | 208, 403 | 6 | 2.8 (5) | 78.1 | 5934 |
| Coho Salmon | 1999 | 209 | 18 | 2.7 (16) | 60.2 | 2 694 |
| | 2006 | 208, 209 | 5 | 2.0 (4) | 52.1 | 1 760 |
| | 2007 | 208, 405 | 6 | 2.7 | 69.6 | 3 145 |
| | 2008 | 208, 209, 403 | 36 | 2 | 57.4 | 1 971 |
| | 2009 | 403 | 18 | 2.1 | 64.9 | 2 389 |
| | 2017 | 403 | 1 | 2 | 43.4 | 1202 |
| Cisco | 1999 | 207, 209, 210 | 138 | 4.2 | 33.8 | 540 (110) |
| | 2000 | 207, 209, 210 | 88 | 3.8 (85) | 31.6 | 469 |
| | 2001 | 207, 209, 210 | 58 | 4 | 33.8 | |
| | 2005 | 207, 210 | 53 | 3 | 32.4 | 358 |
| | 2006 | 210 | 70 | 5.3 | 36.8 | 526 |
| | 2007 | 207, 210 | 65 | 4.1 | 34.9 | 447 |
| | 2008 | 209 | 23 | 4.2 | 36.4 | 531 |
| | 2009 | 207, 210 | 95 | 4.9 (93) | 38.0 | 606 |
| | 2017 | 209, 210 | 92 | | 38.5 | 605 (91) |
| Freshwater Drum | 2017 | 207 | 1 | | 50.8 | 2540 |
| Lake Whitefish | 1999 | 209, 404 | 157 | 4.6 (154) | 41.5 | 614 (156) |
| | 2000 | 210 | 2 | 5 | 49.5 | 1 270 |
| | 2006 | 209 | 7 | 3.3 | 41.2 | 719 |
| | 2007 | 207, 210 | 12 | 4.9 | 42.9 | 794 |
| | 2008 | 209 | 60 | 3.7 | 38.3 | 584 |
| | 2009 | 210 | 6 | | 41.6 | 726 |
| | 2008 | 208, 405 | 11 | 3.1 | 36.3 | 920 |
| | 2009 | 210 | 6 | 5.7 | 41.6 | 726 |
| | 2017 | 208, 210, 403 | 4 | 4 (3) | 46.4 | 1008 |
| Largemouth Bass | 2008 | 208, 405 | 11 | 3.2 | 36.3 | 920 |
| | 2009 | 210 | 1 | | 38.1 | 771 |

Appendix 4, Cont.

| Species | Year | Capture sites | N | Mean Age | Mean Length (cm) | Mean Wt (g) |
|---|---|---|---|---|---|---|
| Muskellunge | 2000 | 207 | 8 | | 108.4 | 8 541 |
| | 2007 | 207 | 1 | | 94.5 | |
| | 2008 | 209 | 1 | 10 | 108.0 | 8 618 |
| | 2009 | 207 | 3 | 4 | 76.7 | 33 817 |
| | | 207, 208, 209, | | | | |
| Northern Pike | 1999 | 210 | 88 | 4.6 (86) | 66.8 (87) | 1 852 (87) |
| | | 207, 208, 209, | | | | |
| | 2000 | 210 | 42 | 4.3 | 66.8 | 1 702 |
| | 2001 | 207, 208, 210 | 22 | 5.6 | 69.6 | 2 208 |
| | 2005 | 207, 210 | 15 | 5.1 | 73.4 | 2 734 |
| | 2006 | 208, 207, 209 | 83 | 3.8 | 65.1 | 1 855 |
| | | 207, 208, 210, | | | | |
| | 2007 | 405 | 70 | 4.4 | 67.3 | 2 223 |
| | 2008 | 208, 209, 405 | 146 | 4.0 | 69.8 | 2 224 |
| | 2009 | 207, 210, 405 | 45 | 5.6 (44) | 66.5 | 1 878 |
| | 2017 | 207, 208, 209, 210 | 74 | 4.6 | 67.6 | 1876 |
| Pink Salmon | 1999 | 208, 209 | 82 | 2.0 (56) | 52.1 | 1 398 |
| | 2000 | 209 | 1 | 1 | 49.3 | 907 |
| | 2008 | 209, 403 | 31 | 1 (14) | 44.3 | 661 |
| | 2009 | 403 | 2 | | 47.2 | 1 089 |
| | 2017 | 208, 209, 403 | 31 | 2 (7) | 50.5 | 1283 |
| Rainbow Trout | 1999 | 209 | 29 | 2.5 (28) | 50.3 | 1 595 (28) |
| | 2000 | 208, 209 | 2 | 2 | 74.2 | 2 381 |
| | 2001 | 208, 209 | 2 | 3 | 61.0 | 2 041 |
| | 2006 | 209 | 11 | 2.5 | 44.9 | 1 064 |
| | 2008 | 208, 209, 403 | 25 | 3.5 (16) | 54.6 | 1 970 |
| | 2009 | 403 | 69 | 4.8 (63) | 63.7 | 2 757 |
| | 2017 | 208, 209, 403 | 32 | 2.5 | 48.5 | 1549 |
| Smallmouth Bass | 1999 | 208 | 10 | 6.3 | 36.5 | 809 |
| | 2000 | 207, 210 | 22 | 6.5 | 39.4 | 1 000 |
| | 2001 | 207, 210 | 12 | 5.6 | 21.9 | 1 104 |
| | 2005 | 207, 210 | 52 | 4.7 | 39.2 | 1 010 |
| | 2006 | 207, 208, 209 | 44 | 5.7 | 41.3 | 1 334 |
| | 2007 | 207, 210, 405 | 57 | 4.8 (56) | 36.5 | 909 |
| | 2008 | 208, 209 | 52 | 5.3 (51) | 40.1 | 1 225 |
| | 2009 | 207, 210, 405 | 63 | 5.7 | 40.0 | 1 172 |
| | 2017 | 207, 208, 209, 210 | 57 | 4 (2) | 39.6 | 1012 (32) |
| | | 207, 208, 209, | | | | |

Appendix 4, Cont.

| Species | Year | Capture sites | N | Mean Age | Mean Length (cm) | Mean Wt (g) |
|---|---|---|---|---|---|---|
| Walleye | 1999 | 210 | 205 | 5.4 (203) | 47.1 | 1 042 |
| | 2000 | 207, 209, 210 | 78 | 5.7 | 48.5 | 1 135 |
| | 2001 | 207, 209, 210 | 211 | 4.1 | 47.7 | 1 046 |
| | 2005 | 207, 210 | 189 | 5.3 | 45.9 | 987 |
| | 2006 | 207, 208, 209 | 148 | 4 | 44.5 | 1 000 |
| | | 207, 210, 208. | | | | |
| | 2007 | 405 | 259 | 4.7 (257) | 44.7 | 1 026 |
| | 2008 | 208, 209 | 183 | 4.8 | 46.7 | 1 095 |
| | 2009 | 207, 210, 405 | 173 | 5.7 (172) | 46.1 | 1 083 |
| | 2017 | 207, 208, 209, 210, 403 | 157 | 5.3 (21) | 46.3 | 1019 (116) |
| Yellow Perch | 1999 | 207, 209, 210 | 258 | 5.5 (255) | 21.9 (257) | 151 (250) |
| | 2000 | 207 210 | 127 | 3.4 | 24.2 | 321 |
| | | 207, 208, 209, | | | | |
| | 2001 | 210 | 100 | 3.8 | 23.0 | 180 |
| | 2005 | 207, 210 | 150 | 3.7 (142) | 21.2 | 125 |
| | | 207, 208, 209, | | | | |
| | 2006 | 210 | 160 | 3.1 (159) | 22.2 | 223 |
| | 2007 | 207, 210, 405 | 199 | 3.2 (195) | 22.7 | 198 |
| | 2008 | 208, 209 | 174 | 3.3 | 21.5 | 135 |
| | 2009 | 207, 210, 405 | 190 | 3.5 (189) | 21.3 | 128 |
| | 2017 | 207, 208, 209, 210 | 170 | 5.3 (3) | 22.9 | 165 (155) |

Appendix 2b: Population dynamics of the St. Marys River fish community 1975 - 2017
(O'Connor et al. 2019)

# Population Dynamics of the St. Marys River Fish Community 1975-2017

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*Abstract-* The St. Marys River fish community was jointly assessed by the member agencies of the St. Marys River Fisheries Task Group under the Great Lakes Fishery Commission in 2017, the 9th such survey since 1975. A gillnet based survey, 44 nets sets each survey year resulted in indices of abundance and population status. Abundance of two cool water species of importance, Walleye and Yellow Perch, were not significantly lower than the 2013 estimates, and have remained stable in the River since 2006. Smallmouth Bass abundance has varied since 2002, with significant peaks in 2006 and 2013. Cisco have maintained stable but lower overall abundance within the River in 2017; however, Northern Pike have continued to increase since 2002, with the highest River abundance reached in 2017. Growth rates, as indicated by length at age at capture, were generally near or below regional averages and may reflect the northern latitude of the St. Marys River. Total annual mortality rates were 59% for Yellow Perch, 49% for Northern Pike, 48% for Smallmouth Bass, 62% for Cisco, and 61% Walleye but were generally deemed within acceptable ranges for these species. Diets varied by species and reflected both piscine prey and invertebrates, especially crayfish. Ruffe were documented for the first time in the Fish Community Survey in 2017, and were reported by anglers in the upper river during the same year. Round gobies continued to be observed in the diets of some predators indicating that they continue to persist in the river fish community. Recommended are timing future surveys with full river-wide creel surveys for maximum information and to increase the frequency of both.

## Introduction

The St. Marys River supports a highly diverse fish community reflecting its varied habitat types. Most of the St. Marys constitutes cool water habitat typical of the nearshore Great Lakes environs, but cold water from Lake Superior also results in cold water habitat beneficial for salmon and trout species. The fish community supports recreational, commercial and subsistence fisheries. Recreational fishing effort can be substantial, amounting to as much as one third the total of the Michigan waters of Lake Huron and has been valued at $8.5 million USD (Godby et al. 2019).

Despite the varied habitat types and high quality water source, the St. Marys River has been the subject of considerable anthropogenic alteration and degradation. The river is channelized throughout much of its reach to accommodate international shipping traffic (Edsall and Gannon 1993). The River was designated as an Area of Concern in the 1987 Great Lakes Water Quality Agreement (GLWQA, 1987). Fishery management challenges also result from the complications of shared resources across multiple fisheries and jurisdictions (Fielder 2002). The St. Marys River constitutes the international boundary water between Michigan and Ontario and includes Native American and Canadian First Nations as well. Fishery management is coordinated through the Great Lakes Fishery Commission's Lake Huron Committee and assessment through its St. Marys River Fisheries Task Group (Fielder 2002). Formed in 1997, representatives of the various management authorities and federal agencies as well as area universities work together for periodic assessment of the fish community. A river fishery assessment plan was developed in 2002 that included the need for and outlined a protocol for a fish community assessment for the St. Marys River (Gebhardt et al. 2002).

The objectives of this survey are to assess and provide information on the abundance, growth, mortality and size structure of important fish populations found in the St. Marys River; to make comparisons to previous surveys; and to comment on the overall current status of certain notable species.

## Study Site

The St. Marys River is a connecting channel between Lakes Superior and Huron (Figure 1). The river flows southeasterly about 112 km and empties into Lake Huron at De Tour, Michigan but also drains into Ontario's North Channel through the St. Joseph Channel and Potagannissing Bay. Four large islands divide the river flow into these various channels and the river is bordered on the northeast by Ontario and Michigan on the other side. The river includes a variety of lacustrine reaches; specifically Lake Nicolet, Lake George, Lake Munuscong, and Raber Bay. For practical purposes, and for this study, Potagannissing Bay is also considered part of the St. Marys River. The rapids at Sault Ste. Marie is perhaps one of the most well-known features of this river, although today 93% of the river flow is diverted for hydroelectric generation (Edsall and Gannon 1993). The St. Marys River aquatic habitat includes an expanse of coastal wetlands that provide spawning and nursery habitat for fish (Albert 2003). Duffy et al. (1987) describes in detail the ecological and physical characteristics of the St. Marys River.

## Methods

This study followed the fish community assessment procedure recommended by Gebhardt et al. (2002) which in turn was based on the methods used by past surveys (Schorfhaar 1975; Miller 1981; Grimm 1989; Fielder and Waybrant 1998) so as to allow comparability. Multifilament nylon gillnets were used to collect fish in this study. In this survey and since 2002 the nets measured 1.8 m deep by 304.8 m long and were comprised of ten different mesh sizes, each of which is a 30.5 m long panel. Mesh sizes were; 38.1mm, 50.8 mm, 63.5 mm, 76.2 mm, 88.9 mm, 101.6 mm, 114.3 mm, 127.0 mm, 139.7 mm, and 152.4 mm stretch measure. The survey nets in 1975, 1979, 1987, and 1995 only utilized four mesh sizes; 50.8 mm, 63.5 mm, 76.2 mm and 114.3 mm stretch measure mesh and panels were 30.5 m in length. Nets were fished overnight on the bottom for all surveys.

Field work was jointly conducted by the member agencies of the St. Marys River Fisheries Task Group. They were the Sault Tribe Natural Resources Department (STNRD), Michigan Department of Natural Resources (MDNR), Ontario Ministry of Natural Resources and Forestry (OMNRF), and the United States Fish and Wildlife Service (USFWS). Net set locations were divided throughout the St. Marys River (Figure 1). Data were organized into seven distinct areas based on habitat and geographic regions within the river; Upper River, Lake Nicolet, Lake George, Lake Munuscong, St. Joseph Channel, Raber Bay and Potagannissing Bay (Figure 1, Table 1) for the purpose of some analyses. Many analyses include results from previous surveys for comparison purposes (Schorfhaar 1975; Miller 1981; Grimm 1989; Fielder and Waybrant 1998; Fielder et al. 2004; Fielder et al. 2007; Schaeffer et al. 2011, Schaeffer et al 2016).

The catch from each lift was identified, weighed (round weight) and measured for total length. Five species of special interest, Walleye, Yellow Perch, Smallmouth Bass, Northern Pike, Cisco, had scales or dorsal spines were collected for aging (see Appendix 1 for a complete listing of all the common and scientific names of fishes mentioned in this report). These same species were internally inspected for sex, maturity (according to the methods of Fielder and Waybrant (1998)), and stomach contents. Stomach contents were identified when possible and enumerated. All Walleye stocked into the St. Marys River were marked with oxytetracycline (OTC) prior to release. All collected Walleye otoliths were examined to determine if collected individuals were stocked or wild fish.

Catch-per-unit-of-effort (CPUE) was calculated in two ways: full net; the total number of each species per net lift per 304.8 m of net across all mesh sizes and the second; traditional net; the total number of each species per net lift from four meshes: 50.8 mm, 63.5 mm, 76.2 mm, and 114.3 mm in 122 m net length, which was then extrapolated to 304.8 m. This second method of expressing CPUE allowed a more direct comparison with the pre-2002 surveys ("traditional nets"). The CPUE values of the two different methods were compared for each species to determine if there were differences in CPUE based on the "traditional" and "full" meshes fished. Total species composition was also compared between the two different "nets": full net, comprised of ten individually sized mesh panels vs. the traditional, four individual mesh panels extrapolated to the full net length of 304.8 m. .

Total annual mortality was derived using the Robson-Chapman method (Van Den Avyle and Hayward 1999) on certain species of interest. Age information was also organized by CPUE so as to compare year class strength. Growth rate was expressed as mean length-at-age-at-capture and compared to Michigan averages according to Schneider et al. (2000) and to Lake Huron averages for those species. The Lake Huron data were means of total length from the North Channel of Lake Huron for collections made in similar times of the year (OMNR unpublished data). Survey growth rate averages were also compared to data from past surveys. Condition was expressed as relative weight (Wr; Ney 1999). Growth parameters were further explored via length / weight relationships and Von Bertalanffy growth equations (Van Den Avyle and Hayward 1999) for some species.

Testing for differences of means between two independent samples used the t-test where possible and the Mann-Whitney U (M-WU) test when the assumption of normality could not be met. We assessed the differences in CPUE within and between survey years using non-parametric Kruskal-Wallis (K-W) tests, with Dunn's post-hoc analysis. Some data and means from past surveys were recalculated for reporting and comparison purposes in this report and may differ slightly from those reported by past authors. Length / weight analysis used log transformed data for linear regressions. All statistical tests were performed at the significance level of $P \leq 0.05$ and followed the methods of Sokal and Rohlf (1981). Analysis was performed using SPSS computer software (SPSS 2001) and R 3.5.0 (R Core Team 2018,), the *ridgeline plots* package (*v.0.5.1*; Wilkie, 2018).

## Results

In the 2017 survey, a total of 44 nets were set throughout the river over a 4 week period beginning the end of July through late August (Figure 1, Table 1). A total of 3226 fish representing 30 different species were collected. CPUE was calculated in two ways: traditional and full nets, as described in the Methods section above. For the traditional nets, the catches from four meshes (50.8 mm, 63.5 mm, 76.2 mm and 114.3 mm) were extrapolated to fill the 304.8 m, to match the panels of the historical nets and the length of the full nets (Table 2). For the full nets, CPUE was calculated for each species for the full ten mesh panels (Table 3). Mean CPUE for 2017 was compared (Mann-Whitney) between the two nets types for five species: Northern Pike, Cisco, Walleye, Yellow Perch, and Smallmouth Bass. In 2017, mean CPUE was not significantly different between the full and traditional nets for any of the five species. Mean CPUE between the two net-types for these five species was also compared from 2002 (first year of the full 10 individual mesh size nets) through 2017. Only in 2006, where mean CPUE for Northern Pike was significantly higher for the extrapolated traditional net (M-WU; P=0.013), was there a difference between the two net groups for any of the five species.

While there was no difference between the net types for the five individual species, there was a significant difference in the number of species captured by the two net sets. In 2017, the number of species collected in the full nets was significantly higher (M-WU; P=0.01) than in the traditional nets. This was consistent for 2002, 2006, 2009, and 2013 (M-WU; P<0.001; all years). The full mesh nets also had a higher cumulative species catch and collected five additional species not caught in the traditional nets: Coho Salmon, Creek Chub, Longnose Dace, Muskellunge, and White Crappie (see Appendix 2 for full summary of cumulative net catch by net type). Based on the mean CPUE and catch comparisons between the two nets, main results for individual species and main groups were based on the full nets, unless otherwise indicated.

### Individual Species CPUE

*Yellow Perch:*

Yellow Perch abundance continued to demonstrate an overall stability on a river-wide basis but was down relative to the 2013 survey (Table 3), however, this was not significantly lower (K-W test, P=0.371). When examined by river reach, significant differences in abundance between the reaches were noted (K-W Tests, P=0.005). Yellow Perch abundance declined in 3 reaches and increased in the other 4 (Table 4). There were declines in abundance In the Upper River, Lake Munuscong, and Potagannissing Bay. Yellow Perch abundance in the Upper River was the lowest recorded since the survey began in 1975 with an average CPUE of 6.0 in 2017. Lake Munuscong declined from a mean CPUE of 26.0 in 2013 to 10.5 in 2017, while Potagannissing Bay declined from a historical high mean CPUE of 88.5 in 2013 to 56.2 (Table 4). Lake Nicolet and Raber Bay Yellow Perch abundances were consistent in 2017 with only small increases relative to the 2013 survey. There were larger increases in Lake George where mean CPUE went from 38.3 in 2013 to 50.0 in 2017 and the St. Joseph Channel where mean CPUE went from 6.9 in 2013 to 21.5 in 2017 (Table 4).

*Northern Pike:*

Northern Pike CPUE has continued to increase since 2002, which was the lowest level measured in the survey series (Table 3). Mean CPUE in 2017 (4.09) was significantly greater (K-W test, P=0.04) than in 2002, 2006 and 2009 (Dunn's Test, P = 0.005, P=0.01, P=0.01, respectively), however, not significantly greater than the 2013 survey mean CPUE (x=2.66) (Dunn's Test, P=0.100). Northern Pike CPUE increased in 2017 in four of the six river reaches (Table 4). Catch was significantly lower in the Upper River (K-W test; P=0.005) compared to lakes Nicolet, George and Munuscong (Dunn's Tests; P=0.013, P=0.028, P<0.001, respectively) and CPUE was significantly lower in Potagannissing Bay compared to Lake Munuscong (M-WU Test, P<0.001). Catches remained similar to the 2013 CPUE in Lake George and Lake Munuscong, with increases in Potagannissing Bay, Raber Bay, and Lake Nicolet in 2017.

*Walleye:*
Mean CPUE of Walleye (3.41) was lower in 2017 compared to the peak CPUE in 2013 (7.58); however, it was not significantly different (M-WU Test, P=0.483). Walleye CPUE has remained stable since 2006, with an increase from the 2002 survey (2.55) (Table 3). The CPUE in 2002 was significantly lower (K-W test, P=0.015), compared to each of the 2006 – 2017 fishing surveys. Within the fishing locations in the river, mean CPUE was the lowest in Lake Nicolet, however, there was no significant difference between the river locations in 2017 (K-W Test; P=0.124)(Table 4).

*Smallmouth Bass:*
Smallmouth Bass mean CPUE dropped to 2.84 in 2017, just under half the 6.63 mean CPUE reached in 2013 which was the highest in the time series (Table 3). Smallmouth Bass mean CPUE was variable over the last five surveys (Table 3), with significant differences among the years (K-W test, P=0.001). The peak catches in 2006 and 2013 were significantly greater than catches in 2002, 2009, and 2017. All reaches showed declines in Smallmouth Bass abundance with the exception of the St. Joseph Channel which increased from a mean CPUE of 8.1 in 2013 to 9.0 in 2017 (Table 45). The St. Joseph Channel also had the highest Smallmouth Bass abundance of any reach in 2017. This was a change from 2013 when Lake George had the highest abundance (16.2), which was the highest recorded abundance for any reach in the time series. Overall, the mean CPUE was significantly different between the reaches (K-W Test; P=0.025), with the catches in Lake George, St. Joseph Channel and Raber Bay having the largest abundance (Table 4).

*Cisco:*
The CPUE of Cisco in the full mesh nets was the second lowest of the time series (mean CPUE = 1.02), however, it was not significantly different over time for 2002 -2017 (K-W test, P=0.831) (Table 3). No Cisco were found in three reaches (Nicolet, Munuscong, and Raber) and Cisco occurred in low abundance in the remaining reaches (Table 4). For the reaches with Cisco, there were no significant differences in the catch CPUE. Early in the time series, the lower most reaches of the St. Marys (Raber and Potagannissing) produced large catches of Cisco, but they have largely been in low abundance since at least 2009.

*Other Species:*
Mean CPUE was calculated for all of the species collected each year. White Sucker mean CPUE remains high and stable, along with Rock Bass and Brown Bullhead, with no difference among years for the surveys from 2002 through 2017 (K-W tests; P=0.382, P= 0.756, P=0.526) (Table 3). Other species including Lake Whitefish, Burbot, and Menominee have remained stable through the survey years, though at lower CPUEs (K-W tests; P=0.645, P= 0.870, P=0.880)(Table 3).

**Aquatic Invasive Species (AIS)**

Several AIS were captured during the 2017 survey: Alewife, Rainbow Smelt, White Perch, Sea Lamprey, and new in 2017, Eurasian Ruffe (Table 3). Alewife CPUE has remained stable in all years following their peak CPUE in 2002 (K-W test, $P<0.001$). Rainbow Smelt and White Perch have remained low and stable in all years (K-W tests, $P=0.653$, $P=0.182$), while Ruffe CPUE (0.23) was the first for this survey in the St. Marys River (Table 3).

**Species of Concern**

A total of 26 Lake Sturgeon were captured in 2017, the highest of any year in the survey series. Mean CPUE was significantly higher in 2017 (0.59) (K-W tests, $P<0.001$) than any of the other survey years (Table 3). Lake Sturgeon were collected in four of the six netting locations below the Compensating Works: Lake George, Lake Munuscong, Raber and Potagannissing bays, with the majority captured in Lake Munuscong (N=11). Sturgeon ranged in size from 330 mm to 865 mm. The increase in Lake Sturgeon catch in the nets is the highest net CPUE since 1975 (Table 3).

**Age, Maturity and Condition**

Scales and dorsal spines were collected for aging from Yellow Perch, Walleye, Smallmouth Bass, and Cisco and cleithra for Northern Pike. These fish were also examined for sex, maturity and stomach contents. In addition to aging, walleye otoliths were also collected. These were examined for oxytetracycline marks to determine whether the individual fish was of native or stocked origin.

*Yellow Perch:*
The 2016 age-1 Yellow Perch year class was not well represented throughout the river, but they may not have fully recruited to the gear yet as has been the case in past surveys. Age-2 fish made up 35% of the Yellow Perch catch river-wide (Table 5). Relative to the MI average the Yellow Perch growth index was +9 in 2017 an increase over the 2013 value of +3 (Table 5).

The total annual mortality rate for Yellow Perch on a river-wide base has been declining since the 2006 survey where it peaked at 0.70 and is down to 0.41 in 2017 (Table 6). Total annual mortality for Yellow Perch declined markedly from 2013 to 2017 in Lake Nicolet, Lake George, and Raber Bay (Table 6). The highest Yellow Perch total annual mortality rate among those reaches that it was calculated for was Lake Munuscong at 0.76 an increase from the 2013 survey mortality rate of 0.63. All size classes in the 2017 maturity schedule for Yellow Perch were above 50% (Table 7). The maturity schedule for Yellow Perch indicates higher proportion of smaller sized females mature relative to the 2013 survey (Chong et al. 2015). Females were fully mature at about 22 cm in total length. Yellow Perch condition, based on mean relative weight, remained high in 2017, similar to the previous years' surveys (Table 8). The condition was lowest in the Yellow Perch caught in the St. Joseph Channel (64) compared with the Yellow Perch from Lake George, where condition was the highest at 102 (Table 8).

*Walleye:*
Walleye were captured in all age classes 1-14 with the exception of age 10 year class (Table 9). The majority of the fish captured (92%) were in the 1 through 6 age class, with age-2 Walleye having the highest CPUE during the survey (1.98). Mean length-at-age for Walleye in the 2017 survey was slightly below the state of Michigan average. The growth index, which compares length-at-age to the state average, was -1 mm (Table 9). Total annual mortality for walleye in 2017 (39%) stayed fairly consistent with the 2013 (32%) and 2009 (38 %) surveys (Table 6). Walleye maturity began at 34 cm, however full maturity for all fish was not achieved until 49 cm in total length (Table 7). Walleye condition increased in 2017, similar to condition measured in 2006 and

previous surveys, increased from the surveys in 2009 and 2013 (Table 8). Walleye condition was relatively stable across all fishing locations in the St. Marys River in the 2017 surveys (Table 8).

Walleye otoliths were examined for oxytetracycline marks. Otoliths were collected from 118 of the 150 fish caught. Of the 118 fish examined, 41 (34.9%) were from hatchery stock. Hatchery stocked fish were found in every reach except Munuscong Bay. Age-1 had the highest percentage of stocked fish with 54%, followed by age-2 at 38%.

*Smallmouth Bass:*
Smallmouth Bass were captured in all age classes from one though ten, with a mean age of 4 (Table 10). The majority of the fish captured (91%) were aged 2-6. CPUE was highest for age 3 and age 5 (0.8). Smallmouth Bass growth index was lower than the Michigan State average at -14, however, this growth rate was higher than in previous years (Table 10). Smallmouth Bass total annual mortality increased in 2017 to 0.52 from a value of 0.35 in 2013 (Table 6). The Smallmouth Bass size at 50% maturity was difficult to determine given the variability in the data (Table 7). Female Smallmouth Bass achieved 100% maturity by 30 cm which is slightly below the 36 cm Michigan minimum length limit. Smallmouth Bass continue to exhibit a high condition level (92-108) in the St. Marys River in each of the six fishing locations where they were collected. It has remained stable in all of the river wide surveys since 1995 (Table 8).

*Northern Pike:*
Northern Pike were found in all age classes from 1 – 10, with the mean age from the catch 4 years (Table 11). CPUE was greatest for age 4 fish (1.0). The majority of fish (90%) were in the age range 2 – 6, with a size range of 445 – 655 cm (Table 11). Northern Pike 2017 (-68) growth index in the St. Marys River as compared to the Michigan Stage average dropped from the index calculated in 2013 (-53) , to the lowest calculated since 2009 (-71). In 2017, overall length-at-age was approximately 68 mm smaller than the Michigan statewide average lengths-at-age for Northern Pike (Table 11). Northern Pike annual mortality remained relatively stable in 2017 compared to the previous years' surveys in 2013, 2002 and 1995, but lower than the rates calculated in 2006 and 2009 (Table 6). Maturity of female Northern Pike was inconsistent until 63 cm in total length (Table 7). Northern Pike condition has remained stable across the years in which the survey has been conducted (Table 8). Condition was highest for Northern Pike sampled from Lake George (97), however, is not much higher than the lowest condition, from the Upper River (85) (Table 8).

*Cisco:*
Cisco age structure was dominated by the 2016 and 2015 year classes (Table 12) but in all, ten cohorts were represented. Generally Cisco grew faster than the state of Michigan average or the Ontario North Channel average rates (Table 12) and condition as indicated by $W_r$ was within the range previously observed (Table 8). Cisco totally annual mortality was 0.39 in 2017, also within the range observed in previous surveys (Table 6). Female Cisco were consistently mature after 33cm in 2017 (Table 7). Cisco condition has remained stable throughout the survey period (Table 8), but was highest in Lake George when compared with the other three collection locations (Table 8).

**Length/Weight Regressions**

Length/weight regression equations and Von Bertalanffy growth equations for five notable species are presented in Appendix 3. Length frequency distributions for these species from the survey catch are presented in the Appendix 4 Figures.

**Diet**

Stomach contents were analyzed for Walleye, Northern Pike, Smallmouth Bass, Yellow Perch, and Cisco. Contents were reported as incidence (percent void and percent with contents) and proportion of occurrence which is the percent of the identified prey items in the total of all prey items consumed by that species (Table 13). The diet of Walleye, at the time of the survey, was dominated by Rainbow Smelt (18.4%), Threespine Stickleback (10.5%) and Cisco at 7.9% (Table 14). Only Walleye were found with Alewife as a food species (5.3%) in the St. Marys River. Crayfish figured prominently in the diet of all other species examined, except Walleye (Table 13). Northern Pike continue to have the most varied diet, with 10 identified fish species utilized as prey (Table 13). Round Goby have become part of the food chain in Walleye (2.6%), Northern Pike (10.2%), and Yellow Perch (7.0%). The proportion of crayfish in the Smallmouth Bass diet declined from 54.9% in 2013 to 36.8% in 2017 coincident with increases in Yellow Perch (13.2%) and Unidentified Insects (15.8%) in their diet (Table 13, Chong et al. 2015). The 2017 diet of Yellow Perch was comparable to previous years (Chong et al. 2015). In 2017, crayfish returned to a great proportion of the diet at 51.1%, similar to the 2006 diet at 60%. This was an increase from the 2013 survey, where by crayfish had fallen to 9.1% of the diet. Almost 94% of the Cisco examined had empty stomachs. For those with food, the identified species were Mayfly and Water Flea each of which comprised 33.3% of the diet. Unidentified fish were the remainder of the stomach contents at 33.3% (Table 13).

**Sea Lamprey Wounding**

The incidence of Sea Lamprey wounding among all of the species sampled was low (Table 14). Wounds were observed in four species on five different fish. Wounding was only observed on fishes collected from two sampling locations; four fishes in Potagannissing Bay and one in Munuscong Bay, Wounding rates ranged from 0.1% (White Sucker) to 3.8% (Lake Whitefish), however, the overall wounding rate for Cisco was 4.4% (Table 14). Three fish had A wounds (Ebener et al. 2006); White Sucker and Lake Whitefish (A1) and one Cisco (A2), while the remaining two fish, Cisco and Northern Pike each had one B1 wound. The total Cisco wounding rate was slightly higher than the 2017 rate (3.9%) No Sea Lamprey wounds were observed on Walleye, Yellow Perch, or Rock Bass in 2017 (Table 14). When examining the wounding rate based on location capture, wounding rates increased to 0.4% (White Sucker), 1.7% (Northern Pike), 5.3% (Lake Whitefish) and 12.5% (Cisco).

## Discussion

*Walleye*

Walleye fell to the sixth most abundant species (as measured by full mesh net CPUE; Table 3) in the St. Marys River during the 2017 survey with Yellow Perch, White Suckers, Rock Bass, Brown Bullhead, and Northern Pike all having a higher CPUE in 2017. Overall, Walleye CPUE has remained stable in the survey years 2006-2017, after increasing from a survey low in 2002. While the mean CPUE was the lowest in Lake Nicolet for the seven river regions, it was not significantly so. Overall in 2017, Walleye appear to be well distributed throughout the St. Marys River.

The decline in the CPUE for 2017 and the variance over the survey years can largely be attributed to the CPUE in Lake George. While CPUE has remained relatively stable in the other reaches, in Lake George, CPUE was highly variable with peaks in 2009 (26.7) and 2013 (34.2) compared with lower CPUE in the years 2002 (8.8), 2009 (9.6) and 2017 (7.9). Water depth may play a role in net efficiency in the Lake George, as lake levels have been highly variable over the past 10 years. .

Walleye CPUE have been traditionally low in Munuscong Bay while at the same time being a popular walleye destination for anglers. Munuscong Bay consists mainly of shallow, warmer water with the deeper cooler water located in or near the shipping channel. Anglers have reported that walleye are found in or near the shipping channel during the traditional survey time period (mid-July through late August); however, our inability to safely set nets in or near the shipping channel may be contributing to a lower CPUE for Munuscong Bay.

Mean CPUE of Walleye in the St. Marys River community survey in 2017 was 5.11, after the survey high of 11.25 in 2013. Age-1 to age-6 had the highest CPUE during the survey, corresponding to the 2011-2016 year classes with walleye up to age-14 captured. In comparison to the St. Marys River, Saginaw Bay is a shallow productive bay of Lake Huron that is well known for its walleye fisheries. While being less productive the St. Marys, Saginaw Bay had similar CPUE to the St. Marys River from 1998-2004 (Chong et.al 2014). With the decline of alewife in Saginaw Bay (Fielder and Thomas 2014), overall walleye production in Saginaw Bay far exceeds the found in the St. Marys River.

Mean length-at-age for Walleye in the 2017 survey was slightly below the state of Michigan average. The growth index, which compares length-at-age to the state average, was -1mm. The St. Marys is fed by outflow from Lake Superior; the cold water from Lake Superior may be what leads the St. Marys to being less productive than other bodies of water throughout Michigan. Total annual mortality for Walleye in 2017 (39%) stayed fairly consistent with the 2013 (32%) and 2009 (38 %) surveys. Mortality is largely attributed to fish angling pressure and predation.

The St. Marys has received stocked Walleye for decades and more consistently since the Walleye stocking protocol was developed in 2008. Hatchery reared fish are OTC marked prior to stocking for identification purposes. River-wide, 34% of the walleye captured were identified as stocked. Stocked fish were found in every reach except Munuscong Bay, with the Upper River having the highest percentage of stocked fish at 92%. The Walleye stocking program began in 2008 and was completed in 2018. The results of this study are currently in preparation for publication.

Rainbow Smelt were the most common identified prey item (32%) followed by Threespine Stickleback (26%) based on identifiable contents of the stomachs of the walleye captured during the survey. This is consistent with what was observed in the 2013 survey. Condition, as measured by mean relative weight increased in 2017 to the 2006 and previous year levels. Relative weights were uniformly high throughout the river in 2017.

