Water-level-induced changes in fish communities in coastal wetlands of eastern Georgian Bay: Final Report

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Introduction

Coastal wetlands occupy the transitional zone between terrestrial and aquatic habitats, making them highly dependent on water levels. There has been a considerable drop in water level of 76 cm (177.10 m to 176.34 m) between 1997 and 2009 in Severn Sound. The majority of this drop occurred from 1997 to 2000 and since then water levels have remained at a comparatively stable level (**Figure 1**). Sellinger et al. (2008) have tracked a negative trend in water levels in Lake Huron since the 1970s and levels are expected to drop between 0.2 to 2.5 m lower by 2050 (Mortsch & Quinn 1996; Magnuson et al. 1997). Water levels in coastal wetlands of the Great Lakes are naturally variable, and it is this year-to-year fluctuation that maintains high biodiversity (Keddy and Reznicek 1986) and keeps the aquatic plant community in a state of perpetual succession (Wilcox & Meeker 1991; Herendorf 2004). A change from a fluctuating hydrologic regime to one that has sustained periods of low or high water levels can allow either meadow or submerged/floating vegetation (respectively) to dominate (Quinlan & Mulamoottil 1987). Such a change can have a domino effect on the fish community, as shown by the direct linkage between fish and aquatic macrophyte communities in wetlands of eastern and northern Georgian Bay (Cvetkovic et al. 2010).

One important role of coastal wetlands is to provide critical habitat for a wide variety of fish species (Jude & Pappas 1992; Wei & Chow-Fraser 2004). Variation in the structure and abundance of vegetated habitat is tied to species richness in the fish community. Jacobus et al (2005) found that the highest levels of diversity were in complex habitats that contained a lot of different patches. A potential reason for this is that increased structural complexity is associated with increased edge effects and an increase in predator-prey interactions (Eklov 1997). While a variable habitat can potentially support a diverse fish community, Trebitz et al (2009) cautions that there is not always a direct link.

Remote sensing has been used extensively to map both habitat and changes that occur therein (Bartlett & Klemas 1980; Houhoulis & Michener 2002; Dechka et al. 2002; Fuller et al. 2005). Wei and Chow-Fraser (2007) were able to use IKONOS satellite imagery, ground control points and a maximum-likelihood classifier to map aquatic vegetation in the coastal wetlands of eastern Georgian Bay. Based on this initial success, Midwood and Chow-Fraser (in review) were able to expand the number of classes that could be mapped and developed an automated classification specific to 2002 IKONOS imagery in eastern Georgian Bay. This work has now been expanded to cover 2008 IKONOS images (Midwood et al. unpublished data). Portions of this change detection analysis are discussed in this report because fish habitat within these wetlands can be associated with changes in the fish community.

A direct study of the impact of declining water levels on the provision and quality of fish habitat and consequently the fish community has not been undertaken in southeastern Georgian Bay. Results of this study will help the OMNR understand the potential negative impact of sustained lower water levels on fish habitat and fish community dynamics in eastern Georgian Bay.

Rationale for study approach

Chow-Fraser (2006a) conducted a large synoptic sampling program, which had been funded as part of the Canada-Ontario Agreement from the Ontario Ministry of Natural Resources in 2003-2006. The goal of that study was to sample as many wetlands as possible throughout eastern and northern Georgian Bay (including some wetlands in the North Channel) to characterize fish habitat in coastal wetlands with respect to water quality and communities of aquatic plants, invertebrates and fish. All sampling had been carried out with standardized protocols between 2003 and 2005. This dataset corresponded to conditions in the wetlands that had been under low water levels since 1999 (approximately 4 to 6 years; see **Figure 1**). We wanted to re-sample these sites in 2009 so that we could compare changes (if any) in the fish and plant communities that would be associated with wetlands that had been under low water levels for 10 years.

Methods

Site Selection

Sites in this study were chosen based on availability of historical data (see **Table 1**). Five sites had been sampled in 2003 (Green Island, Matchedash Bay, Musky Bay, Oak Bay and Quarry Island), five sites in 2004 (Green Island, Matchedash Bay, Moreau Bay, Oak Bay and Robert's Bay) and eight in 2005 (Ganyon Bay, Hermann's Bay, Lily Pond, North Bay, Ojibway Bay, Tadenac Bay 1, Tadenac Bay 2 and Treasure Bay). In 2009, all 15 wetlands were sampled once; we conducted our surveys in 2009 close to the actual time in the year when the sites had been sampled between 2003 and 2005. Wetland size ranged from 1.5 ha (Tadenac Bay 1) to 347.8 ha (Matchedash Bay), the mean size was 37.2 ha but 75% of the wetlands were smaller than 24 ha (**Table 1**). The majority of wetlands were located in the Severn Sound region of southeastern Georgian Bay. Exceptions include Hermann's Bay (Twelve Mile Bay), Moreau Bay (Go Home Bay) and Tadenac Bay 1 and 2 (Tadenac Bay; **Figure 2**).

Water Quality Sampling

Procedures for water quality sampling are those used in Chow-Fraser (2006b). Water samples were collected at mid-water depth in areas with no aquatic vegetation. Samples for total phosphorus, total nitrogen and soluble reactive phosphorus were frozen and stored until they could be processed in the lab. Infield measurements for dissolved oxygen, temperature, conductivity and pH were taken with an YSI 6600 multi-parameter probe with YSI 650 display (YSI, Yellow Springs, Ohio, USA). Turbidity was measured in situ with a LaMotte 2020 turbidimeter (LaMotte Company, Chestertown, Maryland, U.S.A.). Total nitrite-nitrogen and total ammonia-nitrogen were measured in situ with a portable Hach DR890 colorimeter (Hach, Loveland, Colorado, U.S.A.). Water samples were filtered through pre-weighed 0.45-µm GF/C filters and frozen until they could be analyzed at the McMaster University laboratory for chlorophyll *a* and total suspended solids.

Aquatic Macrophyte Sampling

Plant surveys were conducted between late June and late August. Within each wetland, 10-15 (0.75m x 0.75m) quadrats were selected as per the stratified method outlined by Croft & Chow-Fraser (2009). All inundated portions of the wetland were sampled, including emergent, floating, and submerged macrophyte forms, until no new species were found. Meadow portions of wetlands were not surveyed because they are not considered fish habitat. Newmaster et al. (1997) and Chaade (2002) were used as references to identify all plant taxa to species (if possible) within each quadrat.

Fish Sampling

Our fish sampling protocol followed Seilheimer & Chow-Fraser (2006, 2007). Three sets of paired fyke nets were used to sample the fish community. Nets were set parallel to the shoreline in beds of aquatic vegetation. Two pairs of large nets (4.25 m long, 1 m × 1.25 m front opening with 13 and 4 mm bar mesh) were set in approximately 1 meter of water, and one pair of small nets (2.1 m long, 0.5 m x 1.0 m front opening with 4 mm bar mesh). Large nets were set in approximately 1 m of water and small nets were set in approximately 0.5 m of water. After 24 hours, the nets were removed and all fish were measured, counted and identified to species as per Scott & Crossman (1998). All fish were returned unharmed after processing.

Within our database, we identified the 12 most common species as follows: pumpkinseeds (*Lepomis gibbosus*), brown bullhead (*Ameiurus nebulosus*), largemouth bass (*Micropterus salmoides*), bluntnose minnow (*Pimephales notatus*), rock bass (*Ambloplites rupestris*), yellow perch (*Perca flavescens*), longear sunfish (*Lepomis megalotis*), blackchin shiner (*Notropis heterodon*), Tadpole madtom (*Noturus gyrinus*), black crappie (*Pomoxis nigromaculatus*), mimic shiner (*Notropis volucellus*) and bowfin (*Amia calva*).

