Wetland Monitoring for Lake Ontario Adaptive Management

The New York
Natural Heritage Program

March 25, 2016

Wetland monitoring for Lake Ontario adaptive management

Final Report

Timothy G. Howard, Aissa L. Feldmann, Elizabeth Spencer,
Richard M. Ring, Kelly A. Perkins, Jeff Corser
New York Natural Heritage Program –
State University of New York, Environmental Science and Forestry
625 Broadway
Albany, NY 12233-4757

Prepared for
United States Environmental Protection Agency
Assistance ID No.
GL-00E00842-0

This project was funded by the Great Lakes Restoration Initiative

25 March 2016

Please cite this report as follows: Howard, T.G., A.L. Feldmann, E. Spencer, R.R. Ring, K.A. Perkins, and J. Corser. 2016. Wetland monitoring for Lake Ontario adaptive management. New York Natural Heritage Program, Albany, NY.

Cover photos: Timothy Howard and Aissa Feldmann, New York Natural Heritage Program.

Contents

Table of Figures:

Table of Tables

Executive Summary

Since 1960, the levels and flows of Lake Ontario and the St. Lawrence River have been managed through dams, with a primary emphasis on efficient power generation, shipping, and protection of coastal property. It is recognized that this water regulation has altered the natural cycles of high and low levels that maintain coastal wetlands and other natural coastal systems, and an alternative regulation plan is proposed by the International Joint Commission. We have good predictions about how the new water regulation plan may help maintain coastal wetlands and wildlife but field validation is needed in order to best respond to how the effects of this management play out in the landscape. This project initiates a data collection and analysis system for U.S. wetlands to support this adaptive management program of the International Joint Commission.

The primary purpose of this project is to report on ecological metrics collected to inform adaptive management for water regulation in Lake Ontario and the St. Lawrence River. We build on other wetland sampling efforts by sampling for important wetland indicators in a manner consistent with efforts in Canada. Our sample sites were 16 randomly-selected wetlands spanning the U.S. side of Lake Ontario and the upper St. Lawrence River. Included in those 16 are four each of the four primary geomorphic type: barrier beach, drowned river-mouth, open embayment, and protected embayment.

There were four separate components to this work, with each component contributing to different wetland metrics related to water level regulation. We sampled vegetation along transects running from the upland into the water to precisely measure the elevation of each vegetation type. We also collected aerial imagery and mapped the vegetation types to measure size and extent of each type within each wetland. The third component was to estimate muskrat density by conducting winter counts of muskrat houses. Finally, we also conducted searches for rare plant species that are likely to respond to changes in water level dynamics.

Vegetation sampling occurred in 2012 and 2014. We used high-precision GPS units to sample from 76.0 m to 74.0 m of the International Great Lakes Datum (IGLD). At every 20 cm elevation within that range, we collected percent cover information for all vegetation within a 1 x 0.5 m quadrat sampling frame. This was repeated along five transect lines within each of the 16 wetlands. We found the data collected through this system to be consistent and of high enough resolution to effectively capture and track vegetation changes in reference to elevation. These data area aligned with the approach used by the Canadian Wildlife Service and thus contribute to a bi-national data set.

We acquired aerial images for the same time each wetland was sampled in the field (August – September, 2012 and 2014). The primary goal of photo-interpretation was to delineate the extent of meadow marsh and cattail stands. The total wetland area of all sixteen wetlands came out to 3684 acres, which we divided up into 613 different wetland polygons. The high resolution of this mapping exercise allowed us to detect changes in some edges over the two-year time span. These cases were not very frequent and very much dependent on the presence of a distinct edge between the two vegetation types, but exemplified the potential for tracking the change in extent of vegetation types over time.

Our Muskrat sampling was scheduled for the winters of 2011-2012 and 2013-2014 and was intended to target the four drowned river mouth wetlands. Unfortunately, the mild conditions during the winter of 2011-2012 turned out to be very difficult, if not impossible, for conducting this type of winter survey that depends on sustained cold temperatures. We did manage some sampling in the first winter, but then conducted a full survey in the winter of 2012-2013. We found two muskrat houses at a small wetland (North Buck Bay) in the Upper St. Lawrence River, and no houses at the other three drowned river mouth wetland sites.

We searched the 16 wetlands for eight at-risk plant species that are known to occur in different parts of the wetland system. We found and verified the identification of four of these species, often at more than one site. We have a tentative identification for a fifth species (Slender Pondweed, *Stuckenia filiformis*) and did not find any locations for three others. We found and documented Awned Sedge (*Carex atherodes*, S3, Rare) at four of our 16 sites. This species was intermingled with other meadow marsh species and clearly within the meadow marsh vegetation community. We found Marsh Horsetail (*Equisetum palustre*, S2, Threatened) at one site at the lower end of the meadow marsh zone. Finally, in the emergent and submerged aquatics zone, we found Water-plantain (*Alisma gramineum*, S2S3, Threatened) at three sites. Finally, also at the deeper end of the emergent zone, we found Slender Bulrush (*Schoenoplectus heterochaetus*, S1, Endangered) at two locations. We are excited about these finds. We expect these species to respond differentially to water level regulation and tracking and understanding these responses will help us understand the response of the wetlands overall.

In summary, the elevation transect data allow us to evaluate the response of any vegetation type to water-level changes by evaluating its change in average elevation over time. The meadow marsh vegetation type, an indicator identified by the IJC, currently occupies a clear elevation band at approximately 75.0 m IGLD. Other vegetation types occur interspersed among meadow marsh patches and the amount of meadow marsh varies among sites. The vegetation mapping data allow us to track meadow marsh size and extent, another very important metric for this community. The excellent resolution of the aerial imagery permits clear detection of boundary changes, and accordingly some small changes were detected at some wetlands from 2012 to 2014. The results presented here are designed to allow comparisons to earlier and concurrent data collection events and, especially, set the groundwork for continued monitoring of a select set of important ecological indicators related to water-level management in the Lake Ontario-St. Lawrence River system. Regular sampling of these indicators and reporting to the IJC will allow full closure of a feedback loop resulting in an adaptive management regime for this important resource.

Introduction:

Problem definition and background

Contextual history

Lake Ontario's unique biological diversity reflects its freshwater and oceanic origins. This heritage is visible today in the diverse coastal wetlands, beaches, dunes, and sheltered lagoons of the lake's coastal zone, and the native species that depend on these habitats. These habitats and species have evolved since the retreat of the glaciers in response to the natural ebb and flow of the lake and river, with water levels fluctuating on several time scales – ranging from short-term storm surges to long-term cycles of approximately 30 and 150 years. This natural ebb and flow is the engine of biodiversity in this ecosystem, promoting the survival of a diverse array of species, each adapted to different hydrologic conditions (Chow-Fraser *et al.* 1998).

Since 1960, the levels and flows of Lake Ontario and the St. Lawrence River have been managed through dams, with primary emphasis on efficient power generation, shipping, and protection of coastal property. This water regulation has altered the hydrologic regime by stabilizing the lake – removing the natural cycles of high and low levels that maintain coastal wetlands, beaches, and dunes.

Current scientific studies (Wilcox *et al.* 1992, 2005, 2008, Wilcox and Meeker 1995) have demonstrated the serious impacts of these changes on the natural diversity of the Lake Ontario and St. Lawrence coastal zone. For example, stabilization of lake levels enables robust species like cattail to dominate deep and shallow emergent marshes, reducing species diversity. Diverse sedge-grass communities ("meadow marsh" sensu Wilcox *et al.* 2005) have declined as stable water levels have enabled cattail to move upslope.

Responding to these and other shortcomings of the current regulation plan (Plan 1958DD), the International Joint Commission (IJC) has conducted a 5-year study, followed by several years of discussions with the U.S. and Canada governments, with the goal of developing a new plan for regulating levels and flows. This IJC process represents a rare opportunity to restore the artificially managed lake levels closer to a more natural hydrologic regime, and the Commission has stated a preference for a regulation plan that restores more natural flows to benefit the environment, while respecting other interests.

Lake Ontario/St. Lawrence, like most natural systems, is complex. A new regulation plan will be based on simulation models that predict how species, habitats of concern, and economic variables will respond to changes in the regulation of levels and flows. Even the most sophisticated predictive models and scientific research will not resolve all uncertainties about ecological and economic response. In recognition of the uncertainties inherent in implementing a new regulation plan, the International Joint Commission proposes to take an adaptive approach to regulation, measuring progress toward societal, economic, and environmental goals while improving management in response to new information.

The primary purpose of this project is to report on ecological metrics collected to inform this adaptive management. We build on other wetland sampling efforts (Wilcox *et al.* 2005, Tiner *et al.* 2011) by sampling for important wetland indicators in a manner consistent with efforts in Canada. This project is designed to be repeatable for continued monitoring of the effects of water-level management over time.

Relevance to the Great Lakes

This project responds to needs and priorities identified in numerous plans for the Great Lakes, including the Great Lakes Restoration Initiative (GLRI) Action Plan, Focus Area 4: Habitat and Wildlife Protection and Restoration. Within this Focus Area, we will be supporting the *Principal Action* indicated as "Identify, Inventory, and Track Progress on Great Lakes Habitats, Including Coastal Wetlands Restoration" on page 34 of the plan.[1]

This work also fits within EPA's Strategic Plan Sub-objective 4.3.3 (Improve the Health of Great Lakes Ecosystems) as a way to quantify certain measures of progress, including "Number of acres of wetlands and wetland-associated uplands protected, restored, and enhanced."[2]

The work described here directly responds to Lakewide Action and Management Plan (LAMP) needs: water-level regulation is noted as a severe threat to biological systems and monitoring of coastal wetlands indicators is listed as a key activity.[3] A more recent report prepared in cooperation with the LAMP also highlights monitoring coastal wetlands in response to restoring hydrologic periodicity as an important strategy.[4]

Finally, the priorities of the Great Lakes Regional Collaboration Strategy are also addressed through the stated long-term goals of restoring lake-level fluctuations and short-term actions of inventory and assessment of coastal habitats.[5] This monitoring is linked to a management action (water-level regulation), meaning this project has the potential to positively influence wetland restoration on every wetland affected by water-level dynamics in the Lake Ontario-St. Lawrence River (LOSLR) system--about 64,000 ac. Although direct remedial actions may still be required for some wetlands, environmentally responsive water regulation will have far-reaching effects.

Relationship to Consortium and specific needs from IJC

The Great Lakes Coastal Wetlands Consortium (Consortium) was funded by GLRI in 2010 to conduct coastal wetland monitoring throughout the Great Lakes and another five year cycle received funding in 2015. The difference between the monitoring goals of the Consortium and this adaptive management project is that the Consortium aims to monitor the influence of locally induced anthropogenic wetland stressors (e.g., pollution, invasive species, turbidity, and sedimentation; Great Lakes Coastal Wetlands Consortium *et al.* 2008) and we focus on the effects of water-level regulation. While it is critically important to monitor the effects of local stressors on wetlands, this adaptive management effort seeks to isolate the effects of lake-level management from these other anthropogenic effects. The methods being applied by the Consortium unfortunately cannot be used to assess the effects of lake-level management.

The actions taken by this project link directly to the adaptive management needs identified by the IJC.[6] Specifically, we are monitoring some of the Performance Indicators developed as part of the LOSLR studies. Our goal for this sampling is to allow statistically sound extrapolations to the wetlands of the entire lake, following the recommendations of the National Research Council (2006) and Great Lakes Wetlands Consortium (2008). Our targeted performance indicators include meadow marsh extent and muskrat house density. The meadow

---

[1] http://greatlakesrestoration.us/action/wp-content/uploads/glri_actionplan.pdf
[2] Page 35 in http://www.epa.gov/planandbudget/FY11OWNPMGdnce.pdf
[3] http://www.epa.gov/glnpo/lamp/lo_2008/
[4] Strategy 3.3 in http://www.epa.gov/greatlakes/lakeont/reports/lo_biodiversity.pdf
[5] Page 26 in http://www.glrc.us/documents/strategy/GLRC_Strategy.pdf
[6] www.ijc.org/LOSLdocuments/pdf/LOSL_background_adapt_mgmt_e.pdf

marsh extent indicators was evaluated through detailed elevation sampling and GIS mapping based on aerial imagery. We added population parameters of eight at-risk plant species as additional indicators, based on their habitat requirements and threatened conservation status.

Components of wetland sampling that parallel these surveys are also being conducted in Canada, thus maximizing the utility of efforts on both sides of Lake Ontario.

In the following four sections we describe each component of this project individually with separate methods, findings, and discussion, and then in a final section discuss our findings overall.

Section 1: Elevation Sampling

Introduction

The fluctuation of water levels in the Lake Ontario-St. Lawrence River system has a strong influence on the composition and structure of its coastal wetlands (Keddy and Reznicek 1986). In particular, distinct vegetation types occur at specific elevational bands within each wetland and these vegetation types migrate up or down slope in response to flooding and de-watering events (Wilcox *et al.* 2005). We expect, however, that wetland response to any management changes in water-level regulation will be more complex than simple vegetation migration. Will some types expand to the detriment of other types? Will there be an interaction with other factors such as Muskrat, accelerating (or decelerating) the rate of change? Will different geomorphic types of wetlands (barrier beach, drowned river-mouth, open embayment, protected embayment) respond differently? Some of these and other similar questions have been addressed and incorporated into the ecological response model to water-level management (Limno-Tech, Inc 2005). To ensure our hypothesized effects and predicted responses match what happens under a new water-level management regime, we monitored wetland vegetation composition within the range of expected elevations in a selected set of wetlands.

Our goal was to expand upon the excellent past and ongoing work (e.g., Wilcox *et al.* 2005, Tiner *et al.* 2011, Grabas and Rokitnicki-Wojcik 2015), maximizing the effectiveness and transferability of the results.

Methods

Site selection

Using the Great Lakes Coastal Wetland Inventory as our starting point,[7] we identified about 64 wetlands in New York that would accommodate a long-term wetland monitoring program (Figure 2). The original, full database of wetlands consisted of 553 wetland polygons. We first merged polygons with hydrologic connections or locations within the same bay or river corridor. Conversely, groups of patches were split if greater than 200 m of non-marsh separated them. Marshes that did not appear directly linked to LOSL (influenced by lake levels), or whose shore widths were less than 100 m were removed.

Using the 64-wetland data set, we followed the recommendations from the National Research Council (2006) and the Great lakes Coastal Wetlands Consortium (2008) and randomly selected wetlands for long-term monitoring. We conducted a spatially balanced random sample

[7] http://glc.org/projects/habitat/coastal-wetlands/cwc-inventory/

employing the Generalized Random Tessellation Stratified (GRTS) approach (Stevens and Olsen 2003, 2004, Kincaid and Olsen 2011) using the "spsurvey" package (Kincaid and Olsen 2011) in the R statistics software (R Development Core Team 2011). Sites were stratified by geomorphic type (barrier beach, drowned river-mouth, open embayment, protected embayment) and size (greater and less than 50 acres). The final draw consisted of 16 sites with four in each geomorphic type and two of each size within each geomorphic type. We included an additional over-draw of eight wetlands of each geomorphic type in case any of the first draw needed to be excluded because of denied access permissions or other issues.

The final selection included sites on both public and private lands. We obtained permission and permits (when needed) from NYS Parks (Beechwood State Park, Fair Haven Beach State Park, Wellesley Island State Park, Four Mile Creek State Park, Grass Point State Park), NYS DEC (Lakeview WMA, Braddock Bay WMA, Lake Shore Marshes WMA, Dexter Marsh WMA), and private landowners (North Pond Area Wetland, Sterling Creek Wetland, North Buck Bay Area Wetland, Isthmus Marsh). We reached out to each private landowner with a letter and followed up with phone calls to communicate our work and plans. A copy of the mailing is in Appendix 1.

Transect Sampling

Defining Transects

At each of the 16 wetlands we manually identified between 1 and 4 shorelines that would be appropriate for setting up a permanent transect system. Shorelines were mostly straight sections of the entire wetland–water interface greater than 100 m long with some emergent marsh appearing in aerial imagery. For each shoreline, we placed 15 points with equal spacing from an initial randomly selected starting point generated using the "spsample" command in the "sp" package (Pebesma and Bivand 2005) in R. We then overlaid transect lines on these points, running perpendicular to the shoreline (Figure 1). For sites that had more than one set of transects defined, we determined which set to use on our first field visit, depending primarily on accessibility.

Photo 1. Finding a quadrat location in the SAV at Maxwell Bay

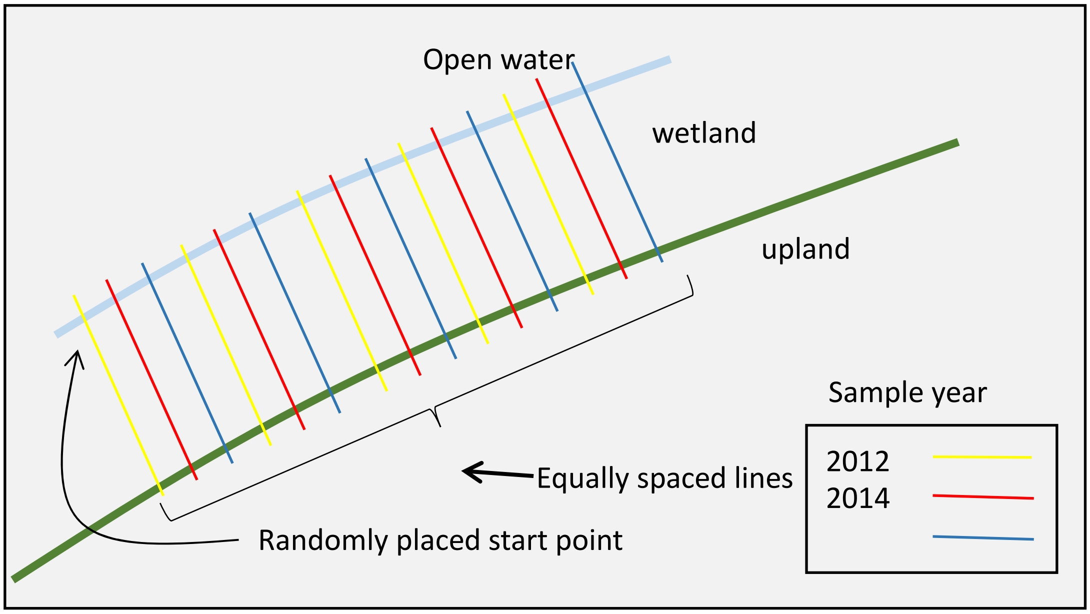


Figure 1. Schematic for transect placement. After an initial random placement along appropriate shoreline, transects were then placed at regular intervals. Beginning with the first transect in 2012 and the second transect in 2014, every third transect was sampled (for five total) each sampling period.

Following the approach of Watton and Grabas (2007), we set extra transects so that residual trampling impacts from one year would have the least effect possible on future sampling by sampling each particular transect only every fourth sampling bout. Our goal was to sample five transects per sampling bout. Thus, with 15 transects delineated, we sampled only transects 1,4,7,10,13 in 2012 and transects 2,5,8,11,14 in 2014 (Figure 1). Transects 3,6,9,12,15 are scheduled for sampling in 2016 with support from the International Joint Commission.

Elevation Benchmarks

In order to obtain the highest elevation accuracy possible, we collaborated with a NYS DEC Division of Lands and Forests, Bureau of Real Property survey team to have permanent benchmarks set close to each wetland. At each of the 16 wetland sites, the survey team connected to the existing survey control network and created one or two new control points on permanent structures as close as possible to each wetland. Permanent structures ranged from concrete bridge abutments to large boulders. For each new control point, the survey team provided us with precise location and elevation information in the NAVD 88 datum for easy configuration and straightforward conversion to International Great Lakes Datum (IGLD 85).

Photo 2. Setting up the RTK base station at Lakeview

When conducting transect surveys in the field, we positioned a GPS base station elevated by a tripod over the appropriate control point (Photo 2). Our rover GPS would communicate directly with this base station and GPS satellites simultaneously, providing precise latitude, longitude, and elevation information. In open vegetation we used a GPS antenna (Trimble R8 GNSS) attached to a 2-meter rover pole and in dense canopy we extended the pole an additional

0.6 m. To minimize, or at least maintain, consistent settling of the GPS pole into the mud, we followed the methods of the Canadian team and attached a 10-cm radius disk to the base of the pole.

Transect Data Collection

We collected vegetation information along each transect using 0.5 × 1.0-meter quadrat sampling devices made with PVC and marked along the edges in 10-cm increments. Eleven sampling locations were targeted by sampling at 20-cm intervals from 76.0 to 74.0 m IGLD (Grabas and Rokitnicki-Wojcik 2015). In uneven terrain we sometimes sampled the same elevation on a given transect more than once for better representation. Sometimes a closed forest canopy especially at higher elevations precluded satellite visibility and those samples were skipped. At the sampling location, the center of the short edge of the sampling quadrat was placed at the target elevation and the long edge was extended along the slope contour. Sites were accessed via either foot or canoe. At the lowest elevations, we collected elevation and quadrat data from a canoe when necessary. Otherwise, we collected data on foot while wearing chest waders (Photo 3).

Photo 3. Sampling SAV at North Buck Bay wetland

Within each quadrat, all species were identified and the aerial percent cover was estimated by stratum. We collected data electronically on tablets using a custom-built database on an Android tablet (Samsung Note 8), increasing efficiency and minimizing data entry errors. Specimens difficult to identify to species in the field were collected and identified later using aquatic and regional floras (Gleason and Cronquist 1991, Crow and Hellquist 2006a, 2006b, Haines 2011).