Ontario fishing regulations presently include no length limits in the St. Marys River while Michigan maintains a 38 cm minimum length limit on the same species. Common fishing regulations between Ontario and Michigan within the St. Marys River would provide continuity for this species.

*Northern Pike*

Coastal wetlands provide critical spawning and nursery habitat for Northern Pike. The Lake Superior outflows via the St. Marys River are set by the International Joint Commission (IJC) and controlled through the Compensating Gates at the head of the rapids. Great Lakes water levels, and Lake Superior in particular increased since 2013(ACE 2019) , which has led to an increase in St. Marys River water levels and in increased river flows since 2014 and have remained high through 2017. These higher water levels have led to an increased wetted coastal wetland, which in turn have provided more spawning and nursery habitat for Esocids. In 2017, Northern Pike gillnet CPUE continued to improve, reversing the downward trend that began in 2002 (Table 3). Although the CPUE has not returned to pre-2002 levels, it has rebounded to more than double that of its lowest point, measured in 2009. Northern Pike CPUE continued to increase in four river reaches (Lake Nicolet, St. Joseph Channel, Raber Bay, Potagannissing Bay) and in two reaches (Lake

George and Lake Munuscong) CPUE is comparable to the higher CPUE's measured in 2013 (Table 5). In the Upper River, Northern Pike catch has remained scarce since 1995 (Table 5).

An increase in the number of age-5 and younger pike (Table 10) coupled with the lowest total annual mortality rate calculated for the survey series (Table 7), provide support for the hypothesis that the increased higher water levels have provided for improved Northern Pike juvenile production in the St. Marys River. In addition to the younger fish, fish were collected in all age brackets from six to 10, continuing the improvement trends noted in the 2013 survey, which also found reduced mortality rates from previous surveys (Chong et al. 2015).

Northern Pike growth slowed somewhat in 2017 compared with the previous survey, with overall lengths-at-age being approximately 68 mm smaller than the Michigan statewide average lengths-at-age for that species (Table 10). Maturity of female Northern Pike began at 42 cm but was inconsistent until 63 cm in total length (Table 12), an increase from the 2013 survey when consistent sexual maturity was reached by 55 cm (Chong et al. 2015).

While abundance has not rebounded to the peak of 1987, cautious optimism for continued improvement in Northern Pike populations remain as river levels have remained high through 2018 and potentially continue throughout 2019, based on current Lake Superior water levels.

This survey series has admittedly not been particularly effective at tracking Esocid populations, particularly Muskellunge (Schaeffer et al. 2011 ). Once again, Muskellunge were not captured during this survey, but they do remain an important part of the fish community and provide a popular sport fishery. The 2017 creel survey of the St. Marys River, which was a companion project to this fish community survey, estimated that 214 muskies were caught in the St. Marys River during the open-water season that year (Godby et al. In Progress). The mean age of Northern Pike captured in the sport fishery was 4.6, while the mean age in this fishery-independent survey was 4.0. Mean length in the sport fishery was 676 mm and was 552 mm in this gillnet survey. These differences could point to gear selectivity; i.e., gill nets aren't effectively sampling older/larger Northern Pike. It is also likely that the sport fishery selects for larger (older) pike. There is also a difference in Northern Pike regulations between Michigan and Ontario. Michigan has a 610 mm (24 in) minimum size limit, while Ontario does not have a minimum size limit. In 2017, approximately 12% of the Northern Pike sampled during the creel survey were less than 610 mm. It is important to continue both the fishery-independent survey and the creel survey of the sport fishery in order to get a complete picture of the fish community.

*Yellow Perch*

Yellow Perch are an important feature of the St. Marys River fishery. Their recreational harvest ranges from 39,241 to a high of 125,000 (Godby et al. 2019) exceeded in harvest only by that of Cisco. Yellow Perch abundance in the St. Marys River decreased in 2017 but the mean CPUE of 31.5 is just below the survey average of 33.2 and the overall trend remains positive since the first survey in 1975. Potagannissing Bay showed the largest decline in abundance but still has the highest mean CPUE among survey reaches at 56.2. Lake George was a close second to Potagannissing Bay with an average CPUE of 50.0. The Upper River was last surveyed in 2006 and had the 3rd highest Yellow Perch mean CPUE that year, and dropped to the lowest value in the St. Marys in 2017 with a mean CPUE of 6.0 which is also the lowest value recorded for this reach.

Growth, as a density dependent indicator of population status relative to carrying capacity of the habitat and available prey base suggests that the Yellow Perch population of the St. Marys River is not depressed. Mean size at age in 2017 is consistent with the 2013 survey with a few older larger sized Yellow Perch in the catch which is reflected in the lower total annual mortality rate. Relative to the Michigan average for Yellow Perch the growth index for the St. Marys River remains positive.

Generally, the total annual mortality rates were within sustainable levels; however some reach-specific rates are high and consistent with heavy exploitation.

*Smallmouth Bass*

Smallmouth Bass abundance in the St. Marys River declined in 2017 after reaching a time-series high in 2013 (Table 3). The declines in Smallmouth Bass abundance occurred in all reaches except the St. Joseph Channel (Table 5). The central portion of the river appears to provide good habitat for Smallmouth Bass. The decrease in river-wide mean CPUE of Smallmouth Bass coincides with an increase in the total annual mortality rate (Table 7). Mean age of Smallmouth Bass has declined in three consecutive surveys with fewer older fish in the catch (Table 9). The Smallmouth Bass diet in the St. Mary's River remains relatively simple still depending heavily on crayfish but with a shift towards a few prey fish species including Yellow Perch, and insects (Table 14).

*Cisco*

Prior to the large scale collapses of many native fish stocks in Lake Huron in the mid Twentieth Century, Cisco were the most abundant pelagic fish in the lake (Koelz 1929) resulting in substantial commercial fishery yields (Baldwin et al. 2009). After collapse, the Lake Huron stock of Cisco only is found in the northern most regions including the St. Marys River (Dobiesz et al. 2005, Ebener 2012). The exact morphotype of the remnant Lake Huron Cisco is not necessarily consistent with the historic artedii form (Eshenroder et al. 2016) and may reflect local adaption since the larger scale collapse.

Cisco in the St. Marys River appear to be less abundant in recent years although overall trends in gillnet CPUE were not significantly different. Cisco in the St. Marys River will concentrate in cooler deeper water in summer months and make something of an upstream migration for spawning purposes (Fielder 2000). Thus their collection in an August survey may reflect distribution as much as trends in abundance. Cisco usage of the St. Marys River might be affected by climate change. Cisco in the St. Marys River are most consistently encountered when spawning (MDNR unpublished data) or in the recreational fishery during the mayfly (*Hexagenia limbatea*) emergence in midsummer (Fielder et al. 2002).

Growth rate of Cisco improved some in 2017 compared to 2013 and was greater than regional averages (Table 12). This may be consistent with lower Cisco abundances and lower population densities resulting in concomitant faster growth rates. The biological metrics including growth rate, mortality, maturity, and condition do not point to a sustainability concern for Cisco, with the exception of the age structure which is dominated by younger fish that could be an indicator of population stress due to exploitation.

Cisco spawning in Potagannissing Bay have become part of an annual gamete collection along with those from the Les Cheneaux Islands performed by the USFWS to provide for culture and reintroduction in central Lake Huron (USFWS unpublished data). It is not readily clear the extent to which St. Marys River Cisco may comingle with those from the Les Cheneaux Islands and the North Channel but Cisco movement in the region is the subject of a new study being conducted by the USGS Great Lakes Science Center.

*AIS*

The encroaching presence of invasive species was evident within the St. Marys River during this assessment. As the river is home to international shipping, it remains especially vulnerable to invasive species transfer both from within the Great Lakes and from International ports. Twelve invasive and or non-native species were noted including Round Gobies, which were found to be a diet item (Table 13). Of remark was the discovery of Eurasian Ruffe in the upper River (Table 3), likely due to natural dispersal into the river from Whitefish Bay of Lake Superior where they have been observed in recent years (U.S. Geological Survey 2018). Two other Ruffe were captured in Little Lake George during 2017 by an angler (S. Chong, OMNRF, Personal Communication). The current status and potential impacts of this species is unknown, as no Ruffe were captured during follow-up sampling during late 2017 and in 2018 by the USFWS (A.Bowen, USFWS, Personal Communication).

Round Goby were present in the diet of a low number of predators collected during the 2017 assessment (Table 13). However this information has limited use to reflect the abundance of Round Goby in The River because Gobies were not vulnerable to the sampling gear and were likely underrepresented in the diet as indicated by a high reporting of unidentified fish remains. In the 2017 survey, identified Round Goby were found in fish collected from Potagannissing Bay to Lake Nicolet, indicating that they may be present in a large area of the River. Round Goby first appeared as a dietary item during the 2013 assessment (Chong et al. 2015); and they were collected in other River surveys conducted by the USFWS (Schaeffer et al. 2017) and commonly reported by anglers (U.S. Geological Survey 2018). The appearance of Round Goby and Ruffe indicate that invasive species from both the lower and upper lakes can find their way to the St. Marys River.

White Perch, first documented in 2002, were collected in low numbers during the assessment (Table 3). Other invasives have been documented during other efforts conducted within the river, including but not limited to Tubenose Goby, Dreissenids (*Dreissena polymorpha* and *Dreissena bugensis*), and Rusty Crayfish (*Orconectes rusticus*). Crayfish are an important component of the diet of many fish in the St. Marys River, and the presence of Rusty Crayfish and potential invasion of the Red Swamp Crayfish (*Procambarus clarkia*) pose threats for both native crayfish and habitat in the St. Marys River.

Nuisance blooms of the algae, Didymo (*Didymosphenia geminate*), were documented in the upper St. Marys River shortly after the 2013 survey; the blooms have the potential to develop thick mats over rocks that may affect spawning substrate and invertebrate habitat. Didymo is well suited to cold oligotrophic waters and the Lake Superior source makes the St. Marys potentially ideal for colonization.

Despite the presence of invasive species, the fish community of the St. Marys River is relatively healthy; and historically, invasives have remained low in abundance in the River (Pratt and O’Connor 2011, Ripley et al. 2011, and Schaeffer et al. 2017). Even so, concerns remain regarding potential impacts that newly introduced species or other threatening species may have on the St. Marys River fish community.

*Lake Sturgeon*

Lake Sturgeon were collected in small numbers in the 1975 through 1987 surveys (Table 2) and again in 2002 (Table 3), however, the largest capture of Lake Sturgeon over the time series occurred in 2017. Lake Sturgeon were captured in 67% of the netting areas below the

Compensation Works, in the lacustrine areas of the River, with the greatest number of fish captured in Lake Munuscong. These areas are more likely representative of Lake Sturgeon habitat during summer months, providing feeding and home range habitats for a variety of juvenile Lake Sturgeon. Lake Sturgeon are more likely to be captured in the faster flowing areas of the river, the Upper River and Lake Nicolet, during the spring spawning migration. Our catch of Lake Sturgeon is likely also limited based on mesh size as our largest mesh fished is 14 cm (5.5'), where most nets targeting Lake Sturgeon use mesh sizes 20 cm (8") and greater (Pratt et al 2016). The increase in Lake Sturgeon CPUE to its highest overall and the increase in both the number of reaches and distribution with those reaches for Lake Sturgeon catch are promising for an increase in abundance within the River.

*Sea Lamprey Wounding Rates*

Overall, Sea Lamprey wounding rates remain low in the St. Marys River, with 0.2% of the total fish collected exhibiting a Sea Lamprey wound. Of the 29 non-lamprey species collected in 2017, four species had individuals with wounds ranging from A1 to B1 (Ebener et al 2006). Of the seven survey locations, marked fishes were only collected in two places in 2017: Potagannissing Bay and Lake Munuscong. When examining the wounding rate based on the location of capture, wounding rates increased to 0.4% (White Sucker), 1.7% (Northern Pike), 5.3% (Lake Whitefish) and 12.5% (Cisco). Sea Lamprey management within the St. Marys River encompasses both assessment of adult and larval populations within the river as well as targeted treatment of larval populations. Assessment and control of the Sea Lamprey population within the St. Marys River remains a priority for DFO-SLCC and USFWS.

*Special Concerns*

Of special concern for the St. Marys River and much of the Great Lakes is the potential for introduction and spread of high risk species including Asian carp, Northern Snakehead, Golden Mussel (*Limnoperna fortunei*), and Killer Shrimp (*Dikerogammarus villosus*, Currie et al. 2017, Herborg et al. 2007, and Sieracki et al. 2014). Researchers have predicted via modeling that Northern Snakehead, Bighead Carp, Black Carp, Grass Carp and Silver Carp would be compatible with most of the USA, Mexico, and southern Canada (Herborg et al. 2007), which would include the St. Marys River. Grass Carp recruitment has been documented in the Lake Erie watershed (Chapman et al. 2013), and dispersal modeling studies based on origins in western Lake Erie (Maumee Bay) indicate that Grass Carp would not likely move into the St. Marys River area quickly due to food resources present within Lake Erie; however if Grass Carp were to establish in southern Lake Michigan, they may disperse into the St. Marys River area within approximately 10 to 20 years based on natural movements (Currie et al. 2017). Furthermore, tagging studies conducted in the St. Marys River and Welland Canal suggest that Grass Carp may move up and downstream through lock areas via natural dispersal (Currie et al. 2017). Modeling has also predicted a potential pathway for the spread of Golden Mussel and Killer Shrimp within the upper Great Lakes vicinity via ballast water discharge (Sieracki et al. 2014).

*Information Needs*

As noted in past survey reports; continued monitoring of the fish community in the St. Marys River remains essential. The frequency should be increased in accordance with the original St. Marys River Fishery Assessment Plan (Gebhardt et al. 2002), possibly timed with future years of lake wide intensive monitoring sponsored by the US EPA. More information is needed on reproductive success and recruitment of all species. The addition of a trawling or electrofishing survey would be greatly beneficial to the understanding of the fish community within the river. The creel survey operated jointly between the MDNR and OMNR has been fragmented in most years and has proved difficult to extract the needed information. Creel survey resources should be saved for when a river-wide survey can be conducted and ideally timed to coincide with the fish community survey. The overall management of the St. Marys River fishery resources would greatly benefit from the development of river-wide joint fish community objectives. These objectives would allow the development of management strategies and a better context with which to interpret findings from the Fish Community Index Surveys. The development of common recreational fishing regulations between Ontario and Michigan remains a need. Development of fish community objectives will drive this effort in addition to the continued assessment of the dynamics of the fish community.

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Figure 1. St. Marys River and location of gillnet sets (stations). See Table 1 for effort by year and agency.

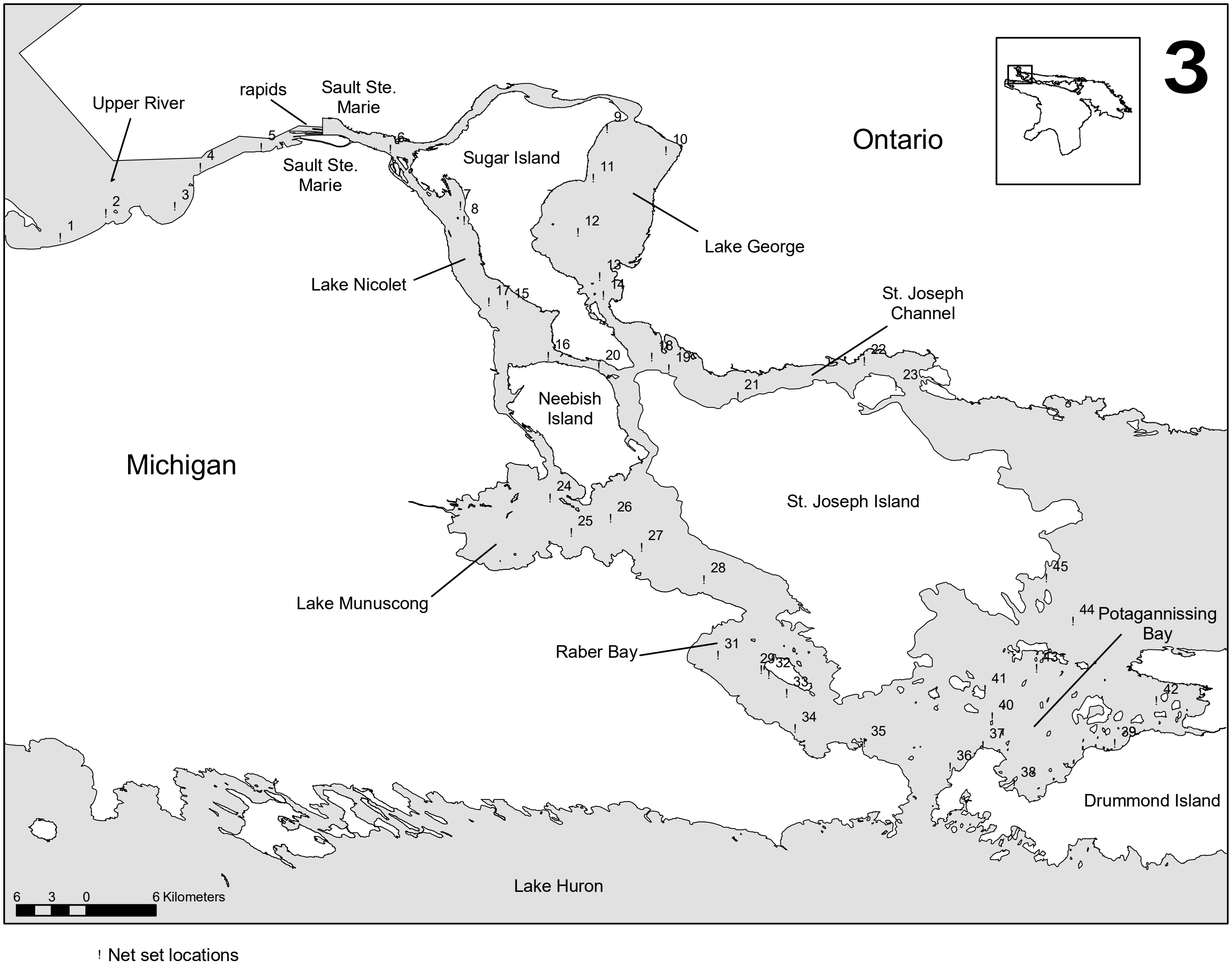


Table 1. Net set locations used to define areas within the St. Marys River for the purpose of certain data analyses, along with a list of the agencies that performed the field work in 2017. See Figure 1 for location of each net number.

| Area | Station numbers | Agency |
|---|---|---|
| Upper River | 1, 2, 3, 4, 5 | MDNR |
| Lake Nicolet | 6, 7, 8, 15, 16, 17, 20 | USFWS |
| Lake George | 9, 10, 11, 12, 13, 14 | STNRD, OMNRF, |
| Lake Munuscong | 24, 25, 26, 27, 28 | MDNR |
| St. Joseph Channel | 18, 19, 21, 22, 23 | OMNRF |
| Raber Bay | 29, 31, 32, 33, 34, 35 | STNRD |
| Potagannissing Bay | 36, 37, 38, 39, 40, 41, 42, 43, 44, 45 | MDNR & OMNRF |

Table 2. Mean Catch-Per-Unit-of-Effort (CPUE) of all species collected from the St. Marys River 1975 through 2017. Means are based on number per 304.8 m (1000 ft) of gillnet representing the traditional mesh sizes, with standard error of the mean in parentheses. Total nets set were 32 each in 1975 and 1979, 27[b] in 1987, 51[c] in 1995, 44 in 2002, 2009, 2017, 39 in 2013, and 42 in 2006, although only 34 sets are represented here due to data recording limitations. The St. Joseph Channel portion of the St. Marys was added to the survey series beginning in 2002.

| Species[a] | 1975 | | 1979 | | 1987[b] | | 1995[c] | | 2002 | | 2006 | | 2009 | | 2013 | | 2017 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alewife | 1.64 | (0.57) | 0.23 | (0.12) | 0.19 | (0.11) | 15.11 | (12.22) | 3.92 | (3.52) | 0.00 | (0.00) | 0.06 | (0.06) | 0.39 | (0.18) | 0.00 | (0.00) |
| Atlantic Salmon | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.09 | (0.07) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.07 | (0.07) | 0.06 | (0.06) |
| Black Crappie | 0.03 | (0.03) | 0.00 | (0.00) | 0.25 | (0.22) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.26 | (0.13) | 0.06 | (0.06) |
| Bloater | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.06 | (0.06) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |
| Bluegill | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.06 | (0.06) |
| Bowfin | 0.03 | (0.03) | 0.03 | (0.03) | 0.40 | (0.40) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.06 | (0.06) |
| Brook Trout | 0.03 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |
| Brown Bullhead | 6.41 | (3.16) | 0.76 | (0.50) | 6.67 | (3.51) | 2.56 | (1.36) | 4.43 | (2.28) | 3.38 | (1.69) | 3.52 | (2.68) | 3.22 | (2.18) | 10.51 | (8.53) |
| Brown Trout | 0.03 | (0.03) | 0.00 | (0.00) | 0.03 | (0.03) | 0.09 | (0.07) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |
| Burbot | 0.05 | (0.04) | 0.00 | (0.00) | 0.00 | (0.00) | 0.05 | (0.05) | 0.06 | (0.06) | 0.00 | (0.00) | 0.17 | (0.10) | 0.20 | (0.15) | 0.11 | (0.08) |
| Carp | 0.16 | (0.08) | 0.00 | (0.00) | 0.03 | (0.03) | 0.00 | (0.00) | 0.00 | (0.00) | 0.07 | (0.07) | 0.00 | (0.00) | 0.07 | (0.07) | 0.00 | (0.00) |
| Channel Catfish | 0.00 | (0.00) | 0.00 | (0.00) | 0.09 | (0.05) | 0.00 | (0.00) | 0.00 | (0.00) | 0.15 | (0.15) | 0.00 | (0.00) | 0.13 | (0.13) | 0.00 | (0.00) |
| Chinook Salmon | 0.00 | (0.00) | 0.03 | (0.03) | 0.46 | (0.29) | 0.08 | (0.05) | 0.28 | (0.12) | 0.15 | (0.10) | 0.06 | (0.06) | 0.20 | (0.11) | 0.06 | (0.06) |
| Cisco | 14.12 | (5.13) | 22.40 | (11.28) | 18.98 | (8.34) | 9.80 | (3.40) | 4.38 | (2.51) | 3.53 | (1.84) | 10.23 | (4.31) | 4.08 | (2.21) | 1.70 | (0.59) |
| Coho Salmon | 0.03 | (0.03) | 0.00 | (0.00) | 0.00 | (0.00) | 0.05 | (0.05) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |
| Freshwater Drum | 0.00 | (0.00) | 0.00 | (0.00) | 0.03 | (0.03) | 0.00 | (0.00) | 0.34 | (0.17) | 0.59 | (0.24) | 0.17 | (0.10) | 0.07 | (0.07) | 0.00 | (0.00) |
| Gizzard Shad | 0.00 | (0.00) | 0.00 | (0.00) | 0.12 | (0.12) | 0.05 | (0.05) | 0.11 | (0.11) | 0.00 | (0.00) | 0.00 | (0.00) | 0.07 | (0.07) | 0.00 | (0.00) |
| Lake Sturgeon | 0.99 | (0.96) | 0.03 | (0.03) | 0.09 | (0.05) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.07 | (0.07) | 0.34 | (0.17) |
| Lake Trout | 0.00 | (0.00) | 0.31 | (0.31) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.07 | (0.07) | 0.17 | (0.17) | 0.07 | (0.07) | 0.06 | (0.06) |
| Lake Whitefish | 1.15 | (0.41) | 0.55 | (0.25) | 2.10 | (0.99) | 0.73 | (0.37) | 0.85 | (0.41) | 0.29 | (0.18) | 2.33 | (1.13) | 0.46 | (0.21) | 0.80 | (0.44) |
| Largemouth Bass | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.07 | (0.07) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |
| Longnose Gar | 0.00 | (0.00) | 0.03 | (0.03) | 0.06 | (0.04) | 0.00 | (0.00) | 0.06 | (0.06) | 0.07 | (0.07) | 0.00 | (0.00) | 0.07 | (0.07) | 0.00 | (0.00) |
| Longnose Sucker | 0.94 | (0.51) | 1.07 | (0.49) | 4.26 | (2.46) | 2.85 | (1.33) | 2.10 | (1.01) | 1.99 | (1.26) | 2.61 | (1.15) | 0.13 | (0.09) | 1.59 | (0.79) |
| Menominee | 0.83 | (0.44) | 0.52 | (0.30) | 0.00 | (0.00) | 1.49 | (0.55) | 0.80 | (0.34) | 0.22 | (0.12) | 3.35 | (1.80) | 0.92 | (0.79) | 5.23 | (2.68) |
| Muskellunge | 0.00 | (0.00) | 0.68 | (0.43) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |

Table 2 continued.

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Northern Pike | 9.04 | (1.77) | 8.07 | (1.31) | 12.69 | (2.11) | 9.26 | (1.64) | 2.61 | (0.61) | 3.82 | (0.81) | 3.01 | (0.75) | 5.13 | (1.29) | 6.99 | (1.26) |
| Pink Salmon | 0.00 | (0.00) | 0.00 | (0.00) | 2.78 | (1.38) | 0.55 | (0.20) | 0.28 | (0.15) | 0.22 | (0.12) | 0.06 | (0.06) | 0.13 | (0.09) | 0.00 | (0.00) |
| Pumpkinseed | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.97 | (0.56) | 0.66 | (0.66) | 0.85 | (0.53) | 0.00 | (0.00) | 0.28 | (0.19) |
| Rainbow Smelt | 4.97 | (2.45) | 1.64 | (0.69) | 1.02 | (0.47) | 0.86 | (0.50) | 0.40 | (0.21) | 0.44 | (0.22) | 1.65 | (1.14) | 1.51 | (1.06) | 2.05 | (1.04) |
| Rainbow Trout | 0.03 | (0.03) | 0.13 | (0.07) | 0.22 | (0.22) | 0.00 | (0.00) | 0.06 | (0.06) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |
| Redhorse spp. | 0.65 | (0.29) | 0.55 | (0.20) | 0.62 | (0.17) | 1.69 | (0.53) | 0.45 | (0.20) | 1.25 | (0.41) | 3.75 | (1.19) | 1.32 | (0..39) | 0.45 | (0.17) |
| Rock Bass | 6.20 | (2.25) | 2.29 | (0.67) | 11.67 | (2.42) | 5.57 | (1.35) | 11.42 | (2.77) | 14.34 | (3.66) | 7.84 | (1.96) | 12.57 | (3.56) | 7.67 | (2.01) |
| Ruffe | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.06 | (0.06) |
| Sculpin | 0.05 | (0.04) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |
| Sea Lamprey | 0.00 | (0.00) | 0.03 | (0.03) | 0.00 | (0.00) | 0.12 | (0.09) | 0.00 | (0.00) | 0.00 | (0.00) | 0.06 | (0.06) | 0.00 | (0.00) | 0.57 | (0.57) |
| Smallmouth Bass | 0.89 | (0.45) | 0.26 | (0.14) | 4.66 | (2.23) | 3.77 | (0.95) | 2.27 | (0.59) | 6.32 | (1.76) | 1.82 | (0.53) | 7.76 | (2.36) | 3.69 | (1.17) |
| Splake | 0.34 | (0.19) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |
| Sucker spp. | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.05 | (0.05) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |
| Sunfish spp. | 0.13 | (0.08) | 0.13 | (0.11) | 1.54 | (0.89) | 0.65 | (0.47) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |
| Trout-Perch | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.56 | (0.56) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |
| Walleye | 4.27 | (1.56) | 4.14 | (1.73) | 7.47 | (1.92) | 3.92 | (0.83) | 3.58 | (1.04) | 11.18 | (2.97) | 6.02 | (1.29) | 11.25 | (2.88) | 5.11 | (0.79) |
| White Bass | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.07 | (0.07) | 0.23 | (0.23) | 0.20 | (0.15) | 0.00 | (0.00) |
| White Crappie | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |
| White Sucker | 21.48 | (3.94) | 13.85 | (2.20) | 25.68 | (5.46) | 20.00 | (2.47) | 24.7 | (3.93) | 17.65 | (2.52) | 23.07 | (3.70) | 20.39 | (3.84) | 22.27 | (4.04) |
| White Perch | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.34 | (0.17) | 0.74 | (0.42) | 0.00 | (0.00) | 0.39 | (0.20) | 0.11 | (0.08) |
| Yellow Perch | 23.02 | (6.28) | 25.68 | (4.93) | 49.48 | (7.16) | 29.97 | (5.85) | 25.3 | (4.50) | 37.21 | (8.94) | 35.34 | (7.62) | 41.71 | (14.95) | 31.53 | (8.17) |
| Unknown Sps. | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.11 | (0.08) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) | 0.00 | (0.00) |

[a] See Appendix 1 for a complete list of common and scientific names of fishes mentioned in this report.
[b] Mean CPUEs for 1987 are calculated from a restored data set that lacked five net sets compared to those summarized in Grimm 1987.
[c] Mean CPUEs for 1995 included the influence of 3.81 cm (1.5 inch) mesh net on some sets performed in the Raber and Potagannissing area of the river. This effort was incorporated in to the calculation of CPUE but may still have slightly inflated mean CPUE for certain species such as Yellow Perch and Alewife.

Table 3. Mean Catch-Per-Unit-of-Effort (CPUE) of all species collected from the St. Marys River in 2002 - 2017 with all ten mesh sizes included (Expanded mesh) and from the traditional mesh (4 mesh sizes). Means are based number per 304.8 m (1000 ft) of gillnet with standard error of the mean in parentheses. There were 44 total net sets in 2002, 2009, 2017 and 39 in 2013. While 42 nets were set in 2006, however, the traditional mesh CPUE values in 2006 reflect a sample size of 34 net sets, due to data recording limitations.

| | 2002 | | 2006 | | 2009 | | 2013 | | 2017 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species[a] | Expanded mesh | Traditional mesh | Expanded mesh | Traditional mesh | Expanded mesh | Traditional mesh | Expanded mesh | Traditional mesh | Expanded mesh | Traditional mesh |
| Alewife | 10.61 (0.21) | 3.92(3.52) | 1.12 (0.73) | 0.00 (0.00) | 0.23 (0.16) | 0.06 (0.06) | 1.61 (0.72) | 0.39 (0.18) | 0.18 (0.16) | 0.00 (0.00) |
| Atlantic Salmon | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.03 (0.03) | 0.07 (0.07) | 0.02 (0.02) | 0.06 (0.06) |
| Black Crappie | 0.00 (0.00) | 0.00 (0.00) | 0.02 (0.02) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.26 (0.15) | 0.26 (0.13) | 0.02 (0.02) | 0.06 (0.06) |
| Bloater | 0.02 (0.02) | 0.06(0.06) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Bluegill | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.02 (0.02) | 0.06 (0.06) |
| Bowfin | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.02 (0.02) | 0.06 (0.06) |
| Brook Trout | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Brown Bullhead | 2.59 (1.21) | 4.43(2.28) | 2.79 (1.13) | 3.38 (1.69) | 1.89 (1.30) | 0.06 (0.06) | 3.11 (2.16) | 0.00 (0.00) | 4.66 (3.57) | 10.51 (8.53) |
| Brown Trout | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Burbot | 0.09 (0.04) | 0.06(0.06) | 0.07 (0.05) | 0.00 (0.00) | 0.16 (0.06) | 0.17 (0.10) | 0.24 (0.17) | 0.20 (0.15) | 0.18 (0.08) | 0.11 (0.08) |
| Carp | 0.05 (0.03) | 0.00 (0.00) | 0.19 (0.12) | 0.07 (0.07) | 0.00 (0.00) | 0.00 (0.00) | 0.05 (0.05) | 0.07 (0.07) | 0.00 (0.00) | 0.00 (0.00) |
| Channel Catfish | 0.02 (0.02) | 0.00 (0.00) | 0.31 (0.20) | 0.15 (0.15) | 0.11 (0.08) | 0.00 (0.00) | 0.13 (0.07) | 0.13 (0.13) | 0.09 (0.07) | 0.00 (0.00) |
| Chinook | 0.64 (0.21) | 0.28(0.12) | 0.29 (0.16) | 0.10 (0.08) | 0.05 (0.03) | 0.06 (0.06) | 0.11 (0.06) | 0.20 (0.11) | 0.05 (0.03) | 0.06 (0.06) |
| Cisco | 2.84 (1.35) | 4.38(2.51) | 3.62 (1.50) | 3.53 (1.84) | 6.64 (2.47) | 10.23 (4.31) | 2.71 (1.51) | 4.08 (2.21) | 1.02 (0.39) | 1.70 (0.59) |
| Coho Salmon | 0.00 (0.00) | 0.00 (0.00) | 0.02 (0.02) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.03 (0.03) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Freshwater | 0.43 (0.18) | 0.34(0.17) | 1.12 (0.35) | 0.59 (0.24) | 0.41 (0.15) | 0.17 (0.10) | 0.37 (0.11) | 0.07 (0.07) | 0.09 (0.05) | 0.00 (0.00) |
| Gizzard Shad | 0.09 (0.09) | 0.11(0.11) | 0.02 (0.02) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.03 (0.03) | 0.07 (0.07) | 0.00 (0.00) | 0.00 (0.00) |
| Lake Sturgeon | 0.02 (0.02) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.11 (0.09) | 0.00 (0.00) | 0.13 (0.11) | 0.07 (0.07) | 0.59 (0.27) | 0.34 (0.17) |
| Lake Trout | 0.00 (0.00) | 0.00 (0.00) | 0.14 (0.09) | 0.07 (0.07) | 0.16 (0.14) | 0.17 (0.17) | 0.05 (0.05) | 0.07 (0.07) | 0.11 (0.11) | 0.06 (0.06) |
| Lake Whitefish | 0.77 (0.35) | 0.85(0.41) | 0.50 (0.20) | 0.29 (0.18) | 1.48 (0.66) | 2.33 (1.13) | 0.42 (0.27) | 0.46 (0.21) | 0.59 (0.26) | 0.80 (0.44) |
| Largemouth | 0.00 (0.00) | 0.00 (0.00) | 0.02 (0.02) | 0.07 (0.07) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Longnose Gar | 0.2 (0.02) | 0.06(0.06) | 0.07 (0.05) | 0.07 (0.07) | 0.00 (0.00) | 0.00 (0.00) | 0.11(0.08) | 0.07 (0.07) | 0.00 (0.00) | 0.00 (0.00) |
| Longnose | 1.20 (0.56) | 2.10(1.00) | 1.29 (0.59) | 1.99 (1.26) | 1.61 (0.66) | 2.61 (1.15) | 0.18 (0.14) | 0.13 (0.09) | 1.18 (0.68) | 1.59 (0.79) |
| Menominee | 0.36(0.15) | 0.80(0.34) | 0.86 (0.54) | 0.18 (0.11) | 1.75 (0.89) | 3.35 (1.80) | 0.45 (0.35) | 0.92 (0.79) | 2.55 (1.28) | 5.23 (2.68) |
| Muskellunge | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.03 (0.03) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |

Table 3 continued.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Northern Pike | 1.55(0.33) | 2.61(0.61) | 1.69 (0.40) | 3.82* (0.81) | 1.82 (0.37) | 3.01 (0.75) | 2.66 (0.65) | 5.13 (1.29) | 4.09 (0.73) | 6.99 (1.26) |
| Pink Salmon | 0.39(0.22) | 0.28(0.15) | 0.14 (0.07) | 0.22 (0.12) | 0.02 (0.02) | 0.06 (0.06) | 0.00 (0.00) | 0.13 (0.09) | 0.00 (0.00) | 0.00 (0.00) |
| Pumpkinseed | 0.41(0.23) | 0.97(0.56) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.11 (0.07) | 0.28 (0.19) |
| Rainbow Smelt | 0.25(0.11) | 0.40(0.21) | 1.40 (0.51) | 0.44 (0.22) | 0.84 (0.49) | 1.65 (1.14) | 1.18 (0.72) | 1.51 (1.06) | 1.00 (0.50) | 2.05 (1.04) |
| Rainbow Trout | 0.02(0.02) | 0.06(0.06) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Redhorse spp. | 0.50(0.14) | 0.40(0.18) | 0.36 (0.20) | 0.44 (0.25) | 3.07 (1.32) | 3.30 (1.21) | 0.74 (0.19) | 0.86 (0.33) | 0.29 (0.13) | 0.17 (0.13) |
| Rock Bass | 5.95(1.15) | 11.42(2.77) | 5.81 (1.32) | 14.34 (3.66) | 4.14 (1.03) | 7.84 (1.96) | 7.50 (2.06) | 12.57 (3.56) | 4.18 (1.09) | 7.67 (2.01) |
| Ruffe | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.23 (0.23) | 0.06 (0.06) |
| Sculpin | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Sea Lamprey | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.02 (0.02) | 0.06 (0.06) | 0.00 (0.00) | 0.00 (0.00) | 0.05 (0.03) | 0.57 (0.57) |
| Shorthead RH | 0.00 (0.00) | 0.00 (0.00) | 0.57 (0.22) | 0.81 (0.36) | 0.30 (0.14) | 0.28 (0.12) | 0.54 (0.19) | 0.46 (0.21) | 0.18 (0.08) | 0.28 (0.12) |
| Silver RH | 0.02(0.02) | 0.06(0.06) | 0.00 (0.00) | 0.00 (0.00) | 0.30 (0.14) | 0.17 (0.10) | 0.05 (0.04) | 0.00 (0.00) | 0.14 (0.06) | 0.00 (0.00) |
| Redhorse (all) | 0.52 (0.15) | 0.45 (0.20) | 0.93 (0.28) | 1.25 (0.41) | 3.66 (1.31) | 3.75 (1.19) | 1.33 (0.29) | 1.32 (0.39) | 0.48 (0.14) | 0.45 (0.17) |
| Smallmouth Bass | 1.48(0.30) | 2.27(0.59) | 4.36 (1.21) | 6.32 (1.76) | 1.73 (0.45) | 1.82 (0.53) | 6.63 (2.36) | 7.76 (2.36) | 2.84 (0.83) | 3.69 (1.17) |
| Splake | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Sucker spp. | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Sunfish spp. | 0.00 (0.00) | 0.00 (0.00) | 0.26 (0.22) | 0.66 (0.66) | 0.39 (0.21) | 0.85 (0.53) | 0.05 (0.04) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Trout-Perch | 0.05(0.03) | 0.56(0.56) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Unknown | 0.05(0.03) | 0.11(0.08) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Walleye | 2.55(0.65) | 3.58(1.04) | 6.07 (1.35) | 11.18 (2.97) | 4.89 (1.09) | 6.02 (1.29) | 7.58 (1.81) | 11.25 (2.88) | 3.41 (0.50) | 5.11 (0.79) |
| White Bass | 0.02(0.02) | 0.00 (0.00) | 0.02 (0.02) | 0.07 (0.07) | 0.30 (0.19) | 0.23 (0.23) | 0.11 (0.08) | 0.20 (0.15) | 0.00 (0.00) | 0.00 (0.00) |
| White Crappie | 0.02(0.02) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| White Sucker | 18.80(2.09) | 24.77(3.93) | 17.88 (2.47) | 17.65 (2.52) | 18.07 (2.84) | 23.07 (3.70) | 17.39 (3.53) | 20.39 (3.84) | 16.04 (2.22) | 22.27(4.04) |
| White Perch | 0.16(0.09) | 0.34(0.17) | 0.50 (0.22) | 0.74 (0.42) | 0.05 (0.05) | 0.00 (0.00) | 0.26 (0.10) | 0.39 (0.20) | 0.16 (0.09) | 0.11 (0.08) |
| Yellow Perch | 23.43(4.25) | 25.34(4.50) | 39.92 (7.15) | 37.21 (8.94) | 37.20 (7.03) | 35.34 (7.62) | 48.11(12.18) | 41.71 | 29.34 (5.65) | 31.53 (8.17) |

- * In 2006, Northern Pike CPUE was significantly higher in the traditional net vs. the full net set.