Statistical Analysis

Univariate analyses were conducted in JMP (version 8.01; SAS Institute Inc., Cary, North Carolina). Multivariate analyses were conducted in CANOCO (ter Braak & Smilauer 1988). When necessary, the years 2003, 2004 and 2005 were combined into a "past" category (linked to the 2002 IKONOS images) and 2009 was used as a "present" category (linked to the 2008 images). Index scores for fish, plants and water quality were calculated as described by Seilheimer & Chow-Fraser (Wetland Fish Index (WFI); 2007), Croft & Chow-Fraser (Wetland Macrophyte Index (WMI), Adjusted Wetland Macrophyte Index (WMIadj); 2007) and Chow-Fraser (Water Quality Index (WQI); 2006b) respectively. The WMIadj takes into account the presence or absence of exotic aquatic macrophytes. To account for differences in total numbers of fish between sampling periods, the fish community data were first expressed as a proportion of overall catch within a wetland per period, and these were subsequently arcsine transformed before we entered them into statistical analyses.

Veech et al. (2002) reviewed the use of Alpha-Beta-Gamma Diversity (first used by Whittaker 1956) for assessing changes in species richness at multiple ecological levels. Alpha-diversity quantifies the diversity of the local community (within wetlands), beta-diversity quantifies diversity among local communities (among wetlands) and gamma-diversity quantifies diversity within a specific region (south-eastern Georgian Bay). Alpha and gamma diversity can be inferred from direct field sampling but beta diversity must be calculated (beta = gamma-alpha). Alpha-Beta-Gamma Diversity was calculated for the 15 wetlands included in this study.

Results

Water Quality

While there was some variation in WQI scores from 2003-2009, we observed no significant change during this period (paired t-test, prob > |t| = 0.1711; **Tables 2**).

Aquatic Macrophytes

There were no significant changes in plant species richness from 2003 to 2009 (paired t-test, prob > |t| <0.3456). Neither were there significant changes in WMI and WMIadj scores (paired t-test, prob > |t| = 0.2461, paired t-test, prob > |t| = 0.9121, respectively; **Table 2**). Since we only determined plant presence, we were unable to assess changes in the proportional representation of plant species. The most common macrophyte species observed when both past and present sampling surveys were combined were: white water lily (*Nymphaea odorata*), yellow pond lily (*Nuphar variegatum*), tape grass (*Vallisneria americana*), pickerel-weed (*Pontederia cordata*), common water-weed (*Elodea canadensis*), clasping-leaved pondweed (*Potamogeton richardsonii*), muskgrass (*Chara* spp.), variable pondweed (*Potamogeton gramineus*), water nymph (*Najas flexilis*), flatstem-pondweed (*Potamogeton zosteriformis*), marsh spikerush (*Eleocharis smallii*), fern-pondweed (*Potamogeton robbinsii*), Eurasian water milfoil (*Myriophyllum spicatum*), and wild rice (*Zizania palustris*). A complete list of aquatic macrophytes is located in **Table 3a and b.**

While several exotic plant species were found, they were not common occurrences except for Eurasian milfoil. Other exotic species included curly pondweed (*Potamogeton crispus*), common reed (*Phragmites australis* subsp. *australis*), and purple loosestrife (*Lythrum salicaria*).

Fish

In total, 40 different fish species were caught in the 15 wetlands during the two sampling periods (**Table 4a and b**). Species richness for the past (2003-2005) survey ranged from 5 to 20 species per wetland, compared with 4 to 10 in the present (2009) survey. The mean richness declined significantly from 13.2 in the past to 7.2 in the present surveys (paired t-test, P>|t| <0.0001). We examined changes in the proportion of catch represented by the 12 most common species sampled in eastern Georgian Bay. Pumpkinseeds (*Lepomis gibbosus*) and bowfin (*Amia calva*), increased significantly as a proportion of our catch while Tadpole madtoms (*Noturus gyrinus*), blackchin shiners (*Notropis heterodon*) and black crappie (*Pomoxis nigromaculatus*) all decreased significantly as a proportion of our catch. No significant changes in the proportion of catch were observed for brown bullhead (*Ameiurus nebulosus*), rock bass (*Ambloplites rupestris*), largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), longear sunfish (*Lepomis megalotis*), mimic shiner (*Notropis volucellus*), and bluntnose minnow (*Pimephales notatus*) although, there were trends towards increasing proportions of brown bullheads and rock bass and decreasing proportions of largemouth bass, longear sunfish, and bluntnose minnows (**Table 5**; **Figure 3**). The proportion of fish in the Cyprinidae (shiners, minnow and small fish) also decreased significantly.

WFI scores associated with the past survey were significantly lower than those associated with the present survey (paired-t-test; prob > |t| 0.0006). We also observed declines in alpha, beta and gamma diversity at all scales, indicating an overall decline in species richness over the two periods. The mean alpha diversity (within wetlands) decreased from 13.2 in 2003-2005 to 7.2 in 2009. Regional diversity (Gamma) also decreased from 37 in 2003-2005 to 24 in 2009. Finally, beta diversity also decreased from 23.8 in 2003-2005 to 16.8 in 2009.

Discussion

Water Quality

Despite the lack of significant overall changes in WQI scores for the 15 sites sampled in southeastern Georgian Bay, there was some variation between the past (2003-2005) and present (2009). Musky Bay was the only wetland with a greatly decreased WQI score over this period (from 1.19 to 0.41). We attribute this change to the sampling conditions in 2009. It had been very windy on the day we sampled and this caused sediment to become re-suspended in the water column. When we returned to Musky Bay the following day to remove fykenets, the wind had died down and the water was comparatively clear again. When we compared individual water-quality variables, it was clear that total suspended solids and inorganic suspended solids had increased greatly in 2009 compared with 2003-2004. Therefore, we feel that the WQI score obtained in 2009 for Musky Bay is an anomaly and that the lower WQI score should be disregarded.

The largest improvement in water quality (+0.85) occurred in Lily Pond, which is located in Honey Harbour. Several marinas and many private residences surround Lily Pond and the channel connecting the wetland to the main bay is a busy waterway for boaters. Shortly before we sampled Lily Pond in 2005, the entrance to Lily Pond had been dredged to remove sediment and to improve navigation. As a result of this dredging, nutrients and suspended solids had been inflated in 2005. In 2009, the negative effects of dredging had subsided and water quality improved from "moderately degraded" to "good" condition. In 2003 and 2004, the water quality in Matchedash Bay fell within the "moderately degraded" category, although it was just below the threshold between "moderately degraded" and "good" (-0.161). In 2009, the water quality in Matchedash Bay improved slightly (+0.27) but was still insufficient to move it from the "moderately degraded" to "good" category. Despite small variations in water quality between the two sampling periods, there were no statistically significant changes in water quality; the general trends, however, show an overall improvement in water quality conditions. As a result, it is unlikely that water quality changes have been responsible for any changes in fish habitat and the fish community in Severn Sound.

Aquatic Vegetation

Not surprisingly, we did not detect any statistically significant changes in macrophyte species richness between the past (2003-5) and present (2009) survey. Since aquatic plant diversity is largely driven by the availability of distinct niches, a dampening of water-level fluctuations and a small reduction in water level would not have affected niche availability. While there were some variations in WMI and WMIadj scores, the changes were not statistically significant. There were no changes in WMI scores for majority of wetlands between the two survey periods, except for one notable exception. WMI score for Matchedash Bay increased from 2.1 to 3.0 (2.1 to 2.8 WMIadj). Croft and Chow-Fraser (2007) established a WMI value of 2.5 as the threshold between wetlands that are "degraded" and wetlands that are in "good" condition. Based on this threshold, Matchedash has transitioned from a "degraded" wetland to one that is in "good" condition and this is consistent with changes seen in WQI scores.