Data Preparation and Analysis

Each elevation in the transect dataset was converted from vertical datum NAVD88 to the IGLD85 using the vertical datum transformation software available from NOAA (vdatum.noaa.gov). These values were written back to the observations database so that both original and transformed elevations were maintained with the species cover data.

As a way to validate our elevation measurement system, we compared on-site water-level readings with the real-time lake-level monitoring stations located throughout Lake Ontario. We used the station closest to each site and plotted the measured water level against the reported water level, calculating the fit of the line. The five real-time gauging stations were Alexandria Bay (8311062), Cape Vincent (9052000), Oswego (9052030), Rochester (9052058), and Olcott (9052076). We compared verified elevation readings within 6 minutes of our water level reading on-site. Station and water-level information was collected from NOAA.[8]

We prepared the species-level data by removing ambiguous identifications (e.g., those at family or genus level) where species within that group may represent more than one habitat type. Conversely, a small number of species were lumped to genus because of similar habitat preference (e.g., *Solidago gigantea*, *rugosa*, and *canadensis* were merged to *Solidago*;

[8] http://tidesandcurrents.noaa.gov/stations.html

Amelanchier arborea and *canadensis* were merged to *Amelanchier*). Statistically, the five transects at a site are pseudo-replicates of each other and these replicates were collected in order to better estimate the vegetation growing at each elevation. Thus, to compare among sites we averaged cover data among quadrats collected at each target elevation. In some cases, sampling was prohibitive because of a blocked GPS signal from a tree canopy, deep muck, or a vertical drop through the target elevation. Target elevations where only one quadrat could be sampled were considered unrepresentative and removed from the analysis.

Our analytic goals were to classify the vegetation types encountered and document the relative abundance of these types at different elevations. We first classified vegetation types with the 2012 and 2014 data sets combined and then looked for similarities and differences in species composition among years. All data analyses and graphics were conducted using the R statistical software (R Core Team 2015) and "RODBC" (Ripley and Lapsley 2015), "vegan" (Oksanen *et al.* 2010), "labdsv" (Roberts 2015) and "ggplot2" (Wickham 2009) packages.

Results

Site Selection

The original 553 wetland polygons present in the New York portion of the Great Lakes Wetland database yielded 63 wetland sites that we felt were good candidates for long-term elevation transect studies (Figure 2). Many of those sites consisted of more than one of the original polygons. Dispersion of the final sample set covered nearly the entire extent of the original sample set. Sites at the northeastern end, downstream end of St. Lawrence River, were among those originally chosen but they were rejected during final review. Each hydrogeomorphic type had high dispersion and there was minimal clustering for each type (Figure 2, right).

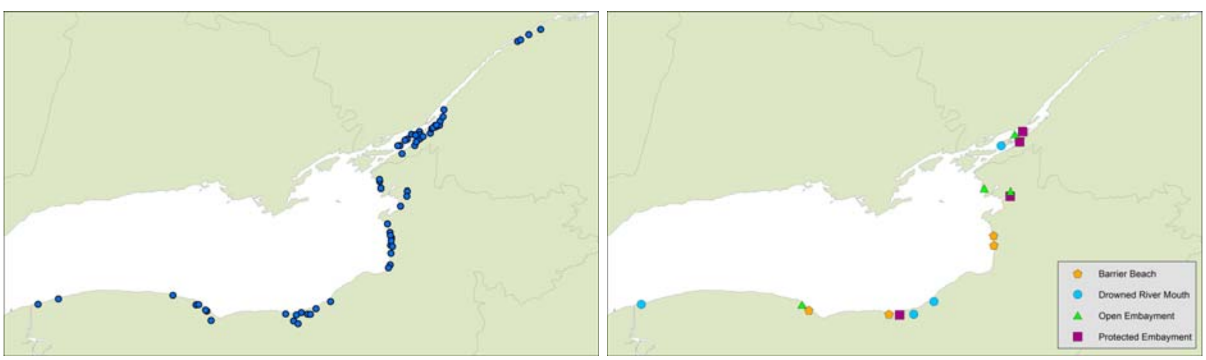


Figure 2. Initial wetland sample pool of 63 wetland sites (left) and final wetland sample of 16 sites after manual checking (right).

The final set of sixteen wetlands includes four sites within the St. Lawrence River and 12 in Lake Ontario. Each of the four hydrogeomorphic types is represented by four wetland sites further stratified by size into sets of two wetlands larger than 50 acres and two smaller than 50 acres. (Table 1). Seven of these sites overlap with the 16 sampled by Wilcox et al. (2005) in 2003. Nine of the sites overlap with wetlands mapped and sampled by Tiner et al. (2011) in 2011.

Table 1. The final selection set of sixteen wetlands. Except where noted, names follow the "WETLAND_NA" field in the Great Lakes Commission wetland dataset. Sites are identified as being in the Lake Ontario basin (LO) or St. Lawrence River (SLR), greater or less than 50 acres (Size), and by the hydrogeomorphic type (BG: barrier beach, DRM: drowned river-mouth, OE: open embayment, PE: protected embayment).

Wetland Name	Waterbody	Size	HGM
Buck Pond	LOS	Large	BB
Lakeview Pond	LOS	Large	BB
Maxwell Bay	LOS	Small	BB
North Pond Area	LOS	Small	BB
Fourmile Creek*	LOS	Small	DRM
North Buck Bay Area	SLR	Small	DRM
Port Bay	LOS	Large	DRM
Sterling Creek	LOS	Large	DRM
Braddock Bay	LOS	Large	OE
Flatiron Marsh	SLR	Small	OE
Isthmus Marsh	LOS	Small	OE
Perch River	LOS	Large	OE
Grass Point	SLR	Small	PE
Muskalonge Bay	LOS	Large	PE
Rift Area	SLR	Small	PE
Sodus Bay	LOS	Large	PE

*The wetland at Fourmile Creek is not in the Great Lakes Commission dataset.

Elevation Benchmarks and final transects

In all, eighteen benchmarks (aluminum survey disks) were placed in accessible locations at the sixteen sites. To place these benchmarks, the surveyors used other registered survey vertical control points (benchmarks with high elevation accuracy) and placed GPS survey systems on these vertical control points and the new benchmarks simultaneously. When linked this way with two or more known locations and allowed to collect many hours of GPS signal, high accuracy can be obtained at the new location. In all, the surveyors found and used (occupied) 33 other locations while placing the new discs. All new disks passed standard survey tests with standard error of elevations generally less than 0.7 cm in loop closure tests.

The final transect set chosen at each site varied based on accessibility. Most were accessible by foot but a few were accessible only or most easily by boat. Within each set of fifteen transects, five were sampled in 2012 and five in 2014. Figure 3 shows the sampled transects and the elevation benchmark used as the RTK base at each site.

Row a: barrier beach wetlands

Row b. drowned river-mouth wetlands

Row c: open embayment wetlands

Row d: protected embayment wetlands

Figure 3. The final transect set collected in 2012 and 2014 at each wetland site depicted with its local elevation benchmark. From left to right, row a: Buck Pond, Lakeview Pond, Maxwell Bay, North Pond Area; row b: Port Bay, Sterling Creek, Fourmile Creek, North Buck Bay; row c: Braddock Bay, Perch River , Flatiron Marsh, Isthmus Marsh; row d: Muskalonge Bay, Sodus Bay, Grass Point, and Rift Area.

Transect Data Collection

Transect surveys began in 2012 on September 5 and were completed on October 11. In 2014, surveys began September 3 and finished on October 1. A heavy tree canopy often precluded our ability to obtain accurate GPS readings at the upper ends of the transects (75.6, 75.8, 76.0 IGLD). This reduced the total number of samples obtained at these higher elevations (Table 2). Similarly, while many of the lowest elevations were accessed by boat, those accessed by foot sometimes had soft mucky substrates too difficult to wade in or that could not support the survey pole; other times, the substrates did not reach the lowest elevations at the survey area. These difficulties reduced the number of samples obtained at the very lowest elevations. Additionally, locations with floating cattail mats would sometimes present a vertical drop in elevation (often up to 1 meter) at the water’s edge, preventing data collection at intermediate elevations. In all, we sampled 1347 quadrats over the duration of the project, 582 quadrats in 2012 and 765 quadrats in 2014 (Table 2).

Table 2. The number of quadrats sampled each year at each site. The hydrogeomorphic type of each wetland (HGM), the sample year, and the sample days are also noted. The Quadrat samples column shows the number of samples collected at the eleven target elevations across all five transects beginning with 74.0 IGLD on the left and finishing with 76.0 IGLD on the right (74.0-74.2-74.4-74.6 … 75.8-76.0).

Site	HGM	year	Dates	Quadrat samples
Buck Pond BB-4	BB	2012	9/20	5-5-5-4-4-5-5-5-4-2-0
Buck Pond BB-4	BB	2014	9/4	5-5-3-4-2-5-7-5-5-2-0
Lakeview Pond BB-3	BB	2012	9/6, 9/11	5-5-5-5-5-5-6-5-5-5-4
Lakeview Pond BB-3	BB	2014	9/17	5-5-5-5-0-5-5-8-4-5-4
Maxwell Bay Wetland BB-1	BB	2012	10/2	0-0-1-3-5-5-5-2-1-1-0
Maxwell Bay Wetland BB-1	BB	2014	9/10	1-1-2-6-6-5-5-4-4-3-3
North Pond Area Wetland BB-2	BB	2012	9/5	0-0-0-5-5-5-5-5-1-0-0
North Pond Area Wetland BB-2	BB	2014	9/16	0-0-1-4-6-5-6-6-4-4-3
Fourmile Creek DRM-20	DRM	2012	9/18	4-4-5-5-5-5-6-7-1-0-0
Fourmile Creek DRM-20	DRM	2014	9/3	5-5-5-5-5-5-8-6-3-3-4
North Buck Bay Area Wetland DRM-16	DRM	2012	10/10	0-0-1-5-5-4-4-5-1-3-1
North Buck Bay Area Wetland DRM-16	DRM	2014	9/30	0-0-4-2-5-5-5-5-4-4-4
Port Bay Wetland DRM-17	DRM	2012	10/4	5-5-5-3-3-4-5-4-3-2-0
Port Bay Wetland DRM-17	DRM	2014	9/11	6-6-3-0-0-3-7-6-5-5-3
Sterling Creek Wetland DRM-13	DRM	2012	10/11	0-0-1-5-5-5-9-3-3-1-0
Sterling Creek Wetland DRM-13	DRM	2014	9/29	5-5-1-0-4-5-6-5-5-5-5
Braddock Bay Wetland OE-38	OE	2012	9/19	3-3-3-3-5-5-5-5-5-5-5
Braddock Bay Wetland OE-38	OE	2014	9/5	4-4-5-2-2-5-5-5-5-5-5
Flatiron Marsh Wetland OE-37	OE	2012	9/25	0-0-2-5-5-5-5-5-1-0-0
Flatiron Marsh Wetland OE-37	OE	2014	9/25	5-5-5-5-5-5-6-5-5-5-4
Isthmus Marsh OE-40	OE	2012	9/27	2-2-3-5-5-5-5-5-5-3-1
Isthmus Marsh OE-40	OE	2014	9/23	5-5-5-5-4-5-5-5-5-5-5
Perch River Wetland OE-39	OE	2012	9/12	3-3-5-5-5-5-5-5-4-2-0
Perch River Wetland OE-39	OE	2014	9/18	4-4-5-5-5-5-5-5-5-5-5
Grass Point PE-34	PE	2012	9/28	2-2-4-5-4-6-5-1-1-1-0
Grass Point PE-34	PE	2014	9/26	6-6-5-5-5-5-5-5-4-3-2
Muskalonge Bay PE-28	PE	2012	9/7	0-0-2-4-5-5-5-5-5-4-4
Muskalonge Bay PE-28	PE	2014	9/19, 9/24	5-5-5-5-3-5-5-5-5-4-4
Rift Area PE-30	PE	2012	9/26	1-1-5-5-5-5-5-5-3-2-1
Rift Area PE-30	PE	2014	10/1	5-5-5-4-5-5-5-5-5-5-5
Sodus Bay Wetland PE-36	PE	2012	9/14, 10/5	5-5-5-4-5-5-5-5-4-1-1
Sodus Bay Wetland PE-36	PE	2014	9/9, 9/12	5-5-5-5-3-4-7-5-5-5-5

During transect data collection, quadrats were always aligned with the long edge (1-m edge) parallel to the elevation contour and the short edge (0.5-m edge) following the fall line. In standing water, the quadrat floated effectively and allowed efficient recording of floating and submerged species. However, at times visibility was so poor that percent cover under water had to be estimated based on vegetation pulled from the water by hand or using a small rake. In emergent vegetation or out of standing water, the quadrat sampler was easy to place over the vegetation and was an effective tool for sampling the representative vegetation at the measured elevation.

We often used the extra extender on the roving GPS pole (making the height to the base of the GPS antenna 2.525 m) to help acquire a GPS signal. The 10-cm radius disk attached to the bottom of the rover pole (between spike and pole) worked as an effective stop in the soft sediment, increasing consistency among measurements and users.

Data Analysis

In both sample years, on-site measurements of water levels closely tracked the water levels reported by the nearest station. Most readings taken were within about 5 cm of station reports/values/records. The highest deviations in 2012 were from measurements on two different sampling days at Lakeview Pond marsh, a barrier beach site (12 and 6 cm). The highest deviation (about 10 cm) in 2014 was from North Buck Bay, a drowned river-mouth site (Figure 4). Lakeview had a relatively high on-site reading in 2014 as well.

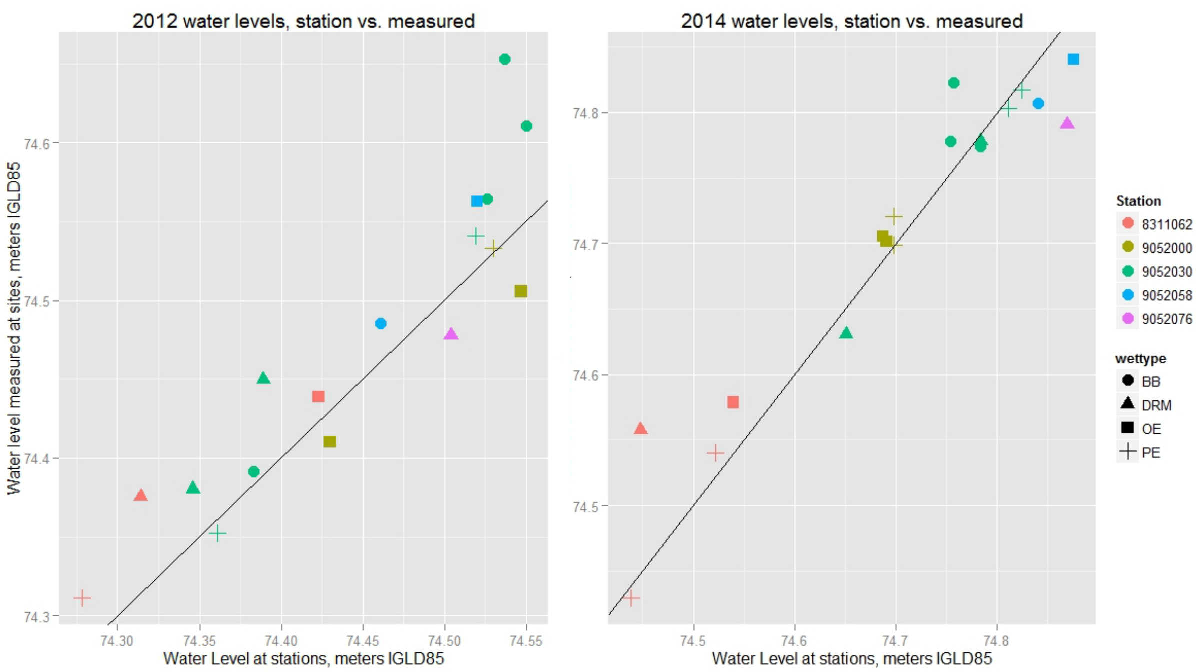


Figure 4. Water levels for Lake Ontario and the St. Lawrence River, measured on-site at the time of survey, in comparison to water levels reported at the same time from nearby stations. The line represents perfect alignment (1:1) and deviations up or down from that line show the difference in the on-site reading from that reported from the station.

We generated 3968 species records tied to 290 transect elevation locations. When abundance was averaged across all sites, species guilds fell out along elevations as expected (Grabas and Rokitnicki-Wojcik 2015). Submerged aquatic vegetation was most abundant at elevations below 74.6 m and cattail were most abundant at 74.8 and 75.0 m (Figure 5). Meadow-marsh species were most abundant at 75.2 and 75.4 m, but cattail and shrubs were also present at these elevations, both intermingling and in single-species patches on the ground.

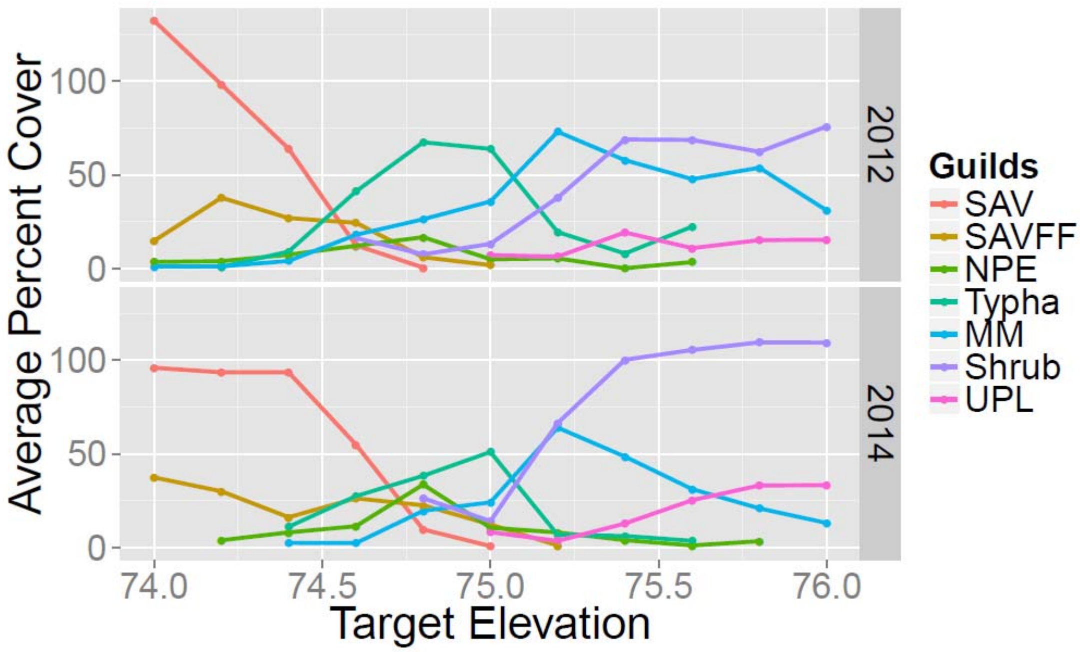


Figure 5. Average abundance of species data collected in quadrats at 16 sites, plotted by targeted elevation and grouped by guilds. Guild definitions follow Grabas and Rokitnicki-Wojcik (2015): SAV = submerged aquatic vegetation, SAVFF = submerged aquatic vegetation free floating; NPE = non-persistent emergent; Typha = cattail; MM = meadow marsh, Shrub = shrubs, UPL = upland species.

An ordination of the two sampling periods combined shows the sampling periods overlapping quite thoroughly in ordination space (Figure 6). As expected, the first ordination axis was strongly related to elevation, showing that the major differences in vegetation composition spread out along the elevation gradient. The second axis shows a dispersion of points at the high elevations and again at low elevations, but points were clustered more tightly at around 75 m elevation.

The most abundant species in quadrats included coontail (*Ceratophyllum demersum*) and white water-lily (*Nymphaea odorata*) at the lowest elevations, hybrid cattail (*Typha x glauca*) and jewelweed (*Impatiens capensis*) at intermediate elevations, followed by meadow-marsh species (*Calamagrostis canadensis* and *Carex lacustris*) and then shrubs and trees such as dogwood (*Cornus racemosa*) and red maple (*Acer rubrum*) (Figure 7).