Table 4. Mean catch-per-unit-of-effort is number per 304.8 m (1000 ft.) collected from the seven habitat areas of the St. Marys River 1975 - 2017 based on catch from traditional mesh sizes. Standard error of the mean is in parentheses.

| Species | Year | Upper River | Lake Nicolet | Lake George | Lake Munuscong | St. Joseph Channel | Raber Bay | Potagannissing Bay |
|---|---|---|---|---|---|---|---|---|
| Yellow Perch | 2017 | 6.0 (3.6) | 10.0 (8.8) | 50.0 (23.0) | 10.5 (2.2) | 21.5 (5.9) | 44.2 (14.8) | 56.2 (30.0) |
| | 2013 | --- | 9.3 (3.1) | 38.3 (13.2) | 26.0 (8.8) | 6.9 (5.2) | 41.2 (13.1) | 88.5 (54.4) |
| | 2009 | 35.0 (32.6) | 5.0 (2.3) | 81.2 (26.5) | 22.5 (3.2) | 11.5 (2.3) | 61.7 (16.4) | 31.8 (18.8) |
| | 2006 | 40.0 (16.8) | 29.5 (12.9) | 66.2 (28.2) | 25.0 (5.4) | 16.5 (5.7) | 57.0 (46.0) | 1.2 (1.2)[b] |
| | 2002 | 26.5 (11.1) | 20.7 (7.8) | 42.5 (20.5) | 17.0 (4.6) | 54.5 (18.3) | 17.9 (7.3) | 11.8 (6.0) |
| | 1995 | 39.0 (17.2) | 21.6 (10.2) | 42.3 (22.6) | 20.3 ( 2.5) | --- | 27.0 ( 6.8)[a] | 29.6 (11.5) |
| | 1987 | 33.9 (15.9) | 30.4 (27.1) | 65.0 (19.0) | 30.0 ( 4.9) | --- | 41.4 ( 4.8) | 62.5 (16.3) |
| | 1979 | 43.1 ( 9.0) | 18.9 ( 9.5) | 26.2 (11.0) | 9.2 ( 2.1) | --- | 9.8 ( 5.0) | 37.3 (11.7) |
| | 1975 | 25.3 (16.6) | 13.9 (10.0) | 31.8 (10.0) | 11.2 ( 6.0) | --- | 6.0 ( 3.6) | 33.5 (16.4) |
| Northern Pike | 2017 | 0.0 (0.0) | 6.7 (2.4) | 10.0 (2.5) | 10.0 (4.3) | 7.5 (2.8) | 6.7 (2.0) | 3.2 (2.1) |
| | 2013 | --- | 4.3 (3.1) | 10.0 (4.5) | 11.5 (5.3) | 6.9 (2.8) | 2.1 (0.8) | 0.8 (0.8) |
| | 2009 | 0.0 (0.0) | 0.7 (0.5) | 7.08 (2.08) | 7.0 (3.2) | 4.5 (1.8) | 3.8 (1.4) | 0.5 (0.5) |
| | 2006 | 1.0 (0.6) | 2.5 (1.4) | 4.2 (1.4) | 5.0 (2.2) | 10.0 (2.8) | 1.5 (0.6) | 0.0 (0.0)[b] |
| | 2002 | 0.0 (0.0) | 0.4 (0.4) | 21.7 (14.7) | 0.0 (0.0) | 7.5 (6.3) | 0.4 (0.4) | 2.2 (1.8) |
| | 1995 | 2.5 ( 1.6) | 8.1 ( 3.4) | 16.3 ( 4.5) | 18.4 ( 5.5) | --- | 12.8 ( 3.4) | 1.6 ( 1.2) |
| | 1987 | 6.9 ( 5.0) | 2.9 ( 2.1) | 27.0 ( 5.2) | 15.6 ( 3.0) | --- | 11.7 ( 3.2) | 8.0 ( 3.0) |
| | 1979 | 1.9 ( 0.3) | 4.7 ( 3.5) | 14.3 ( 3.3) | 11.8 ( 4.6) | --- | 6.0 ( 2.6) | 6.5 ( 1.4) |
| | 1975 | 4.4 ( 4.0) | 11.7 ( 7.1) | 17.3 ( 7.8) | 9.3 ( 2.6) | --- | 5.0 ( 3.0) | 7.1 (2.4) |
| Walleye | 2017 | 5.0 (5.0) | 2.1 (0.8) | 7.9 (1.5) | 2.0 (0.5) | 5.5 (1.4) | 6.7 (1.4) | 6.5 (1.8) |
| | 2013 | --- | 1.8 (0.7) | 34.2 (12.9) | 0.5 (0.5) | 6.2 (2.2) | 15.8 (4.5) | 8.8 (3.8) |
| | 2009 | 6.0 (3.0) | 1.4 (0.7) | 9.6 (5.6) | 1.0 (1.0) | 6.0 (2.0) | 17.9 (3.9) | 2.5 (1.2) |
| | 2006 | 15.5 (6.2) | 4.0 (1.7) | 26.7 (14.0) | 4.2 (1.7) | 3.5 (1.9) | 8.5 (4.4) | 18.8 (6.2)[b] |
| | 2002 | 2.5 (2.5) | 1.1 (0.5) | 8.8 (3.6) | 1.0 (1.0) | 3.0 (1.5) | 7.9 (5.6) | 1.8 (1.2) |
| | 1995 | 2.5 ( 0.8) | 5.6 ( 3.1) | 2.0 ( 6.9) | 2.8 ( 0.9) | --- | 3.6 ( 1.1) | 5.4 ( 2.1) |
| | 1987 | 1.1 ( 0.7) | 0.8 ( 0.0) | 8.0 ( 3.5) | 3.1 ( 1.4) | --- | 21.9 ( 8.0) | 6.3 ( 2.4) |

Table 4 continued

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1979 | 0.0 ( 0.0) | 1.1 ( 0.7) | 4.0 ( 2.8) | 2.9 ( 1.0) | --- | 5.6 ( 2.8) | 6.3 ( 4.8) |
| | 1975 | 0.0 ( 0.0) | 4.7 ( 2.0) | 5.0 ( 4.0) | 2.9 ( 1.8) | --- | 2.1 ( 1.4) | 6.5 ( 4.1) |
| Smallmouth Bass | 2017 | 0.0 (0.0) | 1.1 (0.7) | 7.1 (4.8) | 3.0 (1.5) | 9.0 (4.2) | 2.5 (1.3) | 3.8 (3.5) |
| | 2013 | --- | 2.9 (1.8) | 16.2 (8.8) | 10.5 (3.9) | 8.1 (6.9) | 4.2 (1.9) | 6.8 (6.5) |
| | 2009 | 1.5 (0.6) | 0.0 (0.0) | 0.4 (0.4) | 2.0 (1.5) | 5.0 (2.1) | 3.8 (2.1) | 1.3 (1.3) |
| | 2006 | 0.5 (0.5) | 4.0 (2.0) | 5.0 (1.7) | 13.8 (4.6) | 16.5 (5.7) | 2.5 (1.6) | 1.3 (1.3)[b] |
| | 2002 | 0.0 (0.0) | 1.1 (0.7) | 4.2 (2.9) | 4.5 (1.4) | 4.5 (1.8) | 2.5 (2.0) | 0.8 (0.4) |
| | 1995 | 0.0 ( 0.0) | 3.1 ( 3.1) | 3.5 ( 2.0) | 8.1 ( 2.8) | --- | 5.9 ( 4.5) | 2.5 ( 1.0) |
| | 1987 | 0.6 ( 0.3) | 2.1 ( 1.2) | 15.5 (10.6) | 7.9 ( 5.3) | --- | 2.3 ( 0.4) | 0.2 ( 0.1) |
| | 1979 | 0.0 ( 0.0) | 0.0 ( 0.0) | 0.0 ( 0.0) | 0.3 ( 0.3) | --- | 0.0 ( 0.0) | 0.6 ( 0.4) |
| | 1975 | 0.0 ( 0.0) | 0.0 ( 0.0) | 0.3 ( 0.2) | 1.8 ( 1.2) | --- | 0.0 ( 0.0) | 1.4 ( 1.1) |
| Cisco | 2017 | 0.5 (0.5) | 0.0 (0.0) | 4.6 (1.9) | 0.0 (0.0) | 4.0 (4.0) | 0.0 (0.0) | 2.5 (1.0) |
| | 2013 | --- | 0.4 (0.4) | 2.5 (1.3) | 2.1 (1.5) | 6.9 (6.9) | 16.7 (12.8) | 1.0 (0.7) |
| | 2009 | 0.0 (0.0) | 2.1 (1.5) | 0.0 (0.0) | 0.0 (0.0) | 2.0 (0.9) | 14.2 (7.0) | 34.0 (16.8) |
| | 2006 | 0.0 (0.0) | 0.5 (0.5) | 0.8 (0.5) | 0.0 (0.0) | 0.5 (0.5) | 22.0 (9.4) | 0.0 (0.0)[b] |
| | 2002 | 0.5 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 3.2 (1.2) |
| | 1995 | 0.0 ( 0.0) | 13.4 ( 5.9) | 3.5 (3.2) | 0.0 ( 0.0) | --- | 11.7 ( 9.3) | 19.2 ( 9.8) |
| | 1987 | 0.0 ( 0.0) | 0.8 ( 0.8) | 3.3 ( 2.9) | 0.8 ( 0.6) | --- | 1.2 ( 1.0) | 54.0 (21.1) |
| | 1979 | 0.0 ( 0.0) | 3.1 ( 3.1) | 0.0 ( 0.0) | 0.0 ( 0.0) | --- | 62.7 (62.4) | 39.8 (23.8) |
| | 1975 | 0.0 ( 0.0) | 9.2 ( 8.3) | 0.0 ( 0.0) | 0.1 ( 0.1) | --- | 42.5 (17.8) | 23.0 (11.7) |

[a] Means from these areas included some efforts of 3.51 c, (1.5 in.) mesh. While compensated for in the calculation of CPUE, the influence of the smaller mesh may have slightly inflated the mean for certain species such as Yellow Perch.

[b] Potagannissing Bay mean CPUE values for 2006 reflect only two net sets via the traditional mesh sizes and was probably under-sampled for the purpose of this reach specific analysis.

Table 5. Catch-per-unit-of-effort (CPUE) of Yellow Perch by age for 2017 and mean length-at-age at capture for the St. Marys River, August-September, 1979-2017 by river location. For comparison, mean length-at-age is included from past surveys and the Michigan state average length-at-age[1] as well as the Ontario Lake Huron 2006 North Channel average[2] (ON NC). Unit of effort is one 304.8 m gillnet set. Growth index[1] compares length-at-age to Michigan state average and the 2013 year to the North Channel average. It excludes age groups represented by less than 5 specimens. All lengths and the growth indexes are in mm. CPUE values by age may omit some un-aged fish and therefore may not total to the overall CPUE for this species as reported in Table 3.

| Parameter & Area | Age | | | | | | | | | | Mean age | Mean length | Growth index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | | |
| **Upper River** | | | | | | | | | | | | | |
| Number | 1 | 10 | 2 | 2 | 5 | 2 | 1 | | | | | | |
| CPUE | 0.2 | 0.4 | 0.6 | 0.8 | 1 | 1.2 | 1.4 | | | | | | |
| Frequency (%) | 4.3 | 43.5 | 8.7 | 8.7 | 21.7 | 8.7 | 4.3 | | | | | | |
| Mean length | | | | | | | | | | | | | |
| 2017 | 140 | 156 | 226 | 187 | 257 | 296 | 285 | | | | 3.0 | 204 | +10 |
| 2013 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | | |
| 2009 | | 149 | 195 | 210 | | | | | | | 3.1 | 188 | +1 |
| 2006 | 159 | 186 | 241 | 251 | | | | | | | 2.7 | 219 | +40 |
| 2002 | 146 | 170 | 222 | 251 | 343 | | 361 | | 373 | 372 | 3.0 | 212 | +28 |
| 1995 | | 157 | 184 | 200 | 225 | 244 | 269 | 280 | 298 | 354 | | | -7 |
| 1987 | | | | 201 | 216 | 224 | 254 | 264 | 305 | 312 | | | -20 |
| 1979 | | | 183 | 201 | 216 | 259 | 272 | 302 | 295 | | | | -6 |
| MI average | 127 | 160 | 183 | 208 | 234 | 257 | 277 | 292 | 302 | | | | --- |
| ON NC 2006 | 124 | 173 | 211 | 235 | 243 | 248 | 256 | 276 | | 290 | | | --- |
| **Lake Nicolet** | | | | | | | | | | | | | |
| Number | | 11 | 7 | 2 | 11 | 5 | 2 | 1 | | | | | |
| CPUE | | 1.6 | 1.0 | 0.3 | 1.6 | 0.7 | 0.3 | 0.1 | | | | | |
| Frequency (%) | | 28.2 | 17.9 | 5.1 | 28.2 | 12.8 | 5.1 | 2.6 | | | | | |
| Mean length | | | | | | | | | | | | | |
| 2017 | | 152 | 207 | 214 | 248 | 278 | 311 | 326 | | | 4.0 | 221 | +13 |
| 2013 | | 150 | 170 | 191 | | | | | | | 3.3 | 181 | -13 |
| 2009 | | 153 | 171 | 202 | | | | | | | 3.3 | 181 | -8 |
| 2006 | 143 | 164 | 205 | 235 | | | | | | | 2.6 | 188 | +17 |
| 2002 | | 148 | 162 | 197 | 238 | 239 | 328 | | | | 3.3 | 177 | -10 |
| 1995 | 170 | 147 | 172 | 209 | 227 | 250 | 275 | 284 | | | | | -7 |
| 1987 | | | | 196 | 221 | 231 | 287 | 295 | | | | | -7 |
| 1979 | | | 168 | 185 | 221 | 208 | 244 | | | | | | -18 |
| MI average | 127 | 160 | 183 | 208 | 234 | 257 | 277 | 292 | 302 | | | | |
| ON NC 2006 | 124 | 173 | 211 | 235 | 243 | 248 | 256 | 276 | | 290 | | | -36 |

Table 5. Continued.

| Parameter & Area | Age 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Mean age | Mean length | Growth index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lake George** | | | | | | | | | | | | | |
| Number | 2 | 60 | 27 | 42 | 17 | 16 | 18 | 3 | 1 | | | | |
| CPUE | 0.3 | 5.6 | 21.2 | 7.0 | 2.0 | 1.8 | 1.8 | 1.0 | 0.2 | | | | |
| Frequency (%) | 1.1 | 32.3 | 14.5 | 22.6 | 9.1 | 8.6 | 9.7 | 1.6 | 0.5 | | | | |
| Mean length | | | | | | | | | | | | | |
| 2017 | 145 | 148 | 182 | 216 | 249 | 273 | 271 | 394 | 316 | | 3.8 | 192 | +3 |
| 2013 | | 151 | 171 | 204 | 280 | 291 | 286 | 287 | | | 3.6 | 170 | +8 |
| 2009 | | 148 | 173 | 217 | 263 | 286 | | | | | 3.5 | 182 | +9 |
| 2006 | 156 | 172 | 207 | 246 | 246 | 272 | | | | | 2.3 | 188 | +22 |
| 2002 | 155 | 153 | 194 | 222 | 269 | 311 | 318 | 315 | | | 2.8 | 185 | +12 |
| 1995 | | 148 | 169 | 206 | 233 | 247 | 242 | 263 | 256 | | | | -15 |
| 1987 | | | | 198 | 216 | 256 | 264 | 302 | 323 | | | | -10 |
| 1979 | | | 173 | 190 | 203 | 249 | 282 | 282 | | 297 | | | -12 |
| MI average | 127 | 160 | 183 | 208 | 234 | 257 | 277 | 292 | 302 | | | | |
| ON NC 2006 | 124 | 173 | 211 | 235 | 243 | 248 | 256 | 276 | | 290 | | | +4 |
| **St. Joseph Channel** | | | | | | | | | | | | | |
| Number | 2 | 29 | 15 | 17 | 14 | 11 | 5 | | | 2 | | | |
| CPUE | 0.4 | 5.8 | 3.0 | 3.4 | 2.8 | 2.2 | 1.0 | | | 0.4 | | | |
| Frequency (%) | 2.1 | 30.5 | 15.8 | 17.9 | 14.7 | 11.6 | 5.3 | | | 2.1 | | | |
| Mean length | | | | | | | | | | | | | |
| 2017 | 149 | 159 | 174 | 199 | 234 | 261 | 260 | | | 327 | 3.8 | 200 | -5 |
| 2013 | | 148 | 157 | 158 | 183 | | 231 | | | | 3.6 | 167 | -37 |
| 2009 | | 148 | 153 | 165 | 178 | 190 | | | | | 3.7 | 162 | -42 |
| 2006 | 149 | 155 | 174 | 194 | 212 | 283 | | | | | 2.9 | 167 | +0 |
| 2002 | | 147 | 167 | 217 | 259 | 293 | | | | | 3.2 | 183 | +8 |
| 1995 | | | | | | | | | | | | | |
| 1987 | | | | | | | | | | | | | |
| 1979 | | | | | | | | | | | | | |
| MI average | 127 | 160 | 183 | 208 | 234 | 257 | 277 | 292 | 302 | | | | |
| ON NC 2006 | 124 | 173 | 211 | 235 | 243 | 248 | 256 | 276 | | 290 | | | -48 |

Table 5. Continued.

| Parameter & Area | Age 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Mean age | Mean length | Growth index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lake Munuscong** | | | | | | | | | | | | | |
| Number | 6 | 118 | 7 | 15 | 9 | 3 | 1 | | | | | | |
| CPUE | 1.2 | 23.6 | 1.4 | 3 | 1.8 | 0.6 | 0.2 | | | | | | |
| Frequency (%) | 3.8 | 74.2 | 4.4 | 9.4 | 5.7 | 1.9 | 0.6 | | | | | | |
| Mean length | | | | | | | | | | | | | |
| 2017 | 140 | 148 | 173 | 205 | 224 | 274 | 207 | | | | 2.5 | 162 | -4 |
| 2013 | | 155 | 177 | 194 | 231 | | | | | | 3.2 | 166 | -7 |
| 2009 | | 142 | 172 | 209 | 265 | | | | | | 3.3 | 184 | +1 |
| 2006 | 155 | 182 | 227 | | | | | | | | 2.5 | 205 | +31 |
| 2002 | 153 | 146 | 180 | 208 | 230 | | 275 | | | | 2.6 | 1.66 | -6 |
| 1995 | | 145 | 177 | 213 | 229 | 239 | 256 | 292 | 278 | | | | -11 |
| 1987 | | | | 196 | 226 | 279 | 292 | 325 | | | | | +10 |
| 1979 | | 203 | 193 | 216 | 239 | 284 | 254 | | | | | | +9 |
| MI average | 127 | 160 | 183 | 208 | 234 | 257 | 277 | 292 | 302 | | | | |
| ON NC 2006 | 124 | 173 | 211 | 235 | 243 | 248 | 256 | 276 | | 290 | | | -26 |
| **Raber Bay** | | | | | | | | | | | | | |
| Number | 2 | 37 | 15 | 63 | 12 | 5 | 4 | | 1 | | | | |
| CPUE | 0.3 | 6.2 | 2.5 | 10.5 | 2.0 | 0.8 | 0.7 | | 0.2 | | | | |
| Frequency (%) | 1.4 | 26.6 | 10.8 | 45.3 | 8.6 | 3.6 | 2.9 | | 0.7 | | | | |
| Mean length | | | | | | | | | | | | | |
| 2017 | 136 | 148 | 206 | 209 | 238 | 270 | 293 | | 305 | | 3.6 | 194 | +6 |
| 2013 | | 158 | 194 | 238 | 261 | | | | | | 3.0 | 188 | +17 |
| 2009 | | | | | | | | | | | | | |
| 2006 | 157 | 182 | 207 | 223 | 244 | 273 | | | | | 3.1 | 204 | +20 |
| 2002 | | 152 | 175 | 203 | 246 | 268 | | | | | 3.3 | 185 | -2 |
| 1995 | 137 | 152 | 202 | 227 | 236 | 260 | 268 | 269 | | | | | +4 |
| 1987 | | | 165 | 188 | 231 | 251 | 277 | 297 | 307 | 315 | | | -9 |
| 1979 | | 185 | 196 | 221 | 272 | 262 | | | | | | | +17 |
| MI average | 127 | 160 | 183 | 208 | 234 | 257 | 277 | 292 | 302 | | | | |
| ON NC 2006 | 124 | 173 | 211 | 235 | 243 | 248 | 256 | 276 | | 290 | | | -3 |

Table 5 Continued.

| Parameter & Area | Age 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Mean age | Mean length | Growth index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Potagannissing Bay** | | | | | | | | | | | | | |
| Number | | 81 | 162 | 72 | 22 | 17 | 6 | | 1 | | | | |
| CPUE | | 8.1 | 16.2 | 7.2 | 2.2 | 1.7 | 0.6 | | 0.1 | | | | |
| Frequency (%) | | 22.4 | 44.9 | 19.9 | 6.1 | 4.7 | 1.7 | | 0.3 | | | | |
| Mean length | | | | | | | | | | | | | |
| 2017 | | 154 | 185 | 229 | 301 | 315 | 300 | | 379 | | 3.3 | 190 | +28 |
| 2013 | | 160 | 220 | 230 | | | | | | | 2.8 | 190 | +20 |
| 2009 | | 152 | 177 | 204 | 239 | 326 | | | | | 4.6 | 175 | +11 |
| 2006 | 143 | 181 | 229 | 263 | | | | | | | 2.4 | 202 | +37 |
| 2002 | 157 | 172 | 196 | 247 | 297 | 175 | | | | | 2.6 | 189 | +32 |
| 1995 | 133 | 158 | 167 | 208 | 215 | 243 | 275 | 290 | | | | | -6 |
| 1987 | | | | | 231 | 262 | 272 | 307 | | 330 | | | -1 |
| 1979 | | | 201 | 224 | 249 | 269 | 302 | 323 | 282 | | | | +20 |
| MI average | 127 | 160 | 183 | 208 | 234 | 257 | 277 | 292 | 302 | | | | |
| ON NC 2006 | 124 | 173 | 211 | 235 | 243 | 248 | 256 | 276 | | 290 | | | -3 |
| **River-wide** | | | | | | | | | | | | | |
| Number | 13 | 346 | 235 | 213 | 90 | 59 | 37 | 4 | 3 | 2 | | | |
| CPUE | 0.3 | 7.9 | 5.3 | 4.8 | 2.0 | 1.3 | 0.8 | 0.1 | 0.1 | 0.0 | | | |
| Frequency (%) | 1.3 | 34.5 | 23.5 | 21.3 | 9.0 | 5.9 | 3.7 | 0.4 | 0.3 | 0.2 | | | |
| Mean length | | | | | | | | | | | | | |
| 2017 | 141 | 151 | 186 | 216 | 255 | 284 | 277 | 377 | 333 | 327 | 3.3 | 190 | +9 |
| 2013 | | 156 | 186 | 208 | 249 | 275 | 280 | 281 | | | | | +3 |
| 2009 | | 150 | 172 | 204 | 237 | 251 | | | | | | | -6 |
| 2006 | | 155 | 174 | 220 | 236 | 246 | 280 | 290 | | | | | -1 |
| 2002 | 151 | 153 | 177 | 220 | 258 | 274 | 320 | 315 | 373 | 372 | 3.0 | 184 | +15 |
| 1995 | 140 | 152 | 171 | 211 | 227 | 246 | 260 | 278 | 294 | 354 | | | -7 |
| 1987 | | | 165 | 195 | 223 | 244 | 273 | 296 | 308 | 319 | | | -6 |
| 1979 | | 196 | 196 | 209 | 229 | 264 | 285 | 302 | 291 | 297 | | | +7 |
| MI average | 127 | 160 | 183 | 208 | 234 | 257 | 277 | 292 | 302 | | | | |
| ON NC 2006 | 124 | 173 | 211 | 235 | 243 | 248 | 256 | 276 | | 290 | | | -1 |

[1]From Schneider et al. (2000)

[2]Ontario MNR, unpublished data

Table 6. Comparison of total annual mortality (A) rates for select fish species in the St. Marys River, computed from fish collected in experimental mesh gillnets 1995-2017.

| Species | Area, if not total for the river | 1995 | 2002 | 2006 | 2009 | 2013 | 2017 |
|---|---|---|---|---|---|---|---|
| Yellow Perch | Upper River | 0.25 | 0.54 | 0.70 | 0.63 | Not sampled | 0.59 |
| | Lake Nicolet | 0.38 | 0.70 | 0.59 | --- | 0.61 | 0.39 |
| | Lake George | 0.40 | 0.52 | 0.43 | 0.69 | 0.55 | 0.42 |
| | St. Joseph Channel | Not sampled | 0.64 | 0.50 | --- | 0.71 | --- |
| | Lake Munuscong | 0.41 | 0.61 | 0.78 | 0.62 | 0.63 | 0.76 |
| | Raber Bay | 0.44 | 0.63 | 0.49 | --- | 0.71 | 0.50 |
| | Potagannissing Bay | 0.60 | 0.57 | 0.96 | 0.67 | 0.55 | 0.59 |
| | River Total | 0.38 | 0.68 | 0.70 | 0.64 | 0.60 | 0.41 |
| Northern Pike | | 0.58 | 0.52 | 0.61 | 0.72 | 0.52 | 0.51 |
| Walleye | | 0.51 | 0.49 | 0.38 | 0.38 | 0.32 | 0.39 |
| Cisco | | 0.31 | 0.39 | 0.40 | 0.48 | 0.25 | 0.38 |
| Smallmouth Bass | | 0.36 | 0.37 | 0.55 | 0.50 | 0.35 | 0.52 |

Table 7. Maturity schedule for five notable species expressed as percent maturity of females by length in the St. Marys River. Fish used in the analysis were collected by gillnets in August - September 2017.

| | Species | | | | |
|---|---|---|---|---|---|
| Length (cm) | Walleye | Smallmouth Bass | Northern Pike | Yellow Perch | Cisco |
| 13 | --- | --- | --- | 50 | --- |
| 14 | --- | --- | --- | 79 | --- |
| 15 | --- | --- | --- | 63 | --- |
| 16 | --- | --- | --- | 76 | --- |
| 17 | --- | --- | --- | 73 | --- |
| 18 | --- | --- | --- | 87 | --- |
| 19 | --- | 0 | --- | 77 | 0 |
| 20 | --- | --- | --- | 94 | 0 |
| 21 | --- | 100 | --- | 97 | 100 |
| 22 | --- | 0 | --- | 98 | --- |
| 23 | 0 | --- | --- | 100 | 0 |
| 24 | --- | --- | --- | 93 | --- |
| 25 | --- | 0 | --- | 100 | 100 |
| 26 | 0 | 33 | --- | 100 | --- |
| 27 | --- | --- | --- | 100 | 0 |
| 28 | --- | 100 | --- | 100 | 100 |
| 29 | --- | 100 | --- | 94 | 67 |
| 30 | 0 | 87 | --- | 100 | 50 |
| 31 | 100 | 100 | --- | 92 | 50 |
| 32 | 33 | 100 | --- | 100 | 0 |
| 33 | 80 | 100 | --- | 100 | 100 |
| 34 | 100 | 100 | --- | 100 | 100 |
| 35 | 25 | 100 | --- | 100 | 100 |
| 36 | 50 | 100 | --- | 100 | 100 |
| 37 | 0 | 100 | --- | 100 | 100 |
| 38 | 0 | 100 | --- | 100 | 100 |
| 39 | 25 | 100 | 0 | --- | 100 |
| 40 | --- | 100 | --- | --- | 100 |
| 41 | --- | 100 | --- | --- | 100 |
| 42 | --- | 100 | 50 | --- | 100 |
| 43 | 100 | 100 | --- | --- | 100 |
| 44 | 80 | 100 | --- | --- | 100 |
| 45 | 100 | 100 | --- | --- | 100 |
| 46 | 100 | 100 | 0 | --- | 100 |
| 47 | 100 | 100 | 50 | --- | 100 |

Table 7. Continued.

| | Species | | | | |
|---|---|---|---|---|---|
| Length (cm) | Walleye | Smallmouth Bass | Northern Pike | Yellow Perch | Cisco |
| 48 | 67 | --- | 100 | --- | --- |
| 49 | 100 | 100 | 75 | --- | --- |
| 50 | 100 | --- | 100 | --- | --- |
| 51 | 100 | --- | 50 | --- | --- |
| 52 | 100 | --- | 83 | --- | --- |
| 53 | 100 | --- | 100 | --- | --- |
| 54 | 100 | --- | 83 | --- | --- |
| 55 | 100 | --- | 100 | 100 | --- |
| 56 | 100 | --- | 100 | --- | --- |
| 57 | 100 | --- | 100 | --- | --- |
| 58 | 100 | --- | 100 | --- | --- |
| 59 | 100 | --- | 67 | --- | --- |
| 60 | 100 | --- | 100 | --- | --- |
| 61 | 100 | --- | 100 | 100 | --- |
| 62 | 100 | --- | 33 | --- | --- |
| 63 | 100 | --- | 100 | --- | --- |
| 64 | 100 | --- | 100 | --- | --- |
| 65 | 100 | --- | 100 | --- | --- |
| 66 | 100 | --- | 100 | --- | --- |
| 67 | --- | --- | 100 | --- | --- |
| 68 | --- | --- | 100 | --- | --- |
| 69 | --- | --- | 100 | --- | --- |
| 70 | --- | --- | 100 | --- | --- |
| 71 | --- | --- | 100 | --- | --- |
| 72 | --- | --- | 100 | --- | --- |
| 73 | --- | --- | 100 | --- | --- |
| 74 | --- | --- | 100 | --- | --- |
| 75 | --- | --- | 100 | --- | --- |
| 76 | --- | --- | 100 | --- | --- |
| 77 | --- | --- | 100 | --- | --- |
| 78 | --- | --- | 100 | --- | --- |
| 79 | --- | --- | 100 | --- | --- |
| 80 | --- | --- | 100 | --- | --- |
| 81 | --- | --- | 100 | --- | --- |
| 82 | --- | --- | 100 | --- | --- |
| 83 | --- | --- | 100 | --- | --- |

Table 8. Mean relative weight of select species, by area and river wide, for the St. Marys River, August - September 2017; River wide total values for 1995-2017 are presented for comparison.

| Location | Walleye | Yellow Perch | Smallmouth Bass | Northern Pike | Cisco |
|---|---|---|---|---|---|
| Upper River | 86 | 97 | --- | 85 | --- |
| Lake Nicolet | 91 | 95 | 108 | 94 | --- |
| Lake George | 94 | 102 | 101 | 97 | 114 |
| Lake Munuscong | 84 | 97 | 106 | 96 | --- |
| St. Joseph Channel | 77 | 64 | 92 | 87 | 79 |
| Raber Bay | 87 | 95 | 97 | 96 | 86 |
| Potagannissing Bay | 86 | 92 | 98 | 96 | 82 |
| | | | | | |
| River wide 2017 | 87 | 93 | 100 | 95 | 90 |
| River wide 2013 | 56 | 96 | 103 | 94 | 87 |
| River wide 2009 | 57 | 90 | 112 | 101 | 91 |
| River wide 2006 | 87 | 91 | 109 | 94 | 84 |
| River wide 2002 | 90 | 94 | 106 | 87 | 89 |
| River wide 1995 | 102 | 97 | 106 | 91 | --- |