Fish Community

For the 15 wetlands sampled, the WFI score had declined significantly between the past and present surveys. Similar to the WMI, the WFI was developed to track water quality changes in coastal wetlands, and uses the fish community to deduce the condition of the wetland (Seilheimer & Chow-Fraser 2006, 2007). It has since been shown that the WFI is not as strongly correlated with water quality as is the WMI, and that it is not as sensitive an index in high-quality sites such as Georgian Bay (Seilheimer et al. 2009). Nevertheless, Seilheimer et al. (2009) suggested that biotic indices, like the WFI, might be useful for tracking non-anthropogenically driven changes. Since there had been no significant changes in WQI, WMI, and aquatic vegetation species richness over the six-year period, we can infer that no discernible water-quality deterioration occurred within these sites. Instead, we hypothesize that the decreases in WFI scores, fish species richness, and declines at all levels of diversity are likely the result of changes in habitat availability and suitability.

Midwood and Chow-Fraser (unpublished data) conducted a change detection analysis, comparing wetland habitat between 2002 and 2008 IKONOS satellite imagery. They found that fish habitat availability and quality had changed in the coastal wetlands of eastern Georgian Bay as a result of sustained low water levels. Unfortunately, the majority of the 15 sites in this study were not covered by the IKONOS satellite imagery used in the change analysis. Habitat change was, however, quantified in 84 wetlands within the North Bay/Honey Harbour region and the Tadenac Bay region and we assume that the general changes observed in these wetlands would be consistent for the 15 wetlands sampled for this study. When data for the 84 wetlands were pooled, we found a significant increase in the amount of non-fish-habitat, specifically, meadow vegetation (paired t-test, prob. >|t| = <0.0001, mean diff. = +2020.9 m^2) and a significant decline in the amount of available fish habitat (paired t-test, prob. >|t| = <0.0001, mean diff =-1181.5 m^2). The dystrophic water of eastern Georgian Bay prevented a change analysis for submerged aquatic vegetation (SAV), and hence, it is not possible to quantify the total fish habitat loss between the two 2002 and 2008. In some wetlands, it is possible that the SAV migrated lakeward and maintained the total amount of available habitat. Based on field observations, however, we feel that lakeward expansion of SAV in deeper water would not be sufficient to compensate for habitat lost along the shore since there had only been an overall decrease of 10-cm in water levels between the two time periods.

Midwood and Chow-Fraser (unpublished data) also found changes in the complexity and structure of vegetation within coastal wetlands. From 2002 to 2008, the patch size and overall coverage of low-density aquatic vegetation significantly decreased (data not shown). Low-density aquatic vegetation represents a mixture of both vegetation and open water, maximizing the tradeoff between the protection of vegetation and the productivity of open water. In 2008, large patches of high-density aquatic vegetation dominated in wetlands (Figure 3). While high-density aquatic vegetation provides some habitat, the habitat diversity hypothesis suggests that an intermediate density of aquatic vegetation maximizes species richness (Jude & Pappas 1992). Jacobus and Wade (2005) found that habitat complexity was directly linked to species richness; they also found that the first species to disappear were the least common. Our results agree with their findings; fish from the family Cyprinidae were not very common in the past surveys, and were completely absent in the present.

Jacobus and Wade (2005) identified 128 m^2 as the habitat patch size that maximized species richness. In the change-detection study, patch size in wetlands decreased from 201.2 m^2 in 2002 to 57.1 m^2 in 2008, and this corresponds to the decline in fish species richness. Decreases in habitat availability and a shift to less desirable high-density aquatic vegetation can explain the loss of fish species richness from 2003-2005 to 2009. In terms of species, we observed more pumpkinseeds and bowfins, two species that thrive in shallow, densely vegetated water (Scott & Crossman 1998, Cvetkovic 2008, Holm et al. 2009). Our alpha-beta-gamma analysis indicated that 1) fish species richness is decreasing and 2) fish communities in southeastern Georgian Bay wetlands are becoming more homogeneous.

Hook et al. (2001) found that local habitat features determined fish community composition and that human activities affected fish communities indirectly. Our results show that in eastern Georgian Bay, where there are minimal human influences, the major factor determining the composition of the fish community is the availability and quality of aquatic habitat. The WQI and the WMI, which are metrics designed to measure human impacts, identified no significant changes caused by human sources. Instead, the majority of the changes observed can be seen as an indirect influence of sustained low water levels. Meyers et al. (1999) predicted that rising temperatures and low water levels would result in less aquatic habitat; based on our analysis this prediction appears to be valid.

Despite our confidence that these results reflect the changes in coastal wetlands resulting from sustained low water levels, we must acknowledge that sampling from 2003-2005 was not designed specifically to test the impact of water level fluctuations on the fish community. Ideally, both within-season variation and yearly variation should be tracked to ensure that water level changes are the primary explanation for alterations of the fish community. Overall, we observed no significant changes in water quality and no significant changes in plant species richness or WMI scores between the two survey periods. We attribute the observed significant decline in fish species richness and significant decline in WFI scores not to human disturbance, but to changes in fish habitat availability resulting from sustained low water levels. This research emphasizes the importance of maintaining natural, variable water cycles within the Great Lakes, and the need for regular monitoring programs to track associated changes.

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Table 1. List of wetlands, their locations (decimal degrees) and size in this study.

Wetland Name	Wetland Code	Latitude	Longitude	Wetland Size (ha)
Ganyon Bay	GY	44.91995	-79.81976	1.90
Green Island	GI	44.78574	-79.74797	4.90
Hermann's Bay	HRM	45.08662	-79.99669	2.90
Lily Pond	LY1	44.87076	-79.81547	3.20
Matchedash Bay	MB	44.75885	-79.69687	347.80
Moreau Bay	MO	45.01460	-79.94510	23.60
Musky Bay	MS	44.81197	-79.77945	19.40
North Bay	NB	44.89717	-79.79465	10.30
Oak Bay	OB	44.79466	-79.73221	50.20
Ojibway Bay	OJ	44.88786	-79.85587	1.70
Quarry Island	QI	44.83510	-79.80897	21.20
Robert's Bay	RB	44.85583	-79.83063	6.00
Tadenac Bay 1	TD1	45.03583	-79.99325	1.50
Tadenac Bay 2	TD2	45.03977	-79.98508	2.70
Treasure Bay	TB	44.87190	-79.86013	60.20

Table 2. Summary of Ecological Index scores for wetlands during the past and present. WQI=Water Quality Index (Chow-Fraser 2006); WMI=Wetland Macrophyte Index and WMIadj=Wetland Macrophyte Index adjusted for presence of exotic species (Croft and Chow-Fraser 2007); WFI=Wetland Fish Index (Seilheimer and Chow-Fraser 2007).

