# Great Lakes Coastal Wetland Indicators and Metrics:

# A Summary of Work in Canadian Wetlands

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**ABSTRACT**

The overall goal of the Great Lakes Coastal Wetlands Consortium (GLCWC) is to develop a basin wide monitoring program for Great Lakes coastal wetlands that can report on wetland health. This initiative has evolved from the State of the Lakes Ecosystem Conferences (SOLEC) and the recognized need for binational reporting on Great Lakes ecosystem health. The GLCWC study concept is to further build on work that has been completed as part of SOLEC and previous development of coastal wetland indicators. An essential component of indicator development is the use of indices of biotic integrity (IBI) for the biological communities. Biological communities specifically identified for monitoring are plant, invertebrate, fish, bird and amphibian.

The purpose of this project was to evaluate suitable coastal wetland health indicators and sampling methodologies in Lake Ontario and the St. Lawrence River through a binational effort. This project is one of several Year 1 pilot projects occurring around the Great Lakes. All investigators involved in Year 1 pilot projects agreed to collect the same flora, fauna, physical, and landscape level data using standardized protocols. This report summarizes and discusses the results from the Canadian wetlands only.

Over 35 days, from April to August 2002, field data were collected on water chemistry, site disturbance attributes, invertebrates, vegetation, fish, birds and amphibians in 12 Canadian coastal wetlands in Lake Ontario and the upper St. Lawrence River. Site disturbance rankings were assigned to each site, based on collected abiotic wetland data. Variables from biotic communities (metrics) were assessed along a gradient of site disturbances to determine if increases in disturbance affected the metric. This study tested the response of 32 metrics across vegetation, fish, bird, and amphibian communities to increases in site disturbance. Five metrics were found to be very sensitive and five moderately sensitive metrics in the fish and vegetation communities. Bird and amphibian community metrics did not demonstrate a sensitivity to increasing site disturbance. However, these evaluations are preliminary and the sample size small. A more robust analysis of biological community metrics is planned using an integrated Great Lakes coastal wetland database. The integrated database will include data collected from all Year 1 pilot projects and previously collected data.

In addition, this study reports on the cost of data collection, measurability of the biological indicators, applicability of the field methodology across the Great Lakes basin and within various geomorphic wetland types, and the availability of complementary data.

## ACKNOWLEDGEMENTS

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# 1 INTRODUCTION

The overall goal of the Great Lakes Coastal Wetlands Consortium (GLCWC) is to develop a basin wide monitoring program for Great Lakes coastal wetlands that can report on wetland health. This initiative has evolved from the State of the Lakes Ecosystem Conferences (SOLEC) and the recognized need for binational reporting on Great Lakes ecosystem health. The GLCWC study concept is to build on work that has been completed as part of SOLEC and previous development of coastal wetland indicators. A key component of indicator development is the use of indices of biotic integrity (IBI) for the biological communities. Biological communities specifically identified for monitoring are plant, invertebrate, fish, bird and amphibian. The scientific understanding of these biological communities and the status of IBI development for each vary considerably (Adamus et al. 2001).

Within the flora and fauna indicators identified by the GLCWC, significant research has occurred in an effort to better understand interactions and relationships among abiotic, biotic variables and human disturbance within wetlands of the Great Lakes region (Keddy 1999, Keddy and Reznicek 1986, Keough et al. 1999, Lougheed et al. 2001). More recently, research has focused on developing indicators and metrics of specific biota based on identified responses of the biota to environmental change. Invertebrate (Burton et al. 1999, Lougheed and Chow-Fraser 2001), fish (Randall et al. 1996, Minns et al. 1994) and plant community (Mack et al. 2000) indicators and metrics have received the most attention on wetlands associated with the Great Lakes basin. However, much of this work has been completed on inland wetlands or coastal wetlands within a limited geographic area and of a specific geomorphic type.

Development and implementation of an integrated binational Great Lakes coastal wetland monitoring program requires testing and adaptation of the indicators and metrics to address the environmental variability and wetland diversity associated with the Great Lakes ecosystem. Refinement of Great Lakes wetland indicators also requires coordination and cooperation not only across various environmental disciplines, but also across many political boundaries. The feasibility of implementation and resource requirements at a Great Lakes level also requires significant consideration and evaluation.

## 1.0 Project Description

This project is part of a three year GLCWC initiative to develop a monitoring plan and data support system for Great Lakes coastal wetlands. This project is one of several Year 1 pilot projects occurring around the Great Lakes. The objectives of Year 1 projects were to evaluate coastal wetland indicators and test incorporation of these indicators within a long-term scientific monitoring strategy. Year 1 funding was awarded to several project teams who undertook coordinated projects on subsets of wetland types occurring in various regions of the Great Lakes. All investigators involved in Year 1 pilot projects agreed to collect the same flora, fauna, physical, and landscape level data using standardized protocols. Specific measurements included various aspects of community and population structures of plants, invertebrates, fish, amphibians, and birds. As well, physical characteristics such as water-level fluctuations and wetland water chemistry was characterized. Landscape measures such as aerial extent of wetland by type, habitat adjacent to wetland, land-use classes adjacent to wetland, land-use classes in watershed, extent of upstream channelization, proximity to navigable channels, and proximity to recreational boating activity were also collected.

Year 1 invertebrate, fish and plant databases were compiled by Don Uzarski, Michigan research team, and combined with existing databases for the purposes of metric validation and indicator development through statistical analyses. Steve Timmermans, Bird Studies Canada, is completing similar analyses on compiled and existing bird and amphibian data.

All investigators were required to address seven criteria as identified by the GLCWC. The criteria and expected measurements are described below. This report addresses the first six criteria from the perspective of sampling on Lake Ontario and St. Lawrence River coastal wetlands only. Full consideration of the last four criteria will include results from Michigan research team and Bird Studies

Canada Year 1 project reports. These collaborating investigators are completing a more extensive statistical analyses of the binational data sets.

### 1.0.1 Cost

Total sampling time and equipment costs were tracked by community indicator and parameter measurements. These costs are summarized within each section of the report. Note that several pieces of equipment (i.e., boat, canoe, motors, batteries) were shared among sampling tasks. Symbols in the summary table indicate the tasks in which the equipment was shared.

In addition to the time required to conduct the surveys, staff time was required for selection of appropriate locations for sampling, logistics planning and landowner contacts.

### 1.0.2 Travel and Accommodation

Other costs, such as travel and accommodation, were tracked but are difficult to assess on a per wetland basis. Therefore, a chronological summary of field activities has been summarized in the General Summary (Section 9.2.3) of this report. The table includes the dates and locations of all field tasks as well as details regarding the accommodations sought. Because crew members specialized in individual field tasks (i.e., water chemistry, vegetation surveys), it can be assumed that individual tasks completed at different wetlands required travel. Travel distances can be estimated from Figure 1-1. With this summary, interested parties can formulate travel, personnel, and accommodation cost estimates for one or several of monitoring activities.

### 1.0.3 Measurability

Recommendations regarding the level of expertise and training required to implement each of the methodologies have been reported. Comments and recommendations regarding the methodologies employed to measure the wetland communities are also provided within the project report.

### 1.0.4 Basin-wide Applicability and Sampling by Wetland Type

Distribution of the twelve study sites across the Canadian shoreline of Lake Ontario and St. Lawrence River has allowed reporting of the applicability of the sampling methodologies within the Lake Ontario basin. As well, it allows the applicability of the various sampling methodologies within open bay, protected bay and barrier beach wetland types.

Evaluating the Great Lakes basin-wide applicability of various wetland community metrics is being completed by the Michigan research team and Bird Studies Canada by incorporating data collected on Lake Ontario and St. Lawrence River with data collected on coastal wetlands associated with other Great Lakes basins and existing databases.

### 1.0.5 Availability of Complementary Existing Research or Data

CWS-Ontario and OMNR are also involved in an International Joint Commission, Lake Ontario/St. Lawrence River water regulation review study. Where applicable, data being collected on common coastal wetland study sites was utilized for the purposes of this project.

### 1.0.6 Indicator Sensitivity to Wetland Condition Changes

Data were collected on coastal wetland plant, invertebrate, fish, bird and amphibian communities. The level of degradation was also quantified for each coastal wetland study site. Dose-response relationships and preliminary results of biological indicator sensitivity to wetland condition changes are reported. All project databases have been provided to Don Uzarski and Steve Timmermans and are part of the integrated Great Lakes database indicator sensitivity analyses as proposed by the Michigan research team and Bird Studies Canada.

#### 1.0.7 Ability to Set Endpoint or Attainment Levels

Collection of anthropogenic disturbance variables at all study sites and compilation of the databases by other investigators allowed ranking of human disturbance levels and identification of minimally impacted or reference wetland sites. Metric values obtained within these sites can be used to establish appropriate attainment levels and identify if there is a requirement to set different endpoints within different basins and/or wetland types.

#### 1.0.8 Statistical Approach

Further metric development and testing for plant, invertebrate and fish communities requires additional Great Lakes based data. The integration of these data is being undertaken by the Michigan research team using a large database that includes data collected prior to the Consortium initiative and several Year 1 projects. Metric development and testing for bird and amphibians is being undertaken by Bird Studies Canada using data collected on this and other investigator projects and an existing multi-year Great Lakes database.

In addition to reporting on the first six criteria above, this report evaluates the methodology and the suitability and applicability of the data for use as estimates of site disturbance and biotic metrics. The rationalization for specific statistical testing is explained in the data analysis part of each section. Summary statistics were complied from data collected on twelve Lake Ontario and St. Lawrence River study sites and included within the project report.

## 1.1 Site Selection

Twelve coastal wetland sites were chosen (Figure 1-1) on the Canadian shore of Lake Ontario and the St. Lawrence River. The sites were chosen according to three criteria.

#### 1.1.1 Location

Sites were spread across the Canadian shore of Lake Ontario and the upper St. Lawrence River. Coastal wetland study sites being used for other research were also considered in order to utilize other research resources and data.

#### 1.1.2 Disturbance

There were few data regarding the level of human disturbance for the wetlands. Therefore, sites were chosen that were presumed to show a gradient of human disturbance based on the surrounding land use, such as urban development and agriculture.

#### 1.1.3 Geomorphic Type

The twelve sites were represented by three geomorphic wetland types, open bay, protected bay and barrier beach. Four wetlands of each geomorphic type were chosen (Table 1-1)

Table 1-1. Coastal wetland sites used in this study with geomorphic type, site name acronym and general location.

| Study Site | Site Name Acronym | Wetland Type | Location |
|---|---|---|---|
| Hill Island East | HIE | Protected Bay | St. Lawrence River |
| Bayfield Bay | BB | Protected Bay | St. Lawrence River |
| Parrott's Bay | PB | Protected Bay | Lake Ontario |
| Presqu'ile Bay | PRB | Protected Bay | Lake Ontario |
| Button Bay | BUB | Open Bay | St. Lawrence River |
| Hay Bay South | HBS | Open Bay | Lake Ontario |
| South Bay | SB | Open Bay | Lake Ontario |
| Robinson Cove | RC | Open Bay | Lake Ontario |
| Port Britain | POB | Barrier Beach | Lake Ontario |
| Lynde Creek | LC | Barrier Beach | Lake Ontario |
| Huyck's Bay | HB | Barrier Beach | Lake Ontario |
| Frenchman's Bay | FB | Barrier Beach | Lake Ontario |

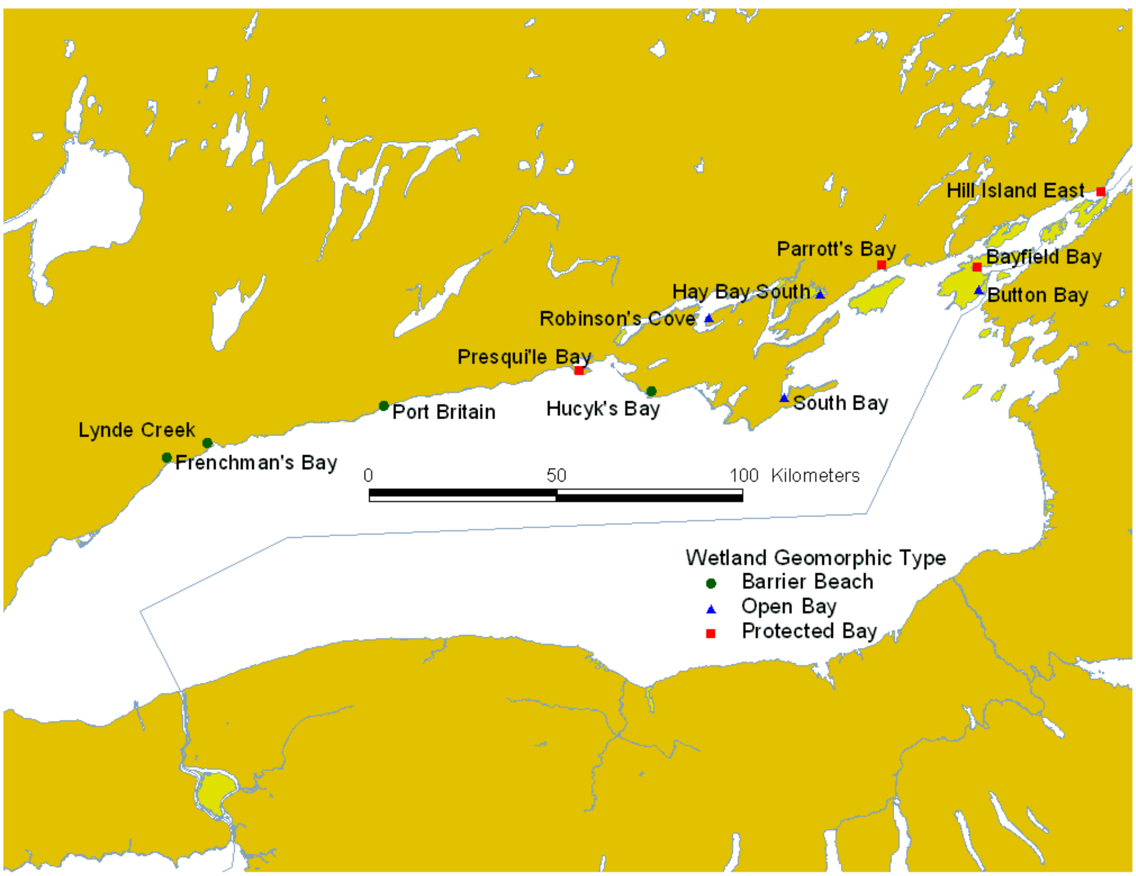


Figure 1-1. The location and geomorphic type of the twelve study wetlands in Lake Ontario and the upper St. Lawrence River.

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# 2 WETLAND ATTRIBUTES AND SURROUNDING LAND USE

## 2.0 Methodology

The purpose of collecting wetland attribute and surrounding land use data was to determine the level of disturbance within the wetland (See Section 4.0). To quantify the disturbance experienced by the 12 coastal wetlands, surveyors estimated and recorded various wetland attributes while standing in a central location of each wetland. The actual location of the survey was done at the discretion of the surveyor and generally occurred at a location in the wetland that afforded a reasonable vantage point to make the necessary assessments. The following site attributes were assessed.

### 2.0.1 General Information

Bay Name: the name of the bay according to the Environmental Sensitivity Atlas for the Lake Ontario's Canadian Shoreline and the Environmental Sensitivity Atlas for the St Lawrence River Shorelines. Descriptors were added to the name of the bay as required. For example, part of the southern portion of a large bay, Hay Bay, was used in this study. The wetland was referred to as Hay Bay South.

Wetland Location in Bay: if the wetland was part of a large bay, the location of the actual study was described here.

Wetland Classification: the wetland geomorphic type barrier beach, open bay or protected bay.

Wetland Plant Zones: a description of the wetland that included the presence of meadow marsh, emergent vegetation, and/or submerged vegetation.

Latitude/Longitude: the geographic location of the wetland.
Crew: the field staff members that were conducting GLCWC studies on the day of the survey.

Weather: a description of cloud cover, temperature and wind.

Date visited: the date that GLCWC work was completed at the wetland.

Time reached/Time leaving site: the time of day that the crew arrived and left the wetland.

### 2.0.2 Field Level Site Attributes

Within the field, a series of site attributes were recorded within and immediately adjacent to the wetland. Qualitative (Table 2-1), quantitative and descriptive data were collected as described below.

Table 2-1. Qualitative presence/absence data collected to describe anthropogenic alterations in the wetland.

| Type of Alteration | Feature |
|---|---|
| Hydrologic | Dewatering in or near the wetland |
| | Point source inlet |
| | Installed outlet or weir |
| | Ditch inlet |
| | Tile inlet |
| | Unnatural connection to other waters (i.e. agricultural dugout) |
| | Presence of dams or waterfalls |
| Landscape - vegetation | Tree removal |
| | Tree plantations |
| | Mowing or grazing |

| | |
|---|---|
| | Shrub removal<br>Coarse woody debris removal<br>Emergent vegetation removal |
| Landscape – substrate/soil | Presence of livestock hooves<br>Presence of vehicle use<br>Presence of grading/bulldozing<br>Presence of filling<br>Presence of dredging<br>Sediment input from inflow or erosion<br>Areas of land in high public use |

Below is a list of quantitative disturbance attributes that were collected to describe anthropogenic alterations in and near the wetland.

Proximity to navigable channels (m)
Proximity to recreational boating activity (m)
Proximity to roadways that receive daily traffic (m)
Number of dwellings
Number of industries
Number of ‘other’ buildings
Number of boat docks
Number of paved parking lots
Number of dirt parking lots
Number of boat launches
Percent hardened shoreline
Percent eroding shoreline
Percent of shoreline containing a dirt road
Percent of shoreline containing a visible paved road

The following descriptive data were also collected at each site:
Habitat types adjacent to the wetland: The amount (percent) of each habitat (i.e., deciduous wood lot, sand dune) that was present adjacent to the wetland as observed from the wetland.

Land use classes adjacent to the wetland: The amount (percent) of each land use (i.e., residential, agricultural) that was present adjacent to the wetland as observed from the wetland.

There were also notes made on construction sites, obvious sedimentation, highways, levees, berms, and other structures built in or around the wetland. Notes were made to describe if any of the activities or structures appeared to restrict the hydrological connections within or to the wetland.

Finally, a description of the degree and type of direct human activity was taken. This included a description of activities such as use of motorized and non-motorized watercraft, water-skiing, fishing and hunting within the wetland.

### 2.0.3 Surrounding Land Use

The land use within one kilometre of the wetland was classified on current 1:10000 colour infrared photographs. The areas of each land use type were measured using a Tamaya Planix 7 digital planimeter. Land uses were classified as residential, non-residential development, crop and improved, pasture, idle field, woodlot and forest, wetland, and beach and dunes.

### 2.0.4 Water Levels

Lake Ontario water levels are variable throughout the year exhibiting a cyclical pattern. Within the annual cycles, the range of water levels is also variable. Monthly water levels during sampling will be investigated to determine the effect of variable water levels on the methodology implementation and possible effects on biotic communities during sampling.

## 2.1 Results

Wetland site attribute data have been submitted to the Michigan research team and Bird Studies Canada for inclusion in a Great Lakes level analysis. The data will be used in specifying the overall disturbance experienced by the wetlands. Then comparisons with biotic community attributes will determine relationships between the level of disturbance and biotic community attributes.

The site attribute data collected for the 12 coastal wetlands are not appropriate for statistical analyses. Summary tables have been tabulated below for qualitative site attributes and surrounding land use classifications. Quantitative land use, general, and descriptive data are too large, even when summarized, and therefore have been included in electronic format only.

### 2.1.1 Hydrologic/Landscape Alterations

The amount of hydrologic and landscape alterations (Table 2-2) varied widely among sites (range=1-13). At all sites, at least one alteration was observed. The fewest total alterations occurred at Hill Island East and Presqu'ile Bay. The most alterations were present at Lynde Creek and Frenchman's Bay.

Table 2-2. The number of hydrologic and landscape alterations observed at the 12 Lake Ontario and St. Lawrence River coastal wetland sites.

| Site | Wetland Type | Hydrologic Alteration | Landscape Alteration | | Total |
|---|---|---|---|---|---|
| | | | Vegetation | Soil/Substrate | |
| Hill Island East | Protected Bay | 0 | 0 | 1 | 1 |
| Bayfield Bay | Protected Bay | 3 | 1 | 4 | 8 |
| Parrott's Bay | Protected Bay | 2 | 0 | 2 | 4 |
| Presqu'ile Bay | Protected Bay | 0 | 0 | 1 | 1 |
| Button Bay | Open Bay | 2 | 1 | 1 | 4 |
| Hay Bay South | Open Bay | 0 | 2 | 0 | 2 |
| South Bay | Open Bay | 1 | 5 | 3 | 9 |
| Robinson's Cove | Open Bay | 2 | 0 | 2 | 4 |
| Port Britain | Barrier Beach | 0 | 3 | 4 | 7 |
| Lynde Creek | Barrier Beach | 3 | 3 | 6 | 12 |
| Huyck's Bay | Barrier Beach | 0 | 0 | 3 | 3 |
| Frenchman's Bay | Barrier Beach | 3 | 4 | 6 | 13 |

### 2.1.2 Quantified Immediate Disturbances

Only some of the qualitative disturbance attributes were variable among wetlands. Meaningful summaries of these data are too large to include in this report. The raw data have been included in electronic format with this report. The suitability of these data for describing site disturbance is addressed in section 4.0.3 of this report.

### 2.1.3 Surrounding Land Use

The land uses surrounding the wetlands varied substantially among sites (Table 2-3). Hill Island East and Presqu'ile Bay had the highest amount of natural area 95.5% and 63.4%, respectively. Parrott's Bay had a moderate amount of natural surrounding land use (30.4%), but all other sites showed low proportions of natural land use (<15.5%) with Frenchman's Bay having only 1.2%.

Table 2-3. The proportional area (%) of each land use within one kilometre of the 12 Lake and St. Lawrence River coastal wetland study sites.

| Site | Residential | Non-residential Development | Crop and Improved | Pasture | Idle Field | Woodlot and Forest | Wetland | Beach and Dunes |
|---|---|---|---|---|---|---|---|---|
| | Non-natural Area | | | | | Natural Area | | |
| Hill Island East | 4.6 | 0.0 | 0.0 | 0.0 | 0.0 | 94.0 | 1.5 | 0.0 |
| Bayfield Bay | 2.9 | 0.0 | 52.3 | 35.8 | 3.9 | 5.1 | 0.0 | 0.0 |
| Parrott's Bay | 6.8 | 0.6 | 12.5 | 9.1 | 40.6 | 30.2 | 0.2 | 0.0 |
| Presqu'ile Bay | 17.2 | 3.0 | 2.5 | 0.9 | 13.1 | 49.5 | 6.8 | 7.1 |
| Button Bay | 3.9 | 1.2 | 71.6 | 7.6 | 7.8 | 8.0 | 0.0 | 0.0 |
| Hay Bay South | 6.5 | 1.5 | 48.6 | 21.1 | 6.8 | 14.4 | 1.1 | 0.0 |
| South Bay | 10.9 | 0.0 | 54.9 | 16.5 | 9.2 | 8.3 | 0.3 | 0.0 |
| Robinson's Cove | 2.9 | 0.0 | 83.2 | 0.0 | 6.3 | 7.6 | 0.0 | 0.0 |
| Port Britain | 8.2 | 0.0 | 59.3 | 1.7 | 20.2 | 9.7 | 0.8 | 0.0 |
| Lynde Creek | 22.3 | 22.8 | 22.8 | 0.0 | 24.6 | 6.5 | 1.0 | 0.0 |
| Huyck's Bay | 4.5 | 0.9 | 82.2 | 2.4 | 3.7 | 4.9 | 1.4 | 0.0 |
| Frenchman's Bay | 68.0 | 16.2 | 1.7 | 0.0 | 12.9 | 1.2 | 0.0 | 0.0 |

### 2.1.4 Water Levels

Lake Ontario water levels during 2002, followed the long term cyclical pattern, but up until the end of August, water levels were above the long term average. Water levels during the field sampling were 10-25 cm above the long-term average (Figure 2-1).

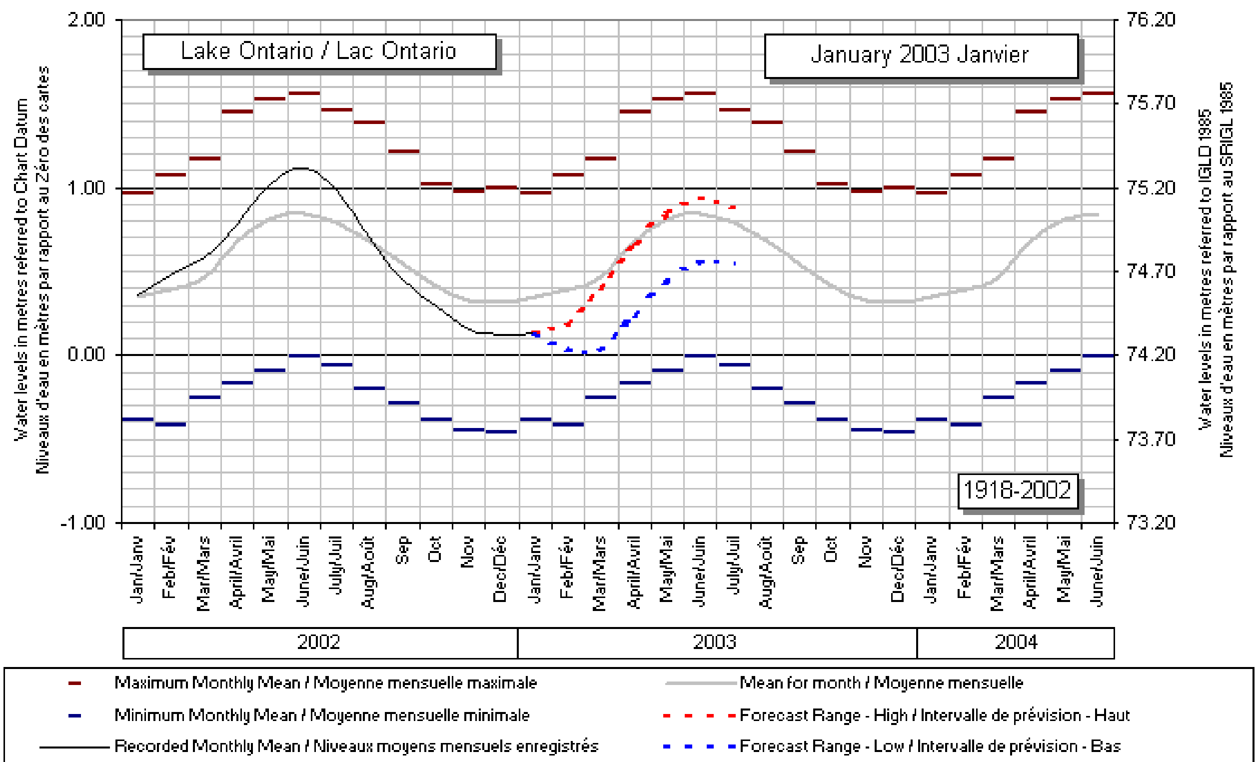



Figure 2-1. Actual and long-term mean water levels in Lake Ontario during 2002. Source: Canadian Department of Fisheries and Oceans.

## 2.2 Discussion

### 2.2.1 Hydrologic/Landscape Alterations

The number of hydrologic and landscape alterations present at a wetland can be used as a measure of disturbance at the site. The fewest total hydrologic and landscape alterations were observed at Hill Island East and Presqu'ile Bay. These two sites are part of National and Provincial parks, respectively, and are thus protected areas. Conversely, the two sites with the most alterations were Lynde Creek and Frenchman's Bay. These two sites are property of local Conservation Authorities but are surrounded by extensive urban development.

The variation in the degree of hydrologic and landscape alterations appears to be linked to the disturbance experienced by the site. This indicates that the degree of hydrologic and landscape alterations is useful in ranking the overall disturbance of the sites.

### 2.2.2 Quantified Immediate Disturbances

These landscape attributes were not analyzed or summarized in this report. However, cursory examination of the data revealed that some of the disturbance attributes are variable and may be used in assigning disturbance ranks for the sites. The applicability of these data for determining site disturbance is addressed in section 4.0.3 of this report.

These data are comprised of mixed variables (distances, count data, and percentage data). Therefore, the utility of these data will likely require separating different types of data and analyzing each subset differently. Wilcox et al. (2002) consider many of the same variables when assigning disturbance ranks to wetlands in their study. However, it appears that these data were presence/absence data and the size or number of each feature was not considered.

### 2.2.3 Surrounding Land Use

Surrounding land use data were similar to the hydrologic/landscape alteration data in that Hill Island East and Presqu'ile Bay, two protected park areas, were surrounded by the most natural area. Parrott's Bay wetland is part of a Conservation Area had a moderate amount of natural surrounding land use. All other sites were not protected natural areas and showed high amounts of non-natural area. In general, non-natural areas were dominated by development in urban areas and by agriculture in more rural areas 1.2%. Although the land use data are dichotomous in terms of natural/non-natural areas, natural land uses appear to be associated with protected, and hence less impacted sites.

Alternative analyses of land use data may reveal a more continuous distribution of proportional natural land use areas. For example, less intense forms of agriculture (idle field and pasture) may be weighted such that a portion of these areas would contribute the overall natural land use surrounding the wetland. Wilcox et al. (2002) used percent forest cover within the watershed as a measure of disturbance in the wetland.

### 2.2.4 Water Levels

The water levels in Lake Ontario during the sampling period were higher than the long-term average. Therefore, open bay and protected bay coastal wetlands experienced higher water levels than normal. The influence of flooding at barrier beach coastal wetlands depends on the status of the barrier. The dynamic nature of many barriers can result in unpredictable intermittent connectivity with the lake. Water levels at these sites cannot be reliably estimated from lake level data and require site specific water level monitoring.

The effect of water levels methodology implementation and possible ramifications on biotic community sampling will be discussed in each section, where applicable.

### 2.3 Cost

#### 2.3.1 Equipment

The following breaks down costs of data collection at the 12 coastal wetlands sampled (Table 2-4). The costs are broken down into consumables (one-time use) and non-consumables (used multiple times). These costs represent those required to initiate the program and conduct sampling for one field season. The values are for all 12 wetlands since cost did not differ among the wetland types.

Table 2-4. Resource costs required to complete the land use and site attribute data collection for 12 wetlands (C=Consumable, N=Non-consumable)

| Item | Cost (CAD) | C/N |
|---|---|---|
| Binoculars[2] | 250 | N |
| Hip/Chest waders[1] | 200 | N |
| GPS Unit[1] | 325 | N |
| Topographical maps/Air photos | 70 | N |
| Clipboard[1] | 5 | N |
| Pens/Pencils[1] | 5 | C |
| Digital planimeter | 1600 | N |
| Air photo overlay transparencies | 12 | C |
| **Total** | **2467** | |

Superscripts indicate equipment shared with other sampling tasks: 1=vegetation, 2= Birds and Amphibians

#### 2.3.2 Personnel

Site attribute data were collected during vegetation sampling. Data sheets took approximately 10 minutes per site to fill out. Land use data were collected after the field season. Delineation, area measurements and spreadsheet compilation of the surrounding land use took approximately six to eight hours per site, depending on wetland size and land use complexity.

### 2.4 Measurability

#### 2.4.1 Expertise and Training

Surveyors should have experience working in Great Lakes coastal wetlands and be able to identify all features required in the data sheet, particularly the less obvious activities (i.e., tile inlet, presence of filling, sediment input). In addition, surveyors should be in good physical shape and be able to traverse difficult wetland terrain.

Skills required for land use data collection basic air photo interpretation ability and planimeter use. Air photo interpretation skills can be limited to an ability to identify broad land use types incorporated in this study. Personnel need not be experience with planimeter use as this skill is easily learned and applied in a very short time.

#### 2.4.2 Recommendations on Methodology

All site attribute variables were easy to collect. Because the data were collected from one central location in the wetland, it was extremely difficult to observe all site attributes from this location. For example, cryptic features such as tree removal, tile inlets, and point source inlets can be easily overlooked. Although the standardized protocol may control for variability in observed cryptic features, focus on conspicuous features or incorporation of more thorough observations from various vantage points should also improve accuracy and repeatability. Nonetheless, the suitability of the data to estimate site disturbance will provide the best insight regarding recommendations on the methodology.

### 2.5 Basin-wide Applicability and Sampling by Wetland Type

The site attribute and land use data collection methodology was easily applied across all study sites and should be applicable for use across the Great Lakes Basin and all wetland geomorphic types. However, intrinsic features of the wetlands such as wetland size and wetland boundary irregularity may influence the repeatability and accuracy of data.

### 2.6 Availability of Complementary Data

Wetland attribute and surrounding and use data are collected by several agencies natural resource agencies. The exact nature and compatibility of these data sets are not clear and requires further investigation. Current air photos or moderate to high resolution classified satellite imagery may be used to estimate general wetland attributes and surrounding land use.

# 3 WATER CHEMISTRY SAMPLING

## 3.0 Methodology

Water samples were collected and analyzed from the 12 study wetlands during July 2002(Table 3-1). For Bayfield Bay, South Bay, Huyck's Bay, Button Bay, Hay Bay and Parrott's Bay additional water samples were collected in June 2002. When present, two vegetation zones within each wetland were sampled, the emergent zone and the wet meadow marsh. Only the following wetlands were sampled in both the meadow and emergent zones: Button Bay, Huyck's Bay, Bayfield Bay and Presqu'ile. Of these four wetlands, only Button Bay and Presqu'ile supported a flooded wet meadow during the main sampling conducted in July 2002. Water chemistry was obtained solely from the emergent zone in the remaining wetlands. Table 3-1 indicates the zones and number of samples collected within each wetland, in either June or July.

Table 3-1. Summary of number of samples collected from each wetland during the two sampling periods.

| Study Site | Wetland Type | Zone | June | July |
|---|---|---|---|---|
| Hill Island | Protected Bay | Emergent | 0 | 3 |
| Bayfield Bay | Protected Bay | Emergent | 3 | 3 |
| | | Meadow Marsh | 3 | 0 |
| Parrott's Bay | Protected Bay | Emergent | 3 | 3 |
| Presqu'ile Bay | Protected Bay | Emergent | 0 | 3 |
| | | Meadow Marsh | 0 | 3 |
| Button Bay | Open Bay | Emergent | 3 | 3 |
| | | Meadow Marsh | 3 | 3 |
| Hay Bay South | Open Bay | Emergent | 3 | 3 |
| South Bay | Open Bay | Emergent | 6 | 3 |
| Robinson Cove | Open Bay | Emergent | 0 | 3 |
| Port Britain | Barrier Beach | Emergent | 0 | 3 |
| Lynde Creek | Barrier Beach | Emergent | 0 | 3 |
| Huyck's Bay | Barrier Beach | Emergent | 3 | 3 |
| | | Meadow Marsh | 3 | 0 |
| Frenchman's Bay | Barrier Beach | Emergent | 0 | 3 |

Three replicate locations were selected within each flooded vegetation zone. These locations were based on the vegetative species dominating the vegetation zone, thus best representing the water chemistry associated with that zone. Sampling locations were approached by walking through the upland and then entering the wetland at appropriate location or by boat with a final approach by wading. Water chemistry measurements and samples were collected within three metres of the vegetation stand. Care was taken to avoid disturbing the sediment while sample collection took place.

A biweekly calibrated Quanta Hydrolab unit was used to measure dissolved oxygen (mg/L), pH, water temperature (°C), conductivity (µS/cm), redox potential (mΩ) and turbidity (NTU). The meter probe was positioned at mid-depth in the water column. A propeller fixed to the unit was turned on to ensure ambient water continually circulated over the sensors. Water depth (m) and Secchi depth (m) measurements were collected at each replicate location using a calibrated Secchi disk. Alkalinity was estimated using a Hach test strip designed to generate an alkalinity estimate within a range of 20 mg/L.

Water samples were collected from the surface using a sterilized 60-mL plastic syringe, triple-rinsed with sample water prior to collecting the sample. Water samples were placed in clean, deionized rinsed, plastic centrifuge tubes prior to analysis. Sample containers used for phosphorus analyses were acid-washed in 20% HCl prior to collection. Chlorophyll *a* samples were collected at two of the water chemistry locations within each vegetation zone of each wetland. Using the same syringe, a sample of 200-500 mL of water was collected and filtered through a 0.45-µm glass fibre filter. These filters were folded in half, wrapped in aluminum foil and stored below 0°C until analysis. All other water chemistry samples were stored in the dark at 4°C until analysis. The storage period for the samples did not exceed 48-hours and generally, the samples were analyzed within 12 hours of collection. No samples were preserved.

Water samples were analyzed for nitrate nitrogen ($NO_3$), nitrite nitrogen ($NO_2$), soluble reactive phosphorus ($PO_4$) and ammonia nitrogen ($NH_4$) using a DR890 colorimeter. The Hach reagents used meet USEPA protocols for the analysis of surface water as they are generated from Standard Methods. A cadmium reduction method was used for the analysis of nitrate nitrogen, salicylate for ammonia, and molybdenum blue for phosphorus.

To meet quality control requirements, ten percent of the samples were collected and analyzed in duplicate. Trip, field, and method blanks were run with each batch of water samples collected from the wetlands. The results from these quality control samples were analyzed to determine the potential for sample contamination and reproducibility of data. Laboratory certified standards were run every two weeks to ensure the field colorimeter was operating accurately.

Detailed information on the location, land use and surrounding vegetation were collected at each replicate location within the vegetation zone. The dominant vegetation was recorded for each sampling location, along with observations of incidental species within three metres of the sampling location. A Magellan GPS 320 global positioning system was used to record each sampling location. General land use characteristics were determined through visual observations from the boat and upland when entering/leaving the site. Additional information was gathered from previously delineated aerial photography.

#### 3.0.1 Data analysis

Data analyses were completed using SAS.Jmp (SAS Institute, 1999). Means and standard deviations were determined for all parameters, separated by the vegetation zone.

Principal component analysis (PCA) was employed to determine those water chemistry parameters that were responsible for structuring the data set. Chlorophyll *a* data were not included in this analysis since only two replicate samples were collected at each location and this would reduce the power associated with the analysis if included. PCA identifies highly correlated parameters that are separated along an axis in multidimensional space. The secondary and tertiary axes are both perpendicular to the first axis in multidimensional space. A correlation matrix was created prior to completing the principal components analysis (PCA) to determine highly correlated variables.

### 3.1 Results

#### 3.1.1 Quality Control

##### *3.1.1.1 Laboratory Precision*

Laboratory precision was measured through duplicate analysis of the standard curves for the three nitrogen and one phosphorus parameter. Certified laboratory standards were diluted with deionized water and analyzed in duplicate. With the exception of phosphorus, the duplicate standards were all within 20% of one another. The problem with phosphorus was later resolved by using distilled water in place of deionized water for the required dilutions.

##### *3.1.1.2 Laboratory Accuracy*

Accuracy in the laboratory was measured through the monthly construction of standard curves for nitrogen and phosphorus parameters. Certified reference standards were used to construct the curves that were analyzed on the colorimeter and actual versus expected concentrations were compared. With the exception of one nitrate measurement and one ammonia measurement (n=36) the recovery of the standard ranged from 80% to 120%, the acceptable limits of the quality assurance program. Difficulties in measuring phosphorus were resolved prior to the initial sampling in July.

##### *3.1.1.3 Potential Contamination*

Blanks were used to capture contamination in the laboratory, field and during transit. The blanks were then analyzed with each set of wetland water samples. The results indicated that with the exception of phosphorus, contamination was not a problem with the sampling technique and methodology. Phosphorus contamination appeared to be an issue early on; however, the problems associated with the control water source were resolved by switching to distilled water for the blanks.