Table 9. Catch-per-unit-of-effort (CPUE) of Walleye by age for 2017 and mean length-at-age at capture for the St. Marys River, August-September, 1979-2017. For comparison, mean length-at-age is included from past surveys and the Michigan state average length-at-age[1] as well as the Ontario Lake Huron 2006 North Channel (ON NC) average[2]. Unit of effort is one 304.8 m gillnet set. Growth index[1] compares length-at-age to state average and the 2017 year to the NC average. It excludes age groups represented by less than 5 specimens. All lengths and the growth index are in mm. CPUE values by age may omit some un-aged fish and therefore may not total to the overall CPUE for this species as reported in Table 3.

| | Age | | | | | | | | | | | | | | Mean | Mean | Growth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | age | length | index |
| Number | 13 | 34 | 21 | 20 | 24 | 24 | 5 | 1 | 1 | | 2 | 2 | 1 | 2 | | | |
| CPUE | 0.3 | 1.9 | 0.9 | 0.6 | 0.5 | 0.6 | 0.1 | 0.1 | 0.0 | | 0.1 | 0.1 | 0.1 | 0.1 | | | |
| Frequency (%) | 8.7 | 22.7 | 14.0 | 13.3 | 16.0 | 16.0 | 3.3 | 0.7 | 0.7 | | 1.3 | 1.3 | 0.7 | 1.3 | | | |
| Mean length | | | | | | | | | | | | | | | | | |
| 2017 | 234 | 334 | 381 | 428 | 477 | 509 | 492 | 557 | 582 | | 631 | 608 | 586 | 657 | 4.2 | 463 | -1 |
| 2013 | 253 | 335 | 420 | 450 | 450 | 513 | 531 | 576 | | 592 | | | | | 4.0 | 408 | +3 |
| 2009 | | 309 | 394 | 439 | 485 | 529 | 536 | 576 | | 592 | | | | | 4.5 | 440 | +2 |
| 2006 | 287 | 363 | 391 | 416 | 483 | 520 | | 561 | | | | | | | 3.0 | 383 | +9 |
| 2002 | 253 | 312 | 393 | 472 | 530 | 421 | 563 | 552 | | 590 | 578 | 660 | 571 | 614 | 4.0 | 434 | +15 |
| 1995 | 209 | 271 | 278 | 363 | 489 | 502 | 560 | 611 | | 604 | | | | | | | -26 |
| 1987 | 240 | 288 | 347 | 407 | 464 | 505 | 549 | 585 | 607 | 660 | | | | | | | -17 |
| 1979 | | 307 | 378 | 447 | 472 | 528 | 513 | 538 | | | | | | | | | -27 |
| MI average | 250 | 338 | 386 | 437 | 472 | 516 | 541 | 561 | 582 | | | | | | | | |
| ON NC 2006 average | | 381 | 410 | 471 | 511 | 538 | | 635 | | 658 | | | | | | | -35 |

[1]From Schneider et al. (2000)
[2]Ontario MNR, unpublished data

Table 10. Catch-per-unit-of-effort (CPUE) of Smallmouth Bass by age 2017 and mean length-at-age at capture for the St. Marys River, August - September, 1987-2017. For comparison, mean length-at-age is included from past surveys and the Michigan state average length-at-age[1] as well as the Ontario Lake Huron North Channel (ON NC) average[2]. Unit of effort is one 304.8 m gillnet set. Growth index[1] compares length-at-age to state average and excludes age groups represented by less than 5 specimens. All lengths and the growth index are in mm. CPUE values by age may omit some un-aged fish and therefore may not total to the overall CPUE for this species as reported in Table 3.

| | Age | | | | | | | | | | | | | | Mean | Mean | Growth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | age | length | index |
| Number | | 6 | 12 | 37 | 21 | 33 | 11 | 1 | 1 | 2 | 1 | | | | | | |
| CPUE | | 0.1 | 0.3 | 0.8 | 0.5 | 0.8 | 0.3 | <0.1 | <0.1 | <0.1 | <1.0 | | | | | | |
| Frequency (%) | | 4.8 | 9.6 | 29.6 | 16.8 | 8.8 | 8.8 | 0.8 | 0.8 | 1.6 | 0.8 | | | | | | |
| Mean length | | | | | | | | | | | | | | | | | |
| 2017 | | 190 | 244 | 296 | 317 | 369 | | | | 438 | | | | | 4.0 | 323 | -14 |
| 2013 | | 148 | 234 | 276 | 349 | 385 | 420 | 430 | 445 | 463 | | | | | 4.4 | 335 | -11 |
| 2009 | | | | 271 | 300 | 344 | 363 | | | | | | | | 4.5 | 313 | -44 |
| 2006 | | 171 | 251 | 282 | 315 | 371 | | 391 | | | | | | | 3.0 | 273 | -18 |
| 2002 | | 146 | 187 | 222 | 291 | 325 | 376 | 398 | 457 | | | 457 | | | 4.1 | 281 | -61 |
| 1995 | | 145 | | 245 | 263 | 278 | 305 | 340 | 359 | | | | | | | | -99 |
| 1987 | | | | 234 | 268 | 330 | 347 | 371 | | | | | | | | | -72 |
| MI average | | 178 | 257 | 305 | 356 | 386 | 406 | 434 | 452 | 475 | | | | | | | |
| ON NC 2003 average | | 128 | 161 | 175 | 256 | 291 | 240 | | | | | | | | | | +94 |

[1]From Schneider et al. (2000)
[2]Ontario MNR, unpublished data

Table 11. Catch-per-unit-of-effort (CPUE) of Northern Pike by age 2017 and mean length-at-age at capture for the St. Marys River, August - September, 1987-2017. For comparison, mean length-at-age is included from past surveys and the Michigan State average length-at-age[1] as well as the Ontario Lake Huron North Channel (ON NC) average[2]. Unit of effort is one 304.8 m gillnet set. Growth index[1] compares length-at-age to state average and the 2017 year to the NC average. It excludes age groups represented by less than 5 specimens. All lengths and the growth index are in mm. CPUE values by age may omit some un-aged fish and therefore may not total to the overall CPUE for this species as reported in Table 3.

| | Age | | | | | | | | | | | | | | Mean | Mean | Growth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | age | length | index |
| Number | | 5 | 16 | 34 | 42 | 27 | 9 | 4 | 2 | 2 | 1 | | | | | | |
| CPUE | | 0.1 | 0.4 | 0.8 | 1.0 | 0.6 | 0.2 | <0.1 | <0.1 | <0.1 | <0.1 | | | | | | |
| Frequency (%) | | 3.5 | 11.3 | 23.9 | 29.6 | 19.0 | 6.3 | 2.8 | 1.4 | 1.4 | 0.7 | | | | | | |
| Mean length | | | | | | | | | | | | | | | | | |
| 2017 | | 378 | 445 | 503 | 561 | 612 | 655 | 637 | 660 | 763 | 851 | | | | 4.0 | 552 | -68 |
| 2013 | | | 455 | 525 | 598 | 610 | 685 | | | | | | | | 4.1 | 583 | -53 |
| 2009 | | 287 | 436 | 520 | 619 | | | | | | | | | | 3.0 | 543 | -71 |
| 2006 | 269 | 429 | 528 | 601 | 642 | | | | | | | | | | 1.8 | 491 | +13 |
| 2002 | 250 | 371 | 455 | 564 | 620 | 669 | | | | | | | | | 2.4 | 477 | -34 |
| 1995 | | 399 | 465 | 538 | 605 | 621 | 722 | 918 | | 1033 | | | | | | | -39 |
| 1987 | | 407 | 468 | 515 | 575 | 672 | 726 | 752 | 754 | | | | | | | | -39 |
| MI average | | 422 | 511 | 579 | 635 | 683 | 732 | 780 | | | | | | | | | |
| ON NC 2002 average | | 377 | 483 | 580 | 657 | 749 | 706 | | | | | | | | | | -60 |

[1]From Schneider et al. (2000)
[2]Ontario MNR, unpublished data

Table 12. Catch-per-unit-of-effort (CPUE) of Cisco by age 2017 and mean length-at-age at capture for the St. Marys River, August - September, 1995-2017. For comparison, mean length-at-age is included from past surveys and the Michigan state average length-at-age[1] as well as the Ontario Lake Huron 2006 North Channel (ON NC) average[2]. Unit of effort is one 304.8 m gillnet set. Growth index[1] compares length-at-age to state average and the 2017 year to the NC average. It excludes age groups represented by less than 5 specimens. All lengths and the growth index are in mm. CPUE values by age may omit some un-aged fish and therefore may not total to the overall CPUE for this species as reported in Table3.

| | Age | | | | | | | | | | | | | | Mean | Mean | Growth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | age | length | index |
| Number | | 10 | 15 | 3 | 2 | 3 | 4 | 3 | 2 | 1 | | | 1 | | | | |
| CPUE | | 0.2 | 0.3 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | | | <0.1 | | | | |
| Frequency (%) | | 22.7 | 34.1 | 6.8 | 4.5 | 6.8 | 9.1 | 6.8 | 4.5 | 2.3 | | | 2.3 | | | | |
| Mean length | | | | | | | | | | | | | | | | | |
| 2017 | | 214 | 304 | 318 | 324 | 401 | 407 | 419 | 416 | 472 | | | 417 | | 3.5 | 318 | +32 |
| 2013 | | 196 | 249 | 272 | 269 | 293 | 314 | 351 | 390 | 384 | 388 | 427 | | | 4.7 | 292 | -15 |
| 2009 | | 207 | 260 | 343 | 366 | 379 | 382 | 398 | 404 | 413 | | | | | 3.7 | 316 | +41 |
| 2006 | | 213 | 232 | 281 | 326 | 387 | 378 | 386 | 377 | 412 | | | | | 3.2 | 280 | +8 |
| 2002 | | 199 | 240 | 306 | 338 | 374 | 383 | 412 | 416 | | | | | | 3.1 | 292 | +26 |
| 1995 | | 200 | 265 | 330 | 289 | 327 | 379 | 399 | 401 | 412 | 446 | | | | | | +16 |
| MI average | | 214 | 241 | 267 | 294 | 321 | 347 | 374 | 400 | | | | | | | | |
| ON NC 2006 average | | | 265 | 263 | 329 | 292 | 358 | 377 | 372 | 388 | 372 | 390 | 374 | 393 | | | -17 |

[1]From Schneider et al. (2000)

[2]Ontario MNR, unpublished data

Table 13. Incidence and percent of occurrence of food items (based on stomach content identification) for select species from the St. Marys River, August – September 2017. Note percent occurrence may total more than 100% due to multiple food species in stomach.

| | Walleye | Northern Pike | Smallmouth Bass | Yellow Perch | Cisco |
|---|---|---|---|---|---|
| **Incidence** | | | | | |
| No. stomachs examined | 141 | 180 | 122 | 716 | 32 |
| % void | 73.0 | 72.8 | 68.9 | 62.0 | 93.8 |
| | | | | | |
| **Percent of Occurrence** | | | | | |
| Unidentified fish remains | 44.7 | 44.9 | 28.9 | 15.8 | 33.3 |
| Crayfish | --- | 16.3 | 36.8 | 51.1 | --- |
| Alewife | 5.3 | --- | --- | --- | --- |
| Rainbow Smelt | 18.4 | 4.1 | --- | --- | --- |
| Mayfly | --- | --- | --- | --- | 33.3 |
| Logperch | --- | 4.1 | --- | --- | --- |
| Unidentified zooplankton | --- | --- | --- | --- | --- |
| Menominee | --- | 2.0 | --- | --- | --- |
| Trout-Perch | --- | 6.1 | --- | --- | --- |
| Yellow Perch | 7.9 | 10.2 | 13.2 | 2.2 | --- |
| Cisco | --- | --- | --- | --- | --- |
| Sculpin | 2.6 | 2.0 | --- | --- | --- |
| Johnny Darter | 5.3 | 2.0 | --- | --- | --- |
| Unidentified insects | 2.6 | 2.0 | 15.8 | 26.1 | --- |
| Ninespine Stickleback | --- | --- | --- | --- | --- |
| Threespine Stickleback | 10.5 | 10.2 | | --- | --- |
| Stickleback sp. | --- | --- | 2.6 | 0.4 | --- |
| Snails | --- | 2.0 | 2.6 | --- | --- |
| White Sucker | --- | 2.0 | --- | --- | --- |
| Round Goby | 2.6 | 10.2 | --- | 7.0 | --- |
| Vegetation | --- | 2.0 | 2.6 | 0.4 | --- |
| Water Flea | --- | --- | --- | --- | 33.3 |

Table 14. Percent of sea lamprey wounds by species exhibiting wounding from the St. Marys River, August - September 2017. N denotes sample size of specimens examined for wounds. Wounds scored according to Ebner et al. (2006).

| Species | N | A1 | A2 | A3 | A4 | B1 | B2 | B3 | B4 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Walleye | 150 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Yellow Perch | 1291 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cisco | 45 | 0.0 | 2.2 | 0.0 | 0.0 | 2.2 | 0.0 | 0.0 | 0.0 | 4.4 |
| Lake Whitefish | 26 | 3.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.8 |
| Northern Pike | 180 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.6 |
| White Sucker | 706 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| Rock Bass | 184 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Appendix 1. Common and scientific names of fishes and other aquatic organisms mentioned in this report.

| Common name | Scientific name |
|---|---|
| Alewife | *Alosa pseudoharengus* |
| Atlantic Salmon | *Salmo salar* |
| Black Crappie | *Pomoxis nigromaculatus* |
| Bloater | *Coregonus hoyi* |
| Bluegill | *Lepomis macrochirus* |
| Bowfin | *Amia calva* |
| Brook Trout | *Salvelinus fontinalis* |
| Brown Bullhead | *Ictalurus nebulosus* |
| Brown Trout | *Salmo trutta* |
| Burbot | *Lota lota* |
| Carp | *Cyprinus carpio* |
| Channel Catfish | *Ictalurus punctatus* |
| Chinook Salmon | *Oncorhynchus tshawytscha* |
| Cisco | *Coregonus artedii* |
| Coho Salmon | *Oncorhynchus kisutch* |
| Eurasian Ruffe | *Gymnouphalus cernuus* |
| Freshwater Drum | *Aplodinotus grunniens* |
| Gizzard Shad | *Dorosoma cepedianum* |
| Johnny Darter | *Etheostoma nigrum* |
| Lake Sturgeon | *Acipenser fulvescens* |
| Lake Trout | *Salvelinus namaycusn* |
| Lake Whitefish | *Coregonus clupeaformis* |
| Largemouth Bass | *Micropterus salmoides* |
| Longnose Gar | *Lepisosteus osseus* |
| Longnose Sucker | *Catostomus catostomus* |
| Menominee | *Prosopium cylindraceum* |
| Northern Hogsucker | *Hypentelium nigricans* |
| Northern Pike | *Esox lucius* |
| Pink Salmon | *Oncorhynchus gorbuscha* |
| Pumpkinseed | *Lepomis gibbosus* |
| Rainbow Smelt | *Osmerus mordax* |
| Rainbow Trout | *Oncorhyhus mykiss* |
| Redhorse spp. | *Moxostoma spp.* |
| Rock Bass | *Ambloplites rupestris* |
| Round Goby | *Neogobius melanostomus* |
| Sculpin | *Cottus bairdi* |
| Sea Lamprey | *Petromyzon marinus* |
| Shorthead Redhorse | *Moxostoma macrolepidotum* |
| Silver Redhorse | *Moxostoma anisurum* |
| Smallmouth Bass | *Micropterus dolomievi* |
| Splake | *S. fontinalis x S. namaycusn* |
| Sunfish spp. | *Lepomis spp.* |
| Muskellunge | *Esox masquinongy* |
| Trout-Perch | *Percopsis omiscomaycus* |
| Walleye | *Sander vitreus* |
| White Bass | *Morone chrysops* |
| White Crappie | *Pomoxis annularis* |

Appendix 1 continued.

| | |
|---|---|
| White Perch | *Morone americana* |
| White Sucker | *Catostomus commersoni* |
| Yellow Perch | *Perca flavescens* |

Appendix 2. Total catch and cumulative species by net set type: Full Mesh Nets (all 10 mesh panels) and Traditional Mesh Nets (4 meshes, extrapolated to 304.8 m) for the surveys years 2002 to 2017. High-lighted are new species for each year.

| | Cumulative Full Mesh Nets | | | | | Cumulative Traditional Mesh Nets | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | 2002 | 2006 | 2009 | 2013 | 2017 | 2002 | 2006 | 2009 | 2013 | 2017 |
| Alewife | 467 | 47 | 10 | 61 | 8 | 69 | | 1 | 6 | |
| Atlantic Salmon | | | | 1 | 1 | | | | 1 | 1 |
| Black Crappie | | 1 | | 10 | 1 | | | | 4 | 1 |
| Bloater | 1 | | | | | 1 | | | | |
| Bluegill | | | | 2 | 1 | | | | | 1 |
| Bowfin | | | | | 1 | | | | | 1 |
| Brown Bullhead | 114 | 117 | 85 | 118 | 205 | 78 | 46 | 62 | 49 | 185 |
| Burbot | 4 | 3 | 7 | 9 | 8 | 1 | | 3 | 3 | 2 |
| Carp | 2 | 8 | | 2 | | | 1 | | 1 | |
| Channel Catfish | 1 | 13 | 5 | 5 | 4 | | 2 | | 2 | |
| Chinook Salmon | 28 | 12 | 2 | 4 | 2 | 5 | 2 | 1 | 3 | 1 |
| Cisco (Lake Herring) | 125 | 152 | 292 | 103 | 45 | 77 | 48 | 180 | 62 | 30 |
| Coho Salmon | | 1 | | 1 | | | | | | |
| Creek Chub | | | 9 | | | | | | | |
| Freshwater Drum | 19 | 47 | 18 | 14 | 4 | 6 | 8 | 3 | 1 | |
| Gizzard Shad | 4 | 1 | | 1 | | 2 | | | 1 | |
| Lake Sturgeon | 1 | | 5 | 5 | 26 | | | | 1 | 6 |
| Lake Trout | | 6 | 7 | 2 | 5 | | 1 | 3 | 1 | 1 |
| Lake Whitefish | 34 | 21 | 65 | 16 | 26 | 15 | 4 | 41 | 7 | 14 |
| Largemouth Bass | | 1 | | | | | 1 | | | |
| Longnose dace | | | 1 | | | | | | | |
| Longnose Gar | 1 | 3 | | 4 | | 1 | 1 | | 1 | |
| Longnose Sucker | 53 | 54 | 71 | 7 | 52 | 37 | 27 | 46 | 2 | 28 |
| Moxostoma sp. | 22 | 15 | 135 | 29 | 7 | 7 | 6 | 58 | 13 | 3 |

Appendix 2 continued.

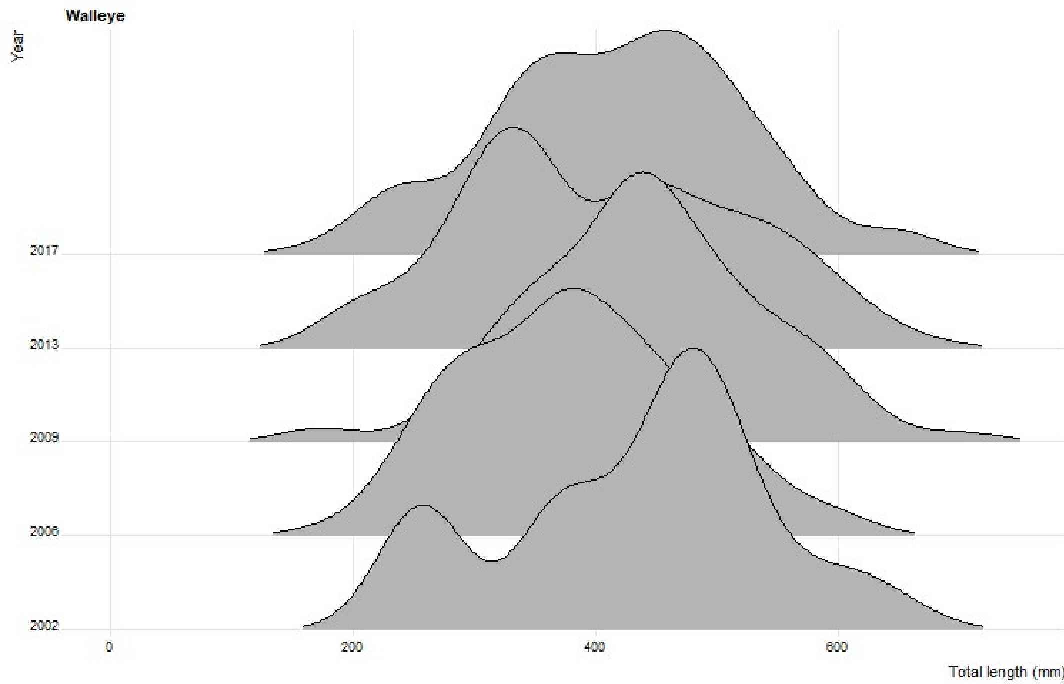
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Muskellunge | | | | 1 | | | | | | |
| Northern Pike | 68 | 71 | 80 | 101 | 180 | 46 | 52 | 53 | 78 | 123 |
| Pink Salmon | 17 | 6 | 1 | 6 | | 5 | 3 | 1 | 2 | |
| Pumpkinseed | 18 | 11 | 17 | 2 | 5 | 17 | 9 | 15 | | 5 |
| Rainbow Smelt | 11 | 59 | 37 | 45 | 44 | 7 | 6 | 29 | 23 | 36 |
| Rainbow Trout | 1 | | | | | 1 | | | | |
| Rock Bass | 262 | 245 | 182 | 285 | 184 | 201 | 195 | 138 | 191 | 135 |
| Round Whitefish (Menonimee) | 16 | 36 | 77 | 17 | 112 | 14 | 3 | 59 | 14 | 92 |
| Ruffe | | | | | 10 | | | | | 1 |
| Sea Lamprey | | | 1 | | 2 | | | 1 | | 1 |
| Shorthead Redhorse | | 24 | 13 | 21 | 8 | | 11 | 5 | 7 | 5 |
| Silver Redhorse | 1 | | 13 | 2 | 6 | 1 | | 3 | | |
| Smallmouth Bass | 65 | 183 | 76 | 252 | 125 | 40 | 86 | 32 | 118 | 65 |
| Trout-perch | 2 | | | | | 1 | | | | |
| Unknown fish species | 2 | 1 | | | | 2 | | | | |
| Walleye | 112 | 254 | 215 | 288 | 150 | 63 | 152 | 106 | 171 | 90 |
| White Bass | 1 | 1 | 13 | 4 | | | 1 | 4 | 3 | |
| White Crappie | 1 | | | | | | | | | |
| White Perch | 7 | 21 | 2 | 10 | 7 | 6 | 10 | | 6 | 2 |
| White Sucker | 827 | 751 | 795 | 661 | 706 | 436 | 240 | 407 | 310 | 392 |
| Yellow Perch | 1031 | 1677 | 1637 | 1828 | 1291 | 446 | 506 | 622 | 634 | 555 |
| Total Catch | 3318 | 3842 | 3871 | 3917 | 3226 | 1585 | 1421 | 1873 | 1715 | 1776 |
| Species Count | 32 | 31 | 29 | 34 | 30 | 27 | 25 | 24 | 29 | 26 |
| Cumulative Total | 32 | 37 | 40 | 43 | 45 | 27 | 33 | 34 | 37 | 40 |
| New Species | 0 | 5 | 3 | 3 | 2 | 0 | 6 | 1 | 3 | 3 |

Appendix 3. Length-weight regression equations and von Bertalanffy growth equations for select species from the St. Marys River August – September 2017. Length/weight equation logs are base 10, weight (wt) is in grams, and 1ength (len) is in mm. Von Bertalanffy equations are based on mean length-at-age data where 't' is age in years.

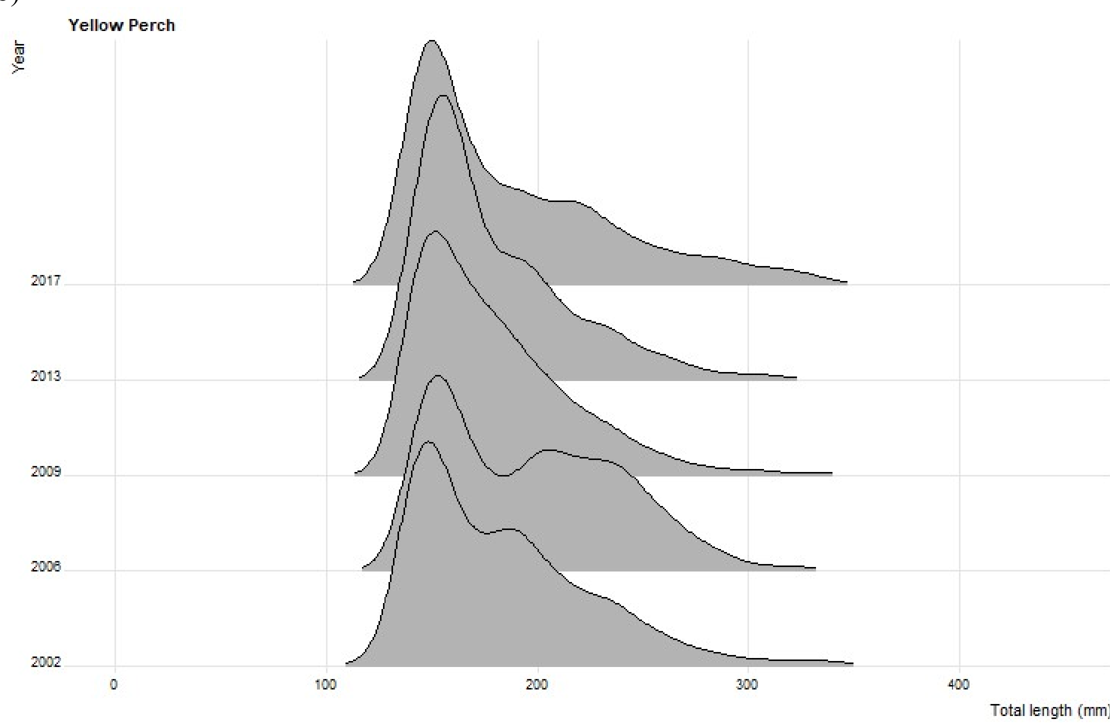
| Species | Length/Weight Equation | Len/Wt $r^2$ | Von Bertalanffy Equation | K | L∞ | $t_o$ |
|---|---|---|---|---|---|---|
| Walleye | log(wt)=3.223 log(len)-5.626 | 0.98 | $L_t=610[1-e^{-0.2708(t-0.26)}]$ | 0.2708 | 610 | 0.26 |
| Yellow Perch | log(wt)=3.118 log(1en)-5.170 | 0.90 | $L_t=348[1-e^{-0.2293(t-0.26)}]$ | 0.2293 | 348 | 0.26 |
| Smallmouth Bass | log(wt)=3.240 log(1en)-5.435 | 0.96 | $L_t=545[1-e^{-0.1703(t+1.51)}]$ | 0.1703 | 545 | -1.51 |
| Northern Pike | log(wt)=3.044 log(1en)-5.355 | 0.94 | $L_t=721[1-e^{-0.2537(t+1.91)}]$ | 0.2537 | 721 | -1.91 |
| Cisco | log(wt)=3.291 log(1en)-5.759 | 0.87 | $L_t=464[1-e^{-0.3348(t+2.32)}]$ | 0.3348 | 464 | -2.32 |

Appendix 4. Length frequencies from survey catch of; (a) Walleye, (b) Yellow Perch, (c) Smallmouth Bass, (d) Northern Pike, (e) Cisco, and (f) Lake Sturgeon from the St. Marys River Fish Community Index Netting Surveys 2002 to 2017.

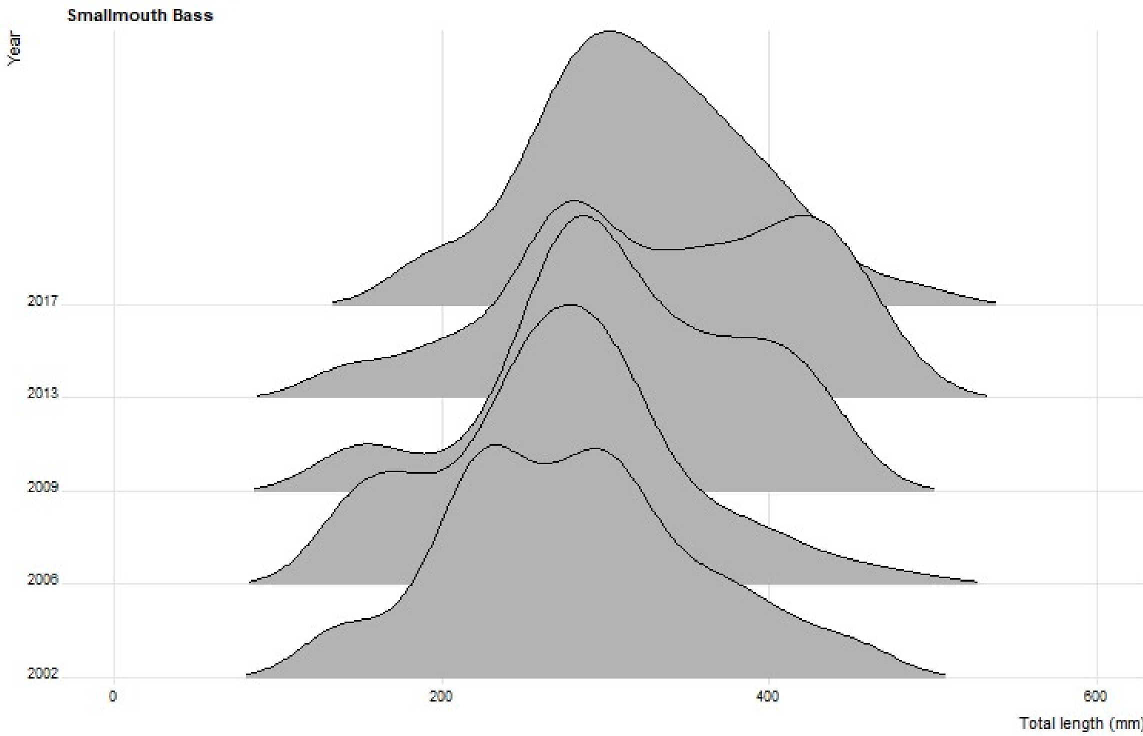
a)




b)

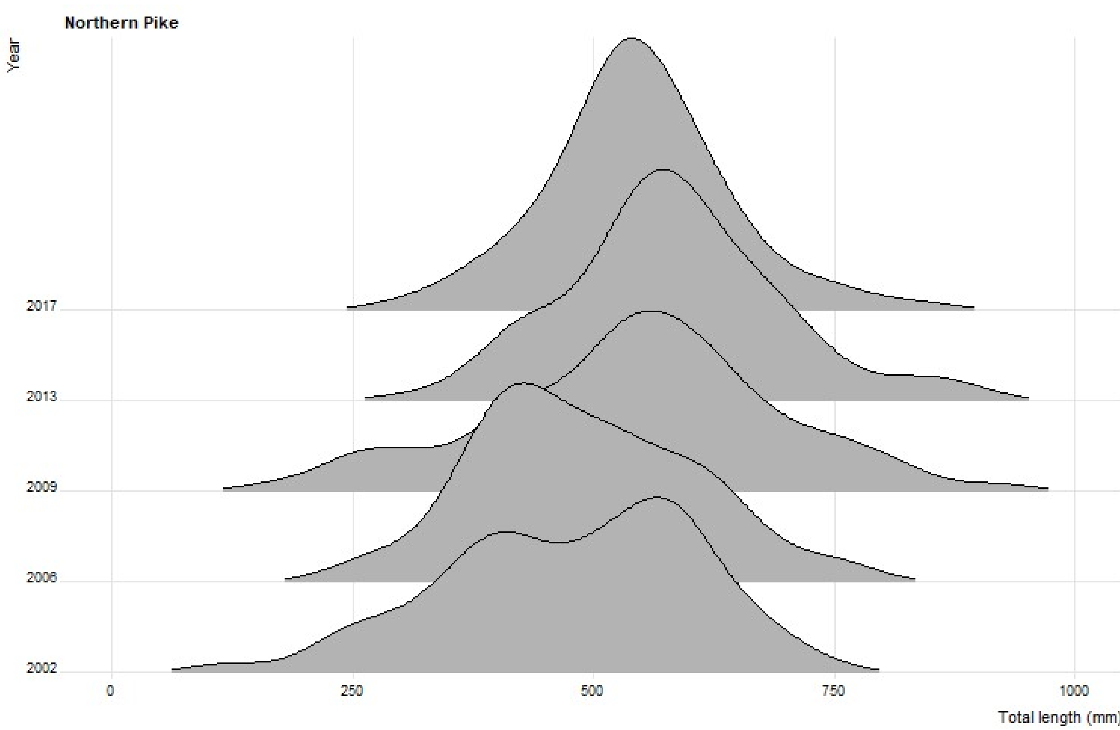


c)



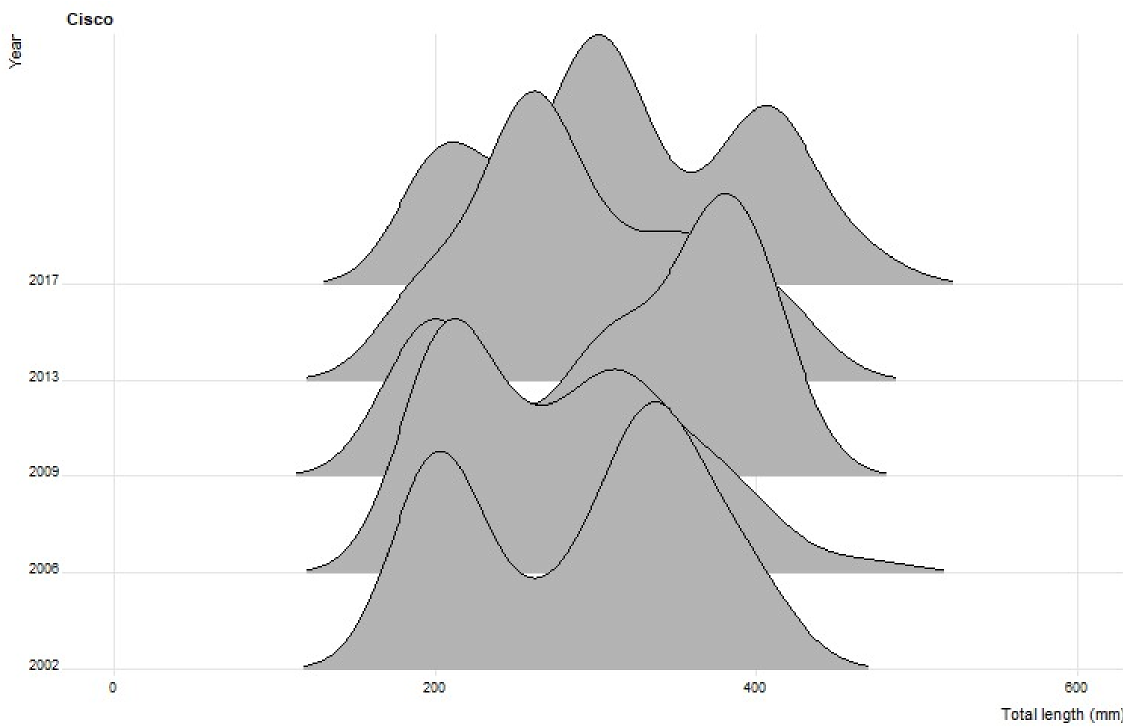
Smallmouth Bass
Year
2017
2013
2009
2006
2002
0
200
400
600
Total length (mm)


d)