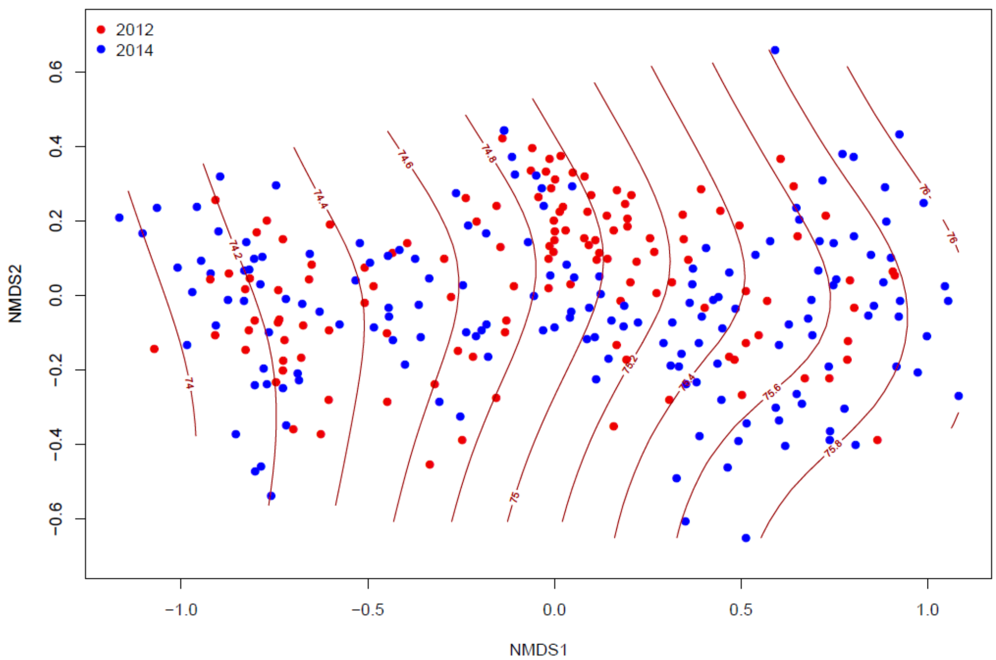


Figure 6. Non-metric multidimensional scaling of transect data for both sample years. Each point represents an average of repeated samples for a targeted elevation at a specific site. Contours show the change in elevation across this ordination space, with lowest elevations on the left and highest elevations on the right.

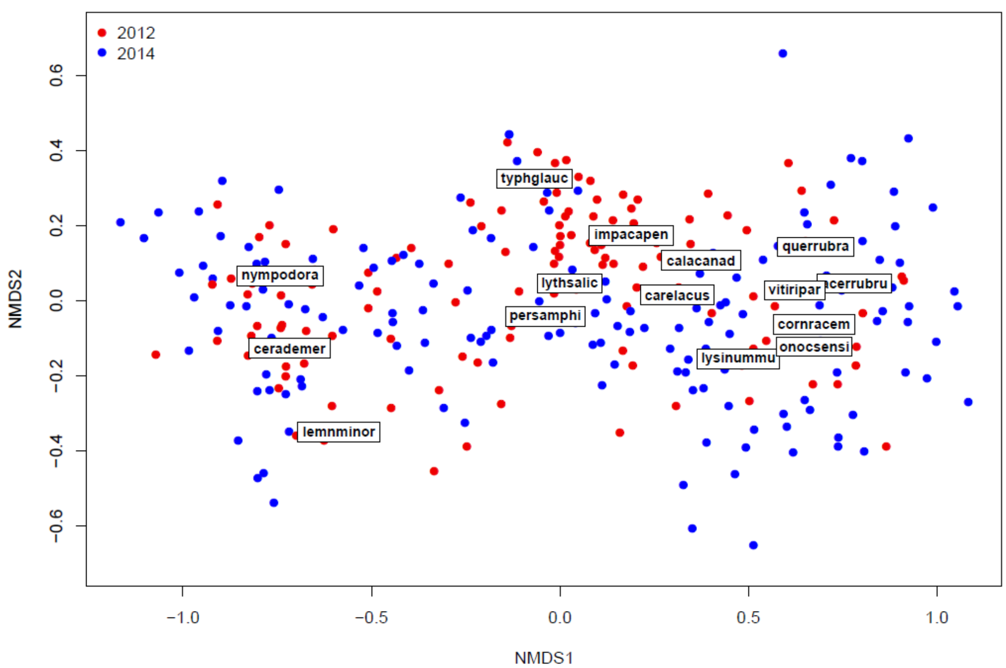


Figure 7. Non-metric multidimensional scaling of transect data for both sample years with the most common species overlain at their center of abundance. Nymphodora = *Nyphaea odorata*; ceratdemer = *Ceratophyllum demersum*; lemnminor = *Lemna minor*; typhglauc = *Typha x glauca*; impacapen = *Impatiens capensis*; lythsalic = *Lythrum salicaria*; persamphi = *Persicaria amphibia*; carelacus = *Carex lacustris*; calacanad = *Calamagrostis canadensis*; querrubra = *Quercus rubra*; acerrubru = *Acer rubrum*;

vitiripar = *Vitis riparia*; cornracem = *Cornus racemosa*; onocsensi = *Onoclea sensibilis*; lysinummu = *Lysimachia nummularia*.

Using cluster analysis and dividing the sample into thirteen groups, we identified two groups that closely match the cattail and meadow marsh vegetation types (Appendix 2). The cattail group occurs around 75.0 m elevation and appears to shift a small amount between sampling years (Figure 8). The meadow marsh community aligns mostly with the samples shown in Figure 9. This group occurs just above the cattail group in elevation and has high abundance of grasses and sedges.

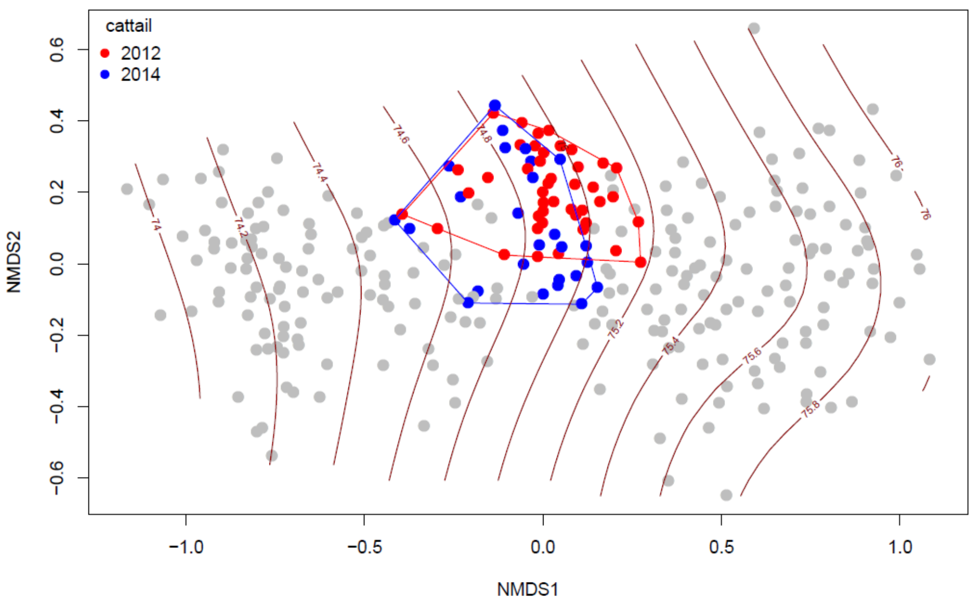


Figure 8. Non-metric multidimensional scaling of transect data for both sample years with elevations mapped with isolines. The cattail vegetation group as identified by cluster analysis is highlighted in color.

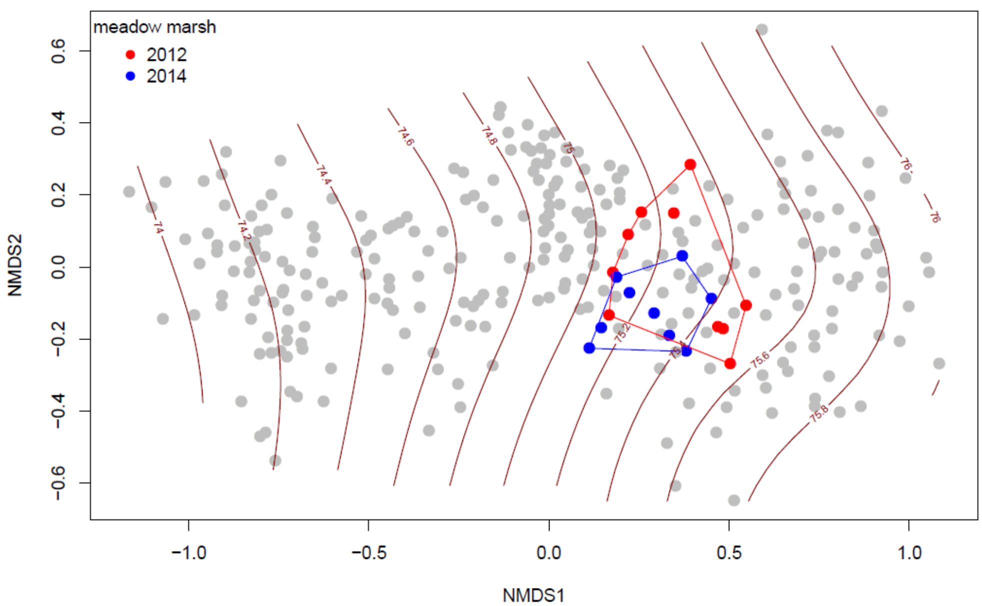


Figure 9. Non-metric multidimensional scaling of transect data for both sample years with elevations mapped with isolines. The group identified by cluster analysis having the highest proportion of meadow marsh vegetation is highlighted in color.

Discussion

The data collected through elevation transect surveys using RTK GPS equipment are consistent and of high enough resolution to effectively capture and track vegetation changes in reference to elevation. The data allow for both qualitative and quantitative assessments of change, ranging from univariate assessments of the abundance of a single species along the elevation gradient to multispecies assessments using multidimensional space.

One of the primary purposes of the 2012 and 2014 data collection events was to align data collection methods with the approach used by the Canadian Wildlife Service. We have now successfully merged data sets in companion work to this project and therefore the data presented here contribute to a bi-national data set.

In our first analytic comparison (Figure 4) our goal was to ensure that the elevation readings acquired on site were equivalent to elevations being reported by the continuous monitoring stations, using the current lake level as the measuring standard. With the majority of on-site readings differing less than 5 cm from station readings, we are confident that our measuring systems worked as expected. The site with the largest deviation in 2012 was Lakeview Pond marsh, a barrier beach site. Higher water levels certainly would be possible at a barrier beach site if the outlet was constricting outflow to a rate lower than the inflow to the wetland. The overall lower water levels in 2012 increase the likelihood that the barrier beach may have been restricting flow at that time.

We also had higher than expected lake level readings in 2012 and 2014 at North Buck Bay (Figure 4). For water-level comparisons at this site, as well as the other three sites in the St. Lawrence River, we used the NOAA water level station at Alexandria Bay (Station ID: 8311062). This station is actually downriver of all of these wetlands. North Buck Bay is farthest upriver (towards Lake Ontario). At approximately 20 km away, this station may be too far to rely upon for accurate readings for North Buck Bay.

Vegetation guilds sorted along the elevation gradient as expected (Figure 5). The submerged and rooted floating-leaved vegetation (SAV) and the free-floating vegetation (SAVFF) had the highest abundance at the lowest elevations. In 2012, SAV had average cover values greater than zero from 74.0 to 74.6 m. In 2014 the range increased to 74.0 to 74.8 m IGLD. Similarly the SAVFF increased its range from 74.0 – 74.8 m in 2012 to 74.0 – 75.0 in 2014. We would expect free-floating vegetation such as duckweed to have this slightly higher elevation range as free-floating species were regularly found on mud amidst cattail stems, near the water's edge. The slight increase in elevations for both of these guilds could be related to the higher lake levels in 2014, but we need additional sampling years to validate that hypothesis.

At upper elevations, the shrub and upland (UPL) guilds had the highest abundance, along with the meadow marsh guild (Figure 5). There is more confusion at these upper elevations because of the higher variability in species and species tolerances picked up in these guilds. For example, buttonbush (*Cephalanthus occidentalis*) and alder (*Alnus incana* ssp. *rugosa*) can tolerate very wet conditions, which can help extend the shrub guild down to 74.8 m. This variability in tolerances also results in vegetation groups being more likely to occur in patches rather than clear bands following contours at these higher elevations. Thus, on some transects at some sites, we may encounter a patch of meadow marsh extending up to 75.6 m, while along other transects the same elevation are occupied by a patch of shrubs or even species more often considered as upland. For the same reasons, species of different guilds are more likely to be interspersed at these elevations, such as some meadow marsh species growing among shrubs.

At 74.8 and 75.0 m cattail are the clear dominants. It is interesting to note the relatively restricted elevational band where cattail are most abundant. This is in stark contrast to the very large areal extent in which cattail are found at each wetland, emphasizing how level the cattail patches are.

When we isolate the cattail group in the ordination diagram (Figure 8) the pattern is perhaps even clearer. There are a few important observations to make about this ordination diagram. First, the cattail groups, even with both years joined together, occupy a relatively tight grouping within the ordination diagram. This indicates the internal similarity in species composition at elevations within each site. Second, the central position this group occupies, with points spreading out (along axis 2) with increased distance to the left or right (e.g., along axis 1), mimicking the shape of a bow-tie, indicates increased variability in vegetation composition at higher and lower elevations. This is strongest at the higher elevations, where many different shrub types occur.

The bow-tie analogy also emphasizes the important role that cattail currently plays in this marsh system. Imagine standing in the uplands above one of these marshes and walking downslope through the marsh and into the water. You might encounter one of many types of shrubby wetland and you might encounter a patch or band of meadow marsh, but you are almost certain to pass through a stand of cattail before entering one or more submerged and floating vegetation types. While the density and extent of cattail stands vary within and among sites all transects passed though some cattail. Increasing our understanding of how cattail stands vary through space and time would improve our ability to maximize the effectiveness of our management activities.

The group identified by cluster analysis that contained the most meadow marsh species occurred directly above the cattail group from around 75.0 to 75.4 m (Figure 9). Species such as *Carex lacustris*, *Phalaris arundinacea*, *Calamagrostis canadensis* var. *canadensis*, and *Impatiens capensis* were generally more abundant at these elevations (Appendix 2). The fact this group is spread out among other grey points in the ordination diagram (Figure 9) indicates the higher variability in species composition, both within this type and for other vegetation types at these elevations.


Photo 4. *Heteranthera dubia*, *Spirodela polyrhiza*, *Azolla caroliniensis*, and *Wolffia* sp.at Sterling Creek.

Overall, these two sample periods of transect monitoring data provide a consistent baseline that shows similar patterns using different analytic tools. Additional years of sampling will allow us to begin assessing patterns in year-to-year variability of vegetation types along the elevation gradient.

Section 2: Vegetation type mapping

Introduction

Meadow marsh extent and total wetland extent are both important indicators for the Lake Ontario LAMP committee and the IJC. Our goal for this section was to collect aerial imagery during each sample period in order to map the vegetation types throughout each of our wetlands.

The primary goal of photo-interpretation was to delineate the extent of meadow marsh and cattail stands. Previous work has shown a substantial response of these community types to LOSLR regulation (Wilcox *et al.* 2008). A second goal was to assess the size and extent of other vegetation types within the wetland to better relate changes observed in the elevational transects to changes in areal extent.

Methods:

Aerial Imagery acquisition

We acquired custom aerial imagery for all sixteen target wetlands in both 2012 and 2014. We accomplished this through a bid-request process and in both years we selected the same local company (EA Maps, Hamlin NY; www.eamaps.com). Contract specifications included the development and submission of a QAPP, acquisition of imagery between August 1 and October 1 of the designated year, and ideally spanning a very short time frame when actually flown. The contractor delivered orthorectified imagery in both natural color and color infrared at a ground resolution of 1 foot (0.3 m) as well as the raw imagery with photogrammetric aerotriangulation (AT) files to allow viewing the imagery in stereo.

Mapping meadow marsh extent and total coastal wetland surface area

In the spring of 2012, we began with an initial mapping of vegetation types using imagery available through the NYS Digital Orthoimagery program.[9]

In August 2012 and 2014, we conducted field work to validate and improve the initial mapping and the 2012 mapping, respectively. Using the GRTS function in the “spsurvey” package (Kincaid and Olsen 2011), we generated spatially balanced random points for sampling. For each of seven vegetation types within each wetland, we set the design to assign 10 randomly generated points. The seven target types were common reed marsh, deep emergent marsh, reedgrass-purple loosestrife marsh, red maple hardwood swamp, shallow emergent marsh, sedge meadow, and shrub swamp. Field staff collected data at as many of these points as possible within one or two field days, depending on the size of the wetland and point accessibility. At each data collection point, we collected vegetation data inside a 1-m^2 quadrat, measuring percent cover of all species present. We compared the final mapped product to the field data with a contingency matrix and kappa statistics (Cohen 1960).

After we acquired the 2012 imagery, we finalized the 2012 delineations. We used the validation point data to improve the boundaries and vegetation type identification. Additional spatial data sources (Bing imagery, USGS topographic maps) were used in support and proved helpful. After we acquired the 2014 imagery and collected field data, we examined the imagery and delineations for any significant changes and delineated vegetation types anew/again. For each wetland, our approach was to pan through the delineation at a scale of 1:2000, with the delineations based on 2012 overlaying the 2014 imagery. We looked for any vegetation edge deviations of 6 m or more, when these were encountered, we modified the delineations at 1:1000 scale. This 6-meter threshold made it more likely that the changes were not artifacts of imagery

[9] https://gis.ny.gov/gateway/mg/

alignment or variation in photo interpretation. For each wetland, we also checked for and corrected any topological errors, such as polygon overlaps or gaps.

Mapping generally followed the rules set forth by Appendix A of Wilcox et. al. (2005). Each polygon was attributed with the Ecological Land Classification (ELC_code) of Southern Ontario (Lee *et al.* 1998), DB_code (Wilcox *et al.* 2005), NY Natural Heritage Program natural community type (Edinger *et al.* 2014), and modifiers to the community type when necessary (e.g., to indicate cattail or non-cattail shallow emergent marsh).

Final products were built into a geodatabase for delivery to EPA and partners.

Results

The total wetland area of all sixteen wetlands came out to 3684 acres, which we divided up into 613 different wetland polygons. An additional 57 polygons were used to characterize upland and open water areas adjacent or within each wetland. The smallest sites were Grass Point, Fourmile Creek, and North Buck Bay. The largest sites were Sterling Creek, Buck Pond, and Lakeview Pond. In some cases, particularly Lakeview, we had to restrict the extent to a manageable size and the extent of the entire wetland complex continued beyond the area mapped. The number of polygons mapped and the acres of mapped wetland for each site are listed in Table 3.

Table 3. The number of wetland polygons and total wetland acres for each study wetland. Hydrogeomorphic type (HGM): BB = barrier beach, DRM = drowned river-mouth, OE = open embayment, PE = protected embayment.

HGM	Site	Polys	Acres
BB	Buck Pond BB-4	90	691.0
BB	Lakeview Pond BB-3	33	653.7
BB	Maxwell Bay Wetland BB-1	29	27.6
BB	North Pond Area Wetland BB-2	22	46.8
DRM	Fourmile Creek DRM-20	12	13.7
DRM	North Buck Bay Area Wetland DRM-16	11	16.9
DRM	Port Bay Wetland DRM-17	73	412.1
DRM	Sterling Creek Wetland DRM-13	74	725.7
OE	Braddock Bay Wetland OE-38	94	448.3
OE	Flatiron Marsh Wetland OE-37	19	56.1
OE	Isthmus Marsh OE-40	12	50.5
OE	Perch River Wetland OE-39	38	223.9
PE	Grass Point Wetland PE-34	15	11.0
PE	Muskalonge Bay Wetland PE-28	45	212.5
PE	Rift Area Wetland PE-30	12	20.8
PE	Sodus Bay Wetland PE-26	34	74.3

Cattails (MAS) totaled 2149 acres, while meadow marsh totaled 209 acres combined across all the wetlands according to the 2014 delineations. Shrub-dominated areas (SWT) totaled nearly 200 acres, while deeper water marshes (SAM) and submerged aquatic vegetation (SAS) totaled 1086 acres (Table 4).

Table 4. The number of wetland polygons delineated by each common wetland type in 2014, as determined by community classes described by Wilcox *et al.* 2005. Note that MAM is equivalent to meadow marsh and MAS is mostly cattail.

Vegetation type	ELC code	Polys	Acres
Marsh – meadow	MAM	140	208.8
Marsh – shallow marsh	MAS	198	2148.8
Shallow water – mixed shallow aquatic	SAM	101	991.3
Shallow water – submerged shallow aquatic	SAS	17	94.8
Swamp – deciduous	SWD	19	41.6
Swamp - thicket	SWT	137	199.2

Between 2012 and 2014 there were some small changes in the extent of vegetation types at nine of the 16 sites. These were detected as edge changes greater than 6 m anywhere along a given edge segment. Changes exceeding this threshold were mapped. There were examples of cattail marsh loss at exposed wetland edges (Figure 10), but more commonly cattail expanded into slightly lower elevations (Figure 11). Marsh loss at the wetland–water edge occurred at two sites, both open embayments (Braddock Bay, Perch River). Marsh expansion into the wetland–water edge occurred in all wetland types and at Sterling Creek, Braddock Bay, Perch River, Isthmus Marsh, Muskalonge Bay, Rift Area Wetland, Maxwell Bay, and North Pond Area Wetland. The final detected change was the expansion of a *Phragmites* patch (Fourmile Creek).