*3.1.1.4 Field Precision*

Field samples were collected in duplicate for a minimum of 10% of the total samples analyzed. The results of this analysis demonstrated that, on most occasions, duplicate samples were within the acceptable 50% difference. However, 14% of the results (7 of the 47) were outside this range and over half of the results were for phosphorus analysis. This indicates that, with the exception of phosphorus, the results are generally reproducible. It is important to note here that the field duplicates were true duplicates (i.e., two separate grabs of water) and not simply split samples. This approach could be responsible for the higher than anticipated variability in the duplicate analysis.

Water Chemistry by Wetland

Water chemistry parameters were summarized by wetland and grouped according to the vegetation zone where they were collected. Mean and standard deviations were used to characterize the results from each wetland, grouping multiple dates or locations within the same community zone (Table A-1; Appendix A).

### 3.1.2 Field Parameters

The water depth of the wetlands ranged from less than 20 cm to over one metre. Secchi depths were similar to water depths due to clear water in the immediate vicinity of the emergent or wet meadow vegetation (Table A-1; Appendix A). Secchi depths were recorded only in more turbid conditions (Hay Bay South, Lynde Creek) or in Parrott's Bay where water depths were close to or greater than one metre. Water temperatures were similar to air temperatures at all sites, with the exception of days when sampling occurred between noon and late afternoon. A large range in dissolved oxygen occurred among the wetlands (Figure 3-1), with the lowest occurring in Huyck's Bay at less than 1 mg/L and the highest at South Bay at 9.90 mg/L. The variability in dissolved oxygen appeared to be loosely related to the time of day during which the sampling took place. Early morning samples at Huyck's Bay were much lower than late afternoon samples at South Bay. The pH was near neutral at all sites (Figure 3-2), as would be expected for wetlands both influenced by Lake Ontario and supported by limestone bedrock. Conductivity was in the 250 to 350 μS/cm range for those wetlands not bounded by roads or urban centres (Figure 3-3). The exceptions to this were Port Britain, Lynde Creek and Frenchman's Bay where conductivity ranged from 400 uS/cm to over 700 uS/cm. The redox potential (Figure 3-4) of the surface water ranged from a low of 220 mΩ at Lynde Creek to a high of 428 mΩ at Hill Island. The redox potential measured at the surface has little meaning since low redox potential only affects the sediment-water interface. Turbidity measurements were generally low at all sites (Figure 3-5), ranging from 0.6 NTU at Presqu'ile Bay to 39 NTU at Hay Bay. Standard deviations associated with turbidity were generally high, indicating the high variability associated with this measurement. The collection of turbidity measurements within the vegetation stands may have generated values that are lower than what is typical of the wetland. This was evident in Frenchman's Bay and Port Britain where low turbidity measurements were obtained (3-10 NTU). The visual observations from the middle of these wetlands indicated poor water clarity that appeared to be high in suspended solids. The narrow range in turbidity among the wetlands suggests that sampling immediately adjacent to the vegetation stand may not be appropriate. Sampling in open water areas may be beneficial in capturing the overall water quality in the wetland.

The alkalinity of the wetlands ranged from 60 mg/L to 220 mg/L with the wetlands falling into the following categories:

0-80 mg/L: South Bay, Robinson Cove

80-160 mg/L: Huyck's Bay, Bayfield Bay, Button Bay, Parrott's Bay, Frenchman's Bay, Presqu'ile Bay (emergent), Hill Island, Port Britain, Hay Bay South

160-240 mg/L: Presqu'ile Bay (Meadow Marsh), Lynde Creek

The majority of the wetlands contained alkalinity values around 100 mg/L.

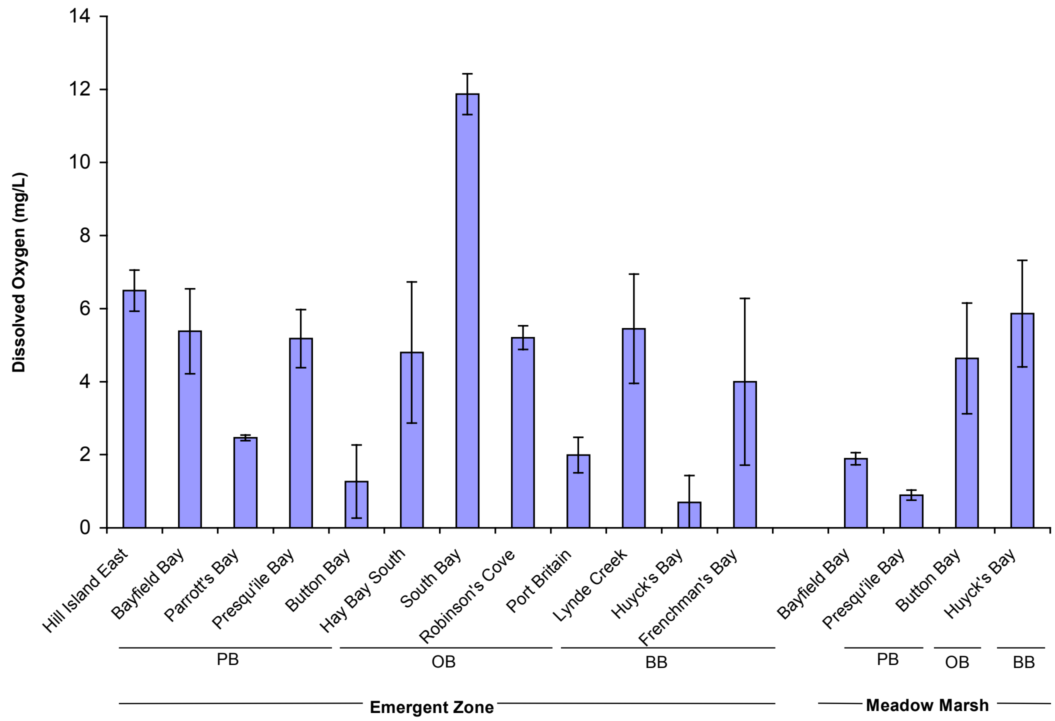



Figure 3-1. Mean concentration of dissolved oxygen in different vegetation zones in twelve Lake Ontario and St. Lawrence River coastal wetlands. Wetlands are grouped in the figure by geomorphic type: PB = protected bay, OB = open bay, BB = barrier beach.

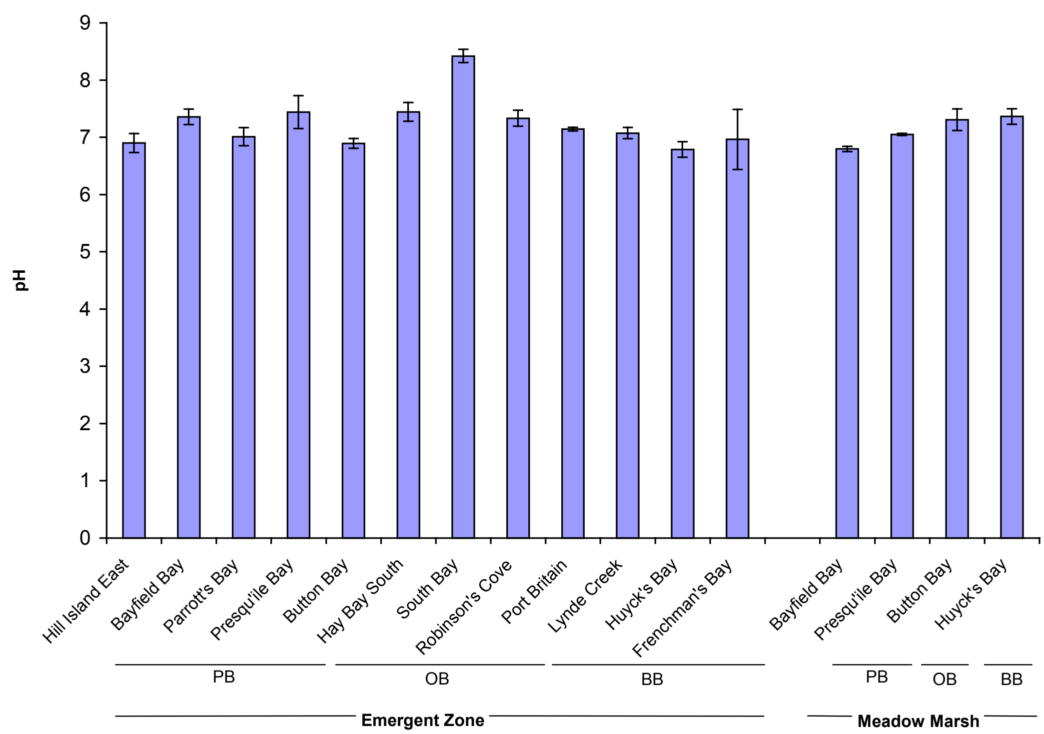


Figure 3-2. Mean pH in different vegetation zones in twelve Lake and St. Lawrence River coastal wetlands. Wetlands are grouped in the figure by geomorphic type: PB = protected bay, OB = open bay, BB = barrier beach.

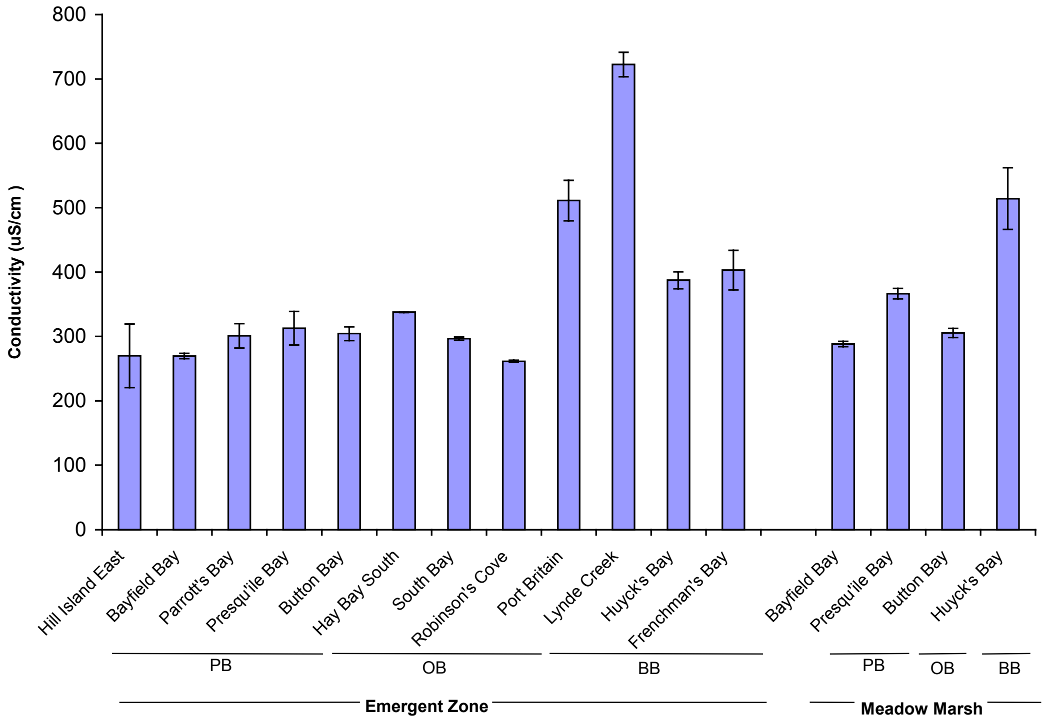



Figure 3-3. Mean conductivity in different vegetation zones in twelve Lake Ontario and St. Lawrence River coastal wetlands. Wetlands are grouped in the figure by geomorphic type: PB=protected bay, OB=open bay, BB=barrier beach.

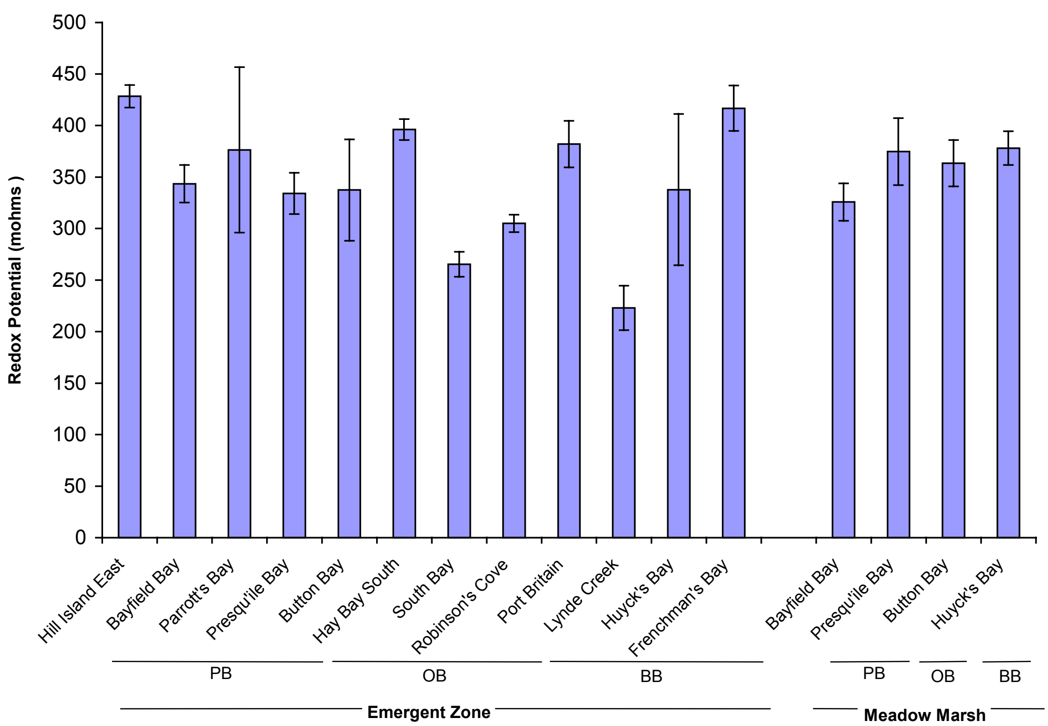


Figure 3-4. Mean redox potential in different vegetation zones in twelve Lake and St. Lawrence River coastal wetlands. Wetlands are grouped in the figure by geomorphic type: PB=protected bay, OB=open bay, BB=barrier beach.

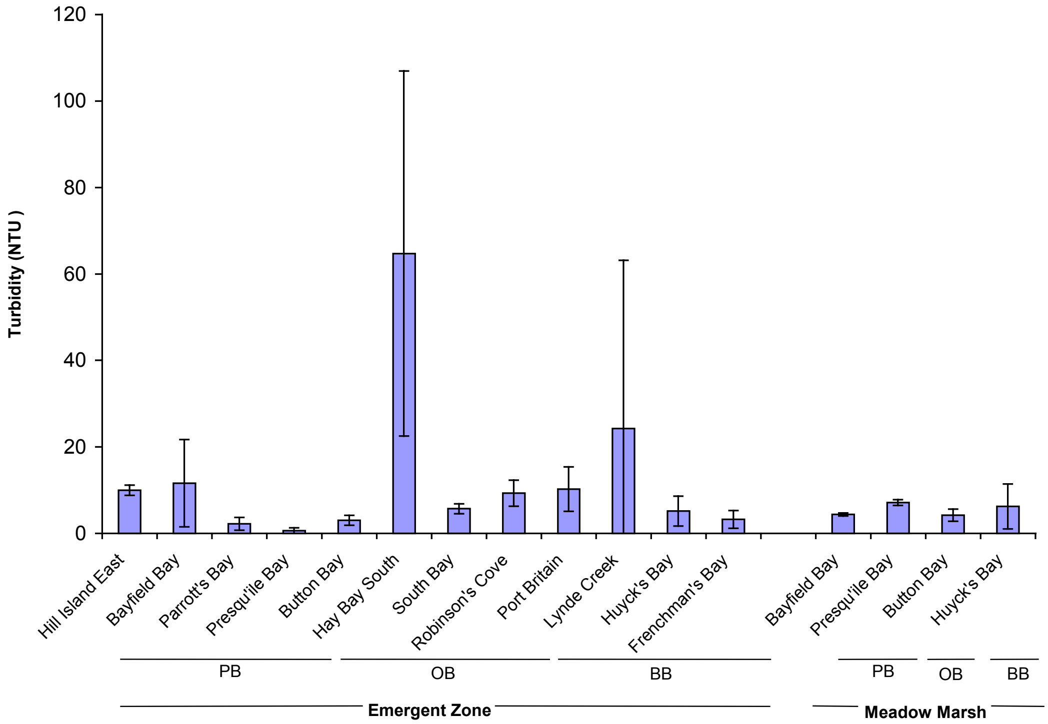



Figure 3-5. Mean turbidity in different vegetation zones in twelve Lake Ontario and St. Lawrence River coastal wetlands. Wetlands are grouped in the figure by geomorphic type: PB=protected bay, OB=open bay, BB=barrier beach.

### 3.1.3 Chemical Parameters

Soluble reactive phosphorus ($PO_4$) in the wetlands ranged from below the method detection limit (0.1 mg/L) in Hay Bay South to 0.68 mg/L in Bayfield Bay (Figure 3-6). Most wetlands had a soluble phosphorus concentration in the range of 0.1 mg/L to 0.3 mg/L in the emergent zone and 0.3 mg/L to 0.6 mg/L in the meadow marsh. The concentration of nitrate in the wetland water samples ranged from 0.3 mg/L at Presqu'ile Bay to 1.4 mg/L at Hay Bay South in the emergent and marsh meadow communities (Figure 3-6). The concentration of nitrite varied from 0.005 mg/L at Huyck's Bay to 0.039 at Hay Bay South (Figure 3-7). The water from the meadow marsh community had nitrite concentration at the lower end of this range. Ammonia nitrogen ($NH_4$) was as low as the method detection limit in Huyck's Bay and Parrott's Bay (0.01 mg/L) and peaked in Hay Bay South at 0.11 mg/L. Most wetland locations contained ammonia between 0.02 mg/L to 0.03 mg/L, with the marsh meadow typically lower than the emergent community (Figure 3-7). In these wetlands, the range in average chlorophyll *a* was from 0.8 µg/L in the emergent zone at Presqu'ile to 29.4 µg/L at Hay Bay. Most wetlands were in the 1 µg/L to 10 µg/L range in both the emergent and meadow marsh zones

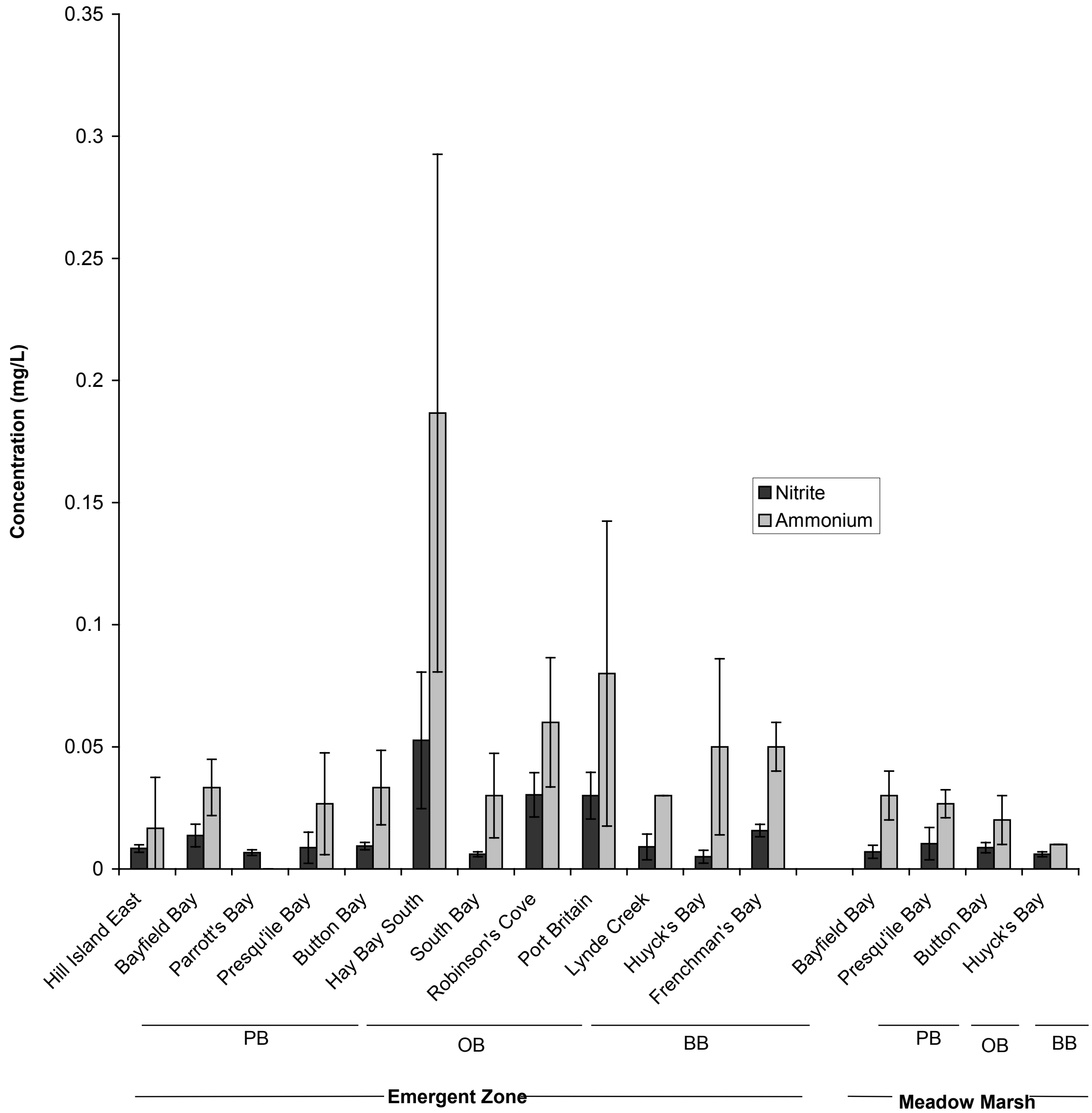



Figure 3-7. Mean concentration of nitrite and ammonium in different vegetation zones in twelve Lake Ontario and St. Lawrence River coastal wetlands. Wetlands are grouped in the figure by geomorphic type: PB=protected bay, OB=open bay, BB=barrier beach.

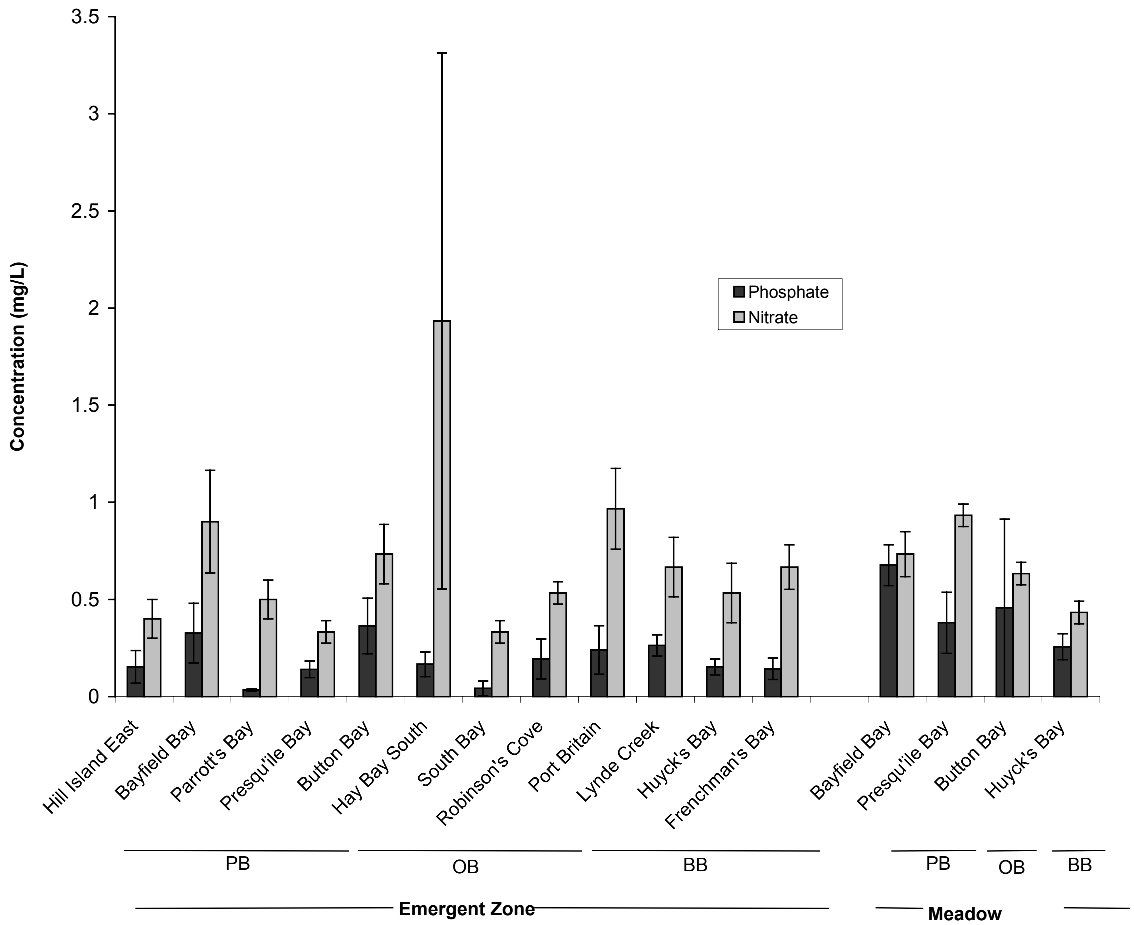



Figure 3-6. Mean concentration of phosphate and nitrate in different vegetation zones in twelve Lake Ontario and St. Lawrence River coastal wetlands. Wetlands are grouped in the figure by geomorphic type: PB=protected bay, OB=open bay, BB=barrier beach.

### 3.1.4 Key Water Chemistry Parameters

Using PCA, the first three principal component axes explained a total of 64% of the variability in the data set. This breaks down to 29% for the first axis, 21% for the second and 14% for the third. None of the remaining axes are considered here as they each represented less than 10% of the variation in the data. The PCA revealed that key variables including nitrate, nitrite and Secchi disk depth characterized the first principal component axis (Table 3-2). This axis reflects the nutrient and water clarity of the various wetlands. The negative correlation with Secchi depth indicates that as the nutrient levels increase the water clarity decreases.

The second principal component axis was highly correlated with water turbidity. Although no other parameter was highly correlated with this axis, nitrate, ammonia, pH and dissolved oxygen were positively related. Water temperature and soluble reactive phosphorus were positively correlated with the third principal component axis.

Table 3-2. Correlation of water chemistry parameters with principal component (PC) axes where the correlation coefficient is greater than 0.65.

| Parameter | PC 1 | PC 2 | PC 3 |
|---|---|---|---|
| Nitrate | 0.76 | | |
| Nitrite | 0.69 | | |
| Secchi | -0.69 | | |
| Turbidity | | 0.71 | |
| Water Temperature | | | 0.78 |
| Soluble Reactive Phosphorus | | | 0.67 |

The plot of the first and second principal components reveals some interesting trends (Figure 3-8). Those variables closely grouped together illustrate a positive correlation, whereas those on opposite sides of the origin are negatively correlated.

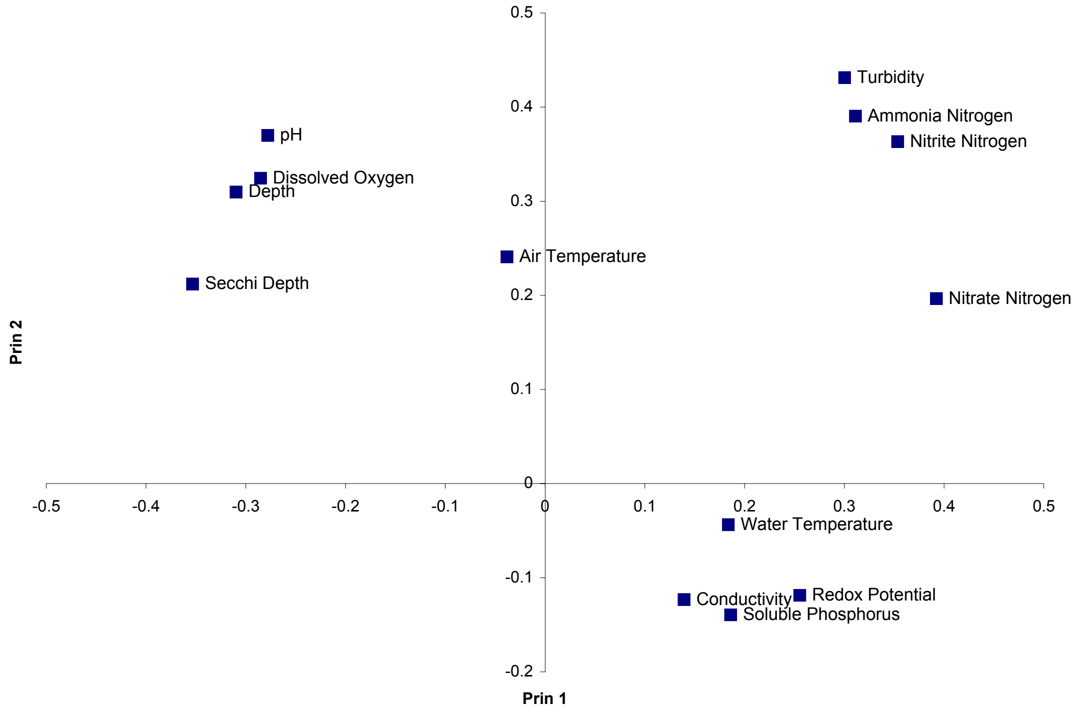



Figure 3-8. Plot illustrating placement of water chemistry variables associated with the principal components axes.

The close association of nutrients and turbidity in this two dimensional plot indicates that those wetlands with higher nutrients also have elevated turbidity and depressed water clarity. The association among pH and dissolved oxygen reflects the high correlation coefficient (Table A-2; Appendix A). This relationship may reflect the influence of primary productivity on both dissolved oxygen and water pH. The final grouping observed was among conductivity, redox potential and soluble reactive phosphorus.

## 3.2 Discussion

### 3.2.1 Field Parameters

To create and validate wetland IBI models, biological metrics are assessed against levels of disturbance impacting the wetland. The levels of disturbance are estimated by determining the level of abiotic parameters that are influenced or directly due to human disturbance within the wetland and the watershed.

Alkalinity, conductivity, redox potential and water temperature can all be affected by human influences, but natural environment influences may also affect these parameters in Lake Ontario and St. Lawrence River coastal wetlands. Therefore, these parameters were not considered in the disturbance ranking of the wetland sites. Theses parameters should be retained in the list of parameters to sample in future years due to the ease in collecting this information.

Low dissolved oxygen is often a sign of poor wetland health due to human disturbance. However, the diurnal variability of this parameter makes the attainment of comparable measurements among wetlands difficult, thus limiting the utility of this parameter for describing the level of wetland disturbance.

Coastal wetland turbidity can be affected by several human related disturbances within the watershed of the wetland (i.e., agriculture, development). Wilcox et al (2002) found turbidity measurements useful in the disturbance ranking process for the coastal wetlands in their study. In addition to human disturbance, common carp (*Cyprinus carpio*) presence is also presumed to increase turbidity within Lake Ontario and St. Lawrence River coastal wetlands. Because this species is exotic and its presence is often considered harmful to wetland health, turbidity measurements were used in ranking site disturbance in this study.

### 3.2.2 Water Chemistry Parameters

The low levels of soluble reactive phosphorus present in the wetland samples proved difficult to measure reliably. This combined with the high potential for contamination, resulted in some samples having lower phosphorus levels than the blanks. The results from 2002 indicate that soluble reactive phosphorus is not a suitable water chemistry variable for ranking of site disturbance because it provided no predictive power with respect to differentiating among wetlands, wetland types or vegetation units. Due to the poor predictive power of this parameter, the problems associated with proper analysis and difficulties in obtaining reproducible results, future monitoring should consider omitting soluble reactive phosphorus from the sampling program. Although total phosphorus may provide more reliable results that indicate wetland condition, turbidity values are much easier to obtain and should suffice since a high correlation between total phosphorus and turbidity has been found in wetlands throughout the Great Lakes basin (Crosbie and Chow-Fraser 1999, Lougheed et al. 2001).

Important water chemistry parameters to include in site disturbance considerations are the three nitrogen forms (nitrate, nitrite, and ammonia) and chlorophyll *a*. These four parameters are indicators of the level of nutrification at the site. Quantities of the three nitrogen parameters can indicate the level of dissolved nutrients in the water, while chlorophyll *a* concentrations reveal the abundance of photosynthetic algae that assimilate the dissolved nutrients. These four parameters are also used to assign degrees of site disturbance to the coastal wetlands in this study because nutrification is human influenced (i.e., fertilizer runoff, sewage discharge).

## 3.3 Cost

### 3.3.1 Equipment

The following table breaks down costs for water quality for the 12 coastal wetlands sampled (Table 3-3). The costs are broken down into consumables (one-time use) and non-consumables (used multiple times). These costs were required to initiate and complete the monitoring program for one field season. In the case of a long-term program, the non-consumable equipment will represent one-time or occasional (*i.e.* when replacement is necessary) costs. The values are for all 12 wetlands since cost did not differ among the wetland types.

Table 3-3. Resource costs required to complete the water quality monitoring of the 12 wetlands (C=Consumable, N=Non-consumable, WC=water chemistry, I=invertebrate, B=both water chemistry and invertebrate tasks).

| Item | Cost (CAD) | C/N | Category |
|---|---|---|---|
| Secchi | 40 | N | B |
| Canoe[1] | 1200 | N | B |
| Paddles[1] | 40 | N | B |
| Lifejackets[1] | 80 | N | B |
| Boat safety kit[1] | 20 | N | B |
| Waders | 200 | N | B |

| Item | Cost (CAD) | C/N | Category |
|---|---|---|---|
| Ethanol | 360 | C | B |
| Kimwipes | 97 | C | B |
| Paper towels | 77 | C | B |
| Gloves | 19 | C | B |
| Lab coats | 95 | N | B |
| Bench mat | 715 | N | B |
| Goggles | 20 | N | B |
| Backpack | 90 | N | B |
| Scissors | 5 | N | B |
| field books | 20 | C | B |
| Cleaning equip | 50 | C | B |
| Forceps | 35 | N | I |
| Pans | 23 | N | I |
| Petri dishes | 105 | N | I |
| Dissecting microscope | 2,205 | N | I |
| Glass vials | 273 | N | I |
| Plastic vials | 97 | N | I |
| D-frame nets | 420 | N | I |
| Hydrolab | 8,010 | N | WC |
| Calibration rack | 99 | N | WC |
| DR890 | 1,685 | N | WC |
| GPS | 325 | N | WC |
| Filtering unit | 132 | N | WC |
| Hand pump | 132 | N | WC |
| Filters | 95 | C | WC |
| Standards (nutrients) | 284 | C | WC |
| Phosver 3 | 78 | C | WC |
| Nitraver 3 | 100 | C | WC |
| Nitraver 5 | 88 | C | WC |
| Ammonia | 197 | C | WC |
| Alkalinity | 76 | C | WC |
| HCl | 81 | C | WC |
| Volumetric Flasks | 55 | N | WC |
| Graduated Cylinders | 237 | N | WC |
| Beakers | 33 | N | WC |
| Pipette | 346 | N | WC |
| Pipette tips | 154 | C | WC |
| Nitric acid | 42 | C | WC |
| Sulfuric acid | 66 | C | WC |
| Sodium hydroxide | 79 | C | WC |
| Turbidity standard | 294 | C | WC |
| Conductivity standard | 35 | C | WC |
| pH standards | 42 | C | WC |
| Thermometer | 55 | C | WC |
| Syringes | 261 | C | WC |
| Syringe filters | 476 | C | WC |
| GFC filters | 95 | C | WC |
| Sampling tubes | 274 | N | WC |
| Test-tube racks | 145 | N | WC |
| Nalgene bottles | 275 | N | WC |

| Item | Cost (CAD) | C/N | Category |
|---|---|---|---|
| Carboys | 368 | N | WC |
| Laboratory Costs | 1050 | Y | WC |
| Total | 22,190 | | |

Superscripts indicate equipment shared with other sampling tasks: 1=vegetation

### 3.3.2 Personnel

Water sampling was conducted by one person at each wetland. The water sampler worked in close proximity or along side other field workers as a safety precaution. The time required to complete water chemistry sampling and analysis at one site was approximately two to three hours in which field parameters and water samples were collected. The chemical analysis took approximately 40 minutes per wetland, including quality control blanks and duplicates.

## 3.4 Measurability

### 3.4.1 Expertise and Training

Properly trained field staff are required to complete water collection and analyses. To ensure field collection and chemical analyses are completed properly, personnel should have at least a college diploma in an environmental program. If personnel are expected to complete data analysis and quality control review, the required education should be a bachelor's degree in biology, environmental science or related science. Preference should be given to individuals with field experience and are capable of problem solving within a field or laboratory setting. Although direct experience with the equipment (i.e., Quanta Hydrolab) is not necessary, individuals should have experience with other field meters to ensure they are familiar with the operation and the necessity for regular calibration. All personnel should be instructed to use the field sheets as a template to ensure all required data are collected in the field.

To ensure that quality control objectives are met, personnel must complete standard curves, analyze blanks, and collect and analyze samples in duplicate on a regular interval. Personnel must have either the appropriate education or experience whereby they demonstrate their understanding of the necessity of following a quality control program. In keeping with the objective of producing reproducible and reliable data, personnel must also have demonstrated that they have good laboratory technique, either through education, experience or adequate in-house training (i.e., demonstrate they can run a standard curve in duplicate within acceptable limits). At least two weeks prior to entering the field for the collection of annual data, a training session should be completed to ensure that all equipment operate properly, provide hands-on training and identify any problems that require resolution. Problems that may be encountered include expired calibration standards, malfunctioning equipment that requires servicing, or logistical issues requiring better access to sites.

### 3.4.2 Comments and Recommendations on Methodology

#### *3.4.2.1 Within Site Sampling Location*

Although water chemistry data were shown to be reproducible, reliable, and accurate, the approach of collecting information on water chemistry within three metres of the vegetation stand may not necessarily provide results indicative of the level of disturbance in the entire wetland. In wetlands that only contain a fringe of emergent vegetation, the stand of macrophytes provides a protected area where suspended solids can drop out of suspension and nutrients utilized for vegetative growth. In 2002, this lead to a narrow range in turbidity, nutrients and other water chemistry parameters (see Figures 3-1 - 3-7). Crosbie and Chow-Fraser (1999) found higher values for these variables when sampling was conducted at an open water location in the wetland. Additional studies are required to determine if the water quality near the emergent vegetation is representative of the water quality in the entire wetland.

#### *3.4.2.2 Variable Environmental Influences*

Sampling was conducted under calm conditions in 2002, with the exception of Hay Bay South, which was sampled during high winds. The results from Hay Bay South suggest that sampling in high wind conditions affects the water chemistry through increasing turbidity, nutrients and decreasing Secchi disk depth. In addition, the high standard deviations associated with this site indicate that, during these conditions, the variability among replicate locations becomes quite high. For water chemistry among sites to be directly comparable in future years, sampling may be completed under calm weather conditions, if possible. However, the nature of open bay sites leaves them more exposed to wind and it is possible that sampling these sites during windy days may provide more representative, albeit highly variable, data.

### 3.5 Basin Wide Applicability and Sampling by Wetland Type

From a water chemistry sampling and analysis perspective the location of the wetland along the Lake Ontario and St. Lawrence River shoreline did not pose any access, sampling or analysis limitations. Wetlands along the St. Lawrence River were sampled with the same ease as those in east, central and western Lake Ontario.