Wetland	Year	WQI	WMI	WMIadj	WFI	Category
Green Island	2003	0.91	3.04	2.76	3.71	Past
Matchedash Bay	2003	-0.15	2.45	2.10	3.48	Past
Musky Bay	2003	1.15	3.48	3.29	3.73	Past
Oak Bay	2003	1.03	2.98	2.75	3.61	Past
Quarry Island	2003	1.34	3.48	3.48	3.84	Past
Green Island	2004	1.38	3.40	3.16	3.72	Past
Matchedash Bay	2004	-0.17	2.45	2.10	4.10	Past
Moreau Bay	2004	1.17	3.64	3.64	4.06	Past
Musky Bay	2004	1.23	3.48	3.29	N/A	Past
Oak Bay	2004	1.12	2.86	2.86	3.75	Past
Quarry Island	2004	1.34	3.48	3.48	N/A	Past
Robert's Bay	2004	1.44	3.11	3.11	3.93	Past
Ganyon Bay	2005	1.43	3.86	3.64	3.69	Past
Hermann's Bay	2005	1.59	3.71	3.50	3.38	Past
Lily Pond	2005	-0.46	3.05	2.82	3.73	Past
North Bay	2005	0.43	3.52	3.52	3.83	Past
Ojibway Bay	2005	1.56	3.67	3.43	3.85	Past
Tadenac Bay 1	2005	1.56	4.10	4.10	3.79	Past
Tadenac Bay 2	2005	N/A	3.96	3.96	3.80	Past
Treasure Bay	2005	1.55	3.55	3.32	3.78	Past
Ganyon Bay	2009	1.51	3.66	3.41	3.43	Present
Green Island	2009	1.73	3.51	3.26	3.42	Present
Hermann's Bay	2009	N/A	3.47	3.47	3.63	Present
Lily Pond	2009	0.39	2.86	2.59	3.71	Present
Matchedash Bay	2009	0.11	3.00	2.75	3.57	Present
Moreau Bay	2009	N/A	3.67	3.44	3.60	Present
Musky Bay	2009	0.41	3.35	3.13	3.08	Present
North Bay	2009	1.21	3.47	3.27	3.00	Present
Oak Bay	2009	1.16	3.43	3.22	3.20	Present
Ojibway Bay	2009	1.83	3.55	3.33	3.00	Present
Quarry Island	2009	1.27	3.50	3.27	3.62	Present
Robert's Bay	2009	1.54	3.65	3.44	3.33	Present
Tadenac Bay 1	2009	2.01	4.00	4.00	3.11	Present
Tadenac Bay 2	2009	N/A	3.80	3.59	3.77	Present
Treasure Bay	2009	1.50	3.41	3.10	3.69	Present

Table 3a. Summary of all aquatic plant species in the 15 wetlands during the past surveys (2003 to 2005 inclusive). Expansion of the 4-letter plant codes is found in the Appendix 1.

Parameter	Green Island	Matchedash Bay	Musky Bay	Oak Bay	Quarry Island	Moreau Bay	Robert's Bay	Ganyon Bay	Hermann's Bay	Lily Pond	North Bay	Ojibway Bay	Tadenac Bay 1	Tadenac Bay 2	Treasure Bay
Adjusted WMI	3.2	2.1	3.3	2.9	3.5	3.6	3.1	3.6	3.5	2.8	3.5	3.4	4.1	4.0	3.3
# submergents	14	14	23	9	18	18	6	16	17	13	14	13	19	18	17
# floating	4	2	4	3	2	4	4	5	5	5	3	4	6	1	2
# emergents	7	9	10	3	5	4	3	6	6	6	6	6	9	6	5
# exotic	1	4	3	0	0	0	0	1	1	2	0	1	0	0	2
Presence (1) or absence (0) of each plant taxon in wetlands															
BIBE	0	1	1	0	1	1	0	1	1	0	1	0	1	1	1
BRSC	1	0	1	0	0	1	1	1	0	1	1	1	1	0	0
CASP	0	0	1	0	0	0	0	1	0	0	0	0	1	1	0
CEDE	1	1	1	0	1	0	1	0	0	1	1	0	0	0	1
CHSP	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1
ELAC	0	0	1	0	0	0	0	0	0	0	1	1	1	1	0
ELSM	1	0	1	0	1	0	0	1	1	1	1	1	1	1	0
ELCA	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
EQFL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ERAQ	1	0	1	0	1	1	0	1	1	0	1	1	1	1	0
SPON	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0
ISSP	0	0	1	0	1	0	0	0	1	0	0	0	1	0	0
LETR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LODO	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0
MYAL	0	0	0	0	1	0	0	1	1	0	1	1	1	0	1
MYHE	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
MYSI	0	1	1	1	1	0	0	0	0	0	1	1	0	1	1
MYSC	1	1	1	0	0	0	0	1	1	1	0	0	0	0	0
MYTE	1	0	1	0	1	0	0	0	0	0	0	0	1	1	0
MYSP	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
NAFL	1	0	1	0	1	1	0	1	1	1	1	1	1	1	0
NISP	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
NUVA	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
NYOD	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NMCO	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

POCO	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
POAM	1	0	1	1	1	0	0	0	1	0	1	1	1	0	1
POCR	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1
POEP	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0
POGR	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1
POIL	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
PONA	1	0	1	1	0	1	1	0	1	1	0	1	0	0	0
POPU	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
PORI	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
PORO	1	0	1	0	0	1	0	1	1	0	1	1	1	1	1
POSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POSR	0	0	0	0	1	1	0	1	1	0	0	0	1	1	0
POZO	1	1	1	1	1	0	0	1	1	1	1	0	0	1	1
RALO	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
RASP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
SGCU	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0
SGGR	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
SGLA	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
SGSP	0	0	0	0	0	0	0	1	1	0	1	1	1	1	0
SCAC	0	0	1	1	1	1	1	0	0	1	0	0	1	0	1
SCAM	0	0	0	0	0	0	0	1	0	0	0	1	1	0	1
SCSP	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0
SCSU	0	0	1	0	0	1	0	1	1	0	0	0	1	1	1
SCVA	1	1	1	0	0	0	0	1	1	0	1	1	1	1	0
SPAD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPCL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPEM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPEU	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1
SPFL	1	0	0	0	0	0	0	0	1	1	1	1	0	1	0
SPSP	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0
STPE	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
TYAN	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1
TYLA	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
TYXG	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
TYSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UTCO	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
UTGE	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
UTGI	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
UTIN	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
UTMI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UTPU	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

UTVU	0	1	0	0	0	1	0	0	1	1	1	0	0	0	1
UTSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VAAM	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ZIPA	0	0	1	1	1	1	1	0	0	1	0	1	1	1	1
LYSA	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
NEAQ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
NUPU	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
NYTE	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
PHRG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POFO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POFR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POOB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POVA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PO SLEN	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0
SCCY	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
UTRR	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
ZODU	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0

Table 3b. Summary of all aquatic plant species in the 15 wetlands during the survey conducted in 2009. Expansion of the 4-letter plant codes is found in the Appendix 1.

Parameter	Green Island	Matchedash Bay	Musky Bay	Oak Bay	Quarry Island	Moreau Bay	Robert's Bay	Ganyon Bay	Hermann's Bay	Lily Pond	North Bay	Ojibway Bay	Tadenac Bay 1	Tadenac Bay 2	Treasure Bay
Adjusted WMI	**3.3**	**2.8**	**3.1**	**3.2**	**3.3**	**3.4**	**3.4**	**3.4**	**3.5**	**2.6**	**3.3**	**3.3**	**4.0**	**3.6**	**3.1**
# submergents	**12**	**14**	**17**	**18**	**15**	**14**	**18**	**13**	**16**	**10**	**21**	**17**	**12**	**20**	**18**
# floating	**4**	**2**	**4**	**5**	**4**	**5**	**4**	**3**	**4**	**4**	**5**	**4**	**4**	**2**	**3**
# emergents	**8**	**8**	**10**	**10**	**6**	**5**	**8**	**6**	**8**	**5**	**6**	**8**	**8**	**6**	**7**
# exotic	**2**	**3**	**3**	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**2**
Presence (1) or absence (0) of each plant taxon in wetlands															
BIBE	1	1	0	1	0	0	0	1	0	0	1	0	0	0	1
BRSC	1	0	1	1	0	1	1	1	1	1	1	1	1	0	1
CASP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CEDE	0	1	0	1	1	0	1	0	0	1	1	1	0	0	1
CHSP	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
ELAC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ELSM	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0
ELCA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
EQFL	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1
ERAQ	0	0	0	0	0	0	1	1	1	0	0	1	1	1	0
SPON	1	0	1	1	1	0	1	0	0	0	1	0	1	1	1
ISSP	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
LETR	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
LODO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MYAL	0	0	0	0	0	0	1	0	0	0	0	1	1	1	0
MYHE	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
MYSI	0	1	0	1	1	0	1	0	0	1	1	1	0	0	1
MYSC	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1
MYTE	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0
MYSP	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
NAFL	1	1	1	1	1	1	0	1	1	0	1	1	1	1	0
NISP	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
NUVA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NYOD	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NMCO	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0
POCO	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

