Great Lakes Coastal Wetlands Consortium Year-One Pilot Project Indicator Research Activities: A Technical Report by Bird Studies Canada

Steven T.A. Timmermans and G. Eoin Craigie

Marsh Monitoring Program, Bird Studies Canada

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MARSH MONITORING PROGRAM

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ABSTRACT

The overall goal of the Great Lakes Coastal Wetlands Consortium (GLCWC) is to develop a basin-wide biological monitoring program for Great Lakes coastal wetlands that can report on wetland health as it pertains to anthropogenic disturbance. 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 done on SOLEC recognized coastal wetland indicators and to begin to utilize these indicators to provide measures of wetland health by applying bio-monitoring state-and-stressor procedures. An essential component of indicator development is to evaluate various sampling protocols for collecting biotic community attribute information. Accepted methodologies can be implemented to collect biotic community attribute data for developing metrics that can be used for developing indices of biological integrity for certain biological communities. Sampling methodologies being evaluated include those for monitoring avian, amphibian, macro invertebrate, fish and plant community dynamics.

The purpose of this project was to evaluate suitable coastal wetland health indicators and sampling methodologies in Long Point, on the north-central shore of Lake Erie through a binational effort. This project is one of several one-year pilot projects occurring at various Great Lakes coastal wetland locations. All investigators in the one-year pilot projects agreed to collect the same flora, fauna, physical and landscape level data using standardized protocols. This report summarizes and discusses implementation of field sampling protocol done at various Long Point coastal wetlands for macro invertebrate, fish, and plant communities, and provides an more in depth evaluation of results form sampling procedures and field data collected for marsh birds and amphibians from coastal wetlands located on Lake Ontario, at Long Point on Lake Erie, Saginaw Bay on Lake Huron, and Arcadia Lake on Lake Michigan.

Over 150 days, from April through August 2002, field data were collected on water chemistry, site disturbance attributes, macro invertebrates, wetland plants, fish, birds and amphibians in 11 coastal wetlands of Long Point, Lake Erie. Site disturbance rankings were assigned to each site, based on collected biotic wetland data. Biotic community attributes were evaluated along a gradient of site disturbances to determine if biotic attributes could predict changes along the site disturbance gradient. This study tested responses of 19-marsh bird and amphibian community attributes to increases site disturbance. One attribute was found to be very sensitive, and a number of others showed some promise in their ability to predict wetland disturbance, however, most attributes were not sensitive to increasing site disturbance. However, these evaluations are preliminary and certain factors likely confounded our ability to detect responses. A more robust analysis of biological community attributes is planned using an integrated Great Lakes coastal wetland database. This integrated database will include data collected from all year-one pilot projects and previously collected data.

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

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1.0 INTRODUCTION

1.1 Background

During the 1990s, scientists, policy makers, managers, and other stakeholders working to monitor and report on the environmental status of the Great Lakes region convened to participate in State of the Lakes Ecosystem Conference (SOLEC). SOLEC provides an inlet and outlet of information sharing and cooperation among its participants who share a common goal – to improve the state of life in the Great Lakes region.

SOLEC's roots are embedded in the Great Lakes Water Quality Agreement, which has an overall purpose to "…*restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem*." Goals and objectives of SOLEC are outlined in detail in its bi-annual reports, the most recent one being *State of the Lakes 2001*. Over the years, SOLEC has evolved to recognize various 'State of the Lakes' (SOL) indicator categories, which are biological, chemical, physical, and societal in nature. One recognized SOLEC SOL indicator category is Coastal Wetlands.

During SOLEC 1998, a wetlands science working group identified and proposed for further development, several candidate coastal wetland indicators. Bird Studies Canada's Marsh Monitoring Program reports on two of these coastal wetland indicators: *4504 - Amphibian Diversity and Abundance* and *4507 - Wetland-Dependent Bird Diversity and Abundance*. These two indicators are among the suite of indicators proposed by SOLEC for further development.

The Great Lakes Coastal Wetlands Consortium (GLCWC) was established through a partnership between the Great Lakes Commission and the United States Environmental Protection Agency – Great Lakes National Program Office. The GLCWC is a coalition of scientific and policy experts who work within the Great Lakes region of the United States and Canada, and who have various responsibilities for coastal wetlands monitoring. Its goal is to build upon SOLEC's indicator development and SOL reporting capacity for coastal wetlands (http://www.glc.org/monitoring/). A Project Management Team consisting of members representing over two-dozen agencies, organizations and institutions provides guidance and direction for various action items associated with Great Lakes coastal wetlands monitoring.

In 2001, the GLCWC issued a Request for Proposals inviting proposals from institutions, organizations, and agencies to conduct scientific research and analysis of Great Lakes coastal wetlands monitoring data.

Bird Studies Canada (BSC) submitted a proposal in request for supporting work to advance development of SOL indicators *4504* and *4507* for reporting on biological integrity of Great Lakes coastal wetlands. BSC proposed to work with GLCWC research partners to collect amphibian and wetland-dependent bird (hereafter marsh bird) data at various select coastal wetland sites throughout the Great Lakes basin, and proposed to conduct its own 2002 GLCWC research activities at coastal wetland sites located at Long Point, Ontario, which occurs in Lake Erie. BSC also proposed to work with GLCWC partners to collect monitoring data for other biological, chemical, and physical indicators at Long Point coastal wetland sites.

This document reports on these activities and focuses on BSC's primary goals to examine MMP data and seek meaningful attributes of these monitoring data to develop Indices of Biotic

Integrity (Karr 1981) specific to amphibians (frogs and toads) and marsh birds that occupy coastal wetland habitats of the Great Lakes basin.

1.1.1 Introduction

The Laurentian Great Lakes system is one of the most prominent pro-glacial features of the North American landscape and provides immeasurable functions and services that extends far beyond the basin's boundary. Despite impacts associated with expansion of intensive urban, agricultural, and industrial development over the last century, Great Lakes ecosystems still provide important benefits to the region's inhabitants. Through several bi-national initiatives, most notably the Great Lakes Water Quality Agreement (GLWQA), governments of the United States and Canada have made public their commitment to conserving and restoring Great Lakes ecosystem functions. These two governments, via State of the Lakes Ecosystem Conference (SOLEC), have begun a coordinated approach for monitoring progress toward meeting GLWQA objectives. Initiatives such as Lakewide Management Plans (LaMPs) and Remedial Action Plans (RAPs) are helping to coordinate protection, restoration, management and stewardship of a wide range of ecosystems and their inhabitants – in some cases targeted as specific areas such as Areas of Concern (AOCs).

Wetlands are important and highly productive natural systems of the Great Lakes basin. These physical, hydrological, chemical and biological zones of transition between aquatic and upland habitats are critical to sustaining and rehabilitating both open lake and terrestrial systems. Floodwater storage (Thibodeau and Ostro 1981, groundwater filtering and recharge, nutrient uptake (Mitsch et al. 1979, Whigham et al. 1988, Johnston 1991) and shoreline stabilization (Wang et al. 1997) are but a few physical and chemical functions provided by healthy wetlands. As host to a wide array of both common and rare plants and animals, wetlands serve as important repositories of Great Lakes biodiversity. Wetlands provide breeding habitat for invertebrates (Batzer et al.1999), fish (Feierabend and Zelazny 1987), amphibians, birds (Wharton et al. 1982, Gibbs 1993) and mammals (Gibbs 1993). Intact wetlands are necessary for sustaining these communities. As sites of natural integrity, wetlands are inherently valuable components of the region's landscape (Mitsch and Gosselink 2000).

Unfortunately, values of healthy wetlands have not always been recognized. Obvious impacts to wetlands such as draining and filling, and more subtle degradations due to water level stabilization, sedimentation, eutrophication, and exotic species invasions have combined to dramatically reduce area and function of Great Lakes wetlands. Groups ranging from local citizen committees to provincial, state and federal agencies are coordinating efforts to restore damaged wetland habitats and to reduce impacts to those few high quality wetlands that still remain. Monitoring their progress and identifying gaps in these efforts are two primary motivations for developing tools (through the SOLEC process), with which to measure status and trends of Great Lakes coastal wetland health.

Tools developed for basin-wide monitoring must provide information about wetland functions in an efficient, comprehensible and geographically extensive manner. Measuring the relative functional condition of wetlands can be achieved by monitoring biological components that are known to be responsive to, and signal changes in physical, chemical, and biological attributes of wetlands and their surrounding landscapes. Essentially, these can serve as tools for assessing health of Great Lakes coastal wetlands.

1.2 Evaluating Coastal Wetland Health

1.2.1 Ecological Health and Integrity

The terms ecological 'health' and 'integrity' are becoming increasingly recognized as the underlying concepts and bases for biological monitoring initiatives. To quote Karr and Chu (1999):

"Health as a word and concept in ecology is useful precisely because it is something people are familiar with. It is not a huge intuitive leap from 'my health' to 'ecological health.' Cells; individual humans, animals, and plants; and complex ecological systems are all products of evolution. We understand that cells and individuals can be healthy or unhealthy; why is it unreasonable to extend the concept to ecosystems?"

Applying this concept specifically to the underlying premises of SOLEC, Karr and Chu (1999) further state that:

"It is no accident that protecting biological or ecological 'integrity' is the core principle of the Clean Water Act, Canada's National Park Act, and the Great Lakes Water Quality Agreement between the United States and Canada. Words like 'health' and 'integrity' are embedded in these laws because they are inspiring to citizens and a reminder to those who enforce the law to keep their minds on the big picture: the importance of living systems to the well-being of human society."

More specifically, applying these concepts to coastal wetlands of the Great Lakes basin, the same processes pioneered by Karr (1981) for evaluating health of biotic freshwater environments can be used to evaluate coastal wetlands health. However, an overview of how the principles described by Karr and Chu (1999) for improving biological monitoring may apply to coastal wetland environments of the Great Lakes basin is essential for laying the groundwork and clarifying the goals of the GLCWC.

1.2.2 Coastal Wetland Health in the Great Lakes

Geophysical factors include chemical, hydrological, geological, physiographical, and climatic factors of the environment. These geophysical factors interact to create conditions for wetlands to persist, and ultimately determine the type and composition of floral and faunal communities that inhabit wetlands. Interaction among biotic communities and their geophysical environment form important ecological functions of wetlands. In the Great Lakes region, wetlands were formed following glacial recession of the Laurentian ice mass during the late Pleistocene epoch (Chapman and Putnam 1984). When the water levels of the Laurentian Great Lakes eventually stabilized to their current hydrologic regimes, geophysical and biological events created coastal wetlands that exist today. The normal functioning capacity of wetland biotic communities have been shaped through evolutionary events, and normal functioning wetlands are resilient to sources of natural variation -- collectively defining a wetland's 'biotic integrity' (Karr and Chu 1999).

Various anthropogenic activities can disrupt certain physical, chemical and/or biological functions of wetlands in manners that perturb the natural balance of wetland ecosystems. If these perturbations become severe, the biotic condition of a given wetland can diverge beyond acceptable thresholds of biotic integrity, at which time action can be taken to remediate sources of ecological degradation. In some jurisdictions of the United States and Canada, environmental policies are measuring how biological condition has diverged from biological integrity and are using this to affect policy for preserving natural systems and their communities (Figure 1-1).

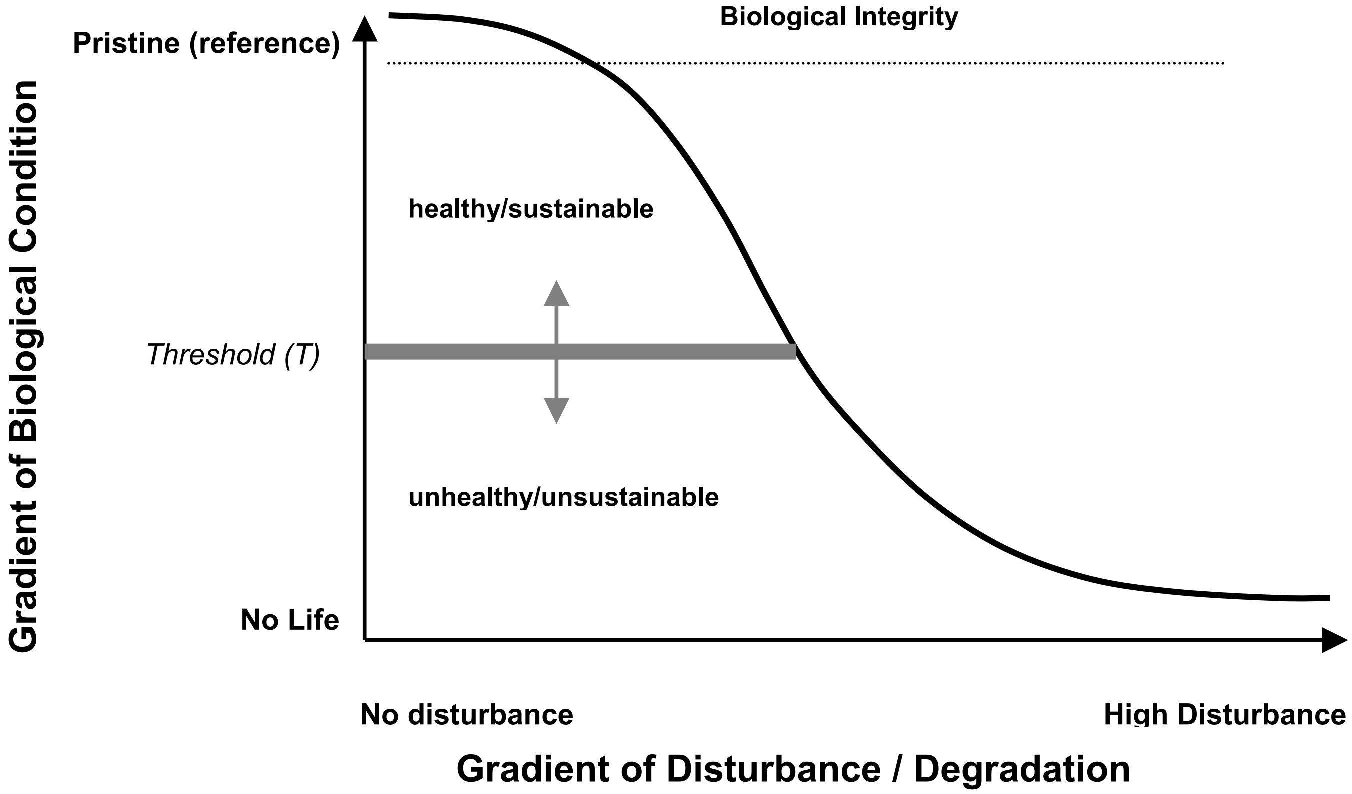

Figure 1-1. Hypothetical plot describing the relationship between gradients of biological condition and gradients of disturbances and degradation influencing ecosystems that support biotic communities (adapted from Karr and Chu 1999).

To evaluate biological integrity (or health) of ecosystems, there are five key suites of information to acquire (Karr and Chu 1999): 1) present biological condition; 2) reference biological condition; 3) present geophysical condition; 4) reference geophysical condition; and 5) anthropogenic disturbance that alter either or both biological and geophysical conditions.

It is useful to adapt Karr and Chu's (1999) model of biological monitoring for detecting anthropogenic sources of biological changes to develop a model for monitoring ecological health and integrity of Great Lakes coastal wetlands (Figure 1-2). The principles are essentially identical, with an obvious change in context to suit coastal wetland environments and values. For example, in the Great Lakes region, physiography of the landscape shaped by more recent glacial events is as, or more important in a geophysical context as is the older, underlying geology.

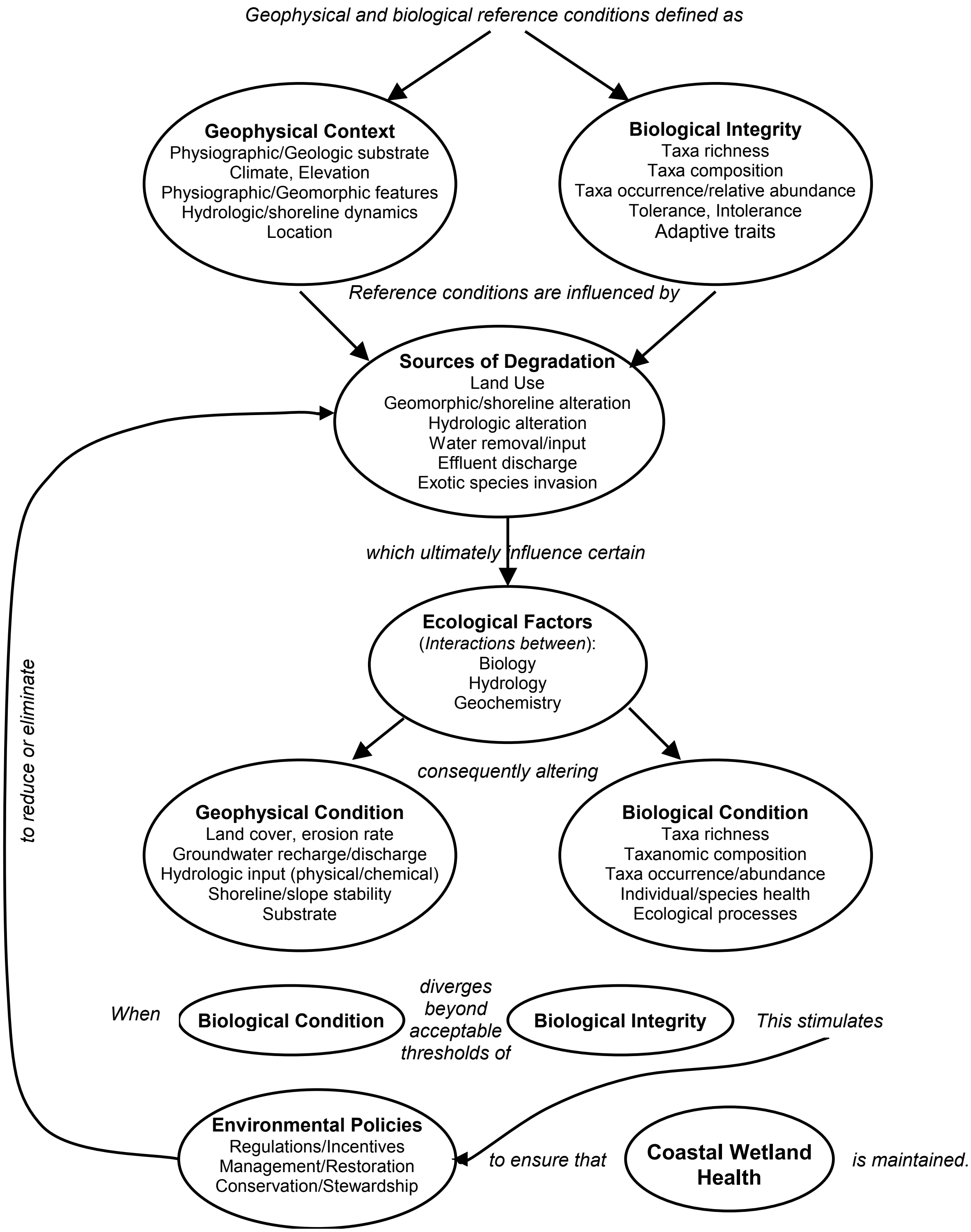

Figure 1-2. Relationships among potential coastal wetland attributes to be measured and evaluated through biological monitoring. Biological condition is the endpoint of primary concern (Adapted from Karr and Chu 1999).

Given our understanding about what constitutes biological integrity (normal, pristine function) of wetlands and how anthropogenic activities can cause wetlands to lose this function, researchers, managers and policymakers are seeking useful attributes of various biological assemblages to measure the ecological condition of wetland areas in relation to influential human-related activities. In doing so, policies affecting human activities within watersheds are being based, in part, on biological goals for wetlands. Consequently, both policymakers and society are using this information to decide if measured anthropogenic changes to biological conditions are acceptable, and are striving to set biological thresholds below which wetland health becomes unacceptable and policy action is necessary.

1.2.3 Goals and Criteria for Monitoring Coastal Wetland Health

The main purpose of this report is to document the research activities that Bird Studies Canada conducted during a one-year pilot study of the GLCWC to evaluate various methods for collecting biological monitoring data from which to seek candidate attributes for developing metrics to measure coastal wetland health.

There are four primary goals that participating members of the GLCWC pilot study were asked to achieve:

A) Work with team members and colleagues to coordinate data collection and analytical methods across sampling sites;
B) Test the variability of indicators within wetland classes across all the Great Lakes;
C) Test the comparability and usefulness of indicators within the wetland classes and eliminate redundant indicators;
D) Test the feasibility of applying indicators in a monitoring plan, including an analysis across six criteria developed by the Consortium:

    1) Cost
    2) Measurability
    3) Basin-wide applicability or sampling by wetland type
    4) Availability of complementary existing research or data
    5) Indicator sensitivity to wetland condition changes
    6) Ability to set endpoint or attainment levels
    7) Statistical approach

1.2.4 Coastal Wetland Classification

Each GLCWC study team was asked to carry out pilot project monitoring activities within one or more of the following three geomorphic wetland classes agreed upon by the GLCWC's Geomorphic Classification Committee (Geomorphic Classification Committee 2001):

1.2.4.1 Open Lacustrine – these lake-based wetlands are directly exposed to nearshore processes with little or no physical protection by geomorphic features. This exposure results in little accumulation of organic sediment, limiting vegetation development to relatively narrow nearshore bands. Exposure to nearshore processes results in variable bathymetry, ranging from relatively steep profiles to more shallow sloping beaches. Two sub-types of open lacustrine wetlands are recognized:

a) Open Shoreline – these wetlands are typically characterized by an erosion resistant substrate of either rock or clay, with occasional patches of mobile substrate. The resultant expanse of shallow water serves to dampen waves, which may result in sand bar development at some sites. There is almost no organic sediment accumulation in this type of environment. Vegetation development is limited to narrow fringes of emergent vegetation extending offshore to the limits imposed by wave climate. Long Point bay contains wetlands of this sub-class.

b) Open Embayment – these wetlands can occur on gravel, sand, and clay (fine) substrate. The embayments are often quite large – large enough to be subject to storm-generated waves and surges and to have established nearshore circulation systems. Most bays greater than three or four kilometers in diameter fit into this class. These embayments typically support wetlands 100 to 500 metres wide over wide expanses of shoreline. Most of these wetlands accumulate only narrow zones of organic sediments near their shoreline edge. Long Point bay contains wetlands of this sub-class.

1.2.4.2 Protected Lacustrine – this wetlands type is also a lake-based system; however, it is characterized by increased protection by bay or sand-spit formation. Subsequently, this protection results in increased organic sediment accumulation, shallower off-shore profiles, and more extensive vegetation development than in open lacustrine type wetlands. Two sub-types of protected lacustrine wetlands are recognized:

a) Protected Embayment – many stretches of bedrock or till-covered shorelines form small protected bays, typically less than three or four kilometers in width. These bays can be completely vegetated with emergent or submergent vegetation. At the margins of the wetlands there is typically 50 to 100 cm of organic accumulation beneath wet meadow vegetation.

b) Sand-Spit Embayment – Sand spits projecting along the coast create and protect shallow embayments on their landward side. Spits often occur along gently sloping and curving sections of shoreline where there is a positive supple of sediment and sand transport is not impeded by natural or man-made barriers. These wetlands are typically quite shallow. Moderate levels of organic soils are typical, similar to those found in other protected embayments. Examples of this sub-class occur at Long Point.

1.2.4.3 Barrier-Protected

a) Barrier Beach Lagoon – these wetlands form behind a sand barrier. Because of the barrier, there is reduced mixing of Great Lakes waters and the exclusion of coastal processes within the wetlands. Multiple lagoons can form, and the water discharge from upland areas and incoming drainages may also contribute significantly to the water supply. Thick organic soils characterize these wetlands at Long Point. Examples of this sub-class occur at the extreme west portion of the Long Point sand spit.

b) Swale Complexes – there are two primary types of swale complex wetlands; those that occur between recurved fingers of sand spits, and those that occur between relict beach ridges. These are known respectively as *sand-spit* and *ridge and swale complexes* (also referred to as dune and swale and strandplain). The former are common within some of the larger sand spits of the Great Lakes, and many examples of the former occur along the length of Long Point's sand spit feature.

1.3 Coastal Wetland Biotic Communities

1.3.1 Marsh Bird Communities as Wetland Condition Indicators

There has been little work done to demonstrate use of observation-based bird IBIs in wetland environments. However, studies have contrasted bird communities in urban/developed environments with similar habitat in rural/undeveloped settings at discrete sites (Craig and Barclay 1992, Dowd 1992), and at extensive regional scales that encompass gradients of anthropogenic influences (Croonquist and Brooks 1993, Blair 1996, Flather and Sauer 1996, Miller et al. 1997, Galatowitsch et al. 1998, Whited et al. 2000, Cam et al. 2000). Adamus (2001) has summarized these studies and supported utility of employing bird species composition (especially of wetland birds) as an indicator of land cover alteration, habitat fragmentation, and anthropogenic influences at several spatial scales.

Excessive nutrient enrichment can cause algal blooms that kill fish, decimate macrophytes through light blockage, and reduce visual foraging efficiency of birds searching for food items in the water column. Perry and Deller (1996) documented this phenomenon in Chesapeake Bay. Excessive nitrates have been attributed to death of some frogs, which are important prey items for some obligate wetland bird species. Studies in Great Britain have found positive associations between breeding waterbird abundance and both water quality variables, and general trophic status.

Sedimentation can alter habitat structure by killing submersed macrophytes, or by altering abundance and/or availability of prey items. Thermal alteration can affect birds by altering seasonal abundance and phenology of prey items. Habitat changes that result from global warming are a significant long-term concern (Poiani and Johnson 1991, Poiani et al. 1996).

Findings have begun to show that vegetation removal and habitat fragmentation of wetlands negatively affects bird communities that depend on these wetland systems (Findlay and Houlahan 1997, Schroeder 1996, Allen and O'Connor 2000, Whited et al. 2000, Rottenborn 1999). Bird richness and community structure have been compared among wetlands having different vegetation cover types (Gibbs et al. 1991, Craig and Barclay 1992, Adamus 1992). Herbicides that reduce vegetation cover can reduce densities of Marsh Wren, Red-winged Blackbird, and Common Yellowthroat (Linz et al. 1993, Blixt et al. 1993). Craig and Beal (1992) found that a larger ratio of vegetation to open water contained more breeding bird species, however, Olson (1992) found no correlation between the ratio of open water to emergent vegetation and numbers of Yellow-headed Blackbird, Song Sparrow, or Sora in prairie wetlands. However, Olson (1992) noted that avian richness in some wetlands of the prairie region cannot always be predicted by wetland vegetation composition.

Birds have sometimes been used to monitor progress in wetland condition following restoration (Weller 1995). Breeding bird communities of natural prairie potholes are generally more diverse than are those of recently restored wetlands (Delphey and Dinsmore 1993, VanRees-Siewert and Dinsmore 1996). In recently restored wetlands, lack of well-developed vegetation zones typifying natural wetlands likely leads to lower numbers of occurrence of Virginia Rail, Sora, Least Bittern, American Bittern, Common Yellowthroat, Swamp Sparrow, and Red-winged Blackbird (Delphey and Dinsmore 1993). Maintenance of diverse submersed aquatic plant communities may benefit avian community recovery in restored and constructed wetlands (Weller et al. 1991, Leschisin et al. 1992, Mulyani and Dubowy 1993). Very dense stands of vegetation are unsuitable for several bird species (Olson 1992, McMurl et al. 1993, Hemesath and Dinsmore 1993, Blixt et al. 1993). Blixt et al. (1993) reported that bird species use of wetlands increases or remains stable as dense stands of vegetation are thinned, and open water begins to occupy spaces cleared of vegetation. Small floating mats of exposed substrate and dead herbaceous vegetation are important to some waterbirds, especially Black Tern.

Bird species composition within wetland sites can change if surrounding land cover is altered (Triquet et al. 1990, Richter and Azous 2000). Studies have attempted to identify indicator species of wetland bird community metrics that statistically are most sensitive to particular types of anthropogenic influences at particular scales (Croonquist and Brooks 1993). Wetland area can be a significant predictor of breeding bird species richness (Craig and Beal 1992, Gibbs et al. 1991). Nest predation can be higher where dikes or trails are built on fill within a wetland, thereby making it easier for predators to gain access (Peterson and Cooper 1991), and wetland size may have interactive effects on the former because larger wetlands often have stretches of water too wide and deep for some terrestrial predators to cross (Picman and Schriml 1994, Esler and Grand 1993).

Frequent active human disturbance in wetlands during bird breeding periods can adversely affect some wetland bird species, especially in close proximity to colonial nesting marshbirds (Dahlgren and Korschgen 1992, Erwin et al. 1993, Klein 1993, Knight and Gutzwiller 1995, Klein et al. 1995, Rogers and Smith 1997). Such disruption can reduce foraging efficiency (Skagen et al. 1991) and courtship activity, which is vital to reproductive success (Gutzwiller et al. 1994). Ultimately, these can lead to temporary or permanent shifts in species richness and abundance (Riffel et al. 1996).

Introduction of exotic fish, invertebrates, and plants can also affect wetland birds, directly or indirectly and these can be beneficial or detrimental, depending on the particular community relationships (Custer and Custer 1996, Hamilton and Ankney 1994, Bouffard and Hanson 1997, Esler 1990). The Great Lakes have seen numerous non-native introductions in each of these taxon groups and considerable work to evaluate these relationships has been done in Long Point wetlands. Global climate change has considerable potential to influence wetland bird communities, by interacting with several of the stressors already described previously (see Larson 1993).

The following are some potential wetland-dependent bird community attributes that could be useful for evaluating Great Lakes coastal wetland condition:

- Species richness (corrected for effort)
- Diversity
- Equitability
- Proportional abundance of blackbirds and starlings (corrected for effort)
- Proportional abundance of Marsh Wren (corrected for effort)
- Percentage of indicator species of all species present
- Total abundance of all species (corrected for effort)

1.3.2 Amphibian Communities as Wetland Condition Indicators

Amphibian-based IBIs are considerably less developed than are those for other wetland taxa. Because amphibians require aquatic habitats, they are especially vulnerable to wetland alteration and contamination (Dodd and Cade 1998, Stebbins and Cohen 1995, Lannoo 1998, Pough et al. 1998, Richter and Azous 1995, 2000). Although amphibians have shown some promise as indicators of wetland and/or landscape integrity, no IBIs based solely on amphibian community composition have yet been developed and validated successfully. Scientific and public concern about amphibian population decline in wetlands has increased during the last decade (Blaustein and Wake 1995, Cohn 1994, Halliday 1993, Livermore 1992, Wake 1991, Wyman 1990, Phillips 1990, Pechmann et al. 1991). Although causes are not yet well understood, amphibian decline has been well documented (Phillips 1990, Wyman 1990, Wake 1991, Crump et al. 1992, Blaustein and Wake 1990, Timmermans and Craigie 2002). Declines have been attributed to multiple factors, acting either singly or combined (Blaustein and Wake 1990), and diseases and parasites have been suggested most often as direct or indirect sources of decline (Carey and Cohen 1999). Some amphibian life stages have been found to be affected by decreasing pH and a variety of chemical contaminants (Beattie and Tyler-Jones 1992, Rowe et al. 1992, Rowe and Dunson 1993).

A few studies have begun to use amphibian assemblages to indicate ecological condition of a large series of wetlands (e.g., Richter and Azous 2000). Investigators in Minnesota sampled 15 wetlands using the following metrics with site disturbance score and/or various land cover types measured within to each of two marsh wetland types, and found positive or negative correlations of 500, 1000 and 2500 m of each wetland:

- Forest glacial marshes: total abundance, species richness.
- Prairie glacial marshes: total abundance, species richness, abundance of Northern Leopard Frog.

Other efforts to develop wetland IBIs using amphibians are underway in Ohio, Maryland, Maine, and elsewhere.

Various researchers have found amphibian species richness to be affected by certain wetland attributes. Snodgrass et al. (2000) found an affect of seasonal wetland permanence on amphibian species richness. Kolozsvary and Swihart (1999) found species richness to be highest in wetlands of intermediate permanence, whereas, Brodman and Kilmurry (1998) found species richness to be greatest in wetlands located nearest to permanent water bodies. Increased seasonal water level fluctuation decreased amphibian species richness in Puget Sound Basin wetlands of Washington (Richter 1997). Presence of fish also relates to species richness in amphibians, as wetlands connected to fish bearing waters tend to have fewer amphibian species, which can be attributed to fish predation on eggs, larvae and adults (Hecnar and M'Closkey 1997, 1998, Babbitt and Tanner 2000). Amphibian richness can be higher in wetlands located close to forested areas (Brodman and Kilmurry 1998, Richter and Azous 2000).

Local or regional amphibian diversity can be influenced by filling and channelling between temporarily or seasonally inundated wetlands. Large wetlands do not necessarily support a wider variety of amphibians (Hecnar and M'Closkey 1996, Richter and Azous 1995, Snodgrass et al. 2000). Loss of vegetated uplands connecting isolated wetlands can suppress population recovery from drought (Pound and Crump 1994), disease, low productivity (Sinsch 1992), and wetland alteration (Dodd and Cade 1998) in amphibians. Lack of suitable upland habitat adjacent to wetlands can influence occurrence of some amphibian species. Changes in land cover that lead to increased isolation of wetland breeding habitat can cause population decline (Blaustein et al. 1994, Lehtinen et al. 1999), and greater population stochasticity and local extinction (Skelly et al. 1999) among some amphibian species.

Impacts to amphibians in developed areas can be attributed to roads (Fahig et al. 1995, Gibbs 1998), on which traffic can cause declines through direct mortality, indirectly through increased exposure to predators (Ashley and Robinson 1996), or by causing reduced mobility by avoiding road crossing, thereby reducing inter-population gene flow (Reh 1989). Amphibian species richness in Minnesota glacial marshes having greater road density was lower at all spatial scales (Lehtinen et al. 1999). Differential breeding phenology can cause avoidance by one species if another is present in a particular breeding wetland. For example, American toads were found to avoid wetlands containing tadpoles of earlier breeding Wood frogs, which feed on eggs and larvae of toads (Petranka et al. 1994).

Few studies have examined specific metrics applicable to using amphibians for monitoring wetland condition. Because many discrete wetlands have few amphibian species, richness and composition would be best applied as metrics of ecological condition and integrity at extensive landscape scales. However, rates of deformities (DELTS), relative abundance, and occurrence of amphibians can be examined for their use as indicators of wetland condition.

The following are some potential wetland-dependent amphibian community attributes that could be useful for evaluating Great Lakes coastal wetland condition:

- Species richness
- Diversity
- Equitability
- Percentage of indicator species of all species present
- Maximum calling code of certain local indicator species (e.g., Northern Leopard Frog)

1.3.3 Fish Communities as Wetland Condition Indicators

Due to their sensitivity to changes in a wide array of environmental conditions, fish community health can provide a valuable assessment of a wetland's biological integrity, and in specific cases, may have advantages over other major taxonomic assemblages when assessing environmental integrity (Karr 1981, Hocutt 1981). For instance, fish communities are often composed of a range of species that represent multiple trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores) and fish diets include food acquired from both aquatic and terrestrial origin (Karr 1981). Due to their position toward the upper level of the aquatic food chain, fish are adequate biological indicators in reflecting the biological effects of pollutants in streams and wetland environments (Hellawell 1986). However, many fish are highly mobile, which allows them to avoid polluted waters and return when conditions are more favourable. Thus, long term studies of fish density and diversity, rather than periodic sampling, are essential when validating indices of biological integrity (IBIs) for fish communities.

Of fish species monitored in coastal wetlands of the Great Lakes, Brown Bullhead (*Ameirus nebulosus*) have been successfully used as an indicator species for water and sediment condition due to their susceptibility to deformities, eroded fins and tumours (DELTs) in areas with elevated contaminant levels (Baumann et al. 1996, Sindermann 1979, Pyron et al. 2001) and because they tend to be less mobile than many other fish taxa. This common fish to the Great Lakes is an excellent organism for monitoring environmental health effects because of its benthic and philopatric life history (Leadley et al 1998). Brown Bullheads are primarily benthic feeders consuming a wide range of aquatic organisms and foraging deep in the soft sediments in search of food, ingesting quantities of organic detritus along with prey items. As a result of this feeding behaviour and a characteristic habit of remaining motionless on the bottom during periods of inactivity, these animals are thoroughly exposed to contaminated sediments by both dietary and dermal routes (Leadley et al. 1998). Direct dermal exposure to the sediment has also been found to be related to the high frequency of external lesions (Sherwood and Mearns 1977). While specific metrics have not been developed to evaluate the number of DELTs observed in a population and contaminant concentrations in sediments, the occurrence of such abnormalities can be a useful indicator of ecosystem health.

Using recent fish studies for developing wetland IBIs by our colleagues and partners, our objectives were to sample fish communities at Long Point wetlands in north-central Lake Erie and provide our data to Dr. Uzarski at Grand Valley State University to aid his attempts to develop fish-based IBIs for monitoring Great lakes coastal wetland health. Herein, we also provide insight into the usefulness of this approach in open lacustrine and open embayment, and protected embayment wetlands based on our experiences in implementing field sampling methods agreed upon by the GLCWC PMT and participating pilot-project study teams.

1.3.4 Macroinvertebrate Communities as Wetland Condition Indicators

A multitude of macroinvertebrate taxonomic groups are distributed in a wide array of freshwater wetland types throughout the Great Lakes basin (Batzer et al. 1999). Many macroinvertebrate species respond to a variety of chemical, physical and biological stressors (Cairns and Niederlehner 1995, Euliss and Mushet 1998), complete their entire life-cycle in wetlands (Merrit and Cummins 1996, Wissinger 1999), and are fundamentally important to wetland food webs, including many fish, reptilian, amphibian, avian and mammalian species (Krapu and Reinecke 1992, Merrit and Cummins 1996, Wissinger 1999). Thus, macroinvertebrates can be quite useful for developing Indices of Biological Integrity (IBI) for monitoring coastal wetland health in the Great Lakes basin. Due to the wide variation of macroinvertebrate life-history traits, these taxa can be useful for monitoring health across an array of wetland types ranging from seasonal, temporal wetlands to permanently flooded wetlands (Hellawell 1986). Abundance and composition of macroinvertebrate taxa in coastal wetlands can provide an easily accessible monitoring tool to aid in measuring the biological integrity of wetlands.

In recent decades, macroinvertebrates have been subject to an array of sampling measures and techniques applied for the purposes of finding easy, yet robust methods for monitoring wetland condition. Biologists working with the Great Lakes Coastal Wetland Consortium (GLCWC) and the Biological Assessment Wetland Working Group (BAWWG) have studied the use of macroinvertebrates (and other taxonomic assemblages) to assess the relative condition of coastal wetlands in the Great Lakes basin. Burton and Uzarski have developed a macroinvertebrate-based wetland monitoring procedure for use in Michigan's coastal wetlands (e.g., Burton et al. 1999). Similarly, Wilcox et al. (submitted) worked to develop IBIs for wetlands in the upper Great Lakes using metrics for macrophytes, fish and macroinvertebrates. Some of their metrics showed promise, but they concluded that natural water level changes were likely to alter communities and confound results using metrics that were intended to monitor effects of human activity on biotic communities. In response to this, Burton and Uzarski developed a method to adjust IBI's as water levels change for macroinvertebrates by sampling by plant community zones and basing the IBI on specific inundated zones, and are confident that their macroinvertebrate IBI is robust to a wide range of water levels. Further, Burton, Uzarski and Albert are confident that fish- and plant-based metrics can be adjusted over water level fluctuations so that a viable IBI can also be developed based on these taxa. Ultimately, their goal is to develop multi-metric IBIs based on macroinvertebrate, fish and plants ,and they propose to test this approach as part of the proposed research.

Using macroinvertebrate monitoring methods agreed upon by GLCWC study team partners, our objectives were to sample a wide array of aquatic macroinvertebrate communities at coastal wetlands of Long Point bay in north-central Lake Erie, and provide these data to Uzarski to assist his efforts in developing macroinvertebrate IBIs for monitoring Great Lakes coastal wetland health.

1.3.5 Aquatic Plant Communities as Wetland Condition Indicators

A variety of aquatic plant communities can be found in Great Lakes coastal wetland ecosystems and these often aid in identification of wetland boundaries and their classification (Keddy 2000, Mitsch and Gosselink 2000). Due to their importance to many fish, reptilian, amphibian, and avian species, coastal wetland aquatic plant species are an essential component of wetland ecosystems. Many species depend on aquatic plant communities for population sustainability and individual survival (Keddy 2000, Mitsch and Gosselink 2000). Aquatic plants can be useful for developing Indices of Biological Integrity (IBIs) for monitoring coastal wetland health in the Great Lakes basin because they are found in all wetlands types and are primarily immobile (Wilcox 1995, Mitsch and Gosselink 2000). Annual and seasonal fluctuations in aquatic plant species composition can be useful for monitoring wetland health across an array of wetland types. Further, many aquatic plant species are biological indicators of natural and anthropogenic stressors affecting the biological integrity of coastal wetlands (Wilcox 1995, Wilcox and Whillans 1999). However, there are limitations to sampling aquatic plant communities. For instance, some aquatic plant species may lag in response to biological and/or anthropogenic stressors, and plant identification and quantitative sampling is restricted to the period of the growing season (Keough et al. 1999) during which most plant taxa are mature and robust. Abundance and composition of aquatic plant taxa in coastal wetlands can provide an easily accessible monitoring tool to aid in measuring the biological integrity of wetlands.

IBIs based on aquatic plant communities have not been widely developed. The only detailed sets of aquatic plant community metrics are those presently being developed for depressional wetlands in Minnesota (Gernes 1998) and Ohio (Mack et al. 2000). However, most of their proposed metrics were not appropriate for Great Lakes coastal wetlands, largely due to differences in the physical environments of these large coastal systems and due to confounding effects of natural variation in taxa composition and abundance. The task force on Great Lakes coastal wetlands from SOLEC 1998 identified two potential metrics based on aquatic macrophytes, 1) area of wetland by type and 2) presence and areal coverage of invasive or exotic plants.

We agreed to provide Uzarski et al. (i.e., Dr. Albert) with plant community data to investigate developing metrics for coastal wetlands of the Long Point region in Lake Erie. We collected these data for each wetland site sampled during the 2002 GLCWC pilot project. Uzarski et al. suggest that certain plant-based metrics have potential for developing coastal wetland plant IBIs based on their previous research (Albert, unpublished report), utilizing plant coverage, water depth, and substrate data collected along transects from more than 100 coastal wetlands (Minc 1997, Minc and Albert 1998). These investigators are examining these parameters for their potential use in an IBI. During their 1997 and 1998 studies, these investigators used clustering algorithms and identified plant community types that were strongly correlated with different geomorphological wetland types and climatic regions. These geomorphic/climatic wetland types provide a basic framework for identifying aquatic plants IBIs and also provide insight for classifying wetlands and for sampling macroinvertebrate communities.

Using aquatic plant monitoring methods agreed upon by GLCWC study team partners, our objectives were to sample a wide array of aquatic plant communities at coastal wetlands of Long Point bay in north-central Lake Erie, and provide these data to Dr. Albert to assist his efforts in developing aquatic plant IBIs for monitoring Great Lakes coastal wetland health.

1.4 Coastal Wetland Stressors

1.4.1 Wetland Attributes and Surrounding Land Uses

A multitude of diverse anthropogenic land uses associated with freshwater wetland types affect a wetland's biological integrity and can potentially threaten a wetland's existence (Keddy 2000, Mitsch and Gosselink 2000). Recent research has indicated that landscape attributes in habitats surrounding wetlands influence a variety of species and their abundance and diversity (Pearson 1993, Vos and Stumpel 1995). For instance, wetland attributes and surrounding habitat provide marsh birds with food, nest sites and allow the completion of natural history requirements (Fairbain and Dinsmore 2001). Due to anthropogenic land use alterations occurring over the last century (i.e., dredging, filling, damming, river straightening, hydrologic alteration, pollution, agricultural runoff, urbanization and industrialization), degradation of many coastal wetlands has occurred in the Great Lakes basin (Karr and Chu 1999, Mitsch and Gosselink 2000). Alterations in land use adjacent to coastal wetlands (especially percent of the watershed that has been cleared of vegetation) can affect the amount of water, sediment, pesticide, and nutrient loading of wetlands, and thus directly affect the composition of a wetland's fish, plant, reptilian, amphibian and avian communities (U.S.- EPA 2002).

Characterization of a wetland's adjacent land use is essential for the evaluation and interpretation of wetland health and integrity (Karr and Chu 1999, U.S.- EPA 2002). For instance, greater anthropogenic alteration to a coastal wetland's watershed will increase the potential risk to a wetland's biological health. Consequently, an assessment of a wetland's adjacent land use can provide estimates of potential anthropogenic risks to their associated wetlands. Adjacent anthropogenic land use and coastal wetland alterations (i.e., hydrologic, land use – vegetation, land use – substrate/soil) can provide an easily accessible monitoring tool to aid in measuring the biological integrity of coastal wetlands.

Using anthropogenic land use and disturbance monitoring methods agreed upon by GLCWC study team partners, our objectives were to record a wide array of anthropogenic factors surrounding coastal wetlands of Long Point bay in north-central Lake Erie and develop land use attributes to rank relative disturbance to Great Lakes coastal wetlands.

1.4.2 Water Quality

Natural and unnatural (anthropogenic) influences have caused the water quality of many freshwater wetland types throughout the Great Lakes basin to be significantly degraded (Karr and Chu 1999, Chow-Fraser 1999). Different amounts of nutrients from agricultural, urban and forested landscapes entering associated wetlands can directly affect the water quality in those wetlands (Crosbie and Chow-Fraser 1999) and may also cause degradation of aquatic plant communities (Chow-Fraser 1999). For instance, pollutants such as toxic materials, oils, trace organics and metals have been purposefully and accidentally added to wetlands from a variety of sources (Mitsch and Gosselink 2000). Consequently, an assessment of limnological criteria on Great Lakes shorelines concluded that 98% of Great Lakes' shore perimeter did not fully support designated uses proposed by the Clean Water Act (Karr and Chu 1999).

Many natural wetland flow systems in the Great Lakes basin have been altered by anthropogenic activities, especially by surface and subsurface inputs into wetlands (Mitsch and Gosselink 2000). Further, natural chemical cycling occurring in Great Lakes basin wetlands have been significantly altered due to anthropogenic influences (Mitsch and Gosselink 2000). Therefore, sampling of wetland limnology can be essential for evaluation and interpretation of wetland health and integrity (Karr and Chu 1999, U.S.- EPA 2002), and an assessment of wetland water quality can provide estimates of potential natural and anthropogenic risks to sampled wetlands.

Using water quality monitoring protocol agreed upon by GLCWC study team partners, our objectives were to sample a wide array of coastal wetlands at Long Point bay in north-central Lake Erie, to provide a measure of disturbance to the health of Great Lakes coastal wetlands.

1.4.3 Site Disturbance Ranking

In order to evaluate the efficacy of utilizing community attributes of a particular taxanomic assemblage to monitor the health of a particular ecosystem, it is essential that an objective procedure is followed to rank a site's condition as a function of stressors deemed to influence such condition. Therefore, understanding biological responses to factors influencing ecosystem health requires measuring biological attributes across a gradient of sites having known or suspected influences (Karr and Chu 1999). In doing so, it is especially important to be able to distinguish between natural and non-natural (i.e., human-induced) variation in biological condition.

Ideally, sampling for such biological attributes should be done at multiple sites within similar or the same type of environment, yet distributed across a range of disturbance/degradation from minimal to severe. Most often, there are several sources of disturbance and degradation that interact to various degrees to affect the overall biological condition of a particular site. Thus, multiple sources of disturbance and degradation can be combined to derive an overall condition ranking for a particular site.

Karr and Chu (1999: 40-45) provide useful premises to guide efforts for ranking sites according to relative intensity of disturbance and degradation, and demonstrate how such ranking schemes can be used to determine how well certain biological attributes respond across gradients of site condition. In this section, we describe how we utilized various components of measured site disturbance and suspected degradation to develop overall ranking of Long Point coastal wetland sites. Site disturbance rankings estimated from each qualitative and quantitative component of our site attribute measurements are combined to produce a univariate estimate of site disturbance.

1.5 Project Description

This project constituted one of several one-year pilot studies to evaluate methodology and applicability of using various candidate SOLEC coastal wetland indicators to measure biological condition of Great Lakes coastal wetlands. This pilot project is part of a three-year GLCWC initiative to develop a monitoring plan and data support system for Great Lakes coastal wetlands. The objectives of the one-year projects were to evaluate coastal wetland indicators and test incorporation of these indicators within a long-term scientific monitoring strategy. Year-one funding was awarded to several project teams, some of whom coordinated to collect floral and faunal biotic community data and landscape attribute data using standard protocol. Activities occurred within subsets of wetland types occurring in various regions of the Great Lakes basin. Specific measurements by the various teams will include various aspects of community and population structures of aquatic plants, macroinvertebrates, fish, amphibians and wetland birds. As well, physical characteristics such as wetland limnology were characterized. Landscape measures such as habitat adjacent to wetland, land use classes adjacent to wetland, extent of upstream channelization, proximity to navigable channels, proximity to recreational boating activity, extent of traveled roadways adjacent to wetlands, and other measures were also collected.

Our objectives during this year-one project were to collected community attributes data and help test sampling protocol for macroinvertebrate, fish, aquatic macrophyte, amphibian and wetland bird communities, and to evaluate data for the latter two taxonomic groups to investigate their use as potential Indices of Biotic Integrity for Great Lakes coastal wetlands.

Each groups of investigators were required to address seven criteria as identified by the GLCWC. These criteria and expected measurements are described below. This report addresses the first six criteria from the perspective of sampling at Long Point, Lake Erie coastal wetlands only, and where applicable, also the seventh criteria. Full consideration of the last four criteria will be assessed by the Michigan study team for macroinvertebrate, fish, and plant community health.

1.5.1 Cost

Equipment costs were recorded by community indicator and parameter measurements. These costs are summarized within each section of the report. Note that several pieces of equipment were shared among sampling tasks. These shared cost centers are indicated in the 'sampling task' column of each cost summary table in each section.

Other costs, such as travel, 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 of this report. With this summary, interested parties can formulate personnel, accommodation, time and cost estimates for one or several of the monitoring activities. However, a schedule of field activities (date, wetland site location, and personnel) is provided in the General Summary section of this report.

1.5.2 Measurability

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

1.5.3 Basin-wide Applicability and Sampling by Wetland Type

Distribution of the eleven study sites across Long Point on Lake Erie's north shore has allowed reporting on the applicability of the sampling methodologies within the Lake Erie basin. As well, it allows examination of the applicability of the various sampling methodologies within open lacustrine, protected lacustrine and barrier protected wetland types.

Evaluating the Great Lakes basin-wide applicability of various wetland community metrics is being completed by the Michigan research team by incorporating data collected at Long Point and at coastal wetlands associated with other Great Lakes basins with existing databases.

1.5.4 Availability of Complementary Existing Research or Data

The Long Point Waterfowl and Wetlands Research Fund has invested considerable effort into mapping vegetation communities within all of Long Point's coastal wetlands and has also mapped all surrounding land use and land cover information. These data are digitized and were available for immediate use for quantifying land cover and land use attributes, and for identifying candidate sampling locations for biotic indicator sampling activities.

1.5.5 Indicator Sensitivity to Wetland Condition Changes

Data were collected on coastal wetland aquatic 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 for amphibian and bird community data to evaluate their use as potential coastal wetland Indices of Biotic Integrity. All appropriate project databases have been provided to Don Uzarski and Dennis Albert and are part of the integrated Great Lakes database indicator sensitivity analyses as proposed by the Michigan research team.

1.5.6 Ability to Set Endpoint or Attainment Levels

Collection of anthropogenic disturbance variables at Long Point study sites and compilation of these data allowed ranking of human disturbance levels and identification of minimally impacted or reference wetland sites within the Long Point wetland complex. 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. At a basin-wide scale all Long Point data can be averaged for each wetland type to compare with other sites throughout the basin. However, lack of standardization of landscape attribute data collection (and therefore site disturbance ranking) will be difficult to set endpoints and attainment levels at a basin-wide scale, because data cannot be combined until such agreement is reached.

1.5.7 Statistical Approach

Further metric development and testing for aquatic plant, invertebrate and fish communities requires additional Great lakes based data. Integration of these data is being undertaken by the Michigan research teams using a large database that includes data collected prior to the GLCWC initiative and several year-one projects, including the Long Point project.

In addition to reporting on the first six criteria above, this report evaluates methodology, suitability and applicability of amphibian and wetland bird community data for use as indices 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 at eleven Long Point study sites and are included within this project.

1.5.8 Site Selection

Eleven coastal wetland sites were chosen at Long Point (Figure 1-3), located on the north-central shore of Lake Erie. The sites were chosen according to three criteria.

1.5.8.1 Location

Sites were dispersed across Long Point on the north-central shore of Lake Erie. Ownership and level of management and protection were criteria in selecting each site. Ownership essentials dictated the exact location of each site.

1.5.8.2 Disturbance

There were few available 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 and land cover, such as urban development, agriculture, or natural habitat.

1.5.8.3 Geomorphic Type

The eleven sites were represented by three geomorphic wetland types, open lacustrine (open shoreline and open embayment), protected lacustrine (protected embayment and sand-spit embayment) and barrier protected (barrier beach lagoons and swale complexes).