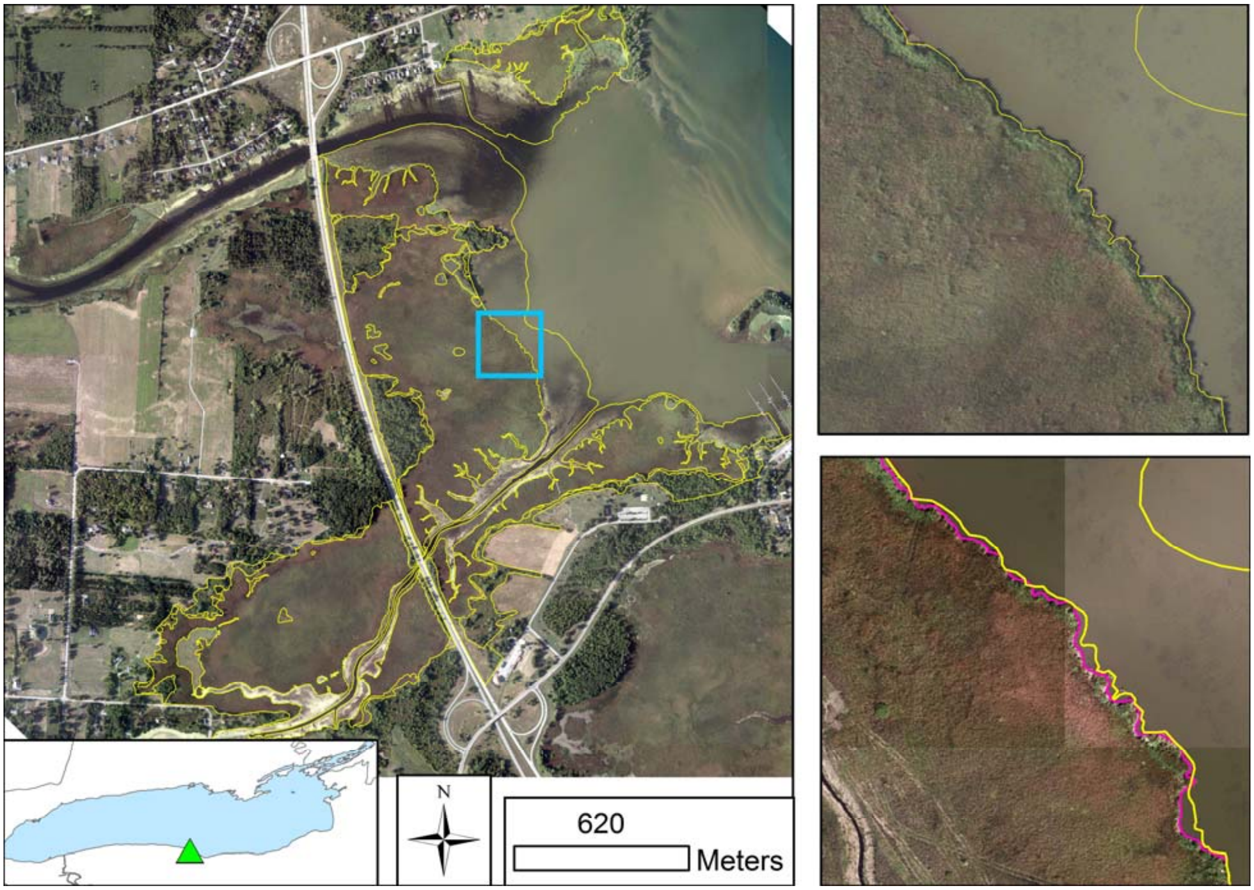


Figure 10. Vegetation delineations for Braddock Bay wetland with true-color imagery. The left-hand panel shows the 2012 imagery and 2012 delineations in yellow. The upper right panel shows a zoom-in (the area outlined by the blue rectangle in the left panel) with the 2012 imagery and delineations. The lower right panel shows the 2014 imagery, 2012 delineations in yellow, and 2014 changes to those delineations in pink. Here, the exposed cattail edge has eroded back into the wetland. Color variations within and among aerial images are due to differences in light and progression of the growing season each year.

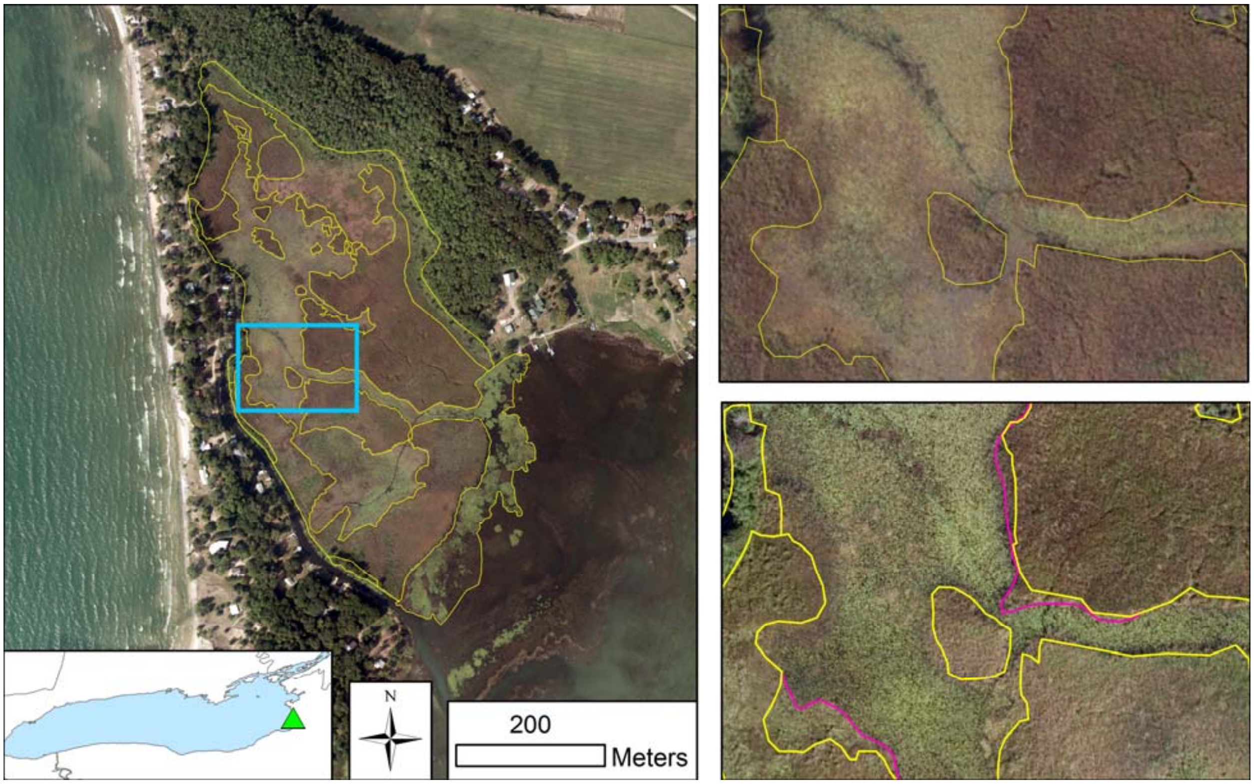


Figure 11. Vegetation delineations for North Pond Area Wetland on top of true-color imagery. The left-hand panel shows the 2012 imagery and 2012 delineations in yellow. The upper right panel shows a zoom-in (the area outlined by the blue rectangle in the left panel) with the 2012 imagery and delineations. The lower right panel shows the 2014 imagery, 2012 delineations in yellow, and 2014 changes to those delineations in pink. Here, cattail has expanded into mudflats and submerged aquatic vegetation. Color variations within and among aerial images are due to differences in light and progression of the growing season each year.

In 2012, we collected 133 samples (1 m^2 quadrats) to support the vegetation mapping. In 2014 we collected an additional 316 samples. Of these 449 samples, 421 occurred within the mapped wetlands. The remaining 28 samples were taken in nearby uplands or wetlands to support the mapping, but weren't within the mapping extent. To compare the mapped polygons to the field samples we simplified our classification into twelve different types: Common Reed Marsh (*Phragmites* stands), Deep Emergent Marsh, Floodplain Forest, Great Lakes Aquatic Bed, Medium Fen, Meadow Marsh, Open Water, Red Maple Hardwood swamp, Shallow Emergent Marsh (cattail stands), Successional Old Field, Shrub Swamp, and Upland. The wetland delineations correctly mapped 363 of the 421 points, giving an overall accuracy of 86% (Table 5). Mapping errors typically occurred as a result of one of these factors: sampled patches were too small to be mapped, sampled locations were just over the mapped boundary, or types with similar signatures (e.g., floodplain forest, red maple-hardwood swamp, and shrub swamp) were difficult to discern from imagery. The overall weighted kappa value was 0.8159 with lower and upper confidence boundaries of 0.7665 and 0.8653, respectively (unweighted kappa = 0.8069, bounds = 0.7614-0.8525).

Table 5. Contingency table for the final vegetation delineations and both years of Accuracy Assessment sampling. The left-hand column shows the vegetation type that was mapped; the top row shows the vegetation type that was detected in the field. In order, the type codes represent Common Reed Marsh, Deep Emergent Marsh, Great Lakes Aquatic Bed, Medium Fen, Meadow Marsh, Open Water, Red Maple-Hardwood Swamp, Shallow Emergent Marsh, Successional Old Field, Shrub Swamp, and Upland Forest.

	CRM	DEM	GLAB	MF	MM	OW	RM-HS	SEM	SOF	SS	UF	Tot
CRM	14	0	0	0	0	0	0	1	0	0	0	15
DEM	0	3	0	0	0	0	0	0	0	0	0	3
GLAB	0	5	50	0	0	0	0	1	0	0	0	56
MF	0	0	0	8	0	0	0	0	0	0	0	8
MM	1	0	0	0	63	0	1	9	1	2	0	77
OW	0	0	3	0	0	0	0	0	0	0	0	3
RM-HS	0	0	0	0	0	0	11	0	0	0	2	13
SEM	4	3	1	0	8	0	0	182	0	4	0	202
SOF	0	0	0	0	0	0	0	0	1	0	0	1
SS	0	0	0	0	5	0	2	4	0	30	0	41
UF	0	0	0	0	0	0	0	0	0	1	1	2
Col Totals	19	11	54	8	76	0	14	197	2	37	3	421

A map of each wetland with the 2014 delineations is provided in Appendix 3. A full crosswalk of classification types used is provided in Appendix 4.

Discussion

The high resolution of mapping vegetation types allowed us to detect differences in some edges over the two-year time span (Figure 10, Figure 11). These cases were not very frequent and very much dependent on the presence of a distinct edge between the two vegetation types. Thus, marsh erosion due to wave action at Braddock Bay could be clearly seen during this short time period. In shallow, protected areas, we detected a few examples of marsh expansion into slightly deeper environments (e.g., Figure 11). This occurred even with our application of a 6-meter threshold for mapping. We excluded edges from remapping where changes were visible but below the six-meter cut-off along the entire edge. This threshold made it more likely that the changes observed were not artifacts of imagery orthorectification and alignment differences or variation in hand digitizing photo interpretation.

The detectable expansion of cattail into shallow water was more common, occurring at eight of the sixteen wetland sites. Granted, the change was very small, but given the two-year time interval, it is still worth noting. Also because of the two-year interval and presence of only two sampling periods in this study, a quantitative analysis of this change in relation to any driving factors would not be possible. However, it is worth noting anecdotally that 2012 saw very low water levels throughout Lake Ontario (74.50 m IGLD was the average for 9/2012, with it reaching the lowest levels of 74.28 m for 12/2012). This was the lowest September level for at least 20 years and there are no historical winter average water levels lower than the levels from the winter of 2012.[10] The year 2013 had more normal de-watering conditions, but it is possible that the effects of 2012 were enough to trigger the slight marsh expansions detected in 2014. Additional years of data collection are needed to more quantitatively address these effects.

As with all vegetation mapping exercises, there were some clearly defined vegetation types with relatively sharp boundaries and others with indistinct boundaries. Similarly, vegetation types with differing hydrologies but similar appearances occurred (such as floodplain forest vs. red maple–hardwood swamp) as well as types that were distinct based on the imagery signature (such as common reed marsh). The sharpest boundaries occurred at shifts in vegetation structure: primarily between woody- and herbaceous-dominated types and also from herbaceous types that were mostly out of the water (during sampling) to submerged types. Having the support of stereo visualization in GIS greatly enhanced our ability to detect structural differences such as height and texture. Also, having aerial imagery from the same season as our field sampling greatly enhanced our ability to identify and delineate different vegetation types.

Even so, single vegetation types such as the extensive cattail stands still contain a tremendous amount of heterogeneity, a phenomenon clearly evident in the images in Appendix 3. This variability reinforces the importance of detailed field visits with quantitative vegetation data collection to support vegetation mapping. Our two years of data collection throughout the marshes for accuracy assessment served this purpose and allowed us to cross-validate our remote classifications as well as improve the mapping product.

Section 3: Muskrat house density

Methods

We sampled Muskrats (*Ondatra zibethicus*) at the wetland scale using the density of houses as a proxy for population size. Our goal was to sample drowned river-mouth wetlands in the winter months. In January 2012 we participated in a training day with John Farrell (SUNY ESF) to learn appropriate methods for winter Muskrat surveys. Winter survey methods depended on solid ice within and adjacent to the wetlands to allow efficient foot or ski travel throughout the targeted area. Muskrat lodges encountered were tallied, measured, and assessed for current occupancy. A team conducted surveys in 2012, focusing on three drowned river-mouth wetlands within our final wetland selection pool that also were amenable to the winter survey method. The targeted wetlands in January – March of 2012 were Cranberry Creek, Lakeshore Pond wetlands, and Salmon River-Mouth wetlands. We conducted our second set of surveys the next winter, in December 2012 - March 2013. The targeted wetlands in 2013 were Four Mile Creek, Sterling Creek, Port Bay, and North Buck Bay.


Photo 5. Documenting an active muskrat house encountered during transect surveys at Buck Pond.

[10] http://www.glerl.noaa.gov/data/dashboard/GLWLD.html

Results

After the training day on 1/30/2012 attended by Heritage Program staff member Jeff Corser, three staff members (Jeff Corser, Aissa Feldmann, Tim Howard) conducted a scouting trip on 2/9/2012 under very poor ice conditions. On 2/26/2012, surveys were attempted at Lakeshore Marsh, but abandoned before their completion due to unsafe ice conditions. On 2/27/2012, marshes at Salmon River-Mouth were surveyed as thoroughly as possible with the open water and thin ice conditions present. No Muskrat houses were observed. Cranberry Creek marsh (St. Lawrence River) was surveyed on 3/6/2012, under good survey conditions. Two small, recently abandoned Muskrat houses were observed. The houses were located on an edge between sedge and monotypic cattail, with shallow water and fresh beaver activity nearby.

On 12/24/12, 2/21/13, 2/22/13, and 3/5/13, our biologists surveyed 4 Mile Creek, Sterling Creek, Wolcott Creek, and North Buck Bay wetlands, respectively, for Muskrat houses. Survey conditions varied but were somewhat better than during the mild winter of 2012 and permitted relatively thorough surveys. Two Muskrat houses were detected and measured at North Buck Bay wetland (on Grindstone Island) but no houses were detected at the other sites. Both rather large active houses were near the mouth of the stream at North Buck Bay, not farther into the monotypic denser cattail stands. At Wolcott Creek we found a Muskrat bank burrow system, an alternative overwintering option for these aquatic mammals.

Photo 6. Air boat used for getting to North Buck Bay for muskrat surveys.

Discussion

The original schedule for Muskrat surveys was to have them coincide with the year summer field work was conducted: the winter of 2011-2012 matched to summer 2012 and the winter of 2013-2014 to match to summer 2014. Unfortunately, the extremely mild conditions during the winter of 2011-2012 turned out to be very difficult, if not impossible, for conducting this type of winter survey that depends on sustained cold temperatures. We made the best of it by visiting drowned river-mouth wetlands at the next best time possible and also specifically choosing wetlands that might allow surveys under difficult conditions. The only wetland we could successfully travel through was Cranberry Creek marsh on the St. Lawrence River.

Because of the mild winter difficulties and incomplete sampling during early 2012, we used our second winter sampling period the following winter (2013). We focused on drowned river-mouth wetlands and watched the weather closely to maximize our success. Although the survey team experienced very difficult ice conditions at North Buck Bay, they successfully sampled all four sites.

The primary research exploring the influence of lake-level dynamics on Muskrat abundance took place in the upper St. Lawrence River (Toner 2006, Toner *et al.* 2010). Interestingly, the only marshes where Muskrat houses were found (Cranberry Creek in 2012 and North Buck Bay in 2013) were also in the upper St. Lawrence area. We did not have any other winter survey detections of Muskrat houses, although we occasionally came across Muskrat houses during summer surveys in other Lake Ontario wetlands and we did see bank burrows along Wolcott Creek at Port Bay wetland.

We do not know whether the lack of detectable houses in some Lake Ontario wetlands is due to water-level dynamics, lower detection rates because of weather or climate, different wetland composition or structure that results in lower population densities, or some other environmental conditions. But the lack of success may be related to many factors uncontrollable by our survey protocol. Also, Muskrats are known to overwinter in bank dens as well as cattail-constructed houses, and we did encounter both of these structures during our surveys. The interplay between the timing and presence of factors that might cause Muskrats to shift among these alternate structures is poorly understood (Proulx and Gilbert 1984, Messier and Virgl 1992) but may be related to population densities (Messier and Virgl 1992) as well as site characteristics. Thus, while we know that muskrat house counts in the upper St. Lawrence work as an excellent and effective indicator (Toner *et al.* 2010), this same metric may be more difficult to implement for the remainder of the LOSLR system.

Section 4: At-risk plant species

Methods

A specific group of rare plants occurs in the lake-level-influenced wetlands of the LOSLR system. These at-risk plant species include (listed with scientific name, NYS rarity rank, and NYS listing status)

- Autumnal Water-starwort (*Callitriche hermaphroditica*, S1, Endangered)
- Lake-cress (*Rorippa aquatica*, S2, Threatened)
- Awned Sedge (*Carex atherodes*, S3, Rare)
- Marsh Horsetail (*Equisetum palustre*, S2, Threatened)
- Slender Bulrush (*Schoenoplectus heterochaetus*, S1, Endangered)
- Sweet-scented Indian-plantain (*Hasteola suaveolens*, S1, Endangered)
- Water-plantain (*Alisma gramineum*, S2S3, Threatened)
- Slender Pondweed (*Stuckenia filiformis*, S1, Endangered)

Because the restricted nature of the vegetation sampling transect protocol generally reduces opportunities for detecting these species, we conducted targeted inventories for them throughout each of the 16 wetlands. These targeted inventories were coordinated with the mapping accuracy assessment sampling during which biologists were traversing as much of the wetland as possible. These species occur in different parts of the wetland transition zone and so an effort was made to ensure searches in all parts of the wetland complex.

Results

In 2012 we re-documented a population of Awned Sedge (*Carex atherodes*) at North Buck Bay wetland on 9/20/2012. This population had been first documented eight years earlier. Plants were scattered throughout a relatively large patch of meadow marsh at this site. In 2014, we documented this occurrence more thoroughly and also found this species at Flatiron Marsh, Isthmus Marsh, and North Pond Area wetland. In all cases, Awned Sedge was intermingled with other meadow marsh species clearly within the meadow marsh band of the wetland.

Photo 7. [left] Meadow marsh with Awned Sedge intermingled at Flatiron Marsh. Note the band clearly occurs between the cattail on the right and the upland forest left/back of the image. [right] Meadow marsh with Awned Sedge intermingled at North Pond Area Wetland. Again note the banding with cattail on the right and forest on the left/back.

Marsh Horsetail (*Equisetum palustre*) occurs in similar zones as the Awned Sedge: toward the upper end of the marsh in mixed meadow marsh vegetation and sometimes with a bit more cattail. We found Marsh Horsetail at Lakeview Pond marsh in 2014 in two different localities. In both cases we discovered the species during our transect surveys.

We discovered Water-plantain (*Alisma gramineum*) at three sites in 2014, having not documented it at all in 2012. In contrast to the Awned Sedge and Marsh Horsetail, this species grows in the submerged and emergent marsh zone, usually in 10-40 cm of standing water. By far the biggest population was at Isthmus Marsh, with over 1,000 individuals counted along a shoreline adjacent to the primary wetland.

Photo 8. [left] A nearly stranded individual of *Alisma gramineum* at Isthmus Marsh. [right] A more common case of *Alisma* emerging from a few decimeters of water at Grass Point.

Slender Bulrush (*Schoenoplectus heterochaetus*) also seems to be found on the deeper end of the emergent zone. We found new locations for Slender Bulrush at Muskalonge Bay and at Perch River in 2014. This finding increases the known extant locations for Slender Bulrush in New York from six to eight.

Photo 9. [left] Small island of Slender Bulrush at Muskalonge Bay in about 0.7 m of water. [right] Slender Bulrush along a shoreline in deeper water than cattail at Perch River.

Finally, we collected and examined many pondweeds in search of *Stuckenia filiformis*. Nearly all of them turned out to be the more common species *Stuckenia pectinata*, or Sago False Pondweed. One specimen, however, had some characters of *Stuckenia filiformis* but not enough for a positive identification, even after examination by an authority in aquatic vascular plants (Dr. Barre Hellquist). At this point we are treating this as a lead for future survey work.

We did not find the remaining three species (Autumnal Water-starwort, Lake-cress, Sweet-scented Indian-plantain) at any of our sites in either 2012 or 2014.

Discussion

The presence of *Carex atherodes* as a clear member of the meadow marsh community is well documented by earlier studies of this vegetation type (e.g., LOSLR indicators[11] and (Limno-Tech, Inc 2005) and we are finding this confirmed in our data as well. While it might be relatively common in localized patches where it is present, it remains a difficult species to notice and identify during surveys conducted at the end of the growing season. By this time all flowers and fruit have fallen and all that remains of the plant are thin vegetative culms and leaves scattered evenly throughout the other vegetation. Once spotted, however, the plant can be positively identified with vegetative characters. The indistinct nature of the species is likely part of the reason we did not find it at the 2014 locations in 2012 and it is possible we will find it at additional localities with more search effort. Better understanding the types of meadow marsh community associated with occurrences of this species and the conditions supporting its growth and reproduction are important for maintaining this species as a member of these wetlands.