POAM	0	0	1	1	0	1	0	0	1	0	0	1	1	1	1
POCR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
POEP	0	0	0	0	0	1	1	1	0	0	1	0	1	1	1
POGR	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
POIL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PONA	1	0	1	1	1	1	1	0	1	1	1	1	0	0	0
POPU	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1
PORI	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1
PORO	1	0	0	1	1	0	1	1	1	0	1	1	0	1	1
POSP	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
POSR	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0
POZO	1	1	1	0	1	0	1	0	1	0	0	1	0	0	1
RALO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RASP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SGCU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SGGR	1	1	1	1	0	0	0	1	1	0	0	1	1	0	0
SGLA	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
SGSP	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
SCAC	1	0	1	1	1	1	1	0	0	0	0	1	1	0	1
SCAM	1	1	0	1	1	1	1	1	0	1	0	1	1	1	1
SCSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCSU	0	0	1	0	0	1	1	0	1	0	1	0	0	1	0
SCVA	1	1	1	0	1	0	1	1	1	0	1	1	0	1	1
SPAD	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
SPCL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPEM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPEU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPFL	0	0	1	0	0	1	1	0	1	1	1	1	0	1	1
SPSP	1	0	1	1	0	0	1	0	1	1	1	1	1	1	1
STPE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYAN	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
TYLA	0	1	1	1	0	0	0	0	1	0	1	0	0	0	0
TYXG	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
TYSP	0	0	0	0	1	0	1	0	0	1	0	0	0	0	1
UTCO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UTGE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UTGI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UTIN	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
UTMI	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0
UTPU	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0
UTVU	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1

UTSP	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0
VAAM	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
ZIPA	0	0	1	1	1	1	1	0	0	0	1	0	1	1	0
LYSA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NEAQ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NUPU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NYTE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PHRG	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
POFO	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
POFR	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
POOB	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
POVA	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
PO SLEN	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
SCCY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UTRR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZODU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4a. Summary of fish caught in this study during the past surveys (2003 to 2005 inclusive). Expansion of the 4-letter fish codes is found in the Appendix 2.

Parameter	Green Island	Matchedash Bay	Musky Bay	Oak Bay	Quarry Island	Moreau Bay	Robert's Bay	Ganyon Bay	Hermann's Bay	Lily's Pond	North Bay	Ojibway Bay	Tadanac 1	Tadanac 2	Treasure Bay
Total Species	18	17	18	11	20	17	15	8	6	8	13	10	10	5	15
AMCA	2	2	1	3	2	2	3	0	3	1	6	2	0	0	3
AMNE	23	14	17	1221	1	5	6	4	15	1	9	0	2	1	11
AMRU	9	5	5	9	23	1	0	20	5	2	2	23	1	0	5
LEGI	25	183	15	97	190	147	42	50	65	85	19	400	175	76	113
LEME	0	0	0	0	0	5	0	6	0	8	3	6	0	0	107
LEOS	3	3	1	7	1	3	5	0	0	0	2	0	8	0	0
MISA	212	21	57	67	24	8	0	7	12	33	67	2	55	9	9
NOGY	5	6	5	4	10	4	1	6	0	0	17	0	0	0	1
NOHN	7	5	15	0	93	10	4	0	0	0	0	1	6	1	2
PEFL	3	4	12	1	18	12	7	7	0	5	12	12	2	0	16
PINO	15	1	6	0	81	163	0	0	0	0	4	54	4	0	5
PONI	3	1	3	0	5	0	70	0	0	0	7	2	0	0	1
CACO	0	0	12	0	5	0	0	0	0	0	0	0	0	0	0
CYCA	4	1	23	0	0	0	0	0	0	0	0	0	0	0	0
CYSP	6	0	0	0	2	0	0	0	0	0	0	0	0	0	0
ESLU	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
ETEX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ETNI	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
FUDI	5	0	9	0	16	1	0	0	0	0	0	0	0	0	0
GAAC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LASI	3	0	6	0	1	1	1	0	0	0	0	0	0	0	1
LEMA	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
LUCO	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0
MIDO	0	0	0	1	27	0	0	0	0	0	0	0	26	2	0
MOAM	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
NOAT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOCR	0	0	0	0	6	2	1	0	0	0	0	0	1	0	4
NOHE	0	0	0	0	0	66	1	0	0	0	2	44	0	0	0
NOHU	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0

NOST	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
NOVO	3	0	0	0	126	82	17	0	0	0	0	0	0	0	0
ONTS	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
PECA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PHEO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POAN	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
UNAM	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0
UNLE	0	1	2	0	7	204	2	1	1	0	10	0	0	0	7
UMLI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UNNO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UNPO	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Total Fish	330	269	192	1415	639	716	166	101	101	136	160	546	280	89	286

Table 4b. Summary of fish caught in this study during the 2009 survey. Expansion of the 4-letter fish codes is found in the Appendix 2.

Label	Green Island	Matchedash Bay	Musky Bay	Oak Bay	Quarry Island	Moreau Bay	Robert's Bay	Ganyon Bay	Hermann's Bay	Lily's Pond	North Bay	Ojibway Bay	Tadanac 1	Tadanac 2	Treasure Bay
Total Species	7	12	9	4	7	6	4	6	5	10	3	7	5	7	8
AMCA	2	3	2	0	4	0	1	152	3	5	0	0	0	0	1
AMNE	2	15	1	16	2	7	0	1	2	4	0	1	0	0	6
AMRU	2	8	2	1	0	0	0	3	3	0	0	13	1	0	13
LEGI	40	9	17	28	160	92	89	88	13	90	64	276	48	56	58
LEME	0	1	0	0	2	0	0	0	0	1	0	0	0	0	10
LEOS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
MISA	2	0	2	0	3	1	0	0	0	2	0	3	6	53	2
NOGY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOHN	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
PEFL	1	6	4	0	3	2	2	0	0	0	0	8	3	1	0
PINO	0	3	1	1	0	0	0	2	0	5	1	2	0	0	0
PONI	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
CACO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CYCA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CYSP	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
ESLU	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
ETEX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ETNI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FUDI	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
GAAC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
LASI	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
LEMA	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
LUCO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MIDO	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
MOAM	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
NOAT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOCR	0	8	0	0	0	0	0	0	0	3	0	0	0	0	0
NOHE	0	0	0	0	0	0	0	0	0	2	0	0	0	4	0
NOHU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOVO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ONTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PECA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PHEO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POAN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UNAM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UNLE	0	1	0	0	0	1	1	23	0	4	1	0	0	49	9
UMLI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UNNO	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
UNPO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Fish	50	57	31	46	175	104	93	269	22	117	66	304	59	170	100

Table 5. Comparison of individual fish species proportions between "past" and "present" sampling period. P-values in bold indicate significant differences between survey periods.