From the perspective of water quality, there appeared to be little no difference among the wetland geomorphic types. The similarity may be related to the selected locations within the wetland since areas immediately adjacent to aquatic vegetation were chosen. Sampling in an open water location of the wetland, or at least 10 metres from the emergent stand, may prove that differences among the wetland types do occur. From the perspective of costs and access, sampling the wetland types was similar. Presqu'ile Bay was the only exception. This site supported a more complex vegetation community and took an additional 2 hours to sample.

### 3.6 Availability of Complementary Data

Research conducted by Dr. Patricia Chow-Fraser's laboratory at McMaster University in Hamilton, Ontario, Canada may provide data that are comparable to the water chemistry produced in this report.

### 3.7 Literature Cited

Crosbie, B, and P. Chow-Fraser. 1999. Percent land use in the watershed determines the water and sediment quality of 22 marshes in the Great Lakes Basin. Can. J. Fish. Aquat. Sci. 56: 1781-1791.

Loughheed, V. L., B. Crosbie, and P. Chow-Fraser. 1998. Predictions on the effect of carp exclusion on water turbidity, zooplankton, and submergent macrophytes in a Great Lakes wetland. Can. J. Fish. Aquat. Sci. 55: 1189-1197.

# 4 RANKING DISTURBANCE AT STUDY SITES

## 4.0 Methodology

For coastal wetland indicator development, biotic metrics must be assessed across a range of site disturbances. Standardized methods for assigning of coastal wetland site disturbance for metric testing are largely undeveloped and unreported in the literature. In this study, methods for site disturbance assessment are developed. Measures of site disturbance are estimated using data collected in the water chemistry, site attribute and surrounding land use sections of this study. The site disturbance rankings that are estimated from each data set are combined to produce a single site disturbance estimate.

Preliminary evaluation of biotic community metrics sensitivity was determined by plotting metrics against site disturbance ranks. The strength of the relationship was described with the correlation coefficient (r), the proportion of explained variation ($r^2$), and the significance of the relationship (p-value). Relationships with a significant p-value ($<0.05$) and an $r^2$ value above 0.40 were deemed sensitive to the level of wetland disturbance and are recommended coastal wetland IBI development.

Evaluation of indicator and metric sensitivity to wetland condition in the 12 Lake Ontario and St. Lawrence coastal wetlands is preliminary and cursory. A complete and rigorous analysis of indicator and metric sensitivity is being completed by the Michigan research team and Bird Studies Canada. This statistical analysis will involve a much larger sample size and include data collected from coastal wetlands associated with several Great Lakes. As indicated previously, data from this study has been provided to these collaborating investigators for this purpose.

### 4.0.1 Surrounding Land Use

The land use within a one-kilometer buffer of each wetland (Table 2-3) was used to quantify the amount of disturbance experienced by the wetland. Land uses were divided into natural and non-natural designations. The percent area of natural land surrounding the wetland within the one-kilometer buffer was used to scale the magnitude of disturbance experienced by the wetland. In this analysis, idle farm field was considered in a transitional state and therefore half of the area occupied by idle farm field was considered natural.

Once the percent natural area surrounding each wetland was determined, disturbance rankings between 1 and 5 were assigned. Disturbance rankings were linearly and inversely proportional the percent non-natural area surrounding the wetland (Table 4-1).

Table 4-1. Parameters for ranking wetland site disturbance based on surrounding land use within one kilometer of the wetland.

| Percent Natural Area | Disturbance Ranking |
|---|---|
| 0-20 | 5 |
| 21-40 | 4 |
| 41-60 | 3 |
| 61-80 | 2 |
| 81-100 | 1 |

### 4.0.2 Qualitative Hydrological and Landscape Alterations

The presence/absence data describing hydrological and landscape alterations experienced by the wetland (Table 2-2) were used to assign a level of disturbance to each wetland. The number of hydrological and landscape alterations were plotted using a box and whisker plot (Figure 4-1). The disturbance ranking was assigned by trisecting the distribution. Sites with a number of alterations above the 75$^{th}$ percentile on the distribution were assigned a disturbance ranking of 5, sites between the 75$^{th}$ and 25$^{th}$ percentile were assigned a 3 and sites below the 25$^{th}$ percentile were assigned a 1. Ideally, a large reference data set should be used to create the distribution and ranking. These type of data are not currently available, so trisection of distribution using an all-sites method (see Mack et al. 2000) was deemed suitable for preliminary evaluation purposes.

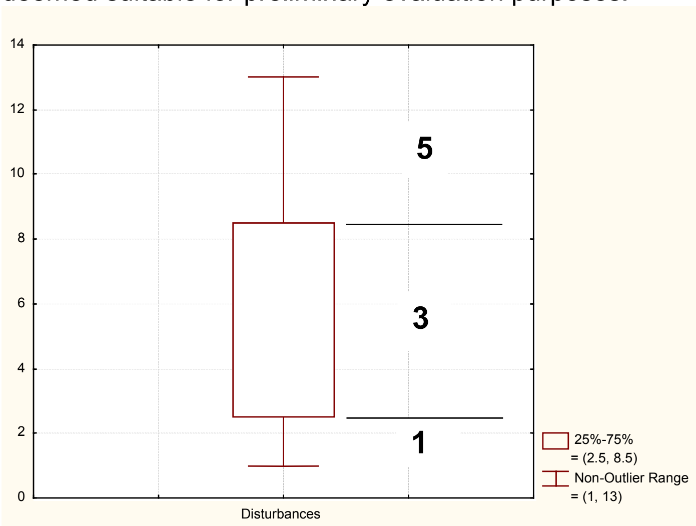



Figure 4-1. Assigning disturbance ranking using a box and whisker plot.

### 4.0.3 Quantified Immediate Disturbances

Quantitative data that were collected regarding the number of immediate disturbances are outlined in section 2.0.2 of this report. These data could not be presented in meaningful summaries and are supplied as electronic data sheets augmenting this report. A review of the data suggests that only some of these data are appropriate for creating an estimate of site disturbance (See Table 4-2 for justification of use). The number of immediate disturbances was summed for each site (i.e., # of dwellings + # of industries + # of ‘other’ buildings, etc) to give the total number of immediate disturbances at each site.

Table 4-2. Quantified immediate disturbance site attribute data applicability for use in site disturbance estimates.

| **Site Attribute** | **Applicability in Site Disturbance Estimate** |
|---|---|
| Proximity to navigable channels (m)<br>Proximity to recreational boating activity (m)<br>Proximity to roadways that receive daily traffic (m) | Not used for disturbance estimates. Data not appropriate for determining disturbance ranking using box and whisker distribution. |
| Number of dwellings<br>Number of industries<br>Number of ‘other’ buildings<br>Number of boat docks<br>Number of paved parking lots<br>Number of dirt parking lots<br>Number of boat launches | Data used for disturbance estimates. |
| Percent hardened shoreline<br>Percent eroding shoreline<br>Percent of shoreline containing a dirt road<br>Percent of shoreline containing a visible paved road | Not used in for disturbance estimates. Very little variation in data –mostly zeros. |

The data subset indicated in Table 4-2 was augmented with data collected at 33 coastal wetlands along the U.S. shore of Lake Ontario by Dennis Albert, Michigan State University. These data were plotted using a box and whisker plot and site disturbance rankings were assigned as previously described.

### 4.0.4 Water Chemistry

The investigation of water chemistry parameters (Section 3.4.2.3) indicates that soluble nitrogen concentrations ($NO_2$ +$NO_3$ and $NH_4$) and turbidity should be considered when ranking site disturbance. on, the concentration of chlorophyll *a* in the water column was also assessed. Because high levels of These parameters indicate degraded wetlands, with highly disturbed wetlands having increased turbidity, nitrogen and chlorophyll *a*. These data were augmented by comparable data taken from 18 additional Lake Ontario coastal wetlands (see Crosbie and Chow-Fraser 1999). These data were plotted using a box and whisker plot and site disturbance rankings were assigned as previously described.

## 4.1 Results

### 4.1.1 Surrounding Land Use

In general, natural land use surrounding the study wetlands was low and the largest contributors to natural land use percentage were treed areas. With this ranking method, eight of the twelve wetlands received the highest disturbance ranking possible (Table 4-3). However, two sites, Lynde Creek and Hay Bay South were within 2 percentage points of receiving a four instead of a five as a disturbance ranking.

Table 4-3. Ranking site disturbance based on surrounding land use within one kilometer of the wetland.

| Site | Idle Field | Woodlot and Forest | Wetland | Beach and Dunes | Total Natural Area | Disturbance Ranking |
|---|---|---|---|---|---|---|
| Hill Island East | 0.0 | 94.0 | 1.5 | 0.0 | 95.4 | 1 |
| Bayfield Bay | 3.9 | 5.1 | 0.0 | 0.0 | 7.1 | 5 |
| Parrott's Bay | 40.6 | 30.2 | 0.2 | 0.0 | 50.7 | 3 |
| Presqu'ile Bay | 13.1 | 49.5 | 6.8 | 7.1 | 69.9 | 2 |
| Button Bay | 7.8 | 8.0 | 0.0 | 0.0 | 11.8 | 5 |
| Hay Bay South | 6.8 | 14.4 | 1.1 | 0.0 | 18.9 | 5 |
| South Bay | 9.2 | 8.3 | 0.3 | 0.0 | 13.1 | 5 |
| Robinson's Cove | 6.3 | 7.6 | 0.0 | 0.0 | 10.8 | 5 |
| Port Britain | 20.2 | 9.7 | 0.8 | 0.0 | 20.7 | 4 |
| Lynde Creek | 24.6 | 6.5 | 1.0 | 0.0 | 19.8 | 5 |
| Huyck's Bay | 3.7 | 4.9 | 1.4 | 0.0 | 8.2 | 5 |
| Frenchman's Bay | 12.9 | 1.2 | 0.0 | 0.0 | 7.6 | 5 |

### 4.1.2 Qualitative Hydrological and Landscape Alterations

The number of observed hydrological and landscape alterations in and immediately close to the wetland was variable (Table 4-4). The disturbance ranking assignment through trisection of the distribution of qualitative disturbance resulted in a relatively even spread of disturbances across sites.

Table 4-4. Ranking site disturbance based on hydrological and landscape alterations affecting the study wetlands.

| Site | Number of Disturbances | Disturbance Ranking |
|---|---|---|
| Hill Island East | 1 | 1 |
| Bayfield Bay | 8 | 3 |
| Parrott's Bay | 4 | 3 |
| Presqu'ile Bay | 1 | 1 |
| Button Bay | 4 | 3 |
| Hay Bay South | 2 | 1 |
| South Bay | 9 | 5 |
| Robinson's Cove | 4 | 3 |
| Port Britain | 7 | 3 |
| Lynde Creek | 12 | 5 |
| Huyck's Bay | 3 | 3 |
| Frenchman's Bay | 13 | 5 |

### 4.1.3 Immediate Disturbances

The number of immediate disturbances at the wetlands was variable among the wetlands with Frenchman's Bay experiencing the highest disturbance (Table 4-5). The number of disturbances was highest at this site because a marina was located with in the wetland. The extremely high number of disturbances in Frenchman's Bay resulted in no other sites receiving a disturbance ranking of 5, although four sites did receive a ranking of 3.

Table 4-5. Ranking site disturbance based on immediate disturbances affecting the study wetlands.

| Site | Number of Disturbances | Disturbance Ranking |
|---|---|---|
| Hill Island East | 4 | 1 |
| Bayfield Bay | 30 | 3 |
| Parrott's Bay | 3 | 1 |
| Presqu'ile Bay | 6 | 1 |
| Button Bay | 4 | 1 |
| Hay Bay South | 2 | 1 |
| South Bay | 19 | 3 |
| Robinson's Cove | 4 | 1 |
| Port Britain | 6 | 1 |
| Lynde Creek | 33 | 3 |
| Huyck's Bay | 33 | 3 |
| Frenchman's Bay | 131 | 5 |

### 4.1.4 Water Chemistry

Turbidity, $NO_2$+$NO_3$, and chlorophyll *a* parameters were variable among sites and resulted in variable disturbance rankings. Ammonium measurements did not vary substantially among wetlands. Within all water chemistry parameters, Hay Bay South received a high disturbance ranking.

| Site | $NO_2$+$NO_3$ | | $NH_4$ | | Turbidity | | Chlorophyll *a* | |
|---|---|---|---|---|---|---|---|---|
| | mg/L | Disturbance Ranking | mg/L | Disturbance Ranking | NTU | Disturbance Ranking | µg/L | Disturbance Ranking |
| Hill Island East | 0.41 | 1 | 0.017 | 1 | 9.9 | 3 | 6.9 | 3 |
| Bayfield Bay | 0.91 | 3 | 0.033 | 1 | 11.6 | 3 | 18.3 | 3 |
| Parrott's Bay | 0.51 | 1 | 0.000 | 1 | 2.2 | 1 | 3.7 | 1 |
| Presqu'ile Bay | 0.34 | 1 | 0.027 | 1 | 0.6 | 1 | 0.8 | 1 |
| Button Bay | 0.74 | 3 | 0.033 | 1 | 3.0 | 3 | 7.9 | 3 |
| Hay Bay South | 1.99 | 5 | 0.187 | 3 | 64.7 | 5 | 29.4 | 5 |
| South Bay | 0.34 | 1 | 0.030 | 1 | 5.7 | 3 | 4.7 | 1 |
| Robinson's Cove | 0.56 | 1 | 0.060 | 1 | 9.3 | 3 | 5.2 | 1 |
| Port Britain | 1.00 | 3 | 0.080 | 1 | 10.2 | 3 | 24.7 | 5 |
| Lynde Creek | 0.68 | 3 | 0.030 | 1 | 24.2 | 5 | 23.1 | 3 |
| Huyck's Bay | 0.54 | 1 | 0.050 | 1 | 5.1 | 3 | 7.4 | 3 |
| Frenchman's Bay | 0.68 | 3 | 0.050 | 1 | 3.2 | 3 | 6.3 | 3 |

### 4.1.5 Overall Site Disturbance Ranking

Overall site disturbance rankings were produced by adding all individual site disturbance rankings, except those created from $NH_4$ concentration (Figure 4-2). The relationship between the combined site disturbance rankings and various metrics describing coastal wetland fish, vegetation, bird and amphibian communities were examined.

The overall site disturbance rankings indicated that the level of disturbance at the study sites was variable. The highest possible disturbance ranking is 30. The highest disturbance rank was 24 and was shared by Frenchman's Bay and Lynde Creek. Hill Island East, Parrott's Bay and, Presqu'ile Bay were exposed to the least disturbance.

There was a marked difference in the level of disturbance among geomorphic types. Protected bay wetlands were the least disturbed (mean disturbance=11.75), followed by open bay wetlands (18.00), and barrier beach wetlands were the most disturbed wetlands (21.25).

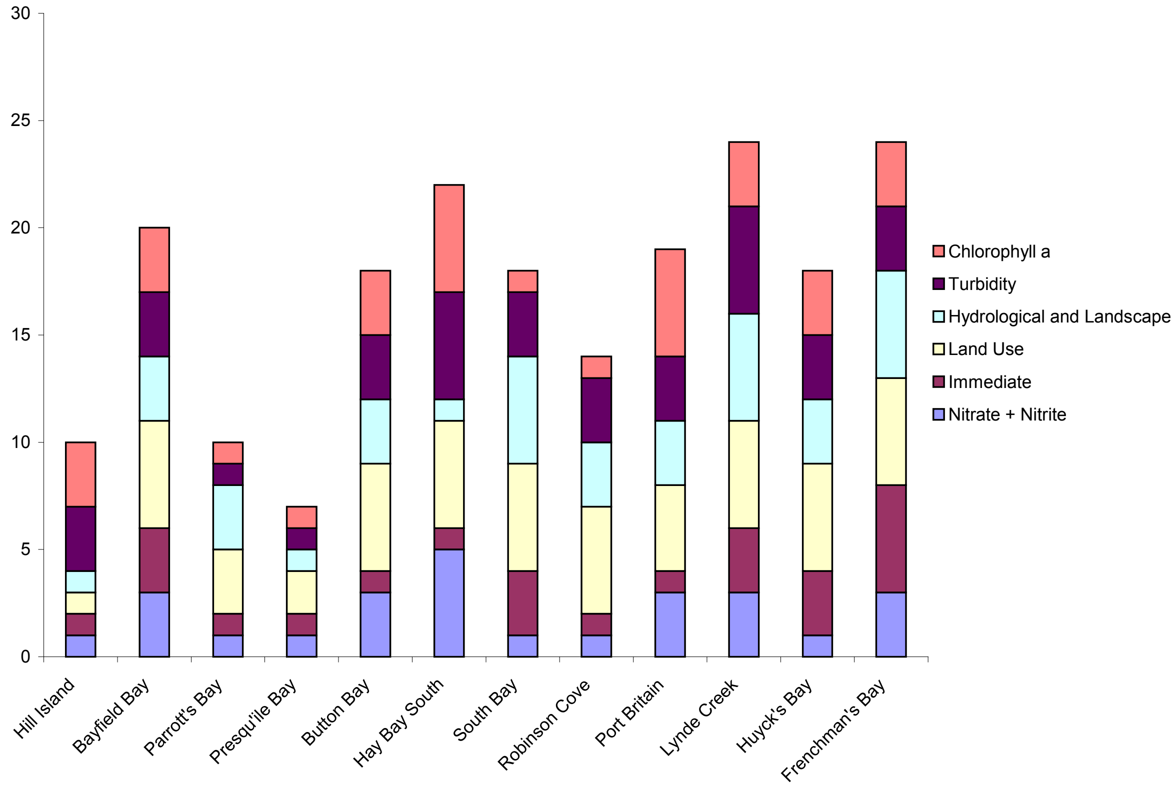



Figure 4-2. Site disturbance rankings for 12 Lake Ontario and St. Lawrence River coastal wetlands.

## 4.2 Discussion

### 4.2.1 Surrounding Land Use

The majority of study sites received a moderate or high disturbance ranking. The sites that scored the lowest ranking Hill Island East (1), Presqu'ile Bay (2) and Parrott's Bay (3) are all inside protected areas, St. Lawrence National Park, Presqu'ile Provincial Park, and Parrott's Bay Conservation Area, respectively. This suggests that the disturbance rankings are accurate and reflect the level of protection and hence disturbance that the wetland experiences.

### 4.2.2 Qualitative Hydrological and Landscape Alterations

Disturbance rankings across sites was variable. Again, the sites that scored the lowest disturbance rankings were protected. These rankings appear to reflect actual disturbance based on hydrologic and landscape alteration observations. However, the types of alterations that required observations were generally difficult to see and were not always apparent from the chosen vantage point in the wetland. The likelihood of observing the required alterations in a wetland is assumed to be relatively constant across wetlands. Therefore, the magnitude of disturbance across wetlands may not be fully representative of the actual disturbance at the site, but will be reliable as a relative measure of disturbance.

### 4.2.3 Immediate Qualitative Disturbances

The high number of disturbances, due to a marina, at Frenchman's Bay cause this site to be the only one to receive a disturbance rank of 5. The high number of disturbances caused the distribution to be skewed, but the augmentation of U.S. based data dampened the effect of this site. This allowed other sites experiencing relatively high number of immediate disturbances to receive ranks of 3. Once again, protected areas received the lowest disturbance rankings. These trends suggest that these data can be used to effectively rank site disturbance among the wetlands

The conspicuous nature of these disturbances (i.e., boat dock, parking lot) allowed these features to be easily observed with the wetland. As such, the estimate of the magnitude of disturbance due to the immediate disturbances should reflect the actual disturbance experienced at by the wetland.

### 4.2.4 Water Chemistry

Disturbance rankings based on turbidity, $NO_2$+$NO_3$ concentration, and chlorophyll *a* concentration were variable among sites and likely respond to the amount of disturbance at the wetland. These parameters were used in the overall disturbance rankings of the study sites. Disturbance rankings based on ammonium concentration was not variable among sites and was not included in the overall disturbance rank of the sites.

Similar to disturbance rankings based on other wetland disturbance parameters, protected sites scored low disturbance rankings. This consistency suggests that these parameters are accurate measures of site disturbance.

Hay Bay South scored high disturbance rankings for all water chemistry parameters tested, including $NH_4$. This site is located at the east end of Hay Bay and often experiences high winds. Frequent strong winds blow along a long open water segment of the bay and form high waves that are likely responsible for resuspending sediment into the water column. As a result water chemistry parameters would be reflect the particularly high disturbance at the site.

### 4.2.5 Overall Site Disturbance Ranking

The overall site disturbance rankings appear to reflect the expected level of disturbance experienced by the wetlands. Frenchman's Bay and Lynde Creek wetlands are located in highly urbanized watersheds, and, according to the rankings, these sites experience the highest disturbance. In addition, Bayfield Bay and Hay Bay South, which are located in highly agricultural watersheds, showed relatively high disturbance. The three least disturbed sites, Hill Island East, Presqu'ile Bay and Parrott's Bay were all in protected areas and experienced the least disturbance.

The three least disturbed wetlands were protected bay wetlands and the most disturbed wetlands were barrier beach wetlands. Although there appears the be a trend with respect to disturbance and wetland geomorphic type, the trend is most likely driven by the such factors as urbanization and conservation and not wetland geomorphic type.

## 4.3 Literature Cited

Crosbie, B, and P. Chow-Fraser. 1999. Percent land use in the watershed determines the water and sediment quality of 22 marshes in the Great Lakes Basin. Can. J. Fish. Aquat. Sci. 56: 1781-1791.

Mack, J.J., M. Micacchion, L.D. Augusta and G.R. Sablak. 2000. Vegetation Indices of Biotic Integrity (VIBI) for wetlands and calibration of the Ohio Rapid Assessment Method for Wetlands v.5.0. Final report of US EPA Grant No. CD9856276, Interim report to US EPA Grant No. CD985875 Volume 1.

# 5 INVERTEBRATE COMMUNITY SAMPLING

## 5.0 Methodology

Aquatic invertebrates were collected on one occasion during the month of July from the 12 wetlands. Three replicate samples were collected from dominant vegetation units or co-dominant vegetation stands where present (Table 5-1).

Table 5-1. Summary of wetlands sampled for invertebrates in emergent and, in some cases, meadow marsh vegetation zones. Triplicate samples were collected, except at Presqu'ile Bay, Huyck's Bay and Robinson Cove where six samples were collected in the emergent zone (2=co-dominance).

| Wetland | Emergent | Meadow Marsh |
|---|---|---|
| Hill Island East | ✔ | |
| Bayfield Bay | ✔ | |
| Parrott's Bay | ✔ | |
| Presqu'ile Bay | 2 | ✔ |
| Button Bay | ✔ | ✔ |
| Hay Bay South | ✔ | |
| South Bay | ✔ | |
| Robinson Cove | 2 | |
| Port Britain | ✔ | |
| Lynde Creek | ✔ | |
| Huyck's Bay | 2 | |
| Frenchman's Bay | ✔ | |

Triplicate samples were collected from the emergent vegetation zone, and the meadow marsh where sufficient standing water was present (>10 cm). A D-frame net with 0.5-mm mesh was used to sweep the entire water column from immediately above the sediment layer to the surface, thereby encompassing all micro-habitat types. These sweeps included open water areas as well as sweeps along the stems of the dominant vegetation.

Within the emergent vegetation zone, the sampling technician generally conducted the sweeps from foot, except in cases where water depths were too great (>1.0 m) or the bottom was unstable. In the case of the latter, the sweep net sampling was conducted from a canoe. The sampler initiated the sweeps at the edge of the vegetation zone and proceeded to move deeper into the vegetation unit in a random pattern. All sampling in the meadow marsh zone was completed by foot because water depths were generally shallow in July.

The contents in the net from each sweep were dumped into a 12"×8" plastic bin. The bottom of the inside of the bin was marked with a grid consisting of 10-cm squares. The number of sweeps required to collect 150 invertebrates differed at each location; resulting in the total time to collect one sample to vary greatly. The number of sweeps was left to the samplers discretion. However, generally the sampling commenced when over 50 invertebrates could be quickly counted in any one of the squares in the grid. After finishing the first replicate, the technicians moved to the next replicate location based on distribution of the dominant or co-dominant vegetation.

After the three replicate samples were collected in the vegetation zone the samples were taken to shore for invertebrate sorting and preservation. A total of 150 invertebrates were removed from each of the samples. One exception was Port Britain where only 100 organisms were retrieved from two of the three replicates. Invertebrates were removed using forceps and placed directly into labeled vials containing 70% ethanol. The invertebrates were picked starting with one square in the grid and moving to the next square once all invertebrates were removed from the first. This process proceeded until 150 organisms were collected or until the prescribed 30-minute period elapsed. This allowed for standardization among sorting technicians. The overall approach ensured that biases such as picking large organisms or readily visible organisms were avoided. Once 150 organisms were removed, the sampling technician continued to sort through debris for new and sometimes cryptic organisms for a few minutes. All samples were labeled according to wetland, vegetation zone, date and replicate number. Samples were shipped to D. Uzarski at Grand Valley State University, Michigan, USA for identification. Taxonmic keys including Thorp and Covich (1991) and Merritt and Cummins (1996), along with mainstream literature were used for identification.

Supporting information collected for the invertebrate community (Table A-6; Appendix A) included UTM location using a Magellan GPS 320 global positioning system, water depth (cm), Secchi depth (cm), water temperature (°C) and air temperature (°C). In most cases, the water chemistry and invertebrate samples were collected in the same location and therefore the water chemistry relates directly with the invertebrate community. The plant community was described in detail at each replicate location, with the dominant species identified and other plant species associated with the dominant vegetation recorded.

## 5.1 Results

As proposed, samples were transferred to Michigan research team for identification and integration within a larger Great Lakes database for statistical analysis. The results of the Lake Ontario and St. Lawrence River invertebrate data will be reported within the Year 1Consortium report produced by the Michigan research team.

## 5.2 Cost

### 5.2.1 Equipment

As with the water quality component, there was no difference in cost with respect to the three wetland types. As mentioned previously, the invertebrate sampling was paired with the water quality and these combined tasks required approximately 4 hours per site. The costs associated with the invertebrate sampling component alone are presented in Table 5-2. These costs do not represent all equipment or field time as they have been discussed elsewhere in this report (See Table 3-2).

Table 5-2. Additional resource costs required to complete the wetland invertebrate sampling of the 12 wetlands (C=Consumable, N=Non-consumable).

| Item | Cost (CAD) | Consumable/Non-consumable |
|---|---|---|
| Hand counters | 40 | N |
| Forceps | 35 | N |
| Pans | 23 | N |
| Petri dishes | 105 | N |
| Glass vials | 273 | N |
| Plastic vials | 9 | N |
| D-frame nets | 420 | N |
| Total | 905 | |

### 5.2.2 Personnel

Invertebrate sweep net sampling was conducted by the same individual that completed the water chemistry. Invertebrates were picked from the holding buckets by the sweep netter with help, in most cases, from vegetation or fish sampling crew members. The total sweep netting time ranged from 30 to 120 minutes and invertebrate picking took 15 to 30 minutes per sample, depending on the abundance of invertebrates and the efficiency of the picker.

## 5.3 Measurability

### 5.3.1 Expertise and Training

Although the lead field technician should have some experience in invertebrate sampling, not all technicians require prior specific training. The lead technician should have at a minimum a college diploma in environmental studies, with an emphasis on field techniques, including some level of experience with invertebrate collection and sorting. This ensures that the lead technician is familiar with identifying invertebrates, which is essential in the sorting of invertebrates captured within the D-frame net. Prior to the field season the lead field technician should conduct a one-day field training exercise where the supporting field staff are taught how to both collect invertebrates with a D-frame net and properly sort and pick invertebrates, according to protocol. This also allows the technicians to familiarize themselves with sampling invertebrates in a wetland setting.

### 5.3.2 Comments and Recommendations on Methodology

#### *5.3.2.1 Repeatability*

The methodology employed to collect invertebrates from the 12 wetlands was adequate for obtaining at least 150 organisms. Future studies should follow this approach to ensure spatial and temporal repeatability. Although some difficulties were encountered in sites with extensive floating mats of emergents, sampling from a canoe appeared to yield an invertebrate community similar to locations where the sampler was able to sample by foot.

#### *5.3.2.2 Variable Within Site Invertebrate Abundance*

Incidental observations in the field suggest that sites where submerged vegetation was immediately adjacent the emergent zone yielded a larger number of invertebrates with less sampling effort. The submerged zone may be an important area to sample in future studies.

#### *5.3.2.3 Sampling Period*

Meadow marsh community zones typically do not contain standing water later in the growing season. Due to above average July water levels (Figure 2-1), a few sites did have sufficient standing water to enable invertebrate collection. Sampling in June may enable collection of invertebrates in more meadow marsh communities, however this time period was not considered ideal for development of the invertebrate index of biotic integrity (Burton et al 1999).

## 5.4 Basin Wide Applicability and Sampling by Wetland Type

No differences were encountered when sampling the 12 wetlands. All wetlands were sampled with the same approach regardless of location or type.

## 5.5 Availability of Complementary Data

Few studies on wetland invertebrates have been completed in the past. Aquatic invertebrate collections in littoral zones of Lake Ontario that may provide comparable data with those collected by Ora Johannsson and Scott Millard at the Canadian Department of Fisheries and Oceans in the Bay of Quinte and Pat Chow-Fraser from McMaster University in Hamilton, Ontario.

## 5.6 Literature Cited

Thorp, J.L., and A.P. Covich. 1991. Ecology and classification of North American Freshwater Invertebrates. Academic Press, New York.

Merritt, R.W. and K.W. Cummins (eds.). 1996. *An Introduction to the Aquatic Insects of North America* (3rd. ed.). Dubuque, IA: Kendall/Hunt Publishing Co. 862 pp.

Burton, T.M., D.G. Uzarski, J.P. Gathman, J.A. Genet, B.E. Keas, and C.A. Stricker. 1999. Development of a preliminary invertebrate index of biotic integrity for lake Huron coastal wetlands. Wetlands 19(4) pp. 869-882.

# 6 VEGETATION COMMUNITY SAMPLING

## 6.0 Methodology

Vegetation communities were previously mapped through interpretation of current (1999-2001), 1:10,000 scale orthorectified colour infrared aerial photographs. Field sampling locations were identified on these photographs. Sampling was generally conducted along transects running perpendicular to the hydrological gradient. At open bay sites, where the wetland vegetation fringe was not extensive, transects were run parallel to the hydrological gradient to accommodate the transect length. Transect start-points were located at a random point within 25 metres of the upland edge of the wet meadow zone. At sites that did not have a sufficient wet meadow zone for sampling (Hill Island East and Frenchman's Bay), transect start-points were located within the emergent vegetation zone. Sampling points were identified by walking 25 metres along the transect then choosing a random bearing and distance (between one and nine metres) to place the 0.5m x 0.5m quadrat. The quadrat was constructed from ½" metal electrical conduit joined at the corners with ½" metal pull-through elbows.

Within each quadrat, the total vegetation cover and grouped estimates of emergent, submerged, and floating-leafed plant cover were recorded as percentages. Cover estimates for each species were also recorded, such that the total coverage within a quadrat could exceed 100% because more than one individual may occupy the same area in the two dimensional sampling plane created by the quadrat. For example, when the quadrat was placed in an area with dense floating-leafed plants, the coverage of a floating leafed plant species in the quadrat could be 75%. In addition, submerged macrophytes may be present under the floating leaves at a density of 50%. The resulting total coverage would then be 125%.

Plants were identified to species level, except for sterile plants (mainly grasses and sedges) that required flowering parts for identification. In cases where sterile, unidentifiable plants were found in the quadrat and morphologically analogous flowering plants were found close to the sample point, the flowering plant was identified and assumed to be the same species as the sterile species within the quadrat. In most cases, plant identifications were made in the field, but occasionally difficult specimens were collected for later identification.

Sampling focussed on three distinct vegetation zones typically found in Great Lakes coastal wetlands: meadow marsh, emergent/submerged (herein emergent), and a purely submerged. Macrophytes were sampled in five quadrats for each of the three zones (Table 6-1). The submerged zone was only sampled if deemed sufficiently extensive by the primary researcher.

Sampling was conducted on foot in the wet meadow and emergent zones and from a canoe or flat-bottomed boat in the submerged zone. Cylindrical pieces of polyethylene foam enveloped two opposite sides of the square quadrat frame to provide flotation for quadrats in the submerged zone. While sampling submerged zones from the water surface, researchers were mindful of parallax and avoided including additional area in the quadrat sample.

Ancillary data collected in each quadrat included: substrate texture, water depth, organic depth, and UTM location. The substrate texture was determined to be sand, loam, clay or gravel by visual and tactile examination. Water depth was measured to the nearest centimetre using a 1.2-metre piece of ½" metal electrical conduit with marked depth graduations. If standing water was not present at the quadrat sampling point, the water depth was replaced with a substrate water content designation – Dry or Saturated. Organic depth was estimated in centimetres by pushing the piece of conduit into the substrate until moderate resistance was encountered. This was considered the organic/inorganic interface. The previously measured water level was subtracted from the new water level plus organic depth measurement to determine the depth of organic material. The UTM location was recorded using a Magellan GPS 320 global positioning system.

After quadrat sampling was completed in each zone, an auxiliary 15-minute plant inventory was completed in the zone. The purpose of this auxiliary survey was to identify incidental plant species that were present in the zone but not represented by the quadrat sampling.

Table 6-1. A summary of the vegetation zones sampled in various Lake Ontario and St. Lawrence River coastal wetlands in 2002

| Study Site | Wetland Type | Wetland Vegetation Zone | | |
|---|---|---|---|---|
| | | Meadow Marsh | Emergent | Submerged |
| Hill Island East | Protected Bay | | ✔ | ✔ |
| Bayfield Bay | Protected Bay | ✔ | ✔ | ✔ |
| Parrott’s Bay | Protected Bay | | ✔ | ✔ |
| Presqu'ile Bay | Protected Bay | ✔ | ✔ | |
| Button Bay | Open Bay | ✔ | ✔ | ✔ |
| Hay Bay South | Open Bay | ✔ | ✔ | ✔ |
| South Bay | Open Bay | ✔ | ✔ | ✔ |
| Robinson Cove | Open Bay | ✔ | ✔ | ✔ |
| Port Britain | Barrier Beach | ✔ | ✔ | |
| Lynde Creek | Barrier Beach | ✔ | ✔ | ✔ |
| Huyck’s Bay | Barrier Beach | ✔ | ✔ | ✔ |
| Frenchman's Bay | Barrier Beach | | ✔ | |

### 6.0.1 Data Analysis

The data presented in this report have been provided to the Michigan research team as part of a larger plant community indicator evaluation. Descriptive statistics were used to provide summaries of various wetland plant community metrics.

#### *6.0.1.1 Species Richness*

Species richness estimates were generated for each vegetation zone within the wetland and as well as the whole wetland. The estimates were generated from data collected from quadrat sampling and compared to estimates derived from augmenting the quadrat sampling data with incidental plant species observations. A one-way ANOVA was used to compare species richness among wetland zones within each site. In cases where significant differences occurred, Tukey’s Honestly Significantly Different (HSD) test was used to determine which means were significantly different. Factorial ANOVAs with wetland zone and geomorphic type as main effects could not be run because the data violated the sample size and normality assumptions of parametric statistics. All statistical analysis was done with StatSoft Statistica (StatSoft, Inc. 2003).

#### *6.0.1.2 Floristic Quality Assessment*

The floristic quality was assessed in each vegetation zone within the wetland as well as the whole wetland following Oldham et al. (1995). This method creates a Floristic Quality Index (FQI) for each natural area that is based on the plant species present and their relative fidelity to a specific habitat.

Comprehensive species occurrence data provide the most accurate FQIs. Therefore, FQIs were calculated using species data collected from both quadrat sampling and incidental observations. FQIs were analyzed per site by vegetation zone using a one way ANOVA and Tukey’s HSD as described for species richness.

Under the recommendations of the protocol, wetland zones would be sampled only if they occurred in an appreciable amount as determined by the surveyors. Therefore, some zones within the study wetlands were not surveyed and the absence of these data prevents reliable comparisons of total species richness and FQIs among sites.

#### *6.0.1.3 Vegetation Cover of Natives and Non-natives*

The relative cover of native and non-native plant species may be a useful vegetation community metric. Vegetation coverage data were estimated in percent. Usually percent data require arcsin transformations to attain a normal distribution of the data due to the truncation of the distribution at 0% and 100%. Because the total vegetation coverage could exceed 100%, as justified above, the coverage estimated created a continuous variable that did not significantly differ from a normal distribution. Vegetation cover and the number of non-native species present per site were analyzed by vegetation zone using one-way ANOVAs and Tukey's HSD as described above.

The distribution of coverage of non-natives among wetland zones was not normal, thus violating an assumption of parametric statistics. Therefore, the non-parametric Kruskal-Wallis ANOVA by Ranks test was used to analyze these data. When significant differences were detected, ranks from the Kruskal-Wallis ANOVA were used in a Tukey-type multiple comparisons test (Zar 1999) to detect where the differences occur.

## 6.1 Results

### 6.1.1 Species Richness

The species richness within a site increased on average by 12 species (±3.1SD, n=12) with the addition of incidental plants species (Table 6-2). In addition, species richness estimates within a vegetation zone (Figure 6-1) were generally increased through incidental observations (mean increase ± SD=5.6 ± 3.4 species, n=30). The emergent zone in Bayfield Bay, was the only case where additional species were not observed. Sampling in this case occurred in a large (>25ha) emergent zone dominated by narrow-leaved cattail (*Typha angustifolia*) and carpeted with the non-native, European frogbit (*Hydrocharis morsus-ranae*). The only other plant species detected during quadrat sampling was marsh bedstraw (*Galium palustre*).

Table 6-2. Species richness estimates generated from quadrat sampling and from quadrat sampling with incidental observations.

| Study Site | Wetland Type | Species Richness (Quadrats) | Species Richness (Quadrats and Incidental Observations) |
|---|---|---|---|
| Hill Island East | Protected Bay | 16 | 26 |
| Bayfield Bay | Protected Bay | 30 | 43 |
| Parrott's Bay | Protected Bay | 13 | 22 |
| Presqu'ile Bay | Protected Bay | 20 | 36 |
| Button Bay | Open Bay | 13 | 26 |
| Hay Bay South | Open Bay | 32 | 43 |
| South Bay | Open Bay | 28 | 36 |
| Robinson Cove | Open Bay | 20 | 35 |
| Port Britain | Barrier Beach | 10 | 18 |
| Lynde Creek | Barrier Beach | 15 | 30 |
| Huyck's Bay | Barrier Beach | 12 | 26 |
| Frenchman's Bay | Barrier Beach | 7 | 14 |

A one-way ANOVA revealed that there was a significant difference (Figure 6-1) in mean species richness among wetland zones ($F_{2, 27}$=12.524, p=0.00014). Tukey's HSD determined that meadow marsh zones (mean ± SD=20.55 ± 6.73) had a higher species richness than emergent zones (11.17 ± 4.72) and submerged zones (9.67 ± 3.31).