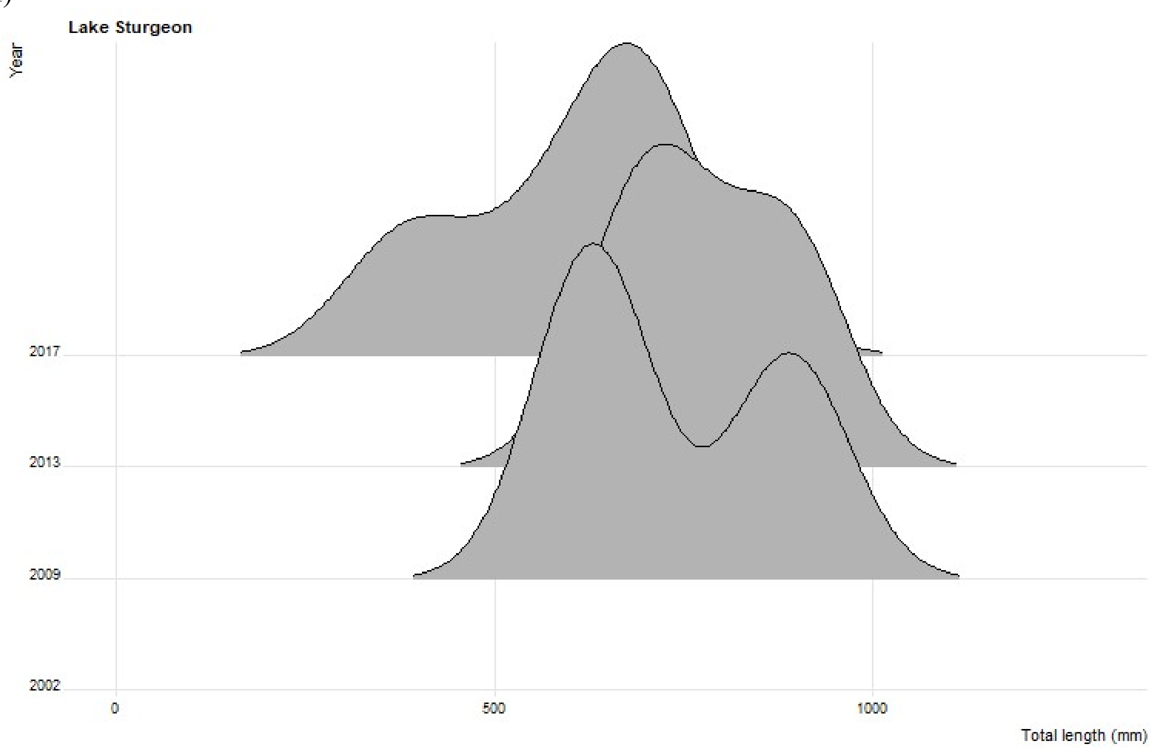


Northern Pike
Year
2017
2013
2009
2006
2002
0
250
500
750
1000
Total length (mm)

e)


Cisco
Year
2017
2013
2009
2006
2002
0
200
400
600
Total length (mm)

f)


Lake Sturgeon
Year
2017
2013
2009
2002
0
500
1000
Total length (mm)

# Appendix 3a: St. Marys River Area of Concern: Coastal Wetland Habitat Assessment Report (Darwin, 2016)

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

## August 2016

Environment and Climate Change Canada
Environnement et Changement climatique Canada

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

**August 2016**

**Environment and Climate Change Canada – Canadian Wildlife Service**

# 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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Cover Photos: Environment and Climate Change 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) 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

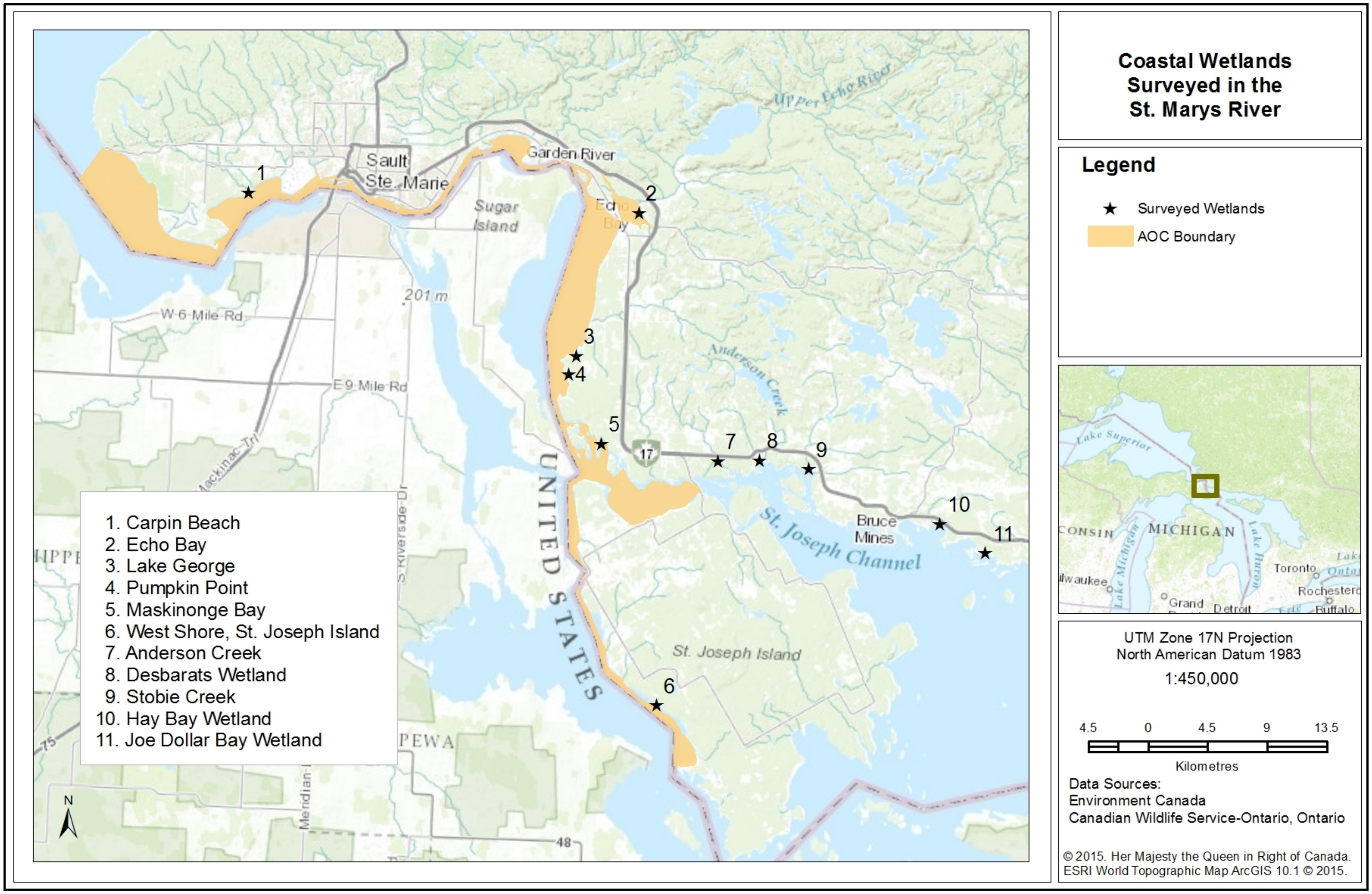


**Figure 1:** Location of coastal wetlands sampled in the St. Marys River from 2012-2015.

# 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.

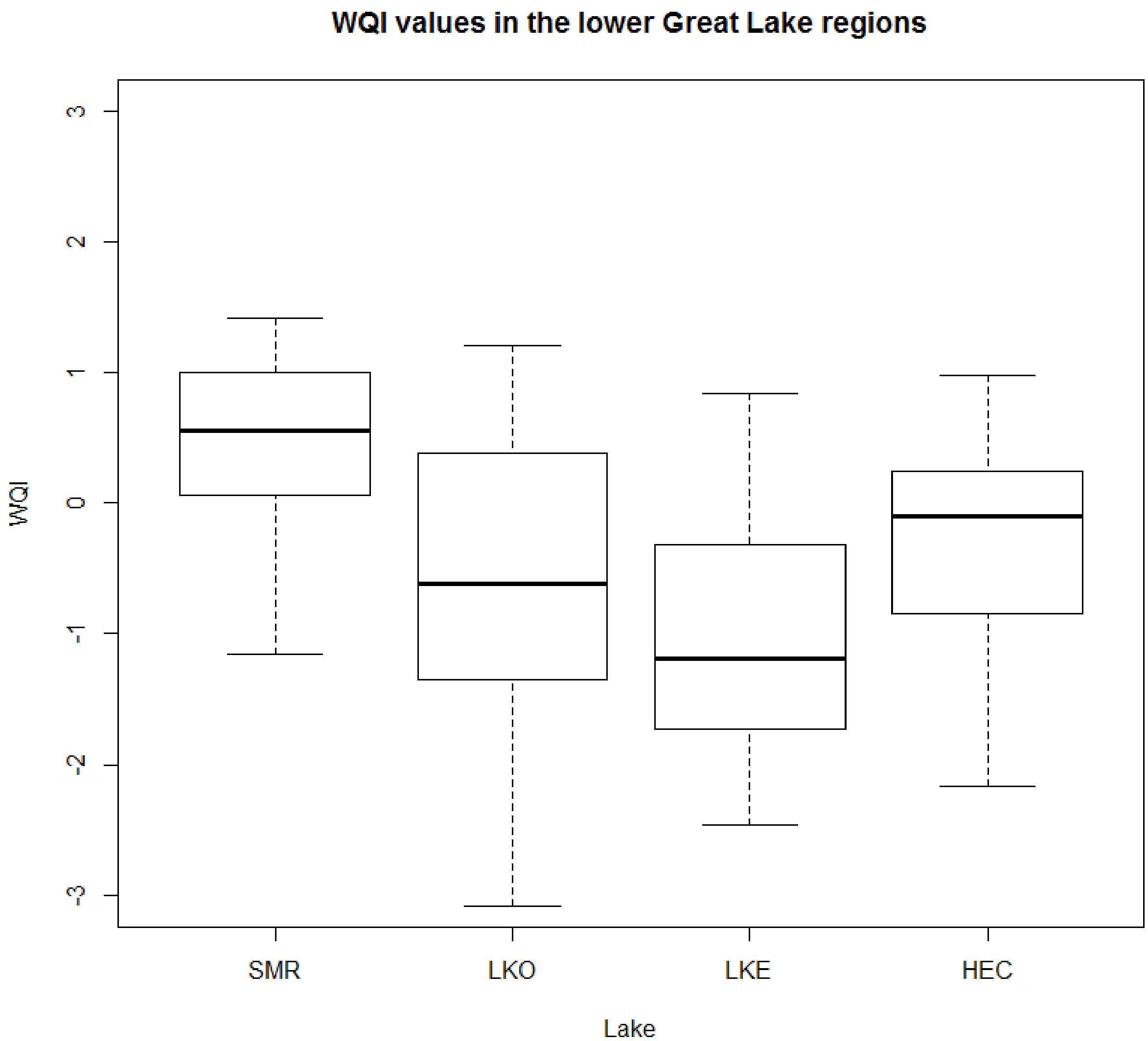


**Figure 2:** Boxplots of the mean WQI values corresponding to each lake/region, where SMR = St. Marys River, LKO = Lake Ontario, LKE = Lake Erie, and HEC = Huron-Erie Corridor. Boxplot "whiskers" indicate the maximum/minimum values, and the top and bottom of the boxplot indicate the 25th and 75th percentiles, 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 ($\mu Scm^{-1}$) 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.

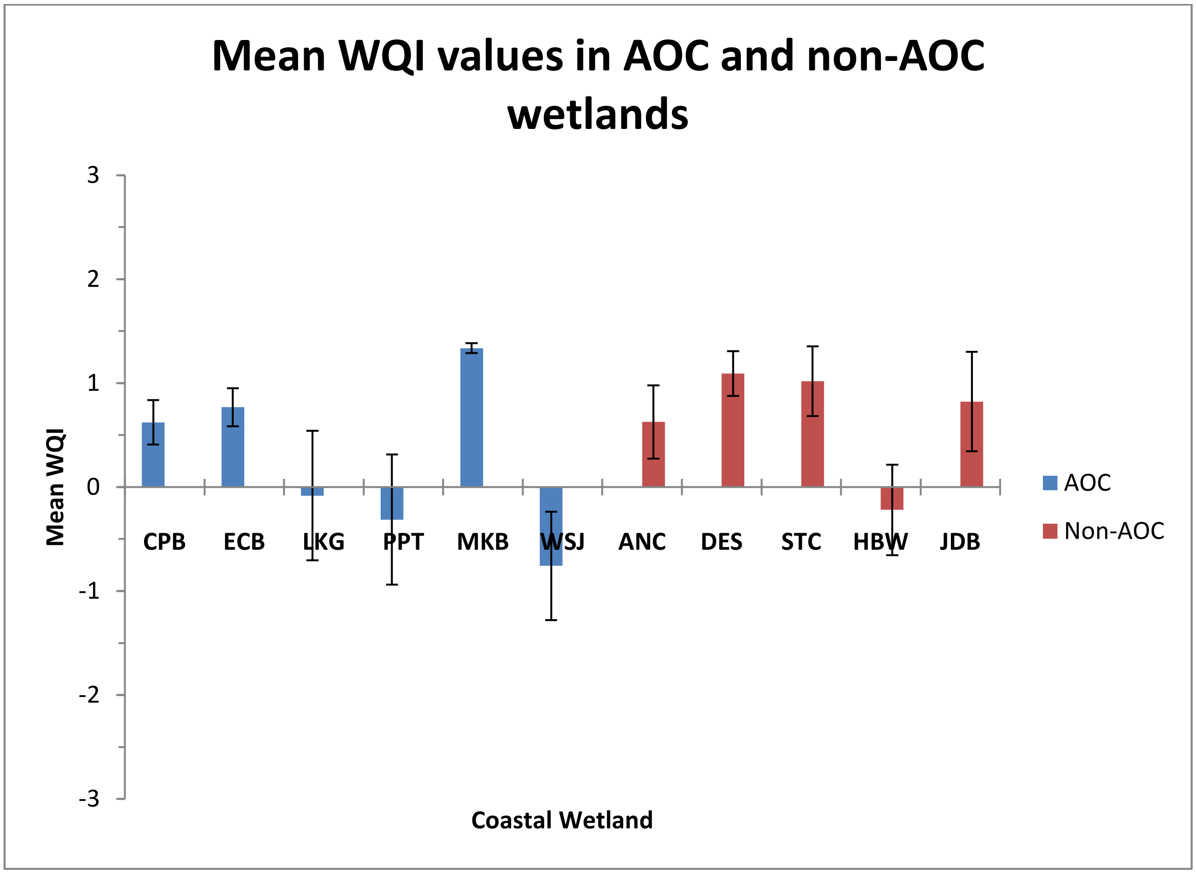


**Figure 3:** Mean WQI values for sampled wetlands during all years for comparisons between sites within the AOC and outside the AOC. CPB = Carpin Beach, ECB = Echo Bay, LKG = Lake George, PPT = Pumpkin Point, MKB = Maskinonge Bay, WSJ = West Shore, St. Joseph's Island, ANC = Anderson Creek, DES = Desbarats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

# Appendix 3b: An Assessment of Breeding Populations of Common Terns and Black Terns in the St. Marys River Area of Concern, Ontario (Hughes et al. 2014)

# An Assessment of Breeding Populations of Common Terns and Black Terns in the St. Marys River Area of Concern (Ontario)

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Environment Canada Environnement Canada

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## Purpose

The purpose of this summary is to report on the results of recent assessments of breeding populations of Common Terns (*Sterna hirundo*) and Black Terns (*Chlidonias niger*) within the St. Marys River Area of Concern (AOC) (Ontario) following the recommended action put forward in the Stage 2 Remedial Action Plan report (Environment Canada *et al.* 2002). These assessments are based on nest count surveys conducted in the AOC and are supplemented with historical breeding data for these species where available. Population trends for other colonial waterbirds based on decadal surveys are also reported to provide a broader historical context of trends in diversity and abundance of breeding colonial waterbirds in the St. Marys River AOC.

## Methods

Since the 1970s, Canadian Wildlife Service (CWS) biologists have conducted four decadal surveys of colonial waterbirds nesting on the Canadian side of the Great Lakes. In the St. Marys River (Ontario), these surveys were completed in 1978/80 (1st survey), 1989 (2nd survey), 1999/2000 (3rd survey) and with the most recent decadal survey (i.e., 4th survey) in 2007/2008 (Blokpoel and Tessier 1996, 1997, 1998; Morris *et al.* 2003, 2010, 2011, 2012; Rush *et al.* in review; CWS unpublished). During these surveys, all nests of colonial waterbirds were counted individually using the total count methods of Blokpoel and Tessier (1996). The results of decadal surveys of colonial waterbirds in the North Channel of Lake Huron are also reported to provide a comparison of trends downstream and beyond the influence of the AOC. For the purpose of reporting on colonial waterbird trends, the North Channel is defined as the area bounded by the contiguous shoreline from McNab Reef in St. Joseph Lake, which is northeast of Campement d'Ours Island, to Frazer Bay, located southeast of McGregor Point on the mainland. The southern boundary of the North Channel includes Manitoulin Island, Cockburn Island and the international boundary.

In addition to the decadal surveys conducted within the AOC, additional surveys were conducted from 2010-2013 as part of two separate Environment Canada (EC) studies of Common Terns in the region. Nest counts from these studies are included to examine more recent trends in abundance in the AOC. One of these studies was conducted in 2011 and 2012 to assess the reproductive status of Common Terns and Herring Gulls breeding within the St. Marys River AOC (Hughes *et al.* 2014). Noteworthy is that in 2011 the only breeding Common Tern colony in the AOC was at an island NNW of Hay Point near the southwestern shoreline of St. Joseph Island. This colony was abandoned early in the breeding season and subsequently a colony located at North Sister Rock, just beyond the AOC boundary in St. Joseph Lake, was selected as the alternate AOC colony. For consistency purposes in this report, this nesting site as well as four other small tern nesting sites (i.e., McNab Reef, Hurt Rock, islet 200m SW of mouth of Sucker Creek, and South Sister Rock) are considered to be part of the AOC. This cluster of nesting sites, consisting of small rocks, are in close proximity to one another and are situated approximately 6 kilometres beyond the eastern AOC boundary at Quebec Bay. Surveys of these Common Tern nesting sites as well as other sites downstream were conducted from 2010-2013 as part of another EC study of breeding site tenacity and productivity of Common Terns on the North Channel (D.J. Moore, CWS unpublished). Similar to that reported above, temporal trends of Common Tern populations in the St. Marys River AOC will be compared to trends reported for tern populations in the North Channel.

As part of the CWS decadal survey of Great Lakes coastal marshes conducted in 2010, marsh habitat within a 5 kilometre band along the St. Marys River shoreline was surveyed for Black Terns, as well as other marsh-nesting waterbirds. Nest counts were determined by either counting individual nests or by halving the maximum number of adult terns counted during a series of sweeps with binoculars and/or a spotting scope. Historical breeding data for Black Terns in the AOC are provided where available. These include CWS decadal surveys of coastal marshes (Graham *et al.* 2002) as well as evidence of breeding status based on data collected for the first and second Ontario Breeding Bird Atlases in the St. Marys River (Cadman *et al.* 1987, 2007).

## Results and Discussion

### Historical Context – Colonial Waterbirds in the St. Marys River AOC (Ontario)

As part of the 4th decadal CWS Great Lakes colonial waterbird survey, four species including the Herring Gull (*Larus argentatus*), Common Tern, Ring-billed Gull (*Larus delawarensis*) and the Great Blue Heron (*Ardea herodias*) were found nesting on the St. Marys River (Ontario) (CWS unpublished; Table 1a). In total, 882 nests (=breeding pairs) were found at eight nesting sites situated on natural habitat that consisted of islands, reefs, shoals, and the mainland (Figure 1). Herring Gulls were the most abundant species nesting at six sites with colonies ranging in size from 42 nests at one of two islands south of Pumpkin Point to 159 nests at the island west of Chene Island in the northern portion of the AOC. Ring-billed Gulls were the next most abundant species and were found nesting at the shoal northeast of Whitestone Reef (262 nests) and the island west of Chene Island (83 nests). Common Terns were found nesting at two sites with colonies on the island NNW of Hay Point near the southwestern shoreline of St. Joseph Island (68 nests) and a nearby shoal west of Hay Point (10 nests). These two Common Tern nesting sites were not visited in 2008 as part of the survey for nesting terns in the St. Marys River; however, they were visited in 2010 and counts at these two sites are considered part of the 4th decadal survey. A single Great Blue Heron nest was found on Whitestone Reef in 2008.

Over the four CWS Great Lakes colonial waterbird decadal surveys on the St. Marys River, numbers of Herring Gull nests have remained high at over 450 nests (Blokpoel and Tessier 1996, 1997; Morris *et al.* 2003; CWS unpublished; Table 1a). Nest numbers decreased by -36.0% between the 3rd and 4th decadal surveys from 716 nests in 1999/2000 to 458 nests in 2007/2008. Ring-billed Gull nests which were relatively fewer in number during the first three decadal surveys (ranging from 0 nests to 14 nests) increased by two orders of magnitude from two nests found in the 3rd decadal survey to 345 nests in the 4th decadal survey (Blokpoel and Tessier 1996, 1997; Morris *et al.* 2011; CWS unpublished). Common Terns nested at two sites, Whitestone Reef and the island NNW of Hay Point, in the AOC in the 1st decadal survey (70 nests) and the 2nd decadal survey (159 nests; Blokpoel and Tessier 1996, 1997). While no nesting of Common Terns was reported in the AOC during the 3rd decadal survey in 1999, numbers of Common Tern nests increased in the 4th decadal survey (78 nests; CWS unpublished). The apparent abandonment of nesting sites by Common Terns in the AOC during the 3rd decadal survey is likely related to the low site fidelity shown by this species (see below), particularly evident in an area where only three nesting sites have been historically reported. Great Blue Heron nests were found in low numbers at two different sites in two of the four decadal surveys: at an island south of Pumpkin Point in the 2nd decadal survey (3 nests) and at Whitestone Reef in the 4th survey in 2008 (1 nest; Blokpoel and Tessier 1998; CWS unpublished). Overall, the total number of colonial waterbird nests on the St. Marys River (Ontario) increased by +22.8% from 718 nests in 1999/2000 to 882 nests in 2007/2008, a finding largely driven by the dramatic increase in nesting Ring-billed Gulls in the AOC.

Table 1. Census data of colonial waterbird nests (=breeding pairs) on the Canadian side of the St. Marys River (a) during the 1st (1978/80), 2nd (1989), 3rd (1999/2000) and 4th (2007/08) decadal surveys as part of the Great Lakes colonial waterbird surveys conducted by the Canadian Wildlife Service (Blokpoel and Tessier 1996, 1997, 1998; Morris *et al.* 2003, 2010, 2011, 2012; CWS unpublished). Census data for colonial waterbirds on the North Channel of Lake Huron during the four decadal surveys are shown in (b). Percent change in nest numbers are based on comparisons between the 3rd and 4th surveys; NC denotes that rate cannot be calculated.

a) St. Marys River (Ontario):

| **Species** | **Census Year** | | | | **Percent** |
|---|---|---|---|---|---|
| | **1978/80** | **1989** | **1999/2000** | **2007/08*** | **Change** |
| Herring Gull | 539 | 612 | 716 | 458 | -36.0% |
| Ring-billed Gull | 0 | 14 | 2 | 345 | +17150% |
| Common Tern | 70 | 159 | 0 | 78 | NC |
| Great Blue Heron | 0 | 3 | 0 | 1 | NC |
| **Totals** | **609** | **788** | **718** | **882** | **+22.8%** |

* Includes census data for two Common Tern nesting sites that were surveyed in 2010.

b) North Channel:

| **Species** | **Census Year** | | | | **Percent** |
|---|---|---|---|---|---|
| | **1980** | **1989/91** | **1997-2001** | **2008/09** | **Change** |
| Herring Gull | 5,551 | 3,706 | 4,291 | 3,377 | -21.3% |
| Common Tern | 2,680 | 1,360 | 1,954 | 1,924 | -1.5% |
| Ring-billed Gull | 53,645 | 48,405 | 35,117 | 23,898 | -31.9% |
| Great Blue Heron | 206 | 82 | 108 | 43 | -60.2% |
| Caspian Terns | 547 | 603 | 338 | 377 | +11.5% |
| Double-crested Cormorant | 159 | 2,177 | 6,716 | 7,380 | +9.9% |
| Black-crowned Night Heron | 0 | 0 | 9 | 48 | +433% |
| Great Black-backed Gull | 0 | 0 | 1 | 0 | -100% |
| **Totals** | **62,788** | **56,333** | **48,534** | **37,047** | **-23.7%** |

Population trends of colonial waterbirds breeding in the North Channel of Lake Huron during the four decadal surveys are provided in Table 1b as a comparison to trends downstream of the St. Marys River AOC (Blokpoel and Tessier 1996, 1997, 1998; Morris *et al.* 2003, 2010, 2011, 2012, Morris *et al.* in press; Rush *et al.* in review; CWS unpublished). Seven species were reported breeding in the North Channel during the 4th decadal survey in 2008/09. In addition to the four species breeding within the AOC, Caspian Tern (*Hydroprogne caspia*), Double-crested Cormorant (*Phalacrocorax auritus*), and Black-crowned Night-Heron (*Nycticorax nycticorax*) were also found nesting. This region has historically

Figure 1. Locations of nesting sites for colonial waterbirds (white circles) and Black Terns (red circle) within the St. Marys River Area of Concern (Ontario) during surveys conducted in 2007/08/10. Also shown is the general location of the five Common Tern nesting sites (McNab Reef, Hurt Rock, Islet SW of mouth of Sucker Creek, North Sister Rock and South Sister Rock) situated just beyond the AOC boundary and considered within the AOC for the assessment of Common Tern populations in this report.

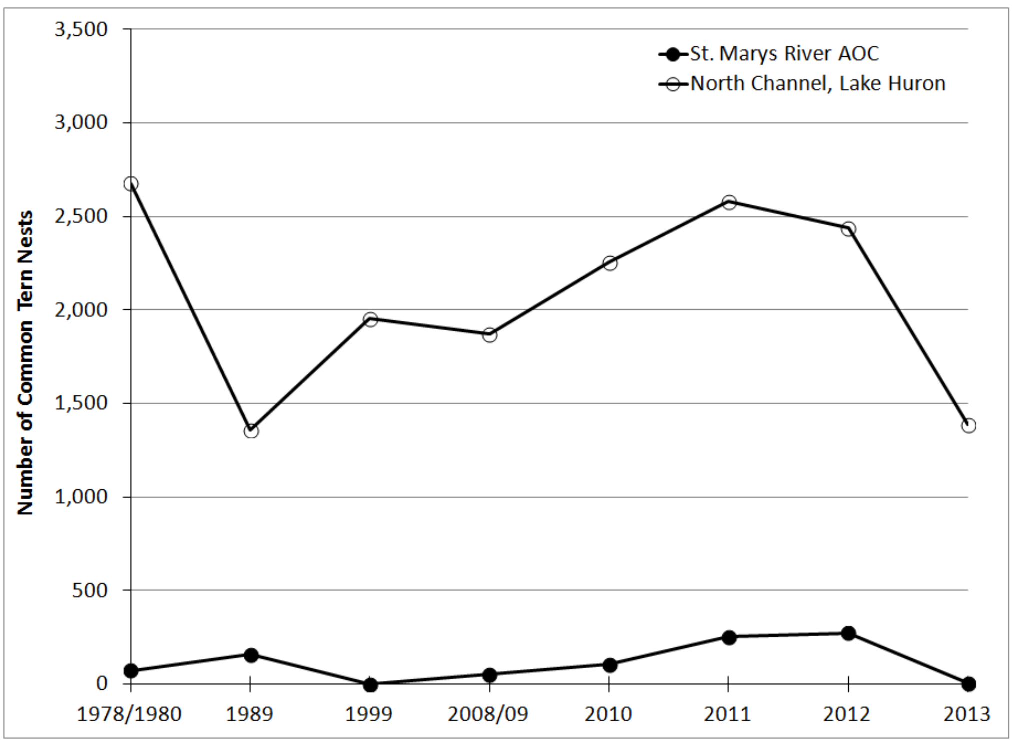

supported a rich diversity of colonially nesting waterbirds owing to its large expansive area consisting of numerous islands, reefs and rocks ideal as nesting habitat with the surroundings waters providing an abundant food supply. Over 37,000 nests were counted at 129 nesting sites during this survey period. Between the 3rd and 4th decadal surveys, increases in nest numbers were found for Caspian Terns (+11.5%), Double-crested Cormorants (+9.9%), and Black-crowned Night-Heron (+433%) in the North Channel. Similar to trends in the AOC, a decrease in nest numbers was found for Herring Gulls (-21.3%) while, in contrast to the AOC, decreases in nest numbers of Common Terns (-1.5%), Ring-billed Gulls (-31.9%), and Great Blue Heron (-60.2%) were found in the North Channel between the two last surveys. While a single Great Black-backed Gull (*Larus marinus*) nest was found in 1999, no nesting was reported by this species in this region in 2009. In the North Channel, a steady decrease in numbers of breeding colonial waterbirds has been found since the first decadal survey with an overall decrease in nest numbers of colonial waterbirds by -23.7% between the 3rd and 4th decadal surveys.

## Trends in Breeding Populations of Common Terns

Based on the results of the four CWS Great Lakes decadal surveys and supplemented with data from recent surveys conducted by EC from 2010-2013, the total nesting population of Common Terns in the St. Marys River AOC generally ranged in size from a total of 53 nests in 2008 to 273 nests in 2012 (Figure

2). These counts include the additional five small nesting sites situated just beyond the AOC boundary as cited in the Methods (Figure 1). In two years, 1999 and 2013, nest numbers in the AOC were notably low with 1 and 3 nests, respectively, at single nesting sites. While a total of eight different nesting sites were occupied in the AOC during these eight surveys, numbers of nesting sites in each survey year ranged from one to five. The largest nesting colonies and corresponding years reported were: island NNW of Hay Point (1980, 1989, 2010: range=39-129 nests), McNab Reef (1999: 1 nest, 2008: 48 nests), South Sister Rock (2011: 109 nests), North Sister Rock (2012: 129 nests), and Hurt Rock (2013: 3 nests). Note that nest counts for two sites (i.e., island NNW of Hay Point and the nearby shoal west of Hay Point) in 2010 are grouped with census data for other colonies surveyed in that year. As a result, the total nest count may be underestimated in 2008/09 since these two colonies were not visited in that period. A complete listing of the eight nesting sites and corresponding nest numbers for the eight survey periods is provided in the Appendix.

Figure 2. Total nest counts of Common Terns in the St. Marys River AOC (Ontario) and the North Channel of Lake Huron for the four decadal surveys, 1978/80, 1989, 1999, and 2008/09 and annual surveys conducted from 2010-2013 as part of two complementary EC studies of Common Terns in the region. Note that the first four time-points on the x-axis are not evenly spaced time periods.




Breeding populations of Common Terns downstream in the North Channel were consistently higher than breeding populations in the St. Marys River AOC in every survey year (Figure 2). Colony sizes were larger and nesting sites were more numerous with total numbers of nesting sites ranging from 13 sites in 2010 to 28 sites in 1980. The largest nesting colonies and corresponding years reported were: island NE of Thessalon Dock (1980: 661 nests), island SW of Henry Island (1989, 2008, 2013: range=307-534 nests), Batture Island (1999: 478 nests) and E island of the Cousins Islands (2010, 2011, 2012: range=525-1,142 nests). Nest numbers in this region were the highest in 1980 (2,677 nests), decreased in 1989 (1,360 nests), slowly increased reaching a peak in 2011 (2,582 nests) and then decreased in 2012 (2,440 nests) and 2013 (1,386 nests). While general declines in breeding populations of Common Terns have been reported throughout the Canadian Great Lakes over the four decadal surveys (Morris *et al.* 2012), declines in nest numbers were not as pronounced at colonies on Lake Huron (including the North Channel, as shown here) as those found on the lower Great Lakes.

Despite differences in the relative sizes of the breeding populations in the St. Marys River AOC and North Channel, there are some similarities in the patterns of abundance and site occupancy of Common Terns between the two regions which contributed to inter-year fluctuations in nest numbers observed. Specifically, nesting sites were not consistently occupied from year to year and there appeared to be considerable turnover in nesting sites between years. In the AOC, five of eight nesting sites (63%) were occupied in only one or two years of eight survey years and the remaining three sites were occupied in either three (South Sister Rock), four (North Sister Rock) or five (island NNW of Hay Point) survey years. This pattern of low site fidelity was effectively demonstrated in a broad EC 2010-2012 study of Common Terns in the North Channel where comparisons of nesting sites showed considerable turnover between consecutive study years: 14-59% of sites were abandoned, 9-55% of sites were newly colonized and 31-42% of sites remained active (D.J. Moore, CWS unpublished). These findings were further supported by the longer term decadal survey data for Common Terns in the North Channel (D.J. Moore, CWS unpublished). Morris *et al.* (2012) found similar evidence of shifts in site occupancy with high rates of abandonment and high rates of colonization of new sites at tern colonies on the Canadian Great Lakes (based on the decadal surveys), Newfoundland and New Brunswick.

These results highlight that low site fidelity in Common Terns is an important life history trait which must be considered in interpreting trends in abundance of Common Terns both at the local level (i.e., nesting colony) and the larger regional area. Inter-year fluctuations in nest numbers would be more pronounced in regions such as the AOC where Common Terns breed in relatively low numbers and at few nesting sites. In addition, the nearby proximity of the North Channel as well as the U.S. side of the St. Marys River with ample suitable habitat may facilitate selection of these regions as alternate nesting sites. This strategy may be beneficial for reproductive success under conditions of stress such as when predators are present. In 2011, significant predation of tern eggs early in the breeding season at the Hay Point colony in the EC Common Tern reproduction study was suspected to have resulted in abandonment of the colony which led to the subsequent selection of the next nearest colony for study at North Sister Rock. Predation was also severe at some North Channel nesting sites from 2010-2013 (CWS unpublished). Other general stressors known to influence productivity of Common Terns include adverse weather and water level fluctuations which were responsible for egg and chick losses at some North Channel nesting sites in 2010-2013 (CWS unpublished). Periods of high water levels in the northern Great Lakes have also been associated with loss of Common Tern nesting sites which would also impact population trends (Schugart and Scharf 1983). Contaminant levels in eggs of Common Terns collected from AOC colonies in 2011 and 2012 were not sufficiently high to impact reproductive success and development (Hughes *et al.* 2014). Based on the evidence from nest count surveys conducted from

1980 to 2013, trends in populations of nesting Common Terns in the AOC are likely related to factors consistent with the life history strategies of the species and that are not specific to influences in the AOC.