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

Study Site	Site Name Acronym	Wetland Classification	Location	Status
Big Creek	BC	Barrier Protected/Drowned Rivermouth	Long Point, Lake Erie	NWA (protected)
Bluff Marsh	BM	Barrier Protected/Protected Embayment	Long Point, Lake Erie	NWA (protected)
Booth's Harbour	BH	Open Shoreline/Open Embayment	Long Point, Lake Erie	public
Crown Marsh	CM	Open Embayment/Protected Embayment	Long Point, Lake Erie	provincially owned
Hahn Marsh	HM	Barrier Protected	Long Point, Lake Erie	NWA
Helmer's Pond	HP	Barrier Protected/Sand Spit Embayment	Long Point, Lake Erie	NWA (protected)
Lee Brown Marsh	LBM	Barrier Bay Lagoon	Long Point, Lake Erie	LPRCA
Little Rice Bay	LRB	Open Embayment/Sand Spit Embayment	Long Point, Lake Erie	NWA
Long Point Provincial Park	LP	Open Embayment	Long Point, Lake Erie	provincial park
Port Rowan	PR	Open Embayment/Open Shoreline	Long Point, Lake Erie	public
Smith Marsh	SM	Open Embayment/Drowned River Mouth	Long Point, Lake Erie	private

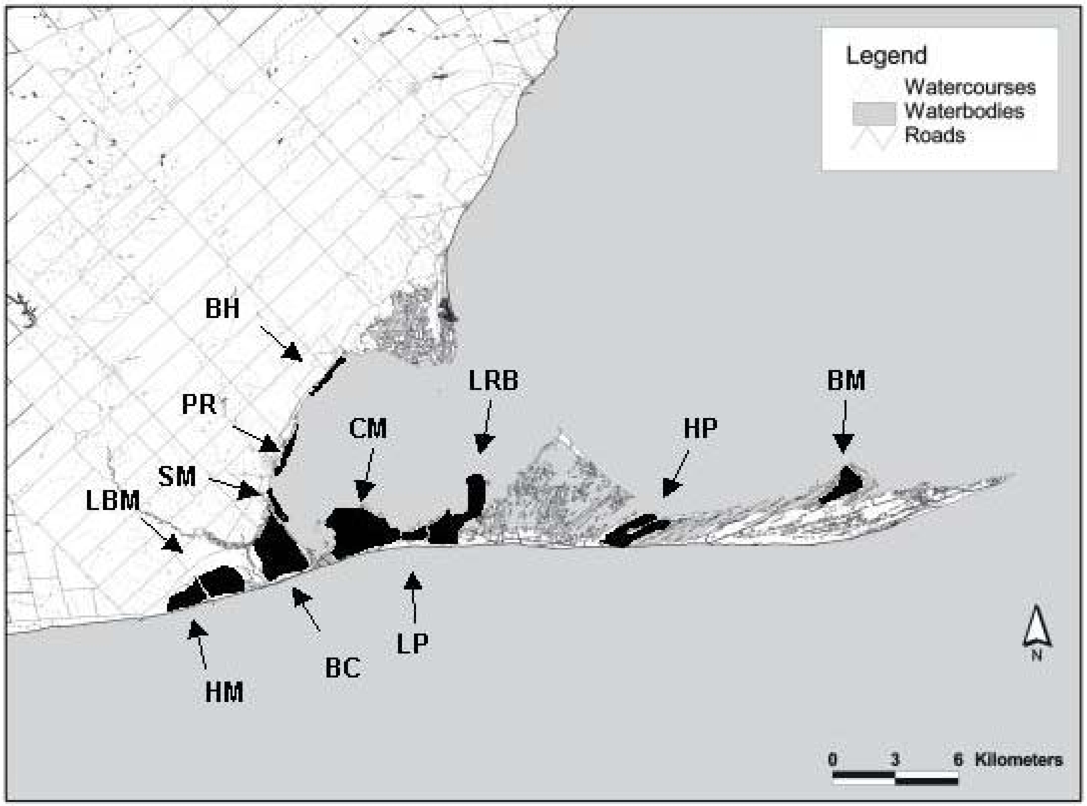

Figure 1-3. Eleven Long Point Bay coastal wetland study sites used in this study.

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2.0 WETLAND ATTRIBUTES AND SURROUNDING LAND USES

2.1 Methodology

2.1.1 General Information

Bay Name: name of bay according to the Environmental Sensitivity Atlas for Lake Erie's Canada Shoreline. All of our wetland sites occurred in Long Point Bay.

Wetland Location in Bay: the location of the study site was chosen to reflect the name most recognized by local researchers, environmental managers, and local community. For example, Hahn marsh is a section of the inner bay wetland area west of the Highway #59 causeway that is owned and managed by the Canadian Wildlife Service of Environment Canada.

Wetland Classification: the wetland geomorphic classification type recognized and documented by the GLCWC's Geomorphic Classification Committee. See Project Design within the Introduction section for detailed descriptions of each wetland classification, and Table 1-1 provides a description of geomorphic class by wetland site

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

Location: the geographical location of the wetland (UTM and Latitude Longitude).

Crew: field staff that conducted GLCWC field data collection at a particular site on a particular day.

Date visited: the date that site attribute data were collected at a particular wetland site.

2.1.2 Qualitative Hydrologic/Landscape Alterations

Qualitative information for a number of site attribute descriptions were recorded within wetlands and within buffers immediately adjacent to wetlands. These qualitative descriptions were recorded as described in Table 2-1 below.

Table 2-1. Qualitative (presence/absence) hydrologic/landscape alteration data collected to describe disturbance, land use, and land alterations within and adjacent to wetland sites.

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
	Presence of dams or waterfalls
Landscape - vegetation	Tree removal
	Tree plantations
	Mowing or grazing
	Shrub removal
	Coarse woody debris removal
	Emergent vegeation removal
Landscape - substrate/soil	Presence of livestock hooves
	Presence of vehicle use
	Presence of grading/bulldozing
	Presence of filling
	Presence of dredging
	Sediment input from inflow or erosion
	Areas of land in high public use

The following descriptive data were also collected at each site: 1) habitat types adjacent to the wetland; 2) proportion of each habitat (i.e., deciduous wood lot, sand dune) that was present adjacent to the wetland as observed from the focal point of the wetland; 3) land use classes adjacent to the wetland (e.g., residential, agricultural).

Observers also noted obvious activities and/or alterations such as excessive sedimentation, presence of highways, juttees, dykes, or marinas, presence of regular traffic, boating activity, and whether any of these activities or alterations was noticeably influencing natural features of the wetland or hydrological action.

2.1.3 Quantitative Land Cover Attributes

Detailed digitized land cover and land use data for Long Point and the surrounding area were already available through the Long Point Wetlands and Waterfowl Research Fund. To quantify these attributes, BSC's Geographic Information Systems (GIS) technician first created 1-kilometer radius polygons around each MMP sampling location. Next, within each polygon, for both wetland and upland combined, and for upland only, we calculated total land area (m2) under occupation for each areal quantitative attribute described in Table 2-2 below.

Table 2-2. Quantitative disturbance attributes collected at Long Point wetland sites to describe anthropogenic alterations in and adjacent to each wetland site.

Type of Attribute	Site Attribute Name[1]
Non-natural	Crop and Improved Development (residential, commercial) Orchard land Camping area Marina Causeway
Natural	Idle Land Treed/Forested Wetland Beach/Dunes

[1] percent coverage based on aereal measurements (m^2)

For each of these areal quantitative attributes, total area was summed among all sample locations, then we calculated the percentage of total area (wetland and upland) and upland area only, occupied by each attribute by dividing the total area of a given attribute among all polygons by the total number of polygons (i.e., sampling points) that occurred within the wetland. Because each wetland site contained several MMP monitoring locations distributed broadly throughout each wetland site, after adding 1 km radius polygons around each sample point, this gave a reasonably regular 1 km buffer within and around each wetland site from which to estimate land cover and land use areas.

We chose to use MMP monitoring locations as foci from which to measure surrounding land cover and land use because these represented the most coverage within any of our wetland sites. It also provided a realistic measure of disturbance, on average, from any vantage point within each wetland.

2.1.4 Immediate Disturbances

Additional quantitative disturbance data were collected at each Long Point wetland site and these attributes are included in Table 2-3 below. Some attributes were not amendable for use in ranking site disturbance through the use of box and whisker plot distribution, and some had largely null data among sites that did not add to any separation of sites with respect to these disturbances. Total road length attribute data were used to develop a box and whisker plot distribution and sites were ranked accordingly for this attribute. Data for the 'Number of…" attributes were summed for each site, and these data were also used to develop a box and whisker plot distribution and thereafter sites were ranked according to the combined results of these two immediate disturbance attributes.

Table 2-3. Quantified immediate disturbances collected in and near Long Point wetland sites and descriptions of those used and not used for disturbance ranking.

Site Attribute Name	Use Status for Site Ranking
Total road length in buffer (km)	Data used
Proximity to Highway (m)	Data not used
Proximity to Roads/streets (m)	Data not used
Proximity to 'other' minor (paths, trails) (m)	Data not used
Proximity to navigable channels (m)	Data not used
Number of dwellings	Data used
Number of Industries	Data used
Number of 'other' buildings	Data used
Number of boat docks	Data used
Number of paved parking lots	Data used
Number of dirt parking lots	Data used
Number of boat launches	Data used
Percent hardened shoreline	Data not used
Percent eroding shoreline	Data not used
Percent shoreline containing a dirt road	Data not used
Percent shoreline containing a paved road	Data not used

2.2 Results

Data were collected for both qualitative (presence/absence) and quantitative (areal extent) components of land use activities and land cover characteristics. These data were forwarded to GLCWC Consortium teams with whom we had agreed to provide these data.

These data are being used by each team to rank each wetland site to determine overall quality/disturbance in relation to various anthropogenic alteration and activities. Certain teams are focusing on developing biological index metrics using specific coastal wetland taxonomic assemblages in order to measure the state of coastal wetlands in relation to gradients of anthropogenic disturbance and degradation.

Land cover and land use data were recorded for 19 different MMP routes, representing 11 somewhat discrete Long Point coastal wetland sites, each defined by notable differences in morphology, influence by human activities, or ownership (i.e., protected National Wildlife Area vs. private hunt club vs. public area), see Table 1-1. It was decided to rank the sites first by each of the three disturbance categories, then combine these to develop an overall site disturbance rank (see Section 4)

2.2.1 Qualitative Hydrologic/Landscape Alterations

Collectively, type and number of hydrologic and landscape alterations varied considerably among Long Point coastal wetland sites (0-14)(Table 2-4). At some sites, none of the specified alterations occurred (i.e., Bluff Marsh, Helmer's Pond, Little Rice Bay). Each of these sites occurs within the bounds of Protected National Wildlife Areas and occurs along the Long Point sand spit feature. The most alterations occurred at Smith Marsh and Port Rowan, both located near the town proper of Port Rowan at the northwest portion of Long Point inner bay.

Table 2-4. Number of hydrologic and landscape alterations observed in proximity to 11 Long Point coastal wetland sites.

Site	Wetland Type[1]	Hydrologic Alteration	Landscape Alteration		Total
			Vegetation	Soil/Substrate	
Big Creek	BB/DRM	3	2	5	10
Bluff Marsh	BB	0	0	0	0
Booth's Harbour	OL	1	3	3	7
Crown Marsh	PE	0	3	4	7
Hahn Marsh	BB	2	2	2	6
Helmer's Pond	BB/PE	0	0	0	0
Lee Brown Marsh	BB	1	4	3	8
Little Rice Bay	PE/OL	0	0	0	0
Long Point Provincial Park	PE/OL	0	1	2	3
Port Rowan	OL	4	4	5	13
Smith Marsh	PE/DRM	5	4	5	14

2.2.2 Quantitative Land Cover Attributes

Land cover and land uses surrounding upland areas of Long Point wetlands varied considerably among wetland sites (Table 2-5). Smith Marsh, Port Rowan, and Lee Brown Marsh had the highest proportion of surrounding land under some type of human use, or described as being 'non-natural'. For Lee Brown Marsh, most of the surrounding land was under agricultural use, whereas Smith Marsh and Port Rowan had surrounding land in use by both agriculture and development (i.e., residential and commercial).

Table 2-5. Summary of natural and non-natural land cover types and uses surrounding Long Point coastal wetlands. Values are presented as percent coverage surrounding each wetland.

	Non-Natural Area						Natural Area			
Site	Crop and Improved	Development	Orchard	Camping Area	Marina	Causeway	Idle Land	Trees/ Forest	Wetland	Beach/ Dunes
Big Creek	28.6	14.2	0	0	5.7	19.2	19.3	8.2	1.4	3.4
Bluff Marsh	0	0.2	0	0	0	0	68.6	3.3	18.9	9
Booth's Harbour	70.1	4.3	0.6	0	2.1	0	0	22.9	0	0
Crown Marsh	0	56.2	0	4.5	2.8	3.1	23.3	5.4	0	4.7
Hahn Marsh	42.3	2.1	0	0	0	0	21	32	0	2.6
Helmer's Pond	0	0.2	0	0	0	0	35.2	14.4	38.2	12
Lee Brown Marsh	72.8	2.4	0.9	0	0	0	11.1	11.7	0	1.1
Little Rice Bay	0	0.3	0	9.7	0	0	85.3	0.2	0	4.5
Long Point Provincial Park	0	15.8	0	12.6	2.3	0	37.9	19.4	0	12
Port Rowan	38.7	22.9	10.6	1	3.6	0	2.8	17.9	2.5	0
Smith Marsh	58.5	16.7	0	0	0.4	3.3	12.9	6.2	2	0

2.2.3 Immediate Disturbances

There was considerable variation among sites in the number of quantified immediate disturbances, and in the length of roadways within a 1 km buffer around each wetland (Table 2-6). The number of disturbances was highest at Crown Marsh because the immediate adjacent area has numerous small cottages. Some of these cottages were also within a 1 km buffer of Big Creek, which contributed mostly to this site's high number of disturbances. Also, a large marina occurs adjacent to Big Creek, and so the number of docks was also high for this site. As expected, Bluff Marsh and Helmer's Pond had the least number of disturbances, and Hahn Marsh, Lee Brown Marsh, and Little Rice Bay also had relatively few disturbances. Because of the high number of cottages and streets at the west end of Long Point, both Crown Marsh and Big Creek were recorded to have the greatest total length of roadways in their adjacent buffer areas, and Port Rowan also had a high total length of adjacent roadways.

Table 2-6. Summary of quantified immediate disturbances in adjacent areas of Long Point wetland sites.

Site	Road Length (km)	Number of Buildings	Number of Docks	Number of Dirt Lots	Number of Paved Lots	Number of Boat Launches	Number of Disturbances
Big Creek	21.9	608	140	5	3	3	759
Booth's Harbour	8.9	56	85	4	2	2	149
Bluff Marsh	0.0	4	0	0	0	0	4
Crown Marsh	41.2	2346	165	15	34	3	2563
Hahn Marsh	5.8	48	1	1	0	1	51
Helmer's Pond	2.0	4	1	0	0	0	5
Lee Brown Marsh	6.0	45	2	1	0	1	49
Long Point Provincial Park	12.0	316	11	5	3	1	336
Little Rice Bay	8.2	58	0	1	0	0	59
Port Rowan	15.9	394	119	31	74	3	621
Smith Marsh	9.4	179	41	17	12	3	252

2.3 Discussion

2.3.1 Qualitative Hydrologic/Landscape Alterations

We found that the type and number of both hydrologic and landscape alterations described in surrounding areas of wetland sites provided some explanation in separating our wetland sites in terms of their relative exposure to certain anthropogenic alterations. Those sites deemed *a priori* to be the least disturbed and therefore most pristine had the fewest or no specified alterations influencing the immediate area. The three least disturbed of these sites (i.e., Bluff Marsh, Helmer's Pond, Little Rice Bay) all occurred within federally protected National Wildlife Areas in remote outer locations of Long Point's sand spit feature. Those sites deemed *a priori* to be the most disturbed occurred in proximity to areas receiving the highest exposure to human activities and development. Although one area that had relatively high numbers of disturbances reported also occurs within a federal Protected National Wildlife Area (i.e., Big Creek), is in close proximity to the two aforementioned sites and is adjacent to a busy two-lane causeway, which is an extension of a provincial highway.

Variation in relative degree of hydrologic and landscape alterations seems to by associated with disturbances that occur at each site. Therefore, hydrologic and landscape alterations are useful to incorporate into an overall ranking scheme for each wetland site.

2.3.2 Quantitative Land Cover/Land Use Attributes

Relative among-site differences in results of our quantitative land cover data were similar to those found for qualitative hydrologic and landscape alteration evaluations. The two sites that had the highest proportion of land under 'non-natural' cover/use were the same two sites that were evaluated to have the most numbers of alterations. Similarly, the three sites that occurred in federally protected Natural Wildlife Areas along the Long Point sand spit feature ((i.e., Bluff Marsh, Helmer's Pond, Little Rice Bay) had by far the highest amount of surrounding land in natural cover. Non-natural areas were dominated by residential and commercial development in 'urban' areas, and by agriculture in rural areas. Clearly, natural land around Long Point wetlands are associated with protected, minimally impacted sites.

2.3.3 Immediate Disturbances

Attributes describing proximity of the wetland to a given attribute (e.g., proximity to navigable channels) were ambiguous in terms of providing reliable measures of disturbance, primarily because it was difficult to describe a focal point within a wetland site from which to record each measurement. For these attributes, we measured the distance from each MMP survey point to a given attribute, then calculated the mean distance among all survey points within the wetland. However, there are many difficulties that can be perceived in using such data to provide reliable estimates of relative disturbance based on such distances. We found that the total length of roadways within a 1 km buffer around each site provided a more objective and reliable means for describing disturbance in relation to traveled roadways. We also found that simple attributes based on numbers of given disturbances seemed to provide a means for describing relative degree of disturbance, but these can not capture the relative amount of activity that occurs at any given described disturbance. Therefore, these disturbance estimates are deemed conservative at best and may not be entirely reflective of the intensity of disturbance that occurs in vicinity to wetland sites. We consider attempts to use these data for ranking sites as preliminary.

2.3.4 Cost

2.3.4.1 Equipment

The following table breaks down costs of data collection at the 11 wetland sites at Long Point examined for macroinvertebrate health (Table 2-7). These costs are broken down into consumable (one-time use) and non-consumable (used multiple time). These costs represent those required to carry out field activities for this indicator. The values are for all 11 wetland sites because costs did not differ considerably among wetland types.

Table 2-7. Costs required to conduct stress indicator sampling in 11 Long Point coastal wetlands (C = Consumable, N = Non-consumable).

Item	Cost (CDN)	Sampling Task[1]	C/N
Field Staff Costs	$1,414.00		C
GIS Specialist (in kind)	$12,276.00		
Water Quality Laboratory Analysis	$688.20		
Bottles (100)	$392.00		N
Boat Rental for Summer	$150.00		C
Gloves, PVC and foam	$34.50	3,4	N
Garbage Can	$12.50		N
HCl and membrane filters	$230.00		C
Rental car to US	$98.00	4	C
Fuel for rental car	$37.00	4	C
Meal	$3.00	4	C
Bridge tolls	$8.00	4	C
Phone	$2.00	4	C
Rental vehicle	$107.00	1, 2, 3, 4, 5	C
Fuel for car rental	$33.00	1, 2, 3, 4, 5	C
Federal Express	$28.00	1, 2, 3, 4, 5	C
Case for Digital Camera	$23.00	1, 2, 3, 4, 5	N
Office Supplies	$14.50	1, 2, 3, 4, 5	C
Flashlight (2)	$44.00	1, 2, 3, 4, 5	N
Dry Sacks (2)	$46.00	1, 2, 3, 4, 5	N
Black Auto Goop	$7.50	1, 2, 3, 4, 5	N
Fox 40 whistles (2)	$10.00	1, 2, 3, 4, 5	N
Trail tape	$13.00	1, 2, 3, 4, 5	C
Batteries	$200.00	1, 2, 3, 4, 5	C
Cowhide gloves (3)	$21.00	1, 2, 3, 4, 5	N
Sun block (3)	$34.50	1, 2, 3, 4, 5	C
Measuring tape - 100 m	$57.50	1, 2, 3, 4, 5	N
Relfective Tape	$28.00	1, 2, 3, 4, 5	C
Safety Tape	$11.50	1, 2, 3, 4, 5	C
Duct Tape	$16.00	1, 2, 3, 4, 5	C
Insect repellent (3)	$23.00	1, 2, 3, 4, 5	C
Hammer	$18.50	1, 2, 3, 4, 5	N
Chest waders (4)	$360.00	1, 2, 3, 4, 5	N
Accessories for boat	$205.00	1, 2, 3, 4, 5	N
Gas and oil for boat	$95.00	1, 2, 3, 4, 5	C
Zip-Loc freezer bags	$2.50	1, 2, 3, 4, 5	N
Plastic gas can	$10.50	1, 2, 3, 4, 5	N
Rope - 50 ft	$11.50	1, 2, 3, 4, 5	N
Total Cost of Stress Indicator Sampling	**$16,765.70**		

2.3.4.2 Personnel
Site attribute data were collected after field activities for all indicators were completed. Qualitative hydrologic/landscape alteration evaluations varied among sites, depending on complexity of surrounding use and access and visibility. Quantitative land use data were calculated and recorded in our GIS computer lab after the field season was completed. It took approximately 12 person-days to compile all of the quantitative land cover and land use data for all Long Point wetland sites.

2.3.5 Measurability

2.3.5.1 Expertise and Training
Personnel should be able to identify and distinguish between all hydrologic and landscape alterations surrounding wetland sites, and should have some understanding of various processes (i.e., dredging, filling, deforestation, sedimentation, point source pollution, etc.).

Specific spatial analytical skills are also required by one or more personnel members, in particular the ability to interpret aerial photography and topographic maps, and the ability to work with digitized spatial datasets. Other manual skills may be more amicable to a broader participant-base program for quantifying land cover attributes (i.e., planimeter for delineating areas).

2.3.5.2 Recommendations on Methodology
Most site attributes were easily measured, however quantification of surrounding land cover can be time consuming and require considerable skill and time to collect the information and digitize into a GIS database for those who chose to use this method. We relied mostly on topographic maps and aerial photographs followed by ground-truthing to collect most of our qualitative site attribute data. We highly recommend that this method be used for any future wetland monitoring scheme rather than attempting to record these attributes from subjectively selected focal points within wetlands. The objective is to collect precise and accurate surrounding disturbance information, therefore efforts must be made to observe all surrounding land either on foot, or from aerial perspectives (i.e., maps, photographs, aerial surveys). We were impressed at how well simple presence/absence qualitative estimates of various land cover and land use attributes were able to describe relative differences in disturbances and we recommend that such data continue to be collected in any future wetland bio-monitoring program.

2.3.6 Basin-wide Applicability and Sampling by Wetland Type

Immediate disturbance and qualitative hydrological and landscape alteration data were collected quite easily by observers among all Long Point wetland sites. However, quantitative land cover data requires considerable work to quantify and to use with interactive GIS data bases. At a minimum, recent aerial photography of wetland sites and surrounding land should be obtained which will enable delineation of such quantitative land cover data through the use of manual planimeter measuring exercises.

2.3.7 Availability of Complementary Data

Fortunately, there were existing digitized land cover data for all of our Long Point wetland sites. These data were collected by the Long Point Waterfowl and Wetland Research Fund, and we needed only to ground-truth the area and make adjustments to our database where necessary. There are many existing spatial databases for many areas of the Great Lakes basin that could be useful for helping to quantify land use and disturbances surrounding coastal wetlands of the Great Lakes. Aerial photographs and satellite imagery are available for certain areas, but scale and currency of these data may vary considerably among wetland sites.

3.0 WATER QUALITY SAMPLING

3.1 Methodology

Water quality parameters were measured and recorded from 11 Long Point study wetlands during July and August (Table 3-1). When present, two vegetation zones (emergent and submergent) within each of the study wetlands were sampled. In general, water samples were collected adjacent to emergent vegetation zones, however the single series of samples collected at Squire's Ridge Beach Barrier wetland (within the Helmer's Pond wetland site) was collected in shallow open water adjacent to a wet meadow emergent zone. Replicate locations were sampled in each wetland site with the exception of Big Creek and Smith Marsh.

Table 3-1. Summary of the study site, wetland type, sample number, plant zone, sample date and UTM northing and easting for all 11 coastal wetlands sampled from July through September, 2002.

Study Site	Wetland Type	Sample No.	Plant Zone	Sampling Date	UTM Northing	UTM Easting
Big Creek	Protected Barrier/Drowned Rivermouth	1	Emergent	14/8/02	4714624	17 544507
Bluff Marsh	Barrier Protected/Protected Embayment	1	Emergent	31/7/02	4711938	17 570596
		2	Submergent	4/9/02	4712738	17 570508
		3	Submergent	4/9/02	4712469	17 570353
		4	Submergent	4/9/02	4712306	17 570029
Hahn Marsh	Barrier Protected	1	Submergent	14/8/02	4713974	17 539466
		2	Submergent	14/8/02	4714092	17 539255
		3	Submergent	14/8/02	4714145	17 539861
Lee Brown Marsh	Barrier Bay Lagoon	1	Submergent	15/8/02	4714521	17 540718
		2	Emergent	15/8/02	4712101	17 540821
		3	Submergent	15/8/02	4713800	17 540214
		4	Submergent	15/8/02	4714182	17 540413
Booth's Harbour	Open Shoreline/Open Embayment	1	Emergent	6/8/02	4722380	17 548318
		2	Submergent	6/8/02	4721875	17 547480
Port Rowan	Open Embayment/Open Shoreline	1	Submergent	6/8/02	4719038	17 545274
		2	Submergent	6/8/02	4719331	17 545403
		3	Emergent	6/8/02	4719717	17 545802
		4	Submergent	6/8/02	4720166	17 546120
Crown Marsh	Open Embayment/Protected Embayment	1	Submergent	8/8/02	4715008	17 547072
		2	Emergent	8/8/02	4714643	17 546688
		3	Submergent	4/9/02	4714926	17 548028
		4	Submergent/ Emergent	4/9/02	4715907	17 547031
Helmer's Pond	Barrier Protected/Sand Spit Embayment	1	Submergent	30/7/02	4712869	17 562482
		2	Emergent	30/7/02	4712775	17 562203
		3	Emergent	30/7/02	4712721	17 561612
		4	Submergent	30/7/02	4712810	17 560931
		5	Emergent	30/7/02	4712331	17 559304
		6	Submergent	30/7/02	4712279	17 562047
Long Point Provincial Park	Open Embayment	1	Emergent	9/8/02	4714993	17 549964
		2	Emergent	9/8/02	4714938	17 550908
		3	Emergent	9/8/02	4715083	17 551813
Little Rice Bay	Open Embayment/Sand Spit Embayment	1	Emergent	9/8/02	4715161	17 552523
		2	Emergent	13/8/02	4715044	17 553178
		3	Emergent	13/8/02	4716250	17 553772
		4	Emergent	13/8/02	4716475	17 554278
		5	Emergent	13/8/02	4715985	17 554161
Smith Marsh	Open Embayment/Drowned Rivermouth	1	Submergent	8/8/02	4717840	17 544811

Sample locations were based on the floral species dominating the vegetation zone, thus representing the water chemistry associated with that zone. All water quality sample locations were accessed either by wading through wetlands, by canoe or by boat. Water chemistry measurement and samples were collected within three metres of the nearest vegetation stand. Care was taken to avoid disturbing any sediment while samples were collected.

Water samples were collected at approximately 20 cm below the surface using sterilized 500 ml Kemmerer sample bottles, each rinsed three times with sample water prior to collected the sample. Each sample was then filtered through a membrane into another acid-washed, rinsed 500 ml Kemmerer bottle, and placed on ice until they were brought to the lab and frozen.

Samples were stored frozen until late September, at which time they were delivered in person to the Annis Water Resources Institute for measurements of soluble reactive phosphorus (SRP) (mg/L), ammonia nitrogen (NH3) (mg/L), and nitrate nitrogen (NO3) (mg/L). Measurements for pH, conductivity (μS/cm), total dissolved solids, (ppm), dissolved oxygen (DO) (mg/L), turbidity (NTU), depth (cm), water temperature (EC), and air temperature (EC) were done *in situ* at each sampling location. A Hanna H1991300 was used to measure pH and conductivity, a YSI Dissolved Oxygen meter 55 was used to measure DO and water temperature, and Hack 2100P Turbidimeter was used to measure turbidity. Sampling occurred during late July and August while collecting fish and plant community data.

Quality assurance/quality control procedures followed protocols recommended by the U.S. EPA and specific details of these can be found in the report submitted by Dr. Uzarski. For SRP, NH3 and NO3, sample blanks (<0.01 mg/L for nitrogen compounds, and <0.02 mg/L for SRP) were run with each batch of samples collected from Long Point wetlands. For QA/QC, for each of these three parameters, initial, matrix spikes and duplicate matrix spikes were measured and recorded for every tenth sample, using known parameter spike concentrations of 0.10 mg/L. Percent measurement recovery was recorded by comparing matrix spikes with initial readings, and a standard curve was produced.

General information about location and surrounding features were collected at each replicate location within the sampling zone. Dominant vegetation was recorded for each sampling location. A Magellan GPS 320 global positioning system was used to record each sampling location.

3.1.1 Data Analysis

Data analyses were completed using SAS PROC SUMMARY (SAS Institute Inc. 2001). Means and standard error were determined for all water quality parameters.

Principal component analysis (PCA) (PROC PRINCOMP, SAS Institute Inc. 2001) was used to determine those water chemistry parameters that were responsible for various structuring of the data set. PCA identifies highly correlated water parameters within a dataset. A correlation matrix was created prior to completing the PCA to determine the highly correlated variables. Correlations between individual parameters and PCA axes 1 and 2 were examined to determine which individual water quality parameters contributed most to explaining variance structure of the data, and to reduce the number of water quality parameters to use for ranking water quality based site disturbances.

3.2 Results

3.2.1 Quality Control

3.2.1.1 Laboratory Precision
Laboratory precision was measured through duplicate analysis of the standard solutions for the two nitrogen and one phosphorus parameters. Certified laboratory standards were diluted with deionized water analyzed in duplicate. All parameter duplicate standards were within 20% of one another.

3.2.1.2 Laboratory Accuracy
Accuracy in the laboratory was measured through construction of standard curves for nitrogen and phosphorus parameters. Certified reference standards (spike concentrations) were used to construct the curves that were analyzed with the spectrophotometer and actual versus expected concentrations were compared. All standard curves indicated high agreement ($P < 0.01$) between actual and expected concentrations.

3.2.1.3 Potential Contamination
Duplicate matrix spikes were run for a minimum of 10% of the total samples analyzed. Results of this analysis demonstrated good rates of duplication between matrix and matrix duplicates. This indicates that the results are reproducible.

3.2.1.4 Water Chemistry by Wetland
Water chemistry parameters were summarized by wetland site. Mean and standard errors were used to characterize results from each wetland site sampled (Table 3-2).

Table 3-2. Mean air temperature (ºC), water temperature (ºC), water depth (cm), turbidity (NTU), conductivity (uS/cm), dissolved oxygen (DO) (mg/L), pH, total dissolved solids (TDS) (ppm), NO3 (mg/L), NH3 (mg/L) and soluble reactive phosphorus (SRP) (mg/L) for 11 coastal wetlands sampled in Long Point.

Study Site	Air Temp.	Water Temp.	Water Depth	Turbidity	Conductivity	DO	pH	TDS	NO3	NH3	SRP
Big Creek	29.00	27.00	80.00	8.00	296.00	7.00	7.19	193.00	0.02	0.17	0.03
Bluff Marsh	24.75	26.58	68.00	0.84	233.50	10.76	7.19	118.75	0.01	0.10	0.02
Hahn Marsh	26.00	25.60	16.67	101.83	396.33	3.87	7.48	201.67	0.44	1.56	0.05
Lee Brown Marsh	26.75	25.53	67.75	6.56	302.75	4.72	7.19	154.50	0.01	0.14	0.02
Booth's Harbour	22.00	22.70	52.00	4.79	324.50	8.34	8.63	165.50	0.01	0.05	0.02
Port Rowan	24.25	23.95	57.00	9.62	271.25	10.33	7.20	137.50	0.01	0.11	0.02
Crown Marsh	25.67	25.73	88.67	4.53	323.00	6.74	7.19	165.00	0.01	0.08	0.02
Helmer's Pond	27.33	28.60	53.33	2.84	243.83	7.43	7.47	126.33	0.01	0.07	0.02
Long Point Provincial Park	26.33	25.70	53.33	3.27	282.33	6.88	7.19	143.00	0.01	0.06	0.02
Little Rice Bay	28.40	26.94	76.80	3.05	224.00	8.92	8.21	113.20	0.01	0.06	0.02
Smith Marsh	25.00	24.20	62.00	6.14	234.00	10.27	7.19	118.00	0.01	0.09	0.02

3.2.1.5 Physical and Chemical Parameter Assessments
Mean air and surface water temperature were similar between the 11 wetland sites (Figures 3-2 and 3-3). The lowest mean air temperature occurred at Booth's Harbour (22 ºC) and the highest

occurred at Big Creek (29 ºC). Similarly, lowest mean surface water temperature occurred at Booth's Harbour (22.7 ºC), while the highest occurred at Helmer's Pond (28.6 ºC).

Mean water depths in sampled wetlands were quite variable and ranged from 16.67 cm (Hahn Marsh) to 88.67 cm (Crown Marsh) (Figure 3-4). Mean water turbidity was quite similar among sampled wetlands, except for Hahn Marsh (Figures 3-5 and 3-6). Turbidity scores ranged from 0.84 NTU (Bluff Marsh) to 101.83 NTU (Hahn Marsh). Similarly, mean water conductivity was quite variable among sampled wetlands (Figure 3-7), values ranged from 224.00 uS/cm (Little Rice Bay) to 396.33 uS/cm (Hahn Marsh). Mean dissolved oxygen was quite similar between sampled wetlands, values ranged from 3.87 mg/L (Hahn Marsh) to 10.76 mg/L (Bluff Marsh) (Figure 3-8).

The pH was near neutral for all sites sampled (Figure 3-9). Total dissolved solids were quite similar between sampled wetlands (Figure 3-10), values ranged from 113.20 ppm (Little Rice Bay) to 201.67 ppm (Hahn Marsh) ppm. All wetlands sampled had nitrate nitrogen readings of <0.01 mg/L, except Big Creek (0.02 mg/L) and Hahn Marsh (0.44 mg/L) (Figure 3-11). Ammonia nitrate readings for all wetlands sampled were quite similar (Figures 3-12 and 3-13), except for Hahn Marsh. Values ranged from 0.05 mg/L (Booth's Harbour) to 0.17 mg/L (Big Creek), however Hahn Marsh had a reading of 1.56 mg/L. All wetlands sampled had soluble reactive phosphorus readings of <0.02 mg/L, except for Big Creek (0.03 mg/L) and Hahn Marsh (0.05 mg/L) (Figure 3-14).

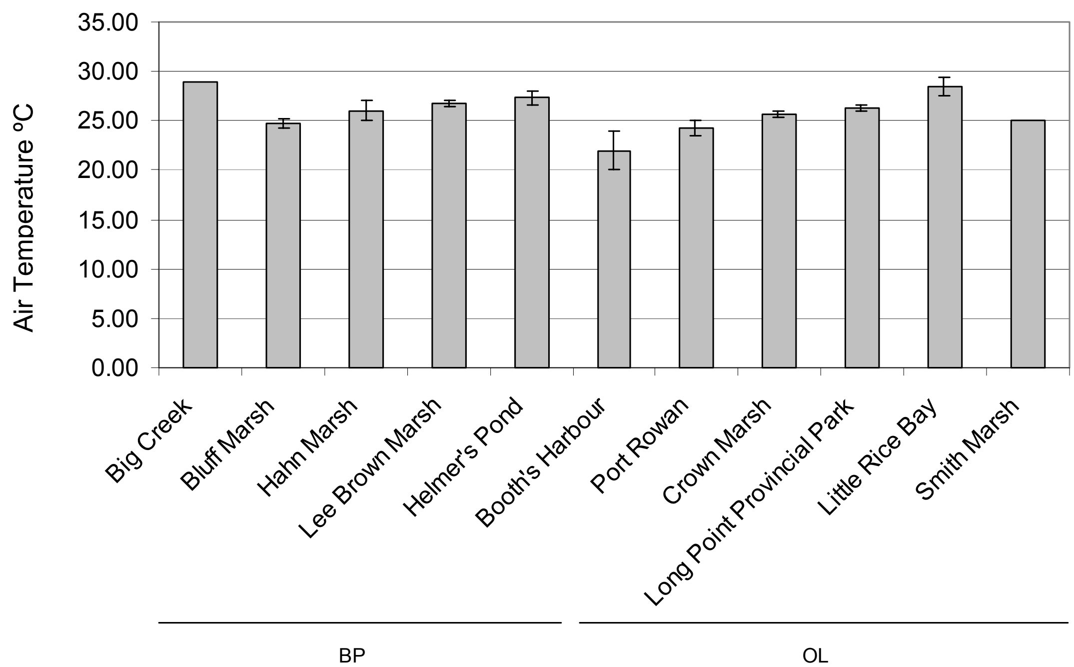


Figure 3-2. Mean air temperature (ºC) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of the two broad geomorphic types: B = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each type.

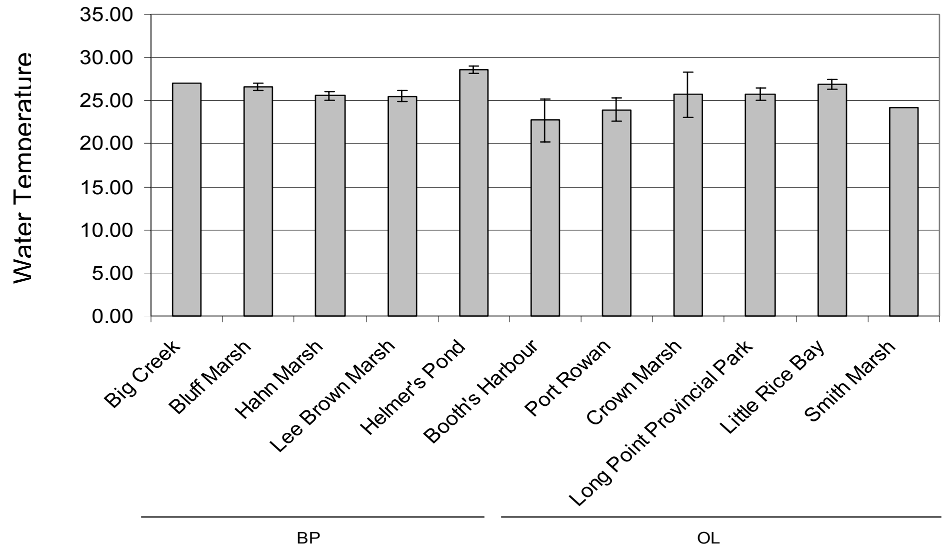


Figure 3-3. Mean surface water temperature (ºC) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of the two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

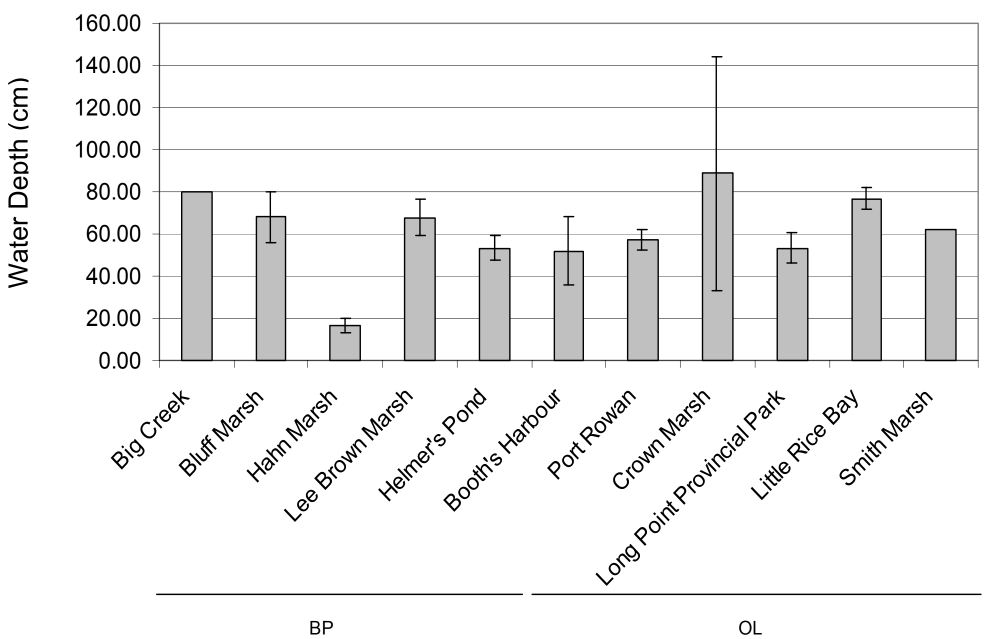


Figure 3-4. Mean water depth (cm) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of the two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

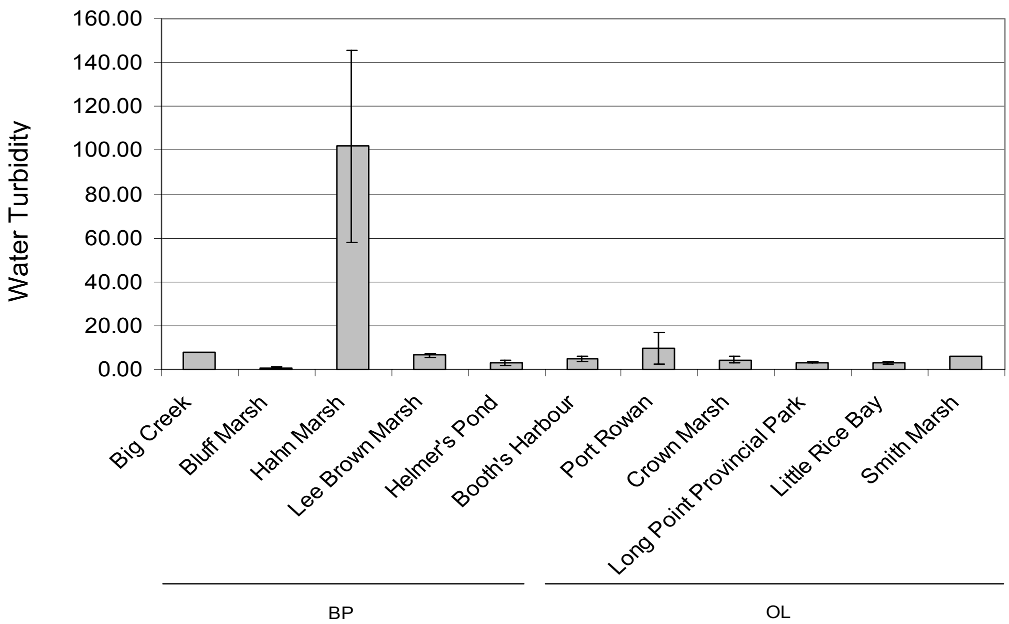


Figure 3-5. Mean water turbidity (NTU) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of the two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

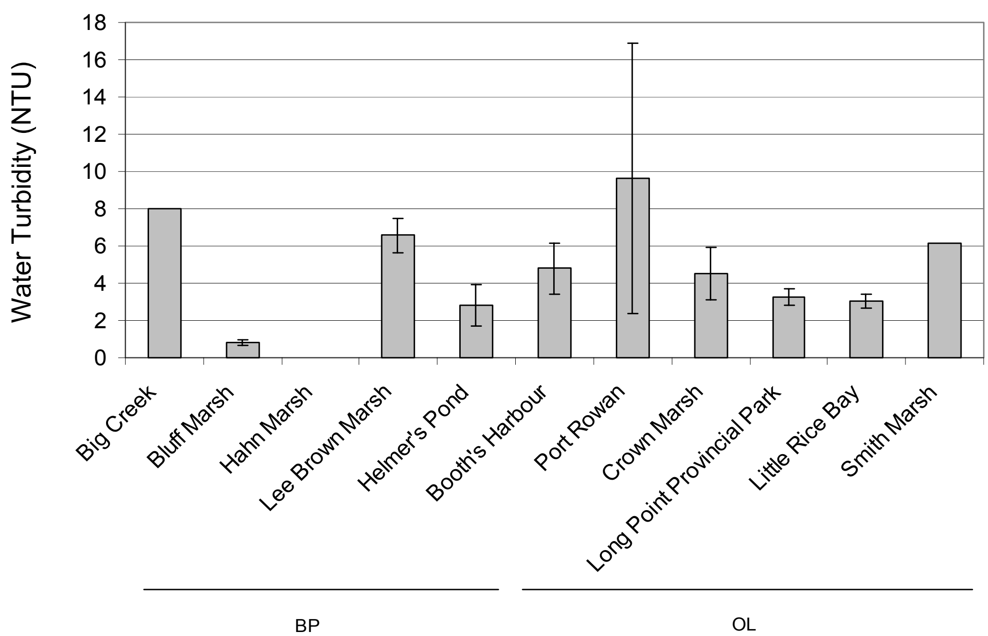


Figure 3-6. Mean water turbidity (NTU) at 10 Long Point coastal wetlands (without data for Hahn Marsh). Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

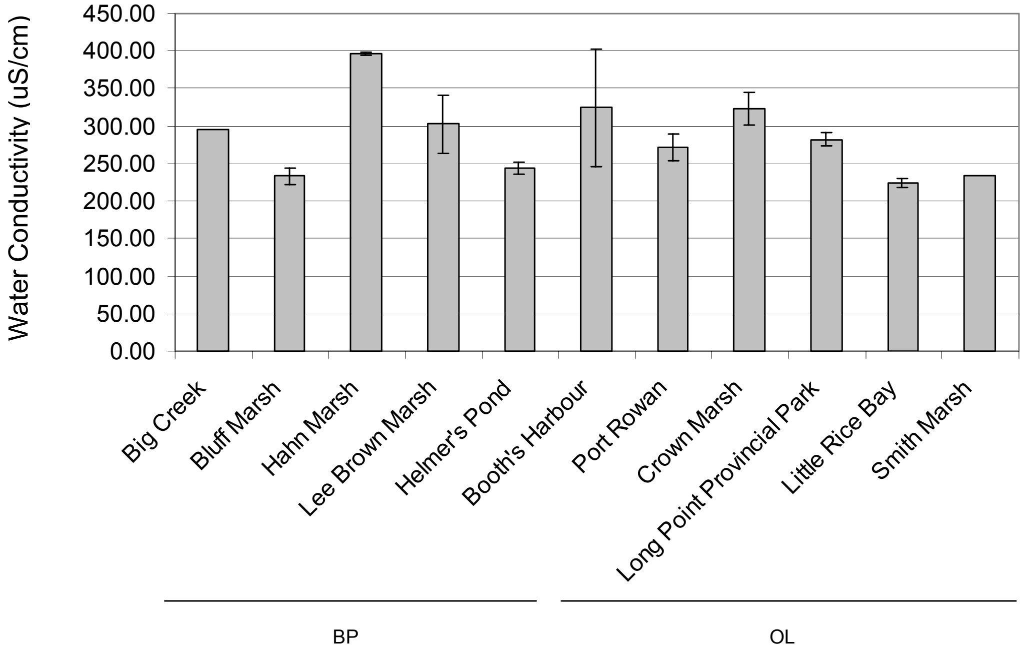


Figure 3-7. Mean water conductivity (uS/cm) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

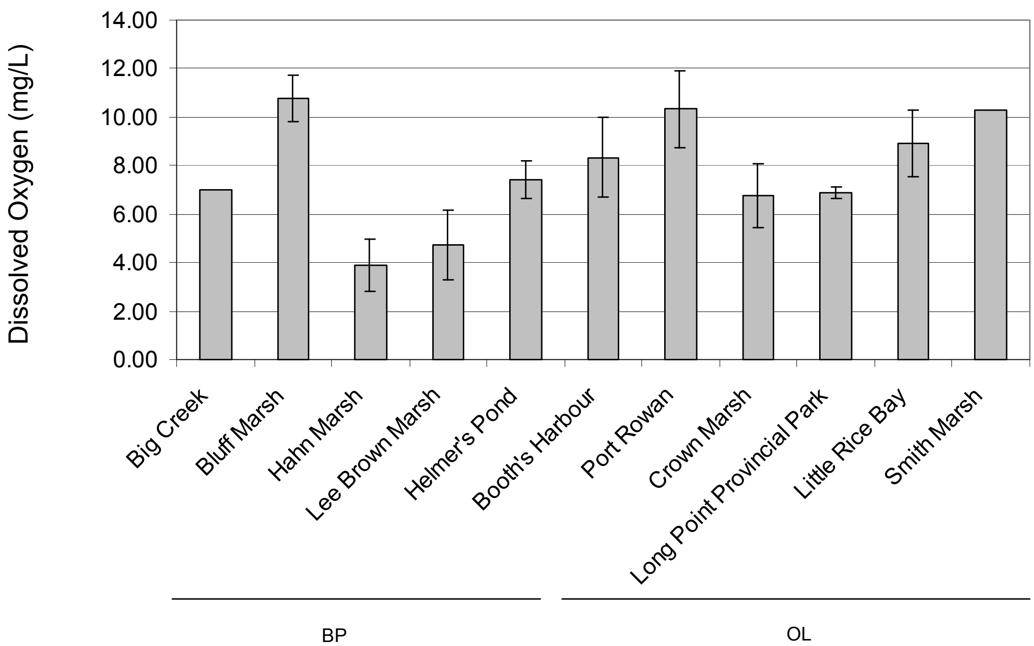


Figure 3-8. Mean dissolved oxygen (mg/L) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

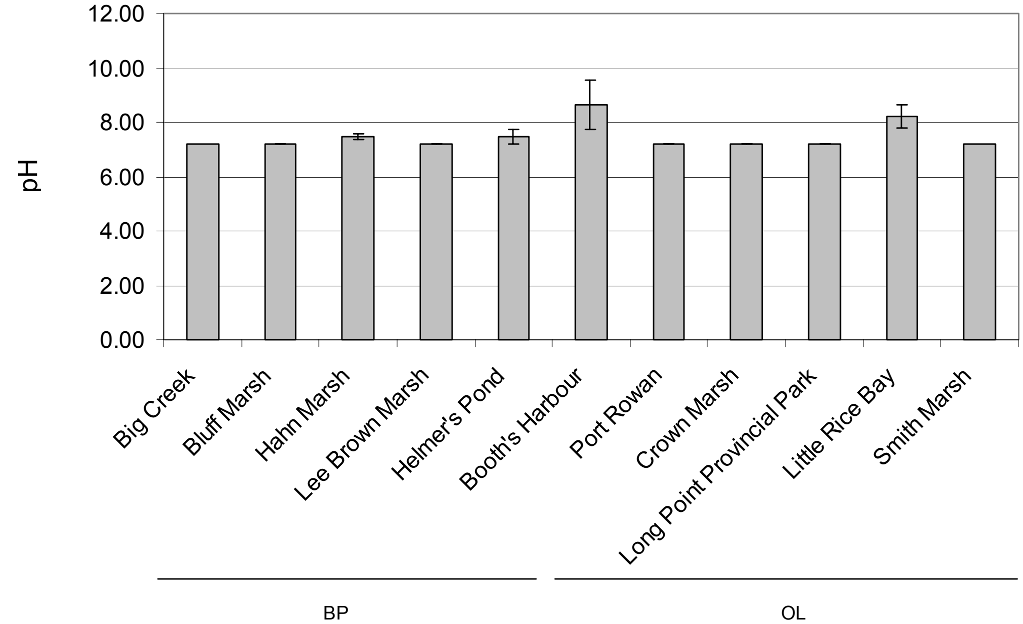


Figure 3-9. Mean water pH at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See table 1-1 for description of specific sub-classes for each site.