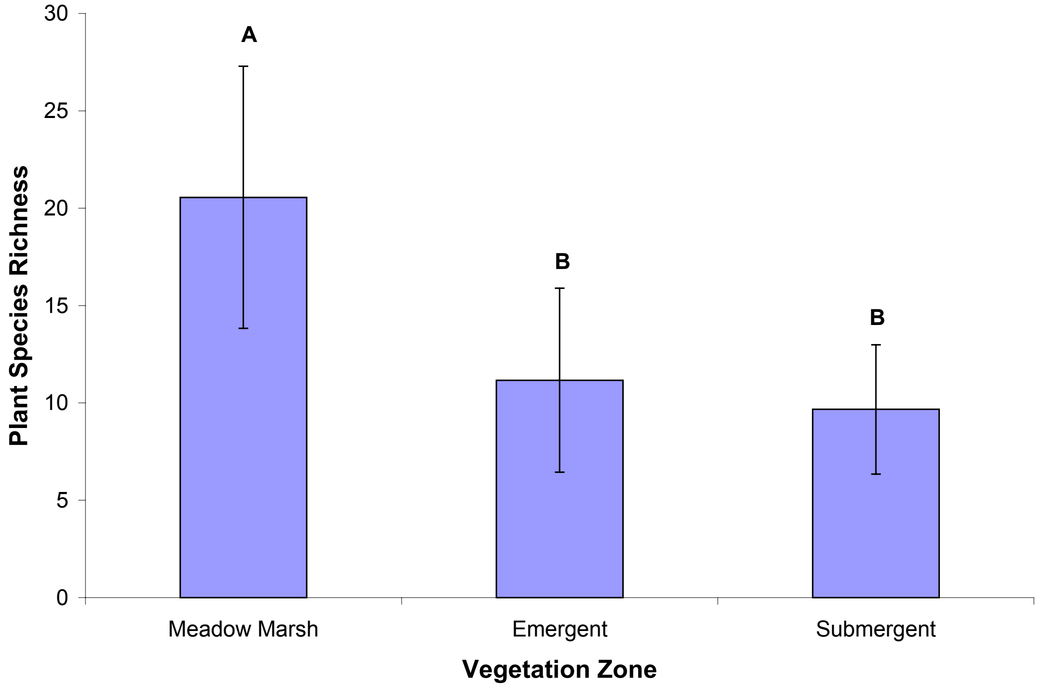



Figure 6-1. The mean species richness ± SD per site in three vegetation zones. Different letters above bars denote significant differences

### 6.1.2 Floristic Quality Assessment

Floristic quality indices (Figure 6-2) are influenced by the species richness measures. Similar to species richness, a one-way ANOVA revealed that there was a significant difference in mean FQIs among wetland zones ($F_{2, 27}$=6.18, p=0.006). Again, Tukey's HSD determined that meadow marsh zones (mean ± SD=17.98 ± 5.71) had a higher FQIs than emergent zones (11.18 ± 4.26) and submerged zones (12.40 ±3.48).

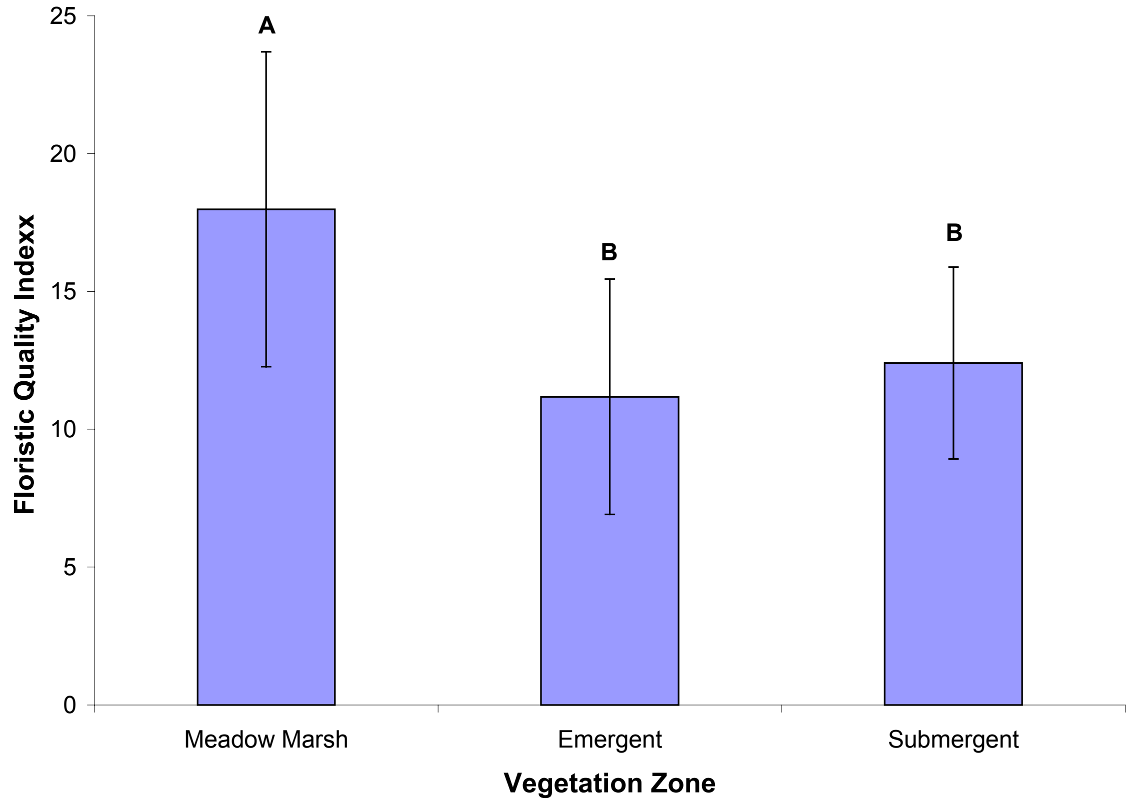



Figure 6-2. The floristic quality index ± SD per site in three vegetation zones. Different letters above bars denote significant differences.

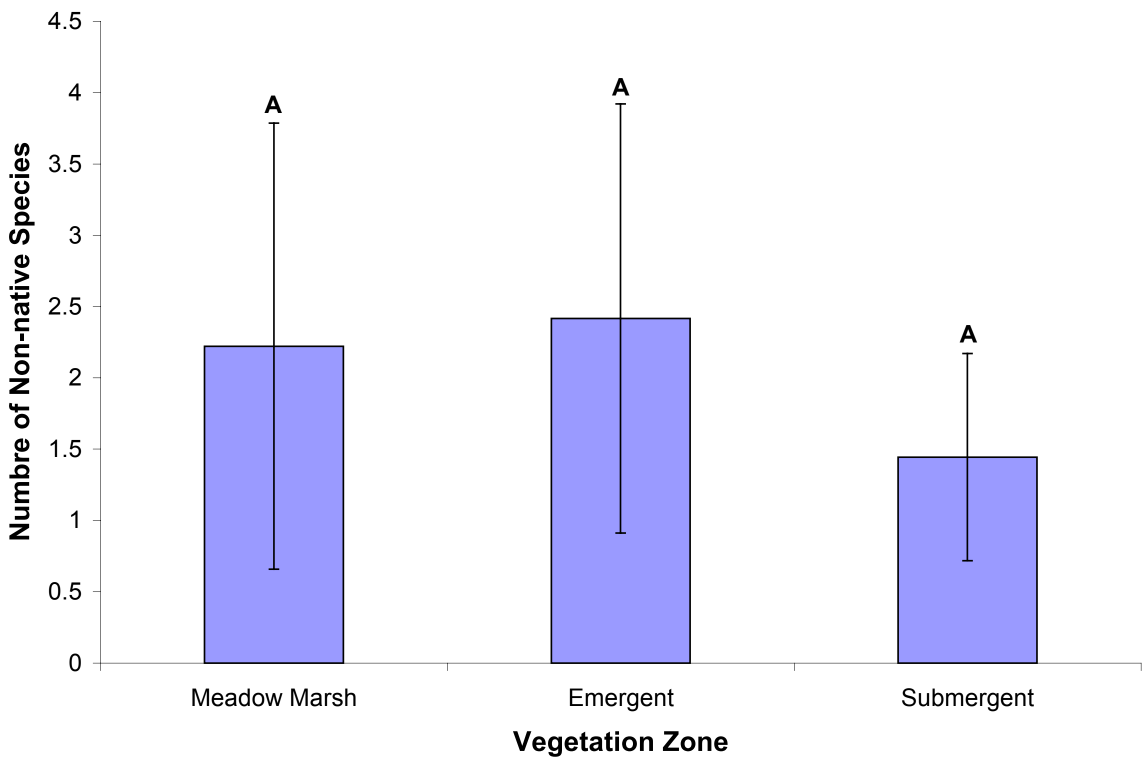



Figure 6-3. The number of non-native species per site ± SD in three vegetation zones. Different letters above bars denote significant differences.

6.1.3 Vegetation Density of Natives and Non-natives

The mean number of non-native (Figure 6-3) species in each zone did not differ among meadow marsh (2.22 ± 1.56) emergent (2.41 ± 1.51) and submerged (1.44 ± 0.72) zones ($F_{2, 27}$=1.43, p=0.26).

The mean vegetation coverage within the quadrats was quite variable within meadow marsh (92.42 ± 11.29), emergent (79.91 ± 29.77) and submerged (84.94 ± 25.28) zones and hence did not differ significantly ($F_{2, 27}$=0.684, p=0.51).

A Kruskal-Wallis ANOVA by Ranks test indicated that there was a significant difference in the coverage of non-native species among zones ($H_{(2, N= 30)}$ =11.59, p=0.003). A subsequent 2-tailed multiple comparison of p- values determined that the coverage of non-native plants in the emergent quadrats was higher than in the meadow marsh and submerged quadrats.

6.1.4 Testing Plant Community Metrics Against Site Disturbance

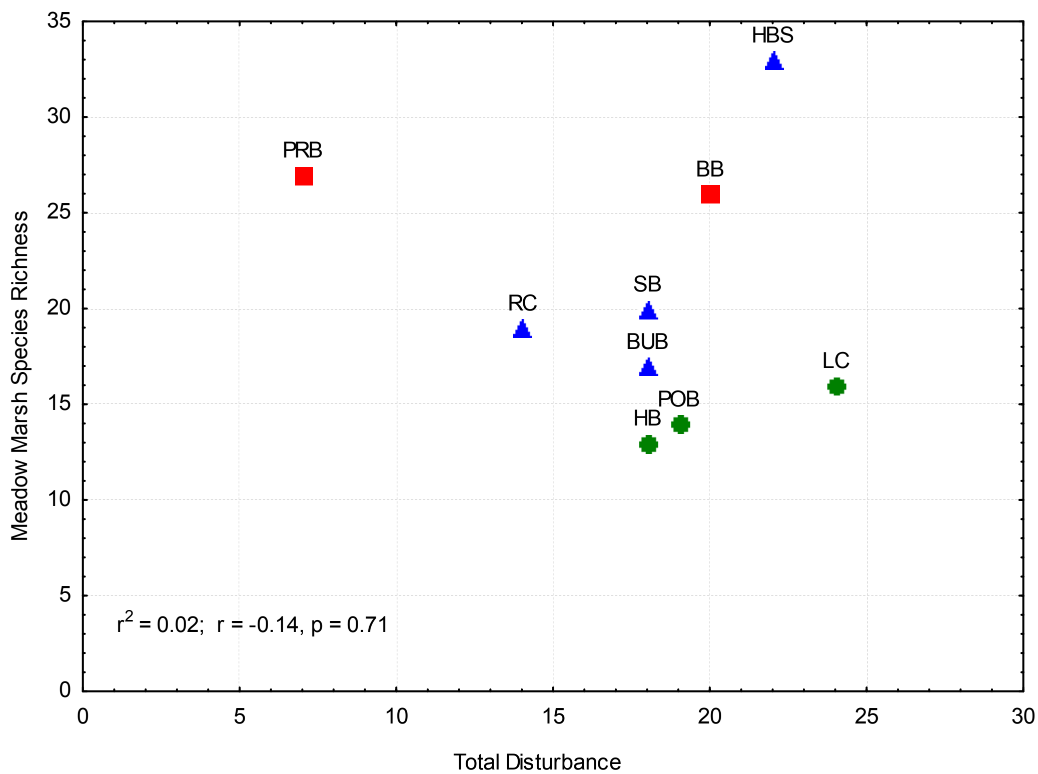
Plant community metric evaluation within this report should be considered preliminary. The Michigan research team has included the Lake Ontario data into a larger Great Lakes coastal wetland database. As proposed in the collaborative Year 1 pilot projects, the Michigan research team will complete a full indicator statistical analysis. This integrated evaluation and report will provide a more definitive conclusion regarding metric sensitivity.

A series of plant community metrics previously published as suitable for use in wetland IBIs were plotted against disturbance ranking for each vegetation zone within a site and for the entire site. Metrics that were evaluated included species richness (Figure 6-4), Floristic Quality Index (Figure 6-5), non-native species richness (Figure 6-6), mean percent vegetation cover (Figure 6-7), and the mean percent cover of non-native species (Figure 6-8).

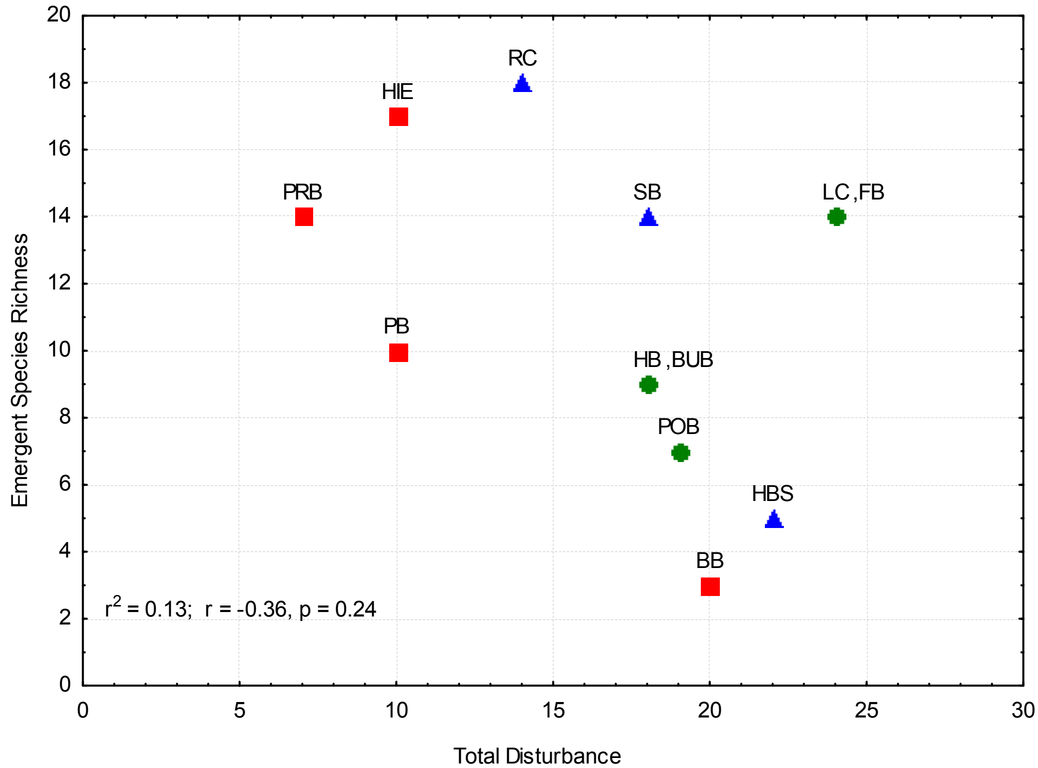
*6.1.4.1 Plant Species Richness*

Plant species richness within any of the vegetation zones or the entire site was not significantly associated with the amount of disturbance at the site (Figure 6-4) and showed limited sensitivity to wetland condition.

A

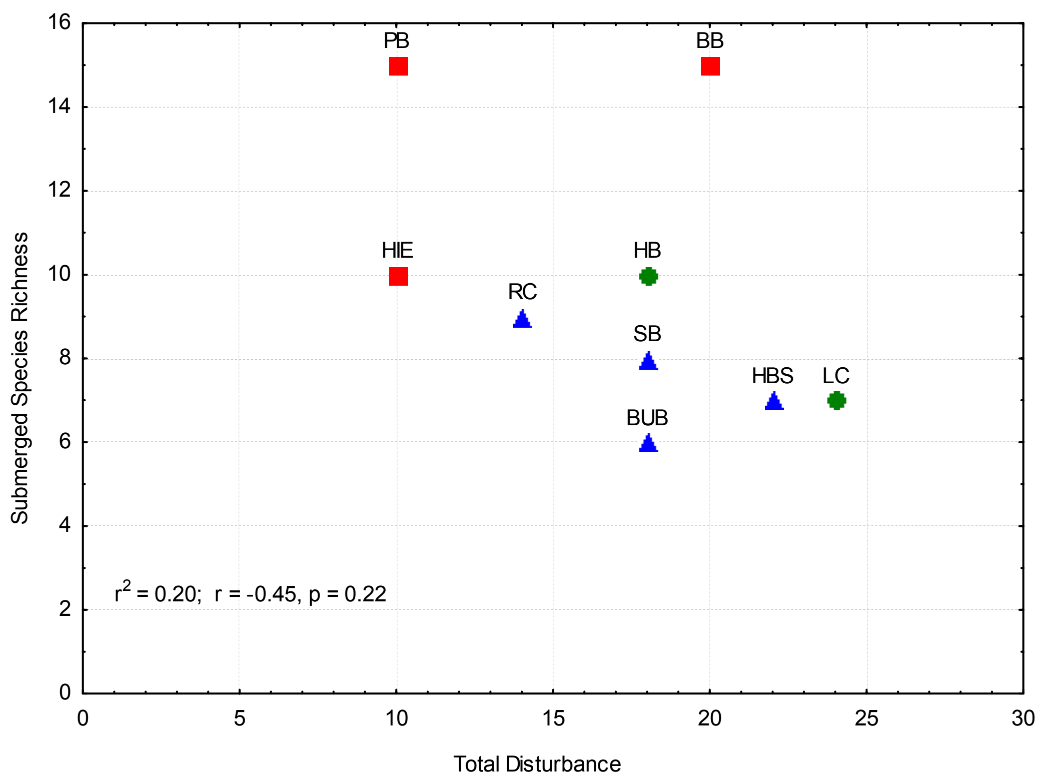


B



Emergent Species Richness
Total Disturbance
RC
HIE
PRB
SB
LC ,FB
PB
HB ,BUB
POB
HBS
BB
r2 = 0.13; r = -0.36, p = 0.24


C



Submerged Species Richness
Total Disturbance
PB
BB
HIE
HB
RC
SB
HBS
LC
BUB
r2 = 0.20; r = -0.45, p = 0.22

D

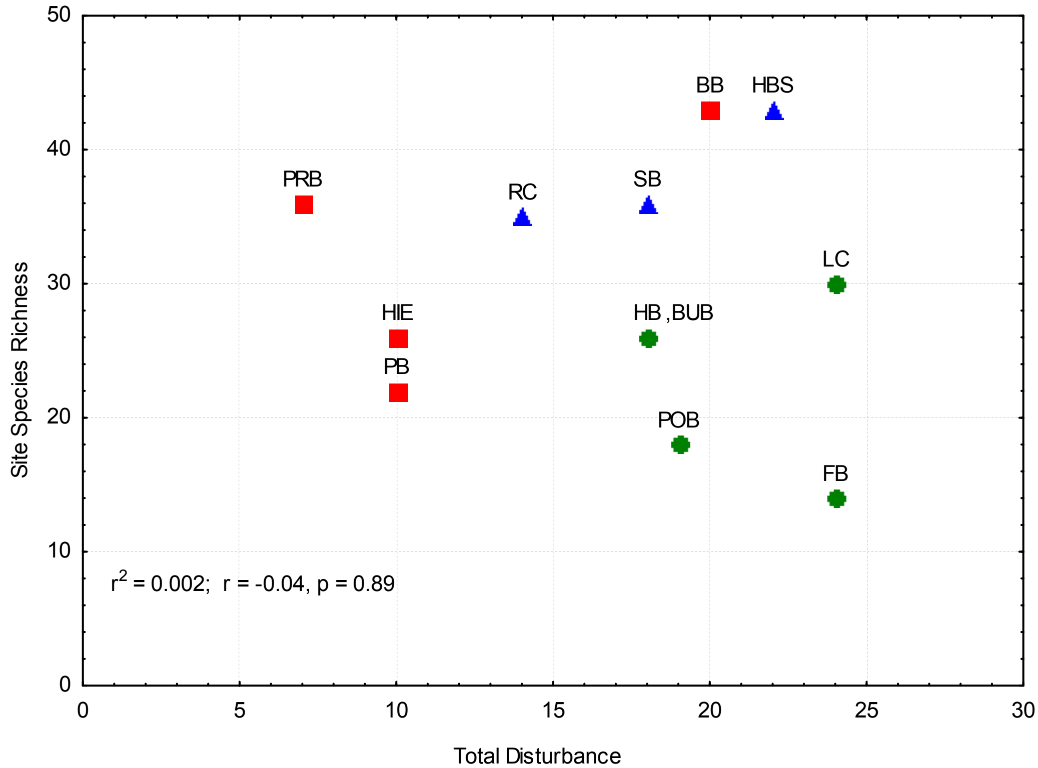
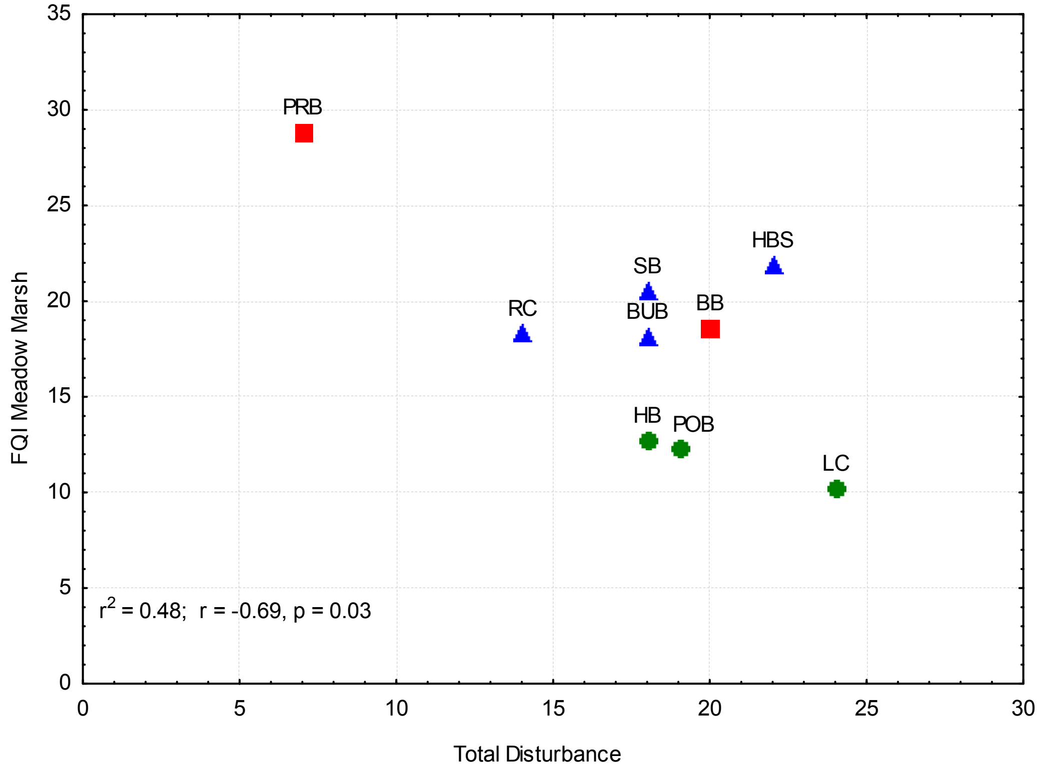



Figure 6-4. The relationship between plant species richness (quadrats and incidental sightings) of A) meadow marsh, B) emergent, C) submerged, and D) entire wetland vegetation communities and site disturbance at Lake Ontario and St. Lawrence River coastal wetlands. Symbols denote wetland geomorphic type: =barrier beach, =open bay, =protected bay. Data points are labeled with wetland site name acronyms (See Table 1-1)

*6.1.4.2 Floristic Quality Indices*

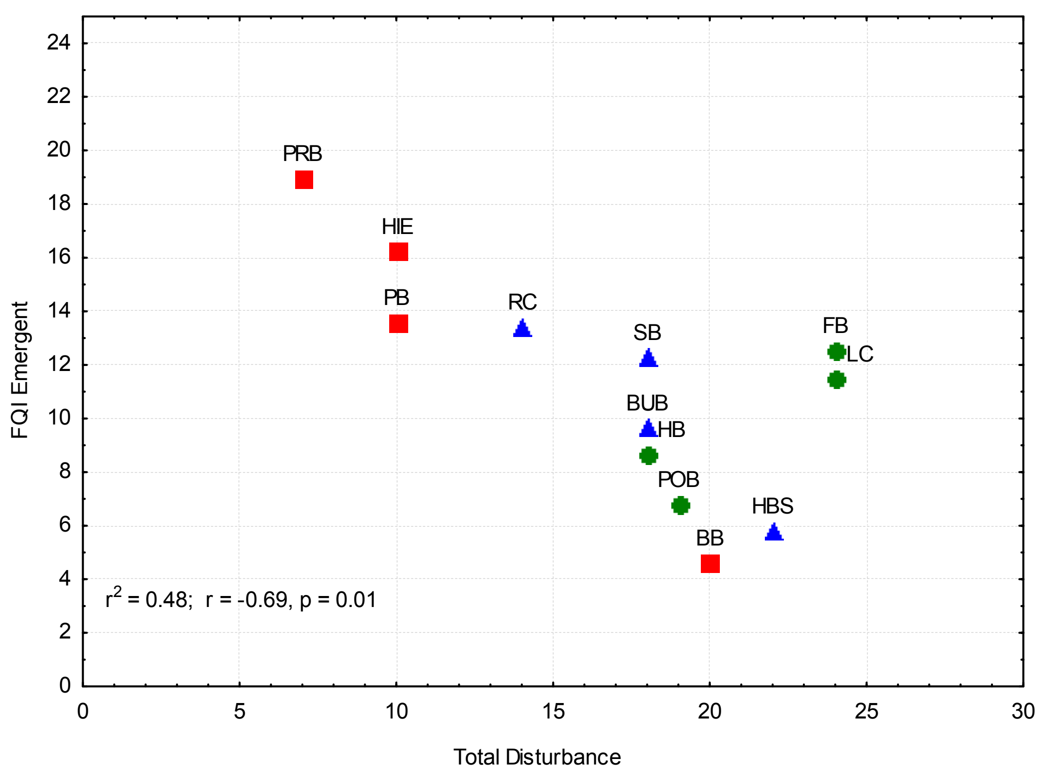
All Floristic Quality Indices that were tested were negatively correlated with site disturbance. However, only meadow marsh (Figure 6-5A) and emergent (Figure 6-5B) FQIs showed significant, somewhat strong, relationships with the level of disturbance at the site.

A



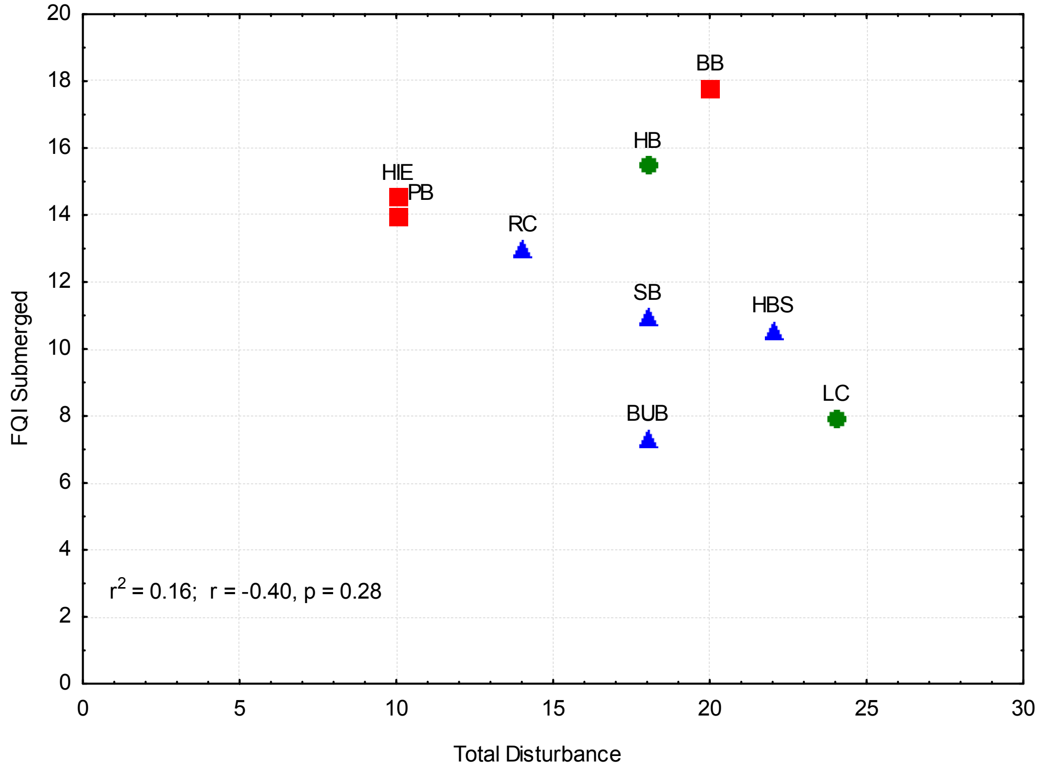
FQI Meadow Marsh
Total Disturbance
PRB
HBS
SB
RC
BUB
BB
HB
POB
LC
$r^2$ = 0.48; r = -0.69, p = 0.03


B



FQI Emergent
Total Disturbance
PRB
HIE
PB
RC
SB
FB
LC
BUB
HB
POB
HBS
BB
$r^2$ = 0.48; r = -0.69, p = 0.01

C




D

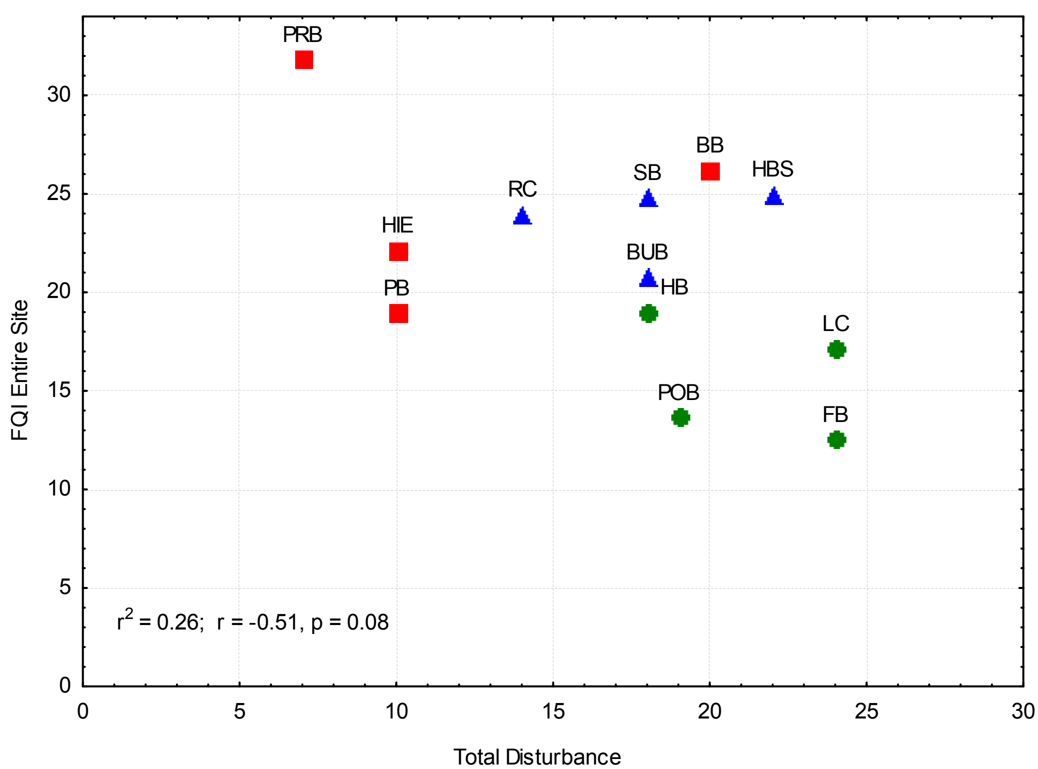
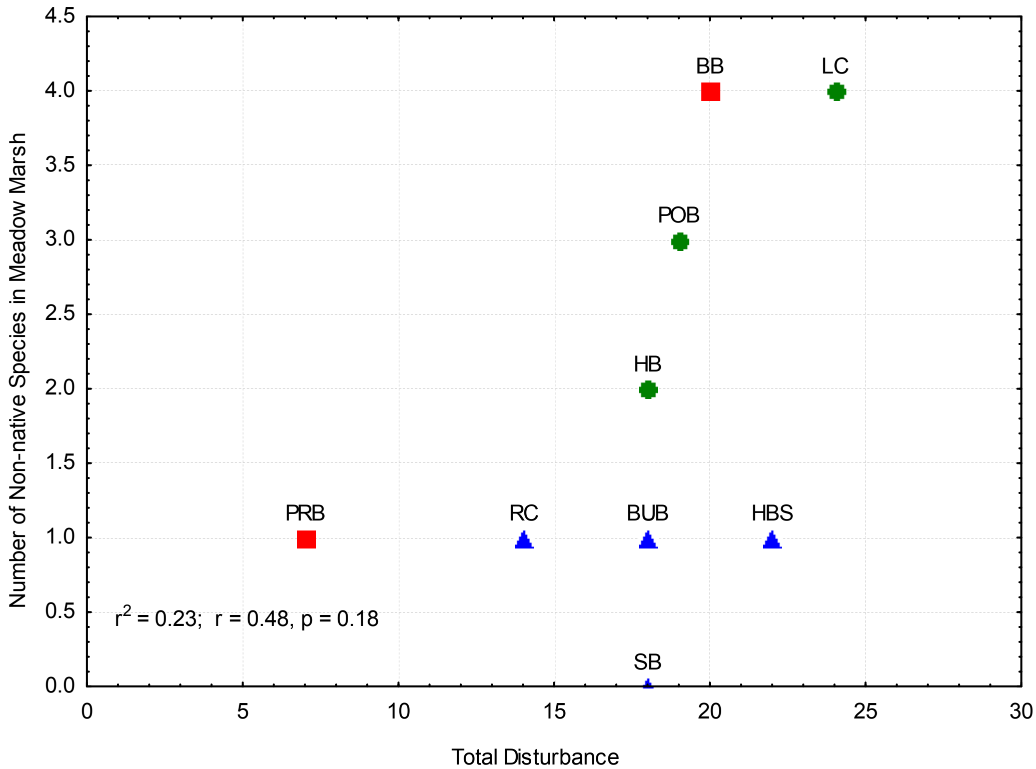



Figure 6-5. The relationship between Floristic Quality Indices of A) meadow marsh, B) emergent, C) submerged, and D) entire wetland vegetation communities and site disturbance at Lake Ontario and St.

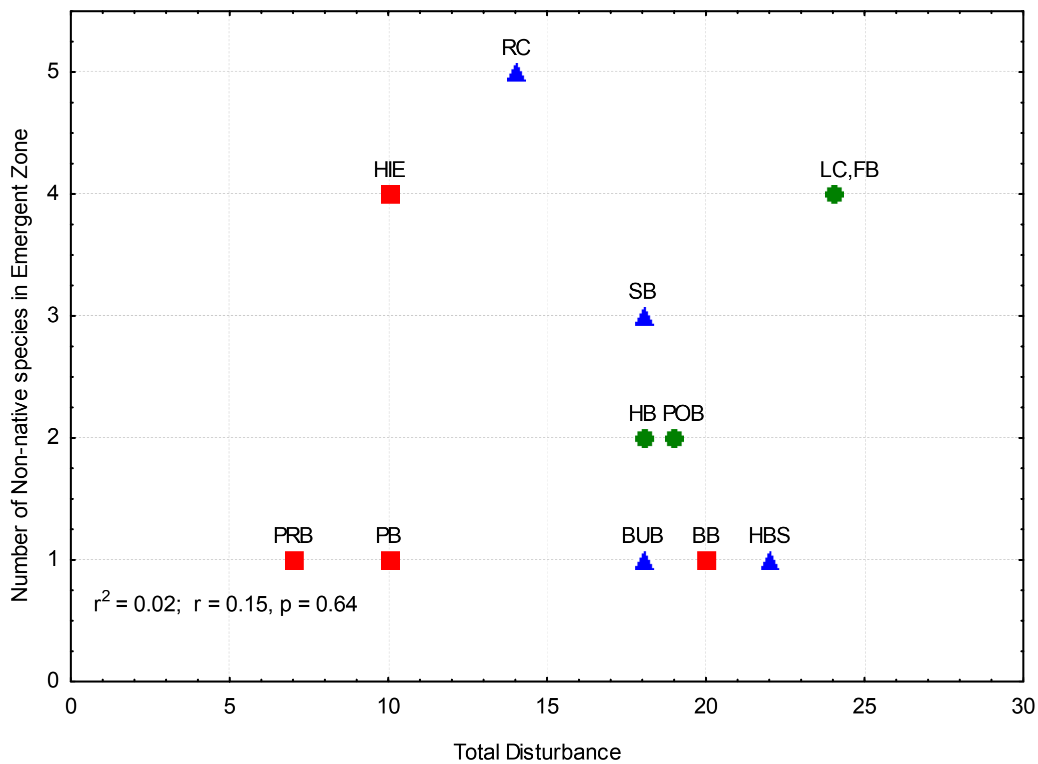
Lawrence River coastal wetlands. Symbols denote wetland geomorphic type: =barrier beach, =open bay, =protected bay. Data points are labeled with wetland site name acronyms (See Table 1-1)

*6.1.4.3 Number of Non-native Species*
There was not a significant relationship between the number of non-native species in each zone and the level of disturbance at the site. However, as disturbance was increased among sites, the number of non-native plant species within the site increased significantly (Figure 6-6).