### Trends in Breeding Populations of Black Terns

Based on the results of the CWS survey of marsh-nesting terns conducted in 2010, a large colony of Black Terns (88 nests) was found at Echo Bay, a large coastal wetland on Lake George (Figure 1). No other breeding colonies of Black Terns were found at coastal marshes along the St. Marys River (Ontario) shoreline. Additional evidence of Black Terns breeding at Echo Bay was also found in 2012 (point count surveys; Environment Canada 2013) and in 2013 when approximately 20 breeding pairs (nests) were counted (T. Hoar, pers. comm.).

Table 2 provides a summary of available data reporting breeding status of Black Terns at sites within the AOC, just beyond the AOC border and on the North Channel shown for comparisons purposes. During the CWS decadal survey conducted in 2001, one Black Tern colony (16 nests) was found on St. Joseph Island (Graham *et al.* 2002). This survey did not include Echo Bay or Pumpkin Point. No nests were found in surveys of sites beyond the AOC border and the North Channel in 2001 and 2010 although only a portion of the North Channel was surveyed in 2010. Overall it is not possible to report on temporal trends in abundance of Black Terns in the AOC since only two CWS surveys were conducted and some sites were not surveyed in both years. While an earlier CWS decadal survey of Great Lakes marsh-nesting terns was conducted in 1991, surveys did not include areas north of McGregor Bay near Little Current, Lake Huron and thus did not include the St. Marys River (Austen *et al.* 1996). Using data collected for the two Breeding Bird Atlases, nesting was confirmed at sites within the AOC during the periods 1981-1985 and 2001-2005 (Cadman *et al.* 1987, 2007). Based on the very limited data reported here, there is no evidence to suggest that breeding status for Black Terns nesting within the AOC differs from those nesting at sites downstream in the North Channel.

The Black Tern is a species of Special Concern in Ontario. Long term trends of Black Terns based on data collected by the Marsh Monitoring Program from 1995 to 2007 indicate a significant Great Lakes basin decline for Black Terns at a rate of -11.4% per year (Archer and Jones 2009). These trends are supported by Breeding Bird Survey data from 1970-2012 that showed population declines for Black Terns in Ontario at a rate of -5.54% per year and regionally in the Boreal Hardwood Transition Zone (Bird Conservation Region 12), which includes regions along the St. Marys River and North Channel shorelines, at a rate of -6.43% per year (Environment Canada 2014). As reviewed by Burke (2012), Black Tern populations in Ontario have disappeared from many traditional nesting sites and have declined at existing sites, particularly in southern Ontario where they were historically most abundant. The destruction and/or degradation of wetlands are among the most important factors contributing to population declines of this species (Dunn and Agro 1995). Habitat quality is also important as Black Terns prefer to nest in a hemi-marsh, i.e., a wetland with 50:50 open water and emergent vegetation. The extensive areas of large coastal wetlands on the St. Marys River provide nesting habitat for Black Terns compared to the sites further downstream in the North Channel which may be less suitable although confirmed breeding was reported on Manitoulin Island (Table 2; Cadman *et al.* 2007). Other

Table 2. Summary of available data reporting breeding status of Black Terns at sites within the St. Marys River AOC, beyond the AOC boundary and in the North Channel from 1981 to 2010. Shown are results of nest counts for surveys conducted by CWS and breeding evidence from the Ontario Breeding Bird Atlas (OBBA) with survey years/periods as indicated. "NS" denotes that the site was not surveyed.

| **Regions** | **OBBA1 square** | **OBBA2 square** | **Site Name** | **CWS Survey# 2001** | **CWS Survey 2010** | **OBBA1^ 1981-85** | **0BBA2^ 2001-05** |
|---|---|---|---|---|---|---|---|
| St. Marys R. AOC | 16GG25 | 16GS25 | Echo Bay | NS | 88 | Possible | Possible |
| St. Marys R. AOC | 16GG24 | 16GS24 | Pumpkin Point | NS | 0 | Confirmed | Confirmed |
| St. Marys R. AOC | 16GG21 | 16GS21 | St. Joseph I. (Everens Pt./Sunset Pt.) | 16 | 0 | Possible | Confirmed |
| St. Marys R. AOC | 16GG22 | 16GS22 | St. Joseph I. (Reed Pt./Court Pt.) | 0 | 0 | Confirmed | Not Breeding |
| St. Marys R. AOC | 16GG31 | 16GS31 | St. Joseph I. (Outlook/Hay Point) | 0 | 0 | Not Breeding | Not Breeding |
| Beyond AOC boundary | 17KB70 | 17KM70 | St. Joseph I. (South A-D) | 0 | 0 | Probable | Not Breeding |
| Beyond AOC boundary | 17KB81 | 17KM81 | St. Joseph I. (Milford Haven) | NS | 0 | Confirmed | Probable |
| North Channel, Lake Huron | 17KB73 | 17KM73 | Desbarats | 0 | 0 | Confirmed | Probable |
| North Channel, Lake Huron | 17LB91 | 17LM91 | Spanish Marsh | 0 | NS | Confirmed | Not Breeding |
| North Channel, Lake Huron | 17MA38 | 17ML38 | Manitoulin Island | 0 | NS | Possible | Confirmed |

# CWS decadal survey of Great Lakes coastal marshes (2001) conducted by Bird Studies Canada (Graham *et al.* 2002)
^ Breeding evidence for the two Ontario Breeding Bird Atlases (Cadman *et al.* 1987, 2007) is categorized as confirmed, probable, possible, or not breeding.

potential stressors include decreased fluctuations in water levels (which can impact the extent of emergent vegetation that is likely more an issue in the lower Great Lakes), increasing numbers of invasive species (that can affect wetland structure) and climate change (Burke 2012). Differences in survey methodology and regions surveyed and few data collection years combined with large-scale population declines make an assessment of trends within the AOC difficult. However, based on the most recent CWS survey of coastal wetlands along the St. Marys River (Ontario) in 2010, the low population size of nesting Black Terns within the AOC is likely reflective of low densities reported throughout region, Great Lakes and Ontario.

## Summary

Recent surveys of Common Terns and Black Terns by CWS on the St. Marys River (Ontario) indicate that these two colonial waterbird species are breeding within the AOC. Common Terns have nested consistently at sites situated both within and just beyond the official AOC boundary in eight survey years. While large inter-year fluctuations in nest numbers were evident at these nesting sites, these patterns are likely related to factors consistent with the life history strategies of this species that are not specific to influences within the AOC. A colony of Black Terns has consistently been reported at Echo Bay, a large coastal wetland, over the last few years. Based on the limited data available, there is no evidence to suggest that breeding status for Black Terns nesting within the AOC differs from that outside of AOC. In addition, the low population size of Black Terns is reflective of low density throughout Ontario rather than conditions specific to the AOC. In general, population declines have been reported for both of these species in the Great Lakes basin. During the most recent CWS decadal survey, four colonial waterbird species were found on the St. Marys River including a new species, the Great Blue Heron, which was not found nesting on this side of the River in the previous survey. Overall, the total number of colonial waterbird nests on the St. Marys River (Ontario) increased by +22.8% from 718 nests in 1999/2000 to 882 nests in 2007/08, a finding largely driven by the dramatic increase in nesting Ring-billed Gulls in the AOC.

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**Appendix.** Nest counts of Common Terns at three sites within the boundary of the St. Marys River AOC (Ontario) as designated by the 41K site ids and the five nesting sites just beyond the AOC border as designated by the 41J site ids. Counts provided are from the four decadal surveys conducted in 1980, 1989, 1999 and 2008 and annual surveys conducted from 2010-2013 as part of two separate EC studies of Common Terns is the region. "-" indicates a site not previously identified and "NS" denotes that the site was not surveyed.

| SiteID | Site Name | 1978/80 | 1989 | 1999 | 2008 | 2010* | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|
| | **Census** | **1** | **2** | **3** | **4** | | | | |
| 41K027 | Whitestone Reef | 31 | 30 | 0 | 0 | NS | 0 | 0 | NS |
| 41K028 | Island NNW of Hay Point | 39 | 129 | 0 | NS | 68 | 18 | 34 | 0 |
| 41K028A | Nearby shoal west of Hay Point | - | - | - | NS | 10 | 0 | 0 | 0 |
| 41J001 | McNab Reef | 0 | 0 | 1 | 48 | 0 | 0 | 0 | 0 |
| 41J002 | Hurt Rock | 0 | 0 | 0 | 0 | 0 | 57 | 0 | 3 |
| 41J002A | Islet 200m SW of mouth of Sucker Creek | - | - | - | 0 | 0 | 3 | 0 | 0 |
| 41J004 | North Sister Rock | 3 | 0 | 0 | 5 | 0 | 68 | 129 | 0 |
| 41J004A | South Sister Rock | - | - | - | 0 | 27 | 109 | 110 | 0 |
| | **Total Number of Nests** | **73** | **159** | **1** | **53** | **105** | **255** | **273** | **3** |
| | **Total Number of Colonies** | **3** | **2** | **1** | **2** | **3** | **5** | **3** | **1** |

* Nest counts for all sites surveyed in 2010 are grouped together and include counts for the two nest sites 41K028 and 41K028A that are considered part of the official 4th decadal CWS survey completed in 2007/08.

## Appendix 3c: Assessment of the Wildlife Reproduction and Deformities Beneficial Use Impairment in the St. Marys River Area of Concern, Ontario (Hughes et al. 2014)

# Assessment of the Wildlife Reproduction and Deformities Beneficial Use Impairment in the St. Marys River Area of Concern (Ontario)

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February 2014

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## ABSTRACT

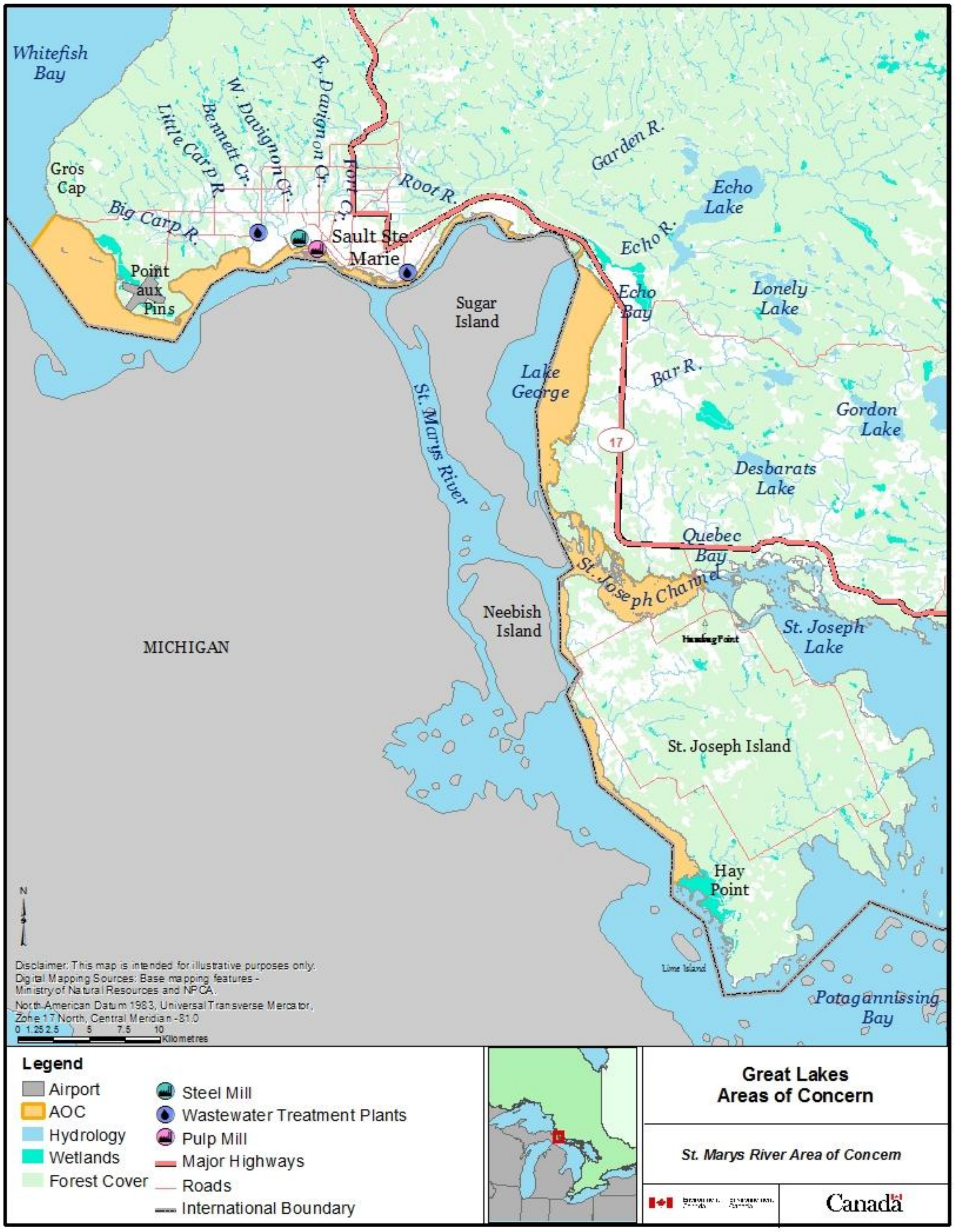
Reproduction and development were examined in herring gulls (*Larus argentatus*) and common terns (*Sterna hirundo*) breeding within the St. Marys River Area of Concern (Ontario) in 2011 and 2012. Freshly-laid eggs were collected from colonies within the Area of Concern (AOC) as well as outside of the AOC, artificially incubated in the laboratory and assessed for embryonic viability, incidence of embryonic deformities, contaminant burdens and other biochemical endpoints. Productivity was determined at the colonies when chicks were $\geq$ 21 days old and chicks were examined for morphological deformities as well as other biological endpoints. Overall, embryonic viability of herring gulls and common terns was high at AOC colonies and herring gull productivity at AOC colonies was within the range required to maintain a stable population. Common tern productivity at AOC colonies, while low, was consistent with rates for common terns within the region and was largely attributable to external stressors, such as predation and severe weather events. No morphological deformities were found in field surveys of juveniles of either species (based on sample sizes of 13-63 chicks); however, a low incidence of embryonic deformities (i.e., 4-8% based on sample sizes of 15-30 embryos) was observed for both species collected from AOC colonies and artificially incubated in the lab. The significance of this finding is unknown at this time. Comparable burdens of non-*ortho* PCBs, 2,3,7,8-TCDD, and TEQs between deformed and normal embryos from AOC colonies of both species rule out the possibility that embryonic deformities were associated with elevated exposure to these compounds. Importantly, contaminant burdens (e.g., PCBs, 2,3,7,8-TCDD, and mercury) in gull and tern embryos from the St. Marys River AOC (Ontario) were comparable and not notably elevated compared to burdens at respective reference colonies in the two study years. Finally, concentrations of PCBs, other organochlorines, PBDEs, dioxins/furans and mercury were not sufficiently elevated in embryos to adversely impact the reproductive success and development of herring gulls and common terns foraging in the St. Marys River AOC.

## INTRODUCTION

The St. Marys River is approximately 112 kilometres in length and is an important and major waterway in the Great Lakes interconnecting Lake Superior and the North Channel of Lake Huron. The St. Marys River Area of Concern (AOC) is one of 43 Great Lakes AOCs which were initially identified by Canada, the United States and the International Joint Commission (IJC) as specific locations where local environmental degradation had severely impacted the area's ability to support aquatic life. Historical discharges of pollutants from local steel and pulp and paper industries, a tannery and manufactured gas plant, and municipal storm sewers and wastewater treatment plants impaired water quality and contaminated sediment along parts of the St. Marys River (OMOE and MDNR 1992). Contaminants of concern included PAHs, mercury and other heavy metals, and polychlorinated biphenyls (PCBs) which contributed to exceedences of water quality objectives, sediment quality guidelines, fish consumption guidelines and impacted biota (OMOE and MDNR 1992; EC *et al.* 2002). The St. Marys River, as a connecting channel, is one of five Great Lakes AOCs jointly shared by Canada and the United States. As directed by Annex 2 of the 1987 Protocol to the Canada-U.S. Great Lakes Water Quality Agreement (GLWQA), a Remedial Action Plan (RAP) for the St. Marys River was developed collaboratively by Canadian and U.S. partners to address environmental concerns that are specific to the Ontario and

Michigan portions of the river, respectively. Implementation of the remedial actions continues. The border of the Canadian portion of the St. Marys River AOC (Ontario) extends from its head at Gros Cap in Whitefish Bay downstream to St. Joseph Island via Lake George to Quebec Bay in the St. Joseph Channel and downstream to Hay Point on the western shore of St. Joseph Island (Figure 1).

Figure 1. The St. Marys River Area of Concern as defined by the boundary in Ontario.



Fourteen beneficial use impairments (BUIs), caused by a detrimental change in the chemical, physical or biological integrity of the Great Lakes system, were used by the Canadian and U.S. federal governments to identify AOCs and then as a framework for directing remediation efforts. One of these BUIs, “bird or animal deformities or reproduction problems”, relates to contaminant exposure or other anthropogenic environmental stressors on reproductive success or deformity rates in wildlife. Based on reports from the 1980s, there were no bird or animal deformities or reproductive problems in the St. Marys River AOC (with limited contaminants data available for wildlife) and this BUI was not impaired (OMOE and MDNR 1992). However, the status of the BUI in the AOC was subsequently changed to “requires further assessment” in the 1990s/early 2000s with the recommendation that reproductive assessments of herring gulls (*Larus argentatus*) and common terns (*Sterna hirundo*) be completed within the AOC (EC *et al.* 2002). It was recommended that deformities be assessed in common terns following evidence of deformities found in three common tern chicks - cross bills - at a colony on Lime Island, Michigan, in 1998. Following this, studies of the potential effects of contaminants on reproduction and development in aquatic-feeding wildlife were initiated by federal, state and provincial agencies to more fully evaluate and assess the current status of this BUI in the St. Marys River AOC.

Fish-eating wildlife, such as colonial waterbirds, are important indicators of exposure to persistent contaminants in the aquatic environment (Fox and Weseloh 1987). As top predators, they occupy a high trophic level in the aquatic food web and therefore can accumulate high levels of contaminants which may in turn adversely affect their reproductive health and development. Two colonial waterbird species which breed and forage within the St. Marys River AOC were selected for assessment purposes. The herring gull is a long-lived, primarily fish-eating colonial waterbird that from the time it reaches breeding age is a year-round resident in the Great Lakes basin. The common tern, as an obligate piscivore, is an excellent bio-indicator for tracking potential problems relating to PCB contamination since they are very sensitive to the dioxin-like effects of certain PCBs (Nisbet 2002). In 2011 and 2012, breeding colonies of these two species were studied by Environment Canada (EC) in the St. Marys River AOC (Ontario). Eggs were collected for artificial incubation in the laboratory to assess embryonic viability, incidence of embryonic deformities, contaminant burdens and biochemical endpoints (i.e., fatty acids and stable isotopes). Under controlled laboratory conditions, this method assesses the effects of embryonic exposure to potentially high levels of contaminants during critical periods of development. Reproduction and development were also assessed in wild populations with visits to colonies to monitor productivity and examine chicks for morphological deformities as well as measure additional endpoints (i.e., stress hormone, thyroxine levels) relating to growth and development which could be influenced by increased contaminant exposure. In combination with the results of extensive reproduction and development studies conducted in Michigan’s AOCs (MDEQ 2012), the results of this study will be used to assess the current status of the wildlife reproduction and deformities BUI in this binational AOC.

## METHODS

Two herring gull colonies within the St. Marys River AOC (Ontario), Hay Point (46°07’N, 83°59’W) and Pumpkin Point (46°23’N, 84°07’W), and one downstream reference colony at Double Island (46°10’N, 82°52’W) in the North Channel of Lake Huron were selected for study purposes. The common tern colony at Hay Point was the AOC colony used in this study. A tern colony on North Sister Rock (46°18’N, 83°54'W) was selected as an alternate AOC colony following abandonment of the Hay Point colony (likely due to predation) early in the breeding season of 2011. This colony is in St. Joseph Lake and is approximately 6 km beyond the AOC boundary at Quebec Bay. A tern colony on Cousins Island (46°04'N, 82°49'W) in the North Channel was selected as the reference colony.

Visits to each colony were made at two times in the breeding season: 1) egg laying (late April for gulls and late May for terns) and 2) when chicks were $\geq$ 21 days old (mid-May for gulls and mid-June for terns) in 2011 and 2012 to assess reproduction and various parameters of health. In 2011, an additional visit in May (i.e., immediately post-hatch) was conducted to assess deformity rates but this was not performed in 2012 in order to minimize disturbance associated with visits to the colony. During the first visit, 15-30 freshly-laid eggs (i.e., not incubated) were collected from one-egg nests at each colony for artificial incubation in the laboratory at the National Wildlife Research Centre (NWRC) in Ottawa. Embryonic viability, incidence of embryonic deformities, contaminant burdens, fatty acid profiles and stable isotope signatures were determined. In addition, a thorough nest count was conducted and contents were recorded. Individual nest enclosures (~1m in diameter and 16" high) were constructed around ten to twelve 3-egg nests at each colony. As a measure of colony health, egg measurements for up to thirty 3-egg clutches were recorded (in millimetres) and egg volume calculated as:

$$\text{Egg volume (cm}^3\text{)} = K_{sp} \times (\text{length} \times \text{breadth}^2)/1000$$

where $K_{sp}$=0.476 and 0.502 for herring gulls and common terns, respectively.

Total clutch volume was determined as the sum volume of the three eggs in the clutch. Intraclutch variation in egg size was calculated as the difference in volume between the largest and smallest egg in the clutch divided by the largest egg size (i.e., volume) and multiplied by 100. During the second visit, when chicks in enclosed nests were $\geq$ 21 days old, productivity was calculated as:

$$\text{Productivity} = \text{no. of} \geq \text{21-day-old chicks/no. of enclosed nests}$$

Enclosed nests that had been abandoned or where there was evidence that chicks had escaped were not included in estimates of productivity. Body measurements of 15 chicks, including mass, tarsus, wing cord, and culmen length (only measured in 2012), were also recorded and chicks were banded with a stainless steel USFW band. A 2 ml blood sample was collected from the brachial vein of chicks using a heparinized syringe to examine thyroxine concentrations in plasma (see below for details). In addition, two secondary covert feathers were collected to quantify corticosterone concentrations as a measure of stress over time in herring gull chicks in 2011 and 2012 and in common tern chicks in 2011 (see below). Chicks were examined for morphological deformities during the post-hatch visit in 2011 and when chicks were $\geq$ 21 days old in 2012. An opportunistic deformity survey was also performed in 2011 on as many chicks as possible from nests outside of the enclosures.

Due to the general unpredictability of common terns during the nesting season (e.g., lack of fidelity to nesting colonies), there were challenges associated with determining productivity using the methods reported above. This was notably evident following abandonment of the Hay Point common tern colony early in the breeding season of 2011 where there was evidence of significant predation of tern eggs. Given these challenges, only one visit was made to Hay Point, North Sister Rock, and Cousins Island in late May for the purpose of collecting freshly-laid eggs for artificial incubation in the laboratory in 2012.

As part of a separate EC study of breeding site tenacity and productivity of common terns on the North Channel, productivity estimates are available for colonies at North Sister Rock and Cousins Island in 2011 and 2012 (D. Moore and D.V. Weseloh, EC unpublished), which will be reported here. In addition, egg measurements for 3-egg clutches of common terns at study sites were collected as part of this intensive EC study and will be included here. In 2011 and 2012, eggs were also measured at one additional AOC tern colony on South Sister Rock (46°18'N, 83°55'W) which is adjacent to North Sister Rock and hence just outside of the AOC boundary.

### Artificial Incubation of Eggs:

Unincubated eggs were collected in the field, transported to NWRC in insulated coolers with foam inserts, gently cleaned and placed in a Petersime incubator (model# MX-1) at 37°C, 58% humidity and turned every two hours. Just prior to the pipping stage of development (i.e., embryonic day 26-27 for herring gulls and day 20-21 for common terns), embryos were removed from their shells and euthanized by decapitation. Each embryo was examined for physical deformities. Embryonic viability was determined as the number of viable embryos that survived to the designated embryonic day (i.e., just prior to pipping) divided by the total number of fertile eggs. Eggs that were nonviable were staged if possible (e.g., infertile; early, mid or late embryo death). Egg contents, including yolk sac, whole carcass and shell membranes, were collected in chemically-cleaned glass jars and frozen until chemical analysis for contaminants. Ten embryos were randomly selected from each colony for chemical analysis in the two study years. The one exception to this was at the Hay Point tern colony in 2011 where twenty embryos were randomly selected for analysis. This occurred because a second AOC tern colony was not available in that year for comparison purposes.

### Contaminant Analyses:

Chemical analyses of individual herring gull and common tern embryos for organochlorine compounds, polybrominated diphenyl ethers (PBDEs), and mercury were conducted at NWRC. Organochlorine compounds measured included *p,p'*-DDE (dichlorodiphenyldichloroethylene), *p,p'*-DDT (dichlorodiphenyltrichloroethane), *p,p'*-DDD (dichlorodiphenyldichloroethane), oxychlordane, *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, hexachlorobenzene (HCB), dieldrin, heptachlor epoxide (HE), octachlorostyrene (OCS), mirex, and PCBs. Sum chlordane is based on the sum concentrations of oxychlordane, *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, and *trans*-nonachlor. Prior to chemical analysis, thawed embryos were homogenized and then underwent neutral extraction and removal of lipids and biogenic compounds by gel permeation chromatography and Florisil column chromatography. Quantitative analysis of organochlorine compounds was performed using gas chromatography-mass selective detection (GC/MSD) operated in selected ion monitoring mode. The first and second injections were for the determinations of organochlorine pesticides and PCBs, respectively, and the third injection using GC/MSD chemical analysis in the NICI mode was for analysis of PBDEs. Sum PCBs and sum PBDEs were based on the sum concentrations of 62 individual or co-eluting PCB congeners and 15 PBDE congeners found above the limit of detection. Double-crested cormorant (*Phalacrocorax auritus*) egg reference material and two additional certified fish reference materials, blanks and duplicate samples were also analyzed for quality assurance purposes. Concentrations of organochlorines and PBDEs are reported in µg/g on a wet weight basis. The detection limit for both organochlorine compounds and PBDEs was 0.0001 µg/g.

Embryos were also analyzed for non-*ortho s*ubstituted PCBs, polychlorinated dibenzo-*p*-dioxins, including 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), and polychlorinated dibenzofurans using gas chromatography-high resolution mass spectrometry (GC/HRMS) at RPC Laboratory in Fredericton, New Brunswick. Methods were based on US EPA Method 1613B and 8290A for dioxins and furans and on US EPA Method 1668C for non-*ortho* PCBs. Reference materials, blanks, and duplicates were also analyzed for quality assurance purposes. Following concerns regarding potential effects associated with elevated exposure to dioxin-like PCBs, dioxins and furans in birds in the AOC, deformed and normal embryos from St. Marys River AOC colonies were analyzed separately. A total of five deformed herring gull and common tern embryos from AOC colonies in 2011 and 2012 were analyzed as individuals. Contaminant concentrations in these individuals were then compared to concentrations in normal embryos from AOC colonies (analyzed as 2 or 3 pools) and each of the reference colonies (analyzed as a single pool). All pools consisted of five individual embryos.

Total mercury was quantified on a dry weight basis using an Advanced Mercury Analyzer (AMA-254) as described in CWS Method No. MET-CHEM-AA-03I. Certified reference materials and duplicate samples were also analyzed to ensure correct calibration, accuracy and reproducibility of test methods. Mercury concentrations in 2011 and 2012 embryos are reported in µg/g on a wet weight basis using percent moisture content.

## Stable Isotopes:

Stable isotope analyses of embryos were conducted at the University of Ottawa's G.G. Hatch Stable Isotope Laboratory in Ottawa, Ontario. Samples were weighed into tin capsules and loaded into an elemental analyser. The sample was flash combusted at about 1800°C (Dumas combustion) and the resultant gas products carried by helium through columns of oxidizing/reducing chemicals optimised for $CO_2$ and $N_2$. The gases were separated by a purge and trap adsorption column and then sent to the Delta Advantage isotope ratio mass spectrometer coupled with Conflo III. Samples were normalized to internal standards and calibrated to international standards. Stable isotope ratios are expressed in δ notation as the deviation from standards in parts per thousand (‰) according to the following relationship:

$$\delta X = (R_{sample}-R_{standard})/R_{standard} \times 1000$$

where X is $^{15}N$ or $^{13}C$ and R is the corresponding ratio $^{15}N/^{14}N$ or $^{13}C/^{12}C$. In this study, $\delta^{15}N$ signatures were compared to infer relative (and not absolute trophic) position at colonies.

Fatty acid analyses of embryos were also conducted to assess diet composition of egg-laying birds. These results are not yet available and, as such, will not be presented at this time.

## Feather Corticosterone:

Feathers from chicks were prepared by first removing the calamus, i.e., the proximal end of the quill to where the feathers start (~ 5 to 10 mm; depending on length of feather). The remaining portion was then minced with scissors until homogenous and 1.5 ml methanol was added. The sample was vortexed, sonicated for 30 minutes at room temperature, and incubated overnight at 50°C while shaking. After centrifuging at 13,000 rpm for 20 minutes, the supernatant was transferred to a fresh tube and re-extracted with 1 ml methanol. The sample was again vortexed for 5 minutes and 0.5 ml of supernatant removed and added to the previous fraction. The methanol fraction was evaporated to dryness overnight in a fume hood and then the sample was reconstituted with 200 µl steroid diluent.

Corticosterone concentrations in the extracted feather sample were determined using a corticosterone EIA kit (Assay Designs – corticosterone enzyme immunoassay kit; product no. 900-097; 96 well kit). This is a competitive immunoassay for the quantitative determination of corticosterone in biological fluids. The kit uses a polyclonal antibody to corticosterone to bind in a competitive manner. Corticosterone in the standard or sample or an alkaline phosphatase molecule which has corticosterone covalently attached to it can be measured.

After a simultaneous incubation at room temperature, the excess reagents were washed away and substrate was added. After a short incubation time, the enzyme reaction was stopped and the sample was read on a SpectraMax 190 UV-VIS microplate reader (Molecular Devices, Sunnyvale, California, USA) at 405 nm. The intensity of the bound yellow color is inversely proportional to the concentration of corticosterone in either standards or samples. The measured optical density was used to calculate the concentration of corticosterone. The average net optical density (OD) bound for each standard and sample is calculated by subtracting the average NSB (non-specific binding) OD from the average OD bound:

Average Net OD = Average Bound OD - Average NSB OD

Then the binding of each pair of standard wells as a percentage of the maximum binding wells (Bo) was calculated using the following formula:

Percent Bound = Net OD x 100 Net Bo OD

The plot of percent bound versus concentration of corticosterone for the standards was graphed using Prism software (GraphPad, La Jolla, California, USA) and a line fitted through the points. The concentration of corticosterone in the unknowns was then determined. An in-house quality control sample was used in each plate. The sensitivity of the method was 27 pg/ml.

## Thyroid Status:

Blood samples were centrifuged for 5 minutes at 14,000 rpm to separate plasma from red blood cells. Plasma was stored at -80°C and red blood cells were stored at 4°C. Concentrations of free thyroxine in the plasma of chicks sampled in 2012 were determined using a commercially available kit (AccuBind Elisa microwells product no. 1225-300 - Monobind Inc., Lake Forest, CA, 92630, USA). The method is based on a competitive enzyme immunoassay format in which a competition is set up between an immobilized antibody, the enzyme-antigen conjugate and the free thyroxine in the sample. When equilibration is reached, the unbound antigen fraction is removed and the enzyme activity in the bound fraction is measured which is inversely proportional to the concentration of free thyroxine in the sample. As per the method, standards, controls and sample plasma, as well as the enzyme reagent, were added to the microplate wells, which contained the immobilized antibody. After an incubation period, the unbound fraction was washed from the wells and the substrate added. The reaction was stopped and the plate was read at 450nm on a SpectraMax 190 UV-VIS microplate reader (Molecular Devices, Sunnyvale, California, USA). Concentrations were determined from the standard curve which was fitted using a variable slope (four parameter) method using Prism software (GraphPad, La Jolla, California, USA).

Controls used were Randox product no. HS2611 assayed human sera levels 2 & 3 (Randox Laboratories Ltd., Antrim, UK). The method gave the intra-assay precision as 10.98, 4.26 and 3.25 % coefficient of variation for low, medium and high controls, respectively. The inter-assay precision was 10.81, 6.01 and 7.90 % coefficient of variation for low, medium and high controls, respectively. The sensitivity of the assay was 0.05 ng/dl.

Thyroxine was also quantified in plasma of herring gull and common tern chicks sampled in 2011 using a different type of kit (radioimmunoassay) and, as a result, is not directly comparable to concentrations determined using the method outlined above for 2012 samples. Thyroxine was also quantified in plasma of embryos from artificially incubated eggs in 2011 but was found at concentrations below the limit of detection in all samples.

### Statistical Analysis:

Contaminants and other biological endpoints were statistically analyzed using either the Student's *t*-test for between-colony comparisons or a one-way ANOVA for among-colony comparisons, which when significant, was followed by Tukey's HSD test. Data were log-transformed ($\log_{10}$) to meet conditions of equal variance and normality for parametric analysis. If data failed these assumptions, comparisons were made using either a Mann-Whitney U non-parametric test or Kruskal-Wallis one way analysis of variance by ranks; post-hoc tests were conducted using non-parametric multiple comparison tests for unequal sample sizes. Concentrations of contaminants found below the limit of detection were given a concentration of one-half of the detection limit. Mercury concentrations in embryos were statistically analyzed on a dry weight basis however are reported on a wet weight basis for comparisons to published values and thresholds. A Spearman rank correlation analysis was performed to examine the relationship between the two stable isotopes for each species. Due to the overall low number of deformed embryos found, the Fisher exact test (one-tailed) was used to compare counts of deformed and non-deformed embryos at AOC colonies and reference colonies which were combined in the two study years. All results were considered significant at $p<0.05$.

Concentrations of 2,3,7,8-TCDD toxic equivalents (TEQs) were calculated for dioxin-like PCBs, furans, and dioxins and are based upon toxic equivalency factors developed by van den Berg *et al.* (1998) for birds. Dioxin-like PCBs include four non-*ortho* PCB congeners (77, 81, 126, and 169) and eight mono-*ortho* PCB congeners (105, 114, 118, 123, 156, 157, 167, and 189). Two of these eight mono-*ortho* PCBs (123 and 167) were not quantified as individual congeners in this study and were not included in the calculation of TEQs. For normal embryos analyzed as pools, mean mono-*ortho* PCB concentrations, quantified in the chemical analysis for organochlorines, were calculated for individuals used to create the pool (where data were available). Due to the random sampling of individuals selected for organochlorine analysis, mono-*ortho* PCB concentrations were not available for one deformed herring gull embryo from Hay Point in 2011. Total TEQ concentration is based on the sum concentration of TEQs calculated for the 4 non-*ortho* PCBs, 6 mono-*ortho* PCBs, and 17 dioxin and furan congeners. Concentrations were compared between deformed embryos and normal embryos of herring gulls from AOC colonies in 2011 and 2012 using a Student's *t*-test; a similar statistical comparison was not possible for common terns due to low sample size (N=2).