Common Name	Scientific Name	P value	Mean "Past" Proportion of Catch	Mean "Present" Proportion of Catch
Pumpkinseeds	*Lepomis gibbosus*	**0.0008**	0.37	0.69
Bowfin	*Amia calva*	**0.0009**	0.01	0.06
Tadpole Madtom	*Noturus gyrinus*	**0.0219**	0.02	0.00
Blackchin Shiner	*Notropis heterodon*	**0.0475**	0.02	0.00
Black Crappie	*Pomoxis nigromaculatus*	**0.0217**	0.03	0.00
Brown Bullhead	*Ameiurus nebulosus*	0.1080	0.13	0.06
Rock Bass	*Ambloplites rupestris*	0.7080	0.03	0.04
Largemouth Bass	*Micropterus salmoides*	0.1580	0.14	0.05
Yellow Perch	*Perca flavescens*	0.7423	0.03	0.03
Longear Sunfish	*Lepomis megalotis*	0.2242	0.27	0.01
Mimic Shiner	*Notropis volucellus*	0.0894	0.02	0.00
Bluntnose Minnow	*Pimephales notatus*	0.0810	0.05	0.01
Carps & Minnows	*Cyprinidae*	**0.0299**	0.15	0.02

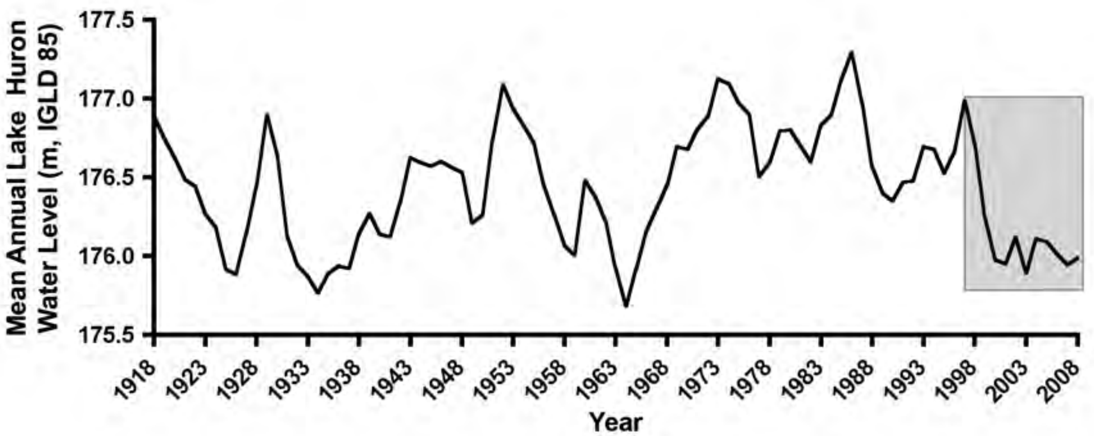

Figure 1 – Hydrograph of Lake Huron from 1918 to 2008. Data from Canadian Hydrographic Services, Department of Fisheries and Oceans.

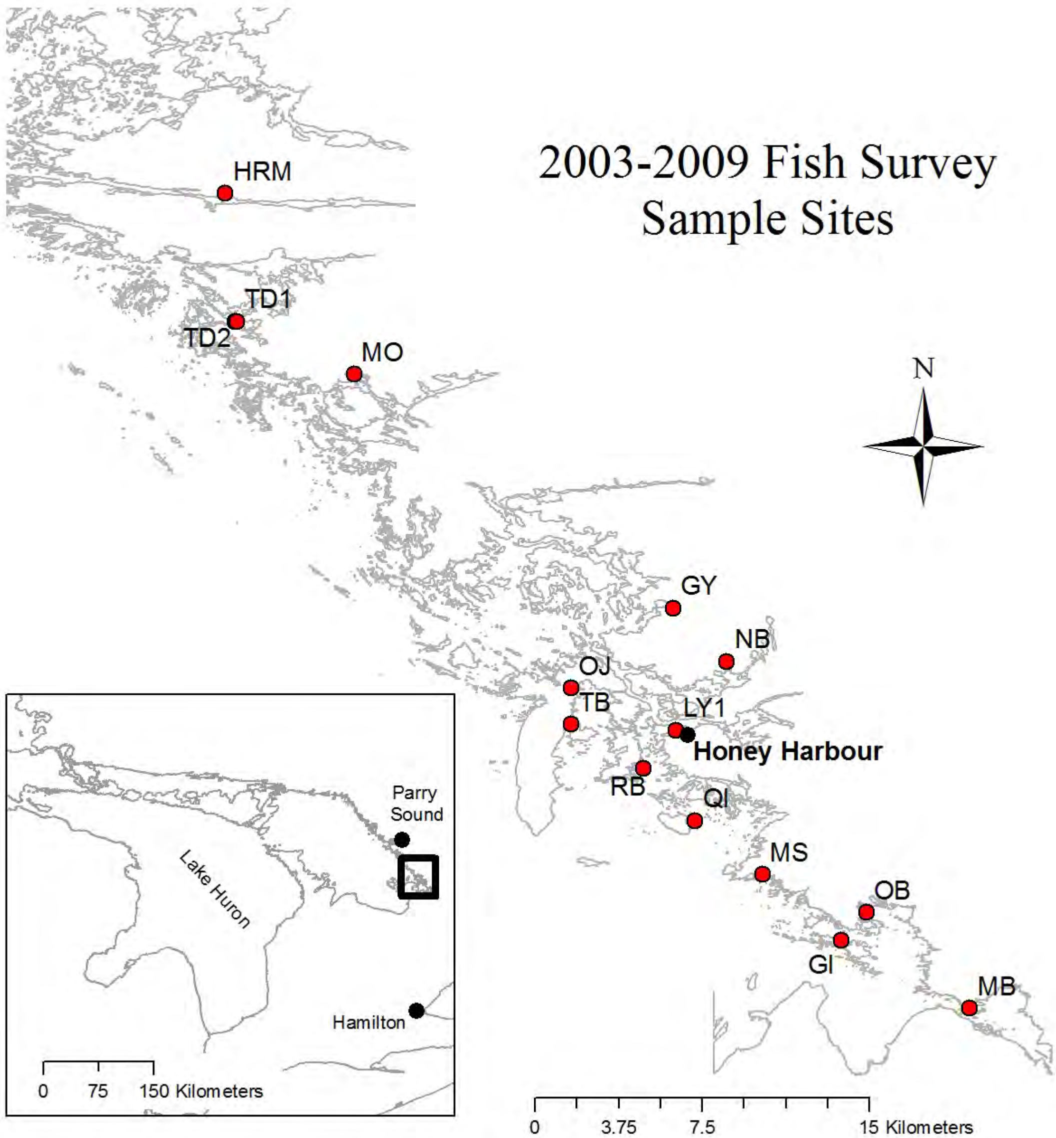

Figure 2 – Location of study sites from 2003-2009. Sites are primarily located in the Severn Sound region of southeastern Georgian Bay.