A

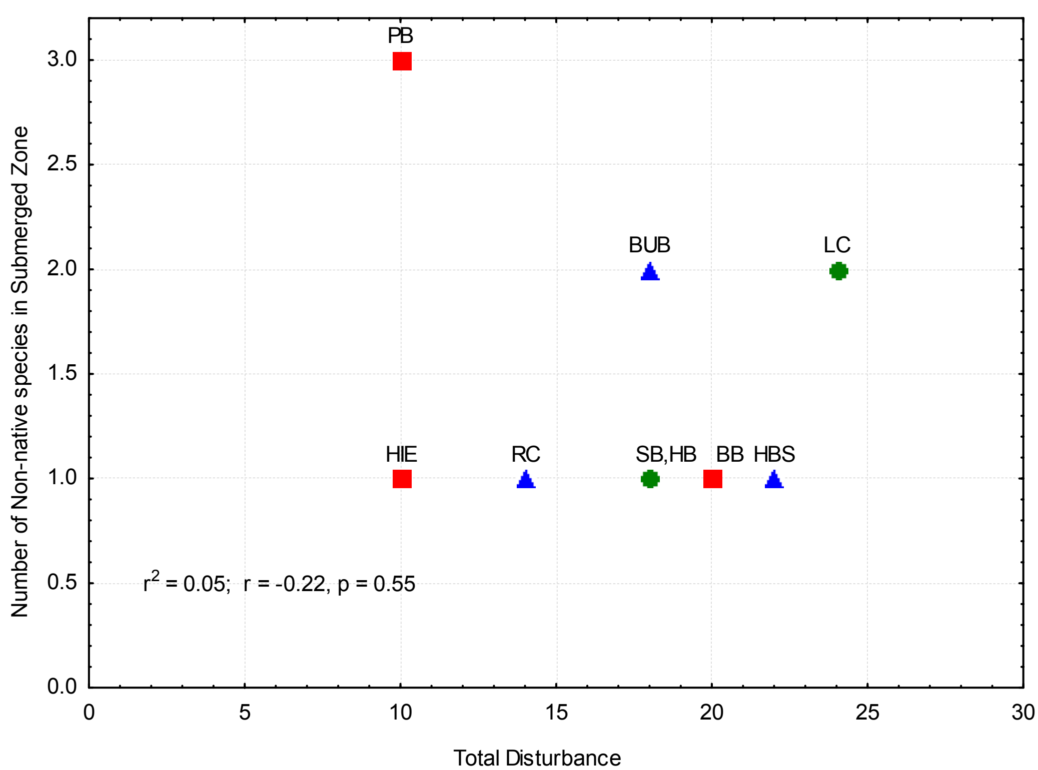


B



RC
HIE
LC,FB
SB
HB POB
PRB
PB
BUB
BB
HBS
$r^2$ = 0.02; r = 0.15, p = 0.64
Number of Non-native species in Emergent Zone
Total Disturbance
0
1
2
3
4
5
0
5
10
15
20
25
30


C



PB
BUB
LC
HIE
RC
SB,HB
BB
HBS
$r^2$ = 0.05; r = -0.22, p = 0.55
Number of Non-native species in Submerged Zone
Total Disturbance
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
5
10
15
20
25
30

D

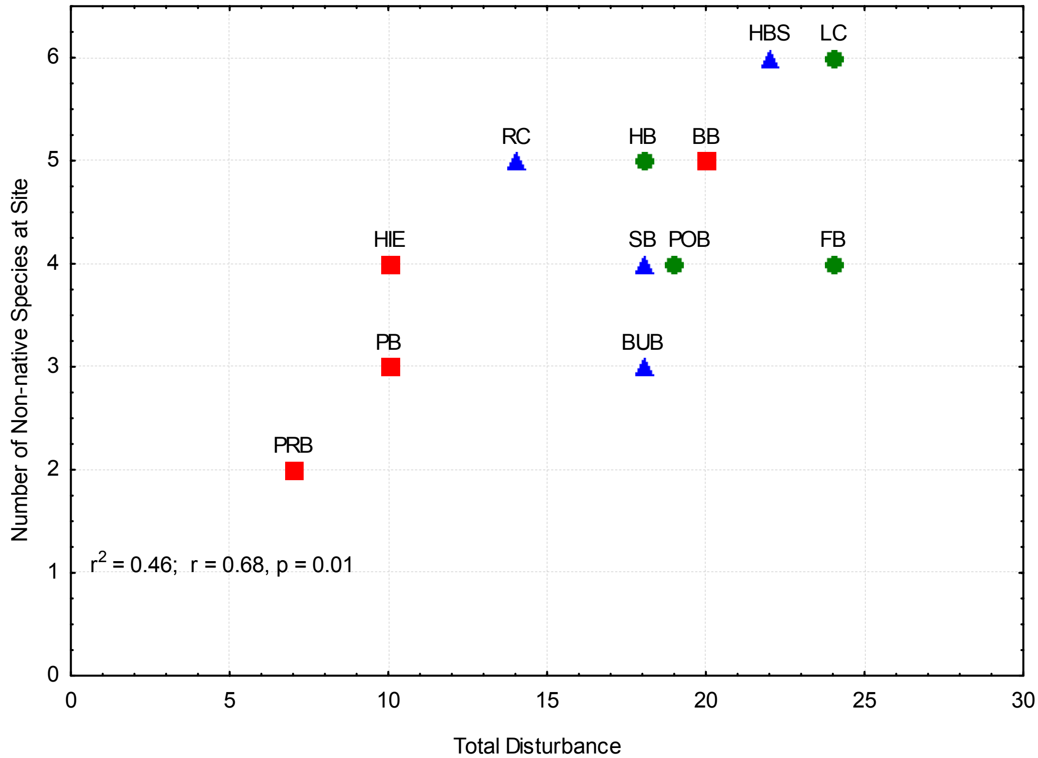
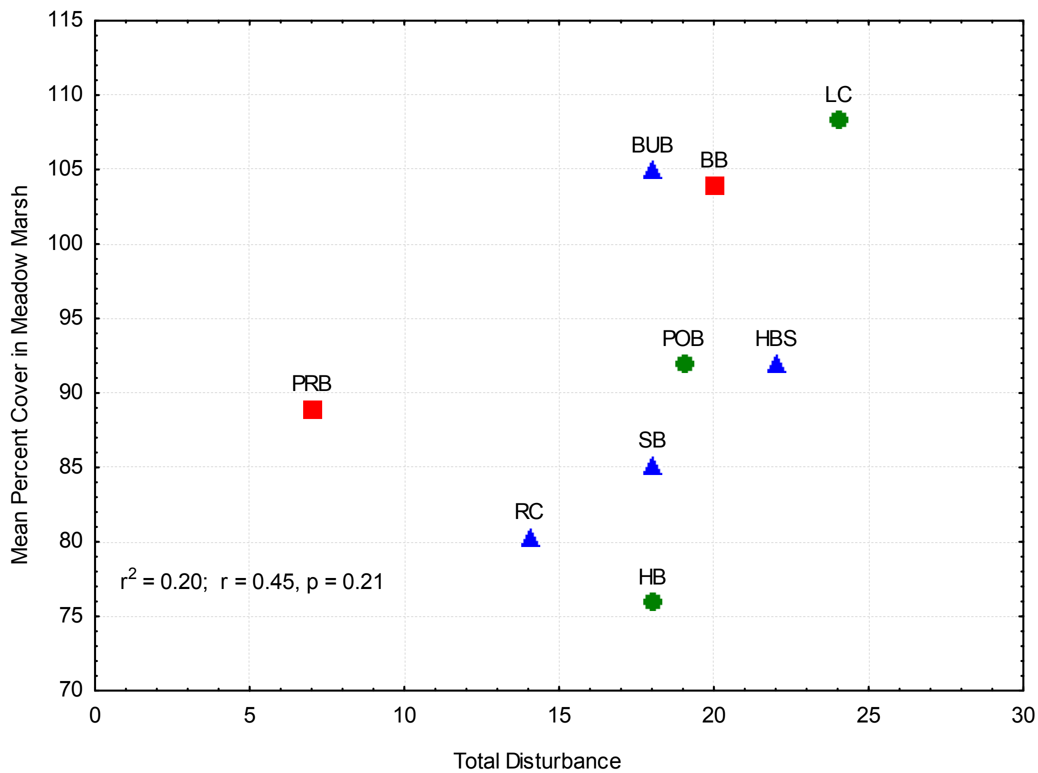



Figure 6-6. The relationship between the non-native species richness of A) meadow marsh, B) emergent, C) submerged, and D) entire wetland vegetation communities and site disturbance at Lake Ontario and St. Lawrence River coastal wetlands. Symbols denote wetland geomorphic type: =barrier beach, =open bay, =protected bay. Data points are labeled with wetland site name acronyms (See Table 1-1)

*6.1.4.4 Vegetation Cover*

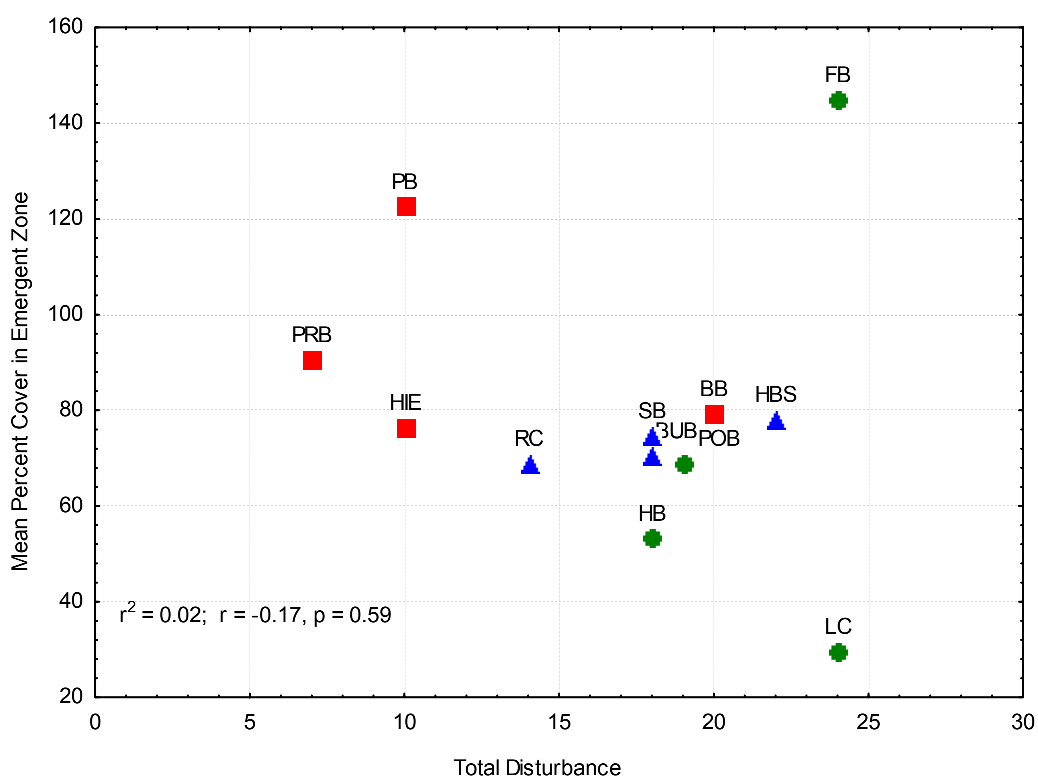
The mean percent vegetation cover within wetland vegetation zones and the entire site were not significantly related to the level of disturbance at the sites (Figure 6-7).

A



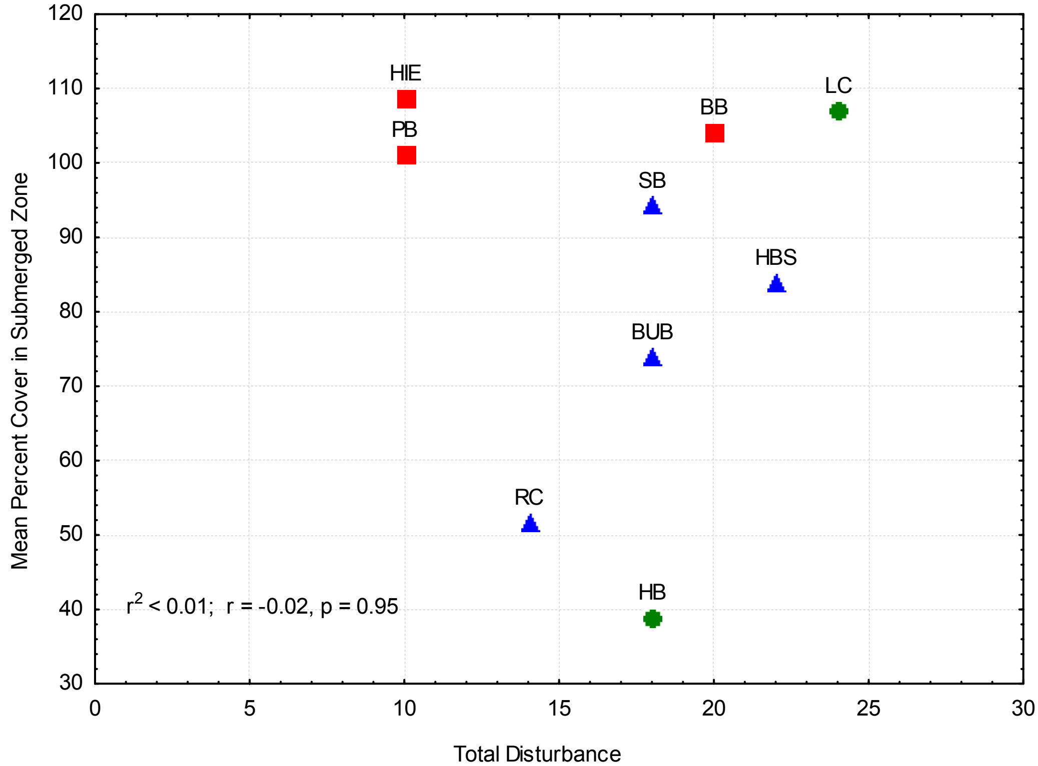
Mean Percent Cover in Meadow Marsh
Total Disturbance
LC
BUB
BB
POB
HBS
PRB
SB
RC
HB
$r^2$ = 0.20; r = 0.45, p = 0.21


B



Mean Percent Cover in Emergent Zone
Total Disturbance
FB
PB
PRB
HIE
RC
SB
BUB
BB
POB
HBS
HB
LC
$r^2$ = 0.02; r = -0.17, p = 0.59

C




D

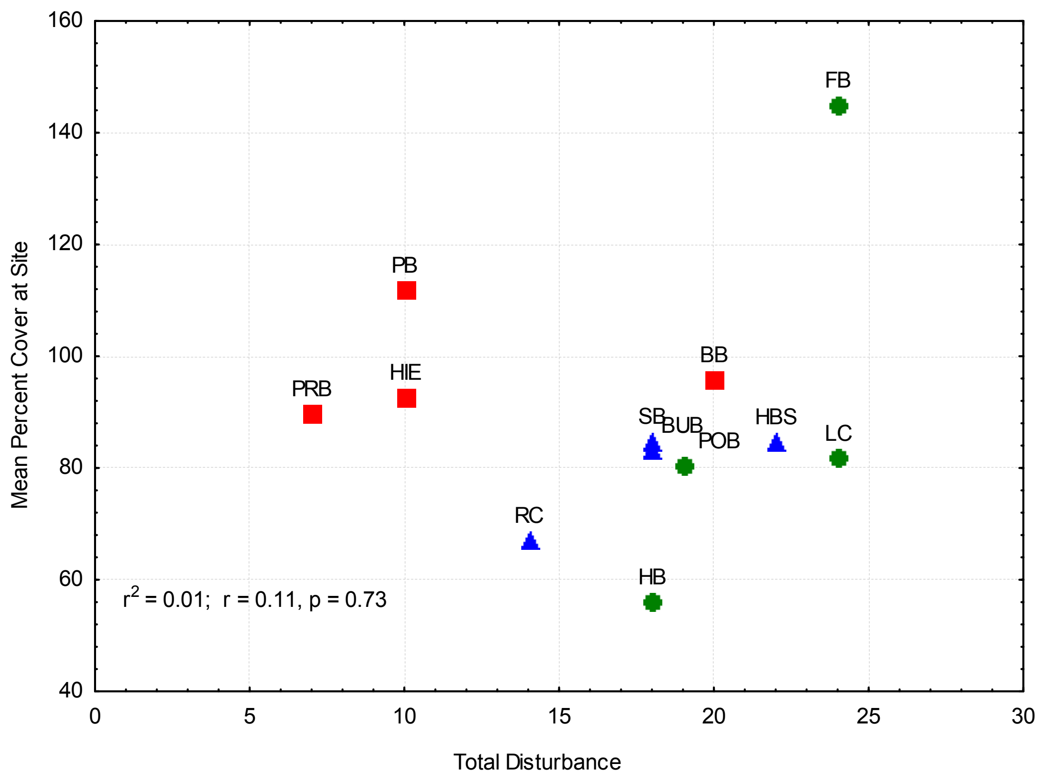


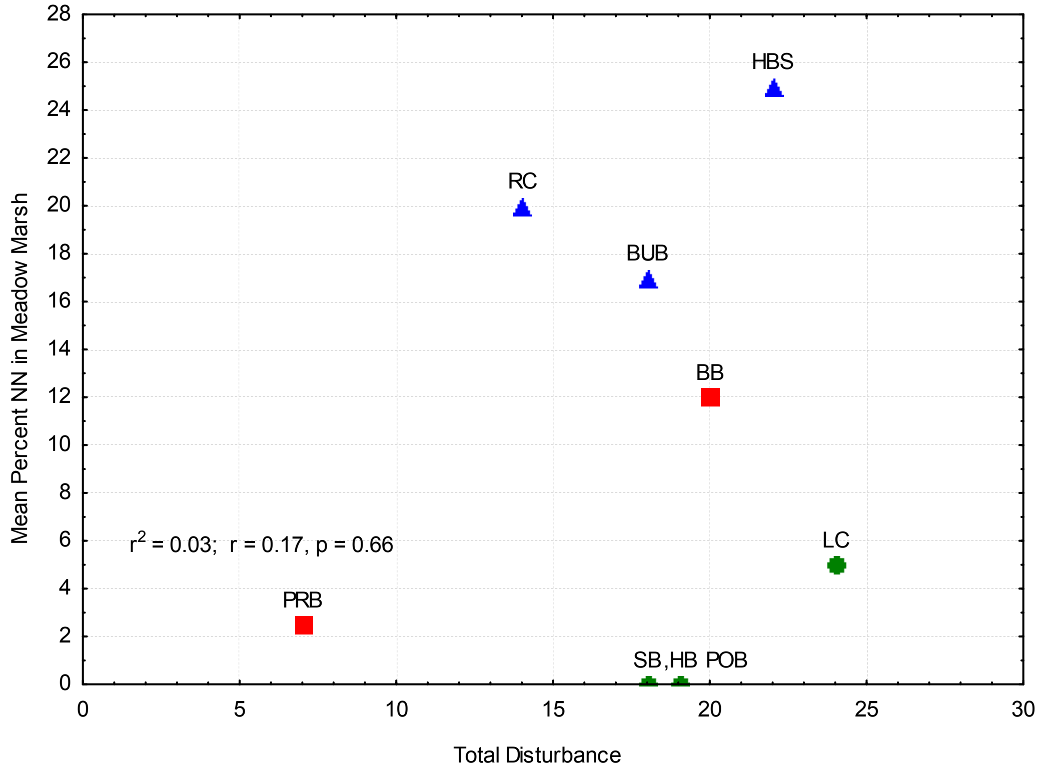

Figure 6-7. The relationship between mean percent vegetation cover of A) meadow marsh, B) emergent, C) submerged, and D) entire wetland vegetation communities and site disturbance at Lake Ontario and St. Lawrence River coastal wetlands. Symbols denote wetland geomorphic type: =barrier beach,

=open bay,   =protected bay.  Data points are labeled with wetland site name acronyms (See Table 1-1)

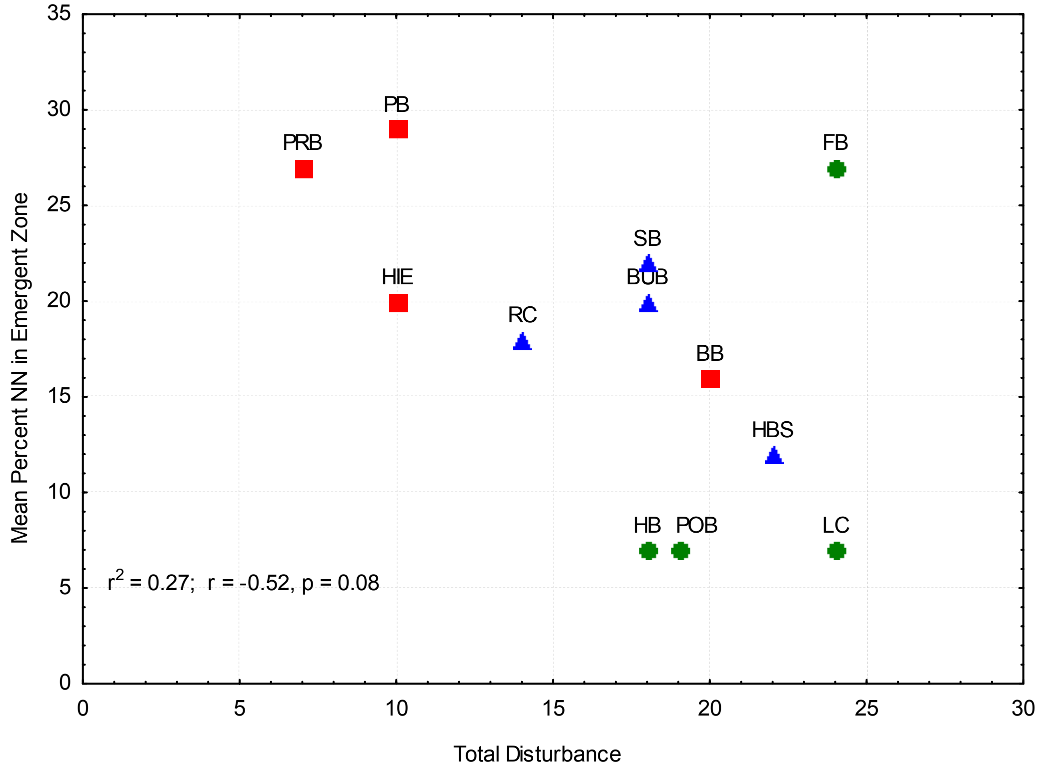
*6.1.4.4     Cover of Non-native Species*

The mean percent cover of non-native species with wetland vegetation zones and the entire wetland did not show a significant relationship with the amount of disturbance experienced by the site (Figure 6-8). Mean percent cover of non-native species in the emergent zone to show some sensitivity to wetland condition.

A

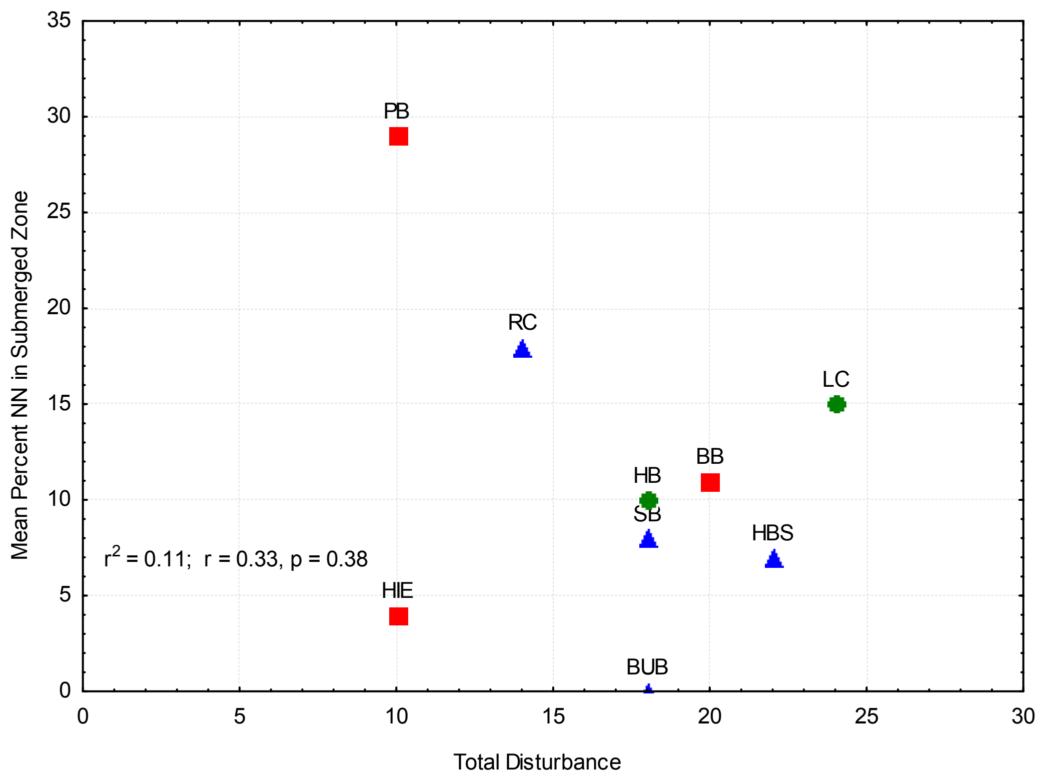


B



Mean Percent NN in Emergent Zone
Total Disturbance
PRB
PB
FB
SB
HIE
BUB
RC
BB
HBS
HB
POB
LC
$r^2$ = 0.27; r = -0.52, p = 0.08


C



Mean Percent NN in Submerged Zone
Total Disturbance
PB
RC
LC
BB
HB
SB
HBS
HIE
BUB
$r^2$ = 0.11; r = 0.33, p = 0.38

D

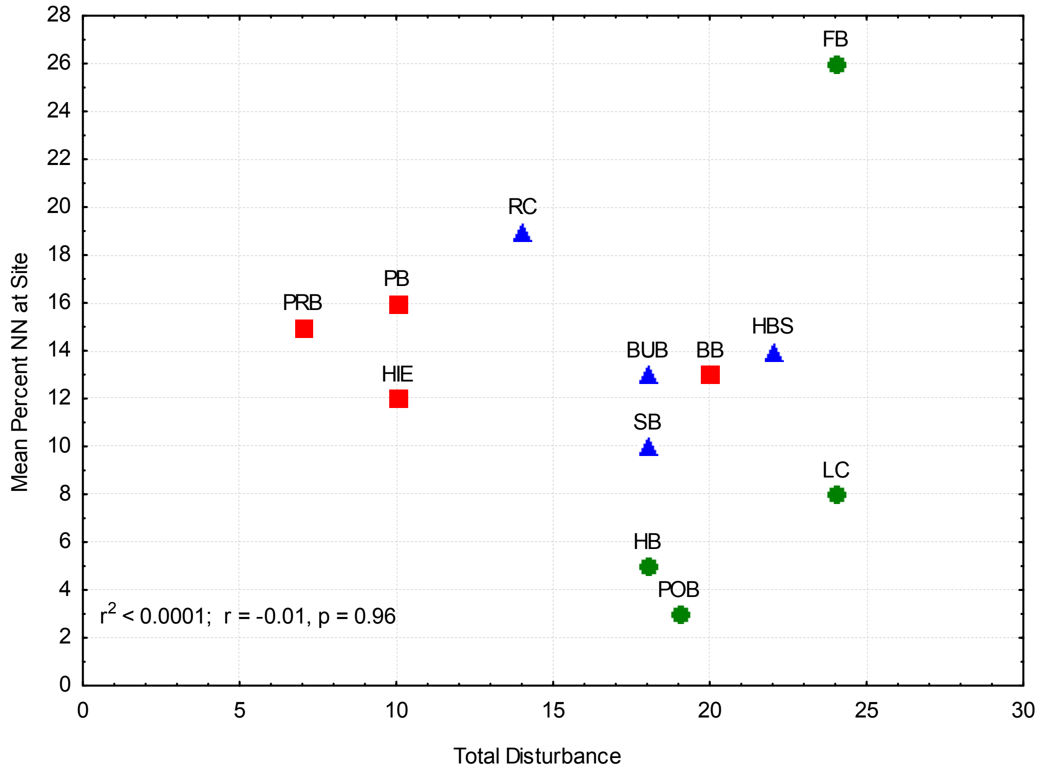



Figure 6-8. The relationship between mean percent cover of non-native plant species of A) meadow marsh, B) emergent, C) submerged, and D) entire wetland vegetation communities and site disturbance at Lake Ontario and St. Lawrence River coastal wetlands. Symbols denote wetland geomorphic type: =barrier beach, =open bay, =protected bay. Data points are labeled with wetland site name acronyms (See Table 1-1)

## 6.2 Discussion

### 6.2.1 Species Richness

Quadrat sampling identified 59.5% ± 10.8% of the species that were identified using combined quadrat sampling and incidental species observations. The range of total species richness in the study wetlands was 14 (Frenchman's Bay) to 43 (Bayfield Bay) species. Using more rigorous quadrat sampling methods, with no incidental plant species observations, Wilcox et al. (2002) found a higher range of native species in Lake Michigan drowned rivermouth coastal wetlands (44-68, n=6) and Lake Superior barrier beach wetlands (32-66, n=6). Additionally, a complete aquatic plant inventory by Cecile (1983) found 361 plant species in Oshawa Second Marsh, a barrier beach wetland approximately 12 km west of Lynde Creek. Although, the number of taxa identified throughout the wetlands is considerably less than the actual species richness, the methods were designed with a recognition of implementation feasibility within a Great Lakes coastal wetlands monitoring program and thus considered a rapid assessment approach. The species richness measure is considered a relative estimate for comparison within wetlands of similar wetland types. This study considered only the species richness generated from quadrat/incidental sampling for metric testing. Whether the species richness measure generated from the number of species identified by quadrat only or by quadrat/incidental observation represents a more suitable metric for wetland health, shall be determined by comparing the relationship of each measure with the disturbance at the site. This comparison has been undertaken by the Michigan research team.

There were significantly more species identified in meadow marshes than other zones. At wetlands where meadow marsh zone of a wetland was sampled, species identified in the meadow marsh accounted for more than half (mean=60.5% ± 12.0 SD) of the overall species richness. Meadow marsh zones have increased species richness because this zone represents a transition zone between terrestrial and aquatic habitats and, as such, may include a suite of species that are tolerant of a wide range of soil moistures. In contrast, emergent and submerged zones support only obligate wetland species. However, disproportionately more species may have been observed in the meadow marsh zone because plant species are easier to find than in emergent and submerged zones due to sight barriers not present in the meadow marsh zone. For example, in the meadow marsh, additional species were often spotted from a distance of approximately five meters whereas water (glare and turbidity) in the submerged zone and dense cattails in the emergent zone would often prevent this from happening.

Plant species richness within each zone of the wetland and within the entire site does not appear to be sensitive to different levels of disturbance among the wetlands. The current data suggest that, under the current methodology, plant species richness is not a suitable metric for use in coastal wetland IBIs. However, the analysis of the larger data set by the Michigan research team should provide a more definitive indication of species richness metric suitability. Although Wilcox et al. (2002) did not identify total plant species richness as a suitable metric, the number of native taxa was used as a metric. Wilcox et al. (2002) also used measures of percent obligate wetland species as a metric, which was not considered in this study.

### 6.2.2 Floristic Quality Assessment

Floristic Quality Indices for the wetlands in this study ranged from 12.5 (Frenchman's Bay) to 31.8 (Presqu'ile Bay). Wilcox et al (2002) found a range of 25.5 - 31.0 (n=6) in Lake Michigan drowned rivermouths and 18.5 – 61.4 (n=6) in Lake Superior barrier beaches. Lopez and Fennessy (2002) found a range of 18 – 37 (n=20) in depressional wetlands in Ohio. In these studies, FQIs were calculated using coefficients of conservatism that were region specific. Similarly, this study used a system that was devised for southern Ontario. Therefore, FQIs among these studies may not be directly comparable due to variability of coefficients of conservatism and sampling effort. For FQIs to be useful metrics in the development of wetland plant community IBI's, consistent binational, basin-wide coefficients of conservatism for wetland plants require development.

The FQI in meadow marshes was higher than emergent and submerged zones. In sites where all zones were sampled, the FQI in the meadow marsh zone was on average 76.05 ± 10.86% SD of the FQI for the entire site. When used as metrics of wetland health, Lopez and Fennessy (2002) found that human disturbance negatively influenced the FQI of depressional wetlands in Ohio, and Wilcox et al. (2002) found the same trend in Lake Michigan drowned rivermouth Lake Superior barrier beach coastal wetlands. In this study, the FQI within the meadow marsh and emergent zone decreased with an increased level of disturbance experienced by coastal wetlands. The strength of the relationship was equal for both metrics (r=-0.69). These results indicate that FQIs for meadow marshes and emergent zones in Lake Ontario and St. Lawrence River coastal wetlands are suitable metrics for IBI development.

However, following the current methodology, meadow marsh zones in some wetlands were not sampled because the amount of meadow marsh present was not deemed sufficient. Of the three wetlands where the meadow marsh was not sampled, two of the sites (Frenchman's Bay and Hill Island East) did have some sections of meadow marsh. Although these meadow marsh zones were not present in sufficient amount to contain a transect for quadrat sampling, sufficient data may have been collected within the patches of meadow marsh to provide FQI estimates for these areas. Conversely, steep banks along Parrott's Bay did not afford any noticeable area of meadow marsh. Although the FQI from meadow marshes appears to be a suitable metric for coastal wetland IBI development, the variable presence and extent of this zone among wetlands should be considered.

In contrast, all of the study sites contained ample quantities of the emergent vegetation zone for sampling. This zone is likely the most reliable and consistent source of FQI data among Lake Ontario and St. Lawrence River Coastal wetlands.

### 6.2.3 Vegetation Density and Non-native species Richness

Although the mean number of non-native species and mean total vegetation coverage was not significantly different among zones, the mean percent coverage of non-natives was significantly higher in the emergent zone. This trend was driven by the presence of European frogbit (*Hydorcharis morsus-ranae*) in the emergent zone. When there were non-native plants present within a quadrat in the emergent zone, European frogbit comprised 96.2% of the area covered by non-native plants. Although this plant contributed considerably to the cover in the quadrat it would only represent a small fraction of the biomass in quadrat, due to its thin, broad leaves. Nonetheless, the coverage of non-native plant species, site-wide or within the various vegetation zones, did not appear sensitive to the degree of disturbance at the site. As such, this metric may not be suitable for coastal wetland IBI development using the methodology employed.

Although the non-native species richness within each vegetation zone showed little sensitivity to wetland condition, when evaluated at the site level, there was a strong significant increase in non-native species richness with an increase in disturbance. This indicates that the number non-native plant species richness may be a suitable metric for coastal wetland IBI development.

In contrast, the mean total vegetation cover was not sensitive to disturbance at the 12 coastal wetland sites and does not appear to be a suitable metric. Wilcox et al. (2002) used metrics such as the sum of the mean percent cover per quadrat by a) turbidity tolerant taxa in the submerged zone and b) invasive taxa in the *Carex* vegetation type. Using the methodology developed for this study, the sum of the mean percent cover per quadrat of turbidity tolerant taxa in the submerged zone could be calculated.

As stated previously, integration and analysis of Lake Ontario and St. Lawrence River data with other Great Lakes coastal wetland data that is underway by the Michigan research team will provide more conclusive results with respect to a suitable suite of plant community metrics that could be utilized within a coastal wetland plant community IBI.

## 6.3 Cost

### 6.3.1 Equipment

Table 6-3 lists the equipment costs associated with completing plant community quadrat sampling in coastal wetlands. The costs are broken down into consumables (one-time use) and non-consumables (used multiple times). In the case of a long-term program, the non-consumable equipment will represent one-time or occasional (*i.e.* when replacement is necessary) costs.

Table 6-3. Equipment costs required to conduct plant quadrat sampling in 12 Lake Ontario and St. Lawrence River coastal wetlands (C=Consumable, N=Non-consumable)

| Item | Cost ($CAD) | C/N |
|---|---|---|
| Canoe[1,2] | 1200 | N |
| Paddles[1,2] | 40 | N |
| Lifejackets[1,2] | 80 | N |
| Boat safety kit[1,2] | 20 | N |
| 14' Flat-bottomed boat | 1400 | N |
| 6 Hp 4-stroke outboard motor | 2200 | N |
| Gasoline for boat motor | 50 | Y |
| Electric motor[3] | 200 | N |
| 2 x 12 Volt battery[3] | 200 | N |
| Battery charger[3] | 30 | N |
| Boat anchor with rope[1,2] | 15 | N |
| Hip/chest waders | 200 | N |
| Metal conduit for depth measurements | 2 | N |
| Duct tape | 4 | C |
| GPS Unit | 150 | N |
| Topographical maps/air photos | 220 | N |
| Compass | 20 | N |
| Plastic specimen bags (Ziplocs) | 5 | C |
| Hand lens | 5 | N |
| Clipboard | 5 | N |
| Pens/pencils (waterproof) | 5 | C |

| | | |
|---|---|---|
| Back pack/fanny pack | 30 | N |
| Plant press | 40 | N |
| Quadrat frame | 10 | N |
| Field guides & taxonomic keys | 250 | N |
| Total | 6381 | |

Superscripts indicated equipment shared with other sampling tasks: 1=invertebrate, 2=water chemistry, 3=fish

Sampling submerged zones required the use of a boat or canoe, and hence represented a much greater cost. Sampling of the wet meadow and the emergent zones did not require this equipment, except in situations where access to suitable sampling areas in these zones was greatly facilitated by, or only possible with, the use of such items.

#### 6.3.2 Personnel

Two workers, a lead researcher and an assistant, conducted the vegetation community sampling at all of the wetlands. Between two and four hours per site were required to complete plant community sampling. Although not all sites supported all three vegetation zones, the majority of the variation in sampling time is related to differing suitability of access points to the wetland and ease mobility within the site. Some variation in sampling time is related to the complexity of plant communities within the site. In general, the meadow marsh zone was the most complex and therefore took the longest time to sample.

### 6.4 Measurability

#### 6.4.1 Expertise and Training

The lead field researcher should be very familiar with coastal wetland plant communities, possess strong plant identification skills and be familiar with standard identification references. In addition, the researchers should be able to identify wetland soil types and have knowledge of plant specimen collection and preservation techniques. These skills would be acquired by an individual with a diploma or degree in an environmental/biological field with an emphasis on botany/plant ecology, and/or experience sampling wetland vegetation communities.

#### 6.4.2 Comments and Recommendations on Methodology

Below are some factors that may influence the accuracy and repeatability of the plant community metric scores.

##### *6.4.2.1 Temporal Shifts in Community Structure*

Vegetation community sampling was conducted during the month of July over a 30-day period. In early August, field workers returned to several of the sites that had been surveyed in early July to complete additional field work for other investigations. Upon returning, there appeared to be marked difference in the vegetation density at many of these sites. Of the three zones sampled, the submerged zone appeared to show the highest increased in density. There are no data, in addition to observational data, to describe the within site increase in vegetation cover at these sites.

Percent coverage estimates across site were analyzed over time through a linear regression for each vegetation zone. Although there were not significant increases in percent cover in the meadow marsh and submerged zone over the study period, there was a significant increase in the emergent zone ($F_{1,43}$=2.33, p,0.0001). In this case, date accounted for only 26% of the variation in percent coverage in this zone. Preferably, the within site variation of coverage over time is sought, but these results suggests that there is a significant temporal shift in vegetation coverage in the coastal wetlands over the 30-day sample period. If coverage estimates are to be used in wetland health assessments, confounding temporal influences must be minimized and a standardized window for vegetation assessment should be identified. Ideally, the window of opportunity should be identified through empirical assessments, but lacking those data, it is recommended that sampling occur over as short a time period as possible from mid July to August.

In addition to temporal changes in coverage, there is temporal variability in species abundance and life history stage of plants (affects ability to identify) within each wetland zone. For generation of FQIs, the density, apparent dominance, or frequency of individual plant species are not relevant factors when considering the qualitative value of a site (Oldham et al. 1995). However, the ability to correctly identify all species encountered is essential. Sampling during a standardized timeframe will also minimize the influence of seasonal variability of these factors.

#### *6.4.2.2 Patchiness and Scale*

The protocol used in this study was considered a rapid assessment approach and required data collection from only five quadrats spaced at 25 meters along a transect perpendicular to the hydrological gradient to characterize a wetland vegetation zone. This approach seems to be appropriate for the smaller wetland sites with plant community zones homogeneously located along a topographic gradient. In larger, more complex sites, the data collected from the quadrat sampling did not seem to characterize the vegetation zone adequately.

This was particularly evident in many emergent zones and in large wetlands, where many species occurred in a patchy distribution. For example, within all sites, emergent zones were dominated with considerable stands of common cattail (*Typha spp.*), but many sites also contained significant stands of other emergent species (i.e., arrowhead (*Sagittaria*), wild rice (*Zizania*)) that were beyond (deeper water) the cattail stand. When quadrat sampling began in the cattail stand, the entire transect was often located within the confines of the cattail stand. In large sites, wetland vegetation zones often contained patches of different vegetation types within the zone that were dispersed heterogeneously throughout the site at distances that were beyond the length of the sampling transect. Although the data collected in this study suggest that FQIs within the emergent zone are suitable for IBI metric development, a more comprehensive site sampling technique may yield more promising results for species richness as wetland plant community metric.

Overall, the protocol appears to provide a characterization of the vegetation in close proximity to the transect only and not the entire wetland. Although, this is considered a rapid assessment technique, and not intended to provide a complete wetland characterization, the patchiness of emergent plant communities at several wetland sites raises the issue of repeatability of wetland plant community metric values. This project did not test this aspect, but should be considered further within the integrated Great Lakes plant community data analysis by the Michigan research team. Additional quadrat data would need to be acquired from various areas in the wetland to attain a more accurate characterization of the wetland vegetation zones. As with sampling of any biological community, trade-offs exist between accuracy/repeatability and ease implementation. The rational used by the Consortium plant community subgroup in proposing the methodology should be revisited during the Year 1 project assessment review process.