## RESULTS

### A) Artificial Egg Incubation Study

#### Embryonic Viability and Deformities:

*i) Herring gulls*

Embryonic viability was high in herring gulls from the two AOC colonies, Pumpkin Point and Hay Point, and ranged between 92%-100% in 2011 and 2012 (Table 1a). Embryonic viability was also high at the Double Island reference colony at 86% and 96% in 2011 and 2012, respectively. Of 52 fertile eggs examined in 2011, a total of five embryos died: one from Pumpkin Point (at developmental stage 26), one from Hay Point (stage 39) and three from Double Island (stages 19, 35, and 39). Of 50 fertile eggs examined in 2012, two embryos died, one from Pumpkin Point (stage 31) and one from Double Island (stage 29). Embryonic deformities were evident in a single embryo from both AOC colonies in at least one study year. Incidences of deformities at Pumpkin Point were 6% (1 deformed embryo/16 viable embryos) in 2011 and 8% (1/12) in 2012 and at Hay Point were 8% (1/13) in 2011 and 0% (0/12) in 2012. Of the two deformed embryos from Pumpkin Point in 2011 and 2012, one had a crossed-bill and part of the lower brain was exposed while the other individual had a split lower mandible. The one deformed embryo from Hay Point had a slightly off-centre lower mandible. No embryonic deformities were evident in incubated eggs from Double Island in either study year. No significant difference was found in the incidence of herring gull embryonic deformities between AOC colonies and the reference colony when counts for sites and years were combined.

*ii) Common terns*

Embryonic viability among artificially-incubated common tern eggs from the two AOC colonies, Hay Point and North Sister Rock, in 2011 and 2012 was high and ranged between 90%-100% (Table 1b). Embryonic viability at the Cousins Island reference colony was comparable at 93% in 2011 and 100% in 2012. Of the 44 fertile eggs examined in 2011, four embryos died: three from Hay Point (stages 6, 8, and 17) and one from Cousins Island (stage 17). Of the 37 fertile eggs examined in 2012, one embryo from North Sister died (stage 25). Similar to herring gulls, embryonic deformities were evident in a single embryo from each of the two AOC colonies in one study year. Incidences of embryonic deformities were 4% (1/26) at Hay Point in 2011 and 8% (1/13) at North Sister Rock in 2012. The deformed embryo from Hay Point had one eye, half a skull and the lower body was shortened while the deformed individual

Table 1. Embryonic viability and incidence of embryonic deformities in artificially-incubated eggs of herring gulls (a) and common terns (b) collected from St. Marys River AOC colonies (Hay Point, Pumpkin Point, North Sister Rock) and corresponding Lake Huron reference colonies (Double Island or Cousins Island) in 2011 and 2012.

a) Herring gulls:

| Colony | AOC/ Ref | Year | Total No. Eggs | No. Infertile Eggs | No. Fertile Eggs | No. Viable Eggs | No. Dead Eggs | Embryonic Viability (%) | No. Deformities | Deformities (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Hay Point | AOC | 2011 | 15 | 1 | 14 | 13 | 1 | 93% | 1 | 8% |
| | | 2012 | 15 | 3 | 12 | 12 | 0 | 100% | 0 | 0% |
| Pumpkin Point | AOC | 2011 | 17 | 0 | 17 | 16 | 1 | 94% | 1 | 6% |
| | | 2012 | 15 | 2 | 13 | 12 | 1 | 92% | 1 | 8% |
| Double I. | Ref | 2011 | 23 | 2 | 21 | 18 | 3 | 86% | 0 | 0% |
| | | 2012 | 26 | 1 | 25 | 24 | 1 | 96% | 0 | 0% |

b) Common terns:

| Site | AOC/ Ref | Year | Total No. Eggs | No. Infertile Eggs | No. Fertile Eggs | No. Viable Eggs | No. Dead Eggs | Embryonic Viability (%) | No. Deformities | Deformities (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Hay Point | AOC | 2011 | 30 | 1 | 29 | 26 | 3 | 90% | 1 | 4% |
| | | 2012 | 15 | 2 | 13 | 13 | 0 | 100% | 0 | 0% |
| North Sister Rock | AOC | 2012 | 15 | 1 | 14 | 13 | 1 | 93% | 1 | 8% |
| Cousins I. | Ref | 2011 | 15 | 0 | 15 | 14 | 1 | 93% | 0 | 0% |
| | | 2012 | 15 | 5 | 10 | 10 | 0 | 100% | 0 | 0% |

from North Sister Rock had long thin limbs. No embryonic deformities were evident in incubated eggs from Cousins Island in either study year. No significant difference was found in the incidence of common tern embryonic deformities between AOC colonies and the reference colony when counts for sites and years were combined.

**Contaminants:**

*i) Herring gulls*

Concentrations of organochlorine compounds were low overall in herring gull embryos from the two AOC colonies and the reference colony in 2011 and 2012 with sum PCBs found at the highest concentrations (Table 2). Mean sum PCB concentrations ranged from 1.13 µg/g in embryos from Double Island in 2012 to 1.92 µg/g in embryos from Pumpkin Point in 2011. The maximum sum PCB concentration of 4.88 µg/g was found in an embryo from Double Island in 2011. Mean concentrations of the remaining organochlorines in embryos were below 0.4 µg/g at the three colonies. Sum PBDE concentrations (determined as the sum concentration of 15 PBDE congeners) were comparable to concentrations of *p,p′*-DDE in embryos and, based on comparisons of means, were at least six times higher than concentrations of other organochlorine pesticides. The maximum sum PBDE concentration (1.01 µg/g) was found in an embryo from Pumpkin Point in 2012. Generally, no significant differences in concentrations of organochlorines, including sum PCBs, and sum PBDEs were found in herring gull embryos among the three colonies in either 2011 or 2012. The one exception was for octachlorostyrene (OCS) in 2011 in which a significantly higher mean concentration was found in embryos from Pumpkin Point compared to those from the Hay Point AOC colony and Double Island reference colony. Concentrations of this compound, however, were among the lowest of all measured in this study. Mean percent lipid content was not significantly different among colonies within a study year and ranged from 6.5% in herring gull embryos from Double Island in 2011 to 8.4% in embryos from Pumpkin Point in 2012.

Mean concentrations of four non-*ortho* PCBs, 2,3,7,8-TCDD, and total TEQs were largely comparable among deformed and normal herring gull embryos from St. Marys River AOC colonies and the Double Island reference colony in 2011 and 2012 (Table 3a). Of the four non-*ortho* PCBs measured in deformed herring gull embryos, concentrations of PCB-126 > 77 > 81 ≈ 169. Patterns in normal embryos from AOC colonies and the reference colony were slightly different with concentrations of PCB-126 > 169 > 81 ≈ 77. The mean 2,3,7,8-TCDD concentration in three deformed embryos (4.76 pg/g) was within the range of concentrations found for normal embryos from AOC colonies (3.30 pg/g) and normal embryos from the reference colony (5.62 pg/g) which was also the maximum concentration found in this study. Mean total TEQ concentrations ranged from 76.78 pg TEQ/g in normal embryos from AOC colonies to 112.76 pg TEQ/g in deformed embryos from AOC colonies. The maximum total TEQ concentration (159.17 pg TEQ/g) was found in a deformed embryo from Hay Point in 2011. Toxicity associated with non-*ortho* PCBs, dioxins and furans, and mono-*ortho* PCBs contributed 84%, 11%, and 7%, respectively, to the mean total TEQ concentration in deformed embryos from AOC colonies in 2011 and 2012. Similar contributions of toxicity associated with non- *ortho* PCBs, dioxins and furans, and mono-*ortho* PCBs to mean total TEQ concentrations were found for normal embryos from AOC colonies (78%, 12%, 10%, respectively) and the reference colony (77%, 13%, and 9%, respectively). Concentrations of non-*ortho*

Table 2. Mean concentrations (SD) of organochlorines and sum PBDEs in herring gull embryos (wet weights) collected from the St. Marys River AOC (Hay Point and Pumpkin Point) and Double Island in Lake Huron (reference colony) in 2011 and 2012 and incubated in the lab. All compounds are shown in µg/g. N values represent number of individual embryos analyzed. Different uppercase letters show significant differences in mean concentrations between colonies within a given year based on a one-way ANOVA.

| **Colony** | **AOC/ Ref** | **Year** | ***p,p'*-DDE** | **Sum Chlordane** | **HCB** | **Dieldrin** | **HE** | **Mirex** | **OCS** | **PCB 1:1**[1] | **Sum PCBs**[2] | **Sum PBDEs**[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hay Point N=10 | AOC | 2011 | 0.376 (0.173) | 0.037 (0.013) | 0.015 (0.005) | 0.024 (0.012) | 0.013 (0.004) | 0.026 (0.034) | 0.002 (0.001) **B** | 3.435 (1.569) | 1.807 (0.842) | 0.244 (0.093) |
| Pumpkin Point N=10 | AOC | 2011 | 0.304 (0.092) | 0.036 (0.007) | 0.018 (0.008) | 0.022 (0.009) | 0.012 (0.002) | 0.013 (0.018) | 0.004 (0.001) **A** | 3.036 (1.219) | 1.922 (0.773) | 0.237 (0.094) |
| Double I. N=10 | Ref | 2011 | 0.324 (0.127) | 0.031 (0.010) | 0.015 (0.006) | 0.019 (0.016) | 0.011 (0.004) | 0.033 (0.038) | 0.002 (0.001) **B** | 3.196 (2.218) | 1.766 (1.338) | 0.311 (0.198) |
| Hay Point N=10 | AOC | 2012 | 0.248 (0.125) | 0.035 (0.025) | 0.009 (0.005) | 0.009 (0.007) | 0.012 (0.015) | 0.010 (0.009) | 0.002 (0.003) | 2.824 (1.181) | 1.433 (0.671) | 0.333 (0.147) |
| Pumpkin Point N=10 | AOC | 2012 | 0.292 (0.111) | 0.029 (0.007) | 0.008 (0.003) | 0.010 (0.006) | 0.008 (0.004) | 0.020 (0.022) | 0.001 (0.001) | 2.359 (1.007) | 1.273 (0.728) | 0.452 (0.258) |
| Double I. N=10 | Ref | 2012 | 0.218 (0.048) | 0.025 (0.005) | 0.008 (0.005) | 0.007 (0.005) | 0.006 (0.001) | 0.010 (0.013) | 0.002 (0.002) | 2.187 (1.177) | 1.131 (0.704) | 0.332 (0.185) |

[1] Based on 1:1 ratio of Arochlor 1254:1260
[2] Based on the sum of 62 PCB congeners
[3] Based on the sum of 15 PBDE congeners

Table 3. Mean concentrations (SD) of non-*ortho* PCBs, 2,3,7,8-TCDD, and 2,3,7,8-TCDD toxic equivalents (TEQ) in embryos of herring gulls (a) and common terns (b) collected from the St. Marys River (SMR) AOC and reference colonies (i.e., Double Island and Cousins Island) in 2011 and 2012 and incubated in the lab (pg/g, wet weight). Concentrations are shown for deformed embryos (analyzed as individuals) and normal embryos based on the analysis of pools consisting of five individuals. Accordingly, N represents either the number of deformed individuals or the number of pools analyzed. TEQs associated with 4 non-*ortho* PCBs, 17 dioxins and furans (PCDD/Fs), and 6 mono-*ortho* PCBs and which together comprise total TEQs are also provided.

a) Herring gulls:

| Colony | AOC/ Ref | N | PCB-77 | PCB-81 | PCB-126 | PCB-169 | 2,3,7,8 – TCDD | TEQ – non-*ortho* PCBs | TEQ – PCDD/Fs | TEQ – mono-*ortho* PCBs[1] | Total TEQs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SMR[2]-Deformed | AOC | 3 | 249.07 (384.48) | 120.10 (53.96) | 699.00 (149.79) | 112.70 (54.67) | 4.76 (0.51) | 94.48 (36.38) | 12.93 (5.10) | 8.03 (0.82) | 112.76 (42.36) |
| SMR[2]-Normal | AOC | 3 | 61.90 (71.18) | 72.30 (9.52) | 497.67 (70.12) | 92.07 (20.57) | 3.30 (1.30) | 60.18 (10.78) | 9.31 (4.21) | 7.30 (0.96) | 76.78 (15.84) |
| Double I. - Normal | Ref | 1 | 36.70 | 98.90 | 680.00 | 121.00 | 5.62 | 79.85 | 13.89 | 9.73 | 103.46 |

b) Common terns:

| Colony | AOC/ Ref | N | PCB-77 | PCB-81 | PCB-126 | PCB-169 | 2,3,7,8 – TCDD | TEQ – non-*ortho* PCBs | TEQ – PCDD/Fs | TEQ – mono-*ortho* PCBs | Total TEQs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SMR[3]-Deformed | AOC | 2 | 617.25 (135.41) | 55.58 (25.49) | 389.75 (259.15) | 68.03 (37.16) | 2.49 (1.84) | 75.46 (35.27) | 19.19 (11.76) | 3.33 (1.94) | 97.98 (48.96) |
| SMR[3]-Normal | AOC | 2 | 548.50 (9.19) | 48.05 (5.73) | 346.00 (82.02) | 70.20 (18.95) | 2.14 (0.64) | 66.90 (8.33) | 16.09 (2.61) | 3.35 (0.60) | 86.34 (6.32) |
| Cousins I. - Normal | Ref | 1 | 1000.00 | 75.80 | 455.00 | 85.20 | 3.80 | 103.17 | 33.24 | 2.73 | 139.14 |

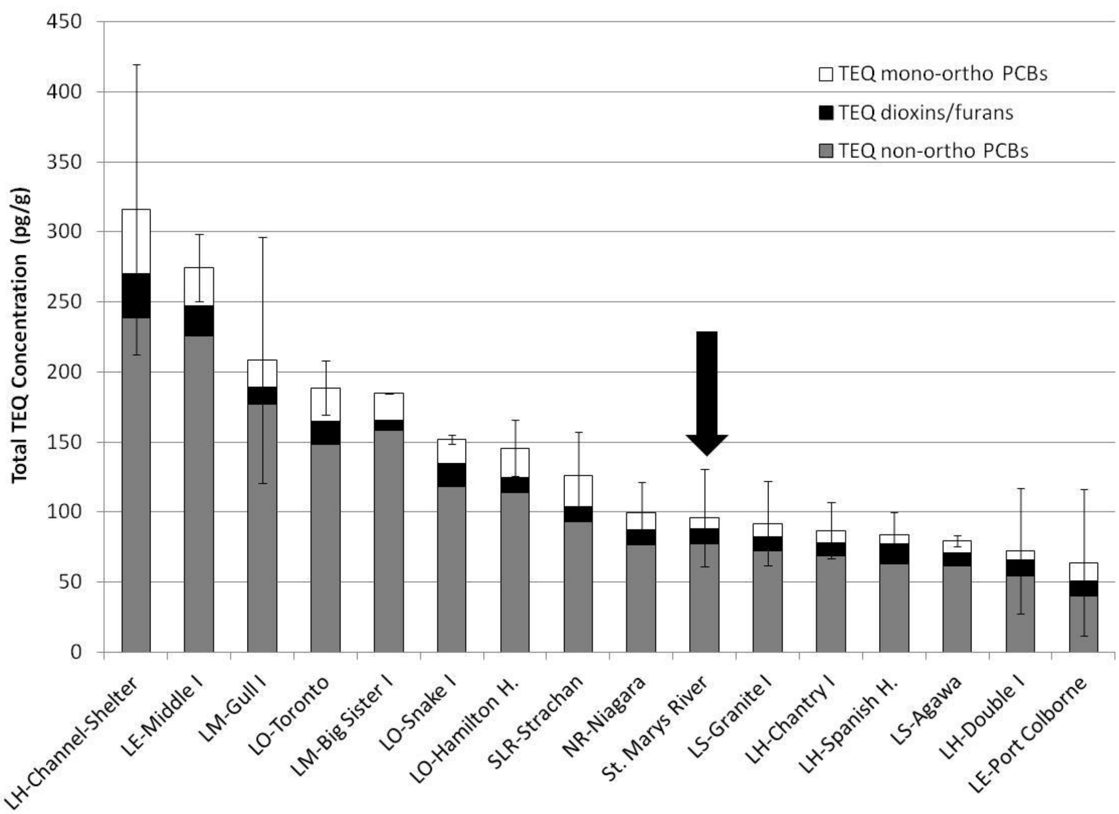
[1] Since TEQ–mono-*ortho* PCBs were quantified in individual embryos (as part of the sum PCB analysis), these concentrations were determined using the mean concentration of individuals which comprised the pool (where data were available with a range of between 1-5 individuals); the mean TEQ–mono-*ortho* PCB concentration for deformed herring gull embryos from SMR is based on N=2 rather than N=3 (see methods for details).

[2] Comprise individuals from Hay Point and Pumpkin Point

[3] Comprise individuals from Hay Point and North Sister Rock

PCBs, 2,3,7,8-TCDD, and TEQs were not significantly different between deformed and normal herring gull embryos from AOC colonies (p>0.05). Overall, the mean total TEQ concentration in deformed and normal embryos from the St. Marys River AOC (N=6 samples total) was 94.77 pg TEQ/g in 2011 and 2012 and was within the range of mean TEQ concentrations in herring gull eggs from other colonies on the Great Lakes in these two years (Figure 2; EC unpublished). A full listing of mean concentrations of non-*ortho* PCBs, mono-*ortho* PCBs, dioxins and furans in deformed and/or normal herring gull embryos from St. Marys River AOC colonies and the Double Island reference colony is provided in Appendix 1.

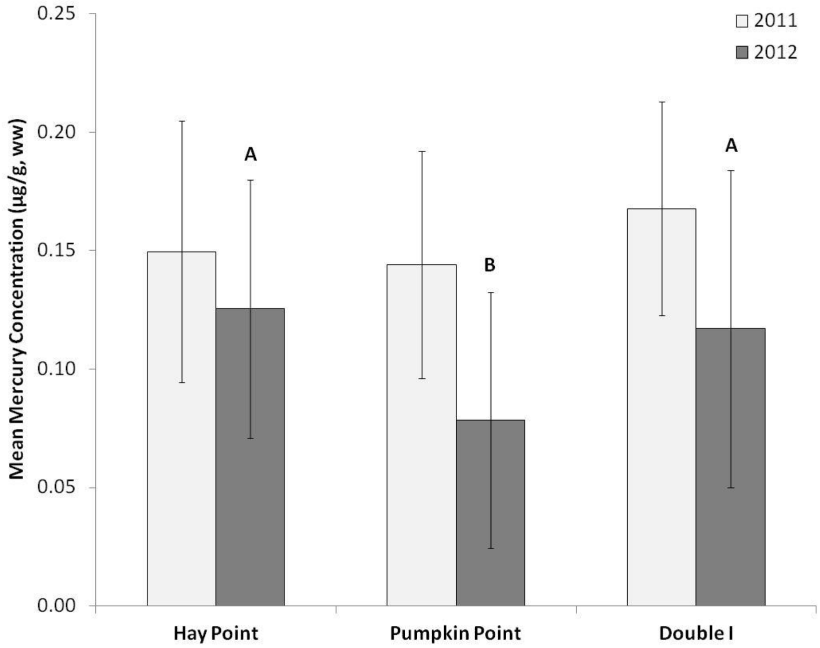
Figure 2. Mean total TEQ concentrations (SD) in deformed and normal herring gull embryos (N=6 samples total) from St. Marys River AOC (Ontario) colonies and in herring gull eggs from Great Lakes colonies in 2011 and 2012 (pg/g, wet weight). The contributions of TEQ concentrations associated with mono-*ortho* PCBs, dioxins and furans, and non-*ortho* PCBs to the total TEQ concentration are shown. Means are arranged in decreasing order from highest to lowest concentrations. Colony locations are associated with the following lakes/rivers: LH=Lake Huron, LO=Lake Ontario, LE=Lake Erie, SLR=St. Lawrence River, NR=Niagara River, LS=Lake Superior, and LM=Lake Michigan.



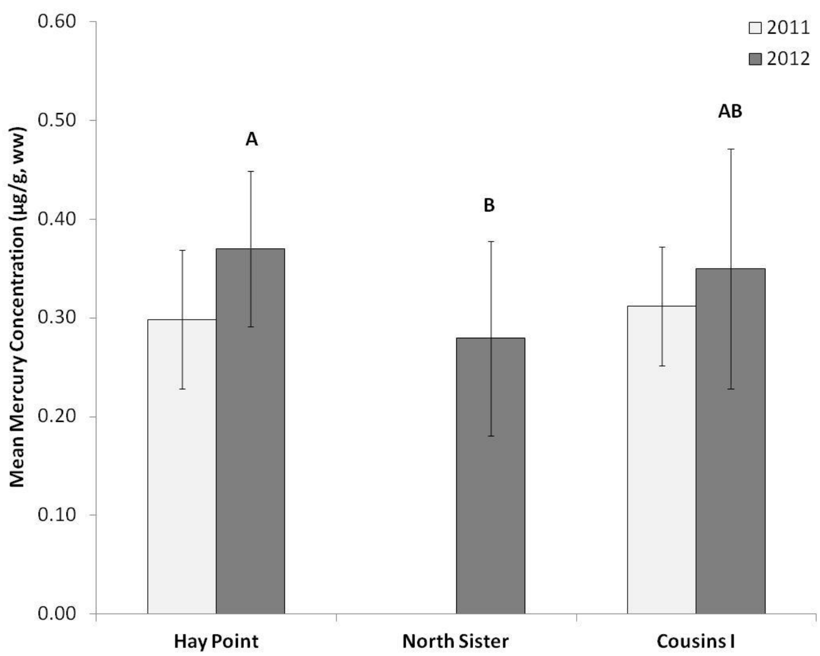

Mean mercury concentrations (SD) in herring gull embryos in 2011 were statistically comparable among the three study sites ranging from 0.14 (0.05) µg/g wet weight at Pumpkin Point to 0.17 (0.05) µg/g at Double Island (Figure 3a). In 2012, some spatial differences among colonies were evident with mean mercury concentrations (SD) ranging from 0.08 (0.05) µg/g at Pumpkin Point to 0.13 (0.05) µg/g at Hay Point. Mercury concentrations in embryos from Hay Point were statistically similar to those from Double Island and embryos from both colonies had significantly higher mercury concentrations than embryos

Figure 3. Mean concentrations (SD) of total mercury (µg/g, wet weight) in embryos of herring gulls (a) and common terns (b) collected from St. Marys River AOC colonies (Hay Point, Pumpkin Point, North Sister Rock) and corresponding Lake Huron reference colonies (Double Island or Cousins Island) in 2011 and 2012 (N=12-30 embryos/colony). Different uppercase letters show significant differences in mean concentrations within a study year and are based on statistical analysis of dry weight mercury concentrations. Note no data are available for common terns at North Sister Rock in 2011.

a) Herring gulls:




b) Common terns:



from Pumpkin Point ($F_{2,42}$=5.54, p=0.007). The maximum mercury concentration was 0.28 µg/g in a herring gull embryo from Hay Point in 2011.

*ii) Common terns*

Contaminant burdens were also very low in common terns from AOC and reference colonies in 2011 and 2012 (Table 4). Sum PCBs were found at the highest concentrations relative to other organochlorines with means ranging from 0.77 µg/g in embryos from Hay Point in 2011 to 1.43 µg/g in embryos from Cousins Island in 2012. The maximum sum PCB concentration reported (2.58 µg/g) was found in an embryo from the Cousins Island reference colony in 2012. Similar to herring gulls, sum PBDEs in common tern embryos at study sites were comparable in concentration to *p,p′*-DDE and higher than concentrations of other organochlorine pesticides. The maximum sum PBDE concentration (0.21 µg/g) was found in an embryo from North Sister Rock in 2012. Some spatial differences were apparent between/among colonies in each of the two study years but in a somewhat unexpected direction. In 2011, significantly higher concentrations of sum PCBs, sum PBDEs, *p,p′*-DDE, sum chlordane and OCS were found in common tern embryos from the Cousins Island reference colony compared to the Hay Point AOC colony. Concentrations of HCB, dieldrin, HE and mirex were comparable between study sites. In 2012, significantly higher concentrations of *p,p′*-DDE, mirex and OCS were found in embryos from the Cousins Island reference colony compared to the Hay Point AOC colony while concentrations were comparable between the reference colony and the North Sister Rock AOC colony. In 2012, concentrations of other contaminants including sum PCBs and sum PBDEs were similar among study sites. Percent lipid content was not significantly different between colonies in 2011 with means in common tern embryos of 6.8% and 7.6% at Hay Point and Cousins Island, respectively. In 2012, percent lipid content was significantly higher in embryos from Cousins Island (mean=9.8%) compared to Hay Point (mean=8.8%; $F_{2,27}$=5.64, p=0.009). As such, the results reported in Table 3 are based on contaminants data in 2012 which were first lipid-normalized prior to statistical analysis.

Mean concentrations of four non-*ortho* PCBs, 2,3,7,8-TCDD, and total TEQs were comparable between deformed and normal common tern embryos from St. Marys River AOC colonies in 2011 and 2012 (Table 3b). Concentrations in tern embryos from the Cousins Island reference colony (analyzed as a pool) were generally slightly higher compared to embryos from AOC colonies and most frequently were the maximum concentration found of all embryos. Of the four non-*ortho* PCBs measured in common tern embryos, concentrations of PCB-77 > 126 > 169 ≈ 81, a pattern which differed to that found in herring gull embryos. The mean 2,3,7,8-TCDD concentration in two deformed embryos (2.49 pg/g) was within the range of concentrations found for normal embryos from AOC colonies (2.14 pg/g) and normal embryos from the reference colony (3.80 pg/g). Mean total TEQ concentrations ranged from 86.34 pg TEQ/g in normal embryos from AOC colonies to 139.14 pg TEQ/g in normal embryos from the reference colony. Toxicity associated with non-*ortho* PCBs, dioxins and furans, and mono-*ortho* PCBs contributed 77%, 20%, and 3%, respectively, to the mean total TEQ concentration in deformed embryos from AOC colonies in 2011 and 2012. Similar contributions of toxicity associated with non-*ortho* PCBs, dioxins and furans, and mono-*ortho* PCBs to mean total TEQ concentrations were found for normal embryos from the AOC and the reference colony. Due to low sample sizes, it was not possible to statistically compare concentrations of non-*ortho* PCBs, 2,3,7,8-TCDD, and TEQs between deformed and normal common tern embryos from AOC colonies. An examination of mean concentrations with associated variation however

Table 4. Mean concentrations (SD) of organochlorines and sum PBDEs in common tern embryos (wet weights) collected from the St. Marys River AOC (Hay Point and North Sister Rock) and Cousins Island in Lake Huron (reference site) in 2011 and 2012 and incubated in the lab. All compounds are shown in µg/g. N values represent number of individual embryos analyzed. Different uppercase letters show significant differences in mean concentrations between colonies within a given year based on a one-way ANOVA.

| Colony | Ref | Year | *p,p'*-DDE | Sum Chlordane | HCB | Dieldrin | HE | Mirex | OCS | PCB 1:1[1] | Sum PCBs[2] | Sum PBDEs[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hay Point N=20 | AOC | 2011 | 0.099 (0.038) **B** | 0.009 (0.005) **B** | 0.011 (0.003) | 0.014 (0.005) | 0.004 (0.002) | 0.004 (0.002) | 0.0013 (0.0005) **B** | 1.348 (0.590) **B** | 0.768 (0.300) **B** | 0.065 (0.021) **B** |
| Cousins I. N=10 | Ref | 2011 | 0.178 (0.044) **A** | 0.014 (0.005) **A** | 0.013 (0.004) | 0.016 (0.006) | 0.005 (0.002) | 0.005 (0.003) | 0.0021 (0.0006) **A** | 2.116 (0.370) **A** | 1.147 (0.165) **A** | 0.094 (0.024) **A** |
| Hay Point N=10 | AOC | 2012 | 0.146 (0.061) **B** | 0.009 (0.006) | 0.013 (0.004) | 0.017 (0.006) | 0.006 (0.002) | 0.003 (0.001) **B** | 0.0012 (0.0005) **B** | 1.902 (0.703) | 0.890 (0.305) | 0.090 (0.032) |
| North Sister N=10 | AOC | 2012 | 0.181 (0.046) **AB** | 0.012 (0.009) | 0.016 (0.004) | 0.019 (0.004) | 0.006 (0.002) | 0.005 (0.002) **A** | 0.0016 (0.0004) **AB** | 2.474 (0.689) | 1.146 (0.311) | 0.124 (0.387) |
| Cousins I. N=10 | Ref | 2012 | 0.238 (0.076) **A** | 0.015 (0.013) | 0.019 (0.005) | 0.017 (0.004) | 0.005 (0.001) | 0.006 (0.002) **A** | 0.0020 (0.0007) **A** | 3.036 (1.262) | 1.430 (0.602) | 0.140 (0.032) |

[1] Based on 1:1 ratio of Arochlor 1254:1260
[2] Based on the sum of 62 PCB congeners
[3] Based on the sum of 15 PBDE congeners

suggests that concentrations between these two groups are very similar. A full listing of mean concentrations of non-*ortho* PCBs, mono-*ortho* PCBs, dioxins and furans in deformed and/or normal common tern embryos from St. Marys River AOC colonies and the Cousins Island reference colony is provided in Appendix 1.

Mercury concentrations in common tern embryos in 2011 were comparable at Hay Point and Cousins Island with means (SD) of 0.30 (0.07) µg/g and 0.31 (0.06) µg/g, respectively (Figure 3b). In 2012, mean mercury concentrations (SD) ranged from 0.28 (0.10) µg/g at North Sister Rock to 0.37 (0.08) µg/g at Hay Point and, similar to that found for herring gulls, a significant spatial pattern among colonies was evident in this year ($F_{2,36}$=3.83, p=0.031). While mean mercury concentrations were statistically similar between each of the AOC colonies and the Cousins Island reference colony, mercury concentrations were significantly higher in common terns from Hay Point compared to those from North Sister Rock. The maximum mercury concentration was 0.59 µg/g in a common tern embryo from Cousins Island in 2012.

## Stable Isotopes:

### *i) Herring gulls*

Significant spatial differences for mean $\delta^{15}N$ values in herring gull embryos were found among study sites in 2011 ($F_{2,42}$=6.94, p=0.003) and 2012 ($F_{2,42}$=4.97, p=0.013; Table 5a). As an indicator of trophic position, mean $\delta^{15}N$ values were significantly higher in gulls from the Double Island reference colony compared to one or both of the AOC colonies in both study years. In addition, mean $\delta^{13}C$ values in gull embryos from Double Island were also significantly more depleted (i.e., more negative) than mean values in embryos from the two AOC colonies in both 2011 ($F_{2,42}$=23.23, p<0.00001) and 2012 ($F_{2,42}$=11.22, p=0.0001). No significant correlation was found between $\delta^{15}N$ and $\delta^{13}C$ values when herring gull embryos from all colonies and years were grouped together.

### *ii) Common terns*

Similar spatial patterns for isotopes were found in common tern embryos (Table 5b). Mean $\delta^{15}N$ values were significantly higher in common terns from the Cousins Island reference colony compared to one or both of the AOC colonies in 2011 (Mann Whitney U=450, p<0.00001) and 2012 ($F_{2,36}$=32.63, p<0.00001). Mean $\delta^{13}C$ values in tern embryos from Cousins Island were significantly more depleted (i.e., more negative) than mean values in embryos from the AOC colonies in both 2011 (Mann Whitney U=91, p=0.001) and 2012 (Kruskal Wallis test H=9.92, p=0.007). Unlike that found for herring gulls, a highly significant negative correlation was found between $\delta^{15}N$ and $\delta^{13}C$ values when common tern embryos from all colonies and years were grouped together ($r_s$=0.72, p<0.00001).

Table 5. Mean (SD) values for $\delta^{15}N$ and $\delta^{13}C$ in embryos of herring gulls (a) and common terns (b) collected from St. Marys River AOC colonies (Hay Point, Pumpkin Point, North Sister Rock) and corresponding Lake Huron Double Island reference colonies (Double Island or Cousins Island) in 2011 and 2012 (N=12-30 embryos/colony). Different uppercase letters indicate significant differences between colonies within a study year.

a) Herring gulls:

| Colony | AOC/Ref | $\delta^{15}N$ | | $\delta^{13}C$ | |
|---|---|---|---|---|---|
| | | **2011** | **2012** | **2011** | **2012** |
| Hay Point | AOC | 9.00 (0.82) **B** | 8.61 (0.44) **B** | -20.40 (1.00) **A** | -21.32 (1.11) **A** |
| Pumpkin Point | AOC | 8.94 (0.39) **B** | 8.77 (0.47) **AB** | -20.75 (0.87) **A** | -21.49 (1.20) **A** |
| Double I. | Ref | 9.80 (0.82) **A** | 9.29 (0.88) **A** | -22.49 (0.82) **B** | -23.05 (1.00) **B** |

b) Common terns:

| Colony | AOC/Ref | $\delta^{15}N$ | | $\delta^{13}C$ | |
|---|---|---|---|---|---|
| | | **2011** | **2012** | **2011** | **2012** |
| Hay Point | AOC | 10.57 (0.61) **B** | 10.53 (0.69) **B** | -25.16 (1.09) **A** | -25.61 (0.88) **A** |
| North Sister Rock | AOC | NA | 11.07 (0.56) **B** | NA | -25.32 (1.48) **A** |
| Cousins I. | Ref | 12.12 (0.32) **A** | 12.29 (0.33) **A** | -25.95 (1.02) **B** | -26.63 (0.50) **B** |

## B) Field Study

### Egg Size Parameters:

*i) Herring gulls*

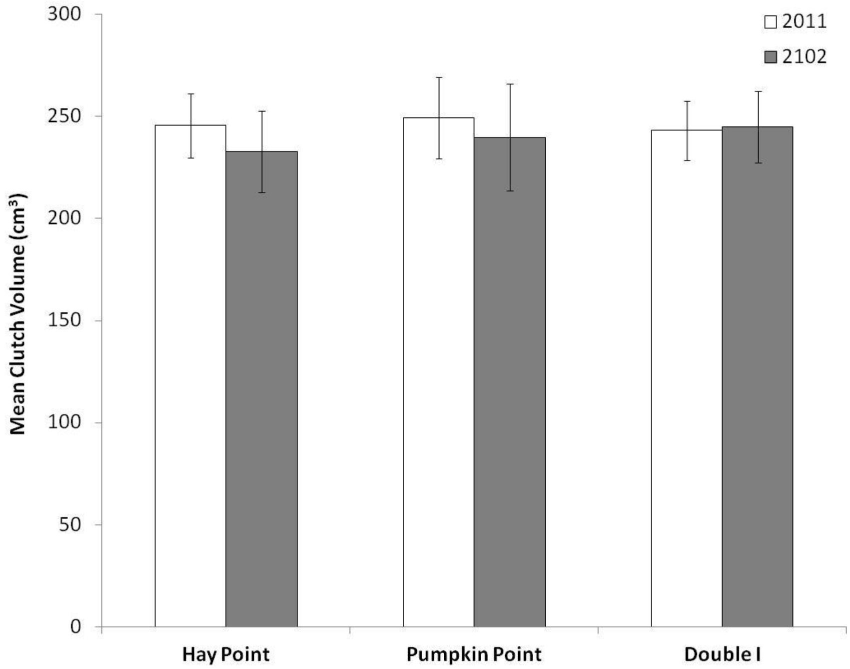
To assess potential food stress in birds, total clutch volume and intraclutch variation in egg size were examined in 3-egg clutches. Mean total clutch volumes (SD) for herring gulls from St. Marys River AOC colonies ranged from 232.8 (19.9) $cm^3$ at Hay Point in 2012 to 249.2 (19.9) $cm^3$ at Pumpkin Point in 2011 and overall were not significantly different from total clutch volumes in gulls from the Double Island reference colony in either of the two study years (Figure 4a). Mean intraclutch variation (SD) in egg size from AOC colonies in the two study years ranged from 9.5 (5.5)% at Pumpkin Point in 2011 to 12.0 (7.2)% at Hay Point in 2012 and were also statistically comparable to means (SD) at the Double Island reference colony of 11.1 (3.3)% and 7.3 (4.4)% in each of 2011 and 2012, respectively.