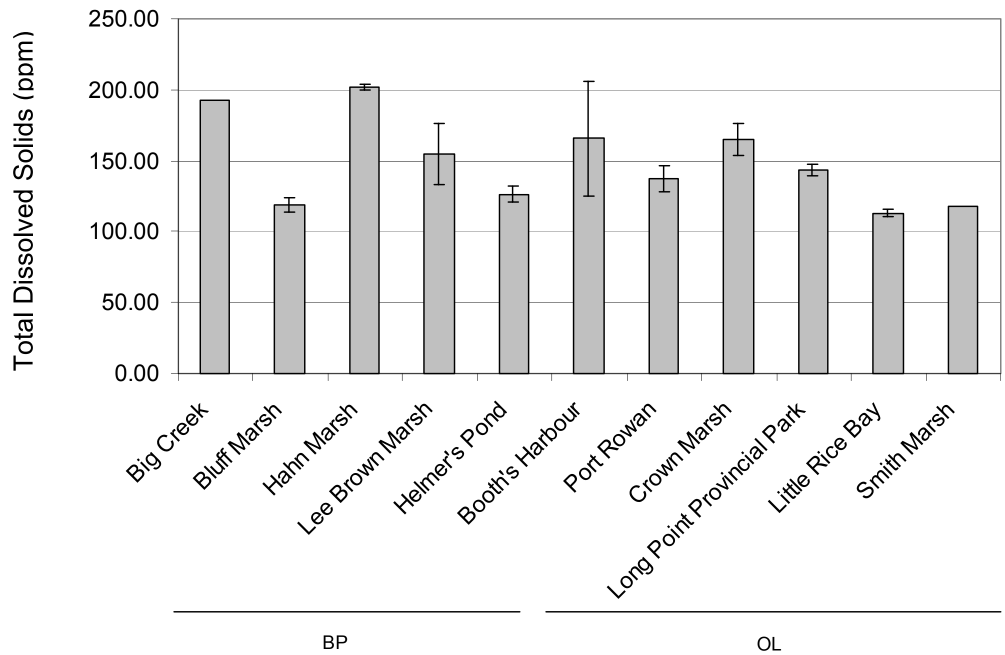


Figure 3-10. Mean water total dissolved solids (ppm) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

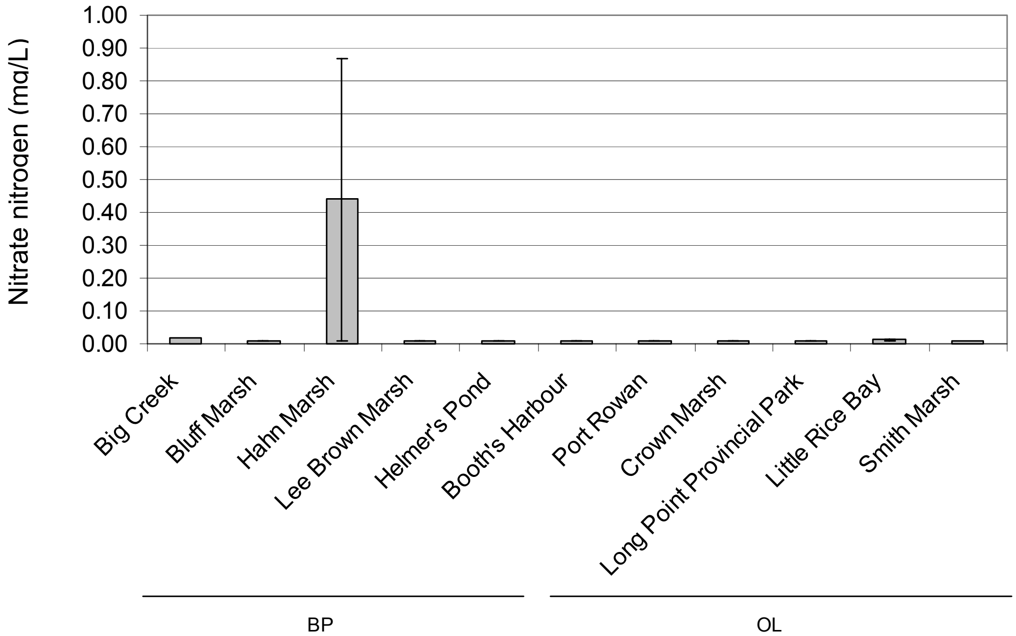


Figure 3-11. Mean water nitrate nitrogen (NO3) (mg/L) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

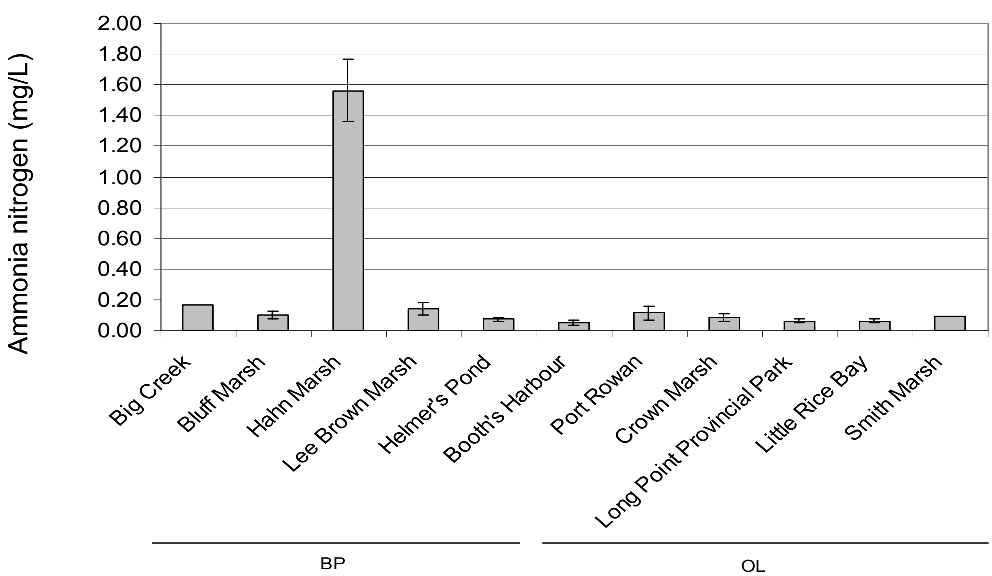


Figure 3-12. Mean water ammonia nitrogen (NH3) (mg/L) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

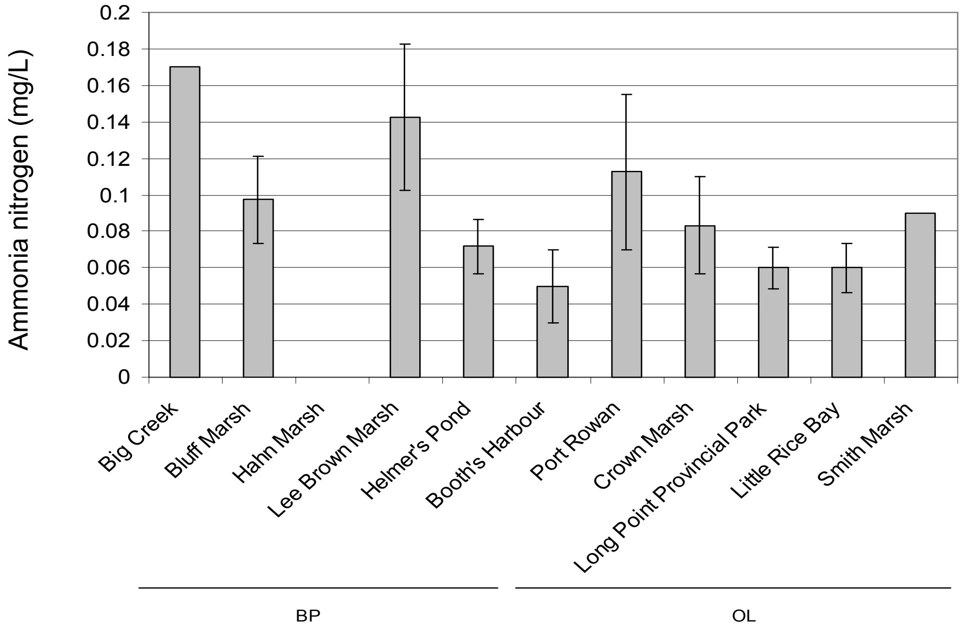


Figure 3-13. Mean water ammonia nitrogen (NH3) (mg/L) at 10 Long Point coastal wetlands (without data for Hahn Marsh). Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-class for each site.

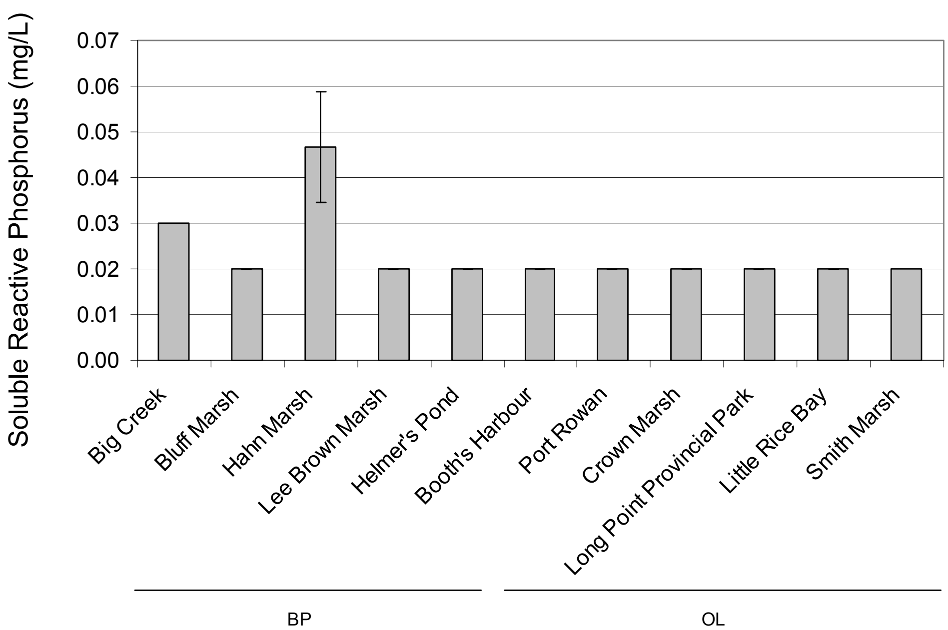


Figure 3-14. Mean water soluble reactive phosphorus (mg/L) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See table 1-1 for description of specific sub-classes for each site.

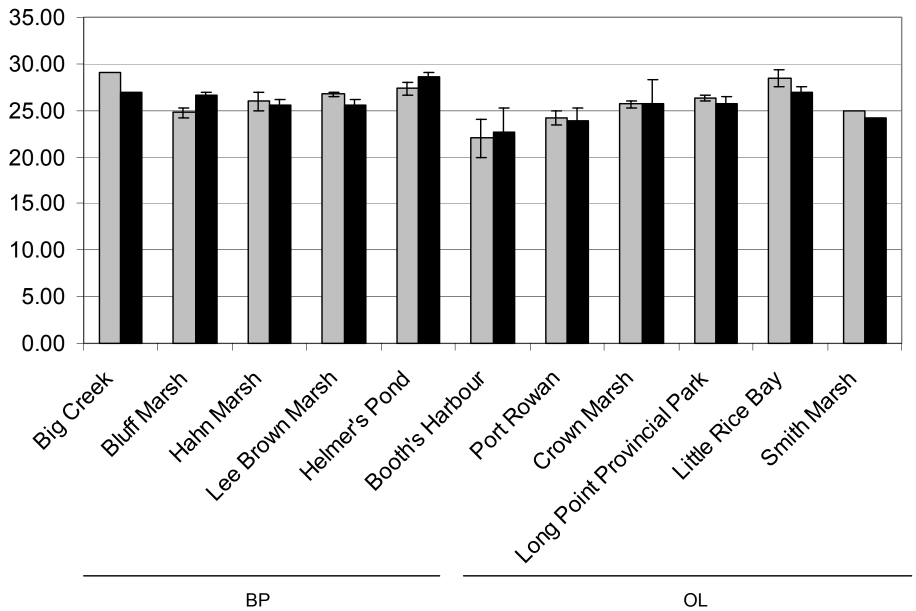


Figure 3-15. Mean water temperature (ºC) and air temperature (ºC) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

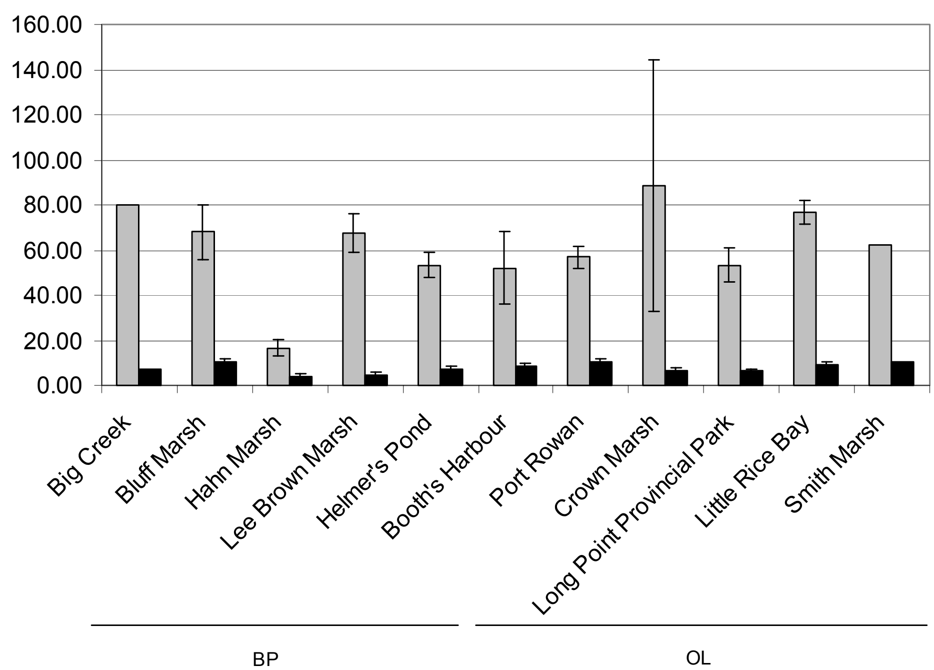


Figure 3-16. Mean dissolved oxygen (mg/L) and water depth (cm) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

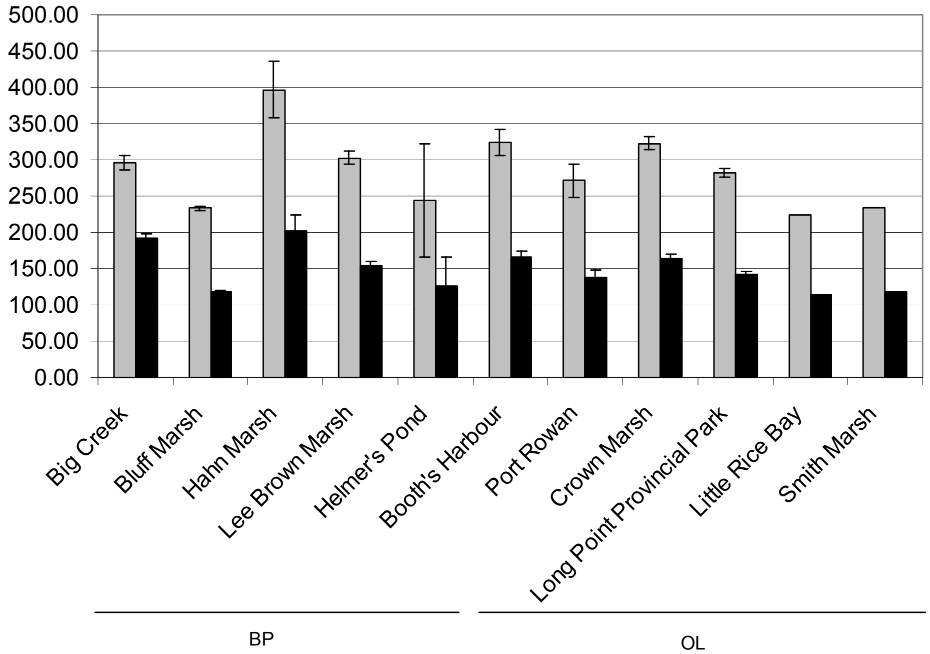


Figure 3-17. Mean total dissolved solids (ppm) and water conductivity (uS/cm) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of two broad geomorphic type: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

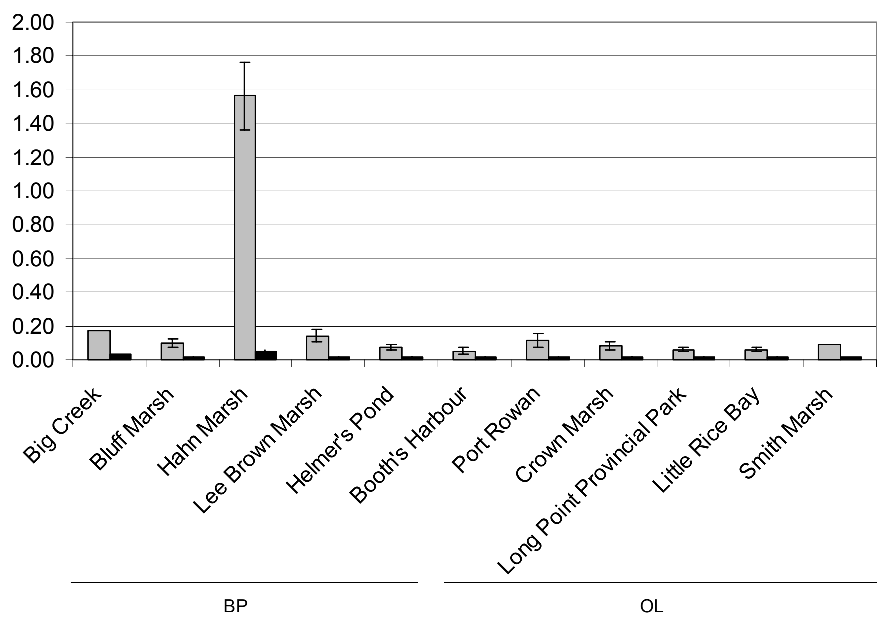


Figure 3-18. Mean soluble reactive phosphorus (mg/L) and ammonia nitrogen (NH3) (mg/L) in water at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

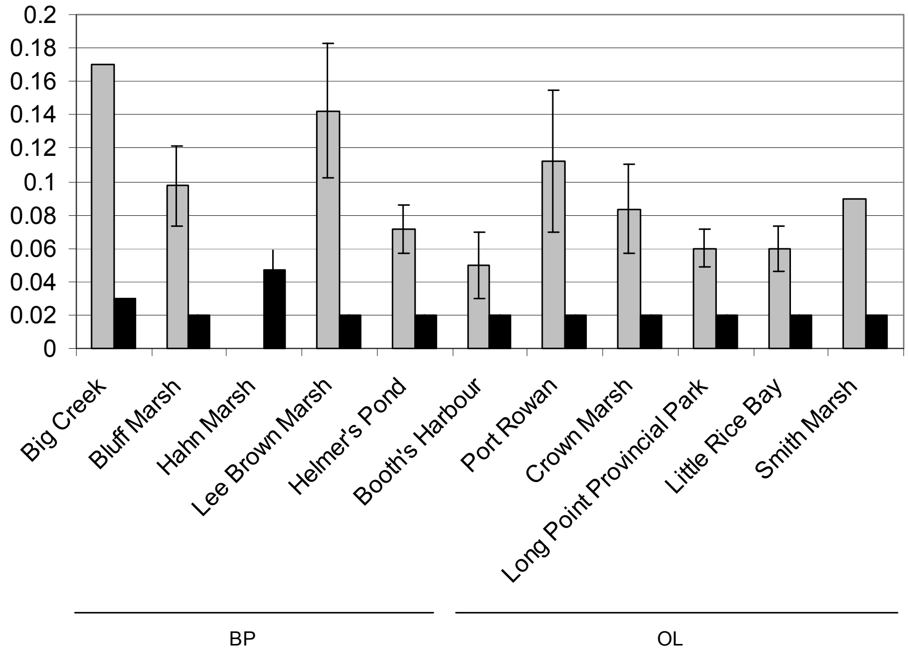


Figure 3-19. Mean soluble reactive phosphorus (mg/L) (without data for Hahn Marsh) and ammonia nitrogen (NH3) (mg/L) in water at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of tow broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

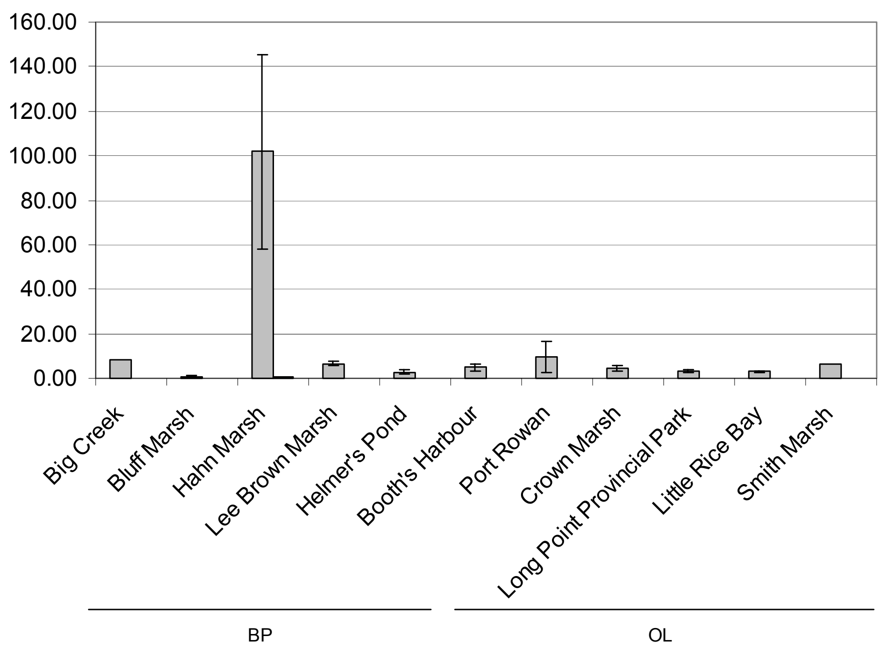


Figure 3-20. Mean nitrate nitrogen (NO3) (mg/L) and water turbidity (NTU) at 11 Long Point coastal wetlands. Wetlands are grouped in the figure by one of two broad geomorphic types: BP = Barrier Protected and OL = Open Lacustrine. See Table 1-1 for description of specific sub-classes for each site.

Table 3-3. Correlation of water quality parameters with principal component (PC) axes.

Parameter	PC Axis 1	PC Axis 2
Ammonia Nitrogen	0.82	
Soluable Reactive Phosphorus	0.75	
Total Dissolved Solids	0.90	
Turbidity	0.63	
Conductivity	0.90	
Water Temperature		0.80
Air Temperature		0.65

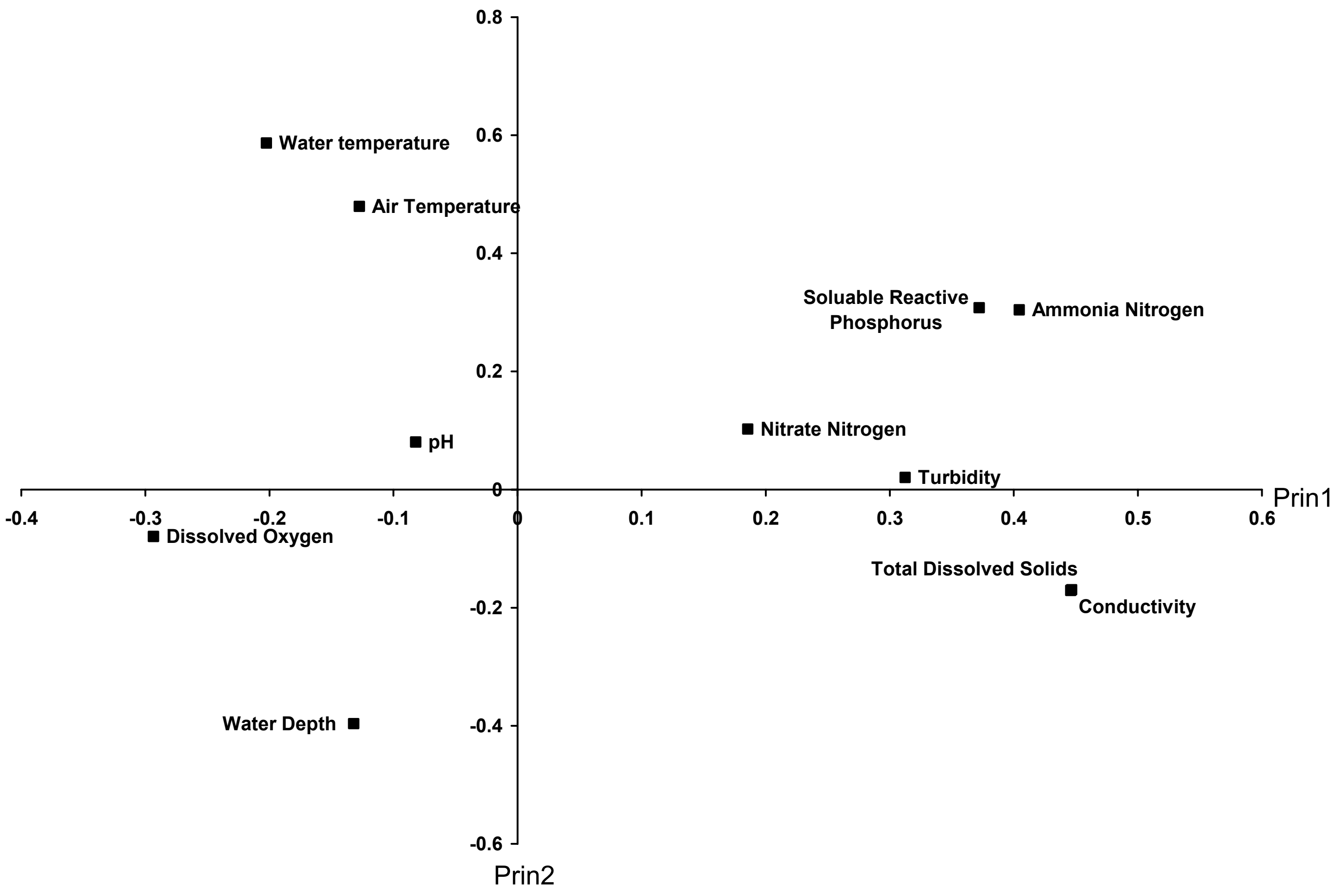


Figure 3-22. PCA biplot describing association of water quality variables in relation to each other and to principle components axis 1 and axis 2 (Prin1 and Prin2).

3.2.1.6 Key Limnological Parameters

Principal component analysis indicated that the first three PC axes explained 71% of the variance in the Long Point water quality data set. Axis one, two and three explained 41%, 17% and 13% of the variance structure in the water quality data set, respectively. Post hoc correlations of individual variables with PC axis one and PC axis two indicated that electrical conductivity, total dissolved solids, ammonia nitrogen, and soluble reactive phosphorus explained most of the data variance structure represented in PC axis one, whereas water temperature and air temperature explained most of the data variance structure represented in PC axis two. Essentially, axis one described nutrient loading and water turbidity, whereas axis two described the remaining variance explained mostly by temperature.

Wetlands with higher nutrients also had higher turbidity, higher conductivity, and higher total dissolved solids. Wetland with higher water temperature readings also had higher air temperature readings, indicating a strong influence of daily air temperature on water temperature of the shallow Long Point bay area.

3.3 Discussion

Among the abiotic response variables that can be use to evaluate how disturbance and land cover/land use changes relate to relative condition of biotic communities, wetland limnology may be useful. Alkalinity (or pH), available dissolved oxygen, water temperature and nutrient loadings can be influenced by certain activities in surrounding watersheds.

Some of these variables may be better predictors of local disturbance than others, as certain variables may be just as prone to sources of variation in the natural environment as they are to unnatural sources of disturbance and degradation. Nutrient loading and turbidity can be affected by any number of disturbances such as runoff from forestry, mining, agriculture and urban activities (Mitsch and Gosselink 2000). Also, physical disturbances from certain exotic species such as Mute Swan (*Cygnus olor*) (Mathiasson 1973) and Common Carp (*Cyprinus carpio*) can increase turbidity and suspended nutrients and solids in the water column, which may have negative influences on wetland biotic communities (Wilcox et al. 2002). Even though turbidity was marginally correlated with PC axis one, this parameter was included in our site disturbance procedure because of its known value in describing wetland disturbances.

Most of the water samples from various sites had very low nitrate nitrogen (NO3) and phosphorus (SRP) levels, such that there was essentially little to no variation in these parameters among sites. The exceptions were Hahn Marsh, and to a lesser extent Big Creek, where values for these parameters were much higher than for any other site. Turbidity, total dissolved solids, and conductivity were also much higher at these sites, which largely explains the high loadings of these parameters on PC axis one. Unfortunately however, these results are primarily a result of collection methodologies, as Hahn Marsh and Big Creek samples were collected quite late during the season, well into a period of drought and high daily air temperatures. At these protected barrier beach lagoon wetlands, high evaporation caused nutrients and all solids to become highly concentrated, such that filtering was unsuccessful in removing all solid material. This, combined with potential leaching of nutrients from solids after sample collection likely contributed to apparent high values for nutrients, turbidity, TDS and conductivity parameters, and to such low DO readings. These samples were most certainly not representative of the water quality that occurs during most of the growing season within these wetlands. In exclusion of these aberrant samples, there was very little variability in water quality parameter values among Long Point wetland sites. This can be largely explained by the close proximity of the sites to each other and that even though surrounding disturbances vary considerably among sites, most sites are similar in their water quality given that they share the same Long Point inner bay water body.

Consequently, we decided to keep water quality disturbance rankings separate from the other landscape attribute disturbance rankings.

3.3.1 Cost

Costs were relatively low for our water quality sampling and processing procedures, because we borrowed several limnological measuring instruments from a local conservation authority, and because nutrient parameter measurement was provided for a low cost by the Annis Water Resources Institute at Grand Valley State University. Table 3-4 provides a breakdown of costs for water quality sampling at 11 Long Point wetland sites.

If equipment is needed to be purchased, then initial costs for implementing water quality monitoring would be considerably higher. However, if sampling is done over a long period, these non-consumable costs may be justified for a long term monitoring program.

Table 3-4. Costs required to conduct stressor indicator sampling in 11 Long Point coastal wetlands (C = Consumable, N = Non-consumable).

Item	Cost (CDN)	Sampling Task[1]	C/N
Field Staff Costs	$1,414.00		C
GIS Specialist (in kind)	$12,276.00		
Water Quality Laboratory Analysis	$688.20		
Bottles (100)	$392.00		N
Boat Rental for Summer	$150.00		C
Gloves, PVC and foam	$34.50	3,4	N
Garbage Can	$12.50		N
HCl and membrane filters	$230.00		C
Rental car to US	$98.00	4	C
Fuel for rental car	$37.00	4	C
Meal	$3.00	4	C
Bridge tolls	$8.00	4	C
Phone	$2.00	4	C
Rental vehicle	$107.00	1, 2, 3, 4, 5	C
Fuel for car rental	$33.00	1, 2, 3, 4, 5	C
Federal Express	$28.00	1, 2, 3, 4, 5	C
Case for Digital Camera	$23.00	1, 2, 3, 4, 5	N
Office Supplies	$14.50	1, 2, 3, 4, 5	C
Flashlight (2)	$44.00	1, 2, 3, 4, 5	N
Dry Sacks (2)	$46.00	1, 2, 3, 4, 5	N
Black Auto Goop	$7.50	1, 2, 3, 4, 5	N
Fox 40 whistles (2)	$10.00	1, 2, 3, 4, 5	N
Trail tape	$13.00	1, 2, 3, 4, 5	C
Batteries	$200.00	1, 2, 3, 4, 5	C
Cowhide gloves (3)	$21.00	1, 2, 3, 4, 5	N
Sun block (3)	$34.50	1, 2, 3, 4, 5	C
Measuring tape - 100 m	$57.50	1, 2, 3, 4, 5	N
Relfective Tape	$28.00	1, 2, 3, 4, 5	C
Safety Tape	$11.50	1, 2, 3, 4, 5	C
Duct Tape	$16.00	1, 2, 3, 4, 5	C
Insect repellent (3)	$23.00	1, 2, 3, 4, 5	C
Hammer	$18.50	1, 2, 3, 4, 5	N
Chest waders (4)	$360.00	1, 2, 3, 4, 5	N
Accessories for boat	$205.00	1, 2, 3, 4, 5	N
Gas and oil for boat	$95.00	1, 2, 3, 4, 5	C
Zip-Loc freezer bags	$2.50	1, 2, 3, 4, 5	N
Plastic gas can	$10.50	1, 2, 3, 4, 5	N
Rope - 50 ft	$11.50	1, 2, 3, 4, 5	N
Total Cost of Stress Indicator Sampling	**$16,765.70**		

3.3.2 Measurability

Our experiences demonstrated that water quality sampling requires rigor and proper training and experience to complete properly. Our personnel lacked in prior training and experience, which we believe complicated and may have confounded our ability to collect reliable and representative water quality data from the Long Point study sites. Even though laboratory analyses of nutrient parameters was done at a highly qualified professional limnological laboratory, results from such measurements were only as good and representative as were the field collection procedures.

Field staff should have prior training in proper physical and chemical parameter collection procedures, instrumentation and calibration of field equipment, and good familiarity with all equipment and proper field methods for collecting water samples. Most importantly, samples should all be collected within a 24 to 48 hour period to minimize temporal variation in results.

To ensure that QC/QA objectives are met, personnel measuring nutrient parameters must be familiar with and have the means to complete standard curves, analyze blanks and duplicates, and be able to determine repeatability of sample results. Thus, samples should either be processed in an appropriate limnological laboratory by professional staff, or adequately trained project personnel must be able to conduct QC/QA activities under improvised laboratory conditions. A training session must be held for any personnel that would be involved in collecting water quality data for any coastal wetlands monitoring program.

3.3.3 Basin-wide Applicability and Sampling by Wetland Type

As long as proper equipment, personnel and procedures are included in any water quality sampling component of a Great Lakes coastal wetland monitoring program, these methods can be applied to any wetland and wetland type throughout the basin. Special attention into timing of sample collection within certain wetland types (in our case beach barrier) may be warranted, as drought conditions can drastically change water levels in some shallow wetlands, which can highly concentrate solids and result in substantially high parameter readings for certain parameters. Sample costs among types did not differ, and most costs differences are likely associated with differences in site accessibility.

3.3.4 Availability of Complementary Data

Some water quality data may be available through the Ontario Ministry of the Environment, but we are not aware of such data collected from the same locations where we conducted our sampling.

3.4 Literature Cited

Mathiasson, S. 1973. Distribution and behaviour of non-breeding Mute swans of the Swedish west coast. Vittrery 8: 400–452.

Mitsch, W.J. and J.G. Gosselink. 2000. Wetlands 3rd Ed. John Wiley & Sons, Inc. New York. 920 pp.

Wilcox, D.A., J.E. Meeker, P.L. Hudson, B.J. Armitage, M.G. Black and D.G. Uzarski. 2002. Hydrologic variability and the application of index of biotic integrity metrics to wetlands: A Great Lakes evaluation. Wetlands. 22:588-615.

4.0 SITE DISTURBANCE RANKING

4.1 Methodology

The following sets of qualitative and quantitative disturbance and degradation data were used to estimate site disturbance rankings :

- Qualitative hydrologic/landscape alterations
- Quantitative land cover attributes
- Immediate disturbances

For both the qualitative hydrologic/landscape alterations and immediate disturbance data sets, data were ranked using a box and whisker plot distribution, which separated the site data into quartile quadrants. Sites with data that occurred in the 0-25% quartile were assigned a score of one, sites with data that occurred within the 25-75% quartile were assigned a score of three, and sites with data that occurred above the 75% quartile were assigned a score of 5. Therefore, for a given set of attribute data, sites that scored one, three or five were deemed to be minimally, moderately or highly disturbed, respectively.

For quantitative land cover attributes, land-use within a one-kilometer buffer around each wetland site was used to quantify areal extent of various natural and non-natural land cover types and uses. These land cover attributes were divided into natural and non-natural categories. Percent area of natural land surrounding the wetland within the buffer area was used to scale the magnitude and extent of disturbance surrounding each site. By categorizing proportion of total natural land cover into intervals spanning 20% (i.e., 0-20%, 21-40, 41-60, etc.), disturbance rankings between 1 and 5 were assigned to each site.

4.2 Results

4.2.1 Qualitative Hydrologic/Landscape Alterations

A box and whisker plot of qualitative hydrological/landscape alterations among Long Point coastal wetland sites is shown in figure 4-1. Site rankings based on this distribution are shown in Table 4-1. Bluff Marsh, Helmer's Pond, and Little Rice Bay were scored minimally disturbed, Port Rowan and Smith Marsh were scored as highly disturbed, and the remainder of sites scored moderately disturbed for this group of attributes.

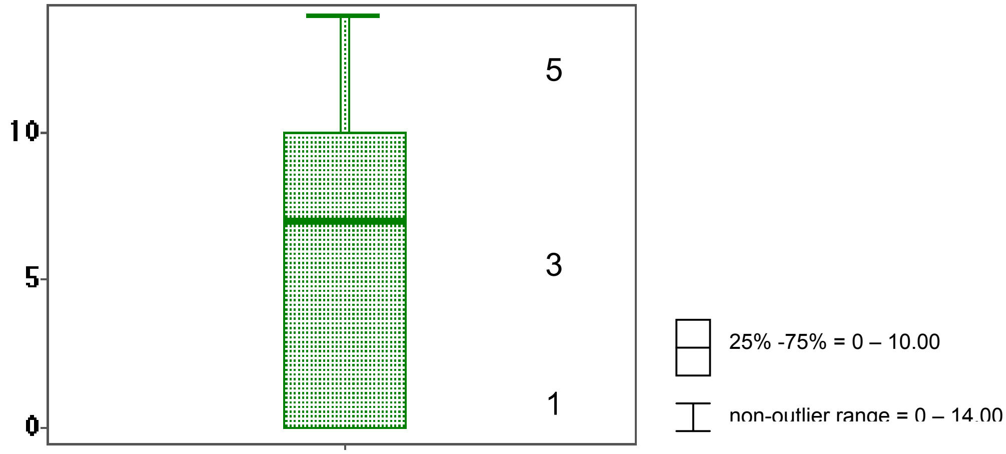


Figure 4-1. Box and whisker plot showing data distribution in relation to quartile ranking for the number of recorded qualitative disturbances surrounding each wetland site. Rank score = 1 included only sites with zero disturbances.

Table 4-1. Summary of qualitative site disturbance rankings for Long Point coastal wetland sites.

Site	Number of Disturbances	Disturbance Ranking
Big Creek	10	3
Bluff Marsh	0	1
Booth's Harbour	7	3
Crown Marsh	7	3
Hahn Marsh	6	3
Helmer's Pond	0	1
Lee Brown Marsh	8	3
Little Rice Bay	0	1
Long Point Provincial Park	3	3
Port Rowan	13	5
Smith Marsh	14	5

4.2.2 Quantitative Land Cover Attributes

Natural land surrounding each site varied considerably among Long Point coastal wetland sites. All sites had at least 20% natural land cover in their buffers, and therefore none of our sites ranked in the highest disturbance ranking category. Six of the eleven sites were scored in the second highest disturbance category (disturbance ranking = 4), three others scored as least disturbed (disturbance ranking = 1), and the remaining two scored two and three. Interestingly, Bluff Marsh, Helmer's Pond and Little Rice Bay were the three sites that scored the lowest level of surrounding disturbance, the same three that scored as minimally disturbed through our qualitative site disturbance ranking scheme.

Table 4-2. Summary of quantitative land cover/land use rankings for Long Point coastal wetland sites.

Site	Idle Land	Trees/ Forest	Wetland	Beach/ Dunes	Total Natural Area	Disturbance Ranking
Big Creek	19.3	8.2	1.4	3.4	32.3	4
Bluff Marsh	68.6	3.3	18.9	9	99.8	1
Booth's Harbour	0	22.9	0	0	22.9	4
Crown Marsh	23.3	5.4	0	4.7	33.4	4
Hahn Marsh	21	32	0	2.6	55.6	3
Helmer's Pond	35.2	14.4	38.2	12	99.8	1
Lee Brown Marsh	11.1	11.7	0	1.1	23.9	4
Little Rice Bay	85.3	0.2	0	4.5	90	1
Long Point Provincial Park	37.9	19.4	0	12	69.3	2
Port Rowan	2.8	17.9	2.5	0	23.2	4
Smith Marsh	12.9	6.2	2	0	21.1	4

4.2.3 Immediate Disturbances

A box and whisker plot of road length and immediate disturbances among Long Point coastal wetland sites is shown in figures 4-2 and 4-3, respectively. Site rankings based on this distribution are shown in Table 4-3. Bluff Marsh and Helmer's Pond were scored minimally disturbed, Big Creek and Crown Marsh were scored as highly disturbed, and the remainder of sites scored moderately disturbed for road length. Similarly, Bluff Marsh and Helmer's Pond were scored minimally disturbed, Big Creek, Crown Marsh and Port Rowan were scored as highly disturbed, and the remainder of sites scored moderately disturbed for number of disturbances.

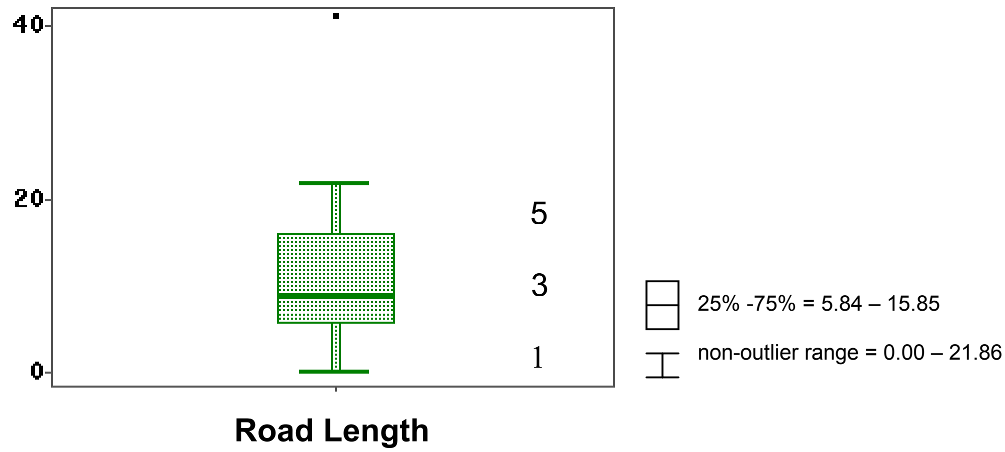


Figure 4-2. Box and whisker plot showing data distribution in relation to quartile ranking for the total road length (km) within a 1 km buffer surrounding each wetland site.

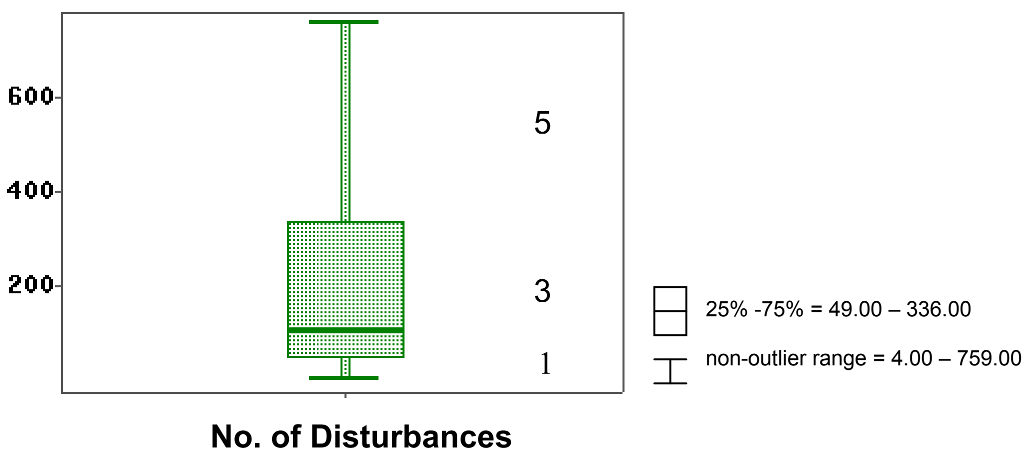


Figure 4-3. Box and whisker plot showing data distribution in relation to quartile ranking for the number of recorded quantitative disturbances within a 1 km buffer surrounding each wetland site.

Table 4-3. Summary of ranking scores for total road length and number of quantitative disturbances recorded within a 1 km buffer surrounding each wetland site at Long Point.

Study Site	Road Length(km)	Disturbance Ranking	No. of Disturbances	Disturbance Ranking
Big Creek	21.86	5	759	5
Bluff Marsh	0.00	1	4	1
Hahn Marsh	5.84	3	51	3
Lee Brown Marsh	5.97	3	49	3
Booth's Harbour	8.85	3	149	3
Port Rowan	15.85	3	621	5
Crown Marsh	41.18	5	2563	5
Helmer's Pond	1.96	1	5	1
Long Point Provincial Park	12.01	3	336	3
Little Rice Bay	8.22	3	59	3
Smith Marsh	9.38	3	252	3

Among all Long Point coastal wetlands, data were summed for qualitative hydrologic/landscape alterations, quantitative land cover attributes, immediate disturbance and road length to create an overall site disturbance ranking (Figure 4-4).

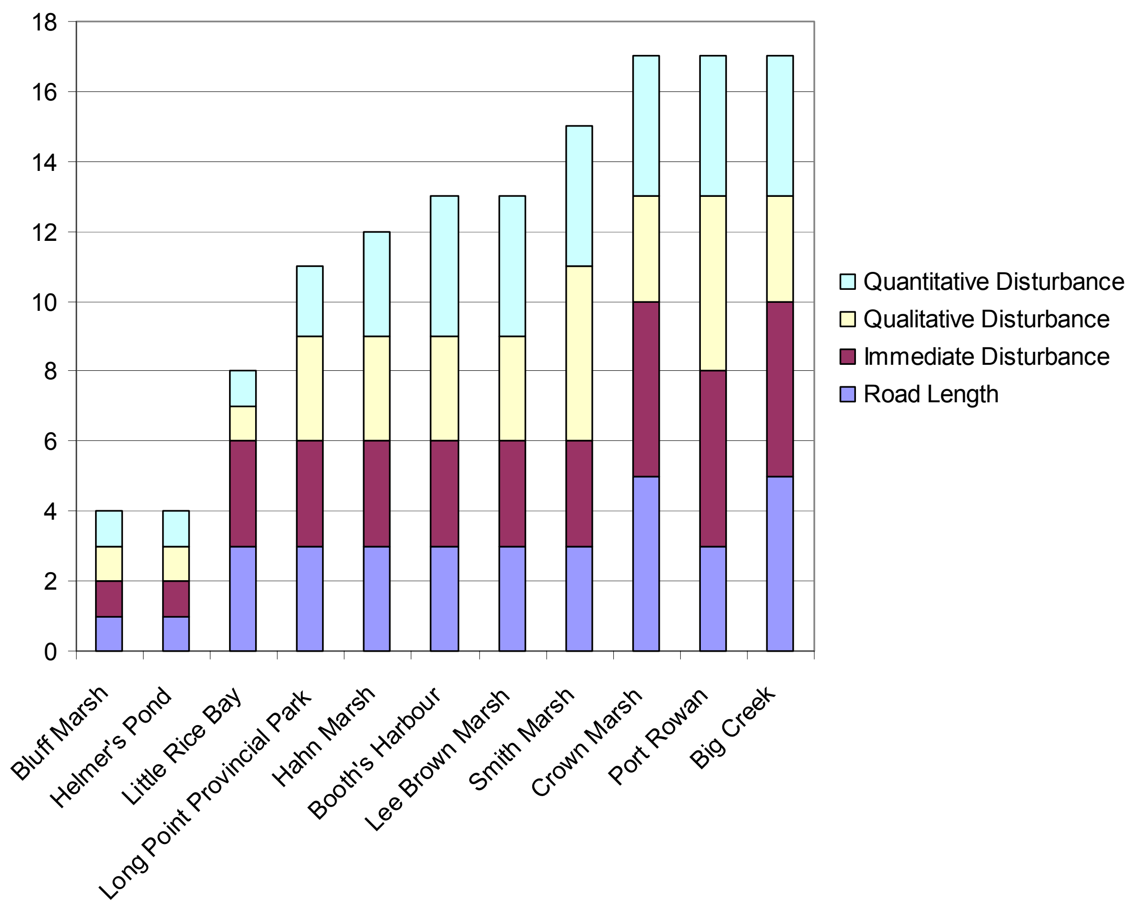


Figure 4-4. Site disturbance rankings for 11 Long Point, Lake Erie coastal wetlands.

4.3.4 Water quality

A box and whisker plot of water quality among Long Point coastal wetland sites is shown in figures 4-5, 4-6, 4-7, 4-8 and 4-9. Site rankings based on this distribution are shown in Table 4-4. Little Rice Bay Bluff Marsh was scored minimally disturbed, Big Creek and Hahn Marsh were scored as highly disturbed, and the remainder of sites scored moderately disturbed for road length.

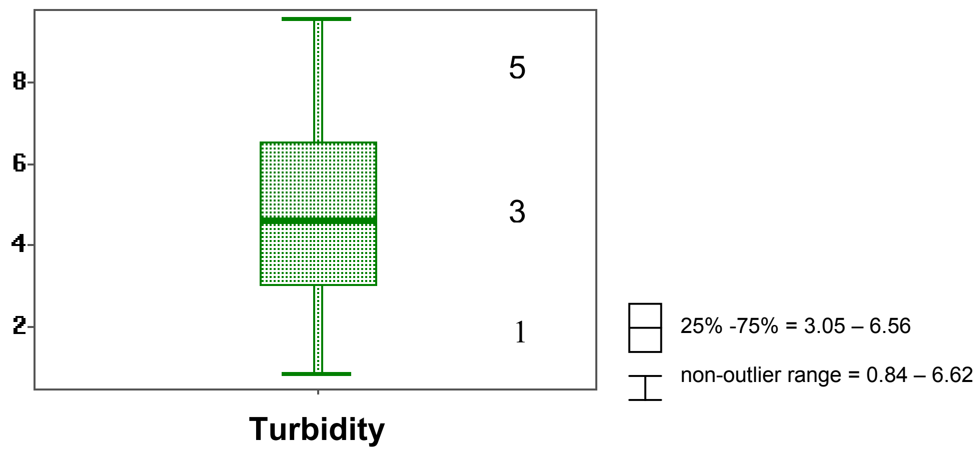


Figure 4-5. Box and whisker plot showing data distribution in relation to quartile ranking for turbidity measured within each wetland site in relation to quartile ranking. Plot was created without data for Hahn Marsh (disturbance ranking = 5).

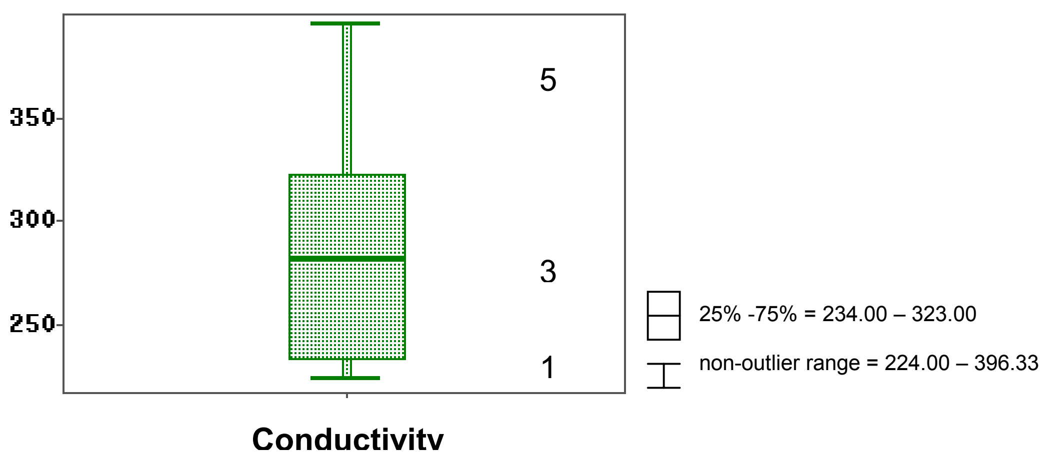


Figure 4-6. Box and whisker plot showing data distribution in relation to quartile ranking for electrical conductivity measured within each wetland site in relation to quartile ranking.

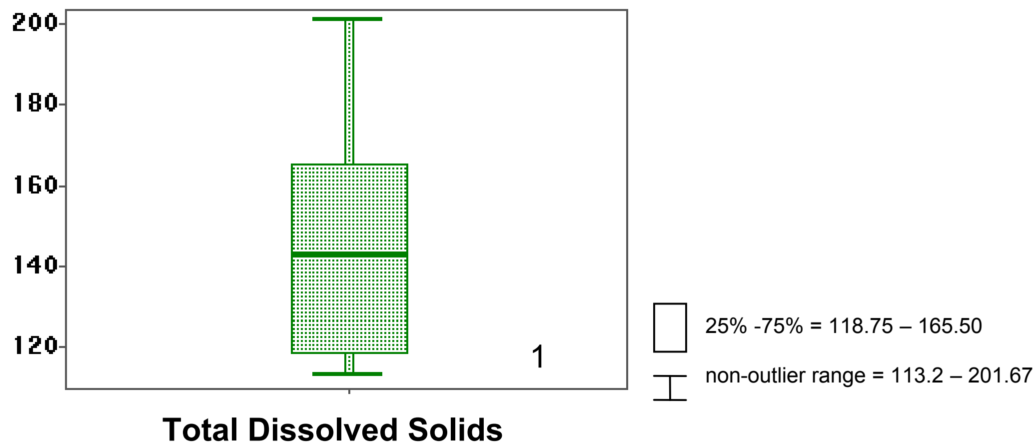


Figure 4-7. Box and whisker plot showing data distribution in relation to quartile ranking for total dissolved solids measured within each wetland site in relation to quartile ranking.

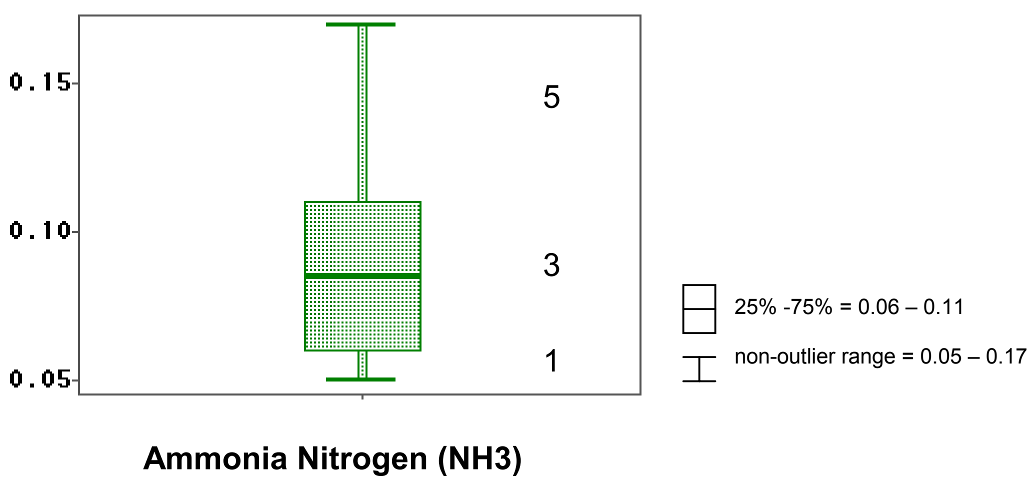


Figure 4-8. Box and whisker plot showing data distribution in relation to quartile ranking for ammonia nitrogen measured within each wetland site in relation to quartile ranking. Plot was created without data for Hahn Marsh (disturbance ranking = 5).

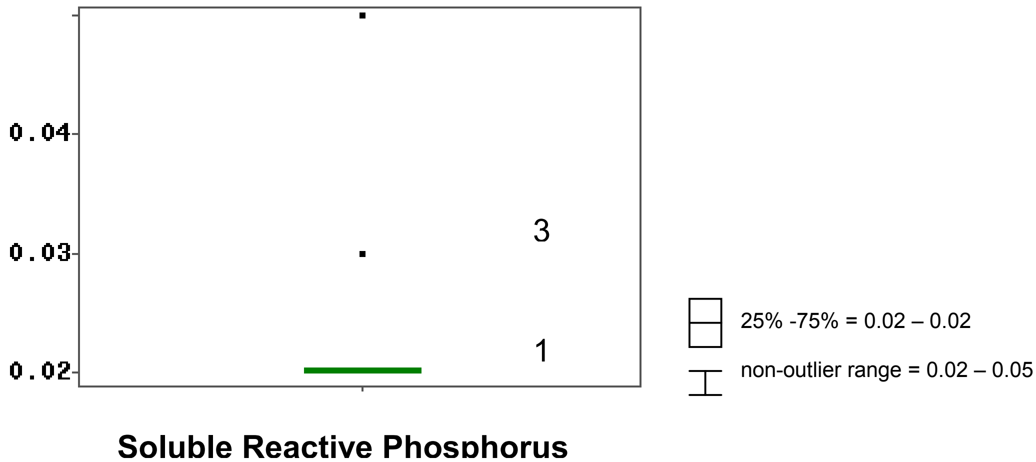


Figure 4-9. Box and whisker plot showing data distribution in relation to quartile ranking for soluble reactive phosphorus measured within each wetland site in relation to quartile ranking.