#### *6.4.2.3 Species Richness Measurements*

Development of a suitable species richness metric may be devised from data collected from quadrats only or from quadrats and incidental observations. If incidental observations prove to be valuable for species richness measurements, then incidental observations should be completed in all zones of the wetland, including those that were deemed too small to warrant quadrat sampling. This could be collected with a minimal cost, but allow for a more balanced approach for comparisons of total species richness among wetlands.

### 6.5 Basin-wide Applicability and Sampling by Wetland Type

Although the sites in this study occurred in a highly varied landscape, the developed methodology was easily applied to each wetland. It is likely that this plant community sampling methodology is applicable at any coastal wetland within the Lake Ontario and St. Lawrence River basin.

Regarding the geomorphic type of wetland, the four open bay wetlands were the only sites that consistently supported all three vegetation zones extensively enough for quadrat sampling. Two protected bay wetlands did not support an adequate meadow marsh zone and one did not support a submerged zone. One barrier beach wetland did not support an adequate meadow marsh zone and two did not have a submerged zone. The equipment and personnel required, and the access issues were consistent among sites.

Further evaluation of the basin-wide applicability of plant community metrics will be completed by the Michigan research team by incorporating the data collected on Lake Ontario and St. Lawrence River with data collected on coastal wetlands associated with other Great Lakes basins and existing databases.

### 6.6 Availability of Complementary Data

CWS-Ontario is involved in an International Joint Commission Lake Ontario/St. Lawrence water regulation review study in which vegetation community quadrat data on plant communities will be collected during 2003 in 16 Lake Ontario and St. Lawrence River coastal wetlands. Eleven of these wetlands are Year 1 GLCWC study sites. These data may be of use as a complement to the data collected in 2002.

### 6.7 Literature Cited

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## 7 FISH COMMUNITY SAMPLING

### 7.0 Methodology

Fish sampling occurred in the 12 coastal wetlands throughout July with some resampling in August to conduct replicate sampling or to resample sites with possible compromised fishing effort due to net damage. Parrott's Bay and Button Bay were resampled because a hole caused by trapped snapping turtles compromised the sampling effort. South Bay was resampled because the nets were set for a short time on the first sampling period.

Fish were captured using fyke nets and minnow traps. Large (height×width =0.92m×1.23m) and/or small (0.46m×0.92m) fyke nets were set in selected emergent plant communities (Table 7-1). Fyke net mesh was 4.76mm and dyed green. Large and small nets had 0.14-$m^2$ and 0.12-$m^2$ funnel openings, respectively. All sites included a set of fyke nets in a *Typha* community. A second set of fykes were also located in wetlands with significant other emergent vegetation communities (i.e., *Scirpus*, *Sagittaria*, *Zizania*, *Typha*/*Sagittaria*). Large fyke nets were set at 0.75m-1.25m depths and small fyke nets were set in water from 0.25m-0.75m deep. At some sites, water levels were either too low or too high to accommodate large or small fyke nets respectively. In these cases, only the appropriate nets were set.

All nets were set perpendicular to the emergent macrophyte stand with a 2.5-m wing extending out both sides from the mouth of the net. A length of leader also was extended into the emergent stand from 0 to 7.7 metres depending on macrophyte stand density. For example, to sample very dense *Typha* with little or no open interstitial water, the end of leaders were set at the edge of the emergent stand. Conversely, for a much less dense stand of open water *Scirpus*, the leaders were set several metres into the stand. Nets and leaders were secured in place by using pieces of ½-inch diameter × 10-foot long metal electrical conduit as stakes.

The nets remained in the water overnight. Fish removed the fyke nets were held in plastic containers pending identification. All fish were identified to species, except for some young of the year sunfish (*Lepomis spp.*). These sunfish where identified to genus. All fish were counted and measured in millimetres. If more than 25 individuals of a species were present, only a subsample of 10 were measured. Measured fish were examined for gross external anomalies. DELT anomalies include 1. **D**eformities, 2. **E**rosion of fins, barbels or gill covers, 3. skin **L**esions including open sores, ulcerations, and exposed tissue, and 4. **T**umors and were recorded as mild or severe using the Ohio EPA (1989) standardized criteria. Measurement data are not currently used in IBI calculations for coastal wetlands and are not considered in this report. Fish length measurements were taken in case there was a future requirement for such data. These data are available from CWS upon request.

Generally, one minnow trap was set in tandem with each net and a third trap was set alone at a third site within the same plant community. Minnow traps were typical commercially available cylidical traps constructed from black vinyl coated ~7.5mm mesh. The traps were approximately 0.4 m long and 0.2 m diameter with funnels on either end leading into the trap. Minnow trap locations varied depending on emergent macrophyte stand density. Traps set in dense *Typha* were usually suspended off the true substrate by stems or roots whereas traps in less dense plant communities were placed on bottom. Minnow traps were set overnight and fish that were caught were processed in the same manner as fish caught in fyke nets. The location (latitude and longitude) of the all fyke net and minnow trap sets was recorded using a Magellan GPS 320 global positioning system.

Table 7-1. Summary of number of fyke net and minnow trap samples collected from each plant community type. (2) Indicates second sampling episode.

| Wetland | Wetland Type | Plant Community | Fyke Nets | Minnow Traps |
|---|---|---|---|---|
| Hill Island | Protected Bay | *Typha* | 3 | 3 |
| Hill Island | Protected Bay | *Scirpus* | 0 | 3 |
| Bayfield Bay | Protected Bay | *Typha* | 4 | 4 |
| Parrott's Bay | Protected Bay | *Typha* | 2 | 3 |
| Parrott's Bay | Protected Bay | *Typha/Sagittaria* | 1 | 1 |
| Parrott's Bay (2) | Protected Bay | *Typha* | 2 | 3 |
| Presqu'ile Bay | Protected Bay | *Typha* | 2 | 3 |
| Presqu'ile Bay | Protected Bay | *Scirpus* | 2 | 3 |
| Presqu'ile Bay | Protected Bay | *Zizania* | 2 | 3 |
| Button Bay | Open Bay | *Typha* | 2 | 3 |
| Button Bay | Open Bay | *Sagittaria/Typha/*grass | 2 | 3 |
| Button Bay (2) | Open Bay | *Typha* | 2 | 3 |
| Button Bay (2) | Open Bay | *Sagittaria/Typha* | 2 | 3 |
| Hay Bay South | Open Bay | *Typha* | 3 | 3 |
| Hay Bay South | Open Bay | *Scirpus* | 0 | 3 |
| South Bay | Open Bay | *Typha* | 3 | 3 |
| South Bay | Open Bay | *Scirpus* | 0 | 3 |
| South Bay (2) | Open Bay | *Typha* | 2 | 3 |
| South Bay (2) | Open Bay | *Scirpus* | 2 | 0 |
| Robinson's Cove | Open Bay | *Typha* | 3 | 3 |
| Port Britain | Barrier Beach | graminoid | 0 | 3 |
| Port Britain | Barrier Beach | *Typha* | 3 | 3 |
| Lynde Creek | Barrier Beach | *Typha* | 3 | 5 |
| Huyck's Bay | Barrier Beach | *Typha* | 3 | 3 |
| Huyck's Bay | Barrier Beach | *Scirpus/Typha* | 2 | 3 |
| Frenchman's Bay | Barrier Beach | *Typha* | 3 | 3 |

7.0.1 Data Analysis

Preliminary data analyses were completed using non-parametric analyses because the equal sample size, data normality and equal sample variance assumptions of parametric statistic analyses were often violated.

*7.0.1.1 Descriptive and Summary Statistics*
The number of fish caught in each wetland was summarized by species and family. The number of non-native species, turbidity intolerant species and piscivorous species as well as the incidence of DELTS in each wetland were summarized.

The relationships between the number of fish captured, total species, total families, non-native species, turbidity intolerant species and piscivorous species site were examined among sites through correlation analysis.

*7.0.1.2 Turtles*
The number and species of turtles caught at each wetland was summarized. To determine if there was an effect of turtle presence on the number of fish in fyke nets, a two tailed Mann-Whitney U test was used to compared number of fish caught in fyke nets that had turtles and those that did not have turtles. In addition, a linear regression was performed to determine a relationship between the number of turtles present in a net and the number of fish caught.

*7.0.1.3 Fyke Net Size*
Two tailed Mann-Whitney U tests were performed on the total number of fish, number of species and number of families among all sites to determine the effect of fyke net size on these variables.

*7.0.1.4 Sampling Occasion*
Some sites were resampled later in the season. Two tailed Mann-Whitney U tests compared the total number of fish, number of species and number of families present within each site between sample periods. The tests were done separately for data collected from fyke net and minnow trap sampling. Fyke net samples were compared using grouped small and large fyke net samples because sample sizes would have been too small to allow for statistical comparisons if separate tests were performed. If there was no significant difference detected in any of the tests the data from the two sampling occasions would be grouped for all other analyses.

*7.0.1.5 Vegetation Type*
A Kruskal-Wallis ANOVAs were used to determine the effect of vegetation type on the total number of fish, number of species and number of families per fyke nets and minnow traps. This nonparametric analysis was used in this case because the two samples had significantly different variances. When significant differences were detected, ranks from the Kruskal-Wallis ANOVA were used in a Tukey-type multiple comparisons test (Zar 1999) to detect where the differences lay.

*7.0.1.6 Variability in Sampling Effort*
Due the heterogeneity of the bathymetry and vegetation types in the wetlands, the number appropriate locations for nets and traps was not even among wetlands. Presumably, the differential sampling effort would affect the results of the study. Therefore, relationship between the number of fyke nets and traps used and the number of fish caught, species present and families present was examined using linear regressions.

## 7.1 Results

### 7.1.1 Descriptive and Summary Statistics

The number of fish caught in both fyke nets and in minnow traps was extremely variable within wetlands (Table 7-2). A total of 12 families and 31 species of fish were represented among the wetlands (Table A-3 and A-4; Appendix A).

Table 7-2. Number of fish captured per fyke net and minnow trap.

| | Fyke Nets | | | | Minnow Traps | | | |
|---|---|---|---|---|---|---|---|---|
| **Site** | **Mean** | **SD** | **N** | **Median** | **Mean** | **SD** | **N** | **Median** |
| Hill Island East | 15.33 | 5.85 | 3 | 13 | 0.17 | 0.42 | 6 | 0 |
| Bayfield Bay | 8.75 | 4.12 | 4 | 8.5 | 18.75 | 35.50 | 4 | 1.5 |
| Parrott’s Bay* | 9.4 | 7.54 | 5 | 8 | 3.86 | 3.55 | 7 | 3 |
| Presqu’ile Bay | 6.17 | 4.80 | 6 | 7 | 1.56 | 2.31 | 9 | 1 |
| Button Bay* | 21.25 | 26.36 | 8 | 7.5 | 1.83 | 2.25 | 12 | 1.5 |
| Hay Bay South | 71.33 | 48.19 | 3 | 53 | 6.83 | 11.37 | 6 | 1.5 |
| South Bay* | 21 | 14.82 | 7 | 22 | 1 | 1.32 | 9 | 1 |
| Robinson’s Cove | 13.33 | 6.43 | 3 | 16 | 0.33 | 0.57 | 3 | 0 |
| Port Britain | 20 | 23.82 | 3 | 11 | 0.83 | 1.18 | 6 | 0.5 |
| Lynde Creek | 63 | 57.30 | 3 | 49 | 1.6 | 1.68 | 5 | 2 |
| Huyck’s Bay | 45.75 | 21.42 | 4 | 45 | 4.5 | 9.09 | 6 | 1 |
| Frenchman’s Bay | 59.67 | 28.68 | 3 | 56 | 21.67 | 35.80 | 3 | 1 |

* pooled for both sampling occasions

Open bay wetlands, South Bay and Button Bay had the highest total number of species per site (Table 7-3). Protected bay wetlands generally had lower total number of species and the lowest number of non-native species, but had a relatively high occurrence of piscivores. Barrier beach sites had an intermediate total number of species, but low numbers of turbidity-intolerant species relative to the other two habitat types.

Table 7-3. Total number of various categories of species across sites and wetland types

| Site | Wetland Type | Total Species Richness | Non-native Species | Turbidity Intolerant Species | Piscivorous Species |
|---|---|---|---|---|---|
| Hill Island East | Protected Bay | 8 | 0 | 1 | 2 |
| Bayfield Bay | Protected Bay | 10 | 1 | 1 | 2 |
| Parrott's Bay | Protected Bay | 9 | 0 | 1 | 3 |
| Presqu'ile Bay | Protected Bay | 10 | 0 | 2 | 2 |
| Button Bay | Open Bay | 14 | 2 | 2 | 1 |
| Hay Bay South | Open Bay | 12 | 2 | 0 | 2 |
| South Bay | Open Bay | 14 | 1 | 3 | 2 |
| Robinson's Cove | Open Bay | 9 | 0 | 1 | 3 |
| Port Britain | Barrier Beach | 12 | 1 | 1 | 1 |
| Lynde Creek | Barrier Beach | 12 | 2 | 0 | 1 |
| Huyck's Bay | Barrier Beach | 12 | 1 | 1 | 2 |
| Frenchman's Bay | Barrier Beach | 10 | 1 | 1 | 2 |

The number of non-native species showed a high positive correlation with the total number of fish captured and the total number of species present but showed a high negative correlation with number of piscivorous species. The number of piscivorous species also showed a high negative correlation with the total number of species (Table 7-4).

Table 7-4. Correlation coefficients for various fish classification parameters among the 12 Lake Ontario and St. Lawrence River coastal wetlands.

| | Total Fish | Total Species | Total Families | Non-native Species | Turbidity Intolerant Species | Piscivorous Species |
|---|---|---|---|---|---|---|
| Total Fish | 1 | | | | | |
| Total Species | 0.57 | 1 | | | | |
| Total Families | 0.34 | 0.34 | 1 | | | |
| Non-native Species | **0.80** | **0.76** | 0.54 | 1 | | |
| Turbidity Intolerant Species | -0.23 | 0.33 | -0.22 | -0.25 | 1 | |
| Piscivorous Species | -0.34 | **-0.63** | -0.24 | **-0.70** | -0.03 | 1 |

Coefficients in bold denote significant correlations.

The rate of DELT external anomalies ranged from 0 to 3.21% (Table 7-5). The most frequently seen anomalies were erosions of fins, barbels or gill covers.

Table 7-5. Numbers of external abnormalities

| Site | Total Fish | Deformities | | Erosions | | Lesions | | Tumours | | Delt Rate(%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | M | S | M | S | M | S | M | S | |
| Hill Island East | 47 | | 1 | | | | | | | 2.13 |
| Bayfield Bay | 110 | | | | | | | | | 0 |
| Parrott's Bay | 74 | | | | | | | | | 0 |
| Presqu'ile Bay | 51 | | | 1 | | | | | | 1.96 |
| Button Bay | 192 | | | 1 | 1 | | 1 | 1 | | 2.08 |
| Hay Bay South | 255 | | | | | | | | | 0 |
| South Bay | 156 | 1 | | 2 | 2 | | | | | 3.21 |
| Robinson's Cove | 41 | | | | | | | | | 0 |
| Port Britain | 64 | | | | | | | | | 0 |
| Lynde Creek | 197 | | | | 2 | 1 | | | | 1.52 |
| Huyck's Bay | 210 | | | | | | | | | 0 |
| Frenchman's Bay | 244 | | | 1 | 1 | 1 | 1 | 1 | | 2.05 |

M=mild, S=severe

### 7.1.2 Turtles

Turtles were captured in fyke nets at 11 of the 12 sites (Table 7-6). The most frequently encountered species was the snapping turtle (*Chelydra serpentina serpentina*) of the family Chelydridae, followed by the painted turtle (*Chrysemys picta*) of the family Emydidae. The family Kinosternidae was represented by a single specimen of stinkpot turtle (*Sternotherus odoratus*) captured at Parrott's Bay. Snapping turtles were more abundant at sites in protected bay wetlands than at open bay or barrier beach sites. Painted turtles were most abundant at sites in barrier beach wetlands and were least abundant at protected bay sites.

Table 7-6. Number of turtles captured in fyke nets

| Site | Wetland Type | *Snapping Turtle* | *Painted Turtle* | *Stinkpot Turtle* |
|---|---|---|---|---|
| Hill Island East | Protected Bay | 2 | 0 | 0 |
| Bayfield Bay | Protected Bay | 2 | 1 | 0 |
| Parrott's Bay | Protected Bay | 5 | 0 | 1 |
| Presqu'ile Bay | Protected Bay | 2 | 0 | 0 |
| Button Bay | Open Bay | 1 | 0 | 0 |
| Hay Bay South | Open Bay | 4 | 4 | 0 |
| South Bay | Open Bay | 1 | 0 | 0 |
| Robinson's Cove | Open Bay | 0 | 2 | 0 |
| Port Britain | Barrier Beach | 2 | 8 | 0 |
| Lynde Creek | Barrier Beach | 3 | 4 | 0 |
| Huyck's Bay | Barrier Beach | 1 | 0 | 0 |
| Frenchman's Bay | Barrier Beach | 0 | 1 | 0 |

Of the 52 fyke nets set, 27 had at least one turtle present. Although nets that had turtles present had more fish present (median=16) than nets with no fish (median=11), a Mann-Whitney U test determined that the number of fish in nets with turtles present was marginally (but not significantly) different than when turtles were not present ($U_{27,25}$=238.00, p=0.068).

A linear regression showed that there was no relationship between the number of turtles trapped in fyke nets and the number of fish caught ($r^2$=0.04, p=0.16, n=52).

### 7.1.3 Fyke Net Size

The number of fish, number of species and the number of families capture each size of fyke net was quite variable. Yet, two tailed Mann-Whitney U tests revealed that large fyke nets captured significantly more fish ($U_{16,36}$=121.00, p=0.0009) and more species of fish ($U_{16,36}$=129.00, p=0.0016) than small fyke nets. In addition, large fyke nets captured marginally but not significantly more families ($U_{16,36}$=190.00, p=0.052) than small nets.

### 7.1.4 Sampling Occasion

Parrott's Bay, South Bay and Button Bay were sampled on two different occasions 20, 31 and 22 days apart, respectively. Two tailed Mann-Whitney U tests performed on data collected from fyke net and minnow trap showed no significant difference between the total number of fish, number of species and number of families within each site between sample periods (Table A-5; Appendix A). Therefore, the data from the two sampling occasions were grouped for all other analyses.

### 7.1.5 Vegetation Type

The majority of fyke net and minnow traps sets occurred in *Typha* stands (see Table 7-1). Using fyke nets, Kruskal-Wallis ANOVAs revealed that there was no significant difference in the number of fish caught ($H_{5,52}$=10.32, p=0.06) or the number of species ($H_{5,52}$ =8.075 p=0.15) among vegetation types. However, was a difference in the number of fish families ($H_{5,52}$=12.47 p=0.02) among vegetation types. A Tukey-type nonparametric multiple comparisons test determined that there were more fish families found in the *Typha* vegetation type than any other.

Using minnow traps, there was no significant difference in the number of fish caught ($H_{6,76}$=11.07, p=0.08), the number of species ($H_{6,76}$=7.548 p=0.27) or the number of fish families ($H_{6,76}$=7.714 p=0.26) among vegetation types.

### 7.1.6 Variability in Sampling Effort

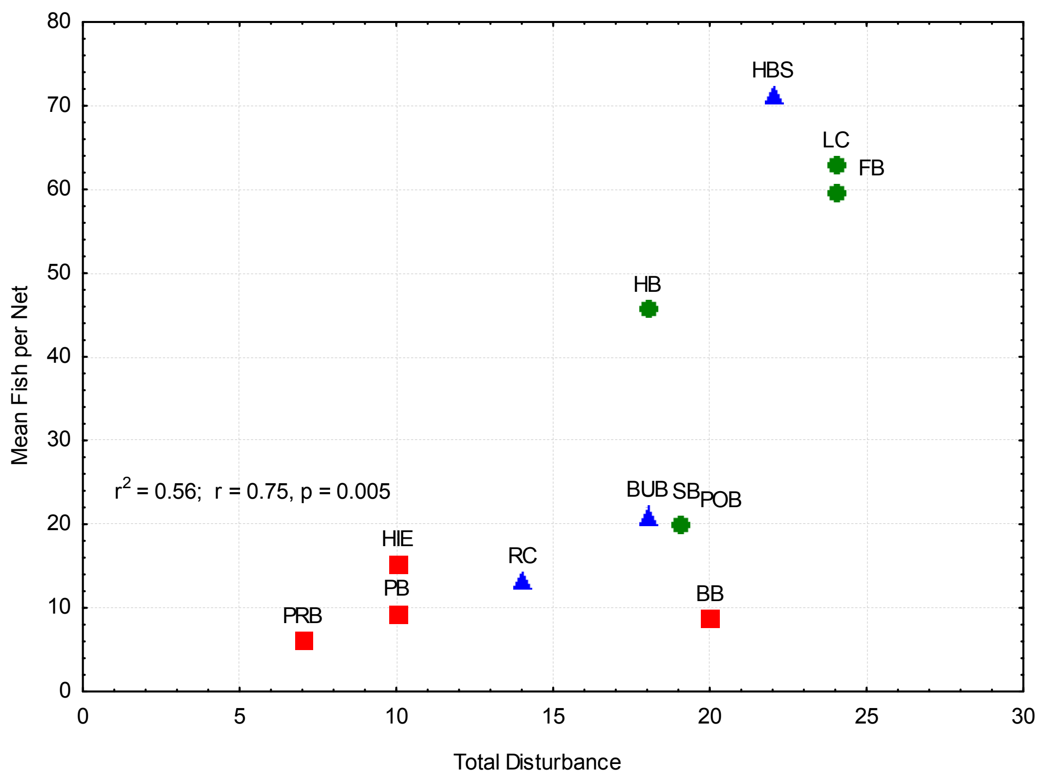
Fish sampling effort ranged from three fyke nets and three minnow traps at Robinson's Cove to eight fyke nets and 12 minnow traps at Button Bay. There were not a strong or significant relationships between the number of nets and traps used and the number of fish captured ($r^2$=0.0003, p=0.95, n=12) or the number of families present ($r^2$=0.077, p=0.38, n=12). However, there was a marginally significant and somewhat strong relationship between the number of nets and traps and the number of species present ($r^2$=0.33, p=0.051, n=12).

### 7.1.7 Testing Fish Community Metrics Against Site Disturbance

#### *7.1.7.1 Fish Yield*

The mean number of fish caught per net showed a significant increase with increasing disturbance at the study sites. The mean number of fish caught per trap was not significantly related to the level of disturbance at the site (Figure 7-1).

A



B

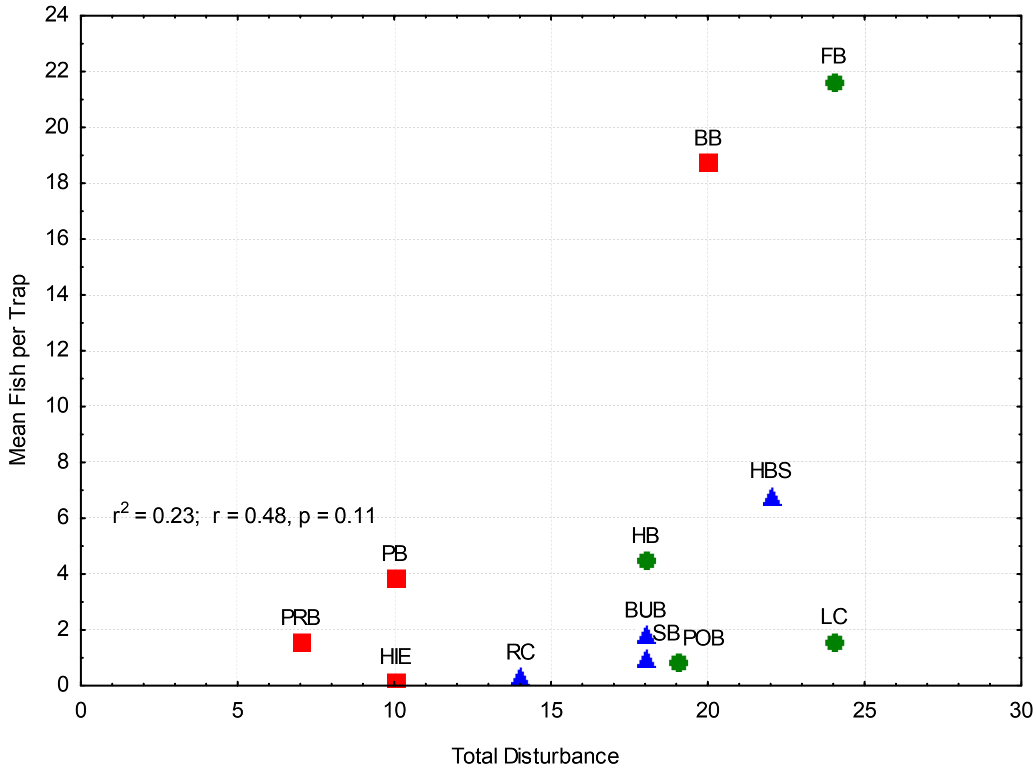
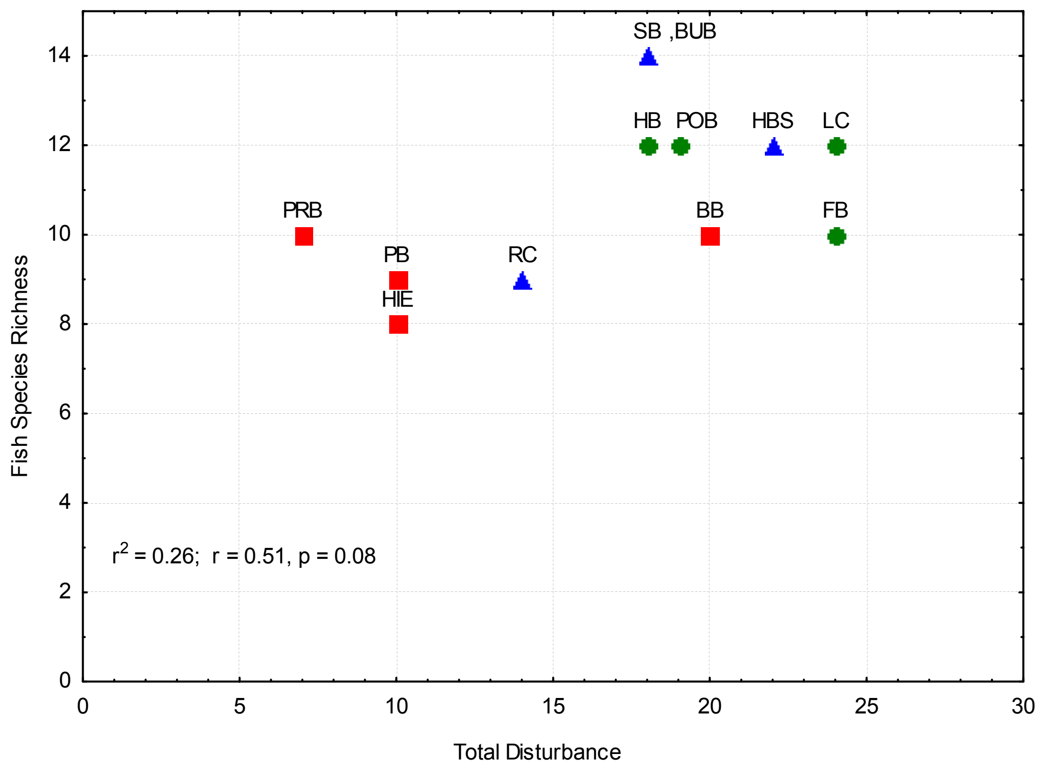



Figure 7-1. The relationship between site disturbance and the mean number of fish caught per A) net and B) trap at Lake Ontario and St. Lawrence River coastal wetlands. Symbols denote wetland geomorphic type: =barrier beach, =open bay, =protected bay. Data points are labeled with wetland site name acronyms (See Table 1-1)

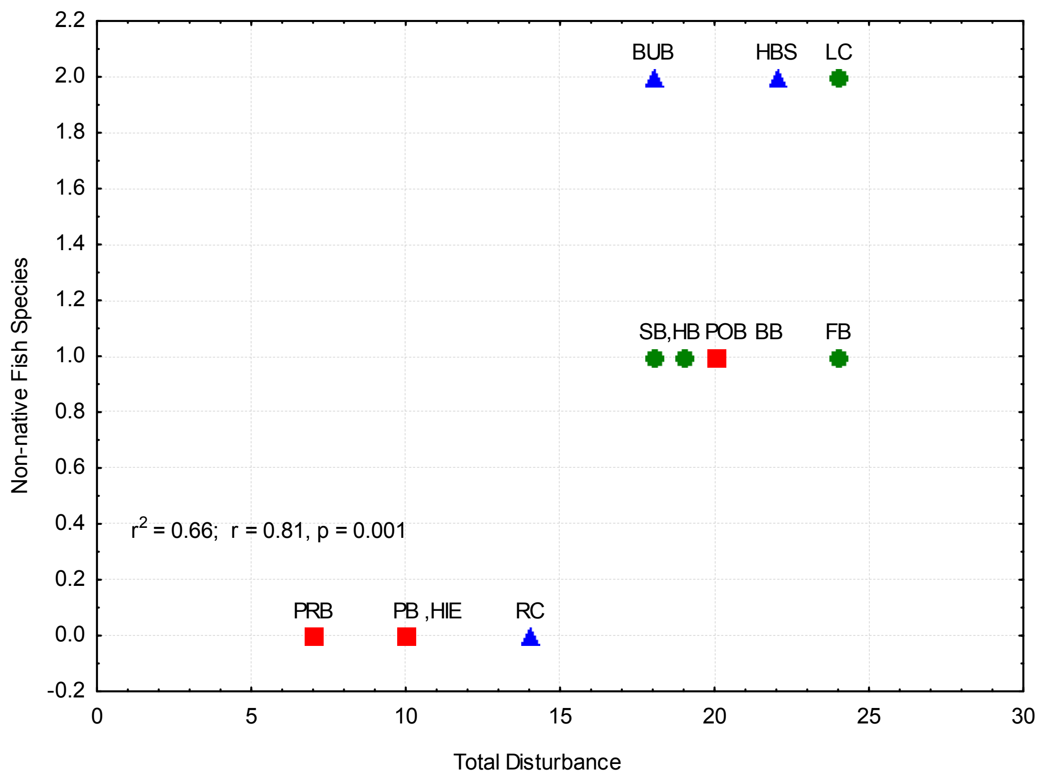
*7.1.7.2 Species and Family Richness*

There was not a significant relationship between the level of disturbance experienced by the site and the number of fish species of fish families captured, the number of turbidity intolerant species or the number of piscivorous species. However, there was a strong significant increase in non-native fish species as disturbance increases (Figure 7-2).

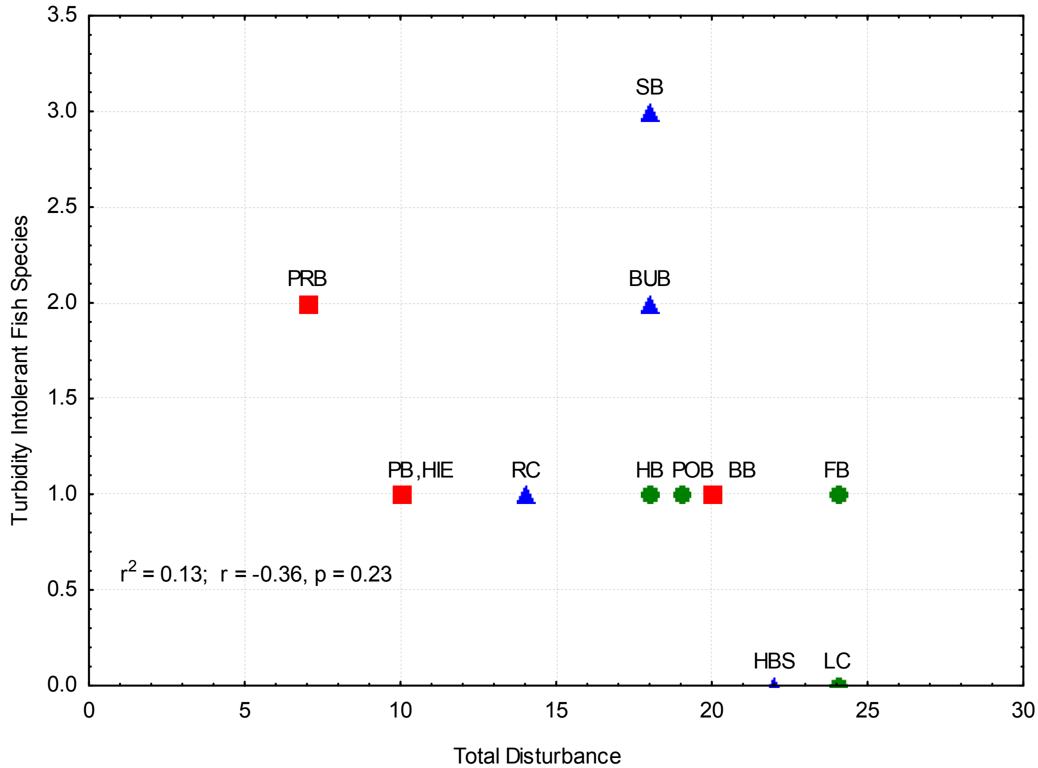
A


SB ,BUB
HB POB HBS LC
PRB BB FB
PB RC
HIE
Fish Species Richness
$r^2$ = 0.26; r = 0.51, p = 0.08
Total Disturbance

B

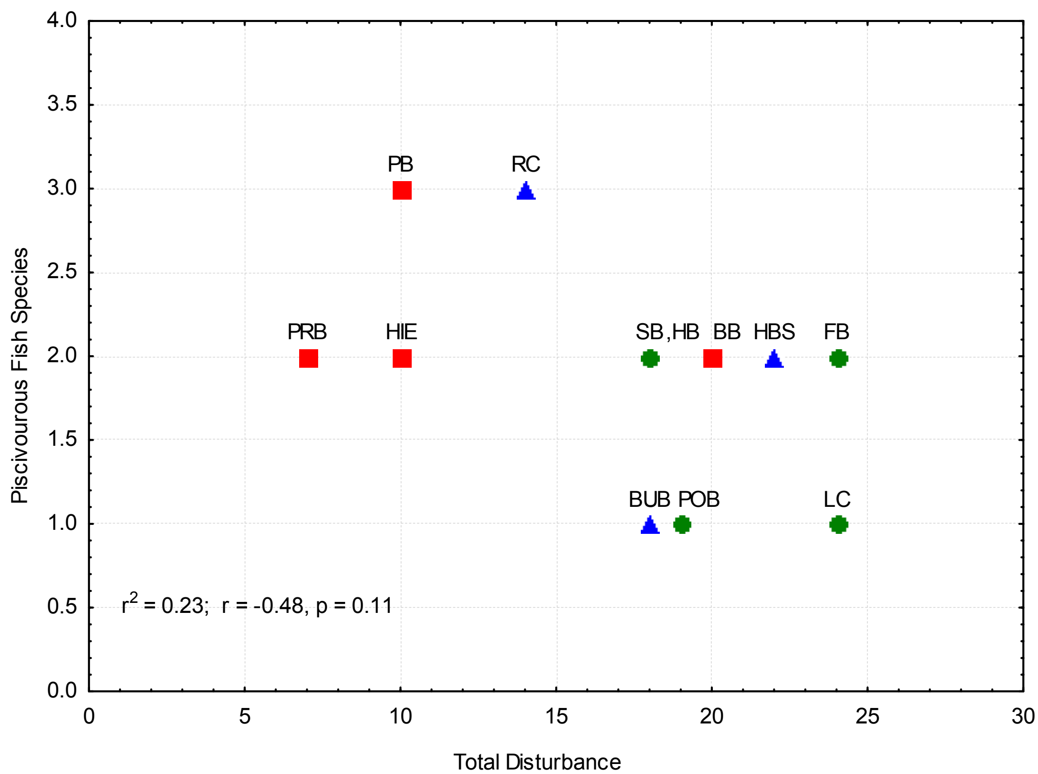

BUB HBS LC
SB,HB POB BB FB
Non-native Fish Species
$r^2$ = 0.66; r = 0.81, p = 0.001
PRB PB ,HIE RC
Total Disturbance

C



Turbidity Intolerant Fish Species
Total Disturbance
SB
BUB
PRB
PB,HIE
RC
HB
POB
BB
FB
HBS
LC
$r^2 = 0.13$; $r = -0.36$, $p = 0.23$


D



Piscivourous Fish Species
Total Disturbance
PB
RC
PRB
HIE
SB,HB
BB
HBS
FB
BUB
POB
LC
$r^2 = 0.23$; $r = -0.48$, $p = 0.11$

E

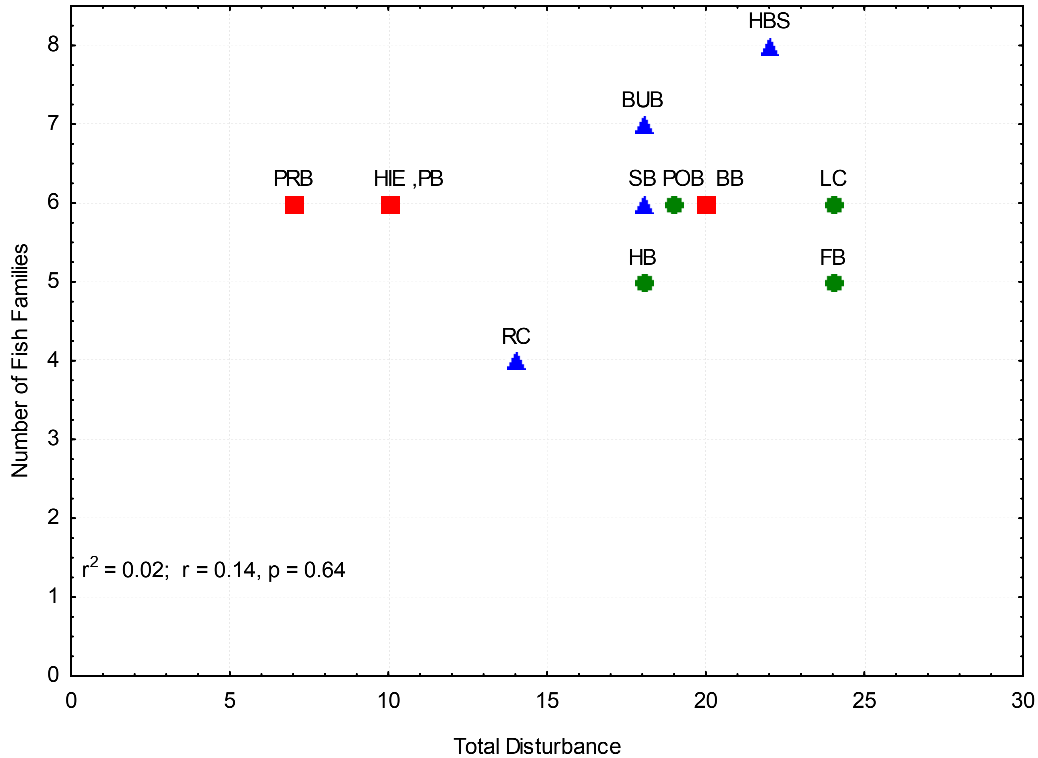



Figure 7-2. The relationship between site disturbance and the richness of A) all species, B) non-native species, C) turbidity intolerant species, D) piscivorous species, and E) fish families at Lake Ontario and St. Lawrence River coastal wetlands. Symbols denote wetland geomorphic type: =barrier beach, =open bay, =protected bay. Data points are labeled with wetland site name acronyms (See Table 1-1)

*7.1.7.3 Incidents of DELTs*

The level of disturbance at the sites did not appear to correlate with the incidence of DELT anomalies in the captured fish (Figure 7-3).