---

[11] http://www.glerl.noaa.gov/data/dashboard/GLWLD.html

Much less is known about how the Marsh Horsetail behaves in these coastal wetlands. A common habitat description is "wetland margins" (Haines 2011), which fits the meadow marsh band. Having at least this one population within the study area allows us to begin to track its response to lake-level variability and other environmental changes over time.

Water-plantain is known to colonize exposed mudflats after a low water-level event (Hudon 2004) and this phenomenon may be driving our pattern of observations for this species. As noted previously, 2012 was a very low water year, with a low similar to the 1999 low documented by Hudon (2004). It is consistent that a positive germination response to this low would have resulted in adult plants that would persist into the summer of 2014, generating the influx of individuals documented that summer. Water-plantain appears to be dependent upon water-level variability to persist (Moravcová *et al.* 2001), indicating that we should expect wide variability in population size over time depending on recent lake-level history.

Although Slender Bulrush occupies a similar elevation zone to the Water-plantain, its rhizomatous, clonal growth habit would suggest that patches of this plant do not respond as quickly to water-level changes. Interestingly, water drawdown did not influence Slender Bulrush location along an elevation cline in prairie potholes (Van der Valk and Davis 1976), but given the differences between these systems it may behave differently here.

We expect that submerged aquatic species such as *Stuckenia* should be able to shift positions along the elevation gradient given the availability of appropriate substrate and light penetration. Which species of submerged aquatic vegetation occur will depend on both physical and chemical conditions of the water at the site and *Stuckenia filiformis* may have very specific requirements met at only a few sites. Understanding what these requirements are and how they may change with lake management will help us understand how this species will respond to different management regimes.

General Discussion

The overarching goal of this project was to begin wetland monitoring in US wetlands of the Lake Ontario-St. Lawrence River system. The primary purpose for this monitoring is to inform the adaptive management process applied to lake-level management. The indicators and metrics we are monitoring follow those identified by previous work and the IJC.

The elevation transect data allow us to evaluate the response of any vegetation type to water-level changes by evaluating its change in average elevation over time. The meadow marsh vegetation type, an indicator identified by the IJC, currently occupies a clear elevation band at approximately 75.0 m IGLD. Other vegetation types occur interspersed among meadow marsh patches and the amount of meadow marsh varies among sites. These data also join seamlessly with the transect data collected by the Canadian Wildlife Service.

The two sampling periods (2012, 2014) during this project do not yet provide enough samples to evaluate how water-level dynamics influences the magnitude and timing of its effects on vegetation composition and structure. Excellent earlier work has already defined the relationship between the timing of marsh de-watering and flooding and vegetation composition (Wilcox *et al.* 2005, Hudon *et al.* 2006), and as the monitoring data set grows, we expect to be able to refine this understanding. Overall, these two sample periods of transect monitoring data provide consistent baseline data that show corresponding patterns using different analytic tools. Additional years of sampling will allow us to begin assessing patterns in year-to-year variability of vegetation types along the elevation gradient.

The aerial imagery data and vegetation mapping data allow us to evaluate the response of wetland extent and meadow marsh community extent to LOSLR water-level dynamics. We mapped about 3,684 acres, with about 5.7 percent mapped as meadow marsh. The excellent resolution of the aerial imagery permits clear detection of boundary changes, and accordingly some small changes were detected at some wetlands from 2012 to 2014. After additional monitoring years, we will be able to evaluate trends in wetland extent and determine the relationship between these changes and water-level regulation.

We had significant difficulty surveying for Muskrats at drowned river-mouth study sites. One of the primary challenges was the inconsistent winter conditions that resulted in open water or dangerously thin ice on the wetlands and along the channels. We did, however, conduct successful searches and document Muskrat houses at one of the four drowned river-mouth sites in the winter of 2012/2013. The very few detections of Muskrat houses at our target wetlands suggested low population levels and that great potential exists for water-level management to increase Muskrat populations throughout the LOSLR system.

Finally, we are excited about the discovery of additional rare plant populations at our target sites. These species can behave as additional indicators of wetland condition and wetland change for different components of the wetland system. The strongest responses might come from *Alisma gramineum*, which appears to increase after dewatering events, and *Carex atherodes,* which is restricted to meadow marsh and will likely respond similarly to any changes in meadow marsh.

The results presented here are designed to allow comparisons to earlier and concurrent data collection events and, especially, set the groundwork for continued monitoring of a select set of important ecological indicators related to water-level management in the Lake Ontario-St. Lawrence River system. Regular sampling of these indicators and reporting to the IJC will allow full closure of a feedback loop resulting in an adaptive management regime for this important resource.

Acknowledgements

Thank you to Shelley Cooke and David Marston for database support; Erin White and David Marston for help in the field; Fiona McKinney for help with grant management; and Greg Edinger, DJ Evans, and Matt Schlesinger for proofreading this report. John Farrell (SUNY ESF) provided valuable training on surveying for Muskrats in the winter and Greg Grabas and Paul Watton (Canadian Wildlife Service) were very generous with over a day of their time in the field discussing transect surveys and imparting the fineries of RTK GPS systems. Thank you to Doug Wilcox for his groundbreaking work on the subjects presented here and for our early discussions pertaining to this project. Numerous landowners gave permission to cross or access their lands for these surveys, as did state and local agencies; thank you! We greatly appreciate the tireless efforts of Fred Luckey, for managing our contract at EPA and shepherding it through our change in parent organizations from The Nature Conservancy to SUNY Research Foundation. This project was funded by EPA through the Great Lakes Restoration Initiative, GL-00E00842.

Bibliography

Chow-Fraser, P., V. Lougheed, V. L. Thiec, B. Crosbie, L. Simser, and J. Lord. 1998. Long-term response of the biotic community to fluctuating water levels and changes in water quality in Cootes Paradise Marsh, a degraded coastal wetland of Lake Ontario. Wetlands Ecology and Management 6:19–42.

Cohen, J. 1960. A coefficient of agreement for nominal scales. Educational and Psychological Measurement 20:37–46.

Crow, G. E., and C. B. Hellquist. 2006a. Aquatic and Wetland Plants of Northeastern North America, Volume I: A Revised and Enlarged Edition of Norman C. Fassett's A Manual of Aquatic Plants, Gymnosperms, and Angiosperms: Dicotyledons1 edition. University of Wisconsin Press, Madison, Wis.

Crow, G. E., and C. B. Hellquist. 2006b. Aquatic and Wetland Plants of Northeastern North America, Volume II: A Revised and Enlarged Edition of Norman C. Fassett's A Manual of Aquatic Plants, Volume II: Angiosperms: Monocotyledons1 edition. University of Wisconsin Press, Madison, Wis.

Edinger, G. J., D. J. Evans, S. Gebauer, T. G. Howard, D. M. Hunt, and A. M. Olivero. 2014. Ecological communities of New York State, second edition. New York Natural Heritage Program, Albany, New York. 136 pages.

Gleason, H. A., and A. Cronquist. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. The New York Botanical Garden, Bronx, NY.

Grabas, G. P., and D. Rokitnicki-Wojcik. 2015. Characterizing daily water-level fluctuation intensity and water quality relationships with plant communities in Lake Ontario coastal wetlands. Journal of Great Lakes Research 41:136–144.

Great Lakes Coastal Wetlands Consortium, T. M. Burton, J. C. Brazner, J. J. H. Cibrowski, G. P. Grabas, J. Hummer, J. Schneider, and D. G. Uzarski. 2008. Great Lakes coastal wetlands monitoring plan. 283 pages.

Haines, A. 2011. Flora Novae Angliae. New England Wildflower Society.

Hudon, C. 2004. Shift in wetland plant composition and biomass following low-level episodes in the St. Lawrence River: looking into the future. Canadian Journal of Fisheries and Aquatic Sciences 61:603–617.

Hudon, C., D. A. Wilcox, and J. Ingram. 2006. Modeling wetland plant community response to assess water-level regulation scenarios in the Lake Ontario-St. Lawrence river basin. Environmental Monitoring and Assessment 113:303–328.

Keddy, P. A., and A. A. Reznicek. 1986. Great Lakes vegetation dynamics: the role of fluctuating water levels and buried seeds. Journal of Great Lakes Research 12:25–36.

Kincaid, T. M., and A. R. Olsen. 2011. spsurvey: Spatial survey design and analysis. R package version 2.2, R package version 2.2.

Lee, H. T., W. D. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhlig, and S. McMurry. 1998. Ecological land classification for southern Ontario: first approximation and its application. Ontario Ministry of Natural Resources, Southcentral Science Section, Science Development and Transfer Branch.

Limno-Tech, Inc. 2005. Development of an Integrated Ecological Response Model (IERM) for the Lake Ontario - St. Lawrence River Study. Ann Arbor, MI.

Messier, F., and J. A. Virgl. 1992. Differential use of bank burrows and lodges by muskrats, Ondatra zibethicus, in a northern marsh environment. Canadian Journal of Zoology 70:1180–1184.

Moravcová, L., P. Zákravský, and Z. Hroudová. 2001. Germination and seedling establishment inAlisma gramineum, A. plantago-aquatica andA. lanceolatum under different environmental conditions. Folia Geobotanica 36:131–146.

National Research Council. 2006. Review of the Lake Ontario-St. Lawrence River studies. National Academies Press, Washington, D.C.

Oksanen, J., F. G. Blanchet, R. Kindt, P. Legendre, B. O'Hara, G. L. Simpson, P. Solymos, M. H. H. Stevens, and H. Wagner. 2010. Vegan: community ecology package. http://CRAN.R-project.org/package=vegan.

Pebesma, E., and R. Bivand. 2005. Classes and methods for spatial data in R. R News 5.

Proulx, G., and F. F. Gilbert. 1984. Estimating Muskrat Population Trends by House Counts. The Journal of Wildlife Management 48:917–922.

R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

R Development Core Team. 2011. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Ripley, B., and M. Lapsley. 2015. RODBC: ODBC database access. R package version 1.3-12.

Roberts, D. W. 2015. labdsv: Ordination and Multivariate Analysis for Ecology.

Stevens, D. L., and A. R. Olsen. 2003. Variance estimation for spatially balanced samples of environmental resources. Environmetrics 14:593–610.

Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262–278.

Tiner, R. W., P. L. M. Veneman, and L. A. Spokas. 2011. Wetlands of the Eastern and Southern Shores of Lake Ontario: Project Completion Report. Department of Plant, Soil, and Insect Sciences, University of Massachusetts, Amherst, MA. 79 pages.

Toner, J. A. 2006. Muskrat house abundance and cattail use in Upper St. Lawrence River tributary wetlands: modeling the effects of water level regulation. SUNY College of Environmental Science and Forestry, Syracuse, NY.

Toner, J., J. Farrell, and J. Mead. 2010. Muskrat Abundance Responses to Water level Regulation Within Freshwater Coastal Wetlands. Wetlands 30:211–219.

Van der Valk, A. G., and C. B. Davis. 1976. Changes in the composition, structure, and production of plant communities along a perturbed wetland coenocline. Vegetatio 32:87–96.

Watton, P., and G. Grabas. 2007. Lake Ontario Coastal Wetlands: Vegetation Community Dynamics Pilot Study. Canadian Wildlife Service, Environment Canada, Ontario, Canada.

Wickham, H. 2009. ggplot2: elegant graphics for data analysis. Springer, New York.

Wilcox, D. A., J. W. Ingram, K. P. Kowalski, J. E. Meeker, M. L. Carlson, Y. Xie, G. P. Grabas, K. L. Holmes, and N. J. Patterson. 2005. Evaluation of water level regulation influences on Lake Ontario and Upper St. Lawrence River coastal wetland plant communities. Ottawa, ON and Washington, DC.

Wilcox, D. A., K. P. Kowalski, H. L. Hoare, M. L. Carlson, and H. N. Morgan. 2008. Cattail invasion of sedge/grass meadows in Lake Ontario: photointerpretation analysis of sixteen wetlands over five decades. Journal of Great Lakes Research 34:301–323.

Wilcox, D. A., and J. E. Meeker. 1995. Wetlands in regulated Great Lakes. Pages 247–249 in *in* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of US Plants, Animals, and Ecosystems, US DOI, National Biological Service, Washington, DC, USA. U.S. DOI, National Biological Service, Washington, DC.

Wilcox, D. A., J. E. Meeker, and J. Elias. 1992. Impacts of water-level regulation on wetlands of the Great Lakes. Phase II Report to Working Committee 2, IJC Water-Levels Reference Study. Washington, DC.

Appendix 1. Permission letter to landowners

New York Natural Heritage Program

625 Broadway, 5th Floor Albany, NY 12233-4757 (518) 402-8935 Fax (518) 402-8925 www.nynhp.org

DATE

Dear «OWNER»:

The New York Natural Heritage Program (NYNHP), a science-based non-regulatory organization responsible for cataloging locations of rare species and high quality natural areas, will be conducting an ecological assessment of wetlands along the shore of Lake Ontario. For this assessment, 16 wetland sampling sites extending from western New York into the St. Lawrence River were randomly selected by computer. The «SITE_NAME» site [on or adjacent to] your property (see enclosed map) was among these randomly selected sites and **we are writing to ask your permission to visit your land**. Our project is focused on initiating a long-term monitoring effort to evaluate coastal wetland plant and muskrat population responses to the International Joint Commission's (IJC) lake-level regulation plan. We are funded by the Environmental Protection Agency (EPA) and supported by partners in New York's Department of Environmental Conservation (DEC) and the IJC.

Field sampling trips (about 3 total days) will be made between July 2012 and March 2013, with revisits scheduled for 2014/2015. In July, one biologist will walk through and observe as much of the marsh as possible to search for rare plant species; this work should take about one day. Our late summer (August-October) fieldwork should also last about one day. During this visit, a team of two biologists will be recording plant species and collecting soil data along survey lines running from the upland, through the marsh, and a short distance into the water. We will collect and remove vegetation only if it is necessary for plant identification purposes. During the winter months (November-March), a zoologist will be spending about one day in the marsh recording the number and location of muskrat houses he finds.

With the enclosed postcard, we are requesting your permission for this work -- to allow Heritage Program field biologists to visit your property for about 3 days between July and March for wetland plant and muskrat house sampling in 2012/2013 and during the same time period in 2014/2015. We realize that working on your property is a privilege and will respect your rights and wishes at all times; we will be happy to share our results with you if you are interested.

Please take a moment to fill out the enclosed postage-paid postcard and drop it in a mailbox by the end of April. If you would like us to let you know what we find, just indicate this on the postcard along with your permission for us to visit your land, and we will send you a description of any significant natural features we encounter on your property. If you would like more information about this project, please feel free to contact me by phone or email (below). We will give you a call to follow up if we don't hear from you by early May.

Thank you so much!

Sincerely,

Aissa L. Feldmann
Ecologist
New York Natural Heritage Program
ph: 518-402-8946
email: feldmann@nynhp.org

Appendix 2. Cluster analysis groups

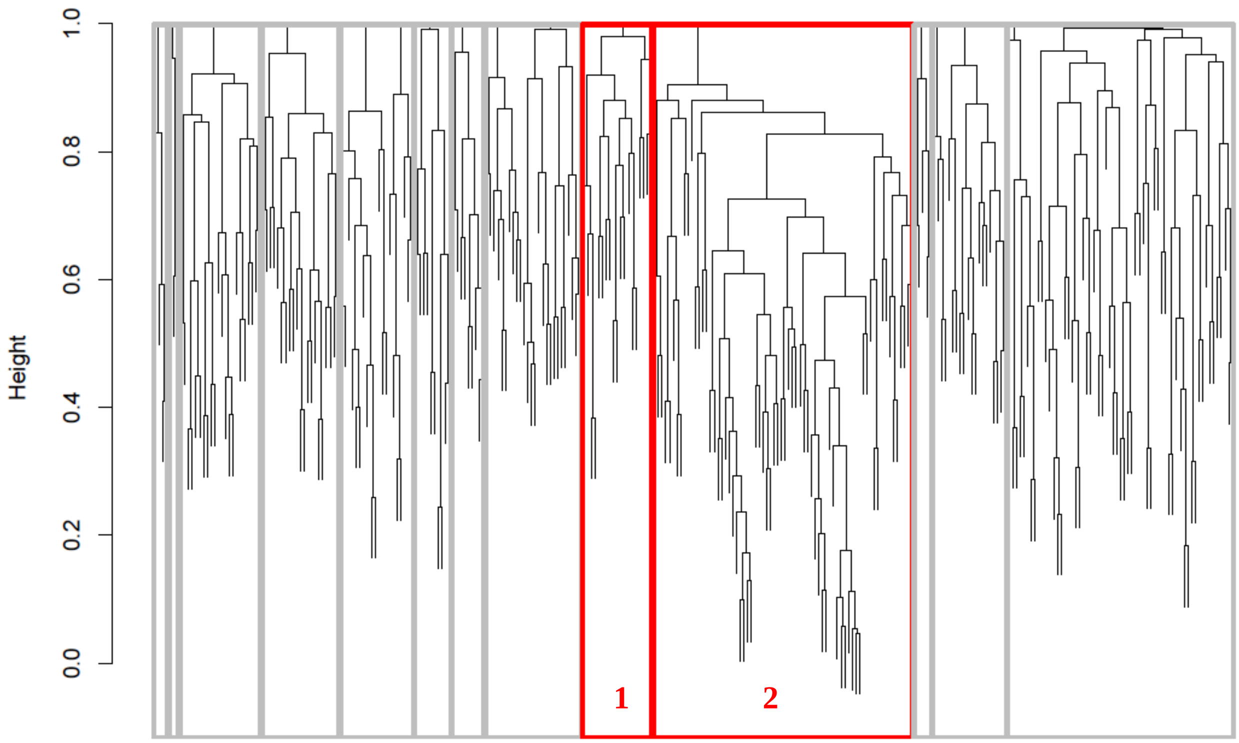


Figure A.1. Cluster analysis of the plot data, split into thirteen groups. The groups boxed in red identify the meadow marsh vegetation (#1) and cattail vegetation (#2).

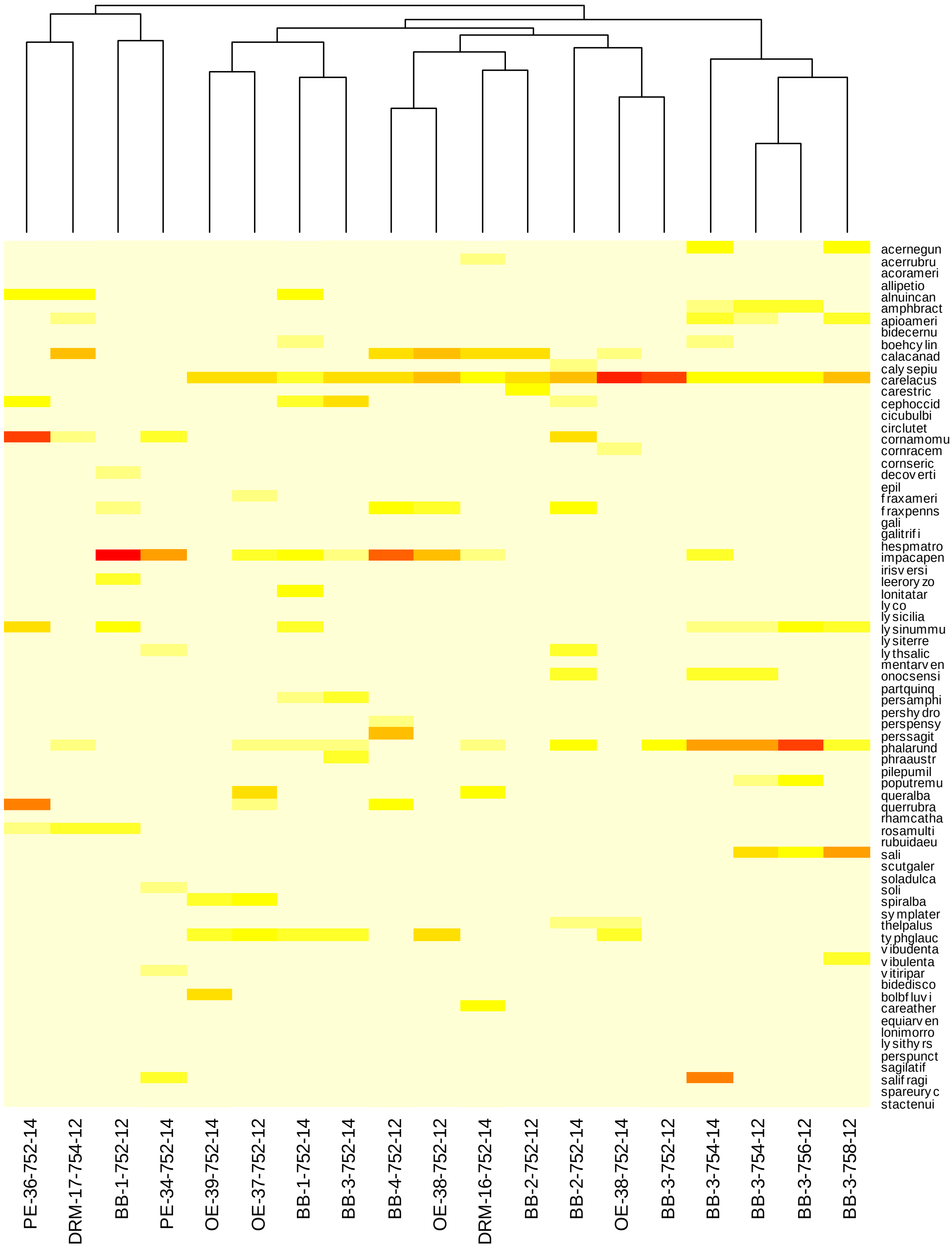


Figure A.2. Heatmap for the samples identified in the meadow marsh group. For clarity, only species occurring in more than eight plots are displayed. Darker tones indicate higher abundance in a plot (indicated at the bottom). The cluster diagram (Jaccard distance) shows the relationship among plots for this group. The species with highest abundance include: carelacus (*Carex lacustris*), cornamomu (*Cornus amomum*), impacapen (*Impatiens capensis*), and phalarund (*Phalaris arundinacea*).