Table 4-4. Summary of water quality rankings for Long Point wetland sites. Higher rankings imply higher nutrient loadings.

Study Site	**Turbidity**		**Condutivity**		**Total Dissolved Solids**		**NH3**		**Soluble Reactive Phosphorus**		**Overall Ranking**
	NTU	**Rank**	**uS/cm**	**Rank**	**ppm**	**Rank**	**mg/L**	**Rank**	**mg/L**	**Rank**	
Big Creek	8.00	5	296.00	3	193.00	5	0.17	5	0.03	3	21
Bluff Marsh	0.84	1	233.50	3	118.75	3	0.10	3	0.02	1	11
Hahn Marsh	101.83	5	396.33	5	201.67	5	1.56	5	0.05	3	23
Lee Brown Marsh	6.56	3	302.75	3	154.50	3	0.14	5	0.02	1	15
Booth's Harbour	4.79	3	324.50	5	165.50	3	0.05	1	0.02	1	13
Port Rowan	9.62	5	271.25	1	137.50	3	0.11	3	0.02	1	13
Crown Marsh	4.53	3	323.00	3	165.00	3	0.08	3	0.02	1	13
Helmer's Pond	2.84	1	243.83	3	126.33	3	0.07	3	0.02	1	11
Long Point Provincial Park	3.27	3	282.33	3	143.00	3	0.06	3	0.02	1	13
Little Rice Bay	3.05	3	224.00	1	113.20	1	0.06	3	0.02	1	9
Smith Marsh	6.14	3	234.00	3	118.00	1	0.09	3	0.02	1	11

Among all Long Point coastal wetlands, data were summed for turbidity, conductivity, total dissolved solids (TDS), ammonia nitrate (NH3) and soluble reactive phosphorus (SRP) to create an overall site disturbance ranking (Figure 4-10).

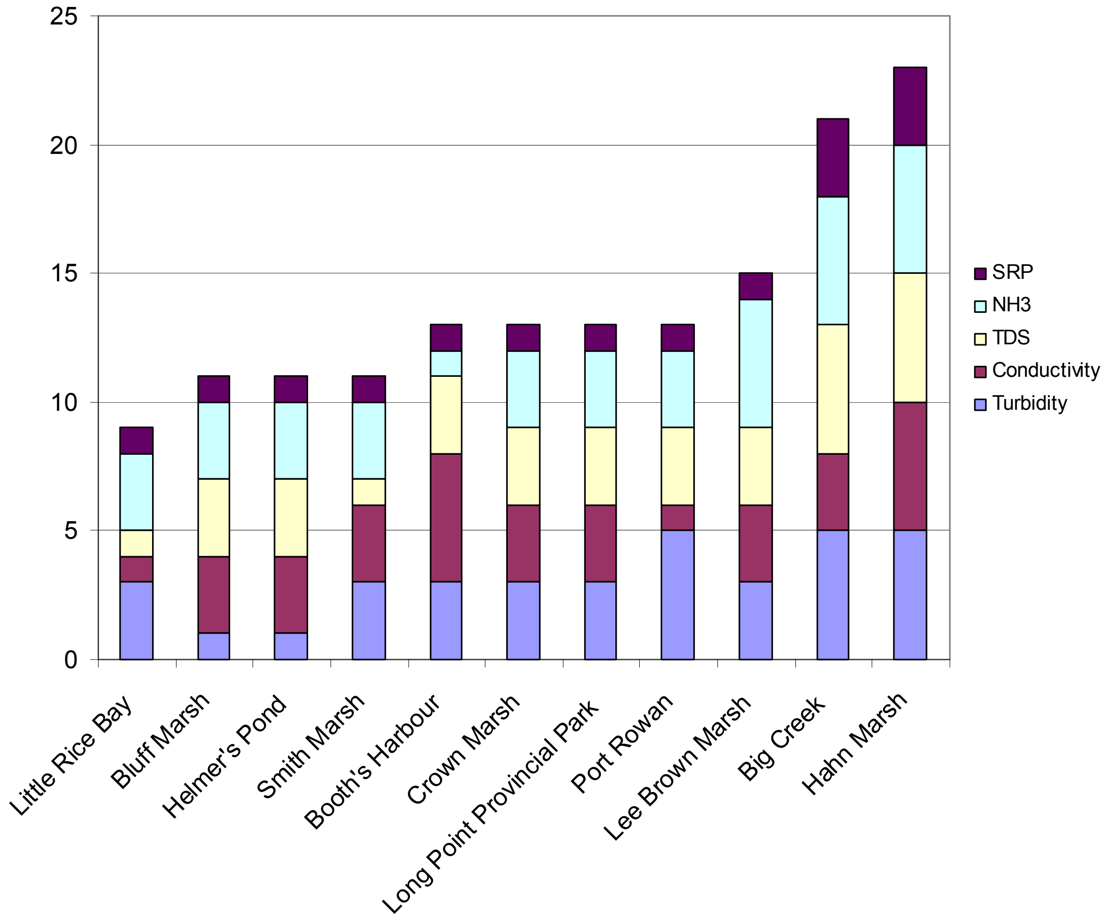


Figure 4-10. Site water quality rankings for 11 Long Point, Lake Erie Coastal wetlands.

4.4 Discussion

4.4.1 Qualitative Hydrologic/Landscape Alterations

Most Long Point wetland sites were ranked moderately disturbed through the qualitative hydrological and landscape alterations exercise. The two sites that scored as highly disturbed (Smith Marsh and Port Rowan) were located close to the town proper of Port Rowan, where most of the human activity occurs. The three sites that scored as least disturbed (i.e., Bluff Marsh, Helmer's Pond, and Little Rice Bay) were all located in remote areas along the Long Point sand spit feature, and all of these sites are federally owned and protected National Wildlife

Areas. Thus, our qualitative hydrological and landscape alterations rankings are accurate and reflect the relative level of protection and relative level of human disturbance that occurs in proximity to each site.

4.4.2 Quantitative Land Cover Attributes

None of the Long Point wetland sites scored in the most highly disturbed category (i.e., > 80% surrounding unnatural land cover), however, roughly half (n=6) of the sites scored in the next most disturbed category, having between 61%-80% surrounding unnatural land cover. Port Rowan and Smith Marsh were both included in this highest disturbance category, and others sites included Big Creek, Lee Brown Marsh, Booth's Harbour, and Crown Marsh. The former three sites all have a significant mainland influence, and all have a high proportion of their surrounding land in use deforested and in use by agricultural activities. The three sites that scored as least disturbed through this quantitative land cover exercise were the same three sites that scored as least disturbed through the qualitative disturbance ranking process. Again, this quantitative land cover attribute ranking process were accurate and reflected the relative level of site protection and the relative level of human landscape alterations and disturbances that occur within a 1 km buffer surrounding each site.

4.4.3 Immediate Disturbances

Port Rowan, Crown Marsh and Big Creek all scored as the most highly disturbed through the immediate disturbance ranking process. These sites scored as most disturbed primarily due to the combined effects of multiple residential, other buildings, number of marinas and docks, and length of roadways within their buffers. Smith Marsh did not score as highly disturbed through this ranking process because of the relatively fewer buildings and docks, less road length, and lack of marinas within its immediate surrounding area. Bluff Marsh and Helmer's Pond, the two most remote wetland sites, were the only two sites that scored as minimally disturbed. Generally, results from this ranking exercise were congruent with those from the other landscape level ranking processes, and this ranking procedure incorporated certain disturbance components that were not captured in the other ranking procedures. This ranking procedure is deemed valuable, and because much of this information was already available in a GIS database, it was done with relative ease for the Long Point wetland sites. Estimates of surrounding immediate disturbances were reflective of the relative disturbance and relative protection that occurs in proximity to the wetland study sites.

4.4.4 Water Quality

As discussed previously, water quality data were likely influenced and therefore likely confounded by how and when samples were collected. Temporal variation in collection dates and lack of experience by field staff in properly collecting and filtering water samples is believed to have confounded our results for water quality. For example, samples collected at Bluff Marsh, Big Creek and one collected at Lee Brown Marsh were collected quite late in the season, and sustained high temperatures and lack of precipitation highly reduced water levels of these barrier protected sites such that these late-collected samples were highly concentrated and had abnormally high readings for several limnological parameters. Even though Bluff Marsh, Helmer's Pond and Little Rice Bay all scored as least disturbed according to their water quality, without the outlier values for Big Creek and Hahn Marsh, there was essentially little variability in overall water quality ranking among sites. Thus, disturbance rankings for water quality were treated separately and were not combined with those rankings from qualitative and quantitative disturbance ranking procedures.

4.4.5 Overall Site Disturbance Ranking

Rankings from qualitative hydrological and landscape attributes, quantitative land cover attributes and immediate disturbances were combined to produce overall disturbance rankings for each Long Point coastal wetland site. This produced a reasonable gradient of least disturbed to most disturbed sites. Qualitative hydrological and landscape attribute rankings and quantitative land cover attribute rankings contributed most to among site disturbance variability. The two least disturbed sites (Bluff Marsh and Helmer's Pond) were 50% less disturbed than the site with the next highest disturbance ranking, and were more than 75% less disturbed than the site with highest overall disturbance ranking. Therefore, Bluff Marsh and Helmer's Pond wetland sites were deemed essentially as reference sites for the Long Point pilot study, and are likely also good candidates as reference sites for the lower Great Lakes region. Port Rowan, Big Creek and Crown Marsh all received the highest level of disturbances, landscape alterations, and development combined in their surrounding land areas. There was not any discernable relationship between overall disturbance ranking and geomorphic wetland type among Long Point wetland sites.

5.0 MARSH BIRD AND ANURAN COMMUNITY HEALTH

5.1 Methods

5.1.1 Bird Survey Protocol

Bird communities were surveyed by Bird Studies Canada (BSC) in cooperation with the Canadian Wildlife Service (CWS) – Ontario Region and (Michigan group). Prior to commencing the GLCWC one-year pilot study, eleven coastal wetlands were chosen at Long Point, Lake Erie (Big Creek, Bluff Marsh, Booth's Harbour, Crown Marsh, Hahn Marsh, Helmer's Pond, Lee Brown Marsh, Little Rice Bay, Long Point Provincial Park, Port Rowan and Smith Marsh), 12 wetland sites in Durham Region, Lake Ontario, (Bayfield Bay, Button Bay, Frenchman's Bay, Hay Bay South, Hill Island East, Huyck's Bay, Lynde Creek, Parrot's Bay, Port Britain, Presqu'ile Bay, Robinson's Cove and South Bay), two coastal wetland routes in Saginaw Bay, Lake Michigan (Saginaw Bay west, Saginaw Bay east), and one route in Arcadia Lake, Michigan to monitor marsh bird community health. Before survey routes were established, a detailed topographical map was obtained for each wetland to aid in sample station placement to ensure that sampling was completed in areas where species abundance and diversity would be greatest. Each route was established in marsh habitat (i.e., dominated by non-woody emergent plants) and each survey station was established within areas where greater than 50% of the wetland was dominated by marsh habitat characteristics.

The GLCWC marsh bird surveys were conducted following Marsh Monitoring Program survey protocol (Anonymous 2001). Each marsh bird survey point count was conducted from a focal point located on the baseline of a 100 m radius semi-circular survey area (or sample station). Survey routes consisted of between one and eight sample stations and stations were separated by at least 250 m in order to minimize the possibility that individuals were sampled twice. At some sites, multiple routes were established to cover all available habitats. Each sample station's focal point was permanently marked with a 3 m metal stake to facilitate relocating sites within and between years. Stakes were pushed at least 1 m into the marsh bottom to withstand wind, wave, ice and frost action. Aluminum tags were used to permanently identify each station and were attached to each stakes by twisting their wire ends together firmly around the metal stake. Each tag was labelled in order of sequential coverage from A to H and inscribed with the station letter using a pen. The metal stake was also labelled using a piece of fluorescent flagging tape and inscribed with the same information as the aluminums tag. Although the fluorescent flagging tape lasted only one field season, the tape was visible from a distance and easily read at low light. To enhance visibility, three or four strips of fluorescent flagging tape were tied to the top of each stake.

Routes were surveyed for marsh birds on two separate nights during spring, between 20 May and 5 July, with at least 10 days occurring between visits. Surveys commenced after 1800 h and ended at or before sunset during evenings with good visibility, warm temperatures (at least 16 EC), no precipitation and little or no wind. Surveys were only done when the wind strength was a 0, 1, 2, or 3 on the Beaufort scale. Before beginning each survey, the observer's name, marsh name, date, visit number, start time, weather conditions, wind speed according to the

Beaufort Scale, UTM Easting and Northing (using a Magellan GPS 320 global positioning system), cloud cover and air temperature in EC were recorded on marsh bird data forms. During the beginning of each ten-minute survey period, a five-minute broadcast tape was broadcast at each station with a tape recorder held at chest height and aimed so that it broadcasted toward the 100 m radius semi-circular survey area. The broadcast tape helped to elicit calls from several normally secretive bird species and contained calls of Virginia Rail, Sora, Least Bittern, Common Moorhen, American Coot and Pied-billed Grebe. The tape featured 30 seconds of calls followed by 30 seconds of silence for each species. The timer began at the sound of the first call on the tape and all marsh birds detected both visually and aurally within the survey station area were recorded. During the five-minute count period, all marsh birds were recorded until the timer signalled the end of the survey. Each individual bird recorded during the survey was assigned to only one of three categories:

Mapped Observation**:** all birds observed or heard actually residing within the boundaries of the 100 m radius semi-circle. These birds make actual, physical contact with the sample area.

Aerial Foragers**:** all birds observed actively foraging in the air within the sample area, no higher than 100 m, and not otherwise using the sample area.

Outside/Flythrus**:** all additional species of marsh birds observed during the ten-minute point count outside the sample area or flying through the sample area without landing.

All visual and aural observations heard within the sample area during the ten-minute survey period, other than those flying through or foraging, were recorded onto a field map and data form. The relative position of each individual was recorded using the appropriate four-letter species code. However, only males were recorded for Red-winged Blackbirds and Yellow-headed Blackbirds. Because calls of the Common Moorhen and American Coot can often be difficult to distinguish, the generic code "MOOT" was used when either species could not be positively identified. The time when the survey route was completed was also recorded after the last station was surveyed. All marsh bird data for each route was summarized for all three visits on a marsh bird route summary sheet.

A training kit, surveying instructions and a broadcast tape for monitoring marsh birds was provided to all working groups participating in the GLCWC prior to the field season to help standardize protocol in which marsh birds were surveyed in the one-year pilot study.

The Lake Ontario CWS study team followed the same protocol as described above, and is described in their year-one GLCWC project report.

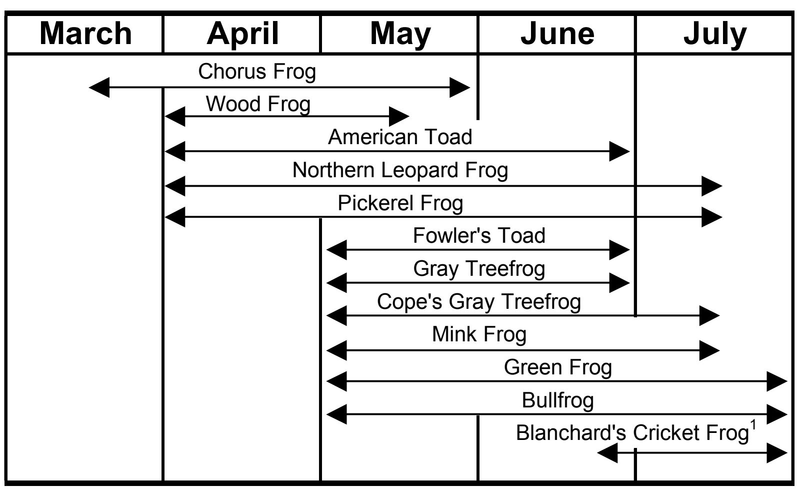
5.1.2 Amphibian Survey Protocol

Amphibian communities were surveyed by Bird Studies Canada (BSC) in cooperation with the Canadian Wildlife Service (CWS) – Ontario Region and (Michigan group). Prior to commencing the GLCWC one-year pilot study, eleven coastal wetlands were chosen in Long Point, Lake Ontario (Big Creek, Bluff Marsh, Booth's Harbour, Crown Marsh, Hahn Marsh, Helmer's Pond, Lee Brown Marsh, Little Rice Bay, Long Point Provincial Park, Port Rowan and Smith Marsh), 12 wetlands in the Durham Region, Lake Ontario (Bayfield Bay, Button Bay, Frenchman's Bay, Hay Bay South, Hill Island East, Huyck's Bay, Lynde Creek, Parrot's Bay, Port Britain, Presqu'ile Bay, Robinson's Cove and South Bay), two routes in Saginaw Bay, Lake Michigan (Saginaw Bay

West and Saginaw Bay East), and one route in Arcadia Lake, Michigan to monitor amphibian health. Before survey routes were established, a detailed topographical map was obtained for each wetland to aid in sample station placement in the wetland to ensure sampling was completed in areas where species abundance and diversity would be greatest. Each route was established in marsh habitat (i.e., dominated by non-woody emergent plants) and each survey station was established within areas where greater than 50% of the wetland was dominated by marsh characteristics.

The GLCWC amphibian surveys were done using the "point count" method. Amphibian survey point counts were conducted from a focal point located on the baseline of a 100 m radius semi-circular sample area (or sample station). Survey routes consisted of between one and eight sample stations and were separated by at least 500 m in order to minimize the possibility that individuals or choruses were sampled twice. Each sample station's focal point was permanently marked with a 3 m metal stake to facilitate relocating sites within and between years. Stakes were pushed at least 1 m into the marsh bottom to withstand wind, waves, ice and frost action. Aluminums tags were used to permanently identify each station and were attached to the stakes by twisting their wire ends together firmly around the metal stake. Each tag was labeled in order of sequential coverage from A to H and inscribed with the station letter using a pen. The metal stake was also labeled using a piece of fluorescent flagging tape and inscribed with the same information as the aluminums tag. Although the fluorescent flagging tape lasted only one field season, the tape was visible from a distance and easily read at low light. To enhance visibility, three or four strips of fluorescent flagging tape were tied to the top of each stake.

Amphibian sampling routes were surveyed for calling amphibians on three separate nights during spring, between the beginning of April to the middle of June, with at least 15 days occurring between visits. See the chart below for information on general breeding periods of amphibians in the Great lakes basin.



[1] Historic calling dates for Pelee Island, Ontario

Because peak amphibian calling periods are strongly associated with temperature and precipitation rather than date, visits were scheduled to occur on three separate evenings according to minimum night air temperatures of 5 °C, 10 °C, and 17 °C. The first survey visit coincided with minimum night-time air temperatures of at least 5 °C and the first or second warm spring shower. The second survey visit coincided with night-time air temperatures of 10 °C and the third coincided with night-time air temperatures of 17 °C. Surveys commenced one-half hour after sunset and ended before midnight and were completed during evenings with little wind and moist conditions with one of the above corresponding temperatures. Before beginning each survey, the observer's name, marsh name, date, visit number, start time, weather conditions, wind speed according to the Beaufort Scale, UTM Easting and Northing (using a Magellan GPS 320 global positioning system), cloud cover and air temperature in EC were recorded on amphibian data forms. Once surveys were ready to begin a one-minute quiet period was held before each three-minute survey period. During the three-minute amphibian survey, observers recorded all species heard in the 100 m radius semi-circle on a map and assigned a Call Level Code to each species detected to estimate the number of calling amphibians in each wetland; for two of these levels, estimated numbers of individuals were also recorded.

Call Level Code 1**:** Calling individuals can be counted and calls were not simultaneous. In this instance, exact counts could be made of the number of calling individuals and surveyors recorded both code and their count.

Call Level Code 2**:** Calls of individuals could be distinguished but some calling was simultaneous. Under these conditions, an exact count was not possible but surveyors were able to make reliable estimates of the number of individuals calling. Surveyors were asked to record both the code and their count estimate.

Call Level Code 3**:** A full calling chorus with calls continuous and overlapping. Reliable counts and estimates were unrealistic at this level of calling intensity and no counts were requested.

Amphibian sampling participants were also asked to use their best judgment to distinguish whether species detected were calling from inside the station boundary only, from outside the station boundary only, or from both inside and outside. All amphibian aural observations heard during the three-minute survey period were recorded onto a field map and data form. The relative position of each individual was recorded using the appropriate four-letter species code and under each species code the Call Level Code was recorded. The time the survey route was finished was also recorded after the last station was surveyed. All amphibian data for each route was summarized for all three visits on an amphibian route summary sheet.

A training kit and surveying instructions for monitoring amphibians was provided to working groups participating in the GLCWC prior to the field season to help standardize protocol in which amphibians were surveyed in the one-year pilot study.

5.1.3 Data Analysis

For both Lake Erie and Lake Ontario data, maximum number of observations (individuals for birds, calling code for amphibians) across all visits first summarized using SAS statistical software (SAS Institute Inc. 1999). Following this, observations were summed across all survey routes. Lastly, route data for all routes within a wetland site were combined, which yielded total observation data for all species observed at each survey station for each study site.

All MMP data analysed were derived from observations recorded within the survey station limits and did not include 'outside/flythroughs'. Bird species richness, diversity and equitability were calculated for each study site using Microsoft Excel software. The Shannon-Weaver Index was used to calculate marsh bird species diversity (Sokal and Rohlf 1995). Equitability (range: 0–1) was a measure of species evenness at the study site and was 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 that a similar number of individuals within each species was observed.

Amphibian (frog and toad) species richness and diversity was summarized for each site using the methods described for birds above. Maximum calling code was substituted for abundance in our calculation of amphibian diversity and equitability.

Wetland sizes differed among sites and because the number of stations surveyed also differed among sites, we evaluated whether there were relationships between survey effort (i.e., number of stations surveyed) and species richness variables through use of linear regression. When such relationships were significant at $P < 0.05$, residual values of the dependent variable from these regressions were used to evaluate the relationships with site disturbance rankings.

5.2 Results

A summary of bird and amphibian survey routes monitored at each study site for both Long Point, Lake Erie and various locations along Lake Ontario is provided in Table 5-1.

Table 5-1. Summary of Marsh Monitoring Program surveys conducted in a) 11 Lake Erie, b) 12 Lake Ontario/St. Lawrence River, and c) three Michigan coastal wetlands during 2002.

Study Site	**Wetland Type**	**Surveyor(s)**	**No. Stations Surveyed[1]**
Big Creek	Barrier Protected/Drowned Rivermouth	BSC	24/19
Booth's Harbor	Open Shoreline/Open Embayment	BSC	3/2
Bluff Marsh	Barrier Protected/Protected Embayment	BSC/volunteers	7/4
Crown Marsh	Open Embayment/Protected Embayment	BSC/volunteers	21/13
Hahn Marsh	Barrier Protected	BSC	12/9
Helmer's Pond	Barrier Protected/Sand-spit Lagoon	BSC/volunteers	14/11
Lee Brown Marsh	Beach Protected	BSC	8/11
Long Point Provincial Park	Open Embayment	BSC	5/4
Little Rice Bay	Open Embayment/Sandspit Embayment	BSC	15/10
Port Rowan	Open Embayment/Open Shoreline	BSC	7/4
Smith Marsh	Open Embayment/Drowned Rivermouth	BSC	6/3

BSC - Bird Studies Canada field staff
[1] Birds/Amphibians

Study Site	**Wetland Type**	**Surveyor(s)**	**No. Stations Surveyed[1]**
Frenchman's Bay	Beach Barrier	TRCA	3/2
Port Britain - Willow Beach	Beach Barrier	CWS/Volunteer	3/0
Presqui'le Prov. Park	Protected Embayment	Volunteer	7/8
Button Bay	Open Embayment	CWS	2/2
South Bay	Open Bay	CWS	2/2
Hay Bay South	Open Embayment	CWS	3/2
Huyck's Bay	Beach Barrier	Volunteer/CWS	2/0
Parrott Bay	Protected Embayment	Volunteer/CWS	2/4
Bayfield Bay	Protected Embayment	CWS	3/3
Lynde Creek	Beach Barrier	Volunteer	7/3
Robinson's Cove -Big Is.	Open Embayment	Volunteer	2/1

CWS - Canadian Wildlife Service field staff, TRCA - Toronto and Region Conservation Authority
[1] Birds/Amphibians

Site	Wetland Type	Surveyors	No. Stations[1]
Arcadia Lake	Barrier Protected	Contractor	6/5
Saginaw Bay East	Open Embayment/Open Shoreline	Contractor	10/10
Saginaw Bay West	Open Embayment/Open Shoreline	Contractor	9/9

[1] - Birds/Amphians

A summary of marsh bird and amphibian species richness, diversity and equitability for Lake Erie Lake Ontario, and Michigan coastal wetland sites is provided in Table 5-2. Summaries of marsh bird and anuran data for Long Point and Lake Ontario are provided in the Appendices.

Table 5-2. Summary of marsh bird and amphibian species richness, diversity and equitability in a) 11 Lake Erie, b) 12 Lake Ontario/St. Lawrence River, and c) three Michigan coastal wetlands during 2002.

Site	Wetland Type	Species Richness[1]	Diversity[1]	Equitability[1]
Big Creek	Barrier Protected/Drowned Rivermouth	29/8	2.53/2.01	0.75/0.969
Booth's Harbor	Open Shoreline/Open Embayment	14/6	2.32/1.67	0.880.931
Bluff Marsh	Barrier Protected/Protected Embayment	10/7	1.45/1.83	0.63/0.934
Crown Marsh	Open Embayment/Protected Embayment	31/6	2.33/1.73	0.68/0.969
Hahn Marsh	Barrier Protected	28/8	2.46/1.97	0.74/0.948
Helmer's Pond	Barrier Protected/Sand-spit Lagoon	30/6	2.34/1.72	0.69/0.96
Lee Brown Marsh	Beach Protected	27/7	2.73/1.86	0.83/0.957
Long Point Provincial Park	Open Embayment	14/6	2.19/1.75	0.83/0.979
Little Rice Bay	Open Embayment/Sandspit Embayment	20/7	2.27/1.84	0.76/0.948
Port Rowan	Open Embayment/Open Shoreline	29/7	2.59/1.91	0.77/0.98
Smith Marsh	Open Embayment/Drowned Rivermouth	23/4	2.55/1.35	0.81/0.975

[1] Birds/Amphibians

Site	Wetland Type	Species Richness[1]	Diversity[1]	Equitability[1]
Frenchman's Bay	Beach Barrier	5/4	0.998/1.33	0.62/0.96
Port Britain - Willow Beach	Beach Barrier	13/4	1.18/1.67	0.46/0.93
Presqui'le Prov. Park	Protected Embayment	15/6	1.42/1.55	0.52/0.96
Button Bay	Open Embayment	11/5	2.02/1.26	0.84/0.91
South Bay	Open Bay	7/7	1.49/1.82	0.77/0.94
Hay Bay South	Open Embayment	8/6	1.64/1.72	0.79/0.96
Huyck's Bay	Beach Barrier	8/4	1.55/1.67	0.74/0.93
Parrott Bay	Protected Embayment	7/6	1.36/1.74	0.7/0.97
Bayfield Bay	Protected Embayment	13/6	2.00/0	0.78/
Lynde Creek	Beach Barrier	19/1	2.26/1.39	0.77/1
Robinson's Cove -Big Is.	Open Embayment	6/NA	1.56/NA	0.87/NA

[1] Birds/Amphibians

Site	Wetland Type	Species[1] Richness	Diversity[1]	Equitability[1]
Arcadia Lake	Barrier Protected	17/6	2.46/1.74	0.87/0.97
Saginaw Bay East	Open Embayment/Open Shoreline	NA/6	NA/1.74	NA/0.97
Saginaw Bay West	Open Embayment/Open Shoreline	NA/6	NA/1.77	NA/0.99

[1] - Birds/Amphians

5.2.1 Bird Community Attributes

5.2.1.1 Species Richness

Species richness was variable among wetland sites at both Lake Erie and Lake Ontario study sites (Lake Erie range: 10-31; Lake Ontario range: 5-19). At Long Point, Bluff Marsh had the fewest species recorded (n=10), however this site also had among the fewest stations surveyed, and there was a highly positive significant relationship ($P < 0.05$) between survey effort (i.e., number of stations surveyed) and species richness among Long Point sites (Figure 5-1). Similarly, also at Long Point, species richness was highest at Crown Marsh, which had the second highest number of stations surveyed (n=21).

Among Lake Ontario study sites, Frenchman's Bay had the lowest bird species richness, but also had among the fewest stations surveyed (n=3) for birds, and there was also a highly positive significant relationship ($P < 0.01$) between survey effort and bird species richness among Lake Ontario sites (Figure 5-24). Similarly, also at Lake Ontario sites, Presqu'ile Bay and Lynde Creek had the two highest bird species richnesses, but both also had the highest number of bird stations surveyed (n=7).

Given that wetland area often dictated the number of survey routes established and surveyed, these findings indicate probable positive bird species richness-area associations. When significant relationships between species richness and effort occurred, residual values of richness-effort regression were used to evaluate these bird and amphibian community attribute relationships (i.e., corrected for effort) with site disturbance rankings.

After correcting for effort, species richness did not vary significantly across site disturbance rankings or across water quality rankings among Long Point wetland sites (Figure 5-2 and Figure 5-3). However, it is important to note that Helmer's Pond was the only site responsible for non-significance of this relationship, as without this site there would have been a strong positive relation between richness and site disturbance at Long Point – the opposite direction as would have been predicted.

Corrected bird species richness did not perform well in predicting the site disturbance gradient among Lake Ontario study sites (Figure 5-25).

5.2.1.2 Species Diversity

Bird species diversity (corrected for effort) at Long Point showed a significant positive relationship with site disturbance ranking, meaning that diversity was higher at more disturbed sites (Figure 5-4). Long Point bird diversity (corrected for effort) did not relate significantly to site water quality rankings, although the direction of the slope was also positive (Figure 5-5).

Among Lake Ontario sites, bird species diversity (corrected for effort) did not relate significantly to site disturbance rankings (Figure 5-26).

5.2.1.3 Equitability
Equitability, which measures the evenness of abundance across species, did not relate significantly to either site disturbance rankings (Figure 5-6) or to site water quality rankings (Figure 5-7) among Long Point wetland sites.

Equitability also did not relate significantly to site disturbance rankings among the 12 Lake Ontario wetland sites (Figure 5-27).

5.2.1.4 Indicator Species Richness
Bird indicator species richness was significantly positively correlated with the number of survey stations among both Long Point (Figure 5-8) and Lake Ontario study sites (Figure 5-28). Thus, for both datasets, residuals of these regressions were plotted against disturbance to correct for effort.

Bird indicator species richness (corrected for effort) was not significantly related to either site disturbance rankings (Figure 5-9) or to site water quality rankings (Figure 5-10) among Long Point wetland sites. This attribute (corrected for effort) was also not significantly related to site disturbance rankings among the 12 Lake Ontario study sites (Figure 5-29).

5.2.1.5 Proportion of Indicator Species of Total Species Observed
Both indicator species richness and total species richness related positively to the number of survey stations at both Long Point and Lake Ontario wetland sites. Given this, neither of these attributes were corrected for effort before calculating proportion of indicator species present of the total species present.

The proportion of indicator species of the total species observed at each site did not relate significantly to site disturbance rankings at Long Point, however, there was a notable pattern in the expected direction in how this attribute varied among the Long Point site disturbance gradient (Figure 5-11). This attribute did not relate in any fashion to site water quality rankings among Long Point study sites (Figure 5-12).

This attribute did not relate significantly in any predictable pattern to site disturbance rankings among Lake Ontario study sites (Figure 5-30).

5.2.1.6 Proportional Abundance of Blackbirds of Total Bird Abundance
Both abundance of blackbirds and total abundance of all bird species related positively to the number of survey stations at both Long Point and Lake Ontario wetland sites. Given this, neither of these attributes were corrected for effort before calculating proportion of indicator species present of the total species present.

The proportion of blackbird abundance (for all blackbird species) of the total abundance of all species observed within MMP stations did not relate significantly to site disturbance rankings among Long Point wetland sites (Figure 13). Although this relationship did approach a positive significant relationship, only one site (Bluff Marsh) contributed to this pattern. There was no relationship between this attribute and site water quality rankings among Long Point wetland sites (Figure 5-14).

Among Lake Ontario wetland sites, there was a significant negative correlation between the proportional abundance of (almost all of which were Red-winged Blackbirds for these sites) blackbirds of total bird abundance and site disturbance rankings, meaning that fewer blackbirds were observed at more disturbed sites than at less disturbed sites (Figure 5-31).

5.2.1.7 Proportional Abundance of Marsh Wren

Similar to results found for proportion of indicator species present of all species present, proportional abundance of Marsh Wren (an indicator species commonly detected on MMP surveys) of the total abundance of all species present did not significantly relate to site disturbance rankings or water quality disturbance rankings of Long Point wetlands, but there were notable patterns in the expected direction in how this attribute varied among sites for both disturbance measures (Figure 5-15 and Figure 5-16).

This attribute was not examined for Lake Ontario study site data, as Marsh Wren occurrence and abundance were both low and did not vary considerable among sites.

5.2.1.8 Total Abundance of All Species

We evaluated if total abundance of all species was related to site disturbance rankings. First, however, abundance data were corrected for effort, as there was a highly significant positive relationship between total abundance and number of survey stations, as expected (Figure 5-17, not shown for Lake Ontario). There was no significant relation between total abundance of all species (corrected for effort), and site disturbance rankings, or between this attribute and site water quality rankings (Figure 5-18 and Figure 5-19) among Long Point wetland sites.

Similarly, there was no significant relation between total abundance of all species observed and site disturbance rankings among Lake Ontario wetland sites (not shown).

5.2.1.9 Aerial Forager Species Richness

We evaluated if aerial forager species richness (corrected for effort) was related to site disturbance rankings. There was a significant positive relation between this attribute and site disturbance among the 11 Long Point wetland sites, meaning that number of aerial forager species was higher in more disturbed sites (Figure 5-20).

This attribute did not perform well in predicting site disturbance rankings among Lake Ontario wetland sites (not shown).

5.2.1.10 Total Abundance of Aerial Foragers

Total abundance of aerial foragers was positively correlated with number of stations among Long Point wetland sites (Figure 5-21), so residuals from this regression were used to relate corrected aerial forager abundance to disturbance rankings of Long Point wetland sites. There was no significant positive relation between this attribute (corrected for effort) and site disturbance rankings, meaning that number of aerial forager individuals was not higher in more disturbed sites (Figure 5-22). Although this relation was also non-significant at the level of 95% confidence among Lake Ontario wetland sites, there was a tendency for more disturbed sites to have higher abundance of aerial foragers (r = 0.50, p = 0.11)(not shown).

5.2.1.11 Proportional Abundance of Aerial Foragers and of Total Bird Abundance
Proportional abundance of aerial foragers of total bird abundance (uncorrected for effort) was not significantly related to site disturbance rankings of Long Point wetlands. However, a pattern across the disturbance gradient similar to that observed for both proportion of indicator species of total species present and proportional abundance of Marsh Wren abundance was noted for this attribute (Figure 5-23). Results for this attribute conflicted with those for Long Point wetland sites, because although non-significant at a level of 95% confidence, there was a tendency for sites of higher disturbance to have a higher proportion of all individuals observed represented by aerial foragers (r = 0.5, p = 0.11)(not shown).

5.2.2 Long Point and Lake Ontario Pooled Analyses
Site disturbance rankings for Long Point and Lake Ontario differed in that Lake Ontario's rankings included water quality rankings, whereas Long Point's did not. Secondly, Long Point's disturbance rankings included a sub-set of disturbance rankings based on total length of travelled roadways within a one-kilometre buffer around each wetland site. Thirdly, the context of site locations varied considerably between study teams, as Long Point sites were all located in a very large and complex coastal sand spit feature of Lake Erie, whereas Lake Ontario sites were distributed broadly across the entire northern shore of this Lake and considerably more independent from one another than Long Point sites. Nonetheless, some effort was made perform analyses of pooled community and site disturbance data from Long Point and Lake Erie.

Prior to pooling Long Point and Lake Ontario data sets to further investigate if any marsh bird community attributes could be used as suitable metrics for bio-monitoring coastal wetland health, it was necessary to standardize disturbance rankings from each site. Therefore, disturbance rankings for water quality were removed from the Lake Ontario ranking scheme, and disturbance rankings for total length of traveled roadway was removed from the Long Point ranking scheme. This yielded disturbance rankings that were presumably comparable. However, caution is warranted in interpreting any of these results, as site disturbance data may not have been collected in the same manner at each site, especially quantitative land cover attribute data.

Marsh bird community attribute data were pooled from both sites, and regressions of each community attribute described above against site disturbance rankings were performed. None of these regressions yielded results that would support the use of any of these community attributes as useful metrics for developing coastal wetland bird IBIs. Results of these analyses are not presented graphically but are discussed in the General Discussion section.

5.2.3 Amphibian (Anuran) Community Attributes

5.2.3.1 Species Richness
Species richness of frogs and toads was not correlated with number of stations surveyed at either Long Point or Lake Ontario study sites. Therefore, richness attribute were not corrected for effort before relating to site disturbance rankings.

Anuran species richness was not significantly related to site disturbance rankings among Long Point wetland study sites (Figure 5-32), or among Lake Ontario wetland sites (Figure 5-). However, the range of species richness and the direction of the pattern (i.e., tendency for fewer species in more disturbed sites) across the range of site disturbances for the Lake Ontario data set indicate that this attribute may warrant further investigation.

This attribute did relate positively to site water quality rankings among Long Point wetland sites, due almost entirely to Big Creek and Hahn Marsh having both high richness and water quality rankings (Figure 5-33).

Although the relationship was not significant, the range of anuran species richness did vary in a predictable fashion among the range of site disturbances across Lake Ontario wetland sites (Figure 5-46).

5.2.3.2 Species Diversity

Anuran species diversity among Long Point wetland sites showed no significant relation to site disturbance rankings of these sites (Figure 5-34), but there was a positive significant relationship between this attribute and water quality rankings among these sites (Figure 5-35). This relationship was driven primarily by high water quality values from Big Creek and Hahn Marsh.

Among Lake Ontario wetland study sites there was no significant relation between anuran diversity and site disturbance rankings (Figure 5-47).

5.2.3.3 Equitability

The range of anuran equitability showed no predictable pattern with the range of site disturbance or water quality rankings among Long Point wetlands (Figure 5-36 and Figure 5-37).

This range of this attribute also did not vary in any significant pattern across the range of site disturbance rankings among Lake Ontario wetland study sites (Figure 5-48).

5.2.3.4 Indicator Species Richness

Anuran indicator species richness did not vary significantly across either disturbance rankings (Figure 5-38) or water quality rankings (Figure 5-39) among Long Point wetland sites.

This attribute also did not vary in any significant direction across the range of Lake Ontario site disturbance rankings (Figure 5-49).

5.2.3.5 Proportion of Indicator Species of Total Species Observed

Although the proportion of anuran indicator species of all species present at a site did not vary significantly across Long Point site disturbance rankings, there was a tendency for least disturbed sites to have a higher proportion of indicator species ($r = -0.47$, $p = 0.14$)(Figure 5-40). This attribute did not prove to be a good indicator of site water quality ranking among Long Point wetland sites (Figure 5-41).

The proportion of anuran indicator species of all species present at a site did not vary significantly across the range of site disturbance rankings among Lake Ontario wetlands (Figure 5-50).

5.2.3.6 Maximum Calling Code of Northern Leopard Frog

Maximum calling code of Northern leopard frog did not prove to be a good attribute for predicting site disturbance ranking or water quality ranking among Long Point wetland sites (Figure 5-42) and Figure 5-43).

This attribute also did not perform well in predicting the site disturbance gradient among Lake Ontario wetland sites (Figure 5-51).

5.2.3.7 Maximum Calling Code of Chorus Frog
Maximum calling code of chorus frog was not able to predict either site disturbance or water quality disturbance gradients among Long Point wetland sites (Figure 5-44 and Figure 5-45).

This attribute also could not predict site disturbance differences among Lake Ontario wetland sites (Figure 5-52).

5.2.3.8 Maximum Calling Code of Bullfrog
Maximum calling code of bullfrog was evaluated as a potential metric for Lake Ontario data only, as this attribute did not vary considerably among Long Point wetland study sites.

Differences in this attribute did not relate significantly to differences in site disturbance rankings, and therefore was not a good predictor of site disturbance among Lake Ontario wetland sites (Figure 5-53).

5.2.4 Long Point and Lake Ontario Pooled Analyses

Site disturbance rankings for Long Point and Lake Ontario differed in that Lake Ontario's rankings included water quality rankings, whereas Long Point's did not. Secondly, Long Point's disturbance rankings included a sub-set of disturbance rankings based on total length of travelled roadways within a one-kilometre buffer around each wetland site. Thirdly, the context of site locations varied considerably between study teams, as Long Point sites were all located in a very large and complex coastal sand spit feature of Lake Erie, whereas Lake Ontario sites were distributed broadly across the entire northern shore of this Lake and considerably more independent from one another than Long Point sites. Nonetheless, some effort was made perform analyses of pooled community and site disturbance data from Long Point and Lake Erie.

Prior to pooling Long Point and Lake Ontario data sets to further investigate if any anuran community attributes could be used as suitable metrics for bio-monitoring coastal wetland health, it was necessary to standardize disturbance rankings from each site. Therefore, disturbance rankings for water quality were removed from the Lake Ontario ranking scheme, and disturbance rankings for total length of traveled roadway was removed from the Long Point ranking scheme. This yielded disturbance rankings that were presumably comparable. However, caution is warranted in interpreting any of these results, as site disturbance data may not have been collected in the same manner at each site, especially quantitative land cover attribute data.

Anuran community attribute data were pooled from both sites, and regressions of each community attribute described above against site disturbance rankings were performed. None of these regressions yielded results that would support the use of any of these community attributes as useful metrics for developing coastal wetland anuran IBIs. Results of these analyses are not presented graphically but are discussed in the General Discussion section.

5.2.5 Arcadia Lake and Saginaw Bay Marsh Bird and Amphibian Data

Summaries of marsh bird and amphibian data collected at Arcadia Lake and Saginaw Bay are presented in tables A-9 to A-11 of the Appendices. Data from these sites were not analysed for community attribute responses to site disturbance. Reasons for this are discussed in the General Discussion below.

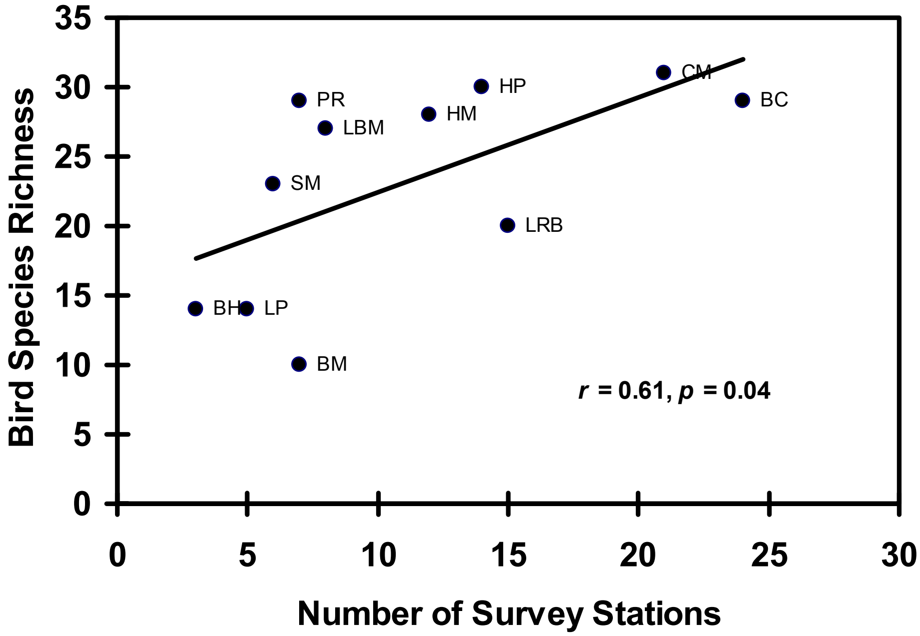


Figure 5-1. Relation between bird species richness and number of survey stations among Long Point wetland sites.

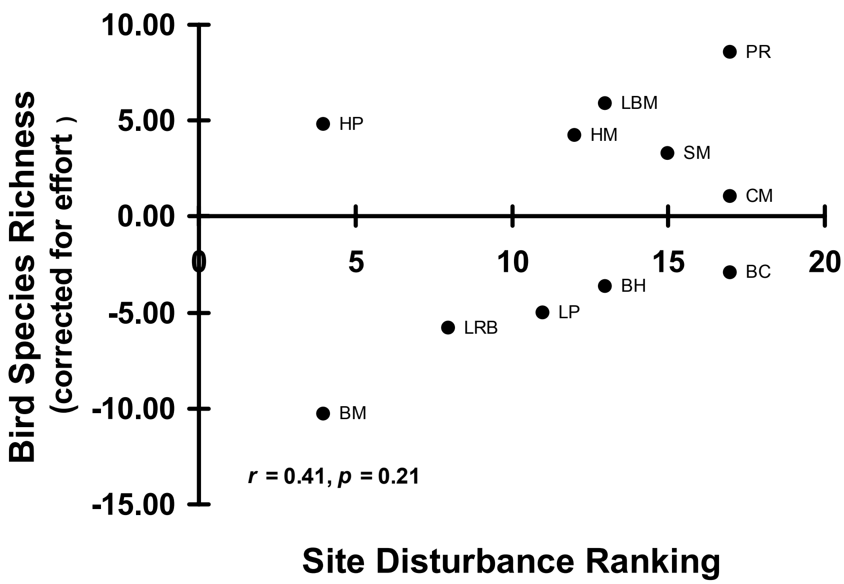


Figure 5-2. Relation between bird species richness (corrected for effort) and site disturbance ranking among Long Point wetland sites.

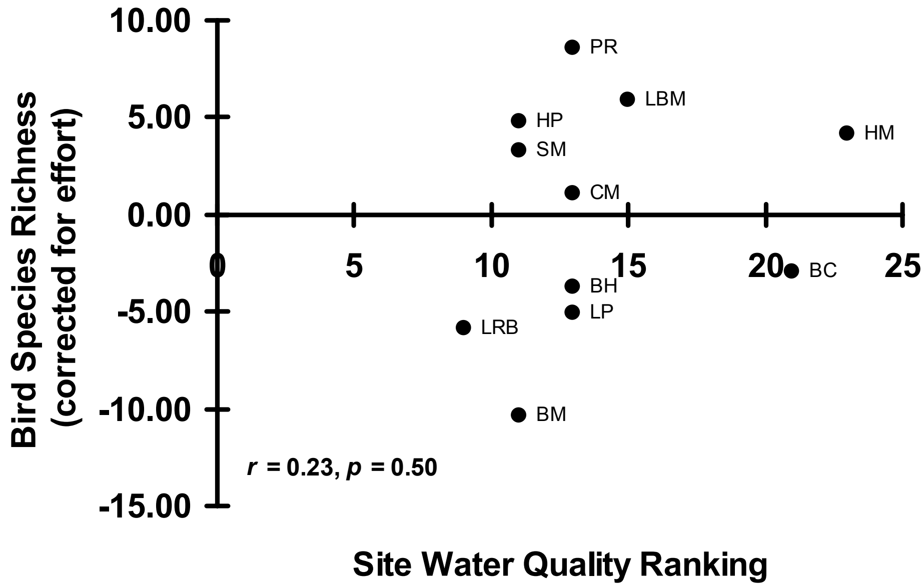


Figure 5-3. Relation between bird species richness (corrected for effort) and site water quality ranking among Long Point wetland sites.

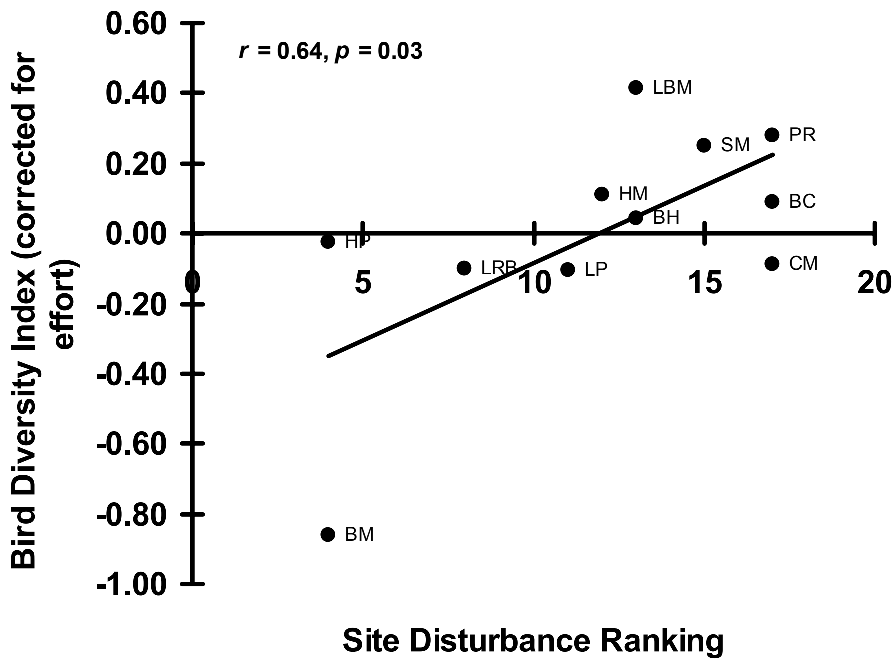


Figure 5-4. Relation between bird diversity index (corrected for effort) and site disturbance ranking among Long Point wetland sites.

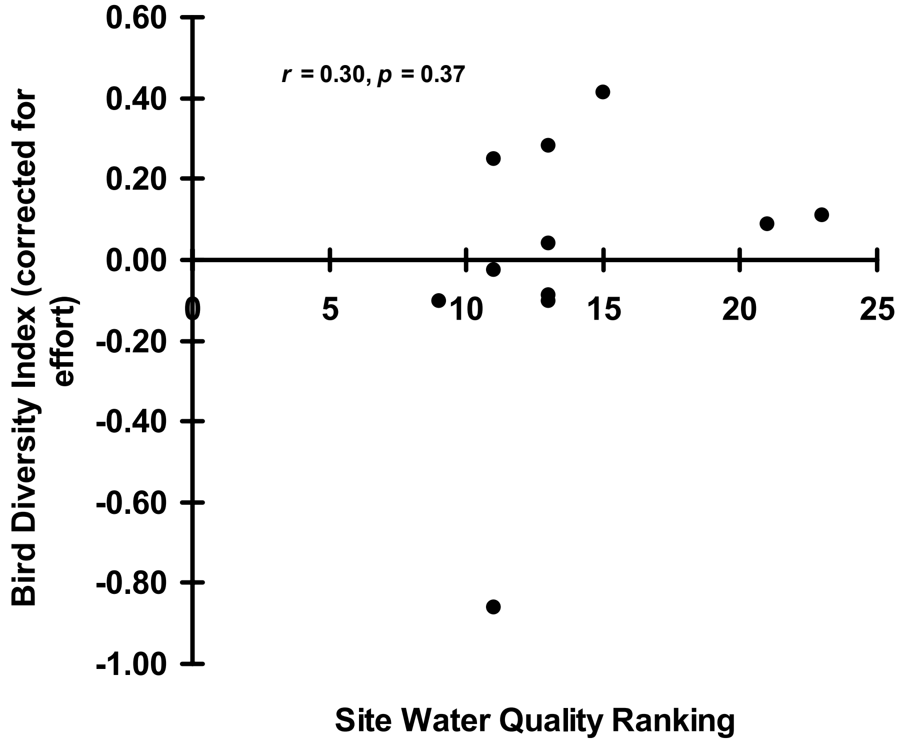


Figure 5-5. Relation between bird diversity index (corrected for effort) and site water quality ranking among Long Point wetland sites.

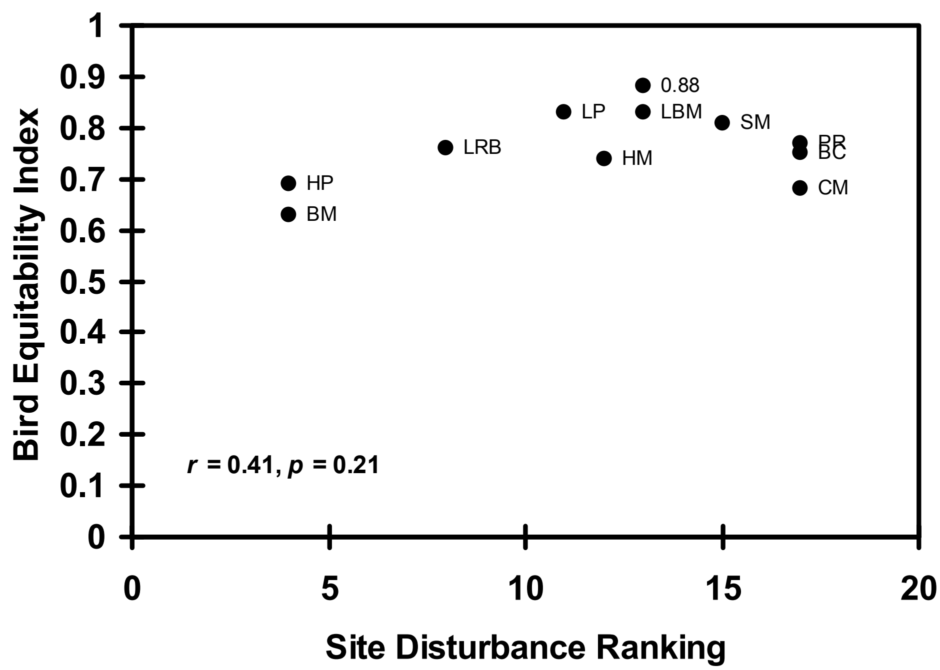


Figure 5-6. Relation between bird equitability index and site disturbance ranking among Long Point wetland sites.