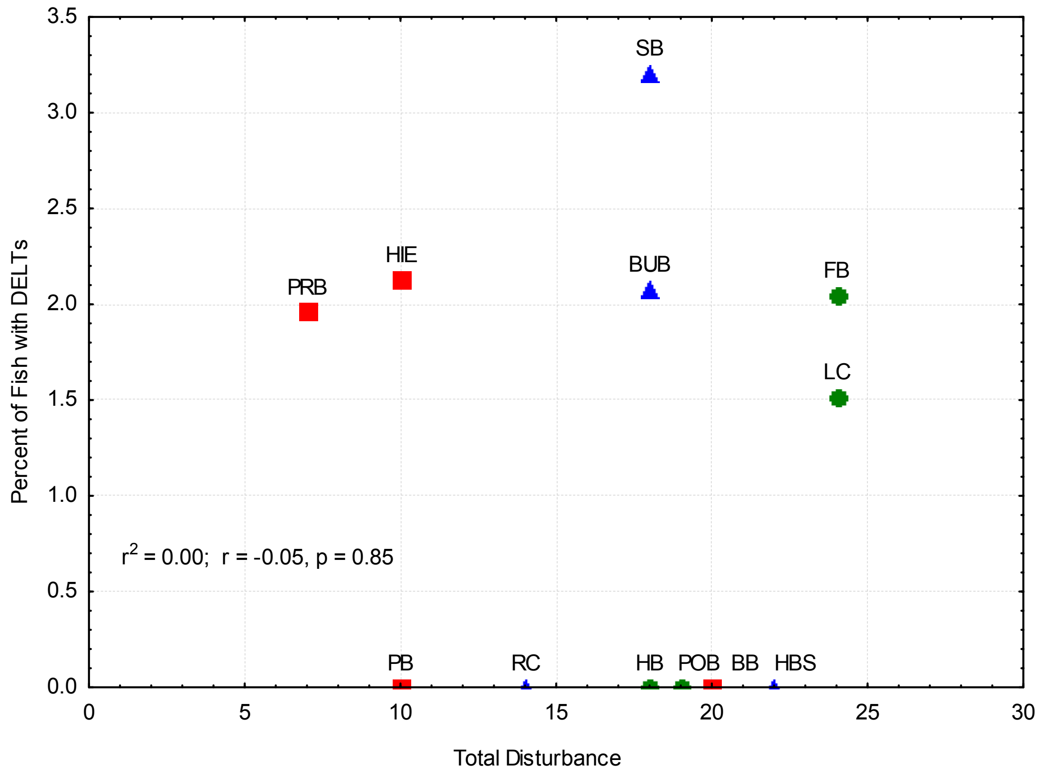



Figure 7-3. The relationship between site disturbance and the incidence of DELT anomalies in fish at Lake Ontario and St. Lawrence River coastal wetlands. Symbols denote wetland geomorphic type: =barrier beach, =open bay, =protected bay.

## 7.2 Discussion

### 7.2.1 Descriptive Statistics

The numbers of fish caught in both fyke nets and minnow traps was extremely variable. This seems to reflect a patchy distribution of fish within the habitats sampled. When nets or traps contained large numbers of fish, the catch was frequently dominated by a single species. At several sites, there were nets or traps containing large numbers of young of the year, which suggests that the number of fish captured may reflect productivity. In fact, the number of fish captured in nets, and to some extent in traps, indicate that as site disturbance increases, so does the number of fish at the site. This relationship may relate to the fact that as site disturbance increases, so does the amount of water-bourne nutrients. The increase in nutrients results in an increase in primary productivity that is reflected within trophic levels. In fish communities, this is evident through increase numbers of fish, particularly young of the year. Nonetheless, the mean number of fish caught in net appears to be suitable metric for coastal wetland IBIs. In contrast, recent studies in Lake Ontario littoral habitats use numbers of native individuals as a metric with a positive influence on the IBI (Minns et al. 1994; Smokorowski et al. 1998). Depending on the nature of the fish yields in this project, the current findings suggest that the number of native fish may have a negative influence on the IBI. The integrated Great Lakes analysis currently underway by the Michigan research team should provide clearer relationships.

Within-site variability in the number of families and total species represented was relatively low. The number of families showed little association with the degree of disturbance at the sites, yet the total number of species appeared to be sensitive to site disturbance (p=0.08). Based on Lake Ontario and St. Lawrence River data alone, the number of families is not a reliable metric, but the total number of species may prove suitable with the collection or augmentation of additional data. If the variation in these metrics is largely driven by the level of disturbance at the study sites, then total native species, as used by Minns et al. 1994 and Smokorowski et al. 1998, may represent a better metric than total species.

Nonetheless, the types of taxa encountered are likely just as important as the number in characterizing differences among sites and wetland types. Families such as the Centrarchidae (sunfish), Cyprinidae (carp, minnows and shiners), Ictaluridae (bullheads), Amiidae (bowfins), and Percidae (perch and darters) were encountered at almost every site, while families such as the Gasterostidae (sticklebacks), Clupeidae (herring), Catostomidae (suckers), Fundulidae (killifish), Esocidae (pikes), Umbridae (mudminnows) and Moronidae (white perch) were encountered less frequently. With the more commonly encountered families, metrics representing variation at the species level such as trophic level, presence of exotic species, and turbidity tolerance may be especially useful in characterizing differences among sites and wetland types. Minns et al. 1994 and Smokorowski et al. 1998 identify Centrarchid species richness and native Cyprinid species richness as important factors that positively affect the biotic integrity of nearshore fish communities in the Great Lakes.

The number of non-native, turbidity intolerant and piscivorous fish species within a site have been documented as suitable metrics for Great Lakes littoral fish communities site. (Minns et al. 1994 and Smokorowski et al. 1998). For the Lake Ontario study wetlands, there was little association between disturbance and turbidity intolerant species and piscivorous species richness. However, the number of non-native species did show an increase with disturbance and may be a suitable metric for coastal wetland IBI development.

In terms of metric development, total species richness and non-native species richness were shown to be sensitive to wetland condition in Lake Ontario coastal wetlands. The strong correlation of these metrics with the number of piscivorous species suggest that the number of piscivorous species may also be a suitable metric. Analysis of the integrated Great Lakes database by the Michigan research team will provide a more definite conclusion with respect to suitable fish metrics for use within a Great Lakes fish community IBI.

##### *7.2.1.1 Incidence of DELTS*

The rate of DELT anomalies was very low and did not appear sensitive to the amount of disturbance at the site. Error in DELT rates could be attributed to difficulties that were encountered when trying to distinguish DELT anomalies from damage caused by the nets themselves or by the thrashing of snapping turtles when nets were being retrieved.

#### 7.2.2 Turtles

Turtles were captured in fyke nets at all sites. The thrashing of the snapping turtles frequently damaged the fyke nets and injured captured fish such that it was sometimes difficult to distinguish injuries from DELT anomalies. There was considerable variation in the number of turtles among sites and wetland types, which suggests that the incidental catch of turtles may yield useful information about differences among sites and wetland types. As with fish, different species of turtles exhibit different habitat preferences and degrees of tolerance to habitat degradation. This report does not address the role of turtle data in metric formation. However, a cursory examination of the turtle capture data (number of individuals and species) does not indicate that these data would be useful as a coastal wetland IBI metrics.

#### 7.2.3 Fyke Net Size

Large fyke nets trapped more species and more fish than small fyke nets. In addition, there was evidence that large fyke nets may also capture more families of fish. It is not discernable whether this trend is due to differences related to habitat characteristics (i.e, vegetation and/or light penetration at greater depths) or a true effect of net size. Although this may not affect metrics that are expressed as proportions or percentages, metrics that are represented by absolute numbers (i.e., species richness, Cyprinid species richness, number of native individuals) would be affected.

#### 7.2.4 Sampling Occasion

The number of fish caught within wetlands between the two dates did not differ significantly. The assemblage and abundance of fish species can vary within coastal wetlands. Spawning fish are more abundant early in the year while young of the year numbers increase later in the summer. Although the numbers of fish caught on the two occasions may not be significantly different, the assemblages of fish may be quite different. Fish community assemblages are not statistically compared here. Although a visual comparison suggests that the assemblages are somewhat different (Table 7-7), the degree to which within-site and temporal variability affect the assemblages is not known.

Table 7-7. The number of fish species that were common to both sampling occasions and unique species found during the first and second sampling occasions.

| Site | Species overlap | Unique species first | Unique species second |
|---|---|---|---|
| Parrott's Bay | 4 | 1 | 4 |
| South Bay | 6 | 5 | 3 |
| Button Bay | 6 | 5 | 3 |

Current IBIs for fish in littoral habitats use metrics involving Centrarchid, piscivorous and non-native species. Non-native carp (*Cyprinus carpio*) were found in South Bay and Button Bay during the first sampling occasion but not during the resampling. In addition, the presence and number of Centrarchid and piscivorous species was quite variable between visits. Calculations using data collected 3-4 weeks apart may yield different IBIs. Therefore, a standardized window for sampling should be established.

#### 7.2.5 Vegetation Type

Fyke nets captured more families of fish per net when set in cattails than in any other habitat. If fish community IBIs that are developed incorporate the number of families caught in each net, the habitats that the nets were set in should be considered.

#### 7.2.6 Sampling Effort

There was not a relationship between the number of fyke nets and minnow traps set at a sight and the total number of fish caught. This emphasizes the effect of within site variability due to the patchy distribution of fish within the wetland. The data suggest that increased net and trap sets results in an increased number of species caught. Fish IBIs generally incorporate various measures of species richness in the metrics. Therefore, the number of traps per wetland should be standardized within wetlands or means/medians per trap used to allow IBIs among wetlands to be comparable.

### 7.3 Cost

#### 7.3.1 Equipment

Table 7-8 lists the equipment costs associated with completing fish community sampling in coastal wetlands. The costs are broken down into consumables (one-time use) and non-consumables (used multiple times). In the case of a long-term program, the non-consumable equipment will represent one-time or occasional (*i.e.* when replacement is necessary) costs.

Table 7-8. Resource costs required to complete GLCWC fish sampling component.

| Item | Cost (CAD) | Consumable |
|---|---:|:---:|
| 14' Flat-bottomed boat | 1400 | N |
| 9.9 HP outboard motor | 2250 | N |
| Gas for outboard motor | 50 | Y |
| Electric motor[1] | 200 | N |
| 2 x 12 Volt battery[1] | 200 | N |
| Battery charger[1] | 30 | N |
| 6 fyke nets | 4000 | N |
| 12 minnow traps | 130 | N |
| Net poles (conduit) | 150 | N |
| Life jackets | 80 | N |
| Waders | 180 | N |
| Secchi disk | 40 | N |
| Boat trailer | 900 | N |
| Fish ID resources | 100 | N |
| Fish measuring board | 20 | N |

| Item | Cost (CAD) | Consumable |
|---|---|---|
| Holding buckets for fish | 45 | N |
| GPS | 325 | N |
| Total | 10100 | |

Superscripts indicate equipment shared with other sampling tasks: 1=vegetation

### 7.3.2 Personnel

Two people, a crew leader and an assistant, were required to complete fish community sampling. The time required to set the nets and traps at each site depended on the number of nets and traps set, weather conditions (wind), site accessibility, and mobility within the site. In general, net and trap setting took two to four hours. Collecting nets and traps and processing fish was also extremely variable and depended on the same factors as net and trap setting, but also depended on the number of fish and turtles caught in each trap. Collecting and processing required between two and six hours per site.

## 7.4 Measurability

### 7.4.1 Expertise and Training

The crew leader should possess at least a Fish and Wildlife Technology diploma or a Bachelors degree in Fisheries Biology with netting and fish identification experience. One of the crew members should also have experience or be able to identify and describe general aquatic plant community types and wetland attributes. Both field workers should be in good physical shape and capable of lifting heavy equipment (i.e., nets full of turtles and fish, outboard motor).

At all wetlands, turtles were trapped in fyke nets. At least one crew member should be familiar with proper techniques for handling turtles to insure that neither the handler nor the turtle suffer injury.

### 7.4.2 Comments and Recommendations on Methodology

*7.4.2.1 Fyke Net Avoidance Behaviour*

Common carp (*Cyperinus carpio*) were easily observed and appeared to be abundant at several sites. It was expected that several of the fish would be captured in the fyke nets at these sites. Although carp were caught at half of the sites, only one carp was caught at each of five sites and 2 carp were caught at a sixth site. These numbers were lower than expected considering the abundance of carp in some of the wetlands. This suggests that carp may have avoided the traps and would be underrepresented in the fish assemblage. An underrepresentation of exotic species would result in an artificially high IBI score for wetlands where carp were abundant. It is not clear whether the carp are exhibiting avoidance behaviour. It may be important to compare the results of fyke net and minnow trap sampling with a more active method of fish sampling (i.e., electroshocking) to determine if carp, and other species, are avoiding fyke nets.

*7.4.2.2 Sampling Various Vegetation Types*

One of the goals of the methodology was to collect a minimum of three paired fyke net/minnow trap sample by vegetation communities. Due to above average lake water levels, attempts to set fyke nets in *Scirpus* stands was often thwarted because these stands generally occurred at water depths that were too deep. Therefore, these habitats may have been underrepresented in the study. Similarly, field workers had a total of three small and three large fykes nets for sampling purposes, in sites with multiple vegetation communities suitable for sampling, sampling effort had to be reduced to two fyke nets per community.

*7.4.2.3 Fyke Net Size*

Both large and small fyke nets were required to capture fish in vegetation communities that occurred in various water depths. Although both nets had equal mesh size, large nets had a larger funnel opening than small fyke nets. It is unclear whether this affected the quality and quantity of fish yields, yet the funnel openings should be standardized, regardless of net size, to ensure improve comparibility of samples in future monitoring.

### 7.5 Basin-wide Applicability and Sampling by Wetland Type

There were some difficulties experienced during fish community sampling. For example, at two open bay sites, South Bay and Robinson's Cove, there was only shallow mineral soil over limestone. In many locations, this made it impossible to drive the net stakes in far enough to secure the fyke nets. Instead, areas within the site that had deeper deposits of sand were sought to set the nets up. Another problem with open bay sites was due to the inherent nature of the site. Open bays are often more exposed to high wind and waves which makes working in and around a small boat very difficult and potentially dangerous. At open bay sites, even a light wind can make net placement and collection markedly more difficult than in protected bays or barrier beaches.

The only other site that was difficult to sample was Parrott's Bay. This bottom of this protected bay site consisted of deep (>1m) unconsolidated sediment that was very difficult to wade through. The setting and collection of nets and traps took longer than at most sites due the difficulty of maneuvering on foot. Furthermore, dense submerged aquatic vegetation rendered the outboard motor useless and exacerbated the maneuverability problem.

### 7.6 Availability of Complementary Data

An extensive coastal wetland fish sampling program is ongoing in the western Lake Ontario wetland, Cootes Paradise. The project is lead by Tys Theysemeyer at the Royal Botanical Gardens. In addition, the Durham Region Coastal Wetland Monitoring Project, lead by the Canadian Wildlife Service and the Central Lake Ontario Conservation Authority, will be repeatedly assessing fish assemblages at 15 Lake Ontario coastal wetlands. The string of coastal wetlands starts just east of Toronto, at the Rouge River and extends east 56 kilometers to Port of Newcastle. Year 1 Consortium based coastal wetland fish community IBI recommendations will also be considered for inclusion into the Durham Region Monitoring Project. This monitoring project may also provide an excellent opportunity for follow up comparison studies.

### 7.7 Literature Cited


Minns, C. K., V. W. Cairns, R. G. Randall and J. E. Moore. 1994. An Index of Biotic Integrity (IBI) for fish assemblages in the littoral zone of Great Lakes' Areas of Concern. Can. J. Fish. Aquat. Sci. 51: 1804-1822.

Smokorowski, K. E., M. G. Stoneman, V. W. Cairns, C. K. Randall, and B. Valere. 1998. Trends in the nearshore fish community of Hamilton Harbour, 1988 to 1997, as measured using an Index of Biotic Integrity. Can. Tech. Rept. Fish. And Aquat. Sci. No. 2230

## 8 BIRD AND AMPHIBIAN COMMUNITY SAMPLING

### 8.0 Methodology

Bird and amphibian communities were surveyed by the Canadian Wildlife Service (CWS)-Ontario Region in cooperation with Bird Studies Canada (BSC). From April to July 2002, CWS and volunteers recruited by CWS and BSC collected data on bird and amphibian communities in the 12 study sites using standard Marsh Monitoring Program (MMP) survey protocols (See The Marsh Monitoring Program 2001). Table 8-1 presents a summary of the surveyors for each site and the number of bird and amphibian stations surveyed.

Table 8-1. Summary of Marsh Monitoring Program surveys conducted in 12 Lake Ontario and St. Lawrence River coastal wetlands in 2002.

| Study Site | Wetland Type | Surveyor(s) | | # of Stations Surveyed |
|---|---|---|---|---|
| Hill Island East | Protected Bay | Amphibians: | Volunteer | A: NS |
| | | Birds: | Volunteer | B: NS |
| Bayfield Bay | Protected Bay | Amphibians: | CWS | A: 3 |
| | | Birds: | CWS | B: 3 |
| Parrott's Bay | Protected Bay | Amphibians: | Volunteer | A: 4 |
| | | Birds: | CWS | B: 2 |
| Presqu'ile Bay | Protected Bay | Amphibians: | Volunteer | A: 8 |
| | | Birds: | Volunteer | B: 8 |
| Button Bay | Open Bay | Amphibians: | CWS | A: 2 |
| | | Birds: | CWS | B: 2 |
| Hay Bay South | Open Bay | Amphibians: | CWS | A: 2 |
| | | Birds: | CWS | B: 3 |
| South Bay | Open Bay | Amphibians: | CWS | A: 2 |
| | | Birds: | CWS | B: 2 |
| Robinson's Cove | Open Bay | Amphibians: | Volunteer | A: NS |
| | | Birds: | Volunteer | B: 2 |
| Port Britain | Barrier Beach | Amphibians: | CWS | A: 2 |
| | | Birds: | Volunteer | B: 3 |
| Lynde Creek | Barrier Beach | Amphibians: | Volunteer | A: 7 |
| | | Birds: | Volunteer | B: 8 |
| Huyck's Bay | Barrier Beach | Amphibians: | Volunteer | A: 1 |
| | | Birds: | CWS | B: 2 |
| Frenchman's Bay | Barrier Beach | Amphibians: | TRCA | A: 2 |
| | | Birds: | TRCA | B: 3 |

CWS – Canadian Wildlife Service
TRCA – Toronto and Region Conservation Authority
NS – Data not submitted/collected

Appropriate survey stations were established in each wetland and point count surveys were conducted on two occasions for marsh bird communities and on three occasions for amphibian communities. One hundred metre radius semicircular point count survey stations were established along the shoreline of each wetland study site in similar areas to other GLCWC flora and fauna sampling. Occurrence and relative abundance of marsh birds and amphibians was recorded at each survey station. Amphibians were sampled entirely through audio detection; the relative abundance of species was recorded using three levels of calling code intensity (See The Marsh Monitoring Program 2001). Marsh bird abundance was recorded through both visual and audio detection. Recorded calls of secretive marsh bird species were broadcast with handheld cassette tape players in attempts to elicit calls from these species. Plant community attribute data were also collected at each survey station. CWS recorded the UTM coordinates for each station using a Magellan GPS 320 global positioning system. Other surveyors either recorded the coordinated of their survey stations or indicated the location on a topographic map or hand drawing of the wetland.

8.0.1 Data Analysis

*8.0.1.1 Descriptive Statistics – Birds*

Bird species richness, diversity and equitability were summarized for each site. The Shannon-Weaver index was used to calculate diversity. The equitability (range : 0-1) is a measure of species evenness at the site and is calculated by dividing the site diversity by the maximum possible diversity that could be attained with the same species richness. High equitability within a wetland indicates similar number of individuals within each species was observed. Using MMP protocol, surveyors note species that were observed using habitat in the plot as well as species that were observed flying through the plot without landing. These analyses do not include individuals that were observed flying through the plot.

As per the Year 1 proposal, all MMP data were forwarded to Bird Studies Canada for inclusion into a more detailed and robust analysis of a Great Lakes MMP database. All conclusions, within this report should be considered preliminary.

*8.0.1.2 Descriptive Statistics – Amphibians*

Amphibian (frog and toad) species richness was summarized for each site. Diversity and equitability calculations could not be performed because the number of individuals of each species was not counted.

*8.0.1.3 Sampling Effort*

Although the number of point count stations used in MMP surveys is limited by the size of the wetland, the number of survey points may influence the number of species observed. The relationship between the number of stations surveyed and the number of species observed was investigated through linear regressions.

## 8.1 Results

8.1.1 Descriptive Statistics – Birds

Species richness was variable among wetlands (range: 5-18). Frenchman's Bay had the least number of observed species while more than three times as many species were recorded in the wetland with the highest richness, Bayfield Bay (Table 8-2). Species diversity was also variable among the wetlands (range: 0.95-2.35). The two sites with the lowest species diversity (Presqu'ile Bay and Port Britain) also exhibited low species equitability, 0.36 and 0.42 respectively. Apart from these two sites, the equitability did not vary substantially among sites (0.72-0.85).

Table 8-2. Bird species richness, diversity and equitability across sites and within wetland types.

| Site | Wetland Type | Total Species Richness | Species Diversity | Species Equitability |
|---|---|---|---|---|
| Hill Island East | Protected Bay | - | - | - |
| Bayfield Bay | Protected Bay | 18 | 2.35 | 0.82 |
| Parrott's Bay | Protected Bay | 9 | 1.62 | 0.73 |
| Presqu'ile Bay | Protected Bay | 14 | 0.95 | 0.36 |
| Button Bay | Open Bay | 14 | 2.25 | 0.85 |
| Hay Bay South | Open Bay | 14 | 2.08 | 0.79 |
| South Bay | Open Bay | 9 | 1.79 | 0.82 |
| Robinson's Cove | Open Bay | 9 | 1.87 | 0.85 |
| Port Britain | Barrier Beach | 12 | 1.05 | 0.42 |
| Lynde Creek | Barrier Beach | 13 | 2.01 | 0.78 |
| Huyck's Bay | Barrier Beach | 7 | 1.47 | 0.76 |
| Frenchman's Bay | Barrier Beach | 5 | 1.16 | 0.72 |

8.1.2 Descriptive Statistics – Amphibians

Only one species of amphibian, a green frog (*Rana clamitans*), was noted at Lynde Creek, while seven amphibian species were heard at South Bay. Although there was a large range in amphibian species richness (1-7), the majority of the sites had species richness estimate between 4-6 (Table 8-3).

Table 8-3. Amphibian species richness, diversity and equitability across sites and within wetland types.

| Site | Wetland Type | Total Species Richness |
|---|---|---|
| Hill Island East | Protected Bay | - |
| Bayfield Bay | Protected Bay | 6 |
| Parrott's Bay | Protected Bay | 6 |
| Presqu'ile Bay | Protected Bay | 6 |
| Button Bay | Open Bay | 5 |
| Hay Bay South | Open Bay | 6 |
| South Bay | Open Bay | 7 |
| Robinson's Cove | Open Bay | - |
| Port Britain | Barrier Beach | 4 |
| Lynde Creek | Barrier Beach | 1 |
| Huyck's Bay | Barrier Beach | 5 |
| Frenchman's Bay | Barrier Beach | 4 |

8.1.3 Sampling Effort

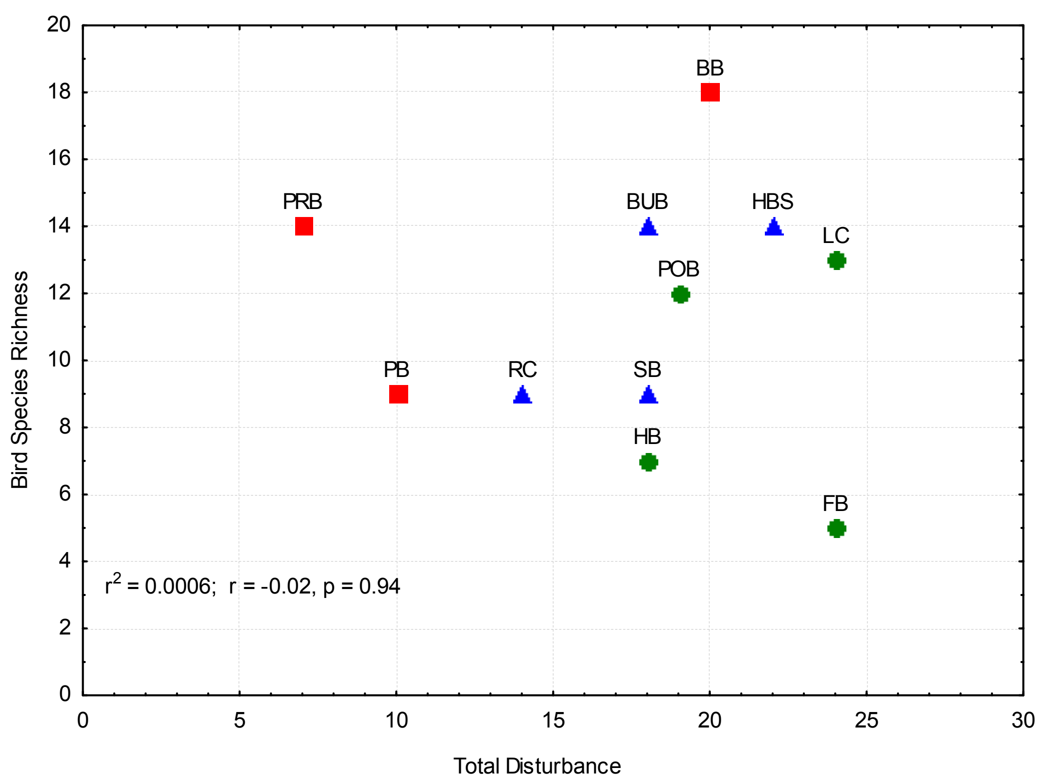
Linear regressions revealed that there was not a strong or significant relationship between the number of survey stations and the number of bird species ($r^2$=0.12, p=0.28, n=11) or amphibian species ($r^2$=0.03, p=0.64, n=10) observed.

8.1.4 Testing Bird and Amphibian Metrics Against Site Disturbance

*8.1.4.1 Bird Species Richness, Diversity, and Equitability*

Preliminary analysis of the 11 Lake Ontario wetland sites showed no significant relationships between Bird species richness, diversity, and equitability and site disturbance (Figure 8-1).

A



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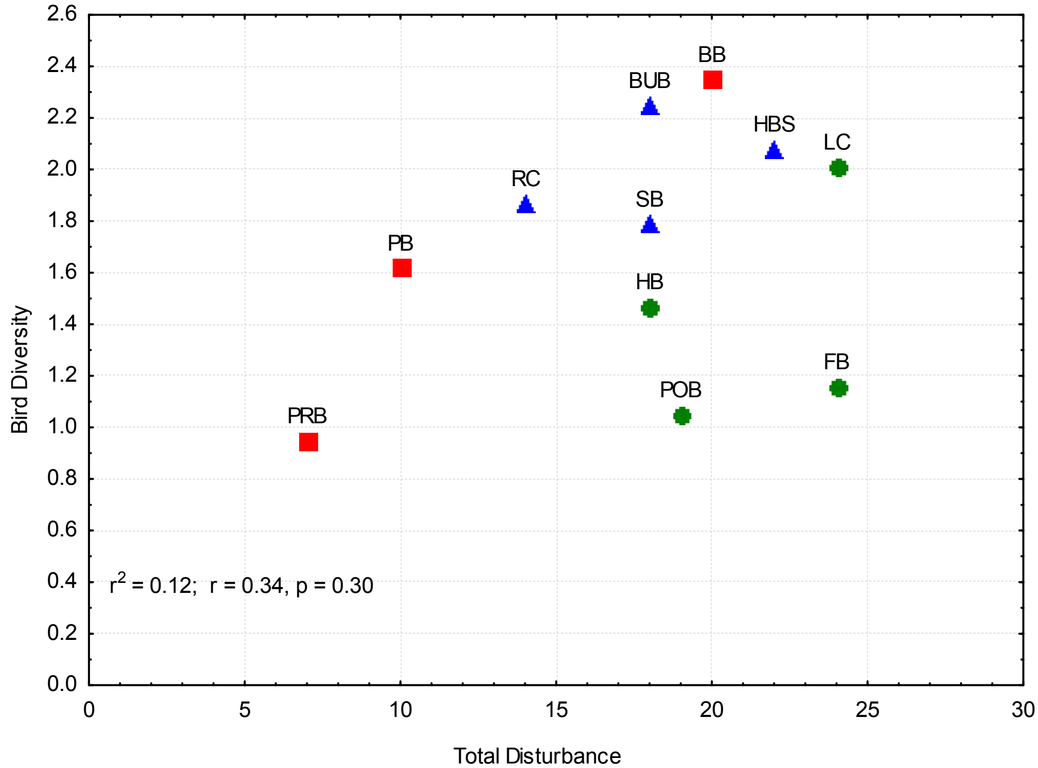


C

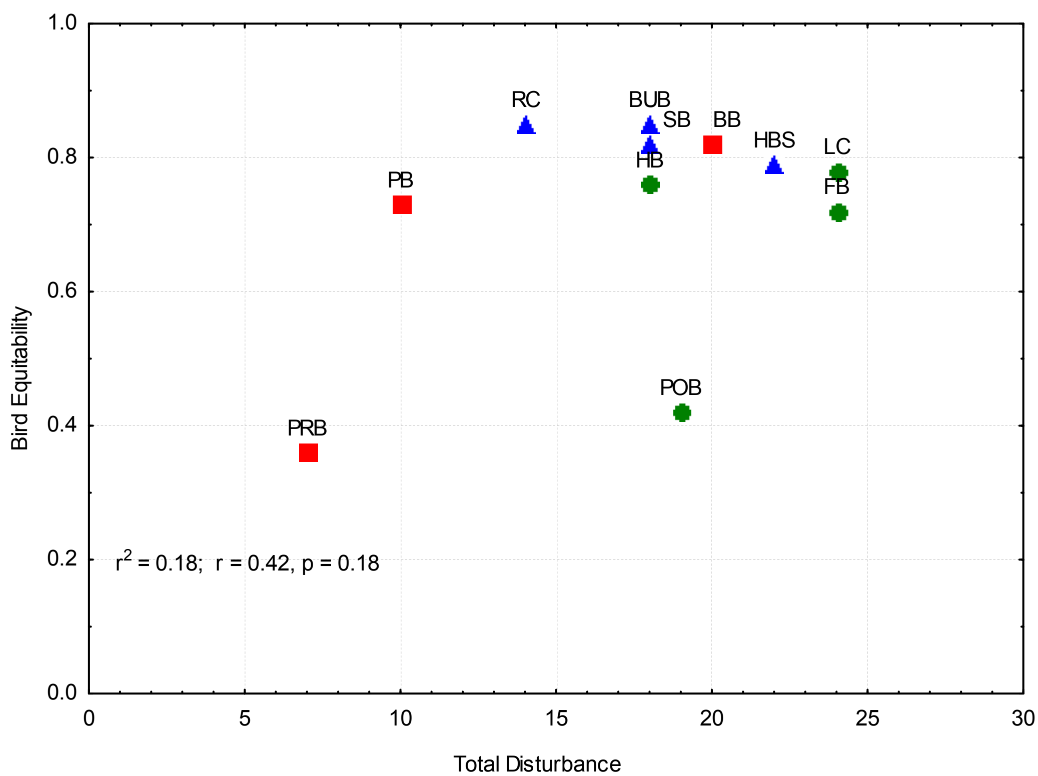


Figure 8-1. The relationship between bird species A) richness, B) diversity, and C) equitability and site disturbance at Lake Ontario and St. Lawrence River coastal wetlands. Symbols denote wetland geomorphic type: =barrier beach, =open bay, =protected bay. Data points are labeled with wetland

site name acronyms (See Table 1-1)

*8.1.4.2 Amphibian Species Richness*
Amphibian species richness did not appear to respond to increasing levels of disturbance across the sites tested (Figure 8-2).

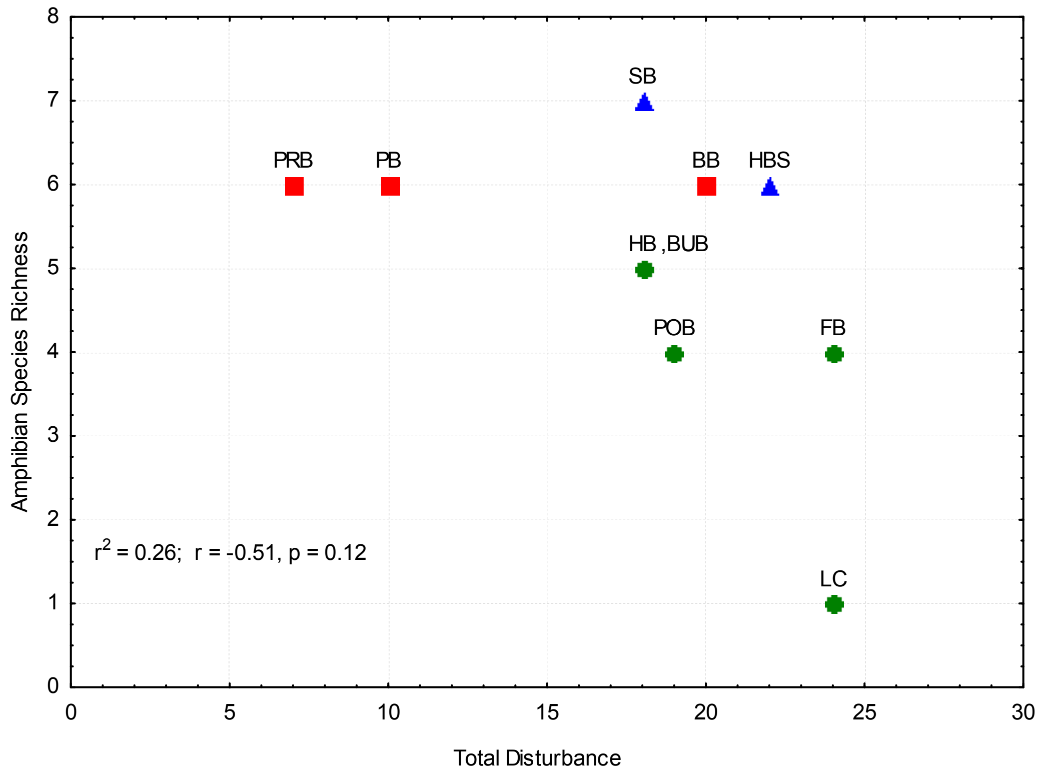


Figure 8-2. The relationship between amphibian species richness site disturbance at Lake Ontario and St. Lawrence River coastal wetlands. Symbols denote wetland geomorphic type: =barrier beach, =open bay, =protected bay. Data points are labeled with wetland site name acronyms (See Table 1-1)

## 8.2 Discussion

### 8.2.1 Birds

A review of the raw data indicates that at sites with relatively high species richness and low diversity (Presqu'ile Bay and Port Britain), the decreased diversity can be attributed to large numbers of red-winged black birds (*Agelauis Phoenixes*) in the sample area. For this reason, wetland bird species diversity measures may not be suitable metrics for coastal wetland IBIs. In this study, the majority of the variability in species diversity can be attributed to red-winged black bird abundance and not the level of human disturbance.

Equitability, which is related to diversity, can also be strongly influenced by large numbers red-winged black birds. Regardless, this parameter did not exhibit considerable variation among wetlands and does not appear a suitable metric for wetland bird community health.

Species richness was variable among the wetlands and may prove suitable for use as a wetland bird community health metric.

Bird Studies Canada, Year 1 report will incorporate Lake Ontario data and other suitable data from around the Great Lakes to further test and evaluate bird and amphibian community metrics. Analysis of this integrated database will provide more conclusive results with respect to metric sensitivity to wetland condition.

### 8.2.2 Amphibians

The range of species richness of amphibians among sites indicates that this metric may be suitable for describing coastal wetland amphibian community health. The Bird Studies Canada study may prove to identify other amphibian community metrics.

### 8.2.3 Sampling Effort

The number of bird and amphibian species identified within a wetland was not strongly influenced by the number of survey stations. If there was a significant relationship between these two variables, then the mean number of species per survey station would be a more suitable measure of species richness in the wetland.

## 8.3 Cost

The resource costs associated with the testing and validation of bird and amphibian community indicators in Year 1 can be broken down into the equipment, personnel and travel required to complete field surveys. Data collection was carried out by paid personnel and volunteers (who are responsible for covering their own costs for travel and equipment). Therefore, it is difficult to provide a complete picture of the resource costs required to implement this program. In addition, future monitoring years may have varying proportions of volunteers secured for data collection. This will influence the required resource costs considerably, particularly in terms of wages and travel expenses. In 2002, CWS-Ontario conducted surveys in 7 of the 12 study sites, comprising a total of 25 bird and/or amphibian survey stations (only 16 different stations, as several stations were used for both amphibian and bird surveys). Surveys at eight of the study sites were completed, partially or entirely, by volunteers or the TRCA.

### 8.3.1 Equipment

The cost of equipment to survey seven of the twelve study sites has been provided. Equipment costs would increase modestly with the increase in study sites surveyed because there are few consumable equipment items. For volunteers and agencies, much of the required equipment consists of common household/workplace items that may already be in the possession of surveyors, thus lowering the total resource costs. Table 8-4 lists the items required to undertake MMP surveys along with an estimate of the cost, necessity and consumable status of each item. This represents the costs incurred by CWS-Ontario in Year 1 of the study as well as potential costs for volunteers undertaking surveys. The costs are broken down into consumables (one-time use) and non-consumables (used multiple times). Clearly in the case of a long-term program the non-consumables will only represent one-time or occasional (*i.e.* when replacement is necessary) costs.

A separate category of equipment costs, covered by BSC, is that of the provision of training and survey materials to all surveyors, both volunteer and paid personnel. These include information mail-outs, an instruction manual, training and playback tapes, metal tags, blank data forms, and newsletters.

### 8.3.2 Personnel

Two paid personnel were required for 12 evenings of field work to complete the seven routes of bird and amphibian surveys. In addition to the wage costs, nine of the evenings required overnight accommodations for both individuals. Amphibian surveys require three separate evening visits for each station, and bird surveys require two separate visits. Each route typically consists of 2-4 survey stations, and surveyors generally cover one route per evening. CWS-Ontario tried to maximize time-efficiency by covering two routes per evening when distance between sites allowed for this. However, there are specific and narrow time windows for surveys to be conducted, and it is not possible to complete a large number of surveys in one evening. In addition to the time required to conduct the surveys, extra staff time was required for logistics planning, site selections, landowner contacts, and survey station identification.

Eight volunteers and staff from TRCA, complemented the personnel required to complete data collection in the 12 study sites. While there were no wage or travel costs where volunteer assistance was available, there were costs incurred by both CWS and BSC in terms of staff time to recruit, support and maintain these volunteers. Furthermore, BSC staff time will be required for compilation and analysis of data.

The costs described above pertain to all the study sites, and there were no discernible differences in cost among the three geomorphic wetland types. The same equipment and personnel needs for conducting MMP surveys apply to each site, regardless of geomorphic type. The most effect method to reduce travel costs would be to recruit volunteer surveyors.