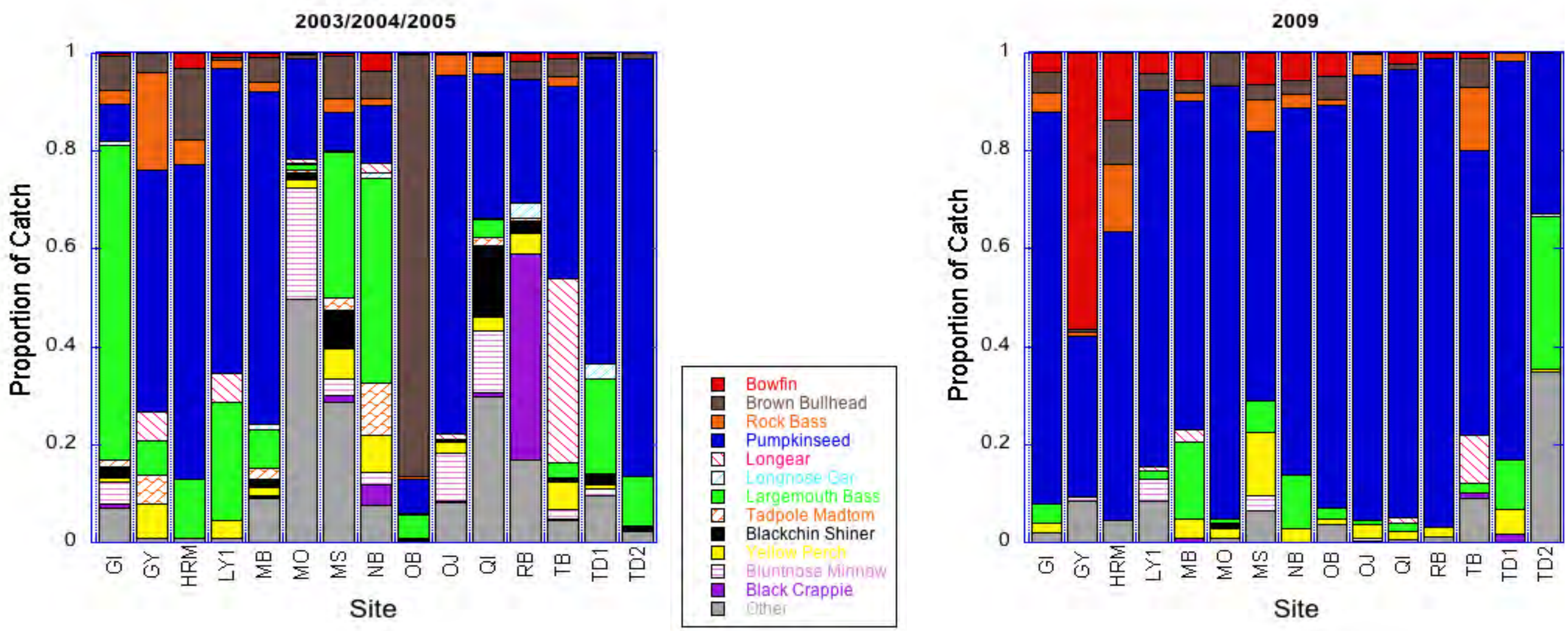

Figure 3 – Comparison of fish community composition from 2003-2009. Values are represented as a proportion of the overall catch.

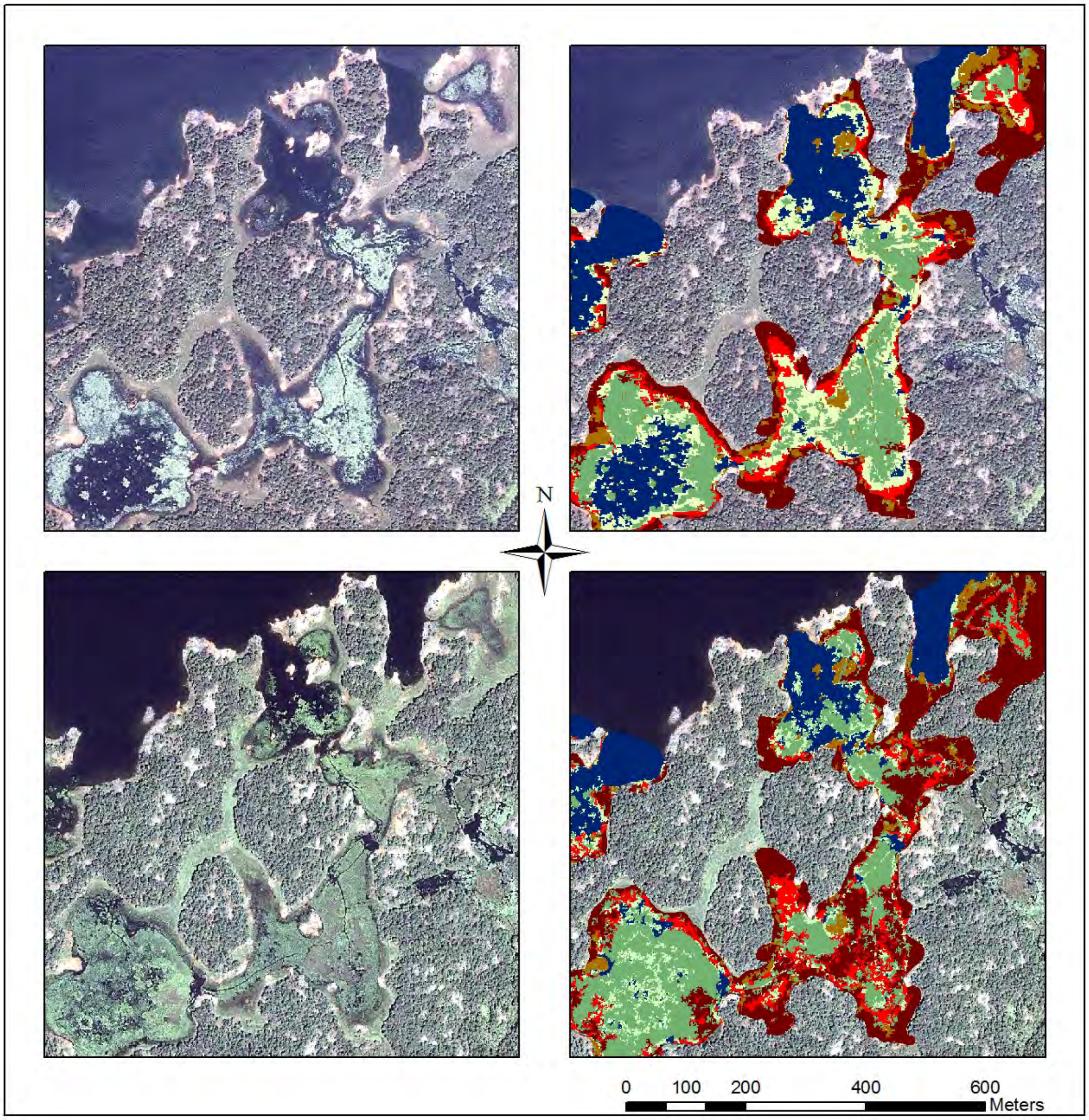

Figure 4 – Habitat changes from 2002 to 2008 in Black Rock Bay, Tadenac Bay. Top left corner, 2002 IKONOS image. Top right corner, Habitat Map based on 2002 imagery. Bottom left corner, 2008 IKONOS image. Bottom right corner, habitat map based on 2008 imagery. Blue = water, Brown = Rock, Maroon= Meadow Vegetation, Red = Emergent Vegetation, Light Green = Low-Density Floating Vegetation, Dark Green = High-Density Floating Vegetation. A clear increase in both meadow and high-density floating vegetation is apparent in the 2008 habitat map when compared to the 2002 map.

Appendix 1:
List of plant common and scientific names corresponding to plant taxa presented in Table 3a and b.

Species Code	**Common Name**	**Scientific Name**
BIBE	Beck's marsh marigold	*Bidens beckii*
BRSC	Water shield	*Brasenia schreberi*
CABO	Fanwort	*Cabomba*
CASP	Water starwort	*Calltiriche sp.*
CEDE	Coontail	*Ceratophyllum demersum*
CHSP	Muskgrass	*Chara sp.*
EICR	Water hyacinth	*Eichhornia crassipes*
ELAC	Needle spikerush	*Eleocharis acicularis*
ELCA	Canadian waterweed	*Elodea canadensis*
ELSM	Marsh spikerush	*Eleocharis smalli*
EQFL	Water horsetail	*Equisetum fluviatile*
ERAQ	Pipewort	*Eriocaulon aquaticum*
HIVU	Mare's tail	*Hippuris vulgaris*
HYMO	Frogbit	*Hydrocharis morsus-ranae*
ISSP	Quillwort	*Isoetes sp.*
LEMI	Lesser duckweed	*Lemna minor*
LETR	Ivy duckweed	*Lemna trisulca*
LODO	Water lobelia	*Lobelia dortmanna*
LYSA	Purple loosestrife	*Lythrum salicaria*
MYAL	Alternate water-milfoil	*Myriophyllum alterniflorum*
MYFA	Farwell's water-milfoil	*Myriophyllum farwellii*
MYHE	Two-leaf water milfoil	*Myriophyllum heterophyllum*
MYSC	Eurasian water-milfoil	*Myriophyllum spicatum*
MYSI	Common water-milfoil	*Myriophyllum sibiricum*
MYSP	Water-milfoil species	*Myriophyllum sp.*
MYTE	Slender water-milfoil	*Myriophyllum tenellum*
MYVE	Whorled water-milfoil	*Myriophyllum verticillatum*
NAFL	Slender water nymph	*Najas flexilis*
NEAQ	North American lake-cress	*Neobeckia aquatica*
NELU	American lotus	*Nelumbo lutea*
NISP	Stonewort	*Nitella sp.*
NMCO	Little floating hearts	*Nymphoides cordata*
NUAD	Spatterdock	*Nuphar advena*
NUVA	Common yellow pond lily	*Nuphar variegata*
NYOD	Fragrant water lily	*Nymphaea odorata*
PIST	Water lettuce	*Pistia stratiotes*
PLAM	Water smartweed	*Polygonum amphibium*
PLSP	Smartweed species	*Polygonum sp.*
PO SLEN	Slender pondweed	*Potamogeton pusillus*
POAM	Large-leaved pondweed	*Potamogeton amplifolius*
POCO	Pickerelweed	*Pontederia cordata*