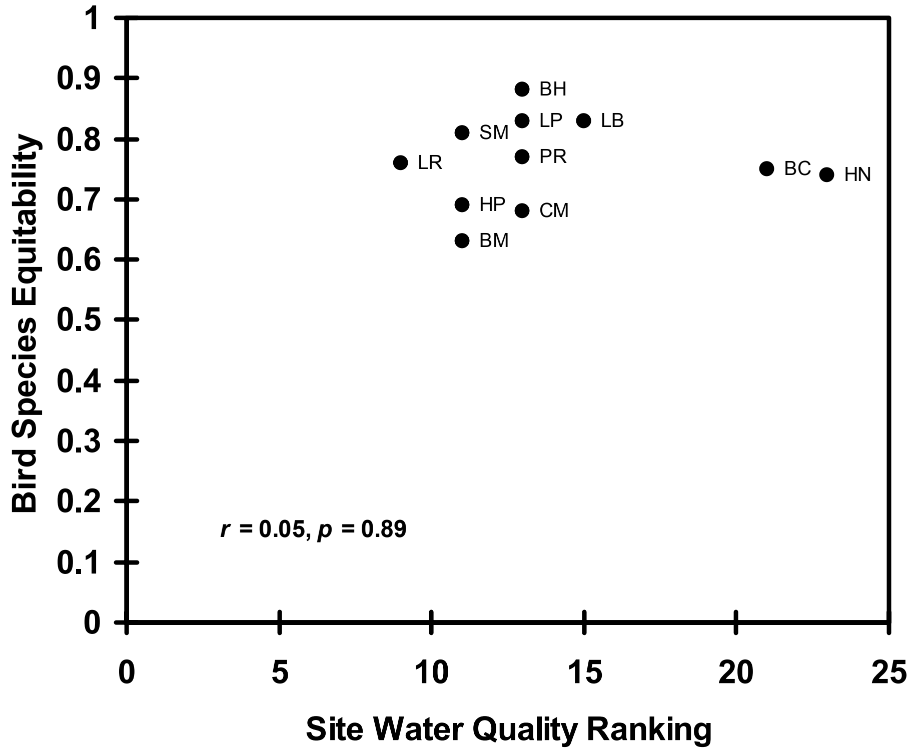


Figure 5-7. Relation between bird equitability index and site water quality ranking among Long Point wetland sites.

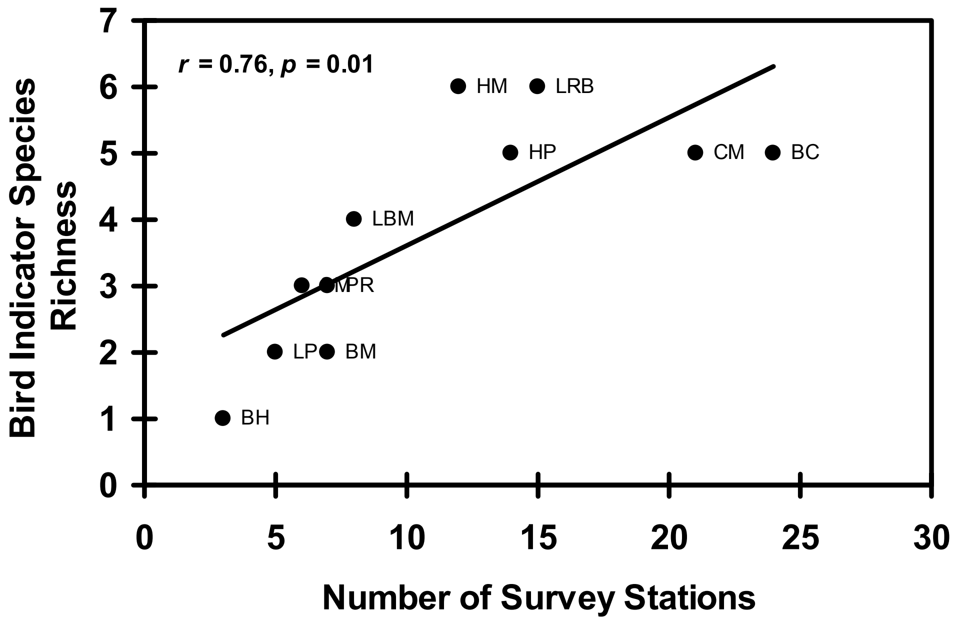


Figure 5-8. Relation between bird indicator species richness and number of survey stations among Long Point wetland sites.

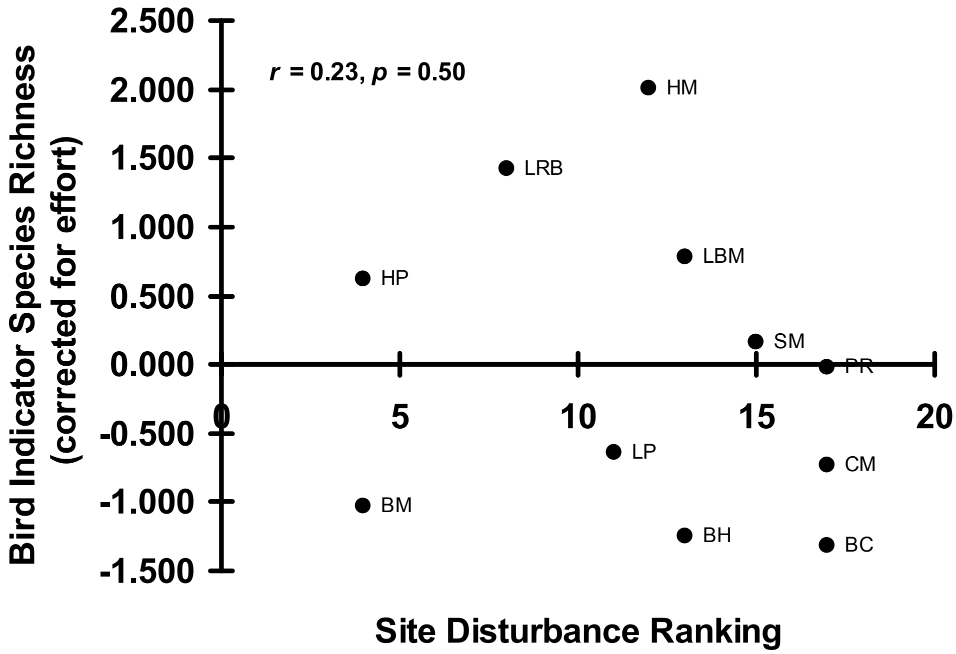


Figure 5-9. Relation between bird indicator species richness (corrected for effort) and site disturbance ranking among Long Point wetland sites.

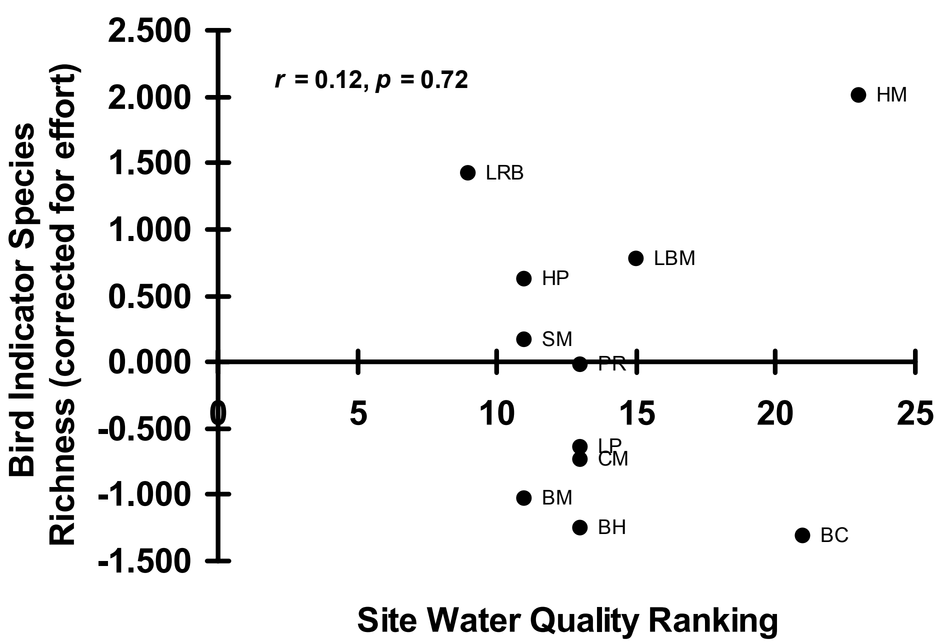


Figure 5-10. Relation between bird indicator species richness (corrected for effort) and site water quality ranking among Long Point wetland sites.

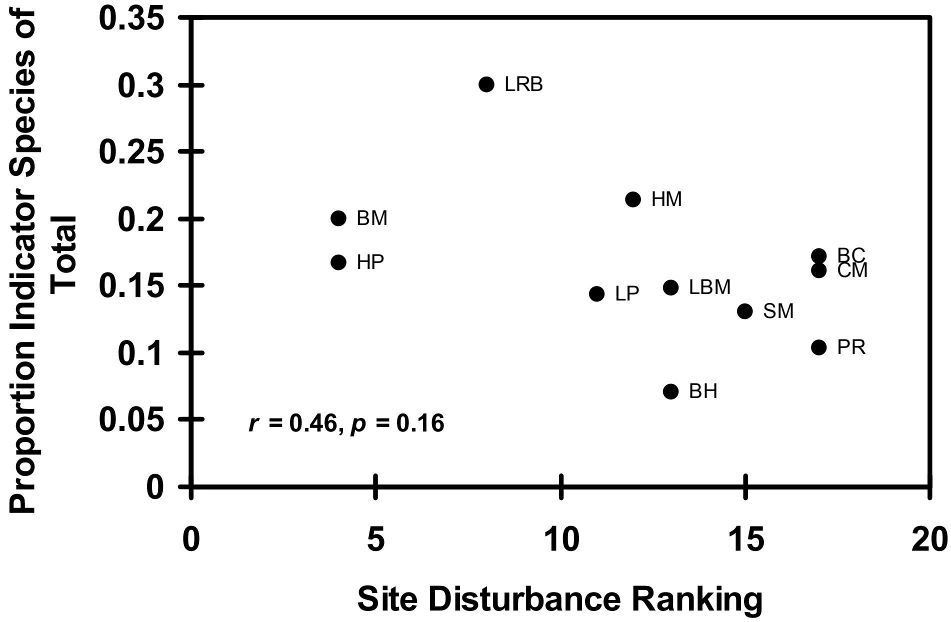


Figure 5-11. Relation between proportion indicator species of total and site disturbance ranking among Long Point wetland sites.

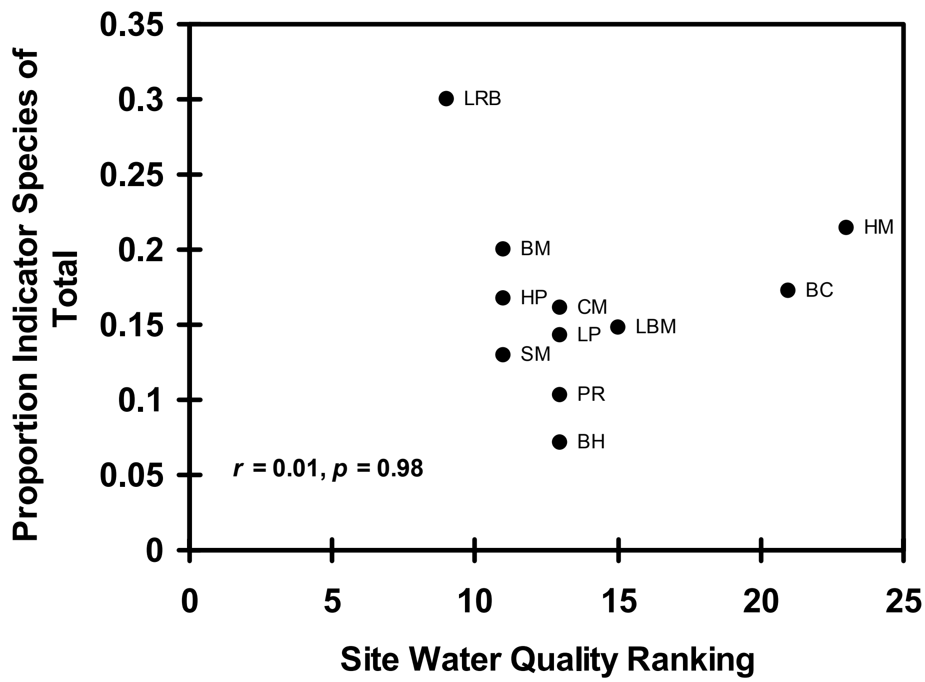


Figure 5-12. Relation between proportion indicator species of total and site water quality ranking among Long Point wetland sites.

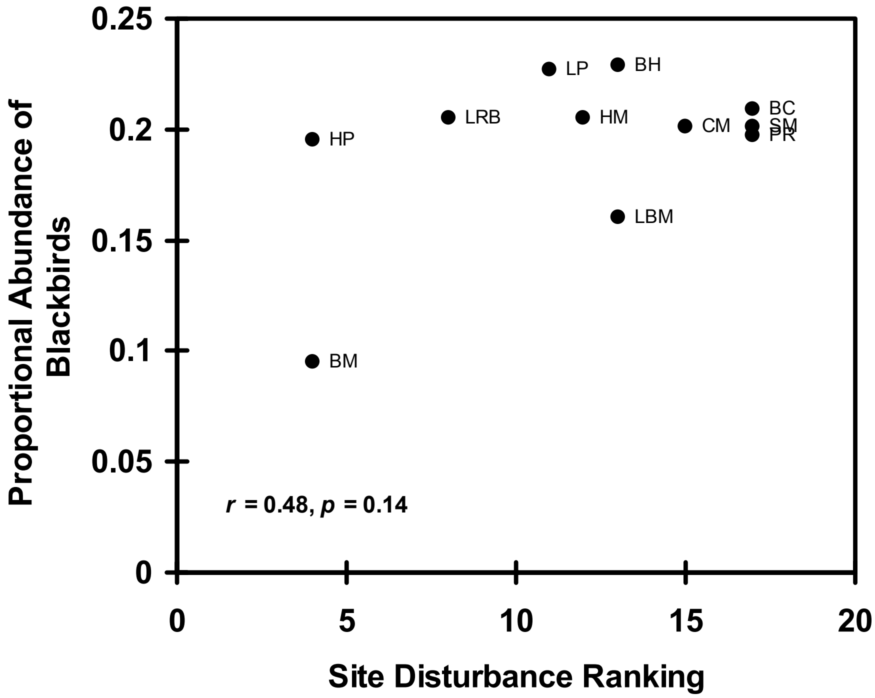


Figure 5-13. Relation between proportional abundance of blackbirds and site disturbance ranking among Long Point wetland sites.

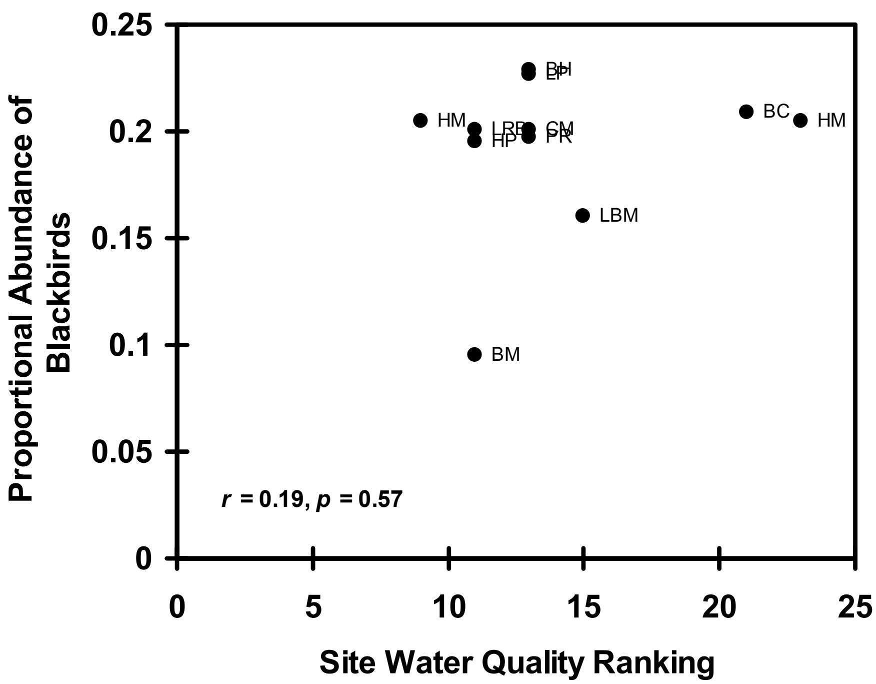


Figure 5-14. Relation between proportional abundance of blackbirds and site water quality ranking among Long Point wetland sites.

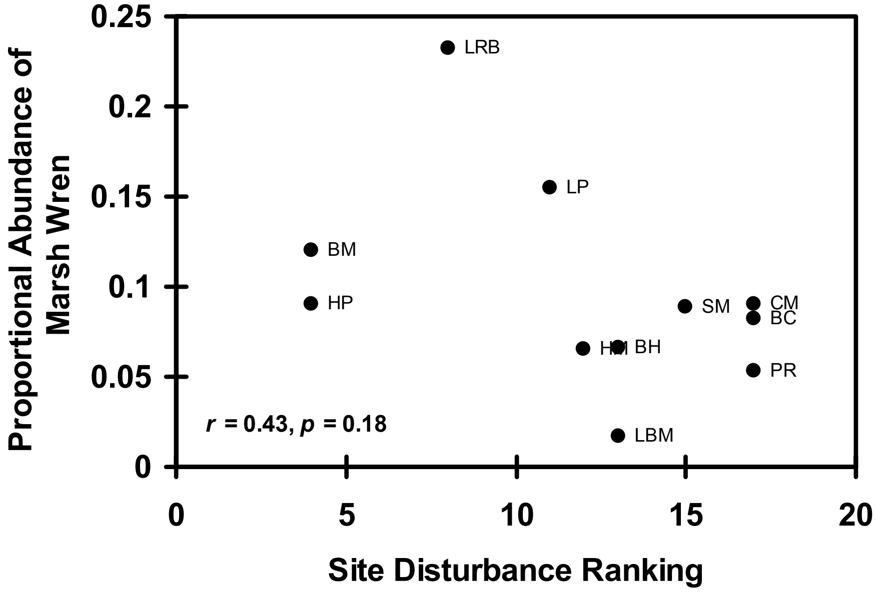


Figure 5-15. Relation between proportional abundance of Marsh Wren and site disturbance ranking among Long Point wetland sites.

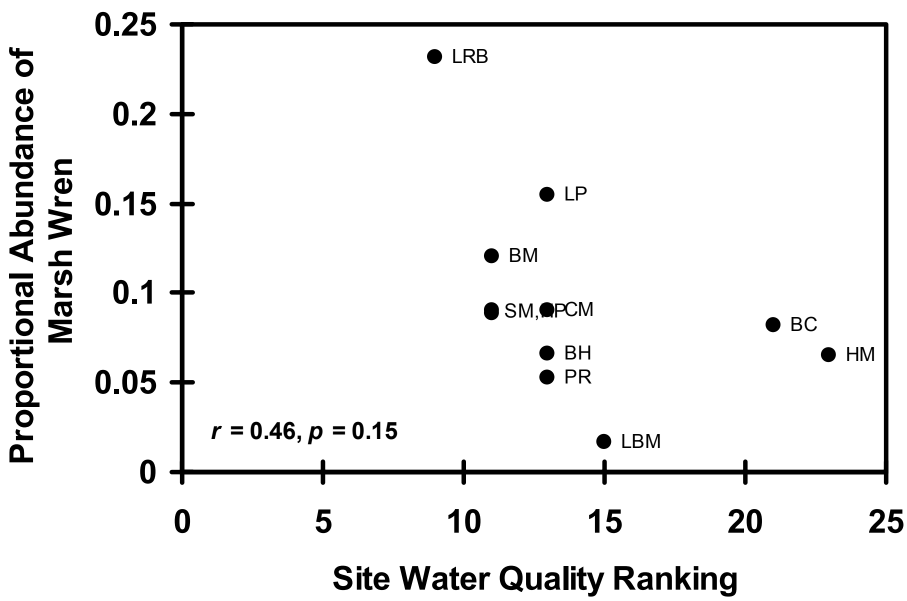


Figure 5-16. Relation between proportional abundance of Marsh Wren and site water quality ranking among Long Point wetland sites.

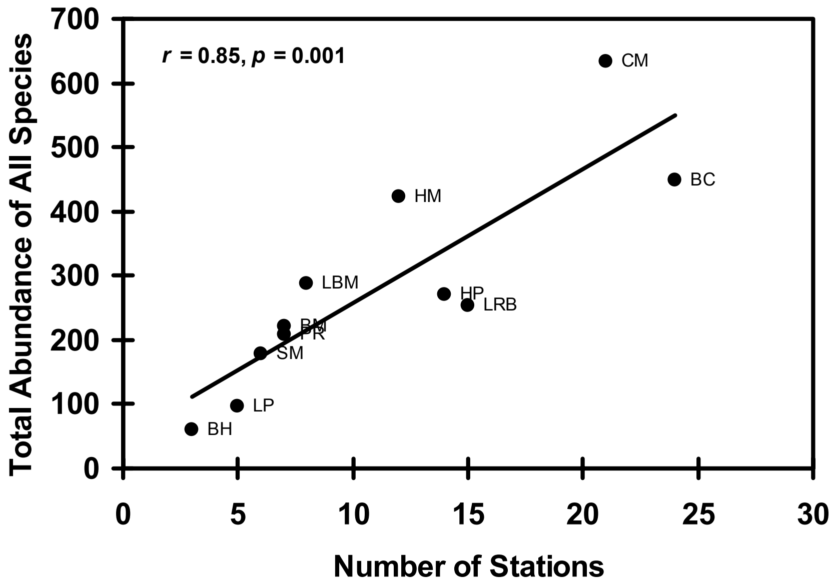


Figure 5-17. Relation between total abundance of all species and number of stations among Long Point wetland sites.

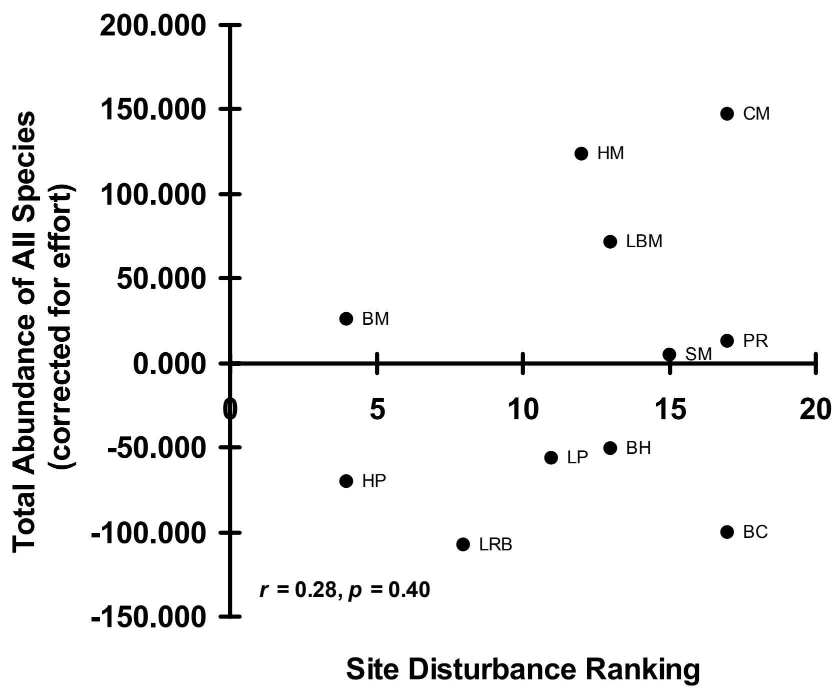


Figure 5-18. Relation between total abundance of all species (corrected for effort) and site disturbance ranking among Long Point wetland sites.

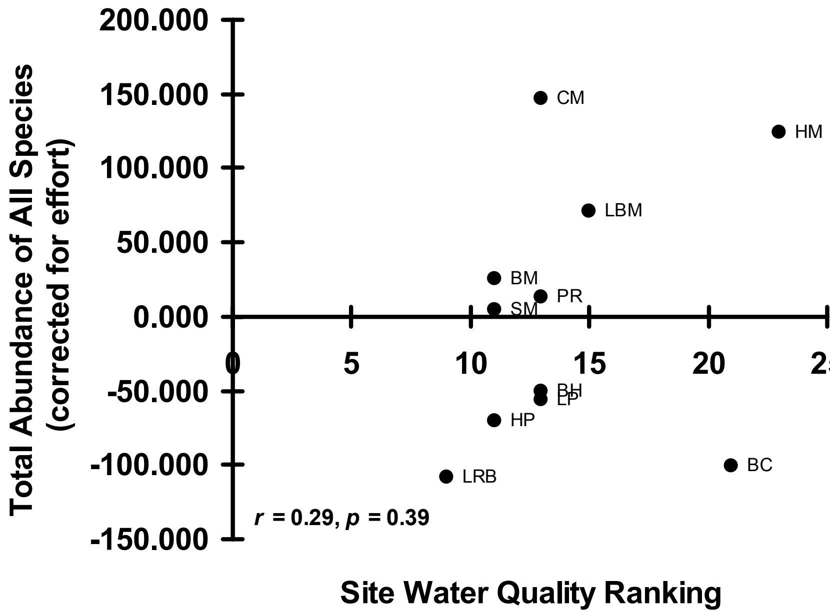


Figure 5-19. Relation between total abundance of all species (corrected for effort) and site water quality ranking among Long Point wetland sites.

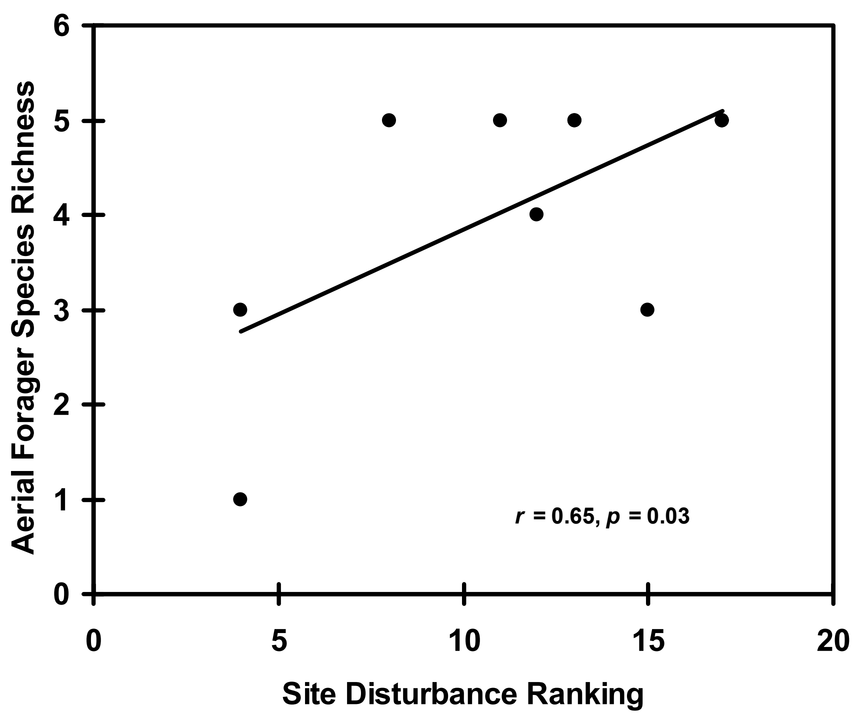


Figure 5-20. Relation between aerial forager species richness and site disturbance ranking among Long Point wetland sites.

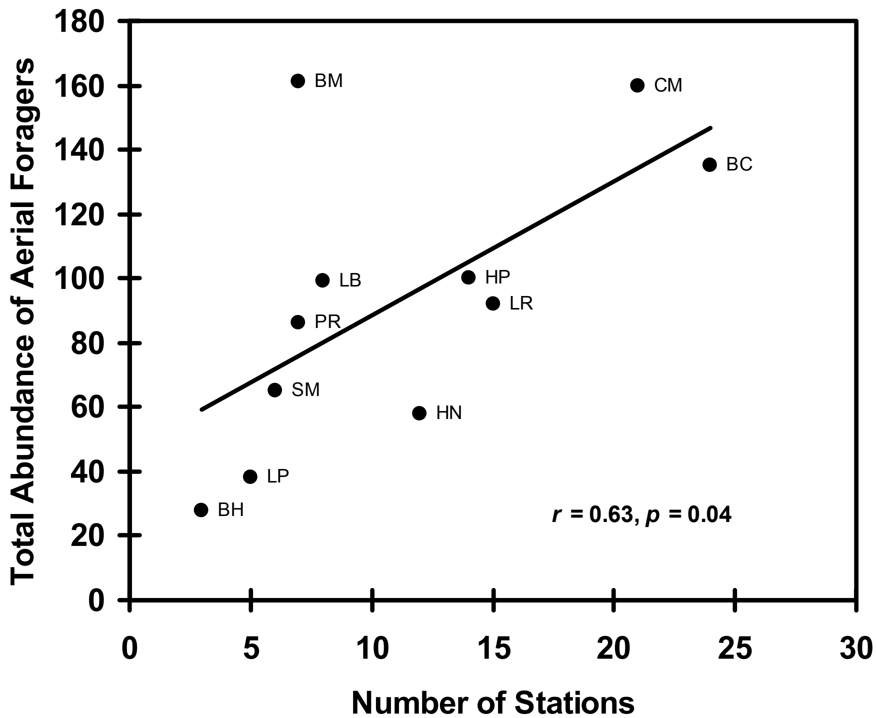


Figure 5-21. Relation between total abundance of aerial foragers and number of stations among Long Point wetland sites.

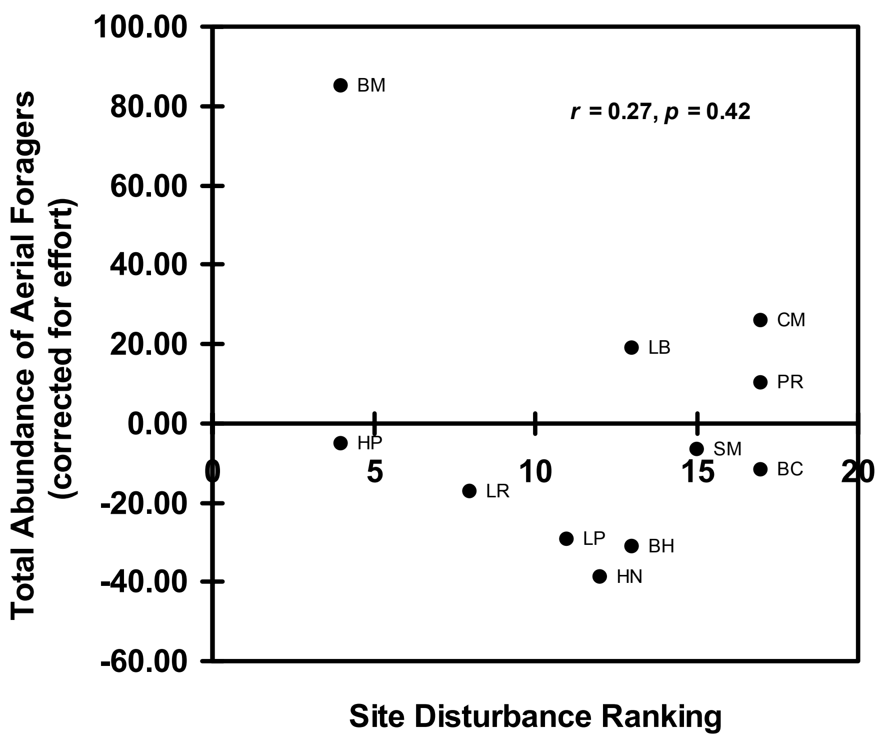


Figure 5-22. Relation between total abundance of aerial foragers (corrected for effort) and site disturbance ranking among Long Point wetland sites.

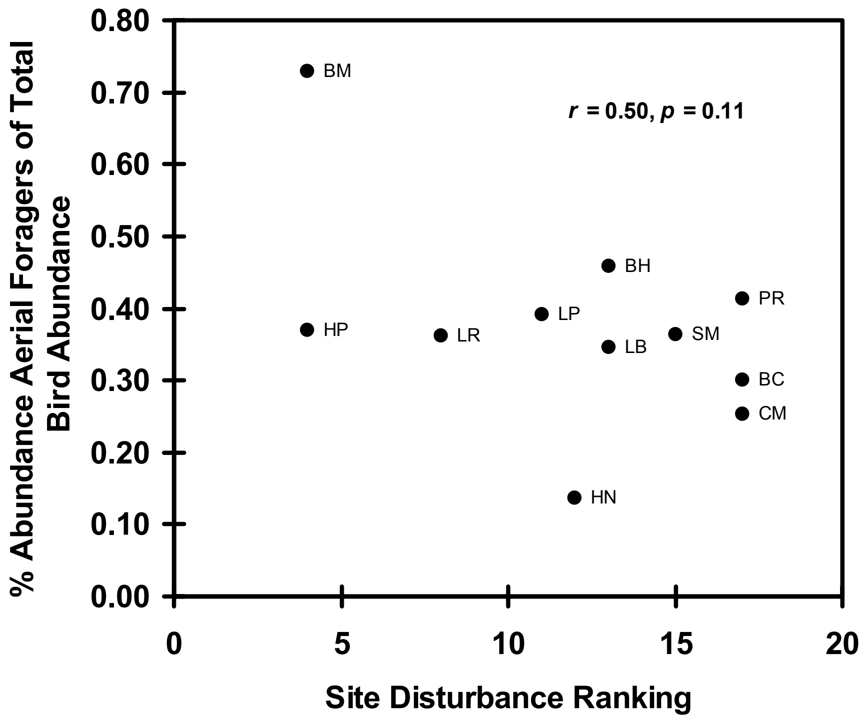


Figure 5-23. Relation between percent abundance of aerial foragers of total bird abundance and site disturbance ranking among Long Point wetland sites.

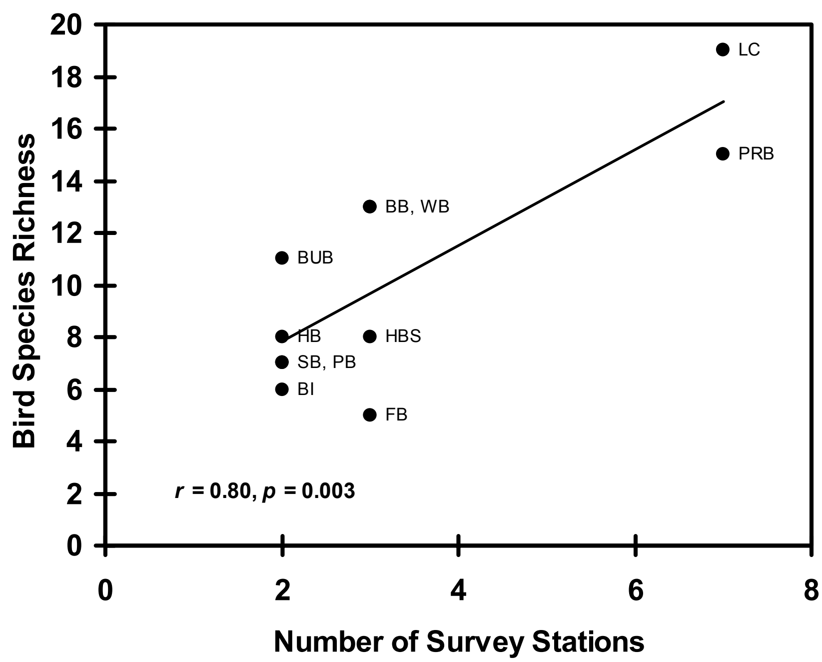


Figure 5-24. Relation between bird species richness and number of survey stations among Lake Ontario wetland sites.

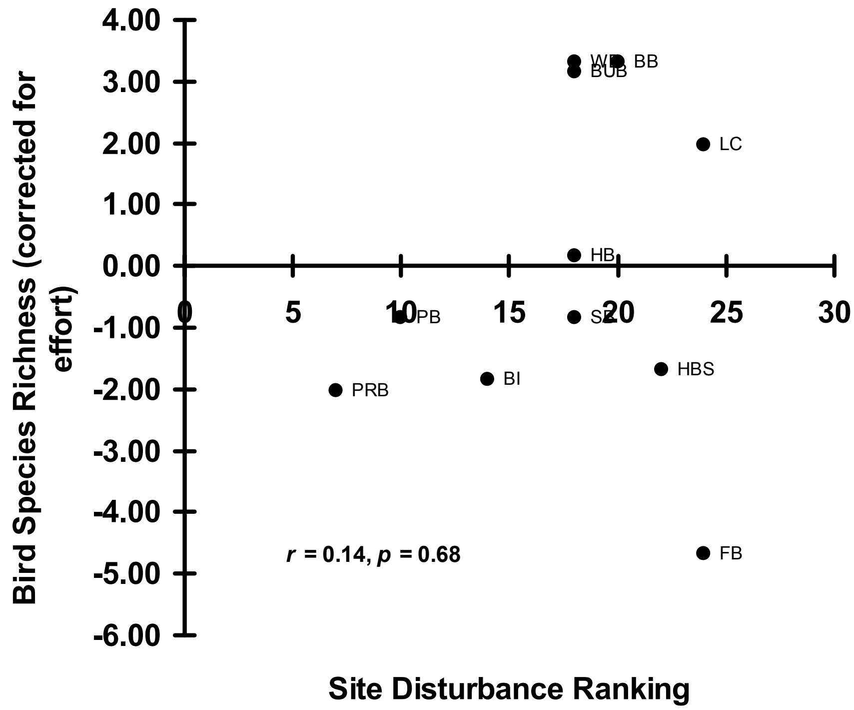


Figure 5-25. Relation between bird species richness (corrected for effort) and site disturbance ranking among Lake Ontario wetland sites.

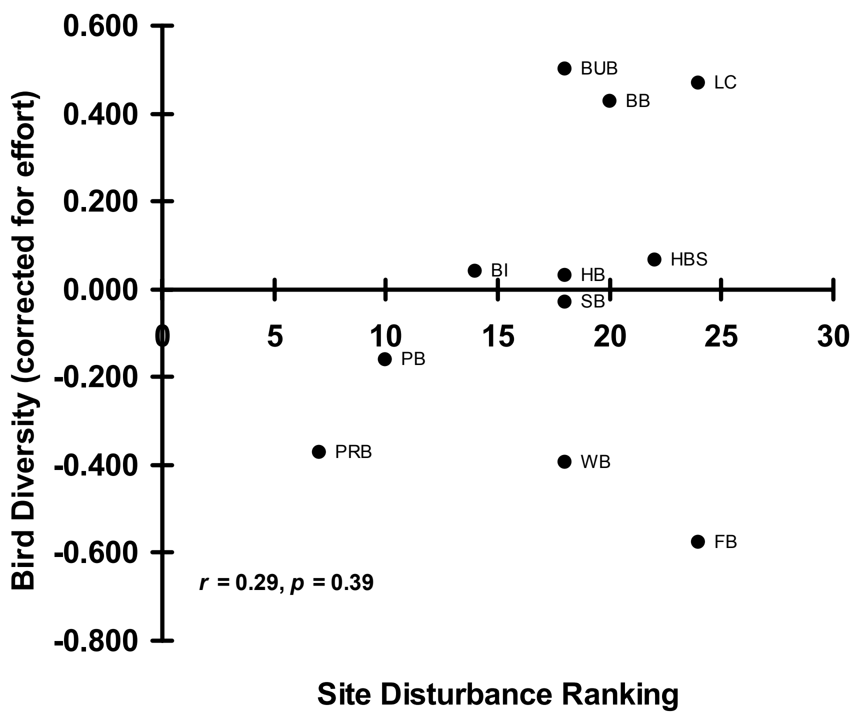


Figure 5-26. Relation between bird diversity (corrected for effort) and site disturbance ranking among Lake Ontario wetland sites.

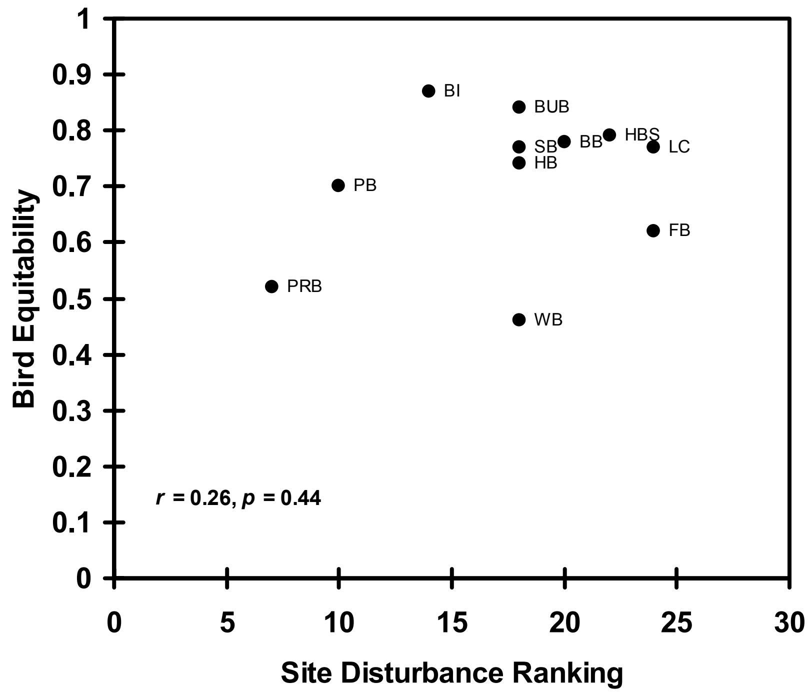


Figure 5-27. Relation between bird equitability and site disturbance ranking among Lake Ontario wetland sites.

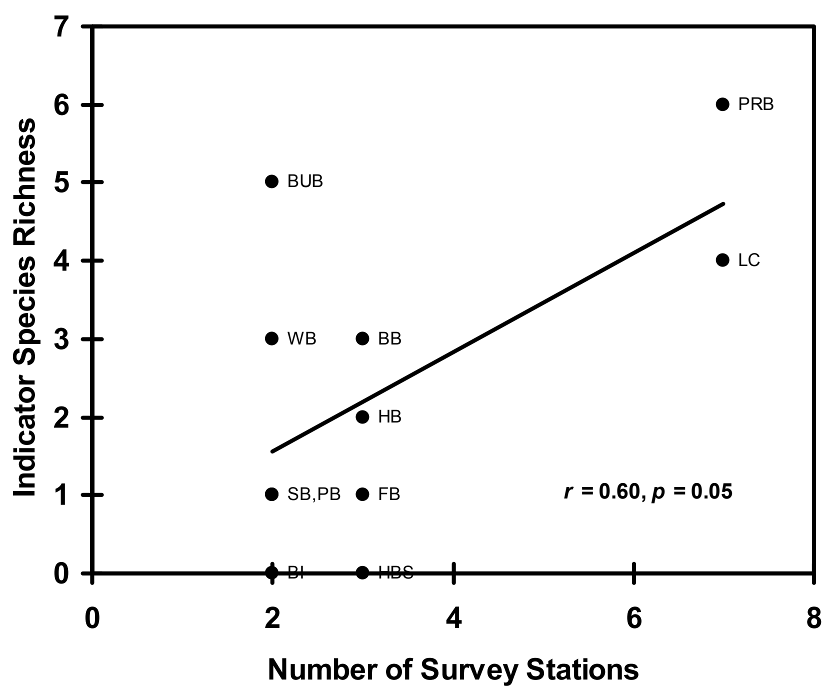


Figure 5-28. Relation between indicator species richness and number of survey stations among Lake Ontario wetland sites.

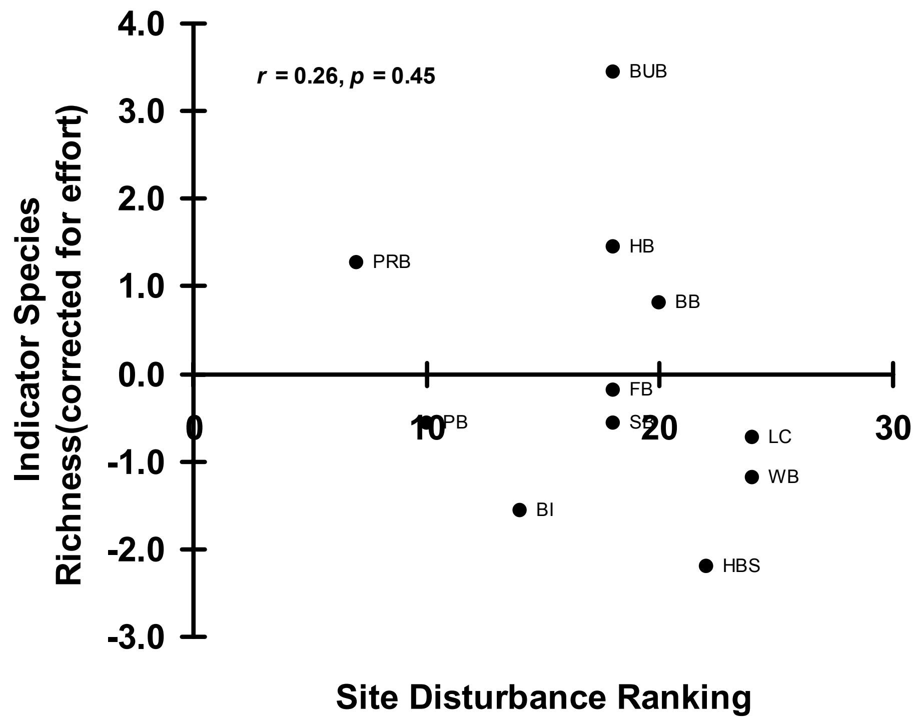


Figure 5-29. Relation between indicator species richness (corrected for effort) and site disturbance ranking among Lake Ontario wetland sites.

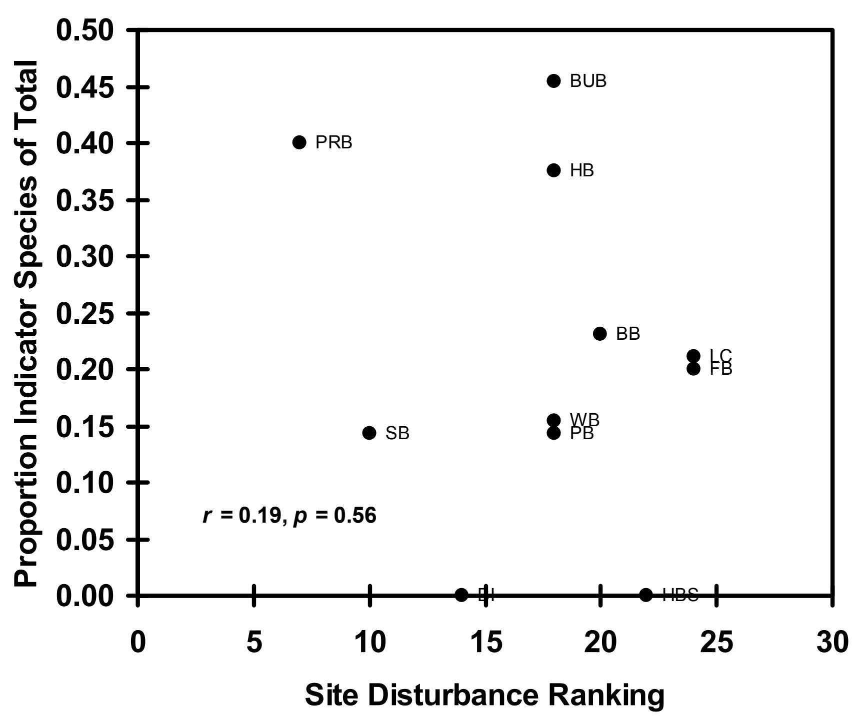


Figure 5-30. Relation between proportion of indicator species of total and site disturbance ranking among Lake Ontario wetland sites.

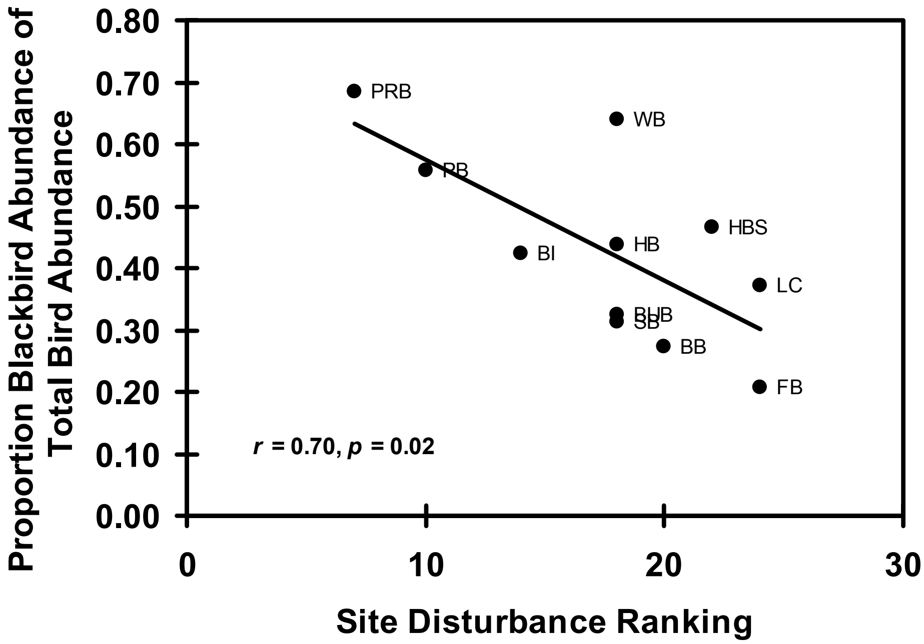


Figure 5-31. Relation between proportion of blackbird abundance of total bird abundance and site disturbance ranking among Lake Ontario wetland sites.

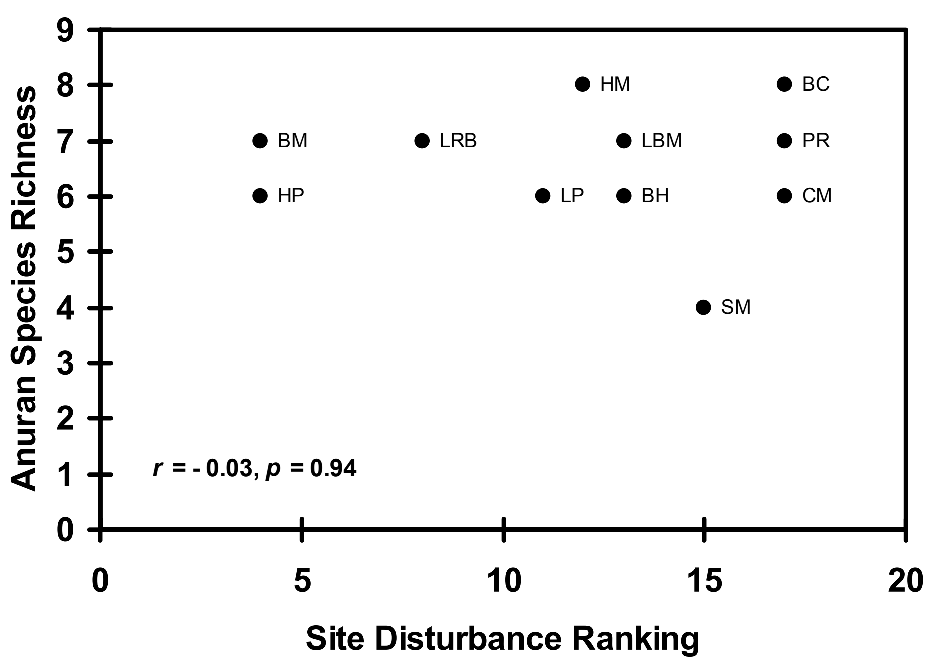


Figure 5-32. Relation between anuran species richness and site disturbance ranking among Long Point wetland sites.

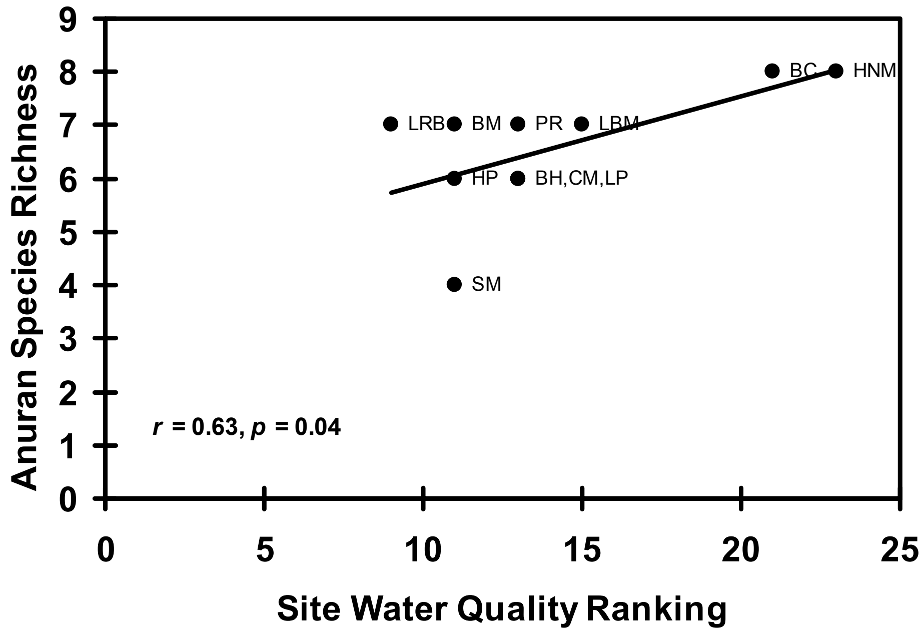


Figure 5-33. Relation between anuran species richness and site water quality ranking among Long Point wetland sites.