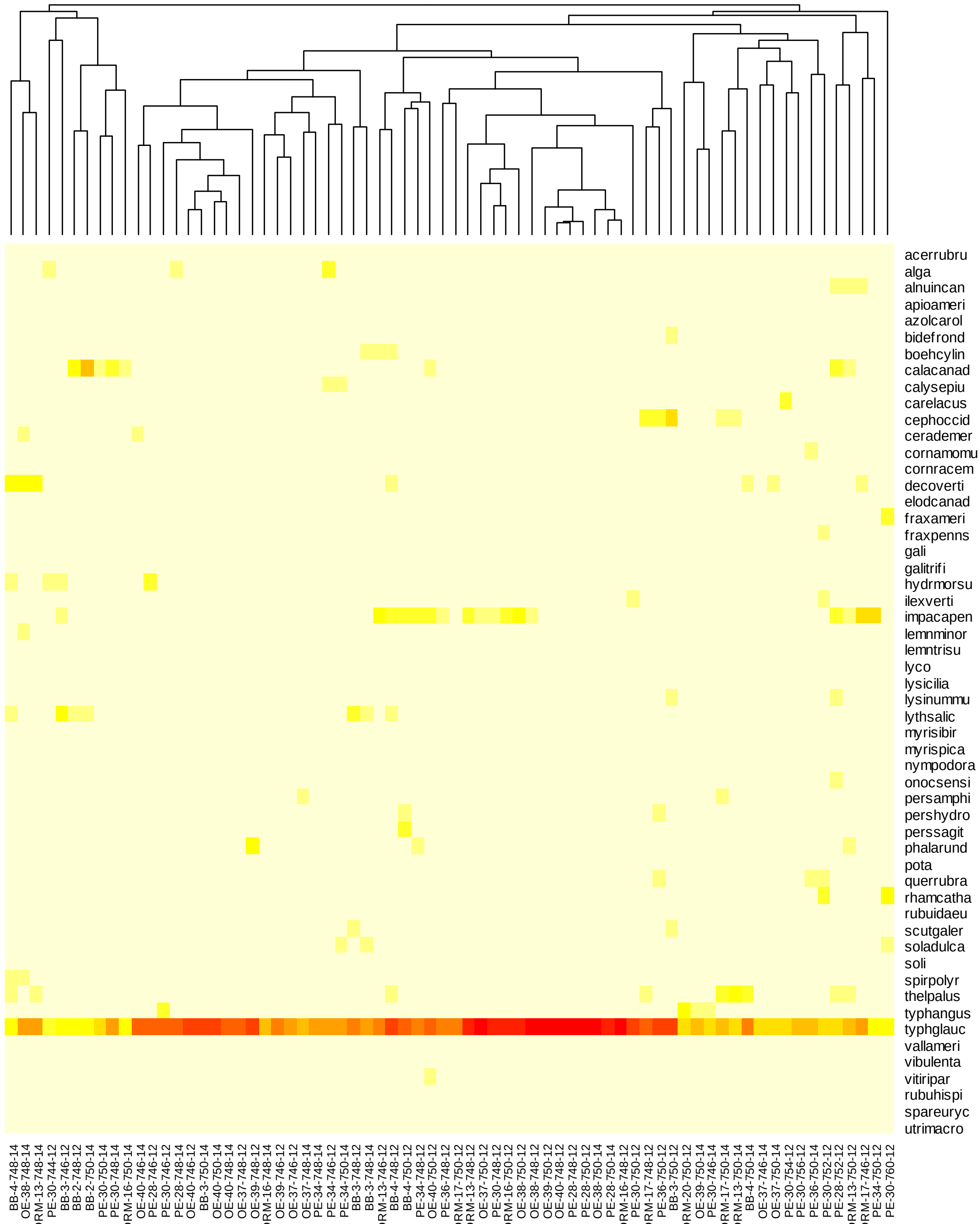
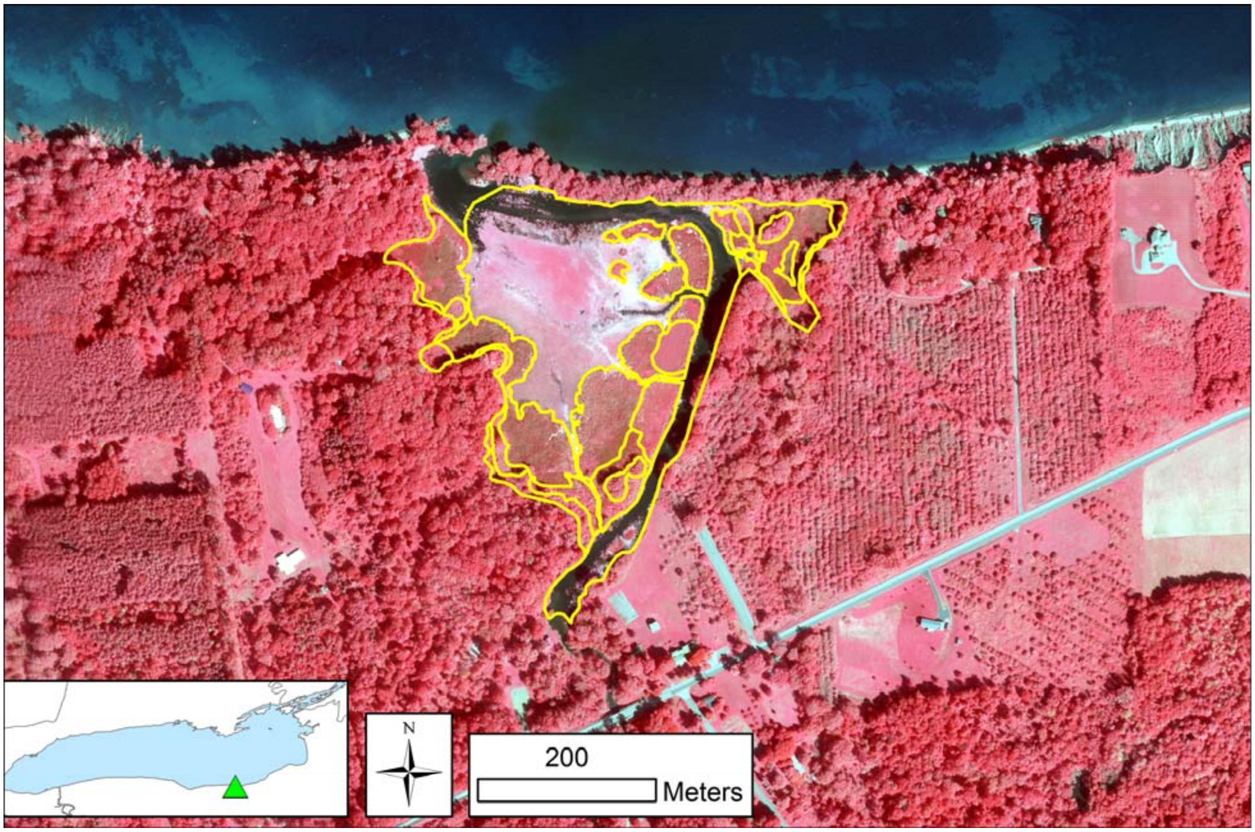
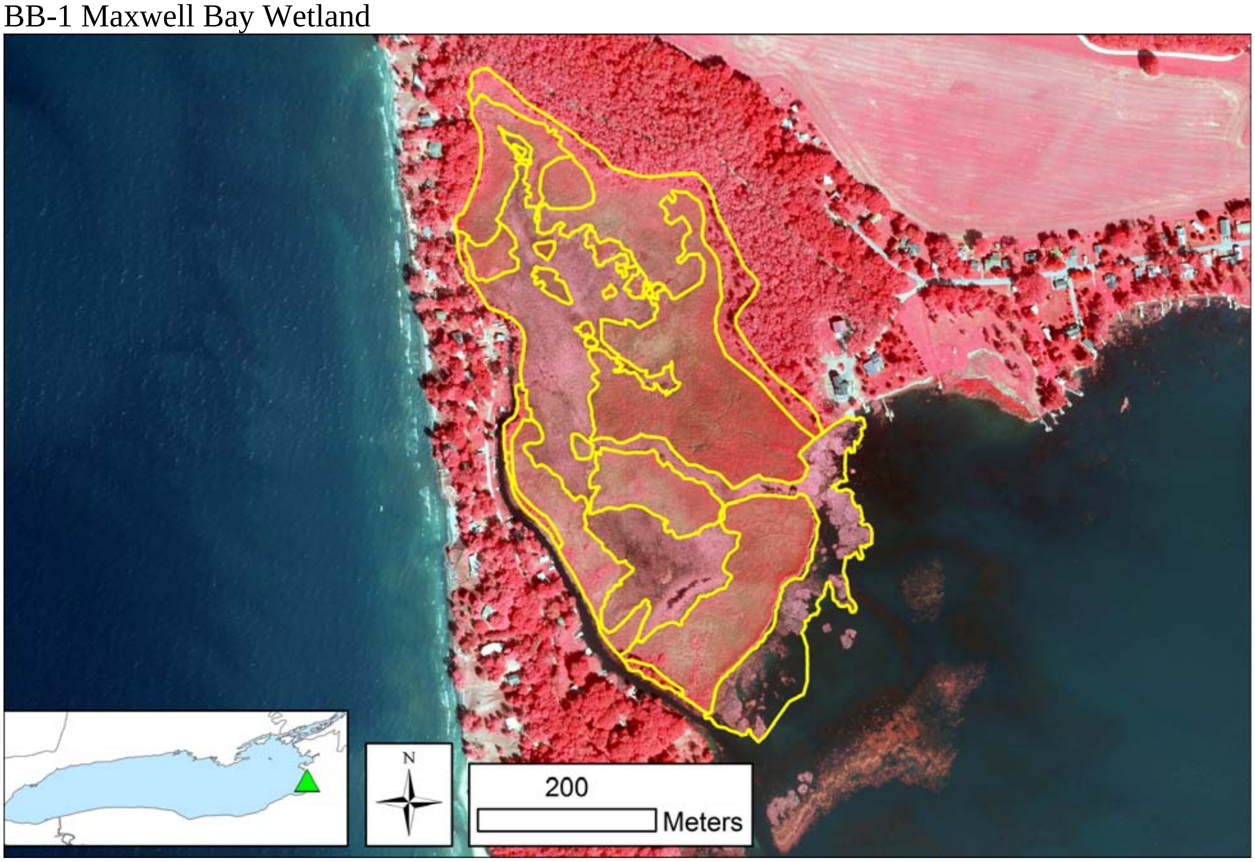


Figure A.3. Heatmap for the samples identified in the meadow cattail group. For clarity, only species occurring in more than eight plots are displayed. Darker tones indicate higher abundance in a plot (indicated at the bottom). The cluster diagram (Jaccard distance) shows the relationship among plots for this group. *Typha x glauca* (typhglauc) is clearly most abundant in all of these plots.