POCR	Curly-leaf pondweed	*Potamogeton crispus*
POEP	Ribbon-leaf pondweed	*Potamogeton epiphydrus*
POFO	Leafy pondweed	*Potamogeton foliosus*
POFR	Fries' pondweed	*Potamogeton friesii*
POGR	Variable pondweed	*Potamogeton gramineus*
POIL	Illinois pondweed	*Potamogeton illinoensis*
PONA	Broad-leaved pondweed	*Potamogeton natans*
POOB	Bluntleaf pondweed	*Potamogeton obtusifolius*
PORI	Clasping-leaved pondweed	*Potamogeton richardsonii*
PORO	Fern-leaf pondweed	*Potamogeton robbinsii*
POSP	Pondweed species	*Potamogeton sp.*
POSR	Northern snailseed pondweed	*Potamogeton spirillus*
POVA	Vaseyi pondweed	*Potamogeton vaseyi*
POZO	Flat-stemmed pondweed	*Potamogeton zosteriformis*
RALO	Buttercup, crowfoot	*Ranunculus longirostris*
RASP	Crowfoot	*Ranunculus sp.*
SCAC	Hardstem bulrush	*Schoenoplectus acutus*
SCAM	Three-square bulrush	*Schoenoplectus americanus*
SCSP	Bulrush species	*Schoenoplectus sp.*
SCSU	Water bulrush	*Schoenoplectus subterminalis*
SCVA	Softstem bulrush	*Schoenoplectus validus*
SGCU	Small arrowhead	*Sagittaria cuneata*
SGGR	Grassy arrowhead	*Sagittaria graminea*
SGLA	Broad arrowhead	*Sagittaria latifolia*
SGSP	Arrowhead species	*Sagittaria sp.*
SPAD	Branched burreed	*Sparganium androcladum*
SPAN	Narrow-leaf burreed	*Sparganium angustifolium*
SPCL	Greenfruit burreed	*Sparganium chlorocarpum*
SPEM	Unbranched burreed	*Sparganium emersum*
SPEU	Giant burreed	*Sparganium eurycarpum*
SPFL	Floating burreed	*Sparganium fluctuans*
SPIR	Greater duckweed	*Spirodela polyrhiza*
SPON	Sponges	Fresh water sponges
SPSP	Burreed species	*Sparganium sp.*
STPE	Sago pondweed	*Stuckenia pectinata*
STVA	Sheathed pondweed	*Stuckenia vaginata*
TRNA	Water chestnut	*Trapa natans*
TYAN	Narrow-leaf cattail	*Typha angustifolia*
TYLA	Broadleaf cattail	*Typha latifolia*
TYSP	Cattail species	*Typha sp.*
TYXG	Hybrid cattail	*Typha x glauca*
UTCO	Horned bladderwort	*Utricularia cornuta*
UTGE	Hidden fruit bladderwort	*Utricularia geminiscapa*
UTGI	Humped bladderwort	*Utricularia gibba*
UTIN	Flat-leaved bladderwort	*Utricularia intermedia*

UTMI	Lesser bladderwort	*Utricularia minor*
UTPU	Purple bladderwort	*Utricularia purpurea*
UTSP	Bladderwort species	*Utricularia sp.*
UTVU	Common bladderwort	*Utricularia vulgaris*
VAAM	Tape grass, eel grass	*Vallisneria americana*
WOLF	Watermeal	*Wolffia sp.*
ZIPA	Wild rice	*Zizania sp.*
ZODU	Water stargrass	*Zosterella dubia*

Appendix 2:
List of fish common and scientific names corresponding to the fish taxa present in Table 4 a and b.

Species Code	**Common Name**	**Scientific Name**
AMCA	bowfin	*Amia calva*
AMNE	brown bullhead	*Ameiurus nebulosus*
AMRU	rockbass	*Ambloplites rupestris*
CAAU	goldfish	*Carassius auratus*
CACA	longnose sucker	*Catostomus catostomus*
CACO	white sucker	*Catostomus commersoni*
COBA	mottled sculpin	*Cottus bairdi*
COCO	slimy sculpin	*Cottus cognatus*
CUIN	brook stickleback	*Culaea inconstans*
CYCA	common carp	*Cyprinus carpio*
CYSP	spotfin shiner	*Cyprinella spilopterus*
DOCE	gizzard shad	*Dorosoma cepedianum*
ESLU	northern pike	*Esox lucius*
ESMA	muskellunge	*Esox masquinongy*
ETCA	rainbow darter	*Etheostoma caeruleum*
ETEX	Iowa darter	*Etheostoma exile*
ETMI	least darter	*Etheostoma microperca*
ETNI	johnny darter	*Etheostoma nigrum*
FUDI	banded killifish	*Fundulus diaphanus*
GAAC	threespine stickleback	*Gasterosteus aculeatus*
HYHA	brassy minnow	*Hybognathus hankinsoni*
ICPU	channel catfish	*Icalurus punctatus*
LASI	brook silverside	*Labidesthes sicculus*
LEGI	pumpkinseed	*Lepomis gibbosus*
LEMA	bluegill	*Lepomis macrochirus*
LEME	longear sunfish	*Lepomis megalotis*
LEOS	longnose gar	*Lepisoteus osseus*
LUCO	common shiner	*Luxilus cornutus*
MAMA	pearl dace	*Margariscus margarita*
MIDO	smallmouth bass	*Micropterus dolomieu*
MISA	largemouth bass	*Micropterus salmoides*
MOAM	white perch	*Morone americana*
MOMA	shorthead redhorse	*Moxostoma macrolepidotum*
NOAT	emerald shiner	*Notropis atherinoides*
NOCR	golden shiner	*Notemigonus crysoleucas*
NOGY	tadpole madtom	*Noturus gyrinus*
NOHE	blacknose shiner	*Notropis heterolepis*
NOHN	blackchin shiner	*Notropis heterondon*
NOHU	spottail shiner	*Notropis hudsonius*
NOST	sand shiner	*Notropis stramineus*
NOVO	mimic shiner	*Notropis volucellus*

OSMO	rainbow smelt	*Osmerus mordax*
PECA	logperch	*Percina caprodes*
PEFL	yellow perch	*Perca flavescens*
PEOM	trout-perch	*Percopsis omiscomaycus*
PHEO	northern redbelly dace	*Phoxinus eos*
PINO	bluntnose minnow	*Pimephales notatus*
PIPR	fathead minnow	*Pimephales promelas*
POAN	white crappie	*Pomoxis annularis*
PONI	black crappie	*Pomoxis nigromaculatus*
PUPU	ninespine stickleback	*Pungitius pungitius*
SAVI	walleye	*Sander vitreus*
SEAT	creek chub	*Semotilus atromaculatus*
UMLI	central mudminnow	*Umbra limi*
UNAM	unknown bullhead	
UNCY	unknown cyprinid	
UNET	unknown darter	
UNLE	unknown sunfish	
UNNO	unknown shiner	
UNPO	unknown crappie	