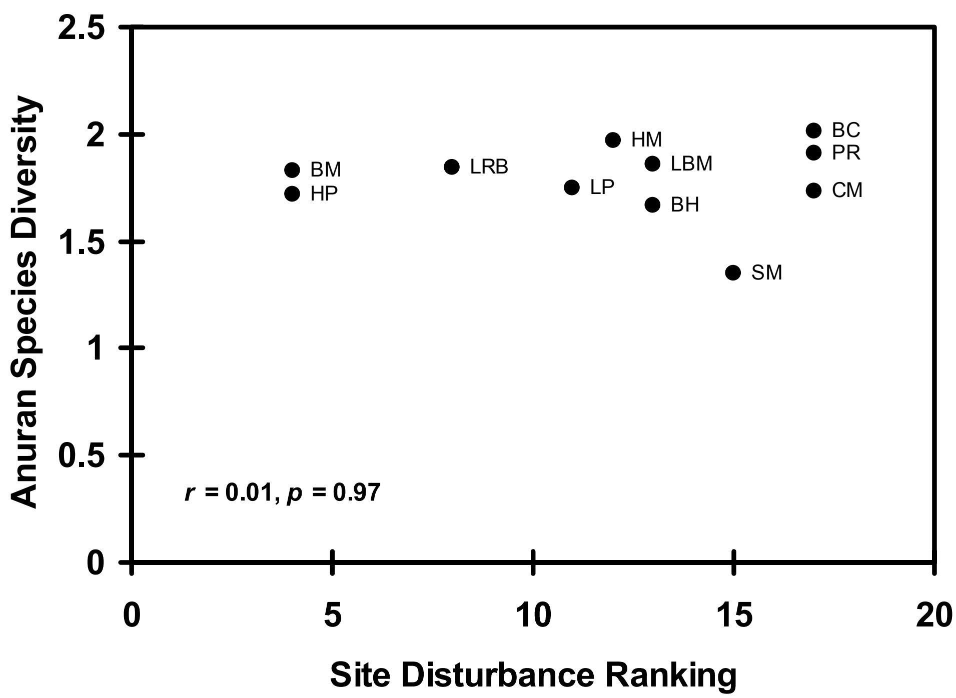


Figure 5-34. Relation between anuran species diversity and site disturbance ranking among Long Point wetland sites.

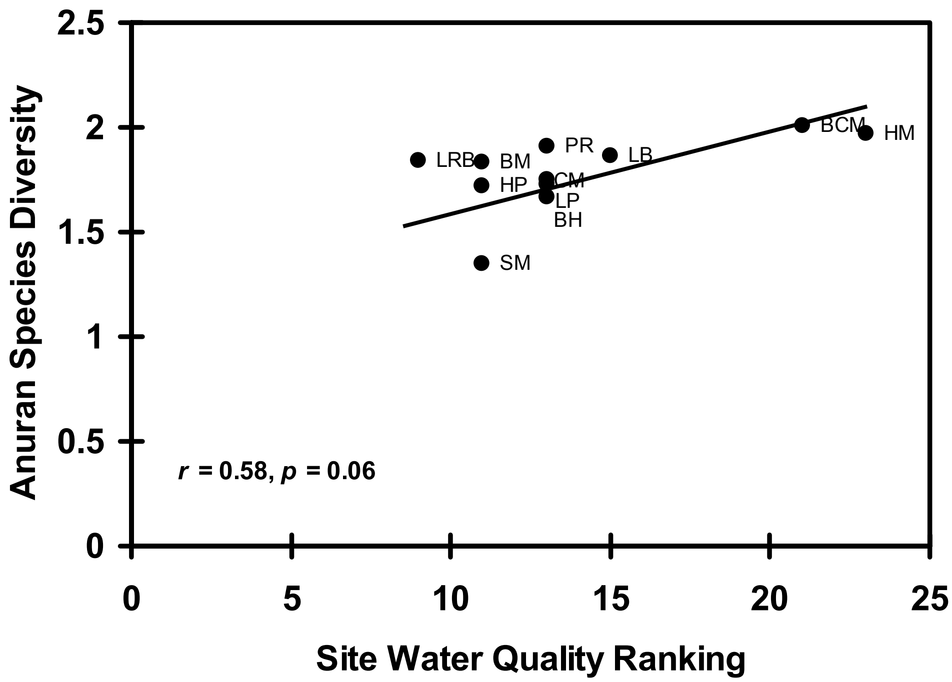


Figure 5-35. Relation between anuran species diversity and site water quality ranking among Long Point wetland sites.

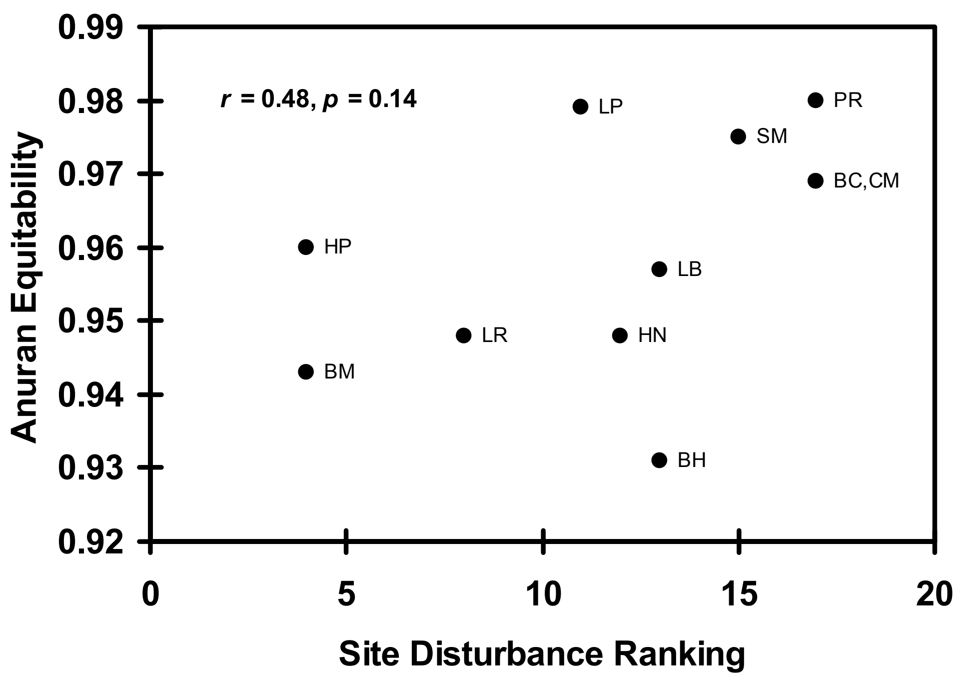


Figure 5-36. Relation between anuran equitability and site disturbance ranking among Long Point wetland sites.

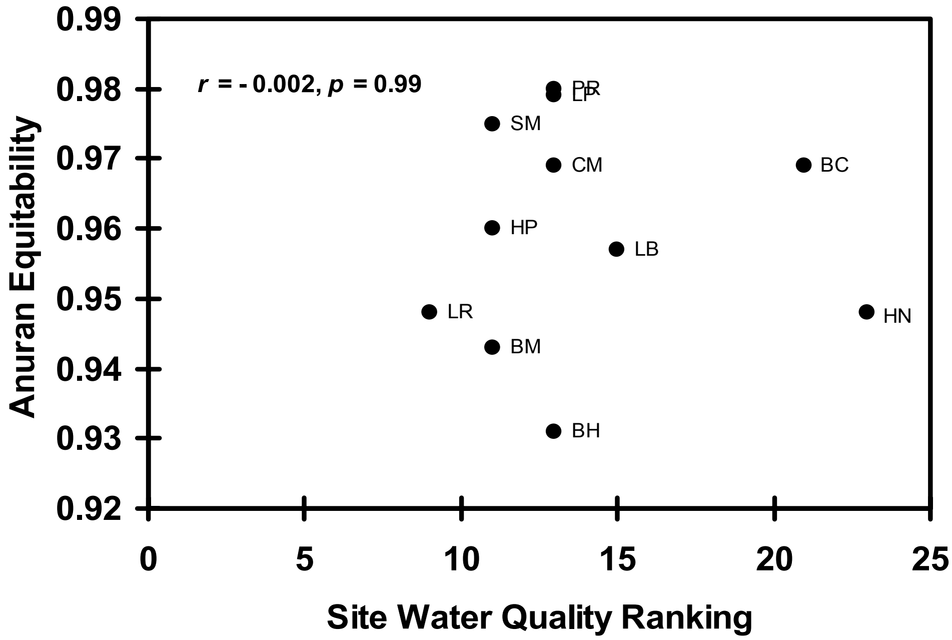


Figure 5-37. Relation between anuran equitability and site water quality ranking among Long Point wetland sites.

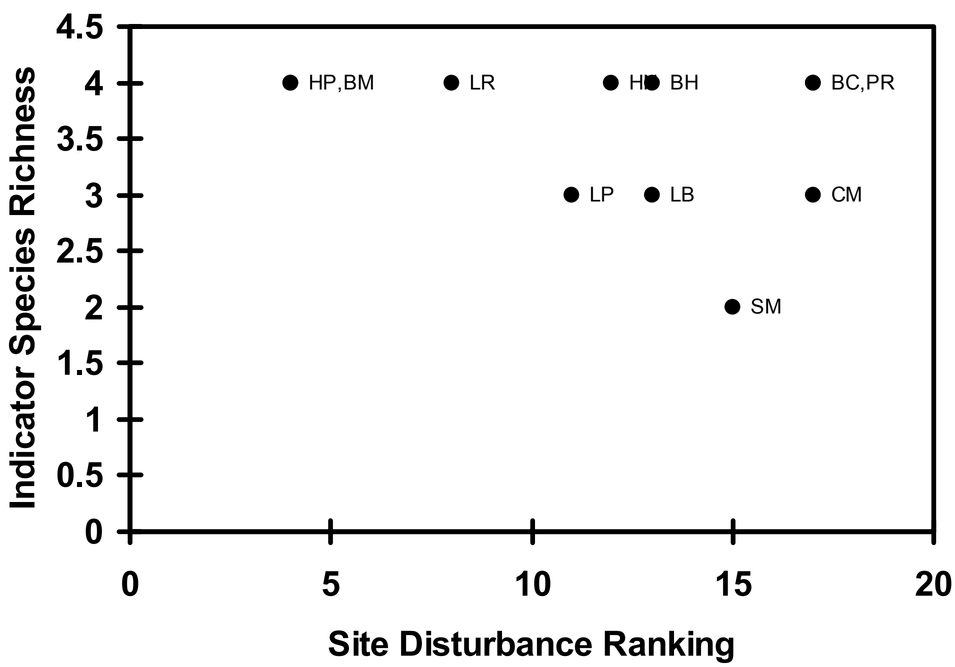


Figure 5-38. Relation between indicator species richness and site disturbance ranking among Long Point wetland sites.

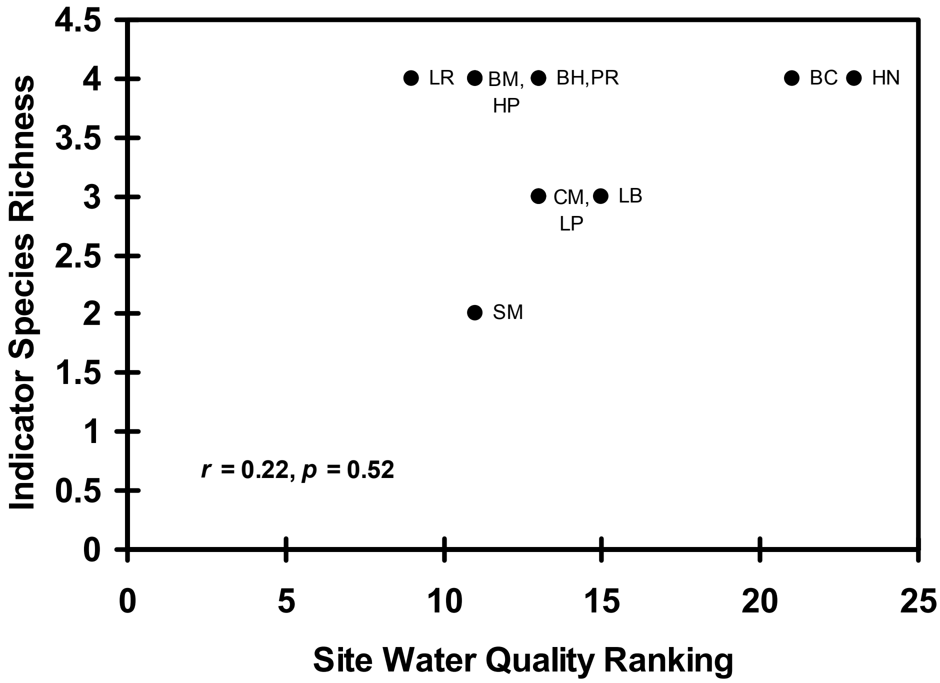


Figure 5-39. Relation between indicator species richness and site water quality ranking among Long Point wetland sites.

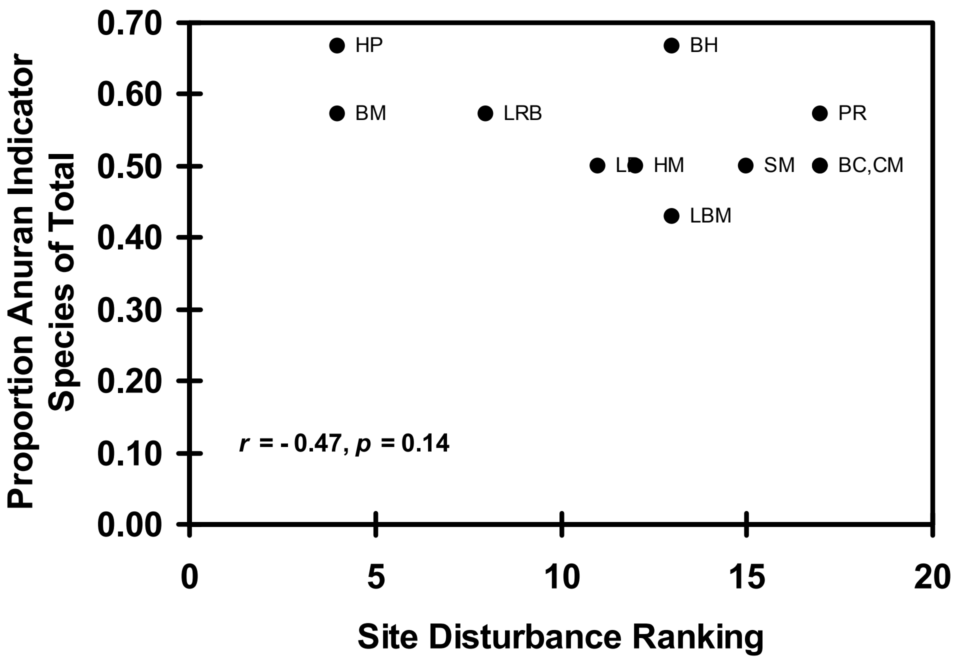


Figure 5-40. Relation between proportional anuran indicator species of total and site disturbance ranking among Long Point wetland sites.

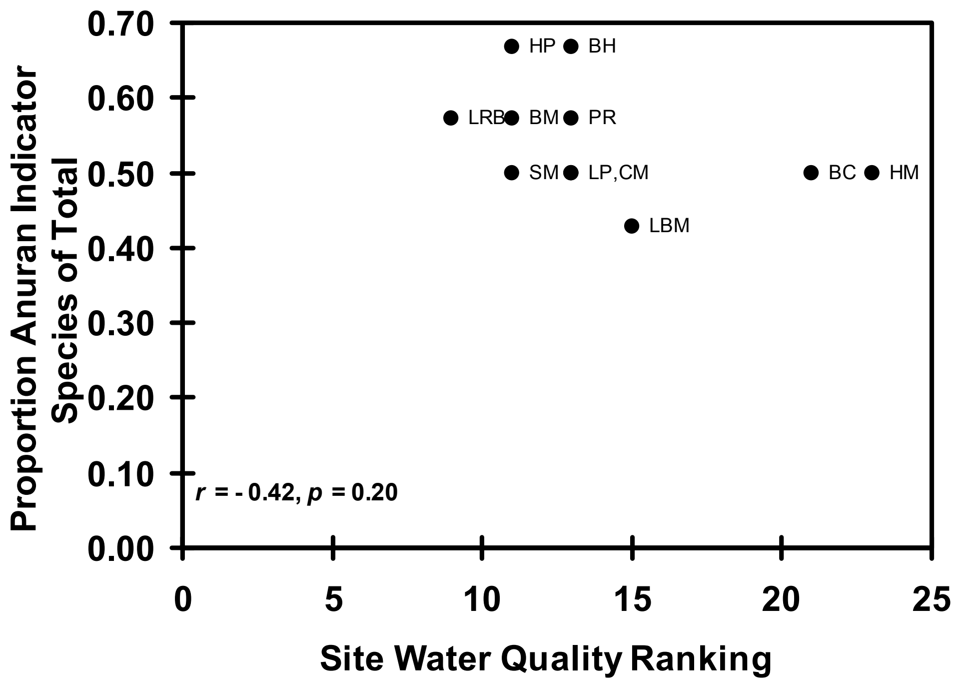


Figure 5-41. Relation between proportional anuran indicator species of total and site water quality ranking among Long Point wetland sites.

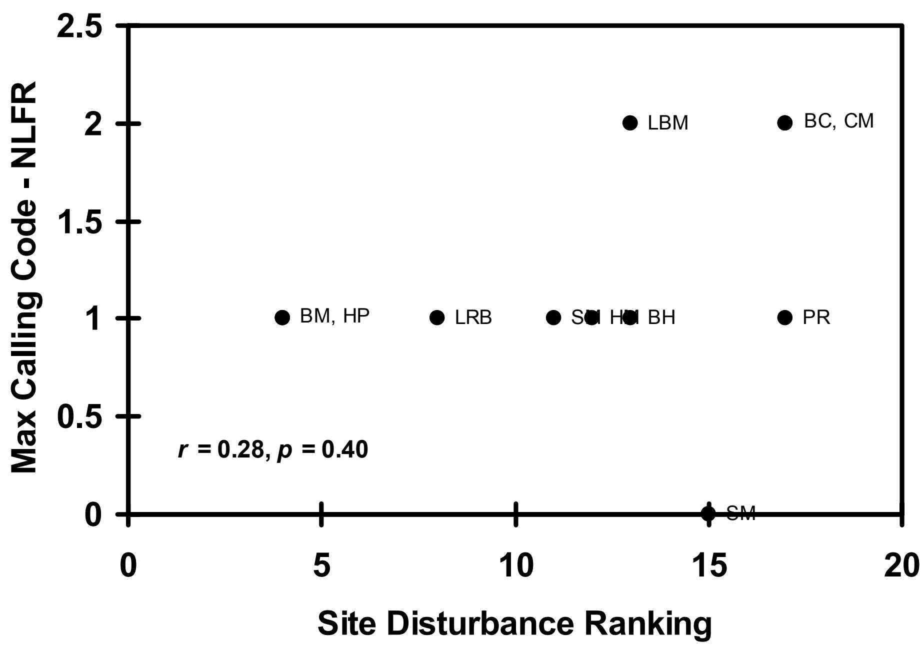


Figure 5-42. Relation between max calling code of Northern Leopard Frog and site disturbance ranking among Long Point wetland sites.

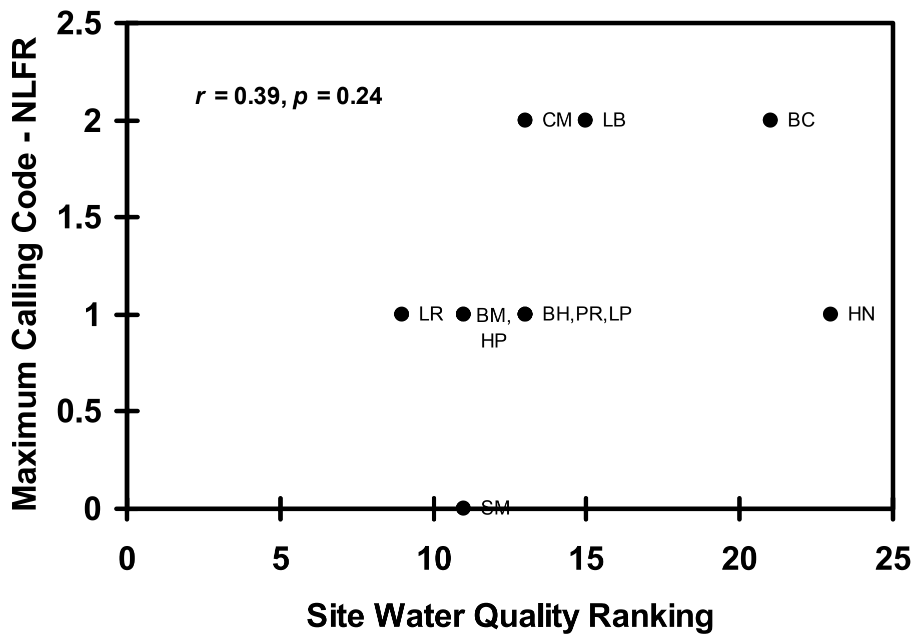


Figure 5-43. Relation between max calling code of Northern Leopard Frog and site water quality ranking among Long Point wetland sites.

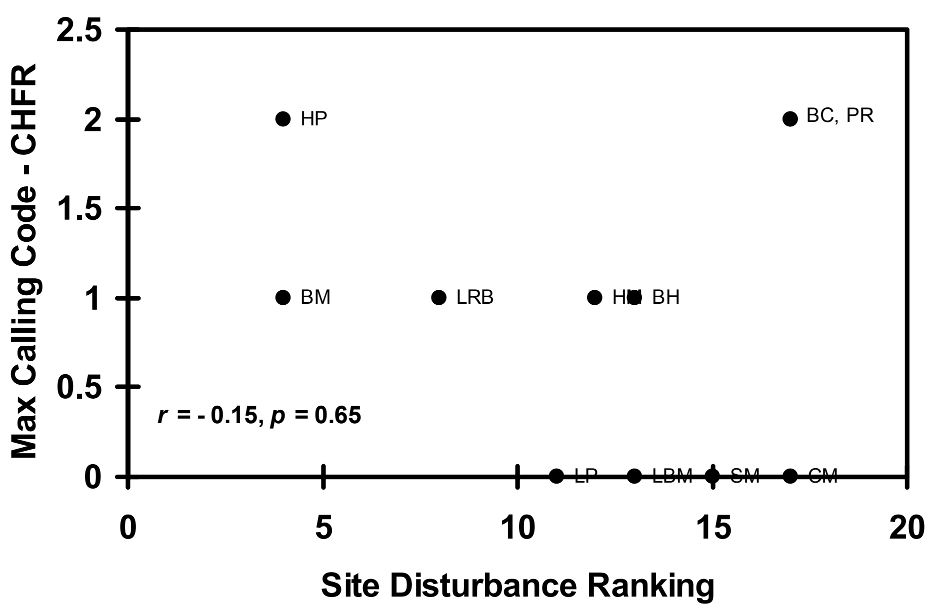


Figure 5-44. Relation between max calling code of Chorus Frog and site disturbance ranking among Long Point wetland sites.

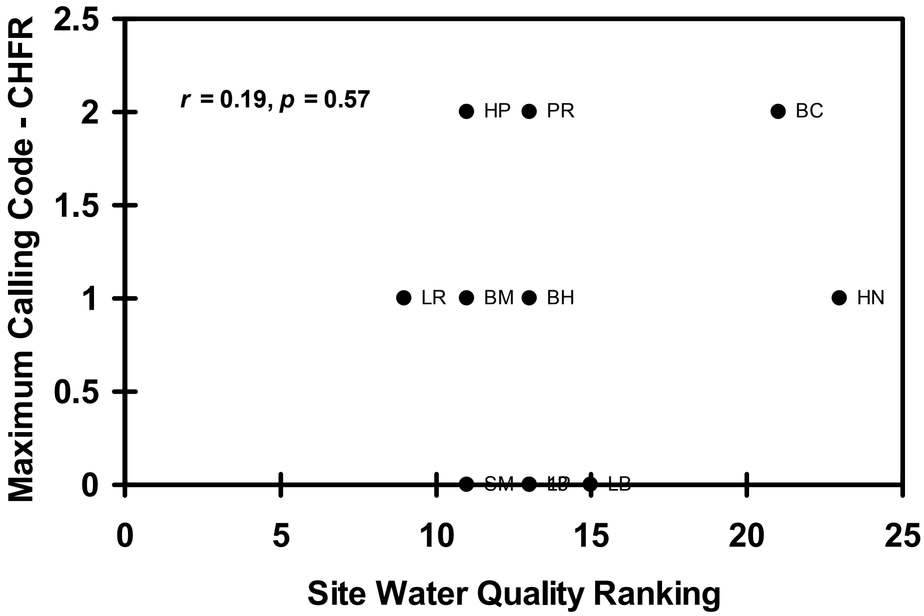


Figure 5-45. Relation between max calling code of Chorus Frog and site water quality ranking among Long Point wetland sites.

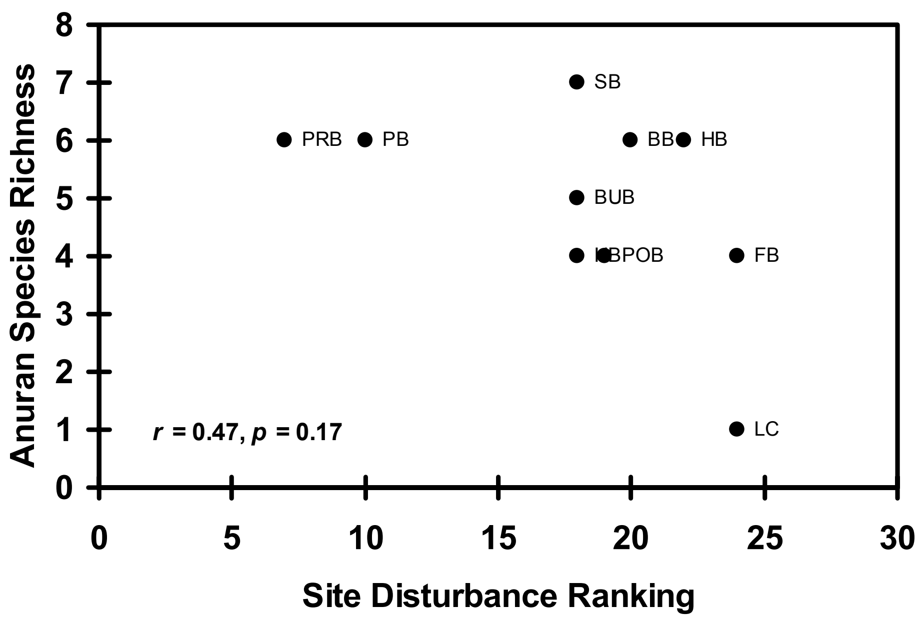


Figure 5-46. Relation between anuran species richness and site disturbance ranking among Lake Ontario wetland sites.

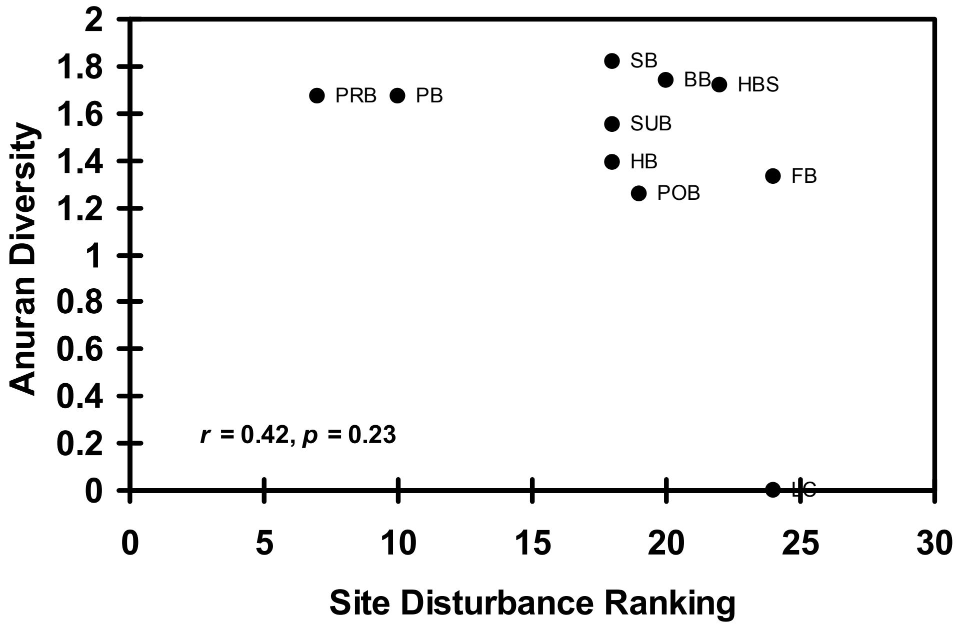


Figure 5-47. Relation between anuran diversity and site disturbance ranking among Lake Ontario wetland sites.

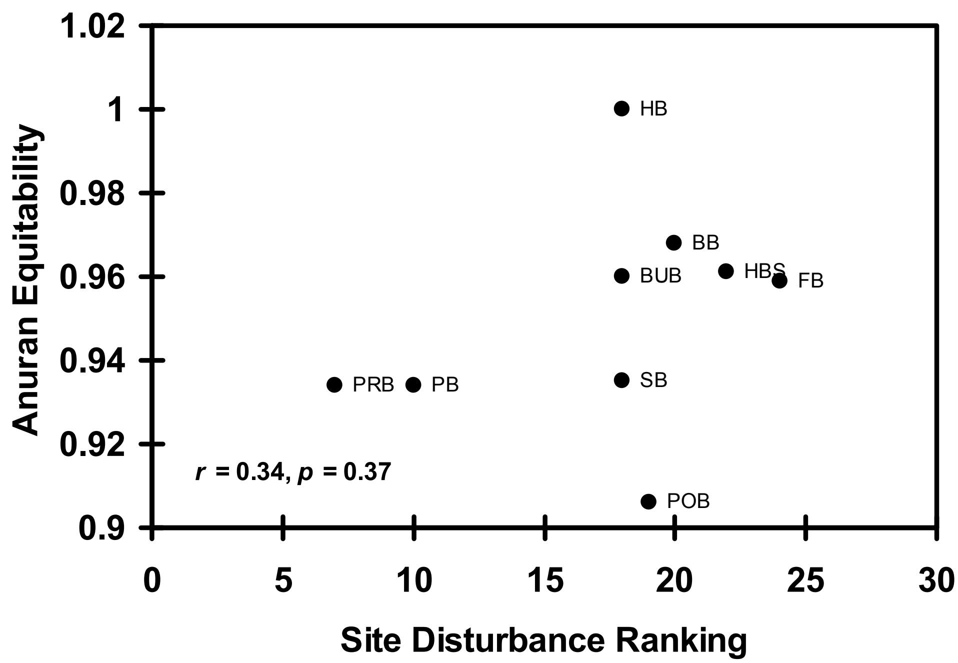


Figure 5-48. Relation between anuran equitability and site disturbance ranking among Lake Ontario wetland sites.

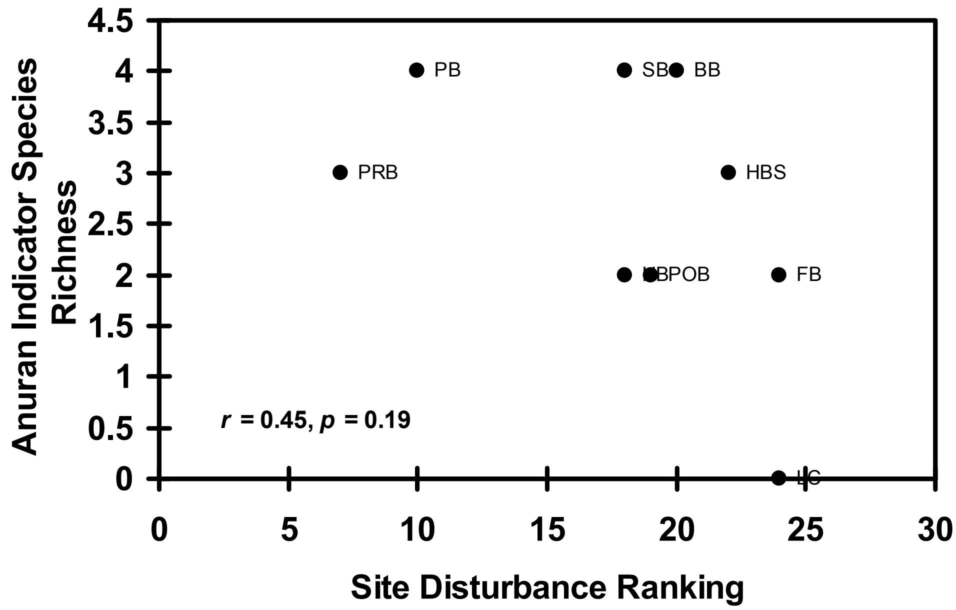


Figure 5-49. Relation between anuran indicator species richness and site disturbance ranking among Lake Ontario wetland sites.

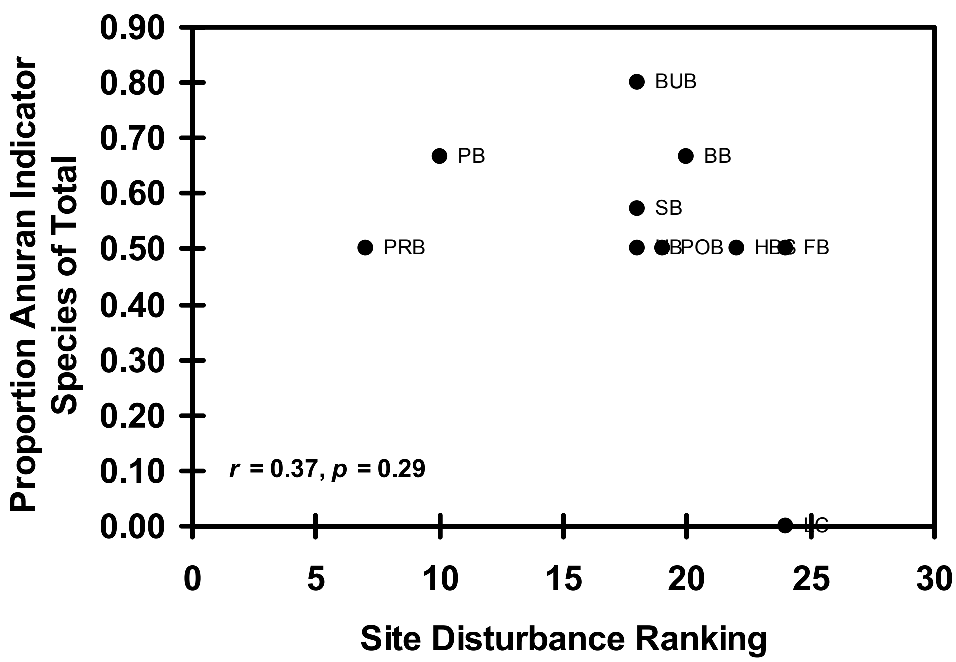


Figure 5-50. Relation between proportion of anuran indicator species of total and site disturbance ranking among Lake Ontario wetland sites.

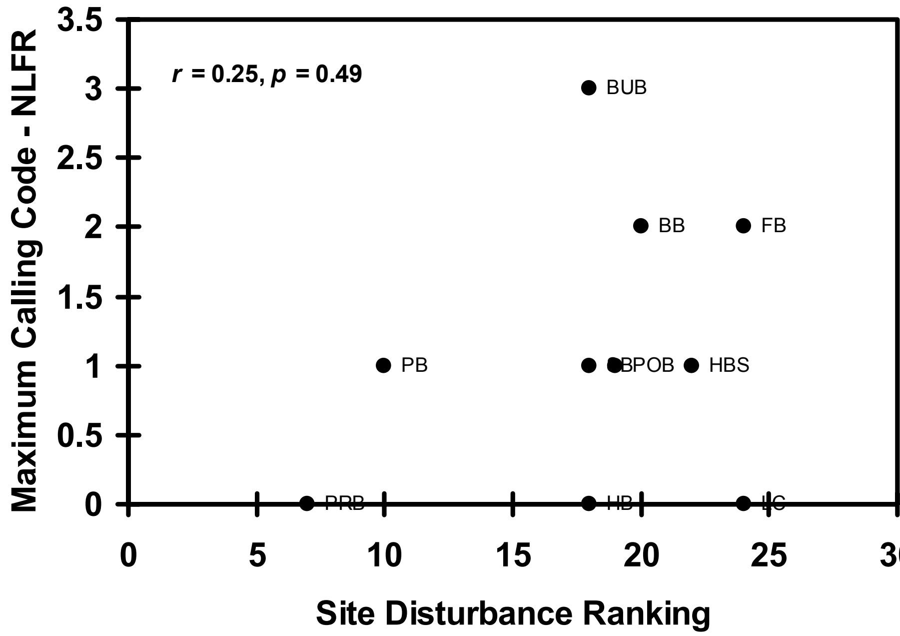


Figure 5-51. Relation between max calling code of Northern Leopard Frog and site disturbance ranking among Lake Ontario wetland sites.

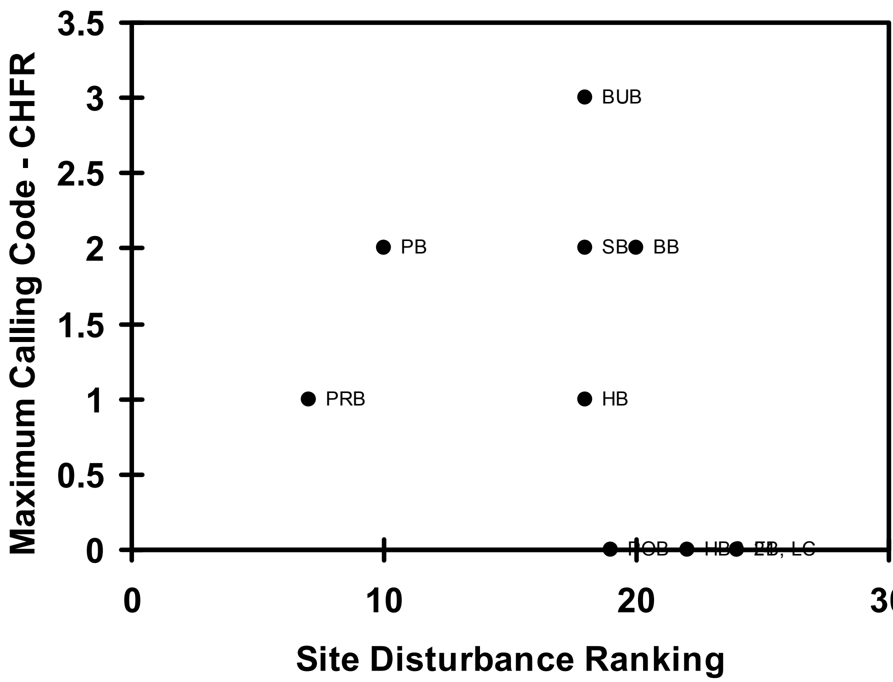


Figure 5-52. Relation between max calling code of Chorus Frog and site disturbance ranking among Lake Ontario wetland sites.

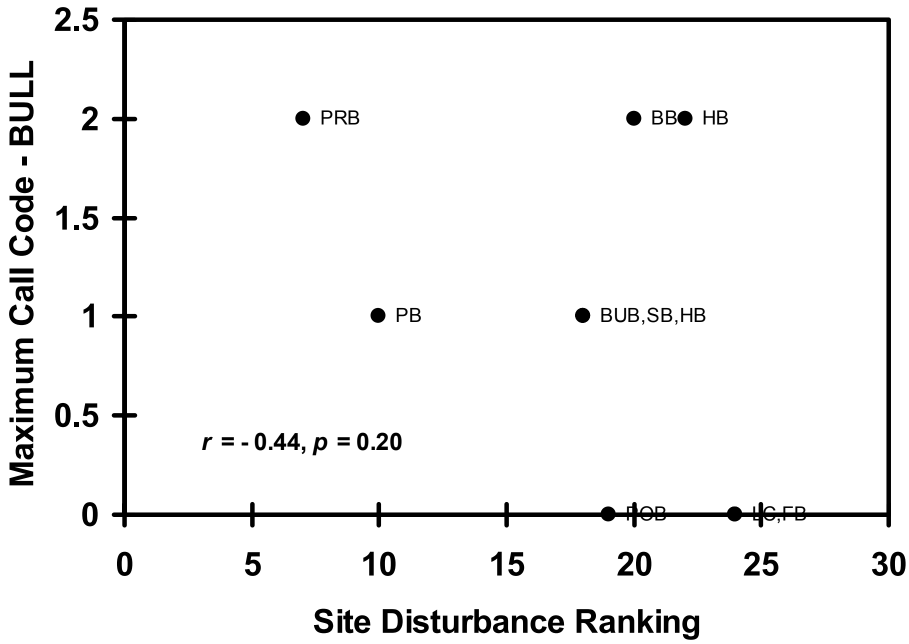


Figure 5-53. Relation between max calling code of Bullfrog and site disturbance ranking among Lake Ontario wetland sites.

5.3 General Discussion

Data from Arcadia Lake and Saginaw bay were not analysed for community attribute responses to wetland disturbance. Bird data from Saginaw Bay were not collected according to MMP protocol, so summaries of these data are not provided. Bird Studies Canada did not receive disturbance data for the Saginaw Bay sites, and quantitative land cover disturbance data and water quality data were provided not provided for Arcadia Lake. Bird Studies Canada and Environment Canada followed the same disturbance ranking scheme for each of their sets of study sites. Therefore, marsh bird and anuran community attribute data from only these two team's study sites were analysed for responses to corresponding site disturbance rankings.

Data collected from Saginaw Bay were collected much differently than how MMP surveys are typically conducted. Typically, surveyors define relatively discrete wetland areas with common local influences, then position and monitor replicate survey stations within each site. Instead, single survey stops, spaced at great distances apart from one another were monitored at Saginaw Bay. These data were provided to BSC in the form of two routes, yet each of these two routes spanned a very broad area and local influences likely varied considerably among survey stations within each 'route'. Even if disturbance data were provided for each individual stop (which they weren't), the analytical power of single station sites would have been highly reduced. In addition, bird surveys were conducted during the evening and were done simultaneously with amphibian surveys, which was not in concordance with standard MMP survey protocol.

5.3.1 Bird Community Attribute Responses to Site Disturbance

5.3.1.1 Species Richness

Our initial investigation into determining community attribute response to site disturbances suggested that although non-significant, there was a tendency for richness to be higher at more disturbed sites among sites investigated at Long Point. This notable pattern is opposite to what we would have expected, but we offer the following possible explanation. The most disturbed sites at Long Point were generally much larger than the less disturbed sites, and species richness is known to be higher in larger, more complex wetlands. Even though we corrected for effort, which to some extent did indirectly control for wetland size, it is likely that the number of survey stations was not directly proportional to wetland size, and that wetland size likely increased at a higher rate than did the number of stations surveyed among Long Point study sites. Thus, some residual remaining variation due to wetland size seemed likely even after controlling for effort. This may have been responsible for the weak pattern that was observed. Future work should attempt to control for wetland area when examining such relationships.

Among Lake Ontario wetland sites, bird species richness did not perform well in predicting relative disturbance recorded among these sites.

Anuran species richness (corrected for effort) did not vary with site disturbance rankings among Long Point sites, therefore based on Long Point data this attribute did not appear to be a useful candidate for predicting site disturbance using the disturbance ranking scheme that we employed. Again though, wetland area may have confounded our ability to detect an effect of this attribute.

There was a significant positive relation between anuran species richness and water quality rankings among Long Point wetland sites, suggesting that species richness increased with decreasing water quality (higher nutrient readings). The sites with the highest water quality rankings are located at the westernmost region of Long Point and are protected by a barrier beach. These sites also have direct connections to the mainland. Both of these provide considerable protection from wind and water currents, creating more stagnant conditions. Such conditions may be favorable to a broader suite of amphibian species. As mentioned in Section 3 however, water quality data may not be entirely accurate and representative due to the fact that time of sample collections varied considerably. Thus, relations between community attributes and water quality rankings may be more apparent than real.

Among Lake Ontario wetland sites, although non-significant at a probability of 95%, anuran species richness did appear to suggest that this attribute may be useful for predicting site disturbance, as the general pattern was that richness tended to be lower at more disturbed sites. Further work should be done to investigate the usefulness of this attribute for developing anuran-based IBIs for measuring wetland condition.

5.3.1.2 Species Diversity

After correcting for effort, bird species diversity (which takes into account both species richness and abundance) increased significantly with site disturbance among Long Point wetland sites. Therefore, wetland bird communities were more diverse in wetlands estimated to be more disturbed. However, as mentioned above it is likely that even after controlling for effort (which was higher in larger wetland sites), there was likely a remaining residual effect of wetland area, which may explain these unexpected results. The wetland sites that had the highest residual diversity (i.e., Lee Brown Marsh, Port Rowan, Smith Marsh, Big Creek) all had direct associations with mainland, which may explain the higher diversity of species observed at these sites. These sites also were scored among the most disturbed, because most human activities are associated with the mainland and the town proper of Port Rowan, which were in closer vicinity to each of these sites. These results indicate that use of wetland bird diversity measures to determine their use as bio-indicators of wetland condition may not be valuable across wetlands having as diverse location contexts as those that occur at Long Point, as environmental factors (i.e., context of location – mainland associated vs. isolated sand-spit associated) may over-ride any non-natural disturbance effect.

Corrected bird diversity showed no appreciable relation to site disturbance rankings among Lake Ontario sites, which may have been due to such high numbers of Red-winged Blackbirds compared to other species.

Equitability, or evenness, was similar among sites at Long Point and Lake Ontario, and therefore this attribute did not provide any predictive ability to measure disturbance across sites. Given that this attribute is a function of richness and diversity

5.3.1.3 Indicator Species Richness and Proportion of Indicator Species of All Species Present

The suites of indicator species chosen for examination for these attributes were selected by the MMP in 1997, and criteria for selecting each species is described in Weeber et al. (1997). A list of MMP bird and amphibian indicator species is given in the Appendices.

Although bird indicator species richness did not prove to be of any value in predicting wetland site condition, a notable pattern in the expected direction in how this attribute varied with site disturbance rankings at Long Point does suggest that this attribute may be useful for measuring coastal wetland condition, and warrants further attention. The three least disturbed sites at Long Point, on average, had the highest proportion of their bird species present represented by indicator species, though this relationship was not significant at a 95% confidence level. Conversely, some of the sites found to have had the highest diversity had the lowest proportion of total bird species present represented by indicator species.

This attribute did not vary in any predictable manner across site disturbance rankings for Lake Ontario sites, suggesting that this is not a useful attribute for measuring condition among Lake Ontario wetlands.

5.3.1.4 Proportional Abundance of Blackbirds of Total Bird Abundance

Among Long Point sites, the proportion of all individual birds observed represented by blackbirds did not vary significantly with site disturbance rankings. However at one site (Bluff Marsh), which is considered to be the most pristine of all Long Point sites and therefore effectively a reference site, there were relatively far few blackbirds observed. Otherwise, relative proportion of individuals represented by blackbirds was quite similar across sites.

This attribute predicted site disturbance across Lake Ontario wetland sites quite well, as the negative correlation between the proportional abundance of blackbirds of total bird abundance and site disturbance rankings approached unity (70 percent). Virtually all blackbirds observed at Lake Ontario wetlands were Red-winged Blackbirds. Thus, fewer Red-winged Blackbirds occurred at sites of high disturbance than at sites of low disturbance.

The differences in results for this attribute between Long Point and Lake Ontario study sites could be explained by some of Long Point's sites having both Red-winged Blackbirds, Common

Grackles, and European Starlings, the latter two which can vary considerably and perhaps even randomly among sites. A post hoc analysis of Long Point data using proportional abundance for only Red-winged Blackbird (i.e., excluding other blackbird species) yielded similar results that suggested this attribute was not useful for predicting differences in disturbance among Log Point sites.

In viewing results from Lake Ontario, one might expect that proportional abundance of blackbirds would be higher at more disturbed sites, because Red-winged Blackbirds are thought to occur ubiquitously and are generalists in their habits as compared to other marsh birds. However, Red-winged Blackbirds breed largely in wetland areas as compared to other ictarids, and there is some concern about long term declines in their population, despite their perceived ubiquity and commonness.

Based on findings from the Lake Ontario study sites, this attribute would appear to be a good candidate for use as a metric for developing wetland bird IBIs for coastal wetland health, at least for Lake Ontario coastal wetlands. It is suspected that one reason for this is because samples sizes for this species are usually high and given the ease in detecting this species, data for this species provides high power to detect changes in relative abundance. Karr and Chu (1999) mention that attributes based on abundance measures are generally not suitable for IBI metrics, because of the difficulty in separating natural and non-natural (disturbance) sources of variation in abundance. Yet this attribute responded well to disturbance rankings among Lake Ontario sites under various levels of disturbance. Further development of this attribute for use as a wetland bird IBI may prove useful for coastal wetland bio-monitoring, and may also provide further insight into sources of long term decline thought by some to be occurring for this species.

5.3.1.5 Proportional Abundance of Marsh Wren of Total Bird Abundance

Marsh Wrens are a species recognized to be an indicator of good wetland quality by the MMP. This is also a species that is recorded often through MMP surveys but often variable in numbers. These factors made this species' proportional abundance an appropriate attribute to have examined. Unfortunately this attribute did not vary in any appreciable degree among Lake Ontario wetland sites, so this attribute was examined only for Long Point data.

The range of variation (lower than 5% at a more disturbed site to almost 25% at a much less disturbed site) and the general pattern of its relationship across site disturbance rankings suggest that this attribute may have some promise as a potential candidate IBI metric for measuring coastal wetland health. Even though the relationships were not significant at confidence levels of 95 percent, this attribute varied in similar fashions across both site disturbance and water quality rankings at Long Point. Little Rice Bay, Bluff Marsh, and Long Point Provincial Park all had proportionally more marsh wrens among all individuals observed and had both lower site disturbance and lower water quality rankings (lower water quality rankings implied better water quality and clarity). Similar to proportional Red-winged Blackbird abundance, further investigation using this attribute may be warranted for any future work to develop wetland bird IBIs for coastal wetlands.

5.3.1.6 Total Abundance of All Species

After correcting for level of effort, total abundance of all species observed at a site was not a good predictor of variability in disturbance rankings among sites for either Long Point or Lake Ontario wetland sites. Many factors unrelated to disturbances that occur in the vicinity of a site can influence total abundance of any given species, and even after correcting for level of effort it was likely that residual effects of many natural sources of variation in species abundance contributed to non-significant results from our analyses.

5.3.1.7 Aerial Forager Species Richness
It is likely that aerial forager species richness increased with site disturbance rankings not because these sites were more disturbed, but because these wetland sites were larger and located in close proximity to mainland terrestrial habitat, whereas the least disturbed wetland sites were smaller and quite distantly removed from mainland contexts. Many aerial forager species forage over wetland habitat, but nest in terrestrial contexts. For example, Barn Swallow often nest in association with human infrastructure (i.e., in old buildings, garages, roof overhangs, etc.), Tree Swallows nest in cavities of dead trees or other crevices of wooded areas, and both Bank and Rough-winged Swallows nest in exposed banks, under bridges and other such mainland associated contexts. These factors most certainly contributed to higher richness of aerial forager species in wetland sites that were in most close association and proximity to areas that support nesting habitat for many species of aerial foragers, despite these sites also having higher levels of surrounding disturbance.

This attribute did not vary among sites having different levels of disturbance across Lake Ontario. If Lake Ontario wetland sites were more similar to one another in terms of their proximity and association to mainland contexts, this may explain why this attribute did not vary across these sites.

Considering results from both Long Point and Lake Ontario, this attribute does not seem to perform well in predicting variation among sites due to level of local disturbances, as factors unrelated to disturbance were likely most responsible for the patterns observed for this attribute among sites. It is suggested that this site is not a suitable attribute for use as an IBI metric for bio-monitoring wetland condition in relation to disturbances.

5.3.1.8 Total Abundance of Aerial Foragers and Proportional Abundance of Aerial Foragers of Total Bird Abundance
Among Long Point wetland sites, total abundance of aerial foragers did not vary in concert with site disturbance rankings, even though number of aerial forager species was higher at more disturbed sites. However, when viewed as a proportion of total bird abundance at each site, there was a tendency for proportion of aerial foragers to be higher at less disturbed sites, even though there were fewer species of aerial foragers recorded at less disturbed sites. This result is likely due to lower total species richness at less disturbed sites, which is likely largely a function of less disturbed sites being smaller in size than more disturbed sites.

Among Lake Ontario sites, both total abundance of aerial foragers and proportion of aerial forager abundance of total bird abundance tended to be higher at more disturbed sites. We offer no explanation of these results without knowing more about the context of these sites as they pertain to suitability for aerial forager species.

5.3.2 Long Point and Lake Ontario Pooled Analyses

None of our analyses examining community attributes using combined Long Point and Lake Ontario site-specific data yielded results that would support use of any attribute in a wetland bird IBI for bio-monitoring coastal wetland health. We suspect that differences in site location and context, level of effort, or methods of characterizing site disturbance may be partly responsible for such null results. Certainly, when examining attribute data separately for each study team's set of sites, there were difference in results for many of the community attributes, which when combined, would largely remove any effect noted for either of the datasets when examined independently.

It is recommended that in any future effort to collect marsh bird and amphibian community data as part of a bio-monitoring program, more effort is made to standardize site selection protocol, site disturbance characterization, and level of monitoring at each site. Also, future analyses should statistically control for wetland size for each site, as this factor likely accounts for considerable variation in community attribute among sites.

5.3.3 Anuran Community Attribute Responses to Site Disturbance

5.3.3.1 Species Richness

Anuran species richness did not predict site disturbance among Long Point wetland sites, however among Lake Ontario sites there was a tendency for more disturbed sites to have fewer species. The latter would indicate that this attribute may warrant further work and development to determine its feasibility for use as an IBI metric for bio-monitoring coastal wetland health.

At Long Point, sites with higher nutrient and solid loadings and lower clarity tended to support more anuran species. These sites were also the largest and among the most directly associated with mainland forested areas, which may explain this result.