Table 8-4. Equipment costs required to complete MMP bird and amphibian surveys at seven of twelve study sites with a total of 16 different stations (C=Consumable, N= Non-consumable)

| Item | Cost (CAD) | C/N |
|---|---|---|
| Binoculars[1] | 250 | N |
| Portable tape player | 65 | N |
| Flashlight | 30 | N |
| Batteries | 15 | C |
| Hip/Chest waders | 200 | N |
| 10' × ½" metal electrical conduit | 60 | C |
| Flagging & reflective tape | 10 | C |
| GPS Unit | 325 | N |
| Topographical maps/Air photos | 70 | N |
| Compass | 30 | N |
| Thermometer | 5 | N |
| Stopwatch | 10 | N |
| Clipboard | 5 | N |
| Pens/Pencils | 5 | C |
| 50-100m Measuring Tape | 10 | N |
| Back Pack or Fanny Pack | 30 | N |
| Insect Repellant | 5 | C |
| Field Guides | 50 | N |
| **Total** | **1175** | |

Superscripts indicate equipment shared with other sampling tasks: 1=site attributes

## 8.4 Measurability

### 8.4.1 Expertise and Training

The Marsh Monitoring Program was designed as a volunteer-based program so no specific education is required to conduct surveys. However, surveyors must have some knowledge of wetland ecosystems and species identification skills. Volunteer participation is most suited to naturalists or biologists with these skills. Specifically, for the amphibian surveys participants must be able to correctly identify the calls of the 13 species of frogs and toads found in the Great Lakes basin. For the marsh bird surveys, participants should be able to correctly identify at least 50 species of wetland birds by both sight and sound (Marsh Monitoring Program 2001). Surveyors are required to complete a habitat description at each station. While this does not require a high level of botanical expertise, participants must be able to recognize and make distinctions between the major groups of wetland plants. Surveyors should also have some familiarity with conducting work in a wetland setting. Despite the fact that the program was designed for volunteers, participants must be aware of the need to record accurate information in a rigourous scientific manner. In general, preference should be given to volunteers or paid staff with demonstrated experience and expertise in these areas when recruiting personnel.

In terms of training, surveyors need to familiarize themselves with MMP instruction booklet training tape provided by BSC. As well, surveyors can use the training tape to ensure that they are able to identify all calls/songs of amphibians and/or birds before commencing their surveys. While it is not necessary for agency staff to hold training sessions, BSC and CWS staff should continue to be available to provide advice and answer questions for surveyors via telephone or e-mail.

### 8.4.2 Comments and Recommendations on Methodology

#### *8.4.2.1 Staff vs. Volunteer Surveys*

Bird Studies Canada has demonstrated that the MMP methodology is of value in yielding species occurrence, relative abundance, distribution and population trend information, providing that participants follow the established protocol (Weeber and Vallianatos 2000). Specific comments regarding the adequacy of the data for reporting on coastal wetland health via community indicators cannot be made until further analysis has been conducted. The binational MMP program has been in place throughout the Great Lakes since 1995 and is showing promise as a long-term, basin-wide monitoring strategy.

The main difficulty encountered in implementing this program was created by the lack of complete coverage by volunteers. With only about 50% of the wetlands having volunteers recruited for surveys, CWS personnel were required to survey the remaining sites. CWS personnel often traveled long distances to survey sites and were not able to conduct surveys due to poor weather conditions. In other instances surveys had to be conducted on pre-scheduled evenings regardless of weather conditions in order to complete surveys within the recommended survey windows. The activity levels of amphibians and birds as well as the detection ability of surveyors are highly influenced by weather conditions. Therefore, the MMP protocol states that surveying occur only in specific weather conditions. However, personnel coming from long distances clearly do not have the flexibility of local volunteers who have a greater ability to initiate surveys on short-notice as soon as conditions become ideal. On these occasions, bird and amphibian activity may have been reduced and/or the surveyor's detection ability impaired. This suggests that the data collected on these occasions may not have been representative of the true state of the wetland.

Securing additional local volunteers that are able to conduct surveys during suitable weather is highly recommended and would reduce these problems. However, access to Lake Ontario coastal wetlands is often difficult and coastal wetlands associated with the Upper Great Lakes will be even more remote. Finding suitable and willing volunteers for these sites may prove difficult. Financial incentives to offset travel costs may help in volunteer recruitment. Alternatively, if sufficient volunteers cannot be recruited to survey sites, agencies should consider allocating more staff field time to complete surveys.

Because the MMP is firmly established with a strong network of experienced volunteers, a good support system, and several years of accumulated data, it is recommended that the GLCWC bird and amphibian monitoring continue to follow this program.

#### *8.4.2.2 Audio Equipment*

During CWS surveys, the use of one tape player did not elicit any responses from the target bird species yet some of these species were later detected using a louder device. Before beginning surveys, surveyors should test that the bird calls played on their tape player can be heard by another person 100 metres away. If the sound cannot broadcast over that distance, a louder tape player should be obtained.

#### *8.4.2.3 Sample Sizes*

Statistical analysis being completed by Bird Studies Canada will reveal if the sample sizes per wetland (*i.e.* the number of stations surveyed) were large enough to yield statistically comparable data for reporting on wetland health. In most cases, CWS staff established the maximum number of stations possible in each study site with respect to the size of the wetland. In a few cases, the maximum numbers of stations could not be established due to CWS time and access constraints. In future years, more stations per wetland could be surveyed with additional personnel.

## 8.5 Basin-wide Applicability and Sampling by Wetland Type

Evaluation of the basin-wide applicability of bird and amphibian community metrics will be completed by BSC by incorporating these data with addition data collected from coastal wetlands in the Great Lakes basin.

No differences with respect to location of the wetland or the geomorphic type were evident during the collection of bird and amphibian community data in the 12 study sites. The equipment, personnel required, sampling methodology and the access issues were generally consistent among sites. Wetlands closer to urban areas or major transport corridors have higher ambient noise than more remote wetlands, thus creating sampling difficulties. However, it may be more difficult to recruit volunteers for wetlands in more rural or isolated locations.

## 8.6 Availability of Complementary Data

Results of MMP surveys conducted on other Lake Ontario and St. Lawrence River coastal wetlands since the program's inception in 1995, as well as future surveys, will serve as a source of comparable and readily available data. CWS-Ontario is also involved in an International Joint Commission Lake Ontario/St. Lawrence water regulation review study for which data on bird communities was collected during the 2002 breeding season in nine of the 12 GLCWC study sites. These data may be of use as a complement to the bird survey data collected, and would be readily available. In addition, there are other volunteer frog survey programs that may yield some complimentary data. The Ecological Monitoring and Assessment Network (EMAN) supports a national FrogWatch program, and CWS supports a backyard and roadside amphibian call surveying program.

## 8.7 Literature Cited

The Marsh Monitoring Program -Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. February 2001. Training Kit and Instructions for Surveying Marsh Birds, Amphibians and Their Habitats. 2001 Revised Edition. 40 pages.

Weeber, R.C. and M. Vallianatos (editors) 2000. The Marsh Monitoring Program 1995 - 1999: Monitoring Great Lakes Wetlands and Their Amphibian Inhabitants. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. 47pp. http://www.bsc-eoc.org/mmpreport.html

## 9.0 GENERAL SUMMARY

### 9.1 Metric Sensitivity

This study preliminarily examined the suitability of 33 metrics across four wetland communities: vegetation, fish, birds and amphibians. The sensitivity of the metrics for coastal wetland IBI development has been summarized below (Table 9-1). Metrics deemed sensitive show significant relationships (linear regression p<0.05) with the level of wetland disturbance. Metrics that respond in a marginally significant manner to disturbance (0.05<p>0.10) and metrics that did not show a relationship (p>0.10) have been included. In addition, the influence of the suitable and marginally suitable metrics on an overall coastal wetland IBI is indicated.

Again, this represents a cursory analysis of 12 Lake Ontario coastal sites only. Some metrics may prove to exhibit a non-linear relationship with site disturbance and other metrics not evaluated in this study may prove suitable in Lake Ontario coastal wetlands. Some metrics that did not show sensitivity to site wetland condition within the 12 Lake Ontario sites, may prove suitable when evaluated within the larger Great Lakes coastal wetland databases. Further, there is currently no standard for ranking site disturbance level and the methodology incorporated in this study may prove to be unsuitable for Great Lakes coastal wetlands.

Table 9-1. A summary of biotic community metric sensitivity based on the 12 Lake Ontario wetland sites

| Sensitive Metrics | Metric | Influence on IBI |
|---|---|---|
| | Vegetation FQI in meadow marsh | + |
| | Vegetation FQI in emergent zone | + |
| | Non-native plant species richness for entire site | - |
| | | |
| | Non-native fish species richness | - |
| | Mean fish per net | - |
| **Moderately Sensitive Metrics** | | |
| | Vegetation FQI for site | + |
| | Mean percent non-native cover in emergent zone | + |
| | | |
| | Fish Species Richness | - |
| | Piscivorous species richness | + |
| | Mean fish per trap | - |
| **Non-sensitive Metrics** | | |
| | Vegetation FQI for submerged zone | |
| | Vegetation species richness in meadow marsh | |
| | Vegetation species richness in emergent zone | |
| | Vegetation species richness in submerged zone | |
| | Vegetation species richness for site | |
| | Mean % non-native plant cover in meadow marsh | |
| | Mean % non-native plant cover in submerged zone | |
| | Mean % non-native plant cover for site | |
| | Mean vegetation coverage in meadow marsh | |
| | Mean vegetation coverage in emergent zone | |
| | Mean vegetation coverage in submerged zone | |
| | Mean vegetation coverage at site | |
| | Non-native plant species richness in meadow marsh | |
| | Non-native plant species richness in emergent zone | |
| | Non-native plant species richness in submerged zone | |
| | | |
| | Turbidity intolerant fish species richness | |
| | Rate of DELT anomalies in fish | |

Fish family species richness

Amphibian species richness

Bird species richness
Bird diversity
Bird equitability

## 9.2 Total Resource Requirements

### 9.2.1 Equipment

An extensive list of equipment was required to complete all the required on each of the 12 coastal wetlands. Over 85% of the equipment costs were related to non-consumable equipment. The lists below summarize the total costs of consumable equipment and non-consumable equipment.

Table 9-2. Consumable equipment list with cost and associated field sampling task.

| Item | Cost (CAD) | Task |
|---|---|---|
| 10’ * ½" metal electrical conduit | 60 | 6 |
| Air photo overlay transparencies | 12 | 1 |
| Alkalinity | 76 | 2 |
| Ammonia | 197 | 2 |
| Batteries | 15 | 6 |
| Cleaning Equipment | 50 | 2 |
| Conductivity standard | 35 | 2 |
| Duct tape | 4 | 4 |
| Ethanol | 360 | 2 |
| Field books | 20 | 2 |
| Filters | 95 | 2 |
| Flagging & reflective tape | 10 | 6 |
| Gas for outboard motor | 50 | 5 |
| Gasoline for boat motor | 50 | 4 |
| GFC filters | 95 | 2 |
| Gloves | 19 | 2 |
| HCl | 81 | 2 |
| Insect Repellant | 5 | 6 |
| Kimwipes | 97 | 2 |
| Laboratory Costs | 1050 | 2 |
| Nitraver 3 | 100 | 2 |
| Nitraver 5 | 88 | 2 |
| Nitric acid | 42 | 2 |
| Paper towels | 77 | 2 |
| Pens/Pencils | 5 | 1,4,6 |
| pH standards | 42 | 2 |
| Phosver 3 | 78 | 2 |
| Pipette tips | 154 | 2 |
| Plastic specimen bags (Ziplocs) | 5 | 4 |
| Sodium hydroxide | 79 | 2 |
| Standards (nutrients) | 284 | 2 |
| Sulfuric acid | 66 | 2 |
| Syringe filters | 476 | 2 |
| Syringes | 261 | 2 |
| Thermometer | 55 | 2 |
| Turbidity standard | 294 | 2 |
| **Total** | **4487** | |

Tasks: 1=site attributes, 2=water chemistry and invertebrate sampling, 3=invertebrate processing, 4=vegetation sampling, 5=fish sampling, 6=bird and amphibian sampling

Table 9-3. Non-consumable equipment list with cost and associated field sampling task.

| Item | Cost (CAD) | Task |
|---|---|---|
| 12 minnow traps | 130 | 5 |
| 14' Flat-bottomed boat | 1400 | 4 |
| 14' Flat-bottomed boat | 1400 | 5 |
| 2 x 12 Volt battery | 200 | 4,5 |
| 50-100m Measuring Tape | 10 | 6 |
| 6 fyke nets | 4000 | 5 |
| 6 Hp 4-stroke outboard motor | 2200 | 4 |
| 9.9 HP outboard motor | 2250 | 5 |
| Back Pack or Fanny Pack | 30 | 6 |
| Back pack/fanny pack | 30 | 4 |
| Backpack | 90 | 2 |
| Battery charger | 30 | 4,5 |
| Beakers | 33 | 2 |
| Bench mat | 715 | 2 |
| Binoculars2 | 250 | 1,6 |
| Boat anchor with rope | 15 | 4 |
| Boat safety kit1 | 20 | 2,4 |
| Boat trailer | 900 | 5 |
| Calibration rack | 99 | 2 |
| Canoe | 1200 | 2,4 |
| Carboys | 368 | 2 |
| Clipboard | 5 | 4,6 |
| Compass | 20 | 4 |
| Compass | 30 | 6 |
| D-frame nets | 420 | 2,3 |
| Digital planimeter | 1600 | 1 |
| Dissecting microscope | 2,205 | 2 |
| DR890 | 1,685 | 2 |
| Electric motor3 | 200 | 4,5 |
| Field Guides | 50 | 6 |
| Field guides & taxonomic keys | 250 | 4 |
| Filtering unit | 132 | 2 |
| Fish ID resources | 100 | 5 |
| Fish measuring board | 20 | 5 |
| Flashlight | 30 | 6 |
| Forceps | 35 | 2,3 |
| Glass vials | 273 | 2,3 |
| Goggles | 20 | 2 |
| GPS Unit | 325 | 2 |
| GPS Unit | 325 | 1,5,6 |
| GPS Unit | 325 | 4 |
| Graduated Cylinders | 237 | 2 |
| Hand counters | 40 | 3 |
| Hand lens | 5 | 4 |
| Hand pump | 132 | 2 |
| Hip/chest waders | 200 | 4 |
| Hip/chest waders | 200 | 2 |
| Hip/chest waders | 200 | 1,5,6 |

| | | |
|---|---|---|
| Holding buckets for fish | 45 | 5 |
| Hydrolab | 8,010 | 2 |
| Lab coats | 95 | 2 |
| Life jackets | 80 | 5 |
| Life jackets | 80 | 2 |
| Life jackets | 80 | 4 |
| Metal conduit for depth measurements | 2 | 4 |
| Nalgene bottles | 275 | 2 |
| Net poles (conduit) | 150 | 5 |
| Paddles | 40 | 2,4 |
| Pans | 23 | 2 |
| Petri dishes | 105 | 2 |
| Pipette | 346 | 2 |
| Plant press | 40 | 4 |
| Plastic vials | 97 | 2 |
| Portable tape player | 65 | 6 |
| Quadrat frame | 10 | 4 |
| Sampling tubes | 274 | 2 |
| Scissors | 5 | 2 |
| Secchi disk | 40 | 2 |
| Secchi disk | 40 | 5 |
| Stopwatch | 10 | 6 |
| Test-tube racks | 145 | 2 |
| Thermometer | 5 | 6 |
| Topographical maps/Air photos | 220 | 1,4,6 |
| Volumetric Flasks | 55 | 2 |
| **Total** | **34776** | |

Tasks: 1=site attributes, 2=water chemistry and invertebrate sampling, 3=invertebrate processing, 4=vegetation sampling, 5=fish sampling, 6=bird and amphibian sampling

### 9.2.2 Staff Resources

Bird and amphibian sampling was completed by two staff members in spring and early summer. The remainder of field sampling activities occurred in July and the first week of August. During this time, sites were generally sampled by a crew in which individuals and groups of individuals were responsible for completing certain tasks (i.e., plant quadrat sampling, fish net setting, water chemistry). However, the sampling was a concerted effort among crew members and there were several instances of overlap in personnel duties between field work tasks. For example, crew members assigned to fish sampling tasks would often support invertebrate collection tasks after fyke nets and minnow traps were set. The range of time required per site has been estimated in total person hours (Table 9-4). A crew of six people was typically used during field sampling in July, a crew of this size typically enable collection of the required data in 1 ½ days per site.

Table 9-4. The expected time and personnel required per site to perform each data collection task.

| Task | Personnel | Minimum Time | Maximum Time |
|---|---|---|---|
| Site attribute data collection | 1 | 10 minutes | 10 minutes |
| Land use measurements | 1 | 6 hours | 8 hours |
| Water chemistry sampling | 1 | 2 hours | 3 hours |
| Water sample analysis | 1 | 40 minutes | 40 minutes |
| Invertebrate sweep net sampling | 1 | 30 minutes | 1.5 hours |
| Invertebrate picking | 1 | 45 minutes | 1.5 hours |
| Vegetation sampling | 2 | 2 hours | 4 hours |
| Fish net and trap setting | 2 | 2 hours | 4 hours |
| Fish collection and processing | 2 | 2 hours | 6 hours |
| Bird sampling (2 visits) | 2 | 4 hours | 6 hours |

| | | | |
|---|---|---|---|
| Amphibian sampling (3 visits) | 2 | 6 hours | 9 hours |
| **Total person hours** | | **42hours, 5 minutes** | **72 hours, 50 minutes** |

Other staff costs to be considered in implementation of a Great Lakes coastal wetland monitoring program, is time required to identify monitoring sites, adjacent landowners and complete landowner contacts where necessary to obtain access to the wetland.

### 9.2.3 Travel and Accommodation

Travel and accommodation, are difficult assess on a per wetland basis. For example, in Prince Edward County, accommodations were not required because the field crew stayed at a cabin owned and maintained by the Canadian Wildlife Service. At other sites, accommodations were required for some of the crew members because the sites were too far from their residences while other crew members returned to their residences.

Weekly field work was completed at sites that were geographically clustered. For example, Button Bay, Bayfield Bay and Parrott's Bay were all assessed in the same week (Table 9-5). Therefore, the distances traveled to and from the sites depended on where the field crew was centred and the order that the sites were assessed.

Due to the difficulty in assessing and reporting the variable cost of travel and accommodation per wetland, a chronological summary of field activities has been summarized here. The table includes the dates and locations of all field tasks as well as details regarding the accommodations sought. Because crew members specialized in individual field tasks (i.e., water chemistry, vegetation surveys), it can be assumed that individual tasks completed at different wetlands required travel.

## 9.3 Summary

The purpose of this project was to evaluate coastal wetland health indicators and metrics and sampling methodologies in Lake Ontario and the St. Lawrence River as part of a binational Great Lakes effort. This report summarizes and discusses the results from the Canadian wetlands only. Data were successfully collected regarding water chemistry, site disturbance attributes, invertebrates, vegetation, fish, birds and amphibians in 12 Canadian coastal wetlands in Lake Ontario and the St. Lawrence River and all proposal objectives fulfilled.

Field data collection occurred over 35 days between April 17 and August 9, 2002. The cost (CAD) of consumable and non-consumable field and data collection equipment was approximately $4487 and $34776, respectively. Throughout the data collection phase, eight different biologists were involved in field data collection. The number of biologists in the field at any one time varied between two and six, depending on the tasks involved. Accommodation requirements over the data collection period amounted to 94 person accommodation nights.

Proposed sampling methodologies were successfully implemented in barrier beach, open and protected bay Lake Ontario coastal wetlands. Considerations and recommendations relating to each methodology have been provided. This report evaluated the response of 32 metrics across vegetation, fish, bird, and amphibian communities to increases in site disturbance. This cursory evaluation determined five suitable metrics and five potentially suitable metrics in the fish and vegetation communities. Only conclusions based on the integrated Great Lakes indicator analysis, as proposed and being completed by the Michigan research team and BSC should used to advance the Consortium objectives.

Table 9-5. The complete filed schedule for GLCWC filed work during 2002.

| Date | Study Site(s) | Activity | Accommodations |
|---|---|---|---|
| April 17 | Bayfield Bay | A | 3 |
| April 17 | Button Bay | A | |
| April 24 | Hay Bay South | A | 2 |

| | | | |
|---|---|---|---|
| April 24 | South Bay | A | |
| May 1 | Port Britain | A | |
| May 22 | Huyck’s Bay | B | |
| May 22 | South Bay | A, B | 2 |
| May 23 | Parrott’s Bay | B | |
| May 23 | Hay Bay South | A, B | 2 |
| May 24 | Bayfield Bay | A, B | |
| May 24 | Button Bay | A, B | |
| May 28 | Port Britain | A | |
| June 18 | Huyck’s Bay | B, H, WC | |
| June 18 | South Bay | A, B, H, WC | 3 |
| June 19 | Bayfield Bay | A, B, H | |
| June 19 | Button Bay | A, B, H, WC | 3 |
| June 20 | Parrott’s Bay | B, H, WC | |
| June 20 | Hay Bay South | A, B, H, WC | 3 |
| June 27 | Port Britain | A, H | |
| July 2 | Lynde Creek | F, V, SA | 4 |
| July 3 | Lynde Creek | F, WC | |
| July 4 | Port Britain | F, WC, V, I | 4 |
| July 5 | Port Britain | F, SA, I | |
| July 8 | South Bay | F, WC, V, SA, I | 6 |
| July 9 | South Bay | F, I | |
| July 9 | Huyck’s Bay | F, | 6 |
| July 10 | Huyck’s Bay | F, WC, V, SA, I | |
| July 10 | Robinson’s Cove | F, V, SA | 6 |
| July 11 | Robinson’s Cove | F, WC, I | |
| July 15 | Button Bay | F, V, SA | 4 |
| July 16 | Button Bay | F, WC, V, I | |
| July 16 | Bayfield Bay | F, WC, I | 6 |
| July 17 | Bayfield Bay | F, V, SA, I | 6 |
| July 18 | Parrott’s Bay | F, WC, V, SA, I | 5 |
| July 19 | Parrott’s Bay | F, I | |
| July 22 | Hay Bay South | F, WC, I | 5 |
| July 23 | Hay Bay South | F, V, SA | 5 |
| July 24 | Presqu’ile Bay | F, WC, V, SA, I | 5 |
| July 25 | Presqu’ile Bay | F | |
| July 29 | Hill Island East | F, WC, V, SA, I | 5 |
| July 30 | Hill Island East | F | |
| July 30 | Frenchman’s Bay | F | 3 |
| July 31 | Frenchman’s Bay | F, WC, V, SA, I | |
| August 6 | Lynde Creek | I | |
| August 6 | Button Bay | F | 2 |
| August 7 | Button Bay | F | |
| August 7 | Parrott’s Bay | F | 2 |
| August 8 | Parrott’s Bay | F | |
| August 8 | South Bay | F | 2 |
| August 9 | South Bay | F | |

For activities: A=amphibians, B=birds, F=fish, I=invertebrates, SA=site attributes, V=vegetation, WC=water chemistry.

## APPENDIX A

Table A-1. Mean values (±standard deviation) for all measured water chemistry parameters in the 12 wetlands, separated by the emergent and meadow marsh vegetation communities.

| Study Site | Depth (m) | Secchi (m) | Air T (°C) | Water T (°C) | DO (mg/L) | pH | COND (μS/cm) | Redox (mΩ) | TURB (NTU) | $PO_4$ (mg/L) | $NO_3$ (mg/L) | $NO_2$ (mg/L) | $NH_4$ (mg/L) | CHL (μg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EMERGENT ZONE | | | | | | | | | | | | | | |
| Hill Island East | 0.40± 0.13 | 0.40± 0.13 | 30± 1 | 28.26± 0.68 | 6.49± 0.56 | 6.90± 0.17 | 270± 49 | 428± 11 | 10.0± 1.2 | 0.15± 0.08 | 0.4± 0.1 | 0.008 ± 0.001 | 0.02± 0.02 | 6.9± 4.2 |
| Bayfield Bay | 0.58± 0.23 | 0.55± 0.26 | 27± 2 | 24.30± 1.14 | 6.09± 1.12 | 7.23± 0.18 | 271± 3 | 315± 38 | 14.1± 7.0 | 0.28± 0.12 | 0.8± 0.2 | 0.012 ± 0.004 | 0.03± 0.01 | 18.3± 16.8 |
| Parrott's Bay | 0.80± 0.18 | 0.56± 0.12 | 26± 3 | 23.60± 1.02 | 5.92± 3.81 | 7.44± 0.48 | 339± 43 | 351± 58 | 11.5± 11.5 | 0.13± 0.14 | 0.4± 0.1 | 0.006 ± 0.001 | 0.01± 0.01 | 3.7± 1.1 |
| Presqu'ile Bay | 0.82± 0.25 | 0.82± 0.25 | 23± 1 | 22.79± 0.14 | 5.18± 0.79 | 7.44± 0.29 | 313± 26 | 334± 20 | 0.6± 0.7 | 0.14± 0.04 | 0.3± 0.1 | 0.009 ± 0.006 | 0.03± 0.02 | 0.8± 0.6 |
| Button Bay | 0.48± 0.13 | 0.48± 0.13 | 23± 3 | 23.49± 0.84 | 5.58± 4.77 | 7.41± 0.58 | 305± 7 | 349± 36 | 7.2± 5.5 | 0.29± 0.14 | 0.6± 0.2 | 0.010 ± 0.002 | 0.06± 0.04 | 7.9± 0.8 |
| Hay Bay South | 0.38± 0.06 | 0.31± 0.13 | 25± 2 | 25.12± 0.63 | 7.28± 2.99 | 7.71± 0.31 | 361± 26 | 344± 58 | 39.0± 38.8 | 0.10± 0.05 | 1.4± 1.0 | 0.039 ± 0.024 | 0.11± 0.11 | 29.4± 23.0 |
| South Bay | 0.48± 0.19 | 0.48± 0.19 | 24± 4 | 16.40± 1.71 | 9.90± 3.86 | 7.82± 0.74 | 307± 16 | 315± 42 | 9.1± 6.6 | 0.49± 0.79 | 0.9± 0.9 | 0.010 ± 0.007 | 0.02± 0.02 | 4.7± 1.1 |
| Robinson Cove | 0.57± 0.06 | 0.57± 0.06 | 27± 1 | 20.95± 0.56 | 5.20± 0.33 | 7.33± 0.14 | 261± 2 | 305± 9 | 9.3± 3.0 | 0.19± 0.10 | 0.5± 0.1 | 0.030 ± 0.009 | 0.06± 0.03 | 5.2± 0.1 |
| Port Britain | 0.40± 0.15 | 0.38± 0.12 | 25± 3 | 25.07± 1.15 | 1.99± 0.49 | 7.14± 0.03 | 511± 31 | 382± 23 | 10.2± 5.1 | 0.24± 0.12 | 1.0± 0.2 | 0.030 ± 0.010 | 0.08± 0.06 | 24.7± 1.3 |
| Lynde Creek | 0.38± 0.03 | 0.38± 0.03 | 23± 1 | 20.75± 0.94 | 5.45± 1.50 | 7.07± 0.10 | 723± 19 | 223± 22 | 24.27± 38.87 | 0.26± 0.06 | 0.7± 0.2 | 0.009 ± 0.005 | 0.03± 0.00 | 23.1± 33.7 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Huyck's Bay | 0.60± 0.11 | 0.60± 0.11 | 21± 2 | 22.44± 0.92 | 0.69± 0.73 | 6.79± 0.13 | 387± 13 | 338± 73 | 5.1± 3.4 | 0.19± 0.07 | 0.5± 0.1 | 0.005 ± 0.001 | 0.03± 0.03 | 7.4± 3.2 |
| Frenchman's Bay | 0.35± 0.05 | 0.35± 0.05 | 26± 2 | 25.01± 0.54 | 4.00± 2.28 | 6.96± 0.53 | 403± 31 | 417± 22 | 3.2± 2.0 | 0.14± 0.06 | 0.7± 0.1 | 0.016 ± 0.002 | 0.05± 0.01 | 6.3± 1.0 |
| MEADOW MARSH | | | | | | | | | | | | | | |
| Bayfield Bay | 0.08± 0.06 | 0.08± 0.06 | 24± 0 | 22.70± 0.17 | 1.89± 0.17 | 6.80± 0.05 | 288± 4 | 326± 18 | 4.4± 0.3 | 0.68± 0.10 | 0.7± 0.1 | 0.007 0.003 | 0.03± 0.01 | |
| Presqu'ile | 0.17± 0.06 | 0.17± 0.06 | 28± 0 | 21.61± 0.18 | 0.89± 0.14 | 7.05± 0.02 | 366± 8 | 375± 32 | 7.1± 0.7 | 0.38± 0.16 | 0.9± 0.1 | 0.010 0.007 | 0.03± 0.01 | |
| Button Bay | 0.26± 0.13 | 0.26± 0.13 | 27± 1 | 24.25± 0.77 | 4.61± 1.55 | 7.13± 0.25 | 304± 5 | 350± 28 | 5.2± 4.0 | 0.40± 0.30 | 0.6± 0.1 | 0.009 0.003 | 0.03 0.01 | |
| Huyck's Bay | 0.20± 0.00 | 0.20± 0.00 | 21± 0 | 25.54± 1.61 | 5.86± 1.46 | 7.36± 0.14 | 514± 48 | 378± 16 | 6.2± 5.2 | 0.26± 0.07 | 0.4± 0.1 | 0.006 0.001 | 0.01 0.00 | |

Table A-2.  The correlation matrix the water chemistry parameters.

| | **Depth** | **Secchi** | **Air T** | **Water T** | **DO** | **pH** | **COND** | **Redox** | **TURB** | **$PO_4$** | **$NO_3$** | **$NO_2$** | **$NH_4$** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Depth** | 1.00 | | | | | | | | | | | | |
| **Secchi** | 0.87 | 1.00 | | | | | | | | | | | |
| **Air T** | 0.17 | 0.04 | 1.00 | | | | | | | | | | |
| **Water T** | -0.12 | -0.16 | 0.29 | 1.00 | | | | | | | | | |
| **DO** | 0.38 | 0.33 | 0.20 | -0.32 | 1.00 | | | | | | | | |
| **pH** | 0.41 | 0.33 | 0.24 | -0.32 | 0.86 | 1.00 | | | | | | | |
| **COND** | -0.20 | -0.28 | -0.27 | 0.19 | -0.19 | -0.03 | 1.00 | | | | | | |
| **Redox** | -0.30 | -0.31 | 0.13 | 0.47 | -0.32 | -0.34 | 0.23 | 1.00 | | | | | |
| **TURB** | 0.04 | -0.19 | 0.17 | 0.15 | 0.05 | 0.07 | -0.01 | 0.11 | 1.00 | | | | |
| **$PO_4$** | -0.31 | -0.33 | -0.24 | -0.23 | -0.10 | -0.31 | -0.09 | 0.03 | 0.04 | 1.00 | | | |
| **$NO_3$** | -0.26 | -0.36 | -0.13 | -0.08 | -0.19 | -0.22 | 0.04 | 0.16 | 0.65 | 0.55 | 1.00 | | |
| **$NO_2$** | -0.12 | -0.21 | 0.12 | 0.16 | -0.11 | -0.02 | 0.13 | 0.15 | 0.75 | 0.06 | 0.72 | 1.00 | |
| **$NH_4$** | -0.03 | -0.12 | 0.15 | 0.23 | -0.11 | 0.02 | 0.06 | 0.18 | 0.75 | -0.07 | 0.56 | 0.75 | 1.00 |

Table A-3. Number of fish captured in fyke nets and minnow traps at the 12 GLCWC study sites. Numbers in parentheses are fish captured during resampling

| Species | Lynde Creek | Port Britain | South Bay | Huyck's Bay | Robinson's Cove | Button Bay | Bayfield Bay | Parrott's Bay | Hay Bay | Presqu'ile Bay | Frenchman's Bay | Hill Island |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Amia calva* | | | 1(1) | 1 | 2 | | 2 | 3(1) | 2 | 1 | 4 | 3 |
| *Alosa pseudoharengus* | 34 | | | | | 46(7) | 1 | | | | 60 | |
| *Dorosoma cepedianum* | 3 | | | | | | | | | | | |
| *Notropis hudsonius* | | | (48) | | | 5(5) | | | | 2 | 13 | |
| *Cyprinella spiloptera* | | | | | | 15(8) | 1 | | | | 5 | |
| *Luxilis cornutus* | 3 | | | | | | | | | | 2 | |
| *Notropis heterolepis* | | | 1 | 1 | 12 | | | | | | | |
| *Notropis heterodon* | | | 2(10) | 6 | | | | | | 1 | | |
| *Pimephales promelas* | 9 | 26 | | | | 1 | | | | | | |
| *Notropis atherinoides* | | | | | | (1) | | | | | | |
| *Notemigonus crysoleucas* | 1 | 3 | (1) | | | 1 | | | | | | |
| *Pimephales notatus* | | 23 | 5 | 1 | | | | | | | | |
| *Cyprinus carpio* | 1 | 1 | (1) | 1 | | (2) | | | 1 | | | |
| *Catostomus commersoni* | | 1 | | | | (1) | | | 2 | | | |
| *Fundulus diaphanus* | | | | | 1 | 6 | | | 7 | 1 | | |
| *Ameiurus nebulosus* | 128 | 1 | 3(1) | 26 | | 48(16) | 83 | 18(1) | 35 | | 121 | 1 |
| *Ameiurus natalis* | | | | | | | | | | | 1 | |
| *Noturus gyrinus* | 6 | | 7(3) | | | | 1 | | | 2 | | |
| *Esox lucius* | 2 | | | | 2 | | | (1) | | | | |
| *Culaea inconstans* | | 3 | | | | | | | | | | |
| *Gasterosteus aculeatus* | | | 3 | | | | | | | | | |
| *Micropterus salmoides* | | 1 | 10(1) | 21 | 8 | 8(7) | 9 | 18(5) | 27 | 12 | 9 | 10 |
| *Ambloplites rupestris* | | 2 | 17(10) | | | 3 | 1 | 3 | | 8 | | 2 |
| *Lepomis macrochirus* | | 1 | | 91 | 2 | | | | | 4 | | 10 |
| *Pomoxis nigromaculatus* | 2 | | | 4 | 2 | | 4 | | 12 | | 14 | 1 |
| *Lepomis gibbosus* | 5 | 2 | 17 | 44 | 1 | 1 | 5 | 4(1) | 4 | 17 | 15 | 18 |
| *Lepomis* sp. | | | | | 7 | | 1 | (14) | 91 | 1 | | |
| *Morone americana* | | | | | | | | | 2 | | | |
| *Etheostoma nigrum* | | | | 1 | | | | (1) | | | | |
| *Perca flavescens* | 3 | 1 | 9 | 12 | 5 | 4(3) | 2 | (3) | 70 | 2 | | 2 |
| *Percina caprodes* | | | | | | | | | 1 | | | |
| *Umbra limi* | | | | | | | | (1) | 1 | | | |
| TOTAL | 197 | 64 | 78(78) | 210 | 42 | 140(52) | 110 | 45(29) | 255 | 51 | 244 | 47 |

Table A-4. Representation of fish families across sites and wetland types

| Site | Wetland type | Family | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ictaluridae | Centrarchidae | Amiidae | Cyprinidae | Gasterostidae | Percidae | Clupeidae | Catostomidae | Fundulidae | Esocidae | Umbridae | Moronidae |
| Hill Island East | Protected Bay | x | x | x | x | | x | x | | | | | |
| Bayfield Bay | Protected Bay | x | x | x | x | | x | x | | | | | |
| Parrott's Bay | Protected Bay | x | x | x | | | x | | | | x | x | |
| Presqu'ile Bay | Protected Bay | x | x | x | x | | x | | | x | | | |
| Button Bay | Open Bay | x | x | | x | | x | x | x | x | | | |
| Hay Bay South | Open Bay | x | x | x | x | | x | | x | x | | x | x |
| South Bay | Open Bay | x | x | x | x | x | x | | | | | | |
| Robinson's Cove | Open Bay | | x | x | x | | x | | | | x | | |
| Port Britain | Barrier Beach | x | x | | x | x | x | | x | | | | |
| Lynde Creek | Barrier Beach | x | x | | x | | x | x | | | x | | |
| Huyck's Bay | Barrier Beach | x | x | x | x | | x | | | | | | |
| Frenchman's Bay | Barrier Beach | x | x | x | x | | | x | | | | | |

Table A-5. Two tailed Mann-Whitney U -test statistics and p-values for number of fish, number of species and number of families per net within each site between sample periods.

| Site | Variable | U | p | n 1st sample | n 2nd sample |
|---|---|---|---|---|---|
| Button Bay | fishes per net | 4.50 | 0.31 | 4 | 4 |
| | species per net | 4.00 | 0.24 | 4 | 4 |
| | families per net | 2.00 | 0.08 | 4 | 4 |
| | fishes per trap | 10.0 | 0.20 | 6 | 6 |
| | species per trap | 13.5 | 0.47 | 6 | 6 |
| | families per trap | 13.5 | 0.47 | 6 | 6 |
| Parrot's Bay | fishes per net | 3.00 | 1.00 | 3 | 2 |
| | species per net | 1.50 | 0.38 | 3 | 2 |
| | families per net | 0.00 | 0.08 | 3 | 2 |
| | fishes per trap | 4.00 | 0.47 | 4 | 3 |
| | species per trap | 5.00 | 0.72 | 4 | 3 |
| | families per trap | 5.00 | 0.72 | 4 | 3 |
| South Bay | fishes per net | 5.00 | 0.72 | 3 | 4 |
| | species per net | 4.00 | 0.47 | 3 | 4 |
| | families per net | 4.50 | 0.59 | 3 | 4 |
| | fishes per trap | 7.50 | 0.69 | 6 | 3 |
| | species per trap | 7.50 | 0.69 | 6 | 3 |
| | families per trap | 7.50 | 0.69 | 6 | 3 |

Table A-6. Summary of invertebrate sampling supporting data for each dominant vegetation unit in the 12 wetlands sampled in July 2002, grouped by emergent and meadow marsh vegetation zones.

| Wetland | Dominant Vegetation | Depth (cm) | Secchi (cm) | Air Temperature (°C) | Water Temperature (°C) |
|---|---|---|---|---|---|
| EMERGENT COMMUNITY | | | | | |
| Hill Island | *Typha* | 0.40±0.13 | 0.40±0.13 | 30±1 | 28.26±0.68 |
| Bayfield Bay | *Typha* | 0.58±0.23 | 0.55±0.26 | 27±2 | 24.30±1.14 |
| Parrott's Bay | *Typha* | 0.80±0.18 | 0.56±0.12 | 26±3 | 23.60±1.02 |
| Presqu'ile Bay | *Typha/Zizania* | 0.82±0.25 | 0.82±0.25 | 23±1 | 22.79±0.14 |
| Button Bay | *Sparganium* | 0.48±0.13 | 0.48±0.13 | 23±3 | 23.49±0.84 |
| Hay Bay South | *Typha* | 0.38±0.06 | 0.31±0.13 | 25±2 | 25.12±0.63 |
| South Bay | *Typha* | 0.48±0.19 | 0.48±0.19 | 24±4 | 16.40±1.71 |
| Robinson's Cove | *Typha/Scirpus* | 0.57±0.06 | 0.57±0.06 | 27±1 | 20.95±0.56 |
| Port Britain | *Typha* | 0.40±0.15 | 0.38±0.12 | 25±3 | 25.07±1.15 |
| Lynde Creek | *Typha* | 0.38±0.03 | 0.38±0.03 | 23±1 | 20.75±0.94 |
| Huyck's Bay | *Sparganium/Typha* | 0.60±0.11 | 0.60±0.11 | 21±2 | 22.44±0.92 |
| Frenchman's Bay | *Typha* | 0.35±0.05 | 0.35±0.05 | 26±0 | 25.01±0.54 |
| MEADOW MARSH COMMUNITY | | | | | |
| Presqu'ile Bay | *Carex* | 0.17±0.06 | 0.17±0.06 | 28±0 | 21.61±0.18 |
| Button Bay | *Phalaris* | 0.26±0.13 | 0.26±0.13 | 27±1 | 24.25±0.77 |