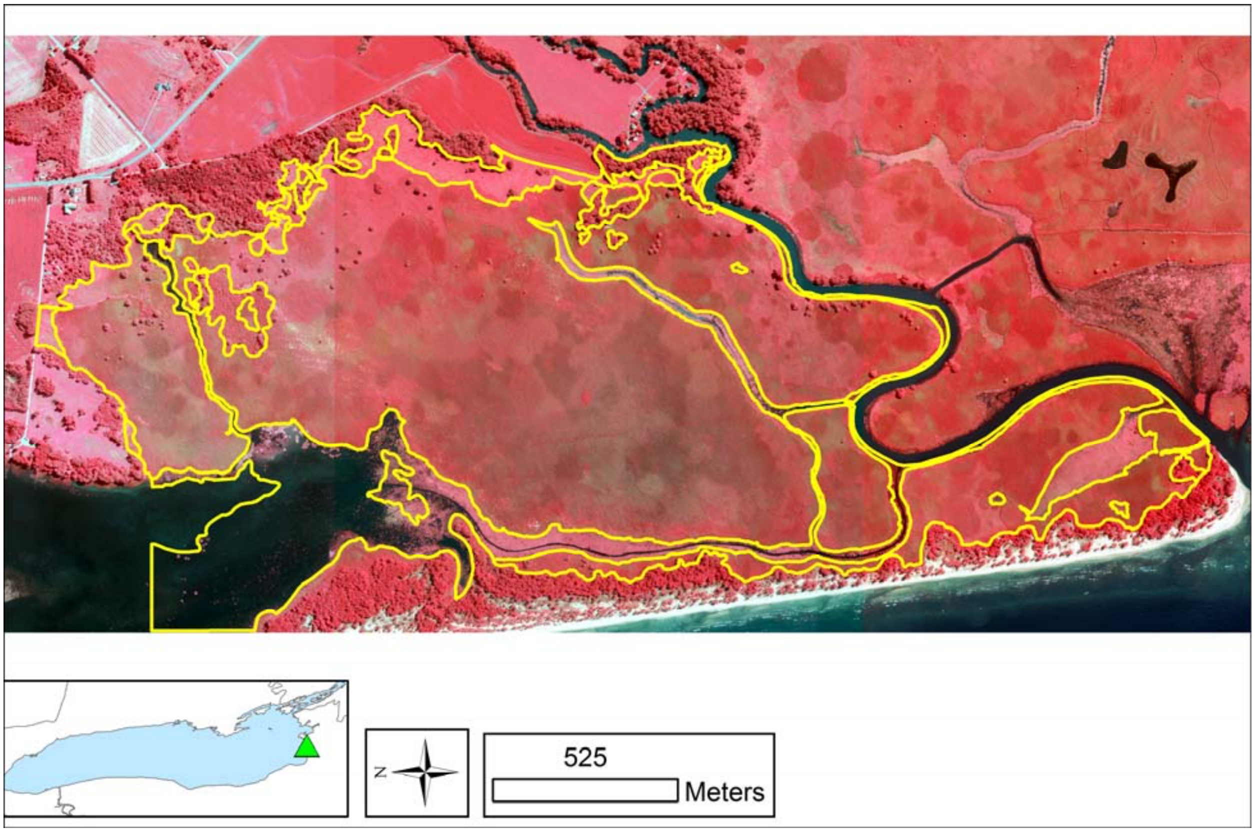
Appendix 3. Wetland Delineations



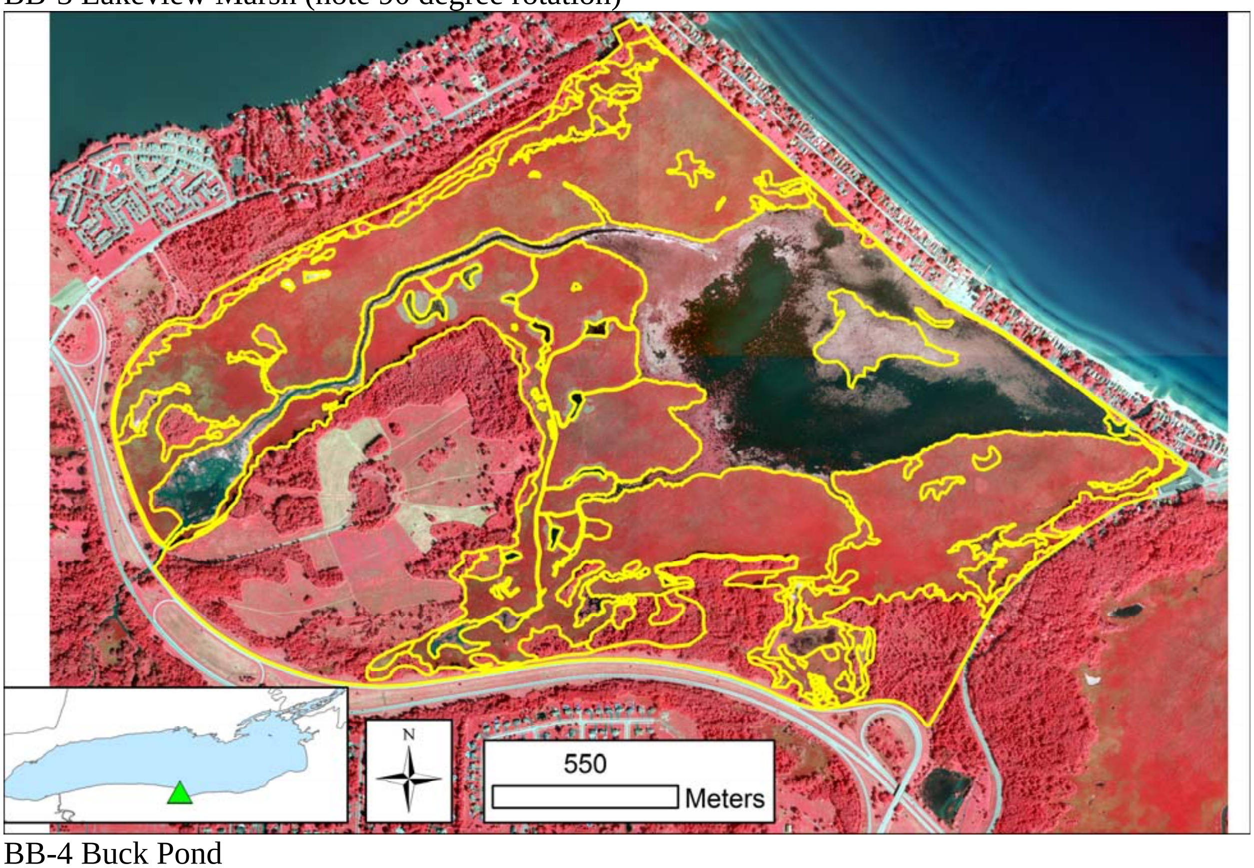
BB-1 Maxwell Bay Wetland



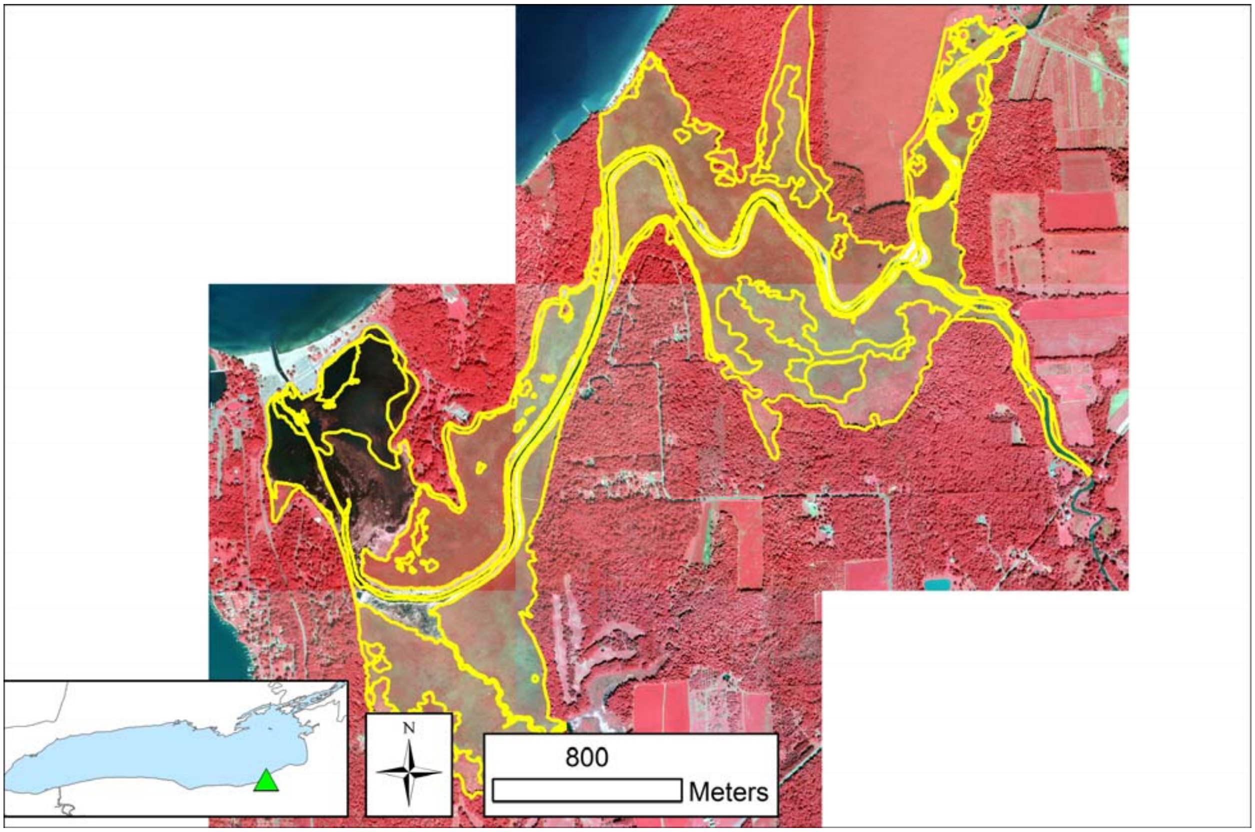
BB-2 North Pond Area Wetland



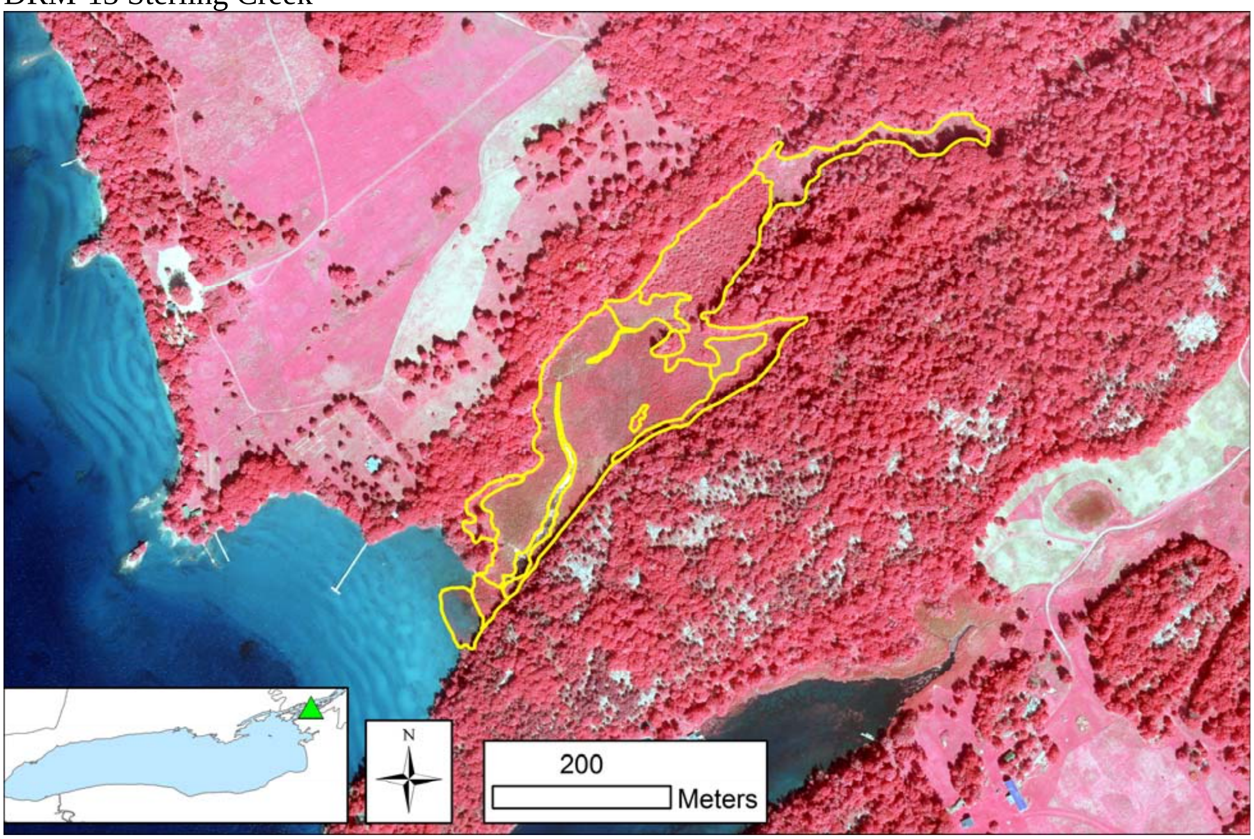
BB-3 Lakeview Marsh (note 90 degree rotation)



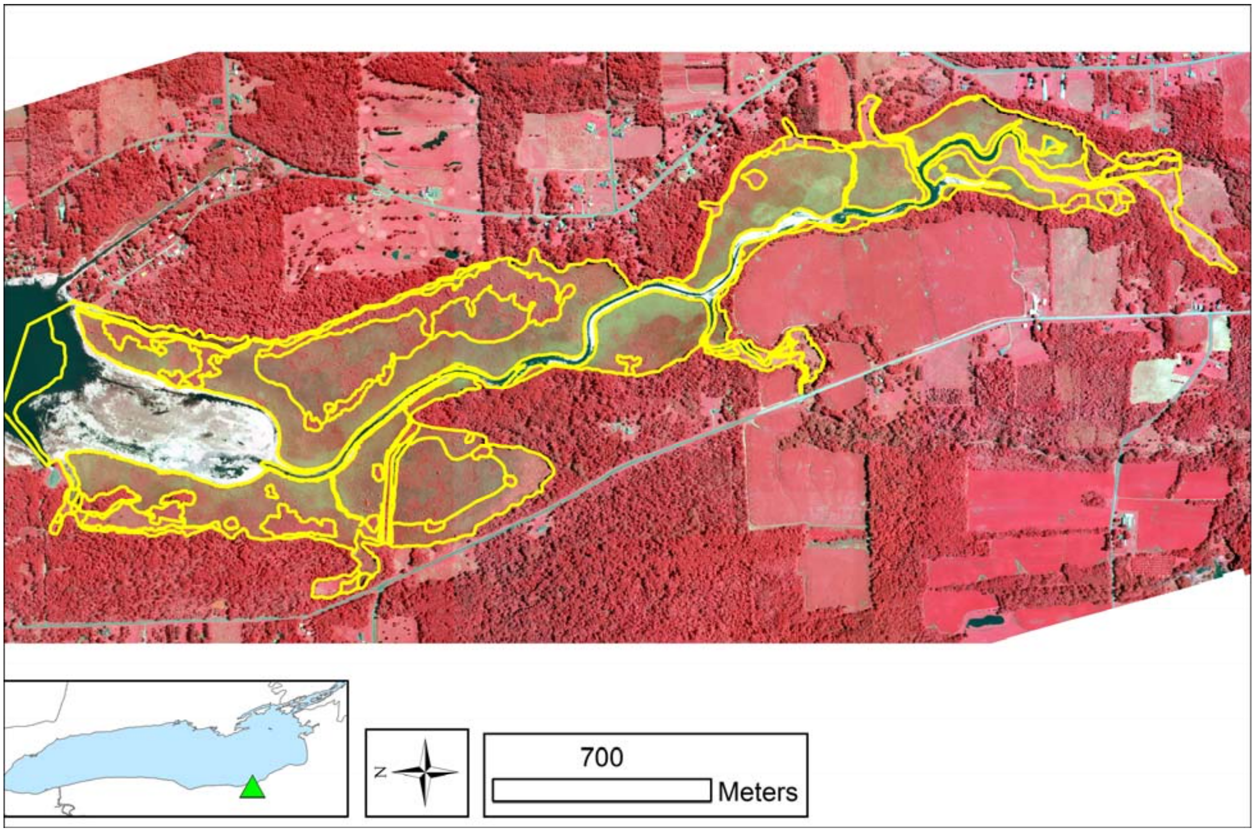
BB-4 Buck Pond



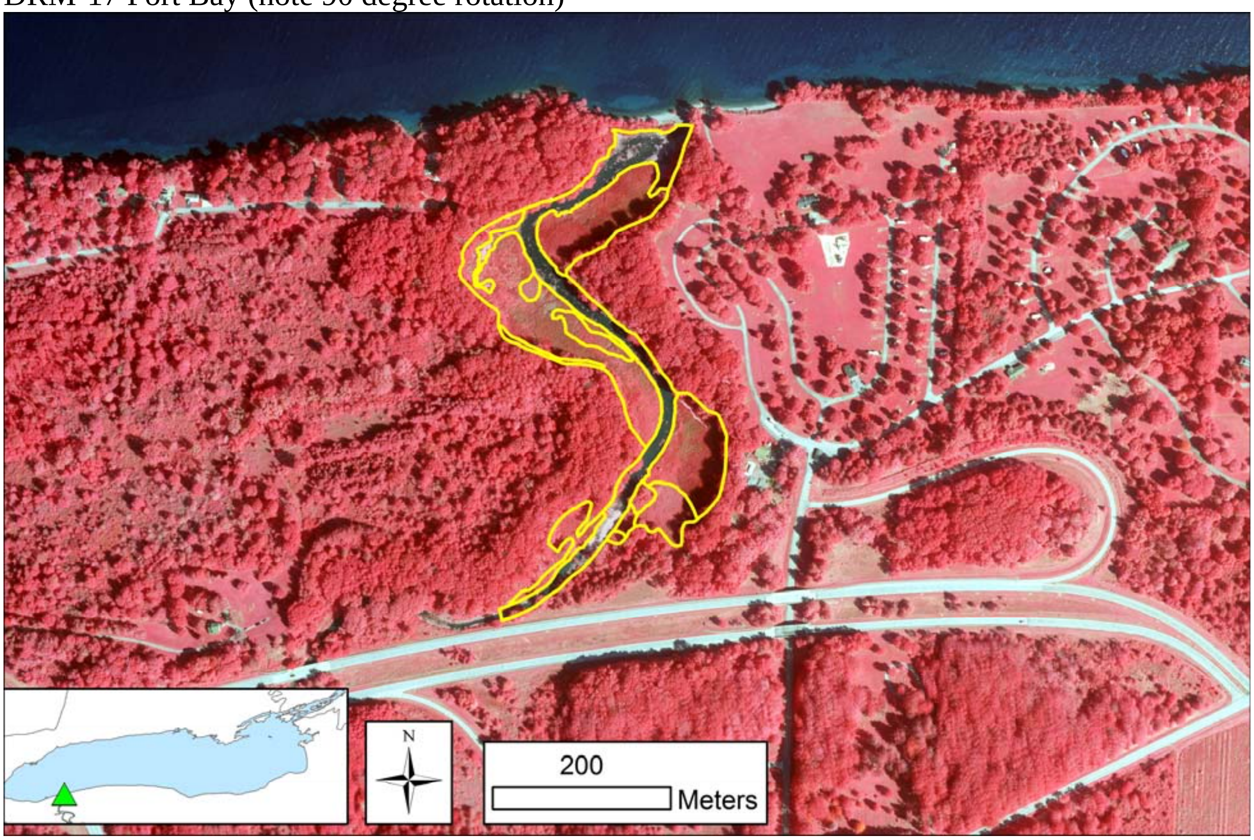
DRM-13 Sterling Creek



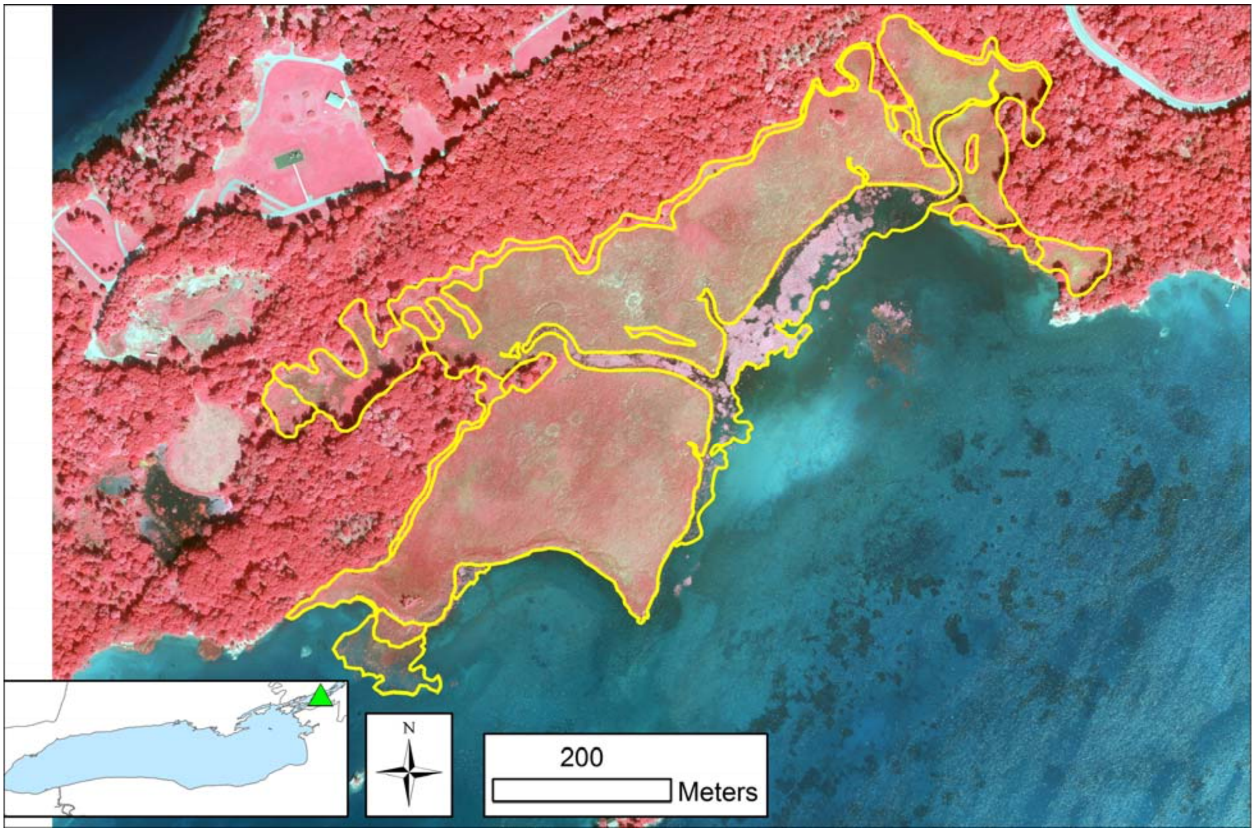
DRM-16 North Buck Bay



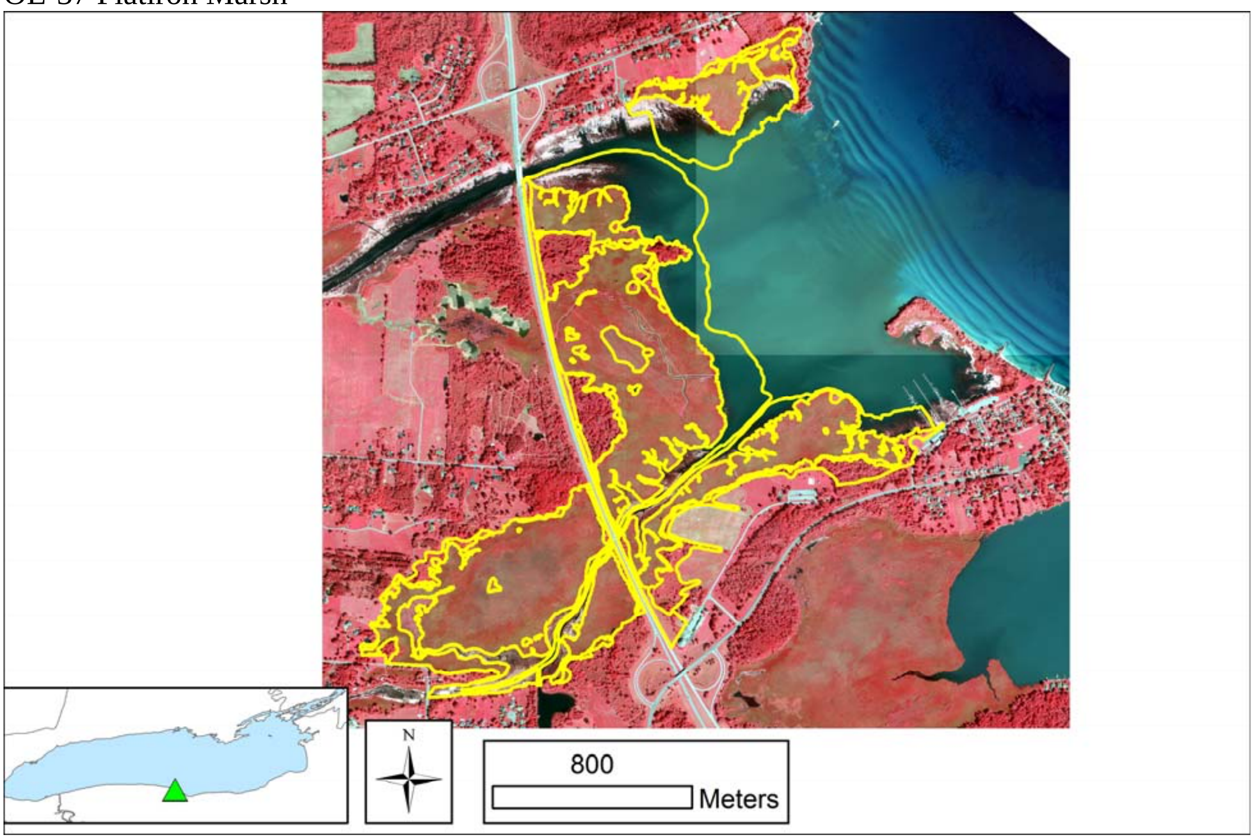
DRM-17 Port Bay (note 90 degree rotation)