5.3.3.2 Species Diversity and Equitability

Species diversity did not vary in concert with site disturbance rankings for either Long Point or Lake Ontario wetland sites, however at Long Point anuran diversity was again higher at sites with higher water quality disturbance rankings. This latter result may be explained by the same phenomenon described above for species richness. Anuran equitability did not predict site disturbances for either Long Point or Lake Ontario wetland sites

It would appear that neither of these attributes lends themselves well as candidate metrics for coastal wetland IBI development.

5.3.3.3 Indicator Species Richness and Proportion of Indicator Species of Total Species Observed

Although number of indicator species per se did not predict level of site disturbance, the proportion of indicator species of all species observed at a site did have a tendency to be higher at less disturbed sites among Long Point study wetlands. Further work investigating anuran community data for use in bio-monitoring may benefit from examining this attribute's response to stressor data.

5.3.3.4 Maximum Calling Code of Northern Leopard Frog, Chorus Frog, and Bullfrog

None of these attributes performed well in predicting level of disturbance among coastal wetland sites at Long Point and across Lake Ontario. It is suggested that these coarse estimators of relative abundance are not suitable attributes for use in developing coastal wetland IBIs.

5.3.4 Long Point and Lake Ontario Pooled Analyses

Even with increased power by combining anuran community data from Long Point and Lake Ontario study sites, pooled analyses did not yield results to strongly support use of any community attributes examined as metrics for IBIs to monitor coastal wetland health. The range of available anuran species is narrow (i.e., 0 – 8 species), and variable breeding phenology among anuran species and their calling sensitivity to weather conditions can present some difficulties in yielding precise and accurate community results at the site level. Also, by not controlling for wetland size, this may have highly reduced our ability to detect levels of site disturbance using the attributes that we examined. Other factors related to timing and breeding phenology will be discussed in section describing basin-wide applicability of this monitoring technique.

5.3.5 Cost

MMP surveys were conducted by both paid field staff and professionals, and varied among study teams. At Long Point, most MMP surveys were conducted by paid field staff with some assistance from local volunteers. At Lake Ontario, roughly half of the surveys were done by paid field staff, while the other half were done by paid field staff. At Arcadia Lake, a paid sub-contractor conducted surveys of amphibians and marshbirds. At Saginaw Bay, Lake Huron, surveys were done by volunteers with academic experience working with amphibians and perhaps also birds. Project costs are higher when surveys are done by paid field staff, as even though volunteer time is considered in-kind cost, it is not a cost that would be incurred by a coastal wetland bio-monitoring project. Although it can be difficult to quantify costs of conducting MMP surveys on a by-wetland basis, costs generally include: 1) equipment and material to conduct surveys such as binoculars, training and survey kit materials and survey stakes, call broadcast unit and tape (for birds), flashlight, batteries and appropriate clothing and footwear for working in marshes, 2) transportation costs to and from wetland sites (including boat and/or canoe if necessary) which varies according to surveyor proximity to the wetland site, and 3) if done by paid field staff, wage or salary burdens for each surveyor. There are costs associated with recruiting, securing and training volunteers to conduct MMP surveys.

Table 5-3 lists costs of completing MMP surveys among the 11 Long Point wetland sites. Because sample effort tended to be lower (i.e., less staff time) at less accessible, remote sites (i.e., higher transportation costs, and accommodations) of Long Point's outer bay, total costs to complete bird and amphibian surveys were generally balanced and did not vary considerably among sites.

5.3.5.1 Equipment

Likely the most expensive item of equipment required for conducting MMP surveys is binoculars for bird surveys (not required for amphibian surveys), and certain personnel that do not already own these may need to purchase these. Binoculars can be purchased at most department stores and general-purpose binoculars can be purchased at a reasonable price. Most other equipment are items that most people typically already possess, such as compact tape players, outdoor clothing, flashlights, batteries, footwear, and even canoes if necessary. One item that most people likely do not own is a sound volume meter used to calibrate broadcast volume of tape recorder units. Survey equipment, information and material are provided to all surveyors by the MMP program administration at Bird Studies Canada and are free of charge to all surveyors.

Table 5-3. Costs required to conduct marsh bird and amphibian community sampling in 11 Long Point coastal wetlands (C = Consumable, N = Non-consumable).

Item	Cost (CDN)	Sampling Task[1]	C/N
Field Staff Costs	$9,460.00	2	C
Binoculars	$800.00		N
Personal vehicle use	$360.00	2	C
Boat Rental for Summer	$150.00		C
Meals	$187.50	2	C
Miscellaneous fuel	$30.00	2	C
Batteries	$53.00	2	C
Thermometer	$10.00	2	N
Metal Poles	$125.00	2	N
Meter and volt-ohm	$5.75	2	N
Spray paint	$12.00	2	C
Flagging tape	$10.00	2	C
Fuel for boat	$62.00	2	C
Fuel	$231.00	2	C
Wood 1 X 4	$15.00	2	N
Federal Express	$82.00	2	C
Rental vehicle	$107.00	2, 3, 4, 5, 6	C
Fuel for car rental	$33.00	2, 3, 4, 5, 6	C
Federal Express	$28.00	2, 3, 4, 5, 6	C
Case for Digital Camera	$23.00	2, 3, 4, 5, 6	N
Office Supplies	$14.50	2, 3, 4, 5, 6	C
Flashlight (2)	$44.00	2, 3, 4, 5, 6	N
Dry Sacks (2)	$46.00	2, 3, 4, 5, 6	N
Black Auto Goop	$7.50	2, 3, 4, 5, 6	N
Fox 40 whistles (2)	$10.00	2, 3, 4, 5, 6	N
Trail tape	$13.00	2, 3, 4, 5, 6	C
Batteries	$200.00	2, 3, 4, 5, 6	C
Cowhide gloves (3)	$21.00	2, 3, 4, 5, 6	N
Sun block (3)	$34.50	2, 3, 4, 5, 6	C
Measuring tape - 100 m	$57.50	2, 3, 4, 5, 6	N
Relfective Tape	$28.00	2, 3, 4, 5, 6	C
Safety Tape	$11.50	2, 3, 4, 5, 6	C
Duct Tape	$16.00	2, 3, 4, 5, 6	C
Insect repellent (3)	$23.00	2, 3, 4, 5, 6	C
Hammer	$18.50	2, 3, 4, 5, 6	N
Chest waders (4)	$360.00	2, 3, 4, 5, 6	N
Accessories for boat	$205.00	2, 3, 4, 5, 6	N
Gas and oil for boat	$95.00	2, 3, 4, 5, 6	C
Zip-Loc freezer bags	$2.50	2, 3, 4, 5, 6	N
Plastic gas can	$10.50	2, 3, 4, 5, 6	N
Rope - 50 ft	$11.50	2, 3, 4, 5, 6	N
Total Cost of Bird and Amphibian Sampling	**$13,013.75**		

5.3.5.2 Personnel

Three paid personnel and three volunteers (who worked on occasional evenings) were required to survey for 140-person evenings to complete 212 bird (two visits) and amphibian (three visits) monitoring stations among 12 Long Point wetland sites. During the period when amphibian and bird monitoring periods overlapped, both bird and amphibian surveys were done at a site during a single evening. Survey effort (i.e., number of stations per wetland site) was higher for many of the very large wetland sites at Long Point in an attempt to gather accurate and precise site-specific marsh bird and amphibian data for this pilot project. Typical effort made by MMP volunteers consists of an average of four to five survey stations per wetland site. This level of effort was not achieved for Lake Ontario wetland sites, and depending on how a wetland site is defined for Saginaw Bay, this level of effort may or may not have been achieved. This level of effort was achieved for the Arcadia Lake wetland site, and surveys done at Long Point wetland often highly exceed this level of effort.

Staff costs incurred to enter, verify, validate, analyze and report on results of data is not included in the cost table for this section but are included in the project budget in Section 9.0 General Summary.

Bird Studies Canada was solicited by Environment Canada to conduct a special training workshop in the metro-Toronto area for numerous purposes, one of these being to train and recruit MMP volunteers for their Lake Ontario GLCWC sites. At many of the GLCWC wetland sites, bird and amphibian surveys were done at the same station locations, thus reducing time and costs for station set-up for those who conducted surveys for both sets of taxa.

5.3.6 Measurability

The Marsh Monitoring Program engages volunteers throughout the Great Lakes basin to conduct surveys of marsh birds and amphibians in marsh wetland habitats. The program is designed to accommodate the needs of surveyors ranging from amateur to novice to professional. The survey expects that all surveyors have some prior general and basic knowledge about the habitats where they survey and either or both the amphibian and/or marsh bird assemblages that they are asked to monitor. The total species assemblage of amphibians is quite narrow and therefore training material provided to MMP surveyors is deemed sufficient to provide adequate abilities for all surveyors to recognize each species aurally and to accurately record their occurrence and relative abundance. Marsh bird species assemblages can be considerably more complex, and greater degrees of skill, involving both visual and aural identification abilities are necessary to survey for marsh bird assemblages. The MMP provides extensive training material to accommodate both amphibian and marsh bird surveyors, and MMP staff and partner support often conduct training seminars and field demonstrations to provide additional training upon demand.

Surveyors are also asked to record habitat descriptions are each of their survey stations to aid in understanding the habitat, location, size and other context information about their survey locations and wetland sites. The MMP is currently preparing to conduct a study to gauge volunteer ability in accurately and precisely documenting this information at their survey stations. At a larger basin-wide scale, the MMP can detect adequately small changes in annual indices for most species if routes are monitored at their current level for ten consecutive years. It is not certain what level of precision and accuracy the MMP is able to attain in understanding changes and differences in various community attributes at site-specific scales, but it is most certainly lower than when viewed at a larger spatial scale.

The MMP has provided detailed and comprehensive training information and instructional material to all surveyors since its inception in 1995. Each year, with feedback from volunteers and through guidance of its Scientific and Technical Advisory Committee, the MMP strives to improve its ability to monitor marsh bird and amphibian communities and their habitat throughout the Great Lakes basin.

To adequately measure amphibian and marsh bird communities across their often intra- and interspecifically dispersed breeding phenologies, multiple surveys are required to capture peak occurrences and abundances across species. This requires at least three survey visits to each station for amphibians and two survey visits to each station for birds. Because timing and weather conditions are critical to gathering accurate and representative observation data for amphibians and birds, special attention must be devoted toward deciding when to conduct each survey. In general, for any given volunteer who surveys one or two routes per year, this need only be as simple as paying attention to weather conditions and choosing an appropriate evening during their window of opportunity for each visit period.

For our surveys done at Long Point where relatively few personnel monitored many stations among 12 sites of varying accessibility, it was at time extremely difficult and challenging to complete all survey visits at each station during their windows of opportunity for both birds and amphibians. The trade-offs were that observer variability was lower for our pilot studies because we employed fewer surveys, but that survey intensity was higher for each participating surveyor. Also, for wetland sites that are dispersed over great distances (which would be the case for any Great Lakes coastal wetland bio-monitoring program), it would extremely challenging, if not impossible for a small team of surveyors to adequately survey all wetland sites for the required number of visits during the appropriate survey periods. Clearly, multiple volunteer surveyors, most or all of whom are situated in close proximity to their respective coastal wetland sites, is the preferred and perhaps the only realistic and feasible option for gaining accurate and precise measurements of marsh bird and amphibian community data.

Our approved project proposal and budget did not include costs to recruit, engage and provide training for volunteers to conduct surveys at GLCWC pilot project sites, but instead to conduct intensive sampling for all indicator suites included in the GLCWC pilot project studies. Also, when we received confirmation about our participation in this project, there was only a narrow window of opportunity to recruit volunteers for any of the GLCWC study sites. Adequate lead-time would be required to effectively establish a volunteer-base for multiple coastal wetland bio-monitoring sites. Another option would have been for Bird Studies Canada to have participated only in bird and amphibian monitoring activities and to have provided necessary work needed to adequately monitor all GLCWC wetland pilot project study sites, which would likely have yielded a more complete and standardized inventory of amphibian and marsh bird community attribute data. However, this would have resulted in not having collected from Long Point wetland sites, community data for the other suites of indicators being tested for this project.

For any future potential of incorporating MMP-based marsh bird and/or amphibian community monitoring into a Great Lakes bio-monitoring program, it is highly recommended that recruitment and securement of local volunteers or paid-personnel is established for each wetland site to be monitored. The MMP is well established and has a broad network of volunteers and contacts distributed variably throughout the Great Lakes basin, and it is suggested that any GLCWC bird and or amphibian monitoring component draw on the MMP's capacity to involve volunteer surveyors.

5.3.7 Basin-wide Applicability and Sampling by Wetland Type

Strictly considering the survey protocol, the MMP is designed to accommodate surveys to capture breeding phenologies of existing species at each latitudinal region of the Great Lakes basin, and has done this at both coastal and inland marsh wetlands since 1995. Survey techniques can be applied to any coastal marsh habitat throughout the basin.

Wetland sites located in remote locations of the basin may be difficult to recruit volunteer surveyors to complete amphibian and/or marsh bird surveys. In such cases, resource personnel from municipal, state, provincial, federal, or non-government agencies, institutions or organizations may be most suitable and appropriate to monitor remote coastal wetland sites. It is likely that volunteers could be engaged to monitor many coastal wetland sites in proximity human habitation. Therefore, likely a most realistic and viable approach for including marsh bird and amphibian monitoring into a Great Lakes coastal bio-monitoring program would be to engage a combination of volunteer citizens, volunteers from any of the above mentioned resource groups, and in certain cases paid personnel.

In examining results from our analyses, we found that site location and context were very important considerations and sometimes were the most likely factors to explain certain patterns of results from Long Point wetland sites. Long Point reference site(s) and more heavily disturbed sites, although relatively quite close to one another, share quite different contexts in that the reference site was located in a remote area of the outer reaches of the sand spit feature (which is quite removed from mainland context), whereas more disturbed sites were quite closely associated and influence by mainland factors. We believe that this may have confounded our ability to examine community attribute responses across the different levels of disturbances that influence each site. Thus, for any future implementation employing marsh bird and amphibian bio-monitoring it is extremely important that sites are selected in a manner that minimizes differences due to such contextual influences, while maximizing differences due to disturbance factors and other stressors against which bio-monitoring data will be examined. This means that special attention needs to be given to site selection criteria. Given how rare sand spit features such as Long Point's occur throughout the basin, it is unlikely that such confounding factors would come into play among other suites of sites as much as they did among our Long Point sites.

5.3.8 Availability of Complementary Data

Existing and future MMP data will be available to complement data collected for any coastal wetland bio-monitoring program that may be implemented. There are other anuran and wetland bird monitoring programs conducted in certain areas of the Great Lakes basin that may be able to provide additional complementary data to the GLCWC. Also, amphibian and marsh bird data being collected through the STAR – grant bio-monitoring project is collected in a similar manner to the MMP and may be available to complement data collected through the GLCWC.

5.3.9 Statistical Considerations

In employing MMP data following state-and-stressor procedures recommended by Karr for examining community attribute data response to stressor factors, statistical methodologies were relatively simple. Because our purposes for this pilot study were exploratory in nature, we summarized our data appropriately across visits within stations, then across stations within sites, then calculated various indices. Using these and other simple community attributes, we performed simple linear regressions against disturbance and water quality ranking stressor variables to determine how well any given attribute could predict our measured gradient disturbance across sites.

The first step was to electronically scan all data into a software program using Teleform data scanning equipment, then transfer these data into a relational database, where numerous verification and validation procedures were performed. Data were queried summarized using SAS statistical software. Community data and site disturbance data were pooled into a common dataset, where various indices were calculated.

Shannon-Weiner diversity and equitability indices were calculated for each site for both bird and amphibian community datasets using the following formulas:

$$[H'] = -\Sigma p_i \ln(p_i),$$

where [H'] is the Shannon-Weiner diversity index for a sampled community and p_i is the percentage that each species represents of the entire assemblage (Pielou 1975), and:

$$E = H'/\ln T,$$

where T is the total number of species present.

These indices were examined for their response across the gradient of site disturbances to determine their utility as potential metrics for bird or amphibian coastal wetland IBIs.

During linear regression statistical analyses, level of survey effort was examined for its influence on certain raw community attributes, including those characterizing richness or abundance of species assemblage data. When significant confounding effects of effort (number of survey stations monitored) were found, residual values from these regressions were used as corrected dependent variables and regressed against stressor variables to determine if any residual effect due to disturbance was evident for that attribute.

Sample sizes varied considerably among project teams and even among sites within project teams. This varied effort added considerably to variance in community attribute results among sites. Even though we statistically controlled for survey effort, residual variation most certainly remained due to variation in marsh size and complexity, factors known to affect amphibian and marsh bird species assemblages. Future work should aim to statistically control for effects of wetland size and differences in habitat structure and composition while examining community attribute response to stressors.

Also, future work should aim to statistically examine relationships between marsh bird and amphibian community attributes and other biotic community attributes such as floristic quality indices and other analogous indices for other wetland taxa. We consider our investigations herein to be preliminary and exploratory, yet insufficient to determine how well marsh bird and amphibian data collected through the MMP can lend itself to IBI development. There is a need to improve upon site selection methodologies, standardizing survey effort, and to greatly improve approaches and standardization of site disturbance attribute information for stressor variable development.

While perhaps not appropriate for small assemblages such as anuran species, with adequate levels of effort and sample sizes collected across multiple sites throughout the Great Lakes basin, multi-variate ordination analyses such as principle component analyses, correspondence analyses, or canonical correspondence analyses may prove useful in selecting the most appropriate candidate taxa from the suite of bird species, whose community data might best describe patterns of variation in stressor factors.

5.4 Literature Cited

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6.0 FISH COMMUNITY SAMPLING

6.1 Methods

Fish sampling was guided by Long Point Region Conservation Authority Lands and Water Specialist, Paul Gagnon, with logistical and research supervision from Bird Studies Canada (BSC) principal investigators. Mr. Gagnon has extensive experience in sampling freshwater fish communities. Twelve discrete sampling locations (representing eleven recognized wetland sites) were sampled for fish community health at Long Point coastal wetlands. Wetland types were classified (barrier protected, open lacustrine, protected lacustrine) prior to commencing field-sampling activities. Fish were sampled in two major plant zones (submergent marsh and emergent marsh) and at each site, sampling occurred between 18 July and 13 August, 2002. Sampling procedures for fish community health involved a combination of fyke net sets and standard minnow trap sets at all wetland sites. Minimum requirements for mesh size (12.5 mm or smaller) and net opening (1.0 m x 1.0 m and/or 1.0 m x 0.5 m) were met and fyke nets were equipped with single leads and two shorter wing leads (~ 5 – 10 m long). Smaller fyke nets (1.0 m X 0.5 m) were set in water approximately 0.25 m to 0.75 m deep and larger nets were set in water depths greater than 0.75 m. Nets were set adjacent to vegetation zones of interest with leads extending into the dominant vegetation zone to optimize fish community sampling in those zones. Minnow traps were used to sample fish communities within emergent vegetation zones and were placed directly within vegetation. Duration of both fyke net and minnow trap sets was approximately 24 hours. For each emergent set, individuals were keyed to species on site, total lengths of each fish were measured ("1 mm) and occurrence of DELTs were noted and number of individuals of each species was tallied. When processing each set's catch, individuals were held in water either in a five-gallon polypropylene basket, or when individuals were numerous and air temperature was high, the compartment of the net holding the fish was held in the water until the entire catch was processed. When more than 100 specimens of any given fish species occurred in a sample, a random sub-sample of 25 specimens were selected for length measurements. All data were recorded on standard data forms, and were later entered into a Microsoft Access relational database.

6.2 Results

Copies of our Long Point fish community database were sent to Dr. Don Uzarski at Grand Valley State University, Annis Water Resources Institute, Lake Michigan Center, where Dr. Uzarski included our data in an analysis to develop fish community IBIs for Great Lakes coastal wetlands.

Below we provide a summary describing locations and dates of our fish community sampling (Table 6-1) and we also provide a summary of our raw data in Appendix 1. Table 6-2 summarizes the rate of DELT external anomalies . Only one deformity, one lesion and two erosions of fins were seen on fish caught in fyke nets in 12 Long Point wetland locations sampled.

Table 6-1. Descriptions, sample site locations, and sample dates of 12 Long Point coastal wetlands sampled for fish community health.

Sampling Area	Study Site[1]	Wetland Type[2]	Plant Zone	Set Number	Check Date[3]	UTM North	UTM East
Booth's Harbour	Booth's Harbour	Open Shoreline/Open Embayment	Emergent	1	18/7/02	4722398	17 548314
			Submergent	2	18/7/02	4722316	17 548292
			Emergent	3	18/7/02	4721903	17 547509
Bluff Marsh	Bluff Marsh	Barrier Protected/Protected Embayment	Emergent	1	21/7/02	4712925	17 570444
			Submergent	2	21/7/02	4712386	17 570565
			Submergent	3	31/7/02	4712631	17 570229
Colletta Bay	Crown Marsh	Protected Embayment/Open Embayment	Submergent	1	25/7/02	4716021	17 546646
Crown Marsh	Crown Marsh	Open Embayment/Protected Embayment	Emergent	1	24/7/02	4715699	17 549112
			Emergent	2	24/7/02	4715756	17 548684
			Emergent	3	24/7/02	4715486	17 548369
Causeway	Causeway[4]	Open Shoreline	Emergent	1	25/7/02	4715909	17 545280
Helmer's Pond	Helmer's Pond	Barrier Protected/Sand Spit Embayment	Emergent	1	31/7/02	4712695	17 541698
			Emergent	2	31/7/02	4712756	17 542142
Lee Brown Marsh	Lee Brown Marsh	Barrier Beach Lagoon	Emergent	1	16/7/02	4714577	17 540720
			Emergent	2	16/7/02	4713863	17 540623
			Emergent	3	16/7/02	4714100	17 540813
Long Point Provincial Park	Long Point Provincial Park	Open Embayment	Emergent	1	23/7/02	4714635	17 550202
			Emergent	2	23/7/02	4715013	17 550710
			Emergent	3	2/8/02	4714731	17 550739
Little Rice Bay	Little Rice Bay	Open Embayment/Sand Spit Embayment	Submergent	1	22/7/02	4715221	17 552533
			Emergent	2	22/7/02	4714967	17 552752
Port Rowan	Port Rowan	Open Embayment/Open Shoreline	Submergent	1	19/7/02	4720773	17 546614
			Emergent	2	26/7/02	4719036	17 545234
			Emergent	3	26/7/02	4719704	17 545789
Smith Marsh	Smith Marsh	Open Embayment/Drowned River Mouth	Emergent	1	26/7/02	4717439	17 544969
Thoroughfare	Little Rice Bay	Open Embayment	Submergent	1	20/7/02	4716325	17 553859
			Submergent	2	22/7/02	4715292	17 553572
			Emergent	3	12/8/02	4716410	17 554273
			Emergent	4	13/8/02	4715493	17 554105

Table 6-2. Number of total fish and external anomalies seen on fish at 12 Long Point coastal wetlands sampled for fish community health.

Sampling Area	Study Site[1]	Total Fish	Deformities	Erosions	Lesions	Tumors	Delt Rate (%)
Booths Harbour	Booths Harbour	215	-	-	-	-	0.000
Bluff Marsh	Bluff Marsh	243	-	-	-	-	0.000
Colletta Bay	Colletta Bay	145	-	-	-	-	0.000
Crown Marsh	Crown Marsh	362	-	-	-	-	0.000
Causeway	Causeway[2]	118	-	-	-	-	0.000
Helmer's Pond	Helmer's Pond	253	-	-	-	-	0.000
Lee Brown Marsh	Lee Brown Marsh	82	1	-	-	-	0.012
Long Point Provincial Park	Long Point Provincial Park	97	-	-	-	-	0.000
Little Rice Bay	Little Rice Bay	74	-	-	1	-	0.014
Port Rowan	Port Rowan	292	-	2	-	-	0.007
Smith Marsh	Smith Marsh	86	-	-	-	-	0.000
Thoroughfare	Little Rice Bay	171	-	-	-	-	0.000

[1] Some sites were combined for subsequent site ranking and MMP indicator analysis due to similarity and proximity.
[2] Study site added after commencement of field season.

6.3 Discussion

Uzarski will provide a discussion of the results for fish community sampling data that were collected at Long Point coastal wetlands, which will be included in his report to the GLCWC. In our discussion we provide information pertaining to our experiences in implementing protocol for sampling fish communities that was agreed upon by the GLCWC PWT and by participating members of GLCWC year-one pilot study teams. Specifically, our discussion is outlined to address the six criteria for testing feasibility of applying indicators in a Great Lakes coastal wetlands monitoring plan. The six criteria are 1) cost, 2) measurability, 3) basin-wide applicability, 4) availability of complementary existing research data, 5) indicator sensitivity to wetland condition changes, and 6) ability to set endpoints or attainment levels. For this indicator, we can provide some discussion on only the first four criteria, as the latter two can be discussed only by Uzarski, who is processing and analyzing Long Point wetlands fish community sampling data to answer the latter two criteria (#5 and #6).

6.3.1 Cost

6.3.1.1 Equipment

The following table breaks down costs of data collection at the 12 wetland locations sampled at Long Point, Lake Erie (Table 6-3). These costs are broken down into consumable (one-time use) and non-consumable (used multiple time). These costs represent those required to carry out field activities for this indicator. The values are for all 12 wetland locations because cost did not differ among wetland types.

Fyke net cost were the most expensive equipment of our fish community sampling. It was somewhat difficult to locate a source for these nets, but we eventually found a manufacturer in Wisconsin to custom build our nets. This cost alone may be prohibitive for an extensive, long-term coastal wetland monitoring program, but the nets are non consumable, making their cost more justified over an extended period of monitoring.

Table 6-3. Equipment costs required to conduct fish sampling in 11 Long Point coastal wetlands (C = Consumable, N = Non-consumable).

Item	Cost (CDN)	Sampling Task[1]	C/N
Field Staff Costs	$2,213.00		C
Gloves, PVC and foam	$30.00	4, 6	N
Minnow Traps (7)	$95.00		N
Customs brokers	$752.00	4	C
Boat Rental for Summer	$150.00		C
Gas and oil for boat	$86.00	4	C
Fyke nets	$4,030.00		N
Steel rulers	$20.00		N
Screw and roller tube	$10.00		N
Plywood	$18.00		N
Rental vehicle	$107.00	1, 2, 4, 5, 6	C
Fuel for car rental	$33.00	1, 2, 4, 5, 6	C
Federal Express	$28.00	1, 2, 4, 5, 6	C
Case for Digital Camera	$23.00	1, 2, 4, 5, 6	N
Office Supplies	$14.50	1, 2, 4, 5, 6	C
Flashlight (2)	$44.00	1, 2, 4, 5, 6	N
Dry Sacks (2)	$46.00	1, 2, 4, 5, 6	N
Black Auto Goop	$7.50	1, 2, 4, 5, 6	N
Fox 40 whistles (2)	$10.00	1, 2, 4, 5, 6	N
Trail tape	$13.00	1, 2, 4, 5, 6	C
Batteries	$200.00	1, 2, 4, 5, 6	C
Cowhide gloves (3)	$21.00	1, 2, 4, 5, 6	N
Sun block (3)	$34.50	1, 2, 4, 5, 6	C
Measuring tape - 100 m	$57.50	1, 2, 4, 5, 6	N
Relfective Tape	$28.00	1, 2, 4, 5, 6	C
Safety Tape	$11.50	1, 2, 4, 5, 6	C
Duct Tape	$16.00	1, 2, 4, 5, 6	C
Insect repellent (3)	$23.00	1, 2, 4, 5, 6	C
Hammer	$18.50	1, 2, 4, 5, 6	N
Chest waders (4)	$360.00	1, 2, 4, 5, 6	N
Accessories for boat	$205.00	1, 2, 4, 5, 6	N
Gas and oil for boat	$95.00	1, 2, 4, 5, 6	C
Zip-Loc freezer bags	$2.50	1, 2, 4, 5, 6	N
Plastic gas can	$10.50	1, 2, 4, 5, 6	N
Rope - 50 ft	$11.50	1, 2, 4, 5, 6	N
Total Cost of Fish Sampling	**$8,824.50**		

[1] Numbers indicate equipment shared with other sampling tasks. 1 = birds, 2 = amphibians, 3 = fish, 4 = macroinvertebrates, 5 = aquatic plants, 6 = water quality and 7 = miscellaneous.

6.3.1.2 Personnel
Costs associated with fish community sampling are included in Table 6-3. Site attribute data and macroinvertebrate community data were collected during the same period as fish community sampling. To set, check and process samples at each net set, it took approximately 3 hours. This included travel time to and from each site, and also included setting and checking minnow traps in addition to all the work required to seta and check fyke nets. Although one field technician can set, check and process either fyke net size, it was much more efficient and timely for at least two technicians working together to carry out fyke net fish community sampling procedures.

Costs for analyzing the community data can be reported only by Dr. Uzarski, as we provided him with all our Long Point coastal wetland fish community data for IBI analyses.

6.3.2 Measurability

6.3.2.1 Expertise and training
Clearly, in order to monitor fish community health using this technique, field monitoring personnel should have some prior knowledge and/or training in the following: 1) small outboard and boat operation; 2) how to properly check, process, repair, monitor and store fyke nets; 3) how to identify freshwater fish species (adult and young-of-the-year) to species, and; 4) how to properly handle, hold, release and measure morphology of fish.

A useful resource for our work to identify fish species was Scott and Crossman (1990), which provided excellent identification and life history information about all freshwater fishes of the Great Lakes region in Canada.

From our experiences during the 2002 pilot project field season, it is our opinion that some prior training to teach field technicians 1) the proper methods for setting, checking and pulling fyke nets and minnow traps, 2) where to set nets and traps, 3) how to process samples, and most importantly 4) adequate taxonomic identification skills are essential to ensure that fish community data in coastal wetlands are collected in a standardized manner. Bird Studies Canada offered to host one- to two-day training workshop for participating GLCWC pilot project teams to ensure that there would be a complete understanding of all methodologies being evaluated and to improve our collection ability to standardize techniques being tested by multiple teams. For various reasons, this workshop did not occur, however, we are quite confident that we correctly carried out fish community sampling procedures according to protocol specified by Uzarski.

6.3.2.2 Recommendations on Methodology
If the GLCWC PMT deems the use of fyke nets as a viable and affordable method for monitoring Great lakes coastal wetland fish community health, then we believe that the use of fyke netting as a primary sampling methodology is quite useful and productive. There are certain species that we know to exist in great abundance at Long Point, such as Northern Pike (*Esox lucius*) and Common Carp (*Cyprinus carpio*) that we believe are not adequately sampled through the use of fyke netting. This poses a serious problem because pike are top-level predators in freshwater fish communities, and because carp a very destructive exotic indicator fish species. Therefore, the inability to adequately sample these species via fyke netting poses problems during interpretation of attribute data for IBI development. The PMT should seriously consider use of

electro-shocking, instead of fyke netting, as a means for rapid sampling of fish communities in any Great Lakes coastal wetland monitoring plan.

6.3.3 Basin-wide Applicability and Sampling by Wetland Type

Certainly, if the GLCWC PMT decides that fyke-netting is a viable field sampling method for monitoring fish community health of coastal wetlands, fyke-netting is applicable to virtually any wetland throughout the Great Lakes basin that has suitable bottom profiles to accommodate proper setting of nets. There might be problems in circumstances where bottom profiles have a steep gradient, as field crews require a certain depth to set the leads, wings, mouth and ends of nets. Also, the substrate must be deep enough and/or stable enough to hold support posts for tying leads, wings and ends of the nets. If substrate is too shallow with underlying bedrock, then this could restrict selection of set sites.

Setting and pulling fyke nets require some training, but because this is a passive method, sampling intensity (i.e., time in field) is minimized as compared to methods that employ electro-shocking. One problem that we encountered was finding a source to borrow or purchase our fyke nets. We resorted to purchasing six fyke nets through a manufacturer in Wisconsin. Although our initial costs for this equipment were rather high, this equipment is non-consumable and through economy of scale, over time if used repeatedly in a long-term monitoring initiative, these costs will be fully justified.

We employed fyke-netting in open lacustrine, protected lacustrine, and barrier protected type coastal wetlands, and were able to adequately set, check, process and pull our nets at each site without encountering any significant problems.

6.3.4 Availability of Complementary Data

In Canada, because fyke-netting is not a commonly employed field method for sampling freshwater fish in the Great Lakes, there are currently little available complementary data from which to compare or combine data that we collected during 2002. Availability of complementary data from other sources that use fyke netting will depend upon whether the methods recommended through the GLCWC are broadly adopted by those who monitor coastal wetlands in the Great Lakes region of Canada.

There are other complementary fish community data that have been collected through use of other sampling methods (e.g., electro-fishing, index netting, seine netting, trap netting) that could be used to compare with data collected by those of us who used fyke netting. In Ontario, most of these data are in the holdings of the Ontario Ministry of Natural Resources' various Fisheries Assessment Units. Some of these data are readily available in reports and publications.

6.4 Literature Cited

Scott, W.B., and E.J. Crossman. 1990. Freshwater fishes of Canada. Department of Ichthyology and Herpetology, Royal Ontario Museum, Toronto. 966pp.

7.0 MACROINVERTEBRATE COMMUNITY SAMPLING

7.1 Methods

Fourteen discrete sampling locations (representing eleven recognized wetland sites) were sampled for macroinvertebrate communities at Long Point. Wetland types were classified (barrier protected, open lacustrine, protected lacustrine) prior to commencing surveys (Geomorphic Classification Committee 2001). Macroinvertebrates were sampled in major plant zones (submergent marsh, emergent marsh, submergent/emergent marsh) at each sample site, and sampling occurred between 16 July and 4 September, 2002. Occasionally, sample sites contained more than one dominant plant species or plant zone, and when this occurred, invertebrates were sampled in each. D-frame sweep nets were used to sample for macroinvertebrates at all sample sites . At each sample site, the D-frame nets were swept through the water at the surface of the water column, in the middle of the water column, and above the sediment surface to ensure that all of microhabitats were included. Contents of each survey were emptied into gridded white enamel pans. As vegetation was removed from the sample, attempts were made to sample specimens by each grid before moving on to the next grid area and we attempted to repeat this process over the course of one half hour, or until 150 invertebrates were sampled. Special consideration was made to ensure that smaller organisms were not missed. As plant detritus was removed it was thoroughly inspected to ensure sessile species were collected. Attempts were made to collect replicate samples within each plant community zone in order to obtain a measure of sampling variance.

Specimens were preserved in 80% ethanol and labeled (i.e., sample number, sample site name, date). All preserved and labeled samples were hand delivered to Don Uzarski's research team at Grand Valley State University, Annis Water Resources Institute, Lake Michigan Center for sorting and identification tot their lowest operational taxonomic unit; usually genus or species. For more information about sampling methodology see sampling and sub-sampling procedures employed by Tom Burton and Don Uzarski (Burton et al. 1999).

7.2 Results

Overall, 32 macroinvertebrate samples were collected from 14 different wetland sample locations at Long Point Bay and were sent to Grand Valley State University for further sorting and taxonomic identification (Table 7-1). At this point, identification of macroinvertebrate samples is in progress, and Uzarski will report on results of macro invertebrate community sampling in his report to the GLC.

Table 7-1. Descriptions of sample site locations and sample dates of 14 Long Point coastal wetlands sampled for macroinvertebrate community health.

Sampling Area	Study Site[1]	Wetland Classification[2]	Plant Zone	Sample I.D. Code	Date	UTM North	UTM East
Booth's Harbour	Booth's Harbour	Open Shoreline/Open Embayment	Submergent/Emergent	BH-01(a)	6/8/02	4712925	17 570444
			Submergent	BH-01(b)	18/7/02	4712386	17 570565
			Submergent/Emergent	BH-03	6/8/02	4712631	17 570229
Bluff Marsh	Bluff Marsh	Barrier Protected/Protected Embayment	Submergent	BM-01	31/7/02	4712631	17 570229
			Submergent	BM-02	4/9/02	4712583	17 570214
			Submergent/Emergent	BM-03	31/7/02	4722398	17 548314
			Submergent/Emergent	BM-04	4/9/02	4722316	17 547509
Colletta Bay	Crown Marsh	Open Embayment/Protected Embayment	Submergent/Emergent	CB-01	25/7/02	4716021	17 546646
Crown Marsh	Crown Marsh	Protected Embayment/Open Embayment	Submergent/Emergent	CM-01	24/7/02	4715699	17 549112
			Submergent	CM-02	24/7/02	4715756	17 548684
			Submergent	CM-03	24/7/02	4715486	17 548369
			Submergent/Emergent	JN-01	4/9/02	4714926	17 548028
Causeway	Causeway[3]	Open Shoreline	Submergent	CW-01	25/7/02	4715909	17 545280
Hahn Marsh	Hahn Marsh	Barrier Protected	Submergent/Emergent	HM-02	14/8/02	4714571	17 539600
Helmer's Pond	Helmer's Pond	Barrier Protected /Open Embayment	Submergent	HP-01	31/7/02	4712695	17 561698
Lee Brown Marsh	Lee Brown Marsh	Barrier Beach Lagoon	Submergent/Emergent	LBM-01	16/7/02	4714577	17 540720
			Submergent	LBM-02	16/7/02	4713863	17 540623
			Submergent	LBM-03	16/7/02	4714100	17 540813
			Submergent	LBM-04	16/8/02	4714635	17 550202
Long Point Provincial Park	Long Point Provincial Park	Open Embayment	Emergent	LPPP	23/7/02	4715096	17 549862
			Submergent	LPPP-02	23/7/02	4715013	17 550710
Little Rice Bay	Little Rice Bay	Open Embayment/Sand Spit Embayment	Submergent/Emergent	LRB-01	27/7/02	4715221	17 552533
			Submergent/Emergent	LRB-02	13/8/02	4715221	17 552752
			Submergent/Emergent	LRB-03	22/7/02	4715410	17 552736
Outer Colletta Bay	Crown Marsh	Open Embayment/Protected Embayment	Submergent/Emergent	OCB-04	4/9/02	4716533	17 547933
Port Rowan	Port Rowan	Open Embayment/Open Shoreline	Submergent/Emergent	PR-01	26/7/02	4720773	17 546614
			Submergent/Emergent	PR-03	26/7/02	4719704	17 545789
			Submergent/Emergent	PR-05	13/8/02	4720226	17 546110
			Submergent/Emergent	PR-06	19/7/02	4722398	17 548314
Smith Marsh	Smith Marsh	Open Embayment/Drowned River Mouth	Submergent	SM-01	26/7/02	4717439	17 544969
Thoroughfare	Little Rice Bay	Open Embayment/Sand Spit Embayment	Submergent/Emergent	TF-02	13/8/02	4715292	17 553572
			Submergent/Emergent	TF-03	13/8/02	4716325	17 553859

[1] Some sites were combined for subsequent site ranking and MMP indicators analysis due to similarity and proximity.
[2] Coastal wetland classifications followed descriptions agreed upon by the GLCWC Geomorphic Classification Committee (2001).
[3] Study site added after field season commencement.

7.3 Discussion

Uzarski will provide a discussion of the results for macroinvertebrate sampling that was done at Long Point coastal wetlands, which will be included in his report to the GLC. In our discussion we provide information pertaining to our experiences in implementing protocol for sampling macroinvertebrate communities that was agreed upon by the GLCWC PMT and by participating members of GLCWC year-one pilot study teams. Specifically, our discussion is outlined to address the six criteria for testing feasibility of applying indicators in a Great Lakes coastal wetland monitoring plan. The six criteria are 1) cost, 2) measurability, 3) basin-wide applicability, 4) availability of complementary existing research or data, 5) indicator sensitivity to wetland condition changes, and 6) ability to set endpoint or attainment levels. For this indicator, we can provide some discussion on only the first four criteria, as the latter two can be discussed only by Uzarski who is processing Long Point wetlands macroinvertebrate samples and analyzing his findings in relation to the latter two criteria (#5 and #6).

7.3.1 Cost

7.3.1.1 Equipment

The following table breaks down costs of data collection at the 14 wetlands sample locations at Long Point, Lake Erie (Table 7-2). The costs are broken down into consumables (one-time use) and non-consumable (used multiple times). These costs represent those required to initiate the program and run it for one field season. The values are for all 14 sample locations since cost did not differ among wetland sites.

7.3.1.2 Personnel

Site attribute data were collected during the same period as community fish sampling. Samples took approximately 40 minutes to collect and sort, and site data recording took approximately 5 minutes to complete. All sample were preserved, labeled and sent to Annis Water Resources Institute, Lake Michigan Center, Grand Valley State University for further sorting and identification.

7.3.2 Measurability

7.3.1.1 Expertise and training

Surveyors should have experience working in Great Lakes coastal wetlands and should be comfortable working from canoes and/or motorized power boats, and wading in wetland habitats. Identification and sorting of marcroinvertebrates by taxonomic group requires skilled technicians who are trained and familiar with aquatic macroinvertebrate identification, and these activities must be carried out in laboratory conditions and may be time consuming.

From our experiences during the 2002 pilot field season, it is our opinion that some prior training to teach field technicians 1) the proper methodology for collecting sweep samples, 2) where to sample, 3) how to process samples, and even 3) basic field taxonomic identification skills are essential to ensure that samples are collected in a standardized manner that captures taxonomic diversity of the community.

Table 7.2. Costs required to conduct macroinvertebrate sampling at 14 Long Point coastal wetland sample locations (C = Consumable, N = Non-consumable).

Item	Cost (CDN)	Sampling Task[1]	C/N
Field Staff Costs	$1,913.00		C
Use of refrigderator for storing field samples	$100.00	5	N
Gloves, foam and PVC	$30.00	3, 6	N
Boat Rental for Summer	$150.00		C
Gas and oil for boat	$86.00	3	C
Bottles, forceps, glass pipette and eye dropper	$80.00		N
Customs broker	$752.00	3	C
Rental car to US	$98.00	6	C
Fuel for rental car	$37.00	6	C
Meal	$3.00	6	C
Bridge tolls	$8.00	6	C
Phone	$2.00	6	C
Rental vehicle	$107.00	1, 2, 3, 5, 6	C
Fuel for car rental	$33.00	1, 2, 3, 5, 6	C
Federal Express	$28.00	1, 2, 3, 5, 6	C
Case for Digital Camera	$23.00	1, 2, 3, 5, 6	N
Office Supplies	$14.50	1, 2, 3, 5, 6	C
Flashlight (2)	$44.00	1, 2, 3, 5, 6	N
Dry Sacks (2)	$46.00	1, 2, 3, 5, 6	N
Black Auto Goop	$7.50	1, 2, 3, 5, 6	N
Fox 40 whistles (2)	$10.00	1, 2, 3, 5, 6	N
Trail tape	$13.00	1, 2, 3, 5, 6	C
Batteries	$200.00	1, 2, 3, 5, 6	C
Cowhide gloves (3)	$21.00	1, 2, 3, 5, 6	N
Sun block (3)	$34.50	1, 2, 3, 5, 6	C
Measuring tape - 100 m	$57.50	1, 2, 3, 5, 6	N
Relfective Tape	$28.00	1, 2, 3, 5, 6	C
Safety Tape	$11.50	1, 2, 3, 5, 6	C
Duct Tape	$16.00	1, 2, 3, 5, 6	C
Insect repellent (3)	$23.00	1, 2, 3, 5, 6	C
Hammer	$18.50	1, 2, 3, 5, 6	N
Chest waders (4)	$360.00	1, 2, 3, 5, 6	N
Accessories for boat	$205.00	1, 2, 3, 5, 6	N
Gas and oil for boat	$95.00	1, 2, 3, 5, 6	C
Zip-Loc freezer bags	$2.50	1, 2, 3, 5, 6	N
Plastic gas can	$10.50	1, 2, 3, 5, 6	N
Rope - 50 ft	$11.50	1, 2, 3, 5, 6	N
Total Cost of Macroinvertebrate Sampling	**$4,679.50**		

[1] Numbers indicate equipment shared with other sampling tasks. 1 = birds, 2 = amphibians, 3 = fish, 4 = macroinvertebrates, 5 = aquatic plants, 6 = water quality and 7 = miscellaneous.

7.3.1.2 Recommendations on Methodology
Bird Studies Canada offered to host a one-to-two day training workshop for participating GLCWC pilot project teams to ensure that there would be a complete understanding of all methodologies being evaluated and to improve our collective ability to standardize technique being tested by multiple teams. For various reasons, this workshop did not occur, and we believe that this may have compromised our ability to be certain that we were correctly employing field sampling procedures for coastal wetland macroinvertebrate communities.

Our recommendation for applying this indicator into a comprehensive coastal wetland monitoring plan is to develop a mechanism that ensures standardization of this sampling technique by who even will participate in any coastal wetland monitoring scheme put forth by the GLCWC. This should include the following components 1) produce copies of standard macroinvertebrate sampling protocols and distribute these to all parties participating in Great Lakes coastal wetland macroinvertebrate monitoring, and 2) produce necessary training materials (presentation materials, sampling equipment) so that training resources are available for those who want to learn how to adopt macroinvertebrate monitoring components of any GLCWC coastal wetland monitoring program.

7.3.3 Basin-wide Applicability and Sampling by Wetland Type

We believe that the macroinvertebrate field collection methodology suggested by the GLCWC was quite was easily applied across all 14 wetland study sites at Long Point, Lake Erie. However, we encountered more uncertainties in how to process samples following Uzarski's protocol because we most often collected considerable aquatic vegetation in our net sweeps. This made it very difficult to sub-sample by grids in the sorting pan, and therefore we often resorted to opportunistically selecting specimens both directly from the vegetation and from the sorting pan. In all cases though we made every effort to collect samples that were representative to the contents of the sweep sample. If proper measures are taken to provide adequate guidelines and training, we believe that this field collection methodology can be easily applied to all wetland types across the Great Lakes basin.

7.3.4 Availability of Complementary Data

Complementary macroinvertebrate community data may be available through the Ontario Ministry of Environment, but we are not aware of such data from Long Point wetland sites.

7.4 Literature Cited

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 19:869-882

Geomorphic Classification Committee. 2001. Great Lakes Coastal Wetlands Classification System. http://www.glc.org/monitoring/wetlands/.

8.0 AQUATIC PLANT COMMUNITY SAMPLING

8.1 Methodology

Aquatic vegetation communities were mapped previously by the Long Point Waterfowl and Wetlands Research Fund using 1:10,000 colour infrared aerial photographs. These community maps were used to identify locations for placing plant community sampling transects within each wetland site.

Aquatic plant sampling was sub-contracted to Dr. J. Bowles, who is an experienced botanist with extensive experience in Long Point plant community dynamics. Dr. Bowles was assisted by our field technician, and together they collected plant community health data at Long Point wetland sites. Seventeen discrete sampling locations (representing eleven recognized wetland sites) were sampled for aquatic plant community health at Long Point coastal wetlands. Wetland types were classified (beach barrier, open lacustrine, protected embayment) prior to commencing field-sampling activities.

Plant communities within major plant community zones (emergent and submerged) were quantitatively sampled using one metre or less quadrats following Don Uzarski/Dennis Albert Grand Valley State University team's methodology. Submergent zones were sampled only when deemed present within any given quadrat. Floristic Quality Indices (FQI) (with lab verification) were assigned to each site following taxonomic identification of wetland plants that occurred in representative plant communities. Collaboration and correspondence with Dr. Dennis Albert was done prior to and during this process.

Sampling was conducted on foot along transects perpendicular to the hydrologic gradient. Along each transect, five randomly located quadrats, 0.5 m square in area, were sampled for aquatic plants in each vegetation zone. The starting point for each transect was randomly located, beginning within 25 m of the upland edge of the wet meadow zone, with sampling points located 25 m apart. The location of the sampling quadrat was based on a random bearing 1 to 9 m from the sampling point. Ecological Land Classification (ELC) community code (herbaceous, shrub swamp, tree swamp, emergent marsh, submergent marsh) and water depth for each quadrat were recorded at each quadrat prior to sampling. Within each quadrat, percent cover was estimated for each plant species for emergent, floating and submergent macrophyte species. Substrate, organic depth, and water clarity (secchi disk) were also recorded in each quadrat. For most wetlands, sampling was restricted to two zones; wet meadow and emergent/submergent zone. In those cases where there was a wide submergent zone without emergent vegetation, additional quadrats were included in sampling at the researcher's discretion. In those cases where there was a narrow emergent zone (e.g., open lacustrine sites), fewer quadrats were sampled in a transect and additional shorter transects were sampled.

Overall species diversity was evaluated by conducting fifteen-minute random observations within each plant zone. Extensiveness of many coastal wetlands required a fifteen-minute random walk to record additional habitat and species diversity data, especially for wet meadow zones. Joint sampling of submergent and emergent zones during random walks proved adequate, but depended on wetland size.

Evaluation of invasive exotic plants required two components; 1) dense monoculture stands were identified and quantified by aerial photos, and 2) ground verification. Thus, it was important to determine presence/absence of lower densities of invasive plants in the 5 random quadrats along transects. Along transects, not only was presence of invasive species measured, but also diversity of different invasive species that were present. All aquatic plant data were recorded on standard data forms, and were later entered into a Microsoft Access relational database.

8.2 Results

Copies of our Long Point wetland aquatic plant community database were sent to Dr. Dennis Albert at Michigan State University, where Dr. Albert has included our data into an analysis to develop aquatic plant community IBIs for Great Lakes coastal wetlands.

Below we provide a summary describing locations and dates of our aquatic plant community sampling (Table 8-1) and we also provide a summary of our raw data in Appendix 1.

8.3 Discussion

Dr. Albert will provide a discussion of the results for aquatic plant community sampling data that were collected at Long Point coastal wetlands, which will be included in his report to the GLCWC. In our discussion we provide information pertaining to our experiences in implementing protocol for sampling aquatic plant communities that was agreed upon by the GLCWC PWT and by participating members of GLCWC year-one pilot study teams. Specifically, our discussion is outlined to address the six criteria for testing feasibility of applying indicators in a Great Lakes coastal wetlands monitoring plan. The six criteria are 1) cost, 2) measurability, 3) basin-wide applicability, 4) availability of complementary existing research data, 5) indicator sensitivity to wetland condition changes, and 6) ability to set endpoints or attainment levels. For this indicator, we can provide some discussion about only the first four criteria, as the latter two can be discussed only by Dr. Albert, who is processing and analyzing Long Point wetlands aquatic plant community sampling data to answer the latter two criteria (#5 and #6).

8.3.1 Cost

8.3.1.1 Equipment

The following table breaks down costs of data collection at the 17 wetland sites sampled at Long Point for plant community health (Table 8-1). These costs are broken down into consumable (one-time use) and non-consumable (used multiple times). These costs represent those required to carry out field activities for this indicator. The values are for all 17 sample locations because cost did not differ considerably among wetland types.

Our itemized costs exclude those for many pieces of equipment required to sample plant community health because our sub-contractor already had purchased this equipment.

Table 8-1. Descriptions of sample site locations, and sample dates for 17 Long Point coastal wetlands sampled for aquatic plant community health.

Sampling Area	Study Site[1]	Wetland Classification[2]	Plant Zone	Transect[3,4]	Date	UTM North	UTM East
Bluff Marsh	Bluff Marsh	Barrier Protected/Protected Embayment	Submergent	1 (5)(1)	31/7/02	4712012	17 570267
			Emergent	2 (4)(1)	4/9/02	4712028	17 569952
			Emergent	3 (4)(1)	4/9/02	4711898	17 569611
			Emergent	4 (4)(1)	4/9/02	4712216	17 569435
Booth's Harbour	Booth's Harbour	Open Shoreline/Open Embayment	Emergent	1(9)(1)	6/8/02	4722383	17 548300
			Emergent	2 (5)(1)	6/8/02	4721898	17 547462
Causeway	Causeway[5]	Open Shoreline	Emergent	1 (5)(1)	8/8/02	4715829	17 545295
Colletta Bay	Crown Marsh	Open Embayment/Protected Embayment	Emergent	1 (4)(1)	8/8/02	4714583	17 546651
			Emergent	2 (4)(1)	8/8/02	4714976	17 547093
Courtright Ridge	Helmer's Pond	Barrier Protected /Open Embayment	Emergent	1 (5)(1)	30/7/02	4712450	17 559270
			Submergent	2 (5)(1)	30/7/02	4712843	17 560916
Hahn Marsh	Hahn Marsh	Barrier Protected	Emergent	1 (4)(1)	14/8/02	4713974	17 539466
			Submergent	2 (3)(1)	14/8/02	4714092	17 539255
			Emergent	3 (4)(1)	14/8/02	4714251	17 539124
			Emergent	4 (4)(1)	14/8/02	4714145	17 539861
Helmer's Pond	Helmer's Pond	Barrier Protected /Open Embayment	Emergent	1 (5)(1)	31/7/02	4712690	17 561567
Lee Brown Marsh	Lee Brown Marsh	Barrier Beach Lagoon	Emergent	1 (7)(1)	15/8/02	4714503	17 540698
			Submergent	2 (5)(1)	15/8/02	4714101	17 540821
			Emergent	3 (5)(1)	15/8/02	4713800	17 540214
			Emergent	4 (3)(1)	15/8/02	4714182	17 540413
			Emergent	5 (4)(1)	15/8/02	4714602	17 540034
Little Rice Bay	Little Rice Bay	Open Embayment/Sand Spit Embayment	Emergent	1 (5)(1)	9/8/02	4715183	17 552490
			Emergent	2 (6)(1)	13/8/02	4715017	17 553178
Lower Big Creek	Big Creek	Barrier Protected/Drowned Rivermouth	Emergent	1 (5)(1)	29/7/02	4714914	17 545837
			Emergent	2 (5)(1)	29/7/02	4714624	17 544507
			Submergent	3 (5)(1)	29/7/02	4715038	17 544678
			Herbaceous	4 (5)(1)	29/7/02	4713986	17 543587
			Herbaceous	5 (5)(1)	29/7/02	4714398	17 543305
Port Rowan	Port Rowan	Open Embayment/Open Shoreline	Emergent	1 (7)(1)	6/8/02	4720278	17 545952
			Emergent	2 (7)(1)	6/8/02	4719839	17 545662
			Emergent	3 (5)(1)	8/8/02	4719362	17 545354
			Emergent	4 (6)(1)	8/8/02	4719057	17 545183
Long Point Provincial Park	Long Point Provincial Park	Open Embayment	Emergent	1 (9)(1)	9/8/02	4714586	17 549848
			Emergent	2 (6)(1)	9/8/02	4714760	17 556857
			Emergent	3 (5)(1)	9/8/02	4714924	17 551707
Smith Marsh	Smith Marsh	Open Embayment/Drowned Rivermouth	Emergent	1 (5)(1)	8/8/02	4717821	17 544737
Squire's Ridge	Helmer's Pond	Barrier Protected /Open Embayment	Herbaceous	1 (5)(1)	30/7/02	4712348	17 562114
			Emergent	2 (5)(1)	30/7/02	4712227	17 561051
			Herbaceous	3 (5)(1)	30/7/02	4712036	17 560219
Thoroughfare	Little Rice Bay	Open Embayment/Sand Spit Embayment	Emergent	1 (5)(1)	13/8/02	4716239	17 553803
			Emergent	2 (5)(1)	13/8/02	4716501	17 554250
			Emergent	3 (4)(1)	13/8/02	4716007	17 554143
Upper Big Creek	Big Creek	Barrier Protected/Drowned Rivermouth	Emergent	1 (5)(1)	13/8/02	4716904	17 544653
Velocity Creek	Little Rice Bay	Open Embayment/Sand Spit Embayment	Emergent	1 (7)(1)	16/8/02	4713988	17 551757
			Emergent	2 (5)(1)	16/8/02	4713903	17 551984
			Emergent	3 (4)(1)	16/8/02	4713869	17 552440

[1] Some sites were combined for subsequent site ranking and MMP indicators analysis due to similarity and proximity.
[2] Coastal wetland classifications followed descriptions agreed upon by the GLCWC Geomorphic Classification Committee (2001).
3
4
[5] Study site added after field season commencement.