*ii) Common terns*

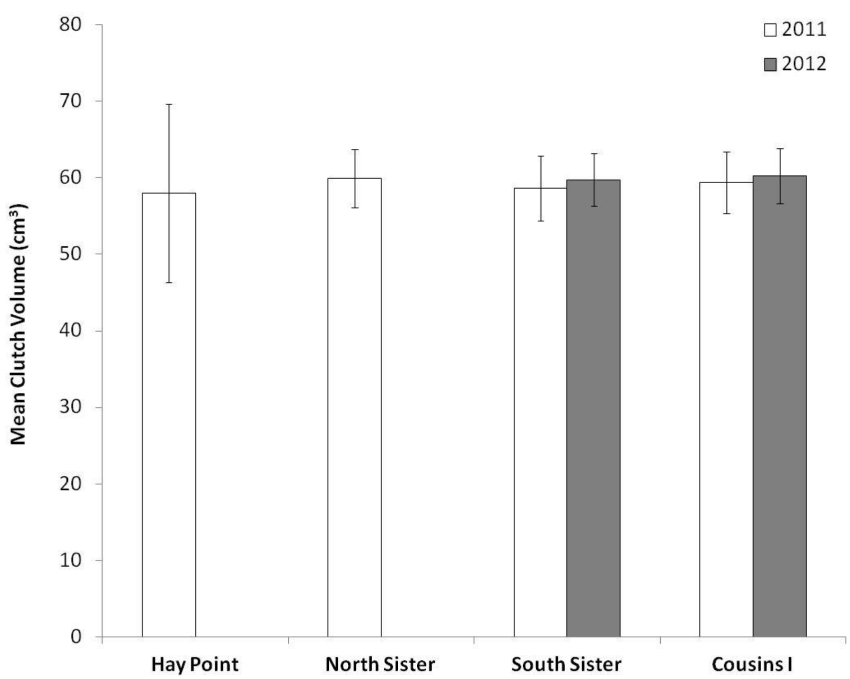
Mean total clutch volume (SD) in 3-egg clutches of common terns at three AOC colonies in 2011 ranged from 58.0 (11.6) $cm^3$ at Hay Point to 60.0 (3.8) $cm^3$ at North Sister Rock and were not significantly different from mean clutch volume at Cousins Island (59.4 (4.0) $cm^3$; Figure 4b). Similarly in 2012, mean total clutch volume (SD) was not significantly different between the South Sister Rock AOC colony (59.8 (3.5) $cm^3$) and the Cousins Island colony (60.3 (3.6) $cm^3$). Mean intraclutch variation (SD) in egg size at AOC tern colonies in the two years ranged from 6.8 (3.2)% at South Sister Rock in 2011 to 9.5 (7.6)% at Hay Point in 2011. Despite relatively lower estimates of mean intraclutch variation (SD) in egg size from Cousins Island of 6.2 (2.8)% and 6.0 (2.6)% in 2011 and 2012, respectively, no significant differences in intraclutch variation were found between AOC tern colonies and the reference colony in either of the two study years.

Figure 4. Mean clutch volume (SD) in 3-egg clutches of herring gulls (a) and common terns (b) from St. Marys River AOC colonies (Hay Point, Pumpkin Point, North Sister Rock, South Sister Rock) and corresponding Lake Huron reference colonies (Double Island or Cousins Island) in 2011 and 2012. Numbers of 3-egg clutches ranged from 8-38 for both species with the exception of the Hay Point common tern colony in 2011 where the mean is based on three clutches of eggs. Note no data are available for common terns at Hay Point and North Sister Rock in 2012.

a) Herring gulls:




b) Common terns:

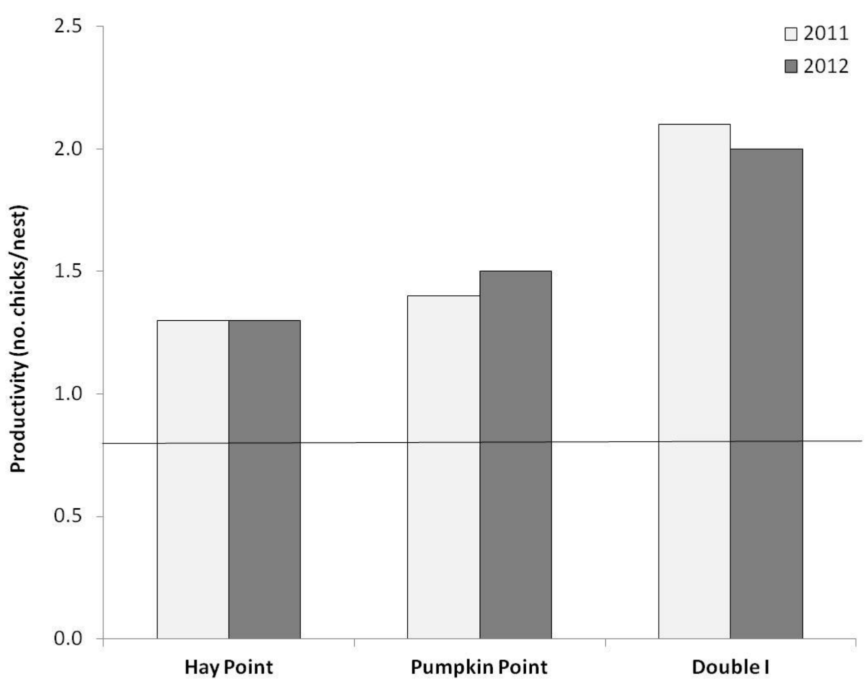


**Productivity & Prevalence of Deformities in Wild Populations:**

*i) Herring gulls*

Herring gull productivity, defined as the number of ≥ 21-day-old chicks produced per nest, was equal to 1.3 chicks per nest at Hay Point (N=7 enclosed nests), 1.4 chicks per nest at Pumpkin Point (N=10 nests), and 2.1 chicks per nest at Double Island (N=9 nests) in 2011 (Figure 5). Similarly, productivity was high in 2012 with estimates equal to 1.3 chicks per nest at Hay Point (N=12 nests), 1.5 chicks per nest at Pumpkin Point (N=10 nests), and 2.0 chicks per nest at Double Island (N=7 nests). Productivity estimates at AOC colonies in both study years were well within the range of productivity levels required to maintain a stable population (0.8-1.4 chicks per nest; Kadlec and Drury 1968).

Figure 5. Herring gull productivity, as the number of ≥ 21-day-old chicks produced per nest, at St. Marys River AOC colonies (Hay Point and Pumpkin Point) and the Double Island reference colony in 2011 and 2012. The solid line indicates the minimum productivity level of 0.8 chicks per nest associated with maintaining a stable herring gull population (range in levels=0.8-1.4 chicks per nest; Kadlec and Drury 1968).




In 2011, no morphological deformities were found in herring gull chicks from the two AOC colonies or the reference colony (N=39-76 chicks). This count included chicks from inside and outside of the enclosures (Table 6). Similarly, no deformities were found in gull chicks from enclosed nests at the three colonies in 2012 where numbers of chicks examined ranged from 14-16 per colony.

Table 6. Prevalence of morphological deformities (%) in herring gull chicks examined in enclosed nests and non-enclosed nests from St. Marys River AOC colonies (Hay Point, Pumpkin Point) and the Double Island reference colony in 2011 and 2012.

| Colony | Year | No. Chicks Examined | | % Deformities |
|---|---|---|---|---|
| | | Enclosed Nests | Non-enclosed Nests | |
| Hay Point | 2011 | 19 | 20 | 0% |
| | 2012 | 16 | - | 0% |
| Pumpkin Point | 2011 | 23 | 40 | 0% |
| | 2012 | 15 | - | 0% |
| Double I. | 2011 | 31 | 45 | 0% |
| | 2012 | 14 | - | 0% |

*ii) Common terns*

Common tern productivity, also defined as the number of ≥ 21-day-old chicks produced per nest, was equal to 0.8 chicks per nest at North Sister Rock in 2011 (N=10 enclosed nests; D. Moore and D.V. Weseloh 2012). This productivity estimate was higher than the estimate of 0.3 chicks produced per nest at the Cousins Island reference colony (N=20 nests). In 2012, tern productivity at 15 enclosed nests was equal to 0 at North Sister Rock as a result of predation of eggs in enclosures. There was however some evidence of renesting and successful nests later in the season at this colony (D. Moore, pers. comm.) Although considered low, productivity at Cousins Island was relatively higher in 2012 at 0.6 chicks per nest (N=16 nests). Productivity estimates for all study colonies were well below the threshold of 1.1 common tern chicks per nest associated with a stable population (DiCostanzo 1980).

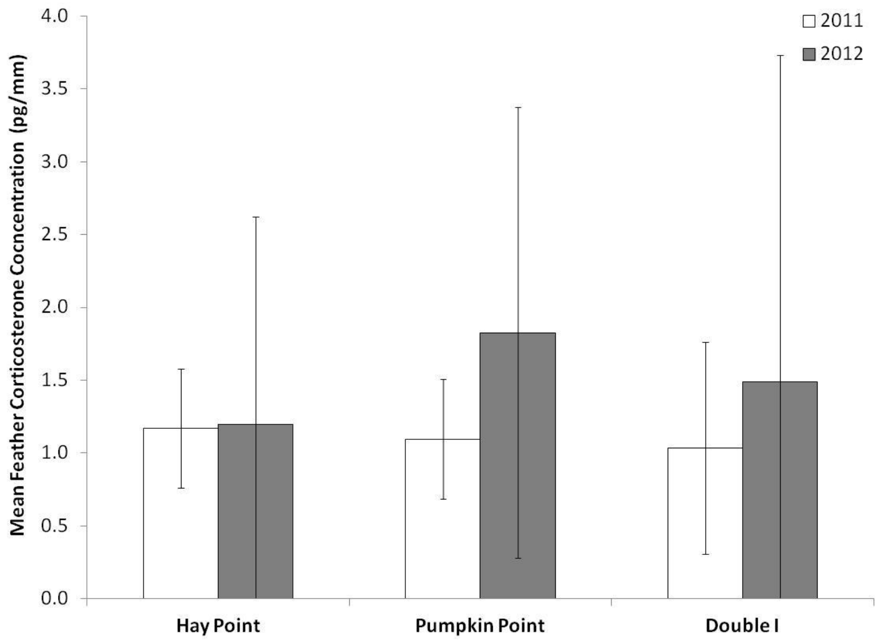
No deformities were observed in common tern chicks examined at non-enclosed nests at North Sister Rock and the Cousins Island reference colony in 2011 (N=13 and 10 chicks respectively). Since common tern colonies were not visited a second time (i.e., when chicks were ≥ 21 days old) in 2012, deformity estimates are not available.

### Corticosterone in Feathers:

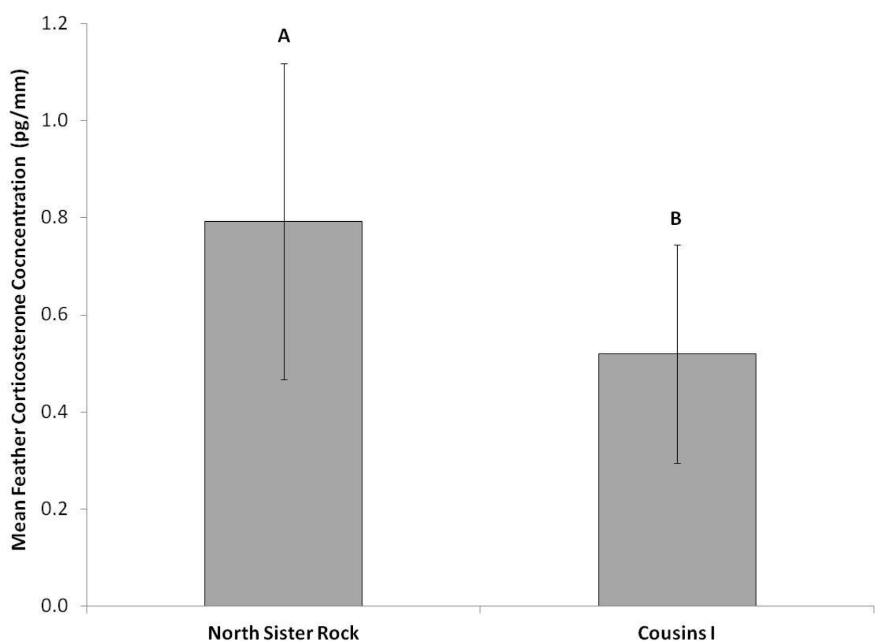
Mean corticosterone concentrations (SD) in herring gull chick feathers from the AOC colonies ranged from 1.1 (0.41) pg/mm to 1.8 (1.6) pg/mm at Pumpkin Point in 2011 and 2012, respectively, and overall were not significantly different from concentrations at the Double Island reference colony in either of the two study years (Figure 6a). However, a significant difference was found for common terns in 2011 (Figure 6b). Chicks from North Sister Rock had a significantly higher mean feather corticosterone concentration compared to those from Cousins Island ($t_{21}$=2.26; p=0.034). No data are available for common tern chicks in 2012.

Figure 6. Mean corticosterone concentrations (SD), expressed as picograms of corticosterone per millimetre of feather, in chicks of herring gulls (a) and common terns (b) from St. Marys River AOC colonies (Hay Point, Pumpkin Point, North Sister Rock) and corresponding Lake Huron reference colonies (Double Island or Cousins Island) in 2011 and/or 2012. Data for common terns are for 2011 only. Numbers of feathers ranged from 10-20 per colony for both species. Different uppercase letters show significant differences in mean concentrations within a study year.

a) Herring gulls:



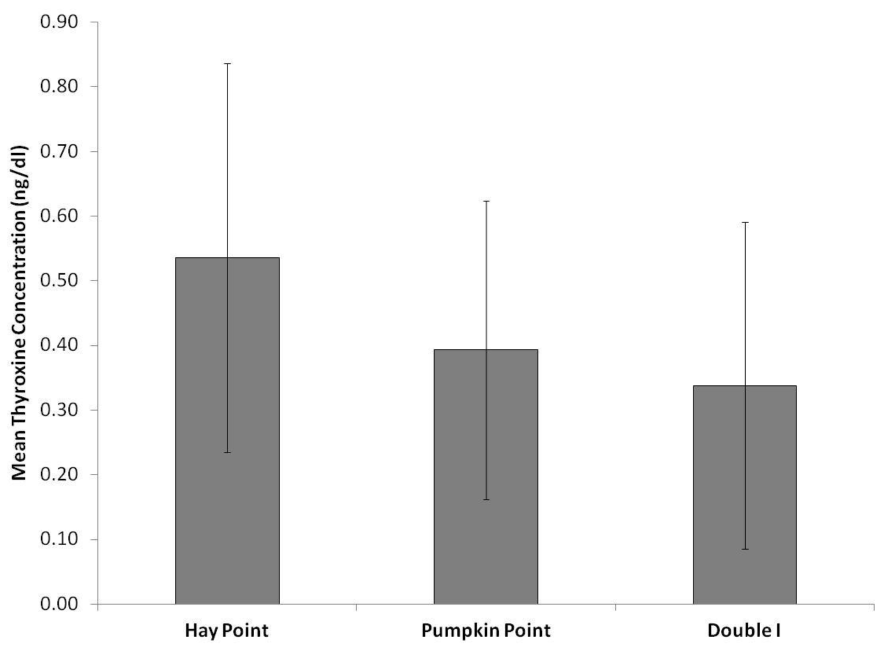

b) Common terns:



### Thyroxine in Plasma of Herring Gull Chicks:

Mean thyroxine concentrations (SD) were 0.54 (0.30) ng/dl and 0.39 (0.23) ng/dl in plasma of herring gull chicks from Hay Point and Pumpkin Point, respectively, and 0.34 (0.25) ng/dl in chicks from Double Island in 2012 (Figure 7). No significant difference in mean concentrations was found among colonies. Similarly, no significant differences in thyroxine concentrations were found between chicks from AOC colonies and corresponding reference colonies for herring gulls or common terns in 2011 (data not shown).

Figure 7. Mean thyroxine concentrations (SD) in plasma of herring gull chicks from St. Marys River AOC colonies (Hay Point and Pumpkin Point) and the reference colony (Double Island) in 2012. Numbers of blood samples collected ranged from 13-15 per colony.




## DISCUSSION

Based on the low overall contaminant burdens reported in embryos in 2011 and 2012, concentrations of PCBs, other organochlorines and PBDEs were not sufficiently elevated to adversely impact the reproductive success of herring gulls and common terns foraging in the St. Marys River AOC. In a broad literature review of PCB effects in birds, Hoffman *et al.* (1996) concluded that sum PCB concentrations in the range of 8 to 25 µg/g in eggs were associated with decreased hatching success for terns and cormorants. Sum PCB concentrations in all embryos of both species were well below the 8 µg/g threshold. Similarly, concentrations of *p*,*p*'-DDE in eggs were well below threshold levels associated with significant effects on reproductive success as reported in black-crowned night-herons (8 µg/g; Henny *et al.* 1984) and cormorants (10 µg/g; Pearce *et al.* 1979). These findings concur with those found in herring gull eggs from two U.S. colonies in the St. Marys River AOC (Michigan) between 2002-2006 where concentrations of both compounds were below recommended threshold levels associated with adverse reproductive effects (MDEQ 2012). Comparatively, median PCB and *p,p'*-DDE concentrations in gulls from these U.S. colonies were approximately two to three times higher than median concentrations in gulls from St. Marys River (Ontario) in 2011 and 2012. Sum PBDE concentrations were also low and well below the lowest-observed effect level on pipping and hatching success in American kestrels (*Falco sparverius*) equal to 1.8 µg/g in eggs (McKernan *et al.* 2009). Overall, concentrations of all compounds in both species were largely comparable between the AOC colonies and the reference colonies and were in fact significantly lower for some compounds (e.g., PCBs and PBDEs in terns) at an AOC colony than the reference colony.

Concentrations of 2,3,7,8-TCDD, dioxin-like PCBs and total TEQs in embryos of herring gulls and common terns from the St. Marys River AOC (Ontario) were not notably elevated relative to birds from the respective reference colonies in 2011 and 2012. Concentrations of these compounds in terns from AOC colonies were also below levels found in a previous study of common terns at a colony at Lime Island, on the U.S. side of the St. Marys River, and which is within 1 km of the Hay Point colony (Senthilkumar *et al.* 2003). In that study, ten unhatched eggs collected in 1999 had concentrations of 2,3,7,8-TCDD (range=1.7-6.6 pg/g), dioxin-like PCBs (range in total concentrations of non-*ortho* PCBs and mono-*ortho* PCBs=161-612 ng/g), and total TEQs (91-219 pg TEQ/g) which were considered to be elevated and which also coincided with the collapse of the colony in that year. Tern embryos from AOC colonies in 2011 and 2012 were below concentrations at the Lime Island colony in 1999 with corresponding concentrations of 2,3,7,8-TCDD (range=1.2-3.8 pg/g), dioxin-like PCBs (range=44-110 ng/g), and total TEQs (range=63-133 pg TEQ/g). Median total TEQs in herring gull embryos in this study (85 pg TEQ/g) were less than one-half of median total TEQs (222 pg TEQ/g) in herring gull eggs from colonies on the U.S. side of the St. Marys River between 2002-2006 (MDEQ 2012). Total TEQs in herring gulls from the St. Marys River AOC were within the range of mean TEQ concentrations in herring gull eggs from other colonies on the Great Lakes in 2011 and 2012 (Figure 2).

With respect to concentrations associated with toxicity, concentrations of 2,3,7,8-TCDD (<6 pg/g) and total TEQs (<160 pg TEQ/g) in herring gull and common tern embryos from colonies in the St. Marys River AOC were below concentrations associated with effects on reproduction in avian species. Median concentrations of 2,3,7,8-TCDD (37 pg/g) and total TEQs (2175 pg TEQ/g) in eggs of Forster's tern (*Sterna forsteri*) from Lake Michigan were associated with a significant reduction in hatching success while no effect on hatching success was found at relatively lower median concentrations of 2,3,7,8-TCDD (8 pg/g) and total TEQ (201 pg TEQ/g) in eggs from the reference colony in 1983 (TEQs based on concentrations of 2,3,7,8-TCDD and dioxin-like PCBs only; Kubiak *et al.* 1989). Concentrations of PCB-126 in common terns embryos from the AOC were two orders of magnitude below the lethal dose associated with 50% embryonic mortality in common terns (104 ng/g based on egg injection; Hoffman *et al.* 1998). In addition, 2,3,7,8-TCDD concentrations were below those associated with decreased embryonic growth and edema in herons (150-250 pg/g; Hoffman *et al.* 1996).

Exposure to high concentrations of mercury can have significant impacts on reproductive success in birds and can also result in teratogenic effects in avian embryos, as demonstrated in egg injection studies with methylmercury in the laboratory (Fimreite 1974; Hill *et al.* 2008; Heinz *et al.* 2011). Overall, mercury concentrations in all embryos were below the predicted threshold of 0.6 µg/g (wet weight) in eggs as being protective against adverse reproductive effects for 95% of non-marine avian species (Shore *et al.* 2011). Two common tern embryos from North Sister Rock and the Cousins Island approached this concentration in 2012 (0.57 µg/g and 0.59 µg/g, respectively). Common terns however may be less sensitive to the effects of mercury exposure relative to other species. Based on the results of egg injection studies with methylmercury, both common terns and herring gulls exhibited medium sensitivity to mercury compared to 24 other avian species where embryo survival was examined (Heinz *et al.* 2009); other studies have also demonstrated species-specific differences in mercury sensitivity (e.g., Braune *et al.* 2012). Fimreite (1974) found no effect on hatching success in common terns at a colony where the mean mercury concentration in eggs (1 µg/g) was at least twice those found in this study. While no deformities were found in these two embryos, sublethal effects that impair chick growth, behavior or survival cannot be ruled out however and these may be apparent in birds with relatively higher mercury burdens. Relative to mercury concentrations in herring gull eggs from other Great Lakes colonies in 2011 and 2012, mercury concentrations in gull eggs from the AOC colonies ranked 10$^{th}$ out of 15 herring gull colonies monitored (ranked as means from highest to lowest; EC unpublished). For both herring gulls and common terns, there was no evidence of significantly higher mercury concentrations in embryos from the St. Marys River AOC compared to reference colonies. These results suggest that current mercury concentrations would unlikely impact reproduction of breeding herring gulls and common terns in the St. Marys River AOC.

Elevated concentrations of PCBs and dioxins in eggs were associated with increased incidences of morphological deformities observed in wild populations of colonial waterbirds in the 1970s-1990s (Gilbertson *et al.* 1976; Ludwig *et al.* 1996). In 1998, Michigan State University researchers found three cross-billed common tern chicks out of 120 birds at the colony on Lime Island (EC *et al.* 2002). In this study, surveys of herring gull and common tern chicks at both AOC and reference colonies revealed no evidence of morphological deformities in both study years, a finding which is consistent with low organochlorine and dioxin burdens found in embryos from these sites. In the artificial incubation study however, embryonic deformities were detected in a single embryo from one or more AOC colonies per year, but out of a small sample size of viable embryos. The detection of a limited number of deformed embryos, but not free-living chicks, may not be surprising since affected individuals in wild populations would likely die before hatching or shortly thereafter and therefore not be captured in a deformity survey. It is somewhat puzzling however that deformed embryos were found only at AOC colonies and not at reference colonies for both species in both years. Specifically, three deformed herring gull embryos were found out of 53 viable eggs (6%) and two deformed common tern embryos were found out of 52 viable eggs (4%) when counts for AOC colonies and study years were combined. No deformed embryos were observed out of 46 viable herring gull eggs and 25 viable common tern eggs examined at the reference colonies, Double Island and Cousins Island, in the two years, respectively. Similar concentrations of non-*ortho* PCBs, 2,3,7,8-TCDD, and TEQs between deformed and normal embryos from AOC colonies of both herring gulls and common terns rule out the possibility that embryonic deformities were associated with exposure to dioxin-like PCBs and dioxins. A third year of egg collection and artificial incubation of eggs in the laboratory will be conducted in 2014 to examine this pattern further at both AOC and reference colonies. Nonetheless, given the low burdens of PCBs, other organochlorines, dioxins and furans, and mercury found in embryos, it is unlikely that this is a contaminant-related issue.

Reproduction based on productivity values for these two species in the St. Marys River AOC was considered good for herring gulls and was within a range considered typical for common terns in this region. Productivity of herring gulls at all study colonies was consistently high and above 1.3 chicks per nest in both study years. This was in the upper range of productivity levels required to maintain a stable herring gull population (range=0.8-1.4 chicks per nest; Kadlec and Drury 1968). Overall productivity of common terns at both the AOC colony and reference colony was low with comparable estimates of 0.40 and 0.45 chicks produced per nest, respectively, in the two study years. These rates are well below those required to maintain a population (1.1 chicks per nest; DiCostanzo 1980). However, these rates are consistent with low productivity observed as part of an intensive study of site tenacity and productivity in common terns conducted by EC throughout the North Channel in 2010-2012 (Moore and Weseloh 2012). In that study, the overall mean annual productivity of common terns in the region was 0.34 chicks per nest with a range in rates at six colonies in three study years from 0 - 1.0 chicks produced per nest. Productivity estimates for North Sister Rock and Cousins Island cited in this report are included in this overall mean annual productivity value. Low productivity in the North Channel was attributed primarily to egg loss and nestling loss caused by severe weather events (e.g. flooding) and predation by birds and mammals. The latter was evident at Hay Point in 2011 where significant predation led to abandonment of this as a nesting site. These results suggest that low productivity observed for common terns in 2011 and 2012 were not localized to the St. Marys River AOC but rather were consistent with low productivity observed in terns in the North Channel during this period. In an earlier study in the St. Marys River, Michigan in 1980, mean productivity of common terns at 12 colonies was also low at 0.36 chicks fledged per nest (Scharf 1981). Habitat loss associated with high water levels and flooding, erosion of natural and made-made islands, and encroachment by vegetation at nesting sites in the St. Marys River were cited as factors contributing to reduced reproductive success at those nesting sites. Overall, external stressors appear to be largely limiting productivity of terns in the AOC and the region. As effectively demonstrated in the artificial incubation study, intrinsic factors (e.g., contaminants) did not appear to impact hatchability of eggs where embryonic viability was high for both terns and gulls at study colonies in the two years.

Stable isotopes of nitrogen and carbon are used to provide information on trophic position and carbon source in the food web, respectively (Hobson 1999). For both herring gulls and common terns, the results of these analyses indicate that there were distinct and consistent differences in diet between birds from AOC colonies and those from reference colonies in the two study years. Significantly higher $\delta^{15}N$ values in embryos from the reference colonies in 2011 and 2012 suggest that the breeding birds from the reference colonies occupied a higher trophic level compared to birds from AOC colonies. Specifically, gulls and terns at the reference colonies may have fed more on fish (or larger fish) compared to birds from AOC colonies which fed at a relatively lower trophic level. For gulls, this could include terrestrial food sources such as small mammals, refuse and plant material (Fox *et al.* 1990). This apparent difference in trophic level between the colonies may have contributed to higher concentrations of some compounds in terns from the reference colony compared to an AOC colony in 2011 and 2012. Based on the isotopic signatures for $\delta^{13}C$, gulls from reference colonies may have fed more on aquatic-based prey types (with more depleted $\delta^{13}C$ signatures) compared to gulls from AOC colonies which fed more on terrestrial-based prey types (with more enriched $\delta^{13}C$ signatures). This is consistent with the spatial pattern evident for $\delta^{15}N$ in gulls. In the case of piscivorous common terns, birds from the reference colony may have fed more on fish from offshore areas compared to terns from AOC colonies which fed on fish from more inshore areas. Determinations of total clutch volume and intraclutch variation in 3-egg clutches for both species were informative for evaluating potential food stress during the egg production period in the two study years. Similarities for these endpoints between AOC and reference colonies suggest that food availability was likely not limited for laying females.

Two additional endpoints relating to growth and development of chicks were also measured in this study. Corticosterone deposited in growing feathers provides important insight into the physiology of stress during the period of feather growth (Bortolotti *et al.* 2009). As an indicator of stress over time, comparable corticosterone concentrations were found in feathers of herring gull chicks between AOC colonies and the reference colony in both years. However, common tern chicks from the AOC colony had a significantly higher mean concentration of corticosterone in feathers compared to reference colony chicks in 2011. Possible stressors could include low food availability, inclement weather, and/or threats of predation that may have been more prevalent at the AOC colony. Food availability may not have been an issue for terns in the AOC based on preliminary analyses of body condition of tern chicks and further supported by the clutch data for breeding females during the egg-laying period. Thyroxine concentrations in plasma of herring gull chicks were comparable among study sites in 2011 suggesting that there were no differences in chick growth and development or possible endocrine disruption among colonies.

In conclusion, the results of this two-year study suggest that there is little evidence of impaired reproduction or deformities in colonial waterbirds attributable to local contamination effects within the St. Marys River AOC (Ontario). Embryonic viability of herring gulls and common terns was high at AOC colonies. Herring gull productivity at AOC colonies was sufficiently high to maintain a stable population. While considered low for common terns, productivity at AOC colonies was consistent with that in the region and was largely attributable to external stressors, such as predation and severe weather events. No morphological deformities were found in $\geq$ 21-day-old chicks of either species. While there was some evidence of deformities in a limited number of embryos from AOC colonies, the significance of this is unknown and further investigation of this will be conducted in 2014. Importantly, contaminant burdens (e.g., PCBs, 2,3,7,8-TCDD, and mercury) in gull and tern embryos from the St. Marys River AOC (Ontario) were not notably elevated and were comparable to burdens at respective reference colonies in 2011 and 2012. Concentrations of PCBs, other organochlorine compounds, PBDEs, dioxins and furans and mercury were not sufficiently elevated to adversely impact the reproductive success and development of herring gulls and common terns foraging in the St. Marys River AOC.

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Appendix 1. Mean concentrations (SD) of 4 non-*ortho* PCBs, 6 mono-*ortho* PCBs, and 17 furans and dioxins in embryos of herring gulls (HERG) and common terns (COTE) collected from the St. Marys River (SMR) AOC and reference colonies (i.e., Double Island and Cousins Island) in 2011 and 2012 and incubated in the lab (pg/g, wet weight). Concentrations are shown for deformed embryos (analyzed as individuals) and normal embryos based on the analysis of pools consisting of five individuals. Accordingly, N represents either the number of deformed individuals or the number of pools analyzed.

| **Compound** | **HERG-SMR AOC** | | **HERG-Double I** | **COTE-SMR AOC** | | **COTE-Cousins I** |
|---|---|---|---|---|---|---|
| | **Deformed N=3** | **Normal N=3** | **Normal N=1** | **Deformed N=2** | **Normal N=2** | **Normal N=1** |
| PCB-77 | 249.07 (384.48) | 61.90 (71.18) | 36.70 | 617.25 (135.41) | 548.50 (9.19) | 1000.00 |
| PCB-81 | 120.10 (53.96) | 72.30 (9.52) | 98.90 | 55.58 (25.49) | 48.05 (5.73) | 75.80 |
| PCB-126 | 699.00 (149.79) | 497.67(70.12) | 680.00 | 389.75 (259.15) | 346.00 (82.02) | 455.00 |
| PCB-169 | 112.70 (54.67) | 92.07 (20.57) | 121.00 | 68.03 (37.16) | 70.20 (18.95) | 85.20 |
| PCB-105 | 48102 (5660) | 42113 (8771) | 59149 | 18067 (8249) | 17970 (279) | 16877 |
| PCB-114 | 3273 (245) | 2754 (116) | 3150 | 1045 (502) | 974 (131) | 713 |
| PCB-118 | 109721 (12333) | 94632 (5426) | 116622 | 45638 (28654) | 47239 (10551) | 34511 |
| PCB-156 | 15096 (1125) | 15201 (285) | 19236 | 7543 (6161) | 7803 (3437) | 4891 |
| PCB-157 | 2609 (129) | 3149 (299) | 3732 | 1931 (1512) | 1906 (1029) | 1251 |
| PCB-189 | 2468 (945) | 2724 (389) | 3299 | 1531 (663) | 1716 (261) | 1478 |
| 2378-TCDD | 4.76 (0.51) | 3.30 (1.30) | 5.62 | 2.49 (1.84) | 2.14 (0.64) | 3.80 |
| 12378-PeCDD | 4.15 (1.93) | 3.13 (0.94) | 4.49 | 4.49 (3.24) | 4.37 (1.75) | 5.87 |
| 123478-HxCDD | 0.39 (0.25) | 0.27 (0.22) | NDR | 1.09 (0.53) | 0.46 (0.64) | 0.95 |
| 123678-HxCDD | 5.78 (1.40) | 4.85 (0.72) | 5.26 | 3.38 (2.10) | 3.99 (0.43) | 3.68 |
| 123789-HxCDD | 1.28 (0.50) | 0.82 (0.16) | 1.15 | 1.22 (0.45) | 1.10 (0.34) | 1.00 |
| 1234678-HpCDD | 3.42 (0.86) | 7.64 (3.44) | 5.63 | 2.56 (0.33) | 1.85 (0.66) | 2.59 |
| 12346789-OCDD | 8.07 (1.62) | 16.26 (8.28) | 11.6 | 5.03 (3.37) | 2.33 (0.72) | 2.57 |
| 2378-TCDF | 0.55 (0.95) | ^ | ^ | 6.55 (2.79) | 4.51 (6.37) | 18.10 |
| 12378-PeCDF | 0.46 (0.80) | 0.03 (0.04) | ^ | 0.17 (0.23) | 0.67 (0.94) | ^ |
| 23478-PeCDF | 2.92 (2.96) | 2.44 (2.14) | 3.17 | 5.11 (3.62) | 4.54 (1.34) | 4.95 |
| 123478-HxCDF | 1.07 (0.43) | 0.99 (0.46) | 1.05 | 0.97 (0.61) | 0.83 (0.32) | 1.01 |
| 123678-HxCDF | 1.43 (0.20) | 0.96 (0.30) | 1.64 | 1.17 (0.89) | 1.07 (0.21) | 1.11 |
| 234678-HxCDF | 0.82 (0.57) | 0.66 (0.19) | 0.97 | 0.90 (0.37) | 0.87 (0.06) | 1.04 |
| 123789-HxCDF | NDR | 0.09 (0.02) | 0.21 | 0.17 (0.09) | 0.11 (0.06) | 0.12 |
| 1234678-HpCDF | NDR | NDR | 5.05 | 0.13 (0.18) | 0.04 (0.06) | 0.12 |
| 1234789-HpCDF | 0.18 (0.08) | 0.09 (0.08) | NDR | 0.07 (0.03) | 0.19 (0.10) | 0.16 |
| 12346789-OCDF | 1.13 (0.51) | 1.04 (0.52) | 1.16 | 0.58 (0.21) | 0.52 (0.05) | 0.53 |

NDR = Not detected due to incorrect isotope ratio; ^ Possible chlorinated diphenyl interference