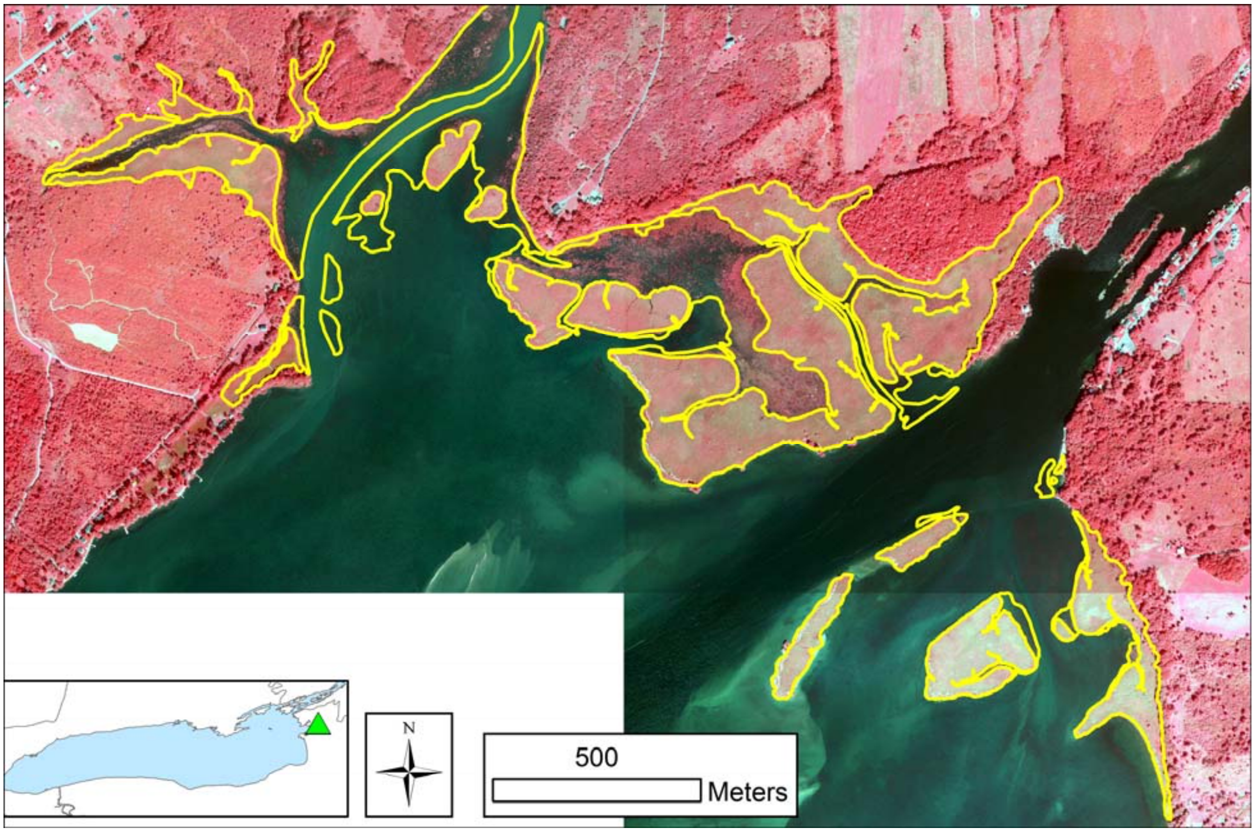
DRM-20 Fourmile Creek



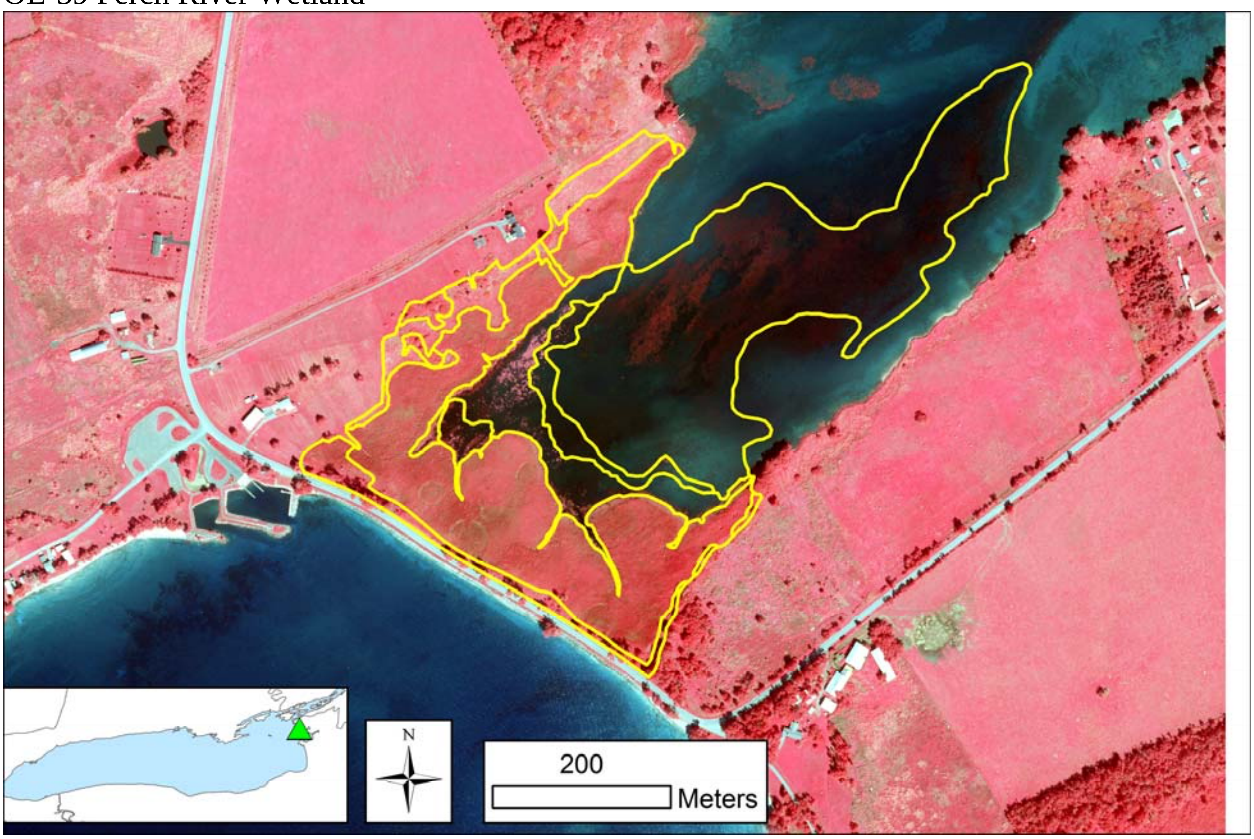
OE-37 Flatiron Marsh



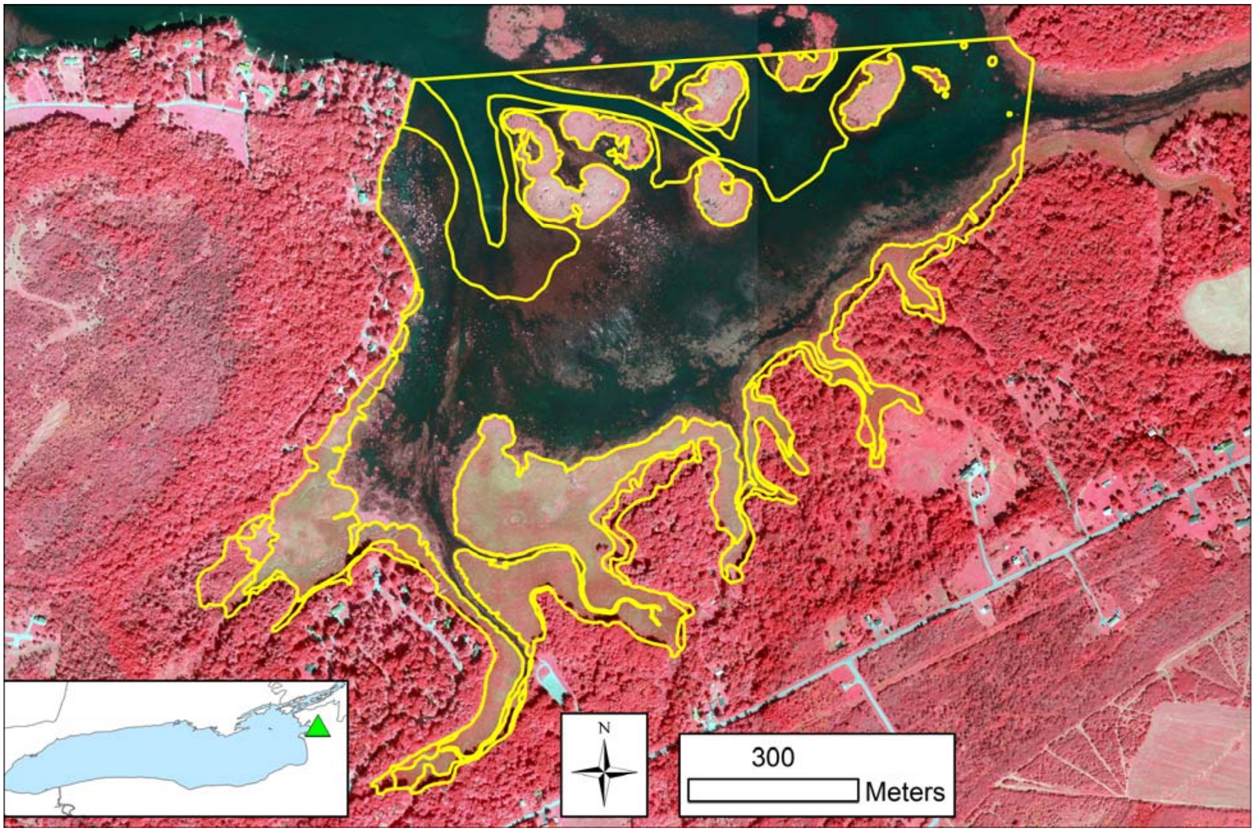
OE-38 Braddock Bay



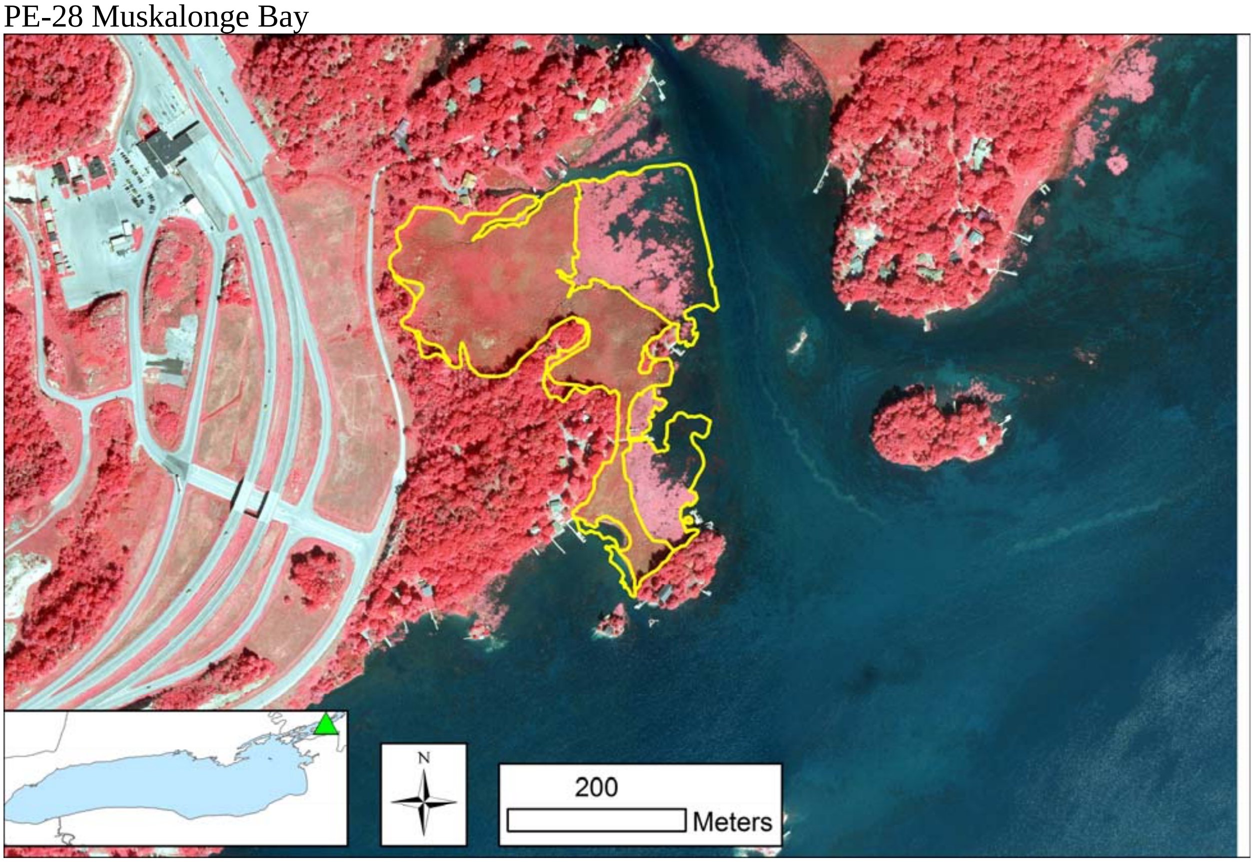
OE-39 Perch River Wetland



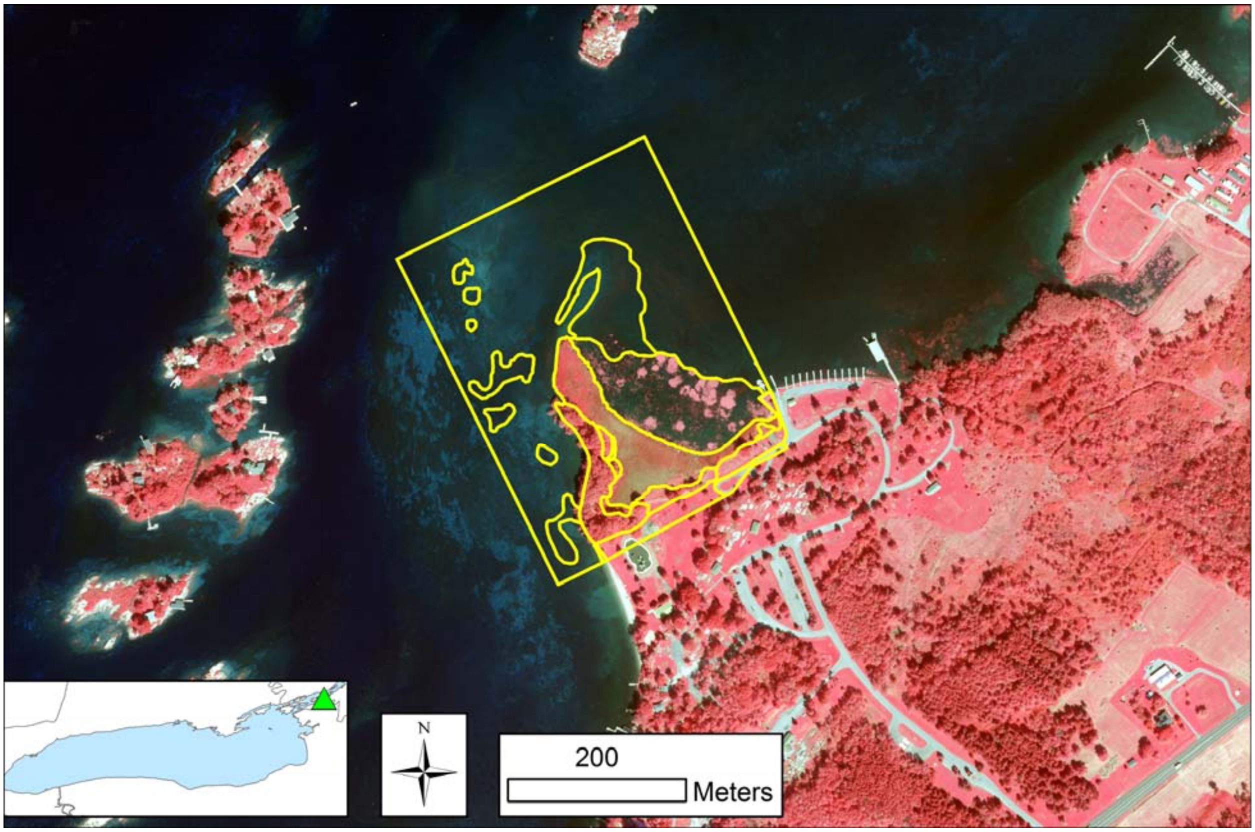
OE-40 Isthmus Marsh

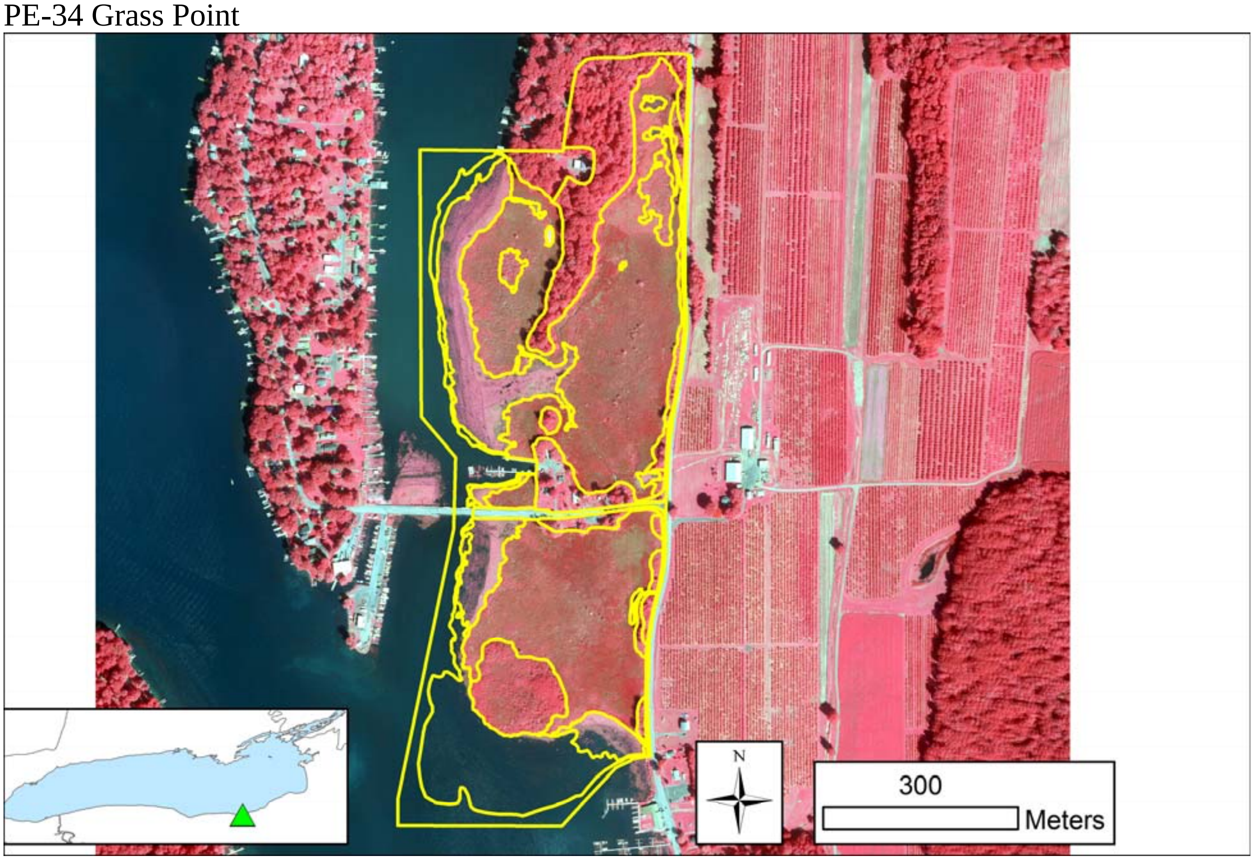


PE-28 Muskalonge Bay



PE-30 Rift Area Wetland



PE-34 Grass Point


PE-36 Sodus Bay

Appendix 4. Classification Crosswalk

Table A-1. The wetland vegetation mapping classification system used by Wilcox et al. (2005) and included in the GIS attribute table for ease of cross-reference. ELC_code is Ecological Land Classification (Lee *et al.* 1998).

ELC_code	Description
BBO	Beach / Bar - Open
CU	Cultural
CUT	Cultural - Thicket
FOD	Forest - Deciduous
MA	Marsh
MAM	Marsh - Meadow
MAS	Marsh - Shallow Marsh
OAO	Open Water - Open Aquatic
SA	Shallow Water
SAM	Shallow Water - Mixed Shallow Aquatic
SAS	Shallow Water - Submerged Shallow Aquatic
SWD	Swamp - Deciduous
SWT	Swamp - Thicket

Table A-2. New York Natural Heritage Program natural community types used in the GIS wetland type delineations and the codes used in the attribute tables. Note that more than one ELC code was applied for some of the community types. Also note that the modifier (NHP_mod) of C (high coverage of cattail) and NC (low coverage of cattail) was applied in many of the categories but was most important in distinguishing different types of shallow emergent marsh, as noted. Detailed information about some of the natural communities is available by following the links provided. The full classification is available here (http://www.dec.ny.gov/animals/29384.html).

NYNHP Community	NHP_comm	NHP_mod	ELC_code
Sand Beach	beach		BBO
Cropland/Field Crops	C/FC		CU
Common Reed Marsh	CRM		MAS
Deep Emergent Marsh (more info)	DEM		MAS
	DEM		SAM
Floodplain Forest (more info**)**	FF		SWD
	FF		SWT
Great Lakes Aquatic Bed	GLAB		MAS
	GLAB		SAM
	GLAB		SAS
Mudflat	M		MA
Medium Fen (more info**)**	MF		MAM
Mowed Lawn/Roadside	ML/R		CU
Open Water	OW		OAO
	OW		SA
Residential	RESID		CU

Red Maple - Hardwood Swamp (more info)	RM-HS		SWD
Road	road		CU
Shallow Emergent Marsh (more info)	SEM	C	MAS
	SEM	NC	MAM
Sedge Meadow (more info)	SM		MAM
Successional Northern Hardwood Forest	SNHF		CUT
	SNHF		FOD
Successional Old Field	SOF		CU
	SOF		CUT
Shrub Swamp (more info)	SS		SWT
Upland Forest*	UF		FOD

* Not classified to a natural community type – outside the scope of this project.

The New York Natural Heritage Program

The New York Natural Heritage Program (www.nynhp.org) is a program of the State University of New York College of Environmental Science and Forestry that is administered through a partnership between SUNY ESF and the NYS Department of Environmental Conservation. We are a sponsored program within the Research Foundation for State University of New York.

The mission of the New York Natural Heritage Program is to facilitate conservation of rare animals, rare plants, and significant New York ecosystems. We accomplish this mission by combining thorough field inventories, scientific analyses, expert interpretation, and a comprehensive database on New York's distinctive biodiversity to deliver high-quality information for natural resource planning, protection, and management.

Established in 1985, our program is staffed by 25 scientists and specialists with expertise in ecology, zoology, botany, information technology, and geographic information systems. Collectively, the scientists in our program have over 300 years of experience finding, documenting, monitoring, and providing recommendations for the protection of some of the most critical components of biodiversity in New York State. With funding from a number of state and federal agencies and private organizations, we work collaboratively with partners inside and outside New York to support stewardship of New York's rare animals, rare plants, and significant natural communities, and to reduce the threat of invasive species to native ecosystems.

In addition to tracking recorded locations, NY Natural Heritage has developed models of the areas around these locations important for conserving biodiversity, and models of the distribution of suitable habitat for rare species across New York State.

NY Natural Heritage has developed two notable online resources: Conservation Guides include the biology, identification, habitat, and management of many of New York's rare species and natural community types; and NY Nature Explorer lists species and communities in a specified area of interest.

NY Natural Heritage also houses *i*MapInvasives, an online tool for invasive species reporting and data management.

In 1990, NY Natural Heritage published *Ecological Communities of New York State*, an all-inclusive classification of natural and human-influenced communities. From 40,000-acre beech-maple mesic forests to 40-acre maritime beech forests, sea-level salt marshes to alpine meadows, our classification quickly became the primary source for natural community classification in New York and a fundamental reference for natural community classifications in the northeastern United States and southeastern Canada. This classification, which has been continually updated as we gather new field data, has also been incorporated into the National Vegetation Classification was developed and refined by NatureServe, The Nature Conservancy, and Natural Heritage Programs throughout the United States (including New York).

NY Natural Heritage is an active participant in NatureServe (www.natureserve.org), the international network of biodiversity data centers. NatureServe's network of independent data centers collect and analyze data about the plants, animals, and ecological communities of the Western Hemisphere. The programs in the NatureServe Network, known as natural heritage programs or conservation data centers, operate throughout all of the United States and Canada, and in many countries and territories of Latin America. Network programs work with NatureServe to develop biodiversity data, maintain compatible standards for data management, and provide information about rare species and natural communities that is consistent across many geographic scales.

New York Natural Heritage Program
A Partnership between the
NYS Department of Environmental Conservation and the
SUNY College of Environmental Science and Forestry
625 Broadway, 5th Floor, Albany, NY 12233-4757
www.nynhp.org