Table 8-2. Costs required to conduct aquatic plant sampling in 11 Long Point coastal wetlands (C = Consumable, N = Non-consumable).

Item	Cost (CDN)	Sampling Task[1]	C/N
Field Staff Costs	$4,052.00		C
Use of refrigerator for storing field samples	$100.00	4	N
Boat Rental for Summer	$150.00		C
Fuel and oil for boat	$42.50		C
Rental vehicle	$107.00	1, 2, 3, 4, 6	C
Fuel for car rental	$33.00	1, 2, 3, 4, 6	C
Federal Express	$28.00	1, 2, 3, 4, 6	C
Case for Digital Camera	$23.00	1, 2, 3, 4, 6	N
Office Supplies	$14.50	1, 2, 3, 4, 6	C
Flashlight (2)	$44.00	1, 2, 3, 4, 6	N
Dry Sacks (2)	$46.00	1, 2, 3, 4, 6	N
Black Auto Goop	$7.50	1, 2, 3, 4, 6	N
Fox 40 whistles (2)	$10.00	1, 2, 3, 4, 6	N
Trail tape	$13.00	1, 2, 3, 4, 6	C
Batteries	$200.00	1, 2, 3, 4, 6	C
Cowhide gloves (3)	$21.00	1, 2, 3, 4, 6	N
Sun block (3)	$34.50	1, 2, 3, 4, 6	C
Measuring tape - 100 m	$57.50	1, 2, 3, 4, 6	N
Relfective Tape	$28.00	1, 2, 3, 4, 6	C
Safety Tape	$11.50	1, 2, 3, 4, 6	C
Duct Tape	$16.00	1, 2, 3, 4, 6	C
Insect repellent (3)	$23.00	1, 2, 3, 4, 6	C
Hammer	$18.50	1, 2, 3, 4, 6	N
Chest waders (4)	$360.00	1, 2, 3, 4, 6	N
Accessories for boat	$205.00	1, 2, 3, 4, 6	N
Gas and oil for boat	$95.00	1, 2, 3, 4, 6	C
Zip-Loc freezer bags	$2.50	1, 2, 3, 4, 6	N
Plastic gas can	$10.50	1, 2, 3, 4, 6	N
Rope - 50 ft	$11.50	1, 2, 3, 4, 6	N
Total Cost of Aquatic Plant Sampling	**$5,765.00**		

[1] Numbers indicate equipment shared with other sampling tasks. 1 = birds, 2 = amphibians, 3 = fish, 4 = macroinvertebrates, 5 = aquatic plants, 6 = water quality and 7 = miscellaneous.

8.3.1.2 Personnel
Costs associated with aquatic plant community sampling are included in Table 8-2. To adequately sample coastal wetlands for plant community health, experienced personnel who are able to identify the many and diverse aquatic taxa are required. This would most often require hiring a professional botanist to carry out these activities. Compared to costs for other indicators, the need to engage experienced botanical personnel may be prohibitive for any extensive coastal wetland monitoring program.

Two workers, a leading botanical researcher and a field technician, were required to complete data collection activities at all of the Long Point wetland sites. Including travel time, each site required about five to six hours to sample. Travel time varied considerably at our sites, as some were easily accessed from main shore on public land, whereas other sites required boat travel to remote sites near the end of the sand spit. Taxonomic complexity of plant communities varied considerable among some sites and also added considerable variation in sampling duration for any sampling transect.

Costs for analyzing the community data can be reported only by Dr. Albert, who will report on all of our Long Point coastal wetland aquatic plant community data for IBI analyses.

8.3.2 Measurability

8.3.2.1 Expertise and training
Clearly, in order to monitor aquatic plant community health using this technique, field monitoring personnel should have some prior knowledge and/or training in the following: 1) small outboard and boat operation; 2) how to identify and key aquatic plant taxa to the level of species or sub-species.

Further, from our experiences during the 2002 pilot project field season, it is our opinion that personnel participating in plant community sampling must have the following qualifications:

1) be able to properly identify localities for transect sampling through the use of air photo interpretation and mapping;
2) be able to properly set up transects and quadrats for sampling in the field;
3) adequate taxonomic identification skills and specimen collection and preservation skills is required by at least one crew member to ensure that aquatic plant communities in coastal wetlands are properly sampled in a standardized manner.

Bird Studies Canada offered to host a one- to two-day training workshop for participating GLCWC pilot project teams to ensure that there would be a complete understanding of all methodologies being evaluated and to improve our collective ability to standardize techniques being tested by multiple teams. For various reasons, this workshop did not occur, however, we are quite confident that we correctly carried out aquatic plant community sampling procedures according to protocol specified by Dr. Albert, primarily because we sub-contracted this work to a professional who consulted extensively with Dr. Albert.

8.3.3 Recommendations on Methodology

If the GLCWC PMT deems the use of this plant community sampling procedure as a viable and affordable method for monitoring Great lakes coastal wetland plant community health, then we believe that the use of the methods that we employed at Long Point coastal wetland sites is quite useful and productive. Our recommendation for applying this indicator into a comprehensive coastal wetland monitoring scheme is to develop a mechanism that ensures standardization of this sampling technique by who ever will participate in any coastal wetland monitoring scheme put forth by the GLCWC. This should include the following components 1) produce copies of standard plant community sampling protocols and data collection forms and distribute these to all parties participating in Great Lakes coastal wetland plant community monitoring, and 2) produce necessary training materials (presentation materials, sampling equipment) so that training resources are available for those who want to learn how to adopt plant community monitoring components into any GLCWC coastal wetland monitoring program.

8.3.4 Basin-wide Applicability and Sampling by Wetland Type

The plant field collection methodology suggested by the GLCWC was quite easily applied by our sub-contractor across all wetland study sites at Long Point, Lake Erie. We believe that this methodology, including sampling protocol and sampling equipment, can be applied to most marsh-type coastal wetland sites throughout the Great Lakes basin. Dr. Albert will report further on the basin-wide applicability of including this indicator into any basin-wide coastal wetlands monitoring scheme.

8.3.5 Availability of Complementary Data

We are not aware of any comparable complementary quantitative plant community data from Long Point wetlands, however the Long Point Waterfowl and Wetlands Research Fund does have extensive information about plant community composition and locations, as well as an increasing inventory of information about invasive non-native wetland macrophyte communities within Long Point coastal wetlands. These data are available at any time to complement data collected by the GLCWC.

8.4 Literature Cited

Geomorphic Classification Committee. 2001. Great Lakes Coastal Wetlands Classification System. http://www.glc.org/monitoring/wetlands/.

9.0 GENERAL SUMMARY

9.1 Marsh bird and Anuran Community Attribute Sensitivity

Nineteen community attributes from marsh bird and anuran species assemblages were evaluated for their response to wetland disturbance rankings developed for 11 Long Point coastal wetland sites and 12 Lake Ontario coastal wetland sites. These included community characteristics describing species richness, diversity, abundance and proportional occurrence and abundance.

For marsh bird community data, attributes that showed the most promise in predicting wetland site disturbance gradients included proportion of indicator species of total species present (Long Point data), proportional abundance of Marsh Wren (Long Point data), proportional abundance of Blackbirds of total bird abundance (Lake Erie data), and proportional abundance of aerial forager species of total bird abundance (Long Point data). Among these, only proportional abundance of Blackbirds (Lake Ontario data) was highly sensitive to the site disturbance gradient. Each of these attributes showed patterns of response in the direction one would expect. Future work should consider further examination and development of these and similar bird community attributes for predicting wetland site disturbances.

Bird diversity responded positively to site disturbance rankings at Long Point, the opposite direction one would expect based on patterns of disturbance.

Other approaches should attempt to examine and explore state-state responses of marsh bird data against other biotic state variables known to respond strongly to stressor gradients.

For anuran community data, only three attributes showed any meaningful promise in their ability to predict wetland site disturbances and these were proportion of indicator species of total species present (Long Point data), anuran species richness (Lake Ontario data), and anuran indicator species richness (Lake Ontario data).

Anuran species richness and anuran species diversity showed positive responses to site disturbance rankings, the opposite direction one would expect based on patterns of disturbance. Other non-disturbance related factors might be responsible for these results.

Overall, most attributes were not able to predict site disturbance rankings and those few that showed some level of response were weak in comparison to attributes for other community assemblages. Attributes showing some level of response may be best combined with other attributes from other wetland taxonomic groups to contribute to multi-metric indices of biotic integrity for Great Lakes coastal wetlands.

Our examinations explored use of simple linear regression analysis but state-stressor relationships may be non-linear or n-order linear in nature.

Further work should focus attention toward standardizing and improving site selection methodologies, standardizing level of sampling effort, coordinating to rigorously characterize level of disturbance and stress affecting each site, and coordinating to standardize and monitoring activities and techniques. Multivariate ordinations and higher order linear regression should be used to examine state-stressor and state-state responses using marsh bird and amphibian community attribute data.

9.2 Total Resource Requirements

Financial Statement

(all dollar figures are quoted in $US at a conversion rate of $ 0.66 Canadian)

LINE ITEM	GLC Contribution	BSC Contribution	Total Budget	Actual Expenses	Balance
Aq. Surveys Sci. wages	$13,156.00		$13,156.00	$13,156.00	$0.00
Aq. Surveys Sci. benefits	$1,973.00		$1,973.00	$1,973.00	$0.00
Senior Scientist wages	$1,375.00		$1,375.00	$2,750.00	-$1,375.00
Senior Scientist benefits	$206.00		$206.00	$412.00	-$206.00
GIS Specialist	$1,056.00		$1,056.00	$1,056.00	$0.00
GIS benefits	$158.40		$158.40	$158.00	$0.40
Field Contractors (2)	$7,656.00		$7,656.00	$7,973.00	-$317.00
Field contractor benefits	$1,148.40		$1,148.40	$1,195.95	-$47.55
Data Mgt/Vol Coordination	$1,980.00		$1,980.00	$1,980.00	$0.00
Data Mgt/Vol Coordination benefits	$297.00		$297.00	$297.00	$0.00
Fish sampling	$2,640.00		$2,640.00	$2,376.00	$264.00
Fish technician benefits	$396.00		$396.00	$356.00	$40.00
Community mapping	$5,280.00	$7,920.00	$13,200.00	$13,200.00	$0.00
Wages/Benefits subtotal	$37,321.80	$7,920.00	$45,241.80	$46,882.95	-$1,641.15
Boat	$990.00		$990.00	$871.00	$119.00
Lab space rental	$198.00		$198.00	$198.00	$0.00
GST paid on purchases	$330.00		$330.00	$642.00	-$312.00
Pers. vehicle mileage	$1,584.00		$1,584.00	$1,594.00	-$10.00
Other travel	$2,475.00		$2,475.00	$1,073.00	$1,402.00
Food & beverage	$2,475.00		$2,475.00	$254.00	$2,221.00
Telephone long-distance	$165.00		$165.00	$463.00	-$298.00
Courier	$66.00		$66.00	$164.00	-$98.00
Photocopying	$165.00		$165.00	$279.00	-$114.00
Postage	$66.00		$66.00	$84.00	-$18.00
Computer	$792.00		$792.00	$950.00	-$158.00
Stationery	$33.00		$33.00	$114.00	-$81.00
Project Mat. and equip.	$4,716.00		$4,716.00	$5,807.00	-$1,091.00
Sub Total	$51,376.80	$7,920.00	$59,296.80	$59,375.95	-$79.15
25% Project mgt/adm on salaries	$9,330.45	$1,980.00	$11,310.45	$11,720.74	-$410.29
Total Budget	**$60,707.25**	**$9,900.00**	**$70,607.25**	**$71,096.69**	-$489.44

10.0 APPENDIX

Table A-1. Correlation matrix of water chemistry parameters.

	Air Temp.	Water Temp.	Depth	Turbidity	Conductivity	DO	pH	TDS	NO3	NH3	SRP
Air Temp.	1.00										
Water Temp.	0.61	1.00									
Depth	0.16	-0.27	1.00								
Turbidity	-0.08	-0.12	-0.40	1.00							
Conductivity	-0.29	-0.49	-0.12	0.53	1.00						
DO	-0.22	0.19	-0.01	-0.39	-0.64	1.00					
pH	0.01	-0.02	-0.05	-0.04	-0.19	0.05	1.00				
TDS	-0.21	-0.44	-0.09	0.51	0.97	-0.64	-0.20	1.00			
NO3	-0.09	-0.06	-0.23	0.12	0.32	-0.11	0.04	0.30	1.00		
NH3	-0.01	-0.10	-0.40	0.88	0.62	-0.44	-0.60	0.58	0.38	1.00	
SRP	0.00	-0.06	-0.36	0.97	0.51	-0.36	-0.50	0.52	0.14	0.87	1.00

Table A-2. Common name, scientific name and species code of marsh bird indicator species.

Common Name	Scientific Name	Species Code
American Bittern	*Botaurus lentiginosus*	AMBI
American Coot	*Fulica americana*	AMCO
Black Tern	*Chilidonias niger*	BLTE
Blue-winged Teal	*Anas discors*	BWTE
Common Moorhen	*Gallinula chloropus*	COMO
Common Moorhen/American Coot		MOOT
Common Snipe	*Capella gallinago*	COSN
Least Bittern	*Ixobrychus exilis*	LEBI
Marsh Wren	*Cistothorus palustris*	MAWR
Pied-billed Grebe	*Podilymbus podiceps*	PBGR
Sora	*Porzana carolina*	SORA
Virginia Rail	*Rallus limicola*	VIRA

Table A-3. Common name, scientific name and species code of amphibian indicator species.

Common Name	Scientific Name	Species Code
Bullfrog	*Rana catesbeiana*	BULL
Chorus Frog	*Pseudacris triseriala*	CHFR
Northern Leopard Frog	*Rana pipiens*	NLFR
Mink Frog	*Rana septentrionalis*	MIFR
Spring Peeper	*Hyla crucifer*	SPPE

Table A-4. Species code, common name and scientific name of marsh bird and amphibian species.

Species Code	Common Name	Scientific Name
Marsh Bird		
ALFL	Alder Flycatcher	*Empidonax alnorum*
AMBI	American Bittern	*Botaurus lentiginosus*
AMCO	American Coot	*Fulica americana*
BANS	Bank Swallow	*Riparia riparia*
BARS	Barn Swallow	*Hirudo rustica*
BLTE	Black Tern	*Chilidonias niger*
BWTE	Blue-winged Teal	*Anas discors*
CAGO	Canada Goose	*Branta canadensis*
CHSW	Chimney Swift	*Chaetura pelagica*
CLSW	Cliff Swallow	*Petrochelidon pyrrhonota*
COGR	Common Grackle	*Quiscalus quiscula*
COMO	Common Moorhen	*Gallinula chloropus*
CONI	Common Nighthawk	*Chordeiles minor*
COSN	Common Snipe	*Capella gallinago*
COYE	Common Yellowthroat	*Geothlypis trichas*
EAKI	Eastern Kingbird	*Tyrannus tyrannus*
LEBI	Least Bittern	*Ixobrychus exilis*
MALL	Mallard	*Anas platyrhynchos*
MAWR	Marsh Wren	*Cistothorus palustris*
MOOT	Undifferentiated Moorhen/coot	
MUSW	Mute Swan	*Cygnus olor*
NRWS	Northern Rough-winged Swallow	*Stelgidopteryx ruficollis*
PBGR	Pied-billed Grebe	*Podilymbus podiceps*
PUMA	Purple Martin	*Pronge subis*
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*
SACR	Sandhill Crane	*Grus canadensis*
SEWR	Sedge Wren	*Cistothorus palustris*
SORA	Sora	*Porzana carolina*
SOSP	Song Sparrow	*Melospiza melodia*
SWSP	Swamp Sparrow	*Melospiza geogiana*
TRES	Tree Swallow	*Iridoprocne bicolor*
VIRA	Virginia Rail	*Rallus limicola*
WILF	Willow Flycatcher	*Empidonax trailli*
YWAR	Yellow Warbler	*Dendroica petechia*
Amphibian		
AMTO	American toad	*Bufo americanus*
BULL	Bullfrog	*Rana catesbeiana*
CHFR	Chorus frog	*Acris crepitans*
GRFR	Green frog	*Rana clamitans*
NLFR	Northern leopard frog	*Rana pipiens*
PIFR	Pickerel frog	*Rana palustris*
SPPE	Spring peeper	*Hyla crucifer*
WOFR	Wood frog	*Rana sylvatica*

Table A-5. Study site, species, indicator species, total abundance and mean abundance of marsh birds among Long Point coastal wetland sampling areas.

Study Site	Species	Indicator Species	Total Abundance	Mean Abundance
BC	AMBI	1	1	1.00
BC	AMCO	1	2	1.00
BC	AMGO	0	2	1.00
BC	AMRO	0	2	1.00
BC	BANS	0	6	1.50
BC	BARS	0	57	3.35
BC	BLTE	1	6	2.00
BC	CAGO	0	5	1.67
BC	CEDW	0	5	5.00
BC	CHSP	0	2	2.00
BC	COGR	0	6	1.20
BC	COMO	1	1	1.00
BC	COYE	0	34	1.62
BC	EAKI	0	4	1.00
BC	GRCA	0	2	2.00
BC	GTBH	0	4	1.33
BC	MAWR	1	37	2.18
BC	MODO	0	1	1.00
BC	MUSW	0	2	1.00
BC	NRWS	0	1	1.00
BC	PUMA	0	12	3.00
BC	RWBL	0	88	3.52
BC	SACR	0	3	3.00
BC	SOSP	0	30	1.50
BC	SWSP	0	61	2.65
BC	TRES	0	59	3.69
BC	WAVI	0	3	1.00
BC	WODU	0	1	1.00
BC	YWAR	0	12	1.50
BH	BANS	0	4	2.00
BH	BARS	0	12	6.00
BH	CEDW	0	1	1.00
BH	COGR	0	1	1.00
BH	COYE	0	3	1.50
BH	EAKI	0	1	1.00
BH	MAWR	1	4	2.00
BH	NOOR	0	4	2.00
BH	NRWS	0	2	2.00
BH	PUMA	0	2	2.00
BH	RWBL	0	13	4.33
BH	SOSP	0	2	1.00
BH	TRES	0	8	2.67
BH	YWAR	0	4	2.00
BM	BANS	0	12	4.00
BM	COYE	0	1	1.00
BM	LEBI	1	5	1.25

BM	MALL	0	1	1.00
BM	MAWR	1	25	3.57
BM	NRWS	0	23	4.60
BM	RWBL	0	21	3.00
BM	SOSP	0	2	2.00
BM	SWSP	0	5	1.67
BM	TRES	0	126	18.00
CM	AMBI	1	5	1.00
CM	AMGO	0	2	1.00
CM	AMRO	0	8	1.14
CM	BANS	0	7	1.40
CM	BARS	0	34	3.40
CM	BLTE	1	4	4.00
CM	CHSP	0	3	1.00
CM	COGR	0	3	3.00
CM	COTE	0	1	1.00
CM	COYE	0	12	1.50
CM	EAKI	0	4	1.00
CM	EUST	0	201	100.50
CM	FOTE	0	3	3.00
CM	GRCA	0	1	1.00
CM	GRHE	1	1	1.00
CM	GTBH	0	2	1.00
CM	HOWR	0	1	1.00
CM	LEBI	1	4	1.33
CM	MAWR	1	64	3.05
CM	MODO	0	3	1.50
CM	MUSW	0	2	2.00
CM	NOCA	0	2	1.00
CM	NRWS	0	6	3.00
CM	PUMA	0	16	2.29
CM	RWBL	0	84	3.82
CM	SOSP	0	16	1.23
CM	SWSP	0	32	2.13
CM	TRES	0	97	5.11
CM	WIFL	0	3	1.00
CM	WODU	0	6	2.00
CM	YWAR	0	7	1.40
HN	AMBI	1	1	1.00
HN	AMRO	0	6	1.00
HN	BANS	0	26	4.33
HN	BARS	0	2	1.00
HN	BOGU	0	130	130.00
HN	CAGO	0	2	2.00
HN	COGR	0	5	1.67
HN	COMO	1	1	1.00
HN	COYE	0	20	1.82
HN	EAKI	0	6	1.20
HN	GRCA	0	3	1.50
HN	GRHE	1	2	1.00
HN	INBU	0	2	2.00

HN	MALL	0	2	1.00
HN	MAWA	0	1	1.00
HN	MAWR	1	19	2.11
HN	MODO	0	1	1.00
HN	PUMA	0	3	3.00
HN	RBGU	0	13	4.33
HN	RWBL	0	55	3.93
HN	SORA	1	2	1.00
HN	SOSP	0	8	1.00
HN	SWSP	0	41	2.93
HN	TRES	0	27	2.70
HN	VIRA	1	5	1.67
HN	WAVI	0	3	1.00
HN	WIFL	0	7	1.17
HN	YWAR	0	30	2.14
HP	AMBI	1	1	1.00
HP	AMGO	0	2	2.00
HP	AMRO	0	1	1.00
HP	BEKI	0	1	1.00
HP	BLTE	1	8	4.00
HP	CHSP	0	3	1.50
HP	COGR	0	1	1.00
HP	COTE	0	1	1.00
HP	COYE	0	17	1.42
HP	DOWO	0	3	1.00
HP	EAKI	0	6	1.50
HP	EUST	0	6	3.00
HP	EWPE	0	3	1.00
HP	GRHE	1	2	1.00
HP	GTBH	0	2	1.00
HP	HOWR	0	1	1.00
HP	LEBI	1	1	1.00
HP	MAWR	1	14	1.75
HP	MODO	0	2	1.00
HP	NOFL	0	1	1.00
HP	NOOR	0	6	6.00
HP	RBGU	0	1	1.00
HP	RWBL	0	46	3.83
HP	SOSP	0	17	1.55
HP	SWSP	0	7	1.40
HP	TRES	0	100	7.14
HP	TUSW	0	1	1.00
HP	WAVI	0	1	1.00
HP	WODU	0	3	3.00
HP	YWAR	0	13	1.30
LB	AMGO	0	1	1.00
LB	AMRO	0	4	1.33
LB	BANS	0	23	4.60
LB	BARS	0	16	4.00
LB	BLTE	1	5	5.00
LB	CATE	0	8	8.00
LB	CEDW	0	6	6.00
LB	CHSP	0	3	1.00

LB	CHSW	0	4	4.00
LB	COGR	0	2	1.00
LB	COYE	0	14	1.75
LB	EAKI	0	6	2.00
LB	FOTE	0	6	6.00
LB	LEBI	1	2	2.00
LB	LIGU	0	23	11.50
LB	MAWR	1	5	2.50
LB	MODO	0	1	1.00
LB	NRWS	0	4	4.00
LB	RWBL	0	44	5.50
LB	SOSP	0	8	1.33
LB	SWSP	0	23	2.88
LB	TRES	0	52	8.67
LB	VIRA	1	1	1.00
LB	WAVI	0	3	1.50
LB	WIFL	0	1	1.00
LB	WODU	0	1	1.00
LB	YWAR	0	21	3.00
LP	BANS	0	3	1.50
LP	BARS	0	10	2.50
LP	COGR	0	1	1.00
LP	COYE	0	6	2.00
LP	FOTE	0	2	2.00
LP	LEBI	1	1	1.00
LP	MAWR	1	15	3.00
LP	NRWS	0	4	1.33
LP	PUMA	0	1	1.00
LP	RWBL	0	21	4.20
LP	SOSP	0	3	1.00
LP	SWSP	0	9	2.25
LP	TRES	0	20	4.00
LP	YWAR	0	1	1.00
LR	AMBI	1	3	1.50
LR	BANS	0	16	3.20
LR	BARS	0	7	1.75
LR	BLTE	1	2	2.00
LR	COGR	0	1	1.00
LR	COYE	0	10	1.43
LR	EAKI	0	1	1.00
LR	GTBH	0	1	1.00
LR	LEBI	1	4	1.33
LR	MAWR	1	59	5.36
LR	NRWS	0	17	3.40
LR	PBGR	1	2	1.00
LR	PUMA	0	7	3.50
LR	RWBL	0	51	4.64
LR	SOSP	0	5	1.25
LR	SWSP	0	18	2.25
LR	TRES	0	45	5.63
LR	VIRA	1	1	1.00
LR	WODU	0	3	1.50
LR	YWAR	0	1	1.00
PR	AMCO	1	1	1.00

PR	AMRO	0	4	2.00
PR	BANS	0	10	2.50
PR	BARS	0	31	5.17
PR	CAGO	0	10	10.00
PR	CARW	0	1	1.00
PR	CHSP	0	1	1.00
PR	CHSW	0	1	1.00
PR	CLSW	0	1	1.00
PR	COGR	0	5	1.67
PR	COMO	1	1	1.00
PR	COYE	0	8	1.33
PR	EAKI	0	1	1.00
PR	EUST	0	1	1.00
PR	GRCA	0	1	1.00
PR	GTBH	0	2	1.00
PR	KILL	0	2	2.00
PR	LESA	0	1	1.00
PR	MAWR	1	11	1.83
PR	MODO	0	2	2.00
PR	MUSW	0	1	1.00
PR	NOCA	0	1	1.00
PR	NOOR	0	1	1.00
PR	RWBL	0	35	5.00
PR	SOSA	0	14	14.00
PR	SOSP	0	8	1.60
PR	SWSP	0	2	1.00
PR	TRES	0	43	7.17
PR	YWAR	0	8	1.33
SM	AMCO	1	7	1.40
SM	AMGO	0	1	1.00
SM	AMRO	0	1	1.00
SM	BANS	0	7	2.33
SM	BARS	0	19	3.17
SM	BEKI	0	2	2.00
SM	COGR	0	6	2.00
SM	COYE	0	13	2.60
SM	DOWO	0	1	1.00
SM	EAKI	0	2	2.00
SM	EUST	0	1	1.00
SM	GTBH	0	4	1.33
SM	KILL	0	2	2.00
SM	LESA	0	3	1.50
SM	MAWR	1	16	2.67
SM	MODO	0	1	1.00
SM	RWBL	0	29	4.83
SM	SORA	1	1	1.00
SM	SOSP	0	8	1.60
SM	SWSP	0	10	2.00
SM	TRES	0	39	6.50
SM	WIFL	0	1	1.00
SM	YWAR	0	5	2.50

Table A–6. Study site, species, indicator species and max calling code of amphibians among Long Point coastal wetland sampling areas.

Study Site	Species	Indicator Species	Max Calling Code
BC	AMTO	0	2
BC	BULL	1	1
BC	CHFR	1	2
BC	FOTO	0	1
BC	GRFR	0	3
BC	GRTR	0	2
BC	NLFR	1	2
BC	SPPE	1	3
BH	AMTO	0	3
BH	BULL	1	1
BH	CHFR	1	1
BH	GRFR	0	1
BH	NLFR	1	1
BH	SPPE	1	1
BM	AMTO	0	1
BM	BULL	1	1
BM	CHFR	1	1
BM	GRFR	0	3
BM	GRTR	0	1
BM	NLFR	1	1
BM	SPPE	1	2
CM	AMTO	0	3
CM	BULL	1	3
CM	FOTO	0	3
CM	GRFR	0	3
CM	NLFR	1	2
CM	SPPE	1	1
HN	AMTO	0	1
HN	BULL	1	1
HN	CHFR	1	1
HN	FOTO	0	2
HN	GRFR	0	1
HN	GRTR	0	1
HN	NLFR	1	1
HN	SPPE	1	3
HP	BULL	1	1
HP	CHFR	1	2
HP	GRFR	0	2
HP	GRTR	0	2
HP	NLFR	1	1
HP	SPPE	1	3
LB	AMTO	0	1

LB	BULL	1	1
LB	FOTO	0	3
LB	GRFR	0	3
LB	GRTR	0	3
LB	NLFR	1	2
LB	SPPE	1	3
LP	AMTO	0	3
LP	BULL	1	1
LP	FOTO	0	2
LP	GRFR	0	1
LP	NLFR	1	1
LP	SPPE	1	1
LR	AMTO	0	3
LR	BULL	1	2
LR	CHFR	1	1
LR	FOTO	0	2
LR	GRFR	0	3
LR	NLFR	1	1
LR	SPPE	1	1
PR	AMTO	0	2
PR	BULL	1	1
PR	CHFR	1	2
PR	GRFR	0	2
PR	GRTR	0	2
PR	NLFR	1	1
PR	SPPE	1	2
SM	AMTO	0	2
SM	BULL	1	1
SM	GRFR	0	2
SM	SPPE	1	2

Table A–7. Study site, species, indicator species, total abundance and mean abundance of marsh birds among Lake Ontario coastal wetland sampling areas.

Study Site	Species	Indicator Species	Total Abundance	Mean Abundance
FB	BCNH	0	2	1.0
FB	CAGO	0	3	1.5
FB	MAWR	1	5	1.7
FB	RWBL	0	16	5.3
FB	TRES	0	51	17.0
WB (HIE)	BANS	0	45	15.0
WB (HIE)	BARS	0	2	1.0
WB (HIE)	COMO	1	2	2.0
WB (HIE)	COYE	0	2	1.0
WB (HIE)	GWTE	0	1	1.0
WB (HIE)	MALL	0	4	4.0
WB (HIE)	RWBL	0	124	41.3
WB (HIE)	SOSP	0	1	1.0
WB (HIE)	SWSP	0	2	2.0
WB (HIE)	TRES	0	5	2.5
WB (HIE)	VIRA	1	3	1.5
WB (HIE)	WIFL	0	1	1.0
WB (HIE)	YWAR	0	2	1.0
PRB	AMBI	1	1	1.0
PRB	CAGO	0	2	2.0
PRB	CATE	0	1	1.0
PRB	COGR	0	2	2.0
PRB	COMO	1	2	1.0
PRB	GTBH	0	2	2.0
PRB	MALL	0	2	2.0
PRB	MAWR	1	1	1.0
PRB	MUSW	0	4	2.0
PRB	PBGR	1	3	1.5
PRB	RWBL	0	52	7.4
PRB	SORA	1	1	1.0
PRB	SOSP	0	1	1.0
PRB	TRES	0	1	1.0
PRB	VIRA	1	1	1.0
BUB	AMBI	1	1	1.0
BUB	BLTE	1	1	1.0
BUB	BWTE	1	2	2.0
BUB	CATE	0	5	2.5
BUB	GTBH	0	1	1.0
BUB	MAWR	1	6	3.0
BUB	RWBL	0	14	7.0
BUB	SOSP	0	1	1.0
BUB	TRES	0	6	3.0
BUB	VIRA	1	4	4.0
BUB	WODU	0	2	2.0

SB	AMRO	0	1	1.0
SB	BARS	0	6	3.0
SB	COTE	0	2	2.0
SB	MAWR	1	1	1.0
SB	RWBL	0	15	7.5
SB	SWSP	0	4	2.0
SB	TRES	0	19	9.5
HBS	BARS	0	5	5.0
HBS	COGR	0	3	1.5
HBS	COYE	0	3	1.5
HBS	RWBL	0	28	9.3
HBS	SOSP	0	2	1.0
HBS	SWSP	0	8	2.7
HBS	TRES	0	9	4.5
HBS	YWAR	0	2	1.0
HB	AMBI	1	1	1.0
HB	BARS	0	1	1.0
HB	MAWR	1	2	2.0
HB	RWBL	0	14	7.0
HB	SWSP	0	3	1.5
HB	TRES	0	9	4.5
HB	VIRA	1	1	1.0
HB	YWAR	0	1	1.0
PB	DCCO	0	1	1.0
PB	MALL	0	2	1.0
PB	OSPR	0	1	1.0
PB	RWBL	0	19	9.5
PB	SWSP	0	6	3.0
PB	TRES	0	4	2.0
PB	VIRA	1	1	1.0
BB	AMBI	1	1	1.0
BB	BARS	0	2	1.0
BB	BHCO	0	11	11.0
BB	CAGO	0	1	1.0
BB	COGR	0	1	1.0
BB	MALL	0	3	1.5
BB	MAWR	1	14	4.7
BB	NOHA	0	1	1.0
BB	RWBL	0	23	7.7
BB	SOSP	0	1	1.0
BB	SWSP	0	6	2.0
BB	TRES	0	18	6.0
BB	VIRA	1	2	2.0
LC	AMRO	0	1	1.0
LC	AMWO	0	1	1.0

LC	BARS	0	3	1.5
LC	BEKI	0	3	1.5
LC	CAGO	0	3	1.5
LC	COGR	0	4	2.0
LC	GRHE	1	1	1.0
LC	MAWA	0	1	1.0
LC	MAWR	1	5	2.5
LC	MUSW	0	2	2.0
LC	RBGU	0	13	4.3
LC	RWBL	0	36	6.0
LC	SORA	1	1	1.0
LC	SOSP	0	1	1.0
LC	SWSP	0	7	1.8
LC	TRES	0	7	3.5
LC	VIRA	1	2	2.0
LC	WIFL	0	1	1.0
LC	YWAR	0	5	1.3
BI (RC)	BARS	0	3	1.5
BI (RC)	COGR	0	1	1.0
BI (RC)	RWBL	0	11	5.5
BI (RC)	SWSP	0	4	2.0
BI (RC)	TRES	0	4	4.0
BI (RC)	YWAR	0	3	1.5

Table A-8. Study site, species, indicator species and max calling code of amphibians among Lake Ontario coastal wetland sampling areas.

Study Site	Species	Indicator Species	Max Calling Code
FB	AMTO	0	2
FB	GRFR	0	1
FB	NLFR	1	2
FB	SPPE	1	1
PRB	AMTO	0	1
PRB	BULL	1	2
PRB	CHFR	1	1
PRB	GRFR	0	1
PRB	GRTR	0	3
PRB	SPPE	1	3
BUB	AMTO	0	2
BUB	BULL	1	1
BUB	CHFR	1	3
BUB	NLFR	1	3
BUB	SPPE	1	3
POB	AMTO	0	3
POB	GRFR	0	1
POB	NLFR	1	1
POB	SPPE	1	3
SB	AMTO	0	1
SB	BULL	1	1
SB	CHFR	1	2
SB	GRFR	0	1
SB	GRTR	0	3
SB	NLFR	1	1
SB	SPPE	1	3
HBS	AMTO	0	2
HBS	BULL	1	2
HBS	GRFR	0	1
HBS	GRTR	0	3
HBS	NLFR	1	1
HBS	SPPE	1	2
PB	AMTO	0	3
PB	BULL	1	1
PB	CHFR	1	2
PB	GRFR	0	1
PB	NLFR	1	1
PB	SPPE	1	3

BB	AMTO	0	1
BB	BULL	1	2
BB	CHFR	1	2
BB	GRFR	0	1
BB	NLFR	1	2
BB	SPPE	1	1
LC	GRFR	0	1
HB	BULL	1	1
HB	CHFR	1	1
HB	GRFR	0	1
HB	WOFR	0	1

Table A-9. Study site, species, indicator species, total abundance and mean abundance of marsh birds among Arcadia Lake coastal wetland sampling areas.

Study Site	Species	Indicator Species	Total Abundance	Mean Abundance
AL	AMGO	0	2	1.0
AL	BARS	0	3	3.0
AL	BEKI	0	2	1.0
AL	CAGO	0	3	1.5
AL	COGR	0	2	1.0
AL	COYE	0	6	1.5
AL	MALL	0	15	5.0
AL	MUSW	0	15	7.5
AL	RWBL	0	16	2.7
AL	SACR	0	1	1.0
AL	SEWR	0	7	2.3
AL	SORA	1	5	1.7
AL	SOSP	0	2	2.0
AL	SPSA	0	1	1.0
AL	SWSP	0	11	1.8
AL	TRES	0	14	4.7
AL	YWAR	0	1	1.0

Table A-10. Study site, species, indicator species and max calling code of amphibians among Arcadia Lake coastal wetland sampling areas.

Study Site	Species	Indicator Species	Max Calling Code
AL	AMTO	0	3
AL	CHFR	1	1
AL	GRFR	0	3
AL	GRTR	0	3
AL	NLFR	1	2
AL	SPPE	1	3

Table A-11. Study site, species, indicator species and max calling code of amphibians among Saginaw Bay coastal wetland sampling areas.

Study Site	Species	Indicator Species	Max Calling Code
SB	AMTO	0	3
SB	CHFR	1	3
SB	GRFR	0	3
SB	GRTR	0	3
SB	NLFR	1	2
SB	SPPE	1	1
SB	AMTO	0	2
SB	CHFR	1	2
SB	GRFR	0	3
SB	GRTR	0	3
SB	NLFR	1	2
SB	SPPE	1	3

Table A-12. Sampling area, study site, fyke net set number, number of species per fyke net set, species name, number of individuals and mean length by species at 12 Long Point coastal wetland sampling areas.

Sampling Area	Study Site	Set No.	No. of species	Species Name	No. of individuals	Mean length by species (mm)
Booth's Harbour	Booth's Harbour	1	10	*Ambloplites rupestris*	1	93.0
				Cyprinus carpio	3	111.3
				Dorosoma cepedianum	1	64.0
				Ictalurus nebulosus	2	71.5
				Lepomis macrochirus	6	91.5
				Micropterus salmoides	38	51.5
				Notemigonus crysoleucas	1	98.0
				Notropis heterodon	1	69.0
				Perca flavescens	1	160.0
				Pimephales notatus	2	71.0
		2	10	*Ambloplites rupestris*	4	93.3
				Cyprinus carpio	1	224.0
				Dorosoma cepedianum	4	84.8
				Fundulud diaphanus	1	54.0
				Lepistosteus osseus	2	461.0
				Lepomis gibbosus	15	114.1
				Micropterus dolomieui	5	42.2
				Micropterus salmoides	19	51.9
				Notropis heterodon	1	59.0
				Pimephales notatus	3	56.7
		3	9	*Ambloplites rupestris*	1	88.0
				Cyprinus carpio (mirror)	1	202.0
				Lepomis gibbosus	17	86.1
				Lepomis macrochirus	23	72.1
				Micropterus dolomieui	3	46.3
				Micropterus salmoides	27	51.5
				Notropis heterodon	25	57.5
				Perca flavescens	5	110.2
				Pimephales notatus	2	70.5
Bluff Marsh	Bluff Marsh	1	7	*Ambloplites rupestris*	3	90.3
				Lepomis gibbosus	1	85.0
				Lepomis macrochirus	1	60.0
				Micropterus salmoides	17	49.8
				Neobobius melanostomus	1	89.0
				Notropis heterodon	25	67.1
				Perca flavescens	1	154.0
		2	9	*Ambloplites rupestris*	10	83.1
				Fundulud diaphanus	1	71.0
				Ictalurus nebulosus	6	48.7
				Lepomis gibbosus	25	87.2
				Lepomis macrochirus	6	38.7
				Micropterus salmoides	17	53.2
				Notropis cornutus	1	62.0
				Notropis heterodon	6	66.5
				Pimephales notatus	33	55.1
		3	10	*Ambloplites rupestris*	11	101.1
				Amia Calva	1	511.0

				Esox lucius	1	560.0
				Ictalurus nebulosus	1	300.0
				Lepomis gibbosus	15	87.3
				Lepomis macrochirus	29	35.4
				Micropterus dolomieui	1	55.0
				Micropterus salmoides	18	58.8
				Notropis heterodon	5	55.4
				Pimephales notatus	7	61.1
Colletta Bay	Crown Marsh	1	10	*Fundulud diaphanus*	4	69.0
				Labidesthes sicculus	3	81.7
				Lepistosteus osseus	1	157.0
				Lepomis macrochirus	34	94.8
				Micropterus dolomieui	1	44.0
				Micropterus salmoides	65	54.0
				Notropis cornutus	1	94.0
				Notropis heterodon	26	55.3
				Perca flavescens	3	92.3
				Pimephales notatus	7	62.9
Crown Marsh	Crown Marsh	1	13	*Ambloplites rupestris*	1	94.0
				Amia Calva	1	535.0
				Cyprinus carpio	1	667.0
				Dorosoma cepedianum	1	47.0
				Ictalurus nebulosus	1	50.0
				Labidesthes sicculus	1	85.0
				Lepomis gibbosus	4	69.8
				Lepomis macrochirus	14	90.1
				Micropterus dolomieui	2	44.5
				Micropterus salmoides	81	53.8
				Notropis cornutus	3	85.7
				Notropis heterodon	1	54.0
				Perca flavescens	1	86.0
		2	11	*Ambloplites rupestris*	1	97.0
				Cyprinus carpio	1	51.0
				Esox lucius	3	96.0
				Ictalurus nebulosus	14	98.0
				Lepistosteus osseus	1	144.0
				Lepomis cyanellus	1	78.0
				Lepomis gibbosus	40	105.1
				Lepomis macrochirus	31	96.9
				Micropterus salmoides	27	57.0
				Notropis cornutus	5	91.4
				Perca flavescens	25	102.1
		3	11	*Ambloplites rupestris*	11	89.9
				Amia Calva	1	492.0
				Esox lucius	2	266.5
				Ictalurus nebulosus	9	51.2
				Lepistosteus osseus	1	170.0
				Lepomis gibbosus	9	103.8
				Lepomis macrochirus	9	96.8

				Micropterus salmoides	49	52.9
				Notropis heterodon	1	44.0
				Noturus gyrinus	4	68.3
				Perca flavescens	5	119.6
Causeway	Causeway[1]	1	7	*Ambloplites rupestris*	1	76.0
				Ictalurus nebulosus	4	118.5
				Lepomis gibbosus	35	68.6
				Lepomis macrochirus	33	85.6
				Micropterus salmoides	35	61.7
				Notropis cornutus	3	151.3
				Perca flavescens	7	132.7
Helmer's Pond	Helmer's Pond	1	14	*Ambloplites rupestris*	22	101.3
				Dorosoma cepedianum	1	55.0
				Fundulud diaphanus	1	69.0
				Ictalurus nebulosus	4	54.3
				Lepistosteus osseus	1	724.0
				Lepomis cyanellus	1	116.0
				Lepomis gibbosus	13	126.5
				Lepomis macrochirus	28	50.3
				Micropterus dolomieui	13	55.6
				Micropterus salmoides	32	67.5
				Notropis heterodon	4	55.0
				Notropis spilopterus	2	70.0
				Perca flavescens	20	117.8
				Pimephales notatus	4	62.0
		2	13	*Ambloplites rupestris*	19	110.4
				Fundulud diaphanus	7	62.0
				Ictalurus nebulosus	2	50.5
				Lepistosteus osseus	5	702.4
				Lepomis gibbosus	1	44.0
				Lepomis macrochirus	2	35.0
				Micropterus dolomieui	14	54.8
				Micropterus salmoides	35	71.4
				Neobobius melanostomus	5	58.2
				Notropis atherinoides	1	74.0
				Notropis cornutus	1	60.0
				Notropis spilopterus	8	59.6
				Pimephales notatus	7	59.1
Lee Brown Marsh	Lee Brown Marsh	1	3	*Ictalurus nebulosus*	1	257.0
				Lepomis gibbosus	1	146.0
				Micropterus salmoides	2	48.5
		2	4	*Ictalurus nebulosus*	1	272.0
				Lepomis gibbosus	18	121.8
				Lepomis macrochirus	7	112.4
				Micropterus salmoides	5	153.6
		3	7	*Ambloplites rupestris*	1	205.0
				Hybopsis biguttata	1	78.0
				Ictalurus nebulosus	2	248.0

				Lepomis cyanellus	11	109.5
				Lepomis gibbosus	18	127.6
				Lepomis macrochirus	11	118.3
				Micropterus salmoides	3	128.0
Long Point Provincial Park	Long Point Provincial Park	1	4	*Ambloplites rupestris*	1	64.0
				Lepistosteus osseus	2	169.0
				Lepomis macrochirus	2	117.0
				Micropterus salmoides	4	51.0
		2	8	*Ambloplites rupestris*	10	274.0
				Dorosoma cepedianum	25	57.0
				Fundulud diaphanus	1	64.0
				Micropterus dolomieui	17	44.3
				Micropterus salmoides	14	50.9
				Neobobius melanostomus	1	58.0
				Notropis atherinoides	3	57.0
				Perca flavescens	1	55.0
		3	6	*Ambloplites rupestris*	3	94.0
				Lepistosteus osseus	2	232.0
				Lepomis gibbosus	2	114.5
				Lepomis macrochirus	1	75.0
				Micropterus dolomieui	1	46.0
				Micropterus salmoides	7	56.4
Little Rice Bay	Little Rice Bay	1	8	*Ambloplites rupestris*	8	79.3
				Ictalurus nebulosus	2	44.0
				Lepistosteus osseus	1	129.0
				Lepomis gibbosus	2	93.5
				Lepomis macrochirus	8	92.9
				Micropterus salmoides	19	49.2
				Notropis heterodon	6	49.2
				Notropis spilopterus	1	51.0
		2	8	*Ambloplites rupestris*	7	90.4
				Amia Calva	1	380.0
				Fundulud diaphanus	1	61.0
				Lepistosteus osseus	1	429.0
				Lepomis gibbosus	4	126.3
				Lepomis macrochirus	5	95.8
				Micropterus salmoides	5	54.4
				Notropis heterodon	3	57.0
Port Rowan	Port Rowan	1	13	*Ambloplites rupestris*	3	99.3
				Cyprinus carpio	1	189.0
				Dorosoma cepedianum	1	51.0
				Fundulud diaphanus	1	60.0
				Ictalurus nebulosus	2	124.0
				Lepistosteus osseus	1	428.0
				Lepomis gibbosus	23	91.5
				Lepomis macrochirus	21	80.5
				Micropterus salmoides	13	48.5
				Notropis cornutus	1	138.0

				Notropis heterodon	1	60.0
				Perca flavescens	22	146.0
				Pimephales notatus	2	60.5
		2	4	*Lepomis gibbosus*	5	68.4
				Lepomis macrochirus	14	35.6
				Micropterus salmoides	38	51.1
				Notropis heterodon	4	57.0
		3	11	*Ambloplites rupestris*	3	101.0
				Cyprinus carpio	1	180.0
				Dorosoma cepedianum	3	57.3
				Ictalurus nebulosus	3	181.3
				Lepomis gibbosus	28	85.3
				Lepomis macrochirus	33	69.3
				Micropterus dolomieui	1	49.0
				Micropterus salmoides	50	50.7
				Notropis heterodon	4	57.0
				Perca flavescens	6	118.8
				Pimephales notatus	7	68.7
Smith Marsh	Smith Marsh	1	7	*Ambloplites rupestris*	2	97.0
				Fundulud diaphanus	1	61.0
				Lepomis gibbosus	28	79.4
				Lepomis macrochirus	30	64.4
				Micropterus dolomieui	1	46.0
				Micropterus salmoides	23	52.1
				Notropis spilopterus	1	75.0
Thoroughfare	Ltiile Rice Bay	1	8	*Ambloplites rupestris*	2	90.0
				Dorosoma cepedianum	1	50.0
				Ictalurus nebulosus	1	44.0
				Labidesthes sicculus	2	82.5
				Lepomis macrochirus	2	176.5
				Micropterus dolomieui	7	44.4
				Micropterus salmoides	3	44.7
				Notropis cornutus	1	93.0
		2	6	*Ambloplites rupestris*	5	69.6
				Amia Calva	1	299.0
				Dorosoma cepedianum	1	47.0
				Labidesthes sicculus	1	89.0
				Lepistosteus osseus	2	564.5
				Micropterus salmoides	24	51.5
		3	11	*Ambloplites rupestris*	5	94.0
				Cyprinus carpio	1	541.0
				Fundulud diaphanus	1	61.0
				Lepistosteus osseus	1	253.0
				Lepomis gibbosus	2	122.0
				Lepomis macrochirus	22	41.9
				Micropterus salmoides	53	63.3
				Notemigonus crysoleucas	1	88.0
				Notropis cornutus	2	97.0
				Notropis heterodon	5	55.8

				Perca flavescens	10	121.2
		4	6	*Ictalurus nebulosus*	1	61.0
				Lepomis gibbosus	1	82.0
				Lepomis macrochirus	6	38.8
				Micropterus salmoides	4	63.0
				Notropis spilopterus	1	56.0
				Perca flavescens	2	124.5

Table A-13. Sampling area, study site, transect number, quadrat number, species common name and cover code at 17 Long Point coastal wetland sampling areas.

Sampling Area	Study Site	Transect No.	Quadrat No.[1]	Common name	Cover Code
Booth's Harbour	Booth's Harbour	1	1	(T. angustifolia x T. latifolia)	5
		1	1	Pale Touch-me-not	4
		1	2	Hedge Bindweed	3
		1	2	Calico Aster	3
		1	2	(T. angustifolia x T. latifolia)	7
		1	2	Spotted Touch-me-not	3
		1	3	Bulb-bearing Water-hemlock	3
		1	3	Common Arrowhead	10
		1	3	Soft-stem Bulrush	2
		1	3	Giant Bur-reed	2
		1	3	Frog's-bit	6
		1	4	Common Duckweed	3
		1	4	Rice Cut Grass	2
		1	4	Water-milfoil	4
		1	4	Common Arrowhead	8
		1	4	(T. angustifolia x T. latifolia)	4
		1	4	Bugleweed	2
		1	4	Frog's-bit	3
		1	5	(T. angustifolia x T. latifolia)	8
		1	5	Common Duckweed	9
		1	5	Common Arrowhead	6
		1	5	Fragrant Water-lily	4
		1	5	Soft-stem Bulrush	3
		1	5	Frog's-bit	6
		1	6	Common Duckweed	2
		1	6	Common Arrowhead	5
		1	6	Bulb-bearing Water-hemlock	2
		1	6	(T. angustifolia x T. latifolia)	8
		1	6	Soft-stem Bulrush	3
		1	7	Common Arrowhead	5
		1	7	Hedge Bindweed	5
		1	7	(T. angustifolia x T. latifolia)	6
		1	7	Common Dodder	3
		1	7	Three-cleft Bedstraw	5
		1	7	Spotted Touch-me-not	7
		1	8	Hedge Bindweed	9
		1	8	European Stinging Nettle	2
		1	8	(T. angustifolia x T. latifolia)	3
		1	8	Spotted Touch-me-not	7
		1	8	Common Dodder	4
		1	9	Tape-grass	8
		1	9	Sago Pondweed	4
		1	9	Bushy Naiad	2
		1	9	Water-milfoil	3
		1	9	Curly-leaved Pondweed	4
		1	X	Stiff Arrowhead	O
		1	X	Nodding Beggarticks	O
		1	X	Swamp Loosestrife	O

		1	X	American Water-horehound	R
		1	X	Great Hairy Willow-herb	O
		1	X	Mild Water-pepper	R
		1	X	Flat-topped White Aster	R
		1	X	Perennial Sow-thistle	R
		1	X	Red-rooted Cyperus	O
		1	X	Common Skullcap	R
		1	X	Perennial Sow-thistle	R
		1	X	Marsh Hedge-nettle	O
		1	X	Climbing Nightshade	O
		1	X	Pilewort	R
		1	X	Common Ragweed	R
		1	X	Canada Thistle	R
		1	X	Boneset	O
		1	X	Bulrush	R
		2	1	Lake Sedge	3
		2	1	Soft Rush	9
		2	1	Knotted Rush	2
		2	1	Narrow-leaved Cattail	3
		2	1	Rice Cut Grass	4
		2	1	Bulrush	5
		2	1	Spotted Touch-me-not	3
		2	1	Coltsfoot	5
		2	1	Bebb's Sedge	2
		2	2	Canada Water-weed	6
		2	2	Water Star-grass	5
		2	2	Threesquare	5
		2	2	Stonewort	4
		2	2	Bushy Naiad	5
		2	2	Water-milfoil	4
		2	3	Common Arrowhead	8
		2	3	Common Coontail	8
		2	4	Sago Pondweed	3
		2	4	Tape-grass	9
		2	4	Water-milfoil	4
		2	5	Common Arrowhead	8
		2	5	Tape-grass	7
		2	5	Water-milfoil	2
		2	X	Bulb-bearing Water-hemlock	O
		2	X	Heart-leaved Willow	O
		2	X	Curly-leaved Pondweed	O
		2	X	Soft-stem Bulrush	O
		2	X	Great Hairy Willow-herb	R
		2	X	American Water-horehound	O
		2	X	Hedge Bindweed	O
		2	X	Late Goldenrod	X
		2	X	Common Reed	R
		2	X	Pale Smartweed	O
		2	X	Reed Canary Grass	R
		2	X	Fragrant Water-lily	R
		2	X	Small's Spike-rush	O

		2	X	Fox Sedge	O
		2	X	Blue Vervain	O
Bluff Marsh	Bluff Marsh	1	1	Hard-stemmed Bulrush	1
		1	1	Alpine Rush	2
		1	1	Bushy Naiad	2
		1	1	Stonewort	1
		1	1	Red-based Spike-rush	4
		1	1	Threesquare	5
		1	1	Twig-rush	2
		1	1	Variable-leaved Pondweed	3
		1	2	Stonewort	10
		1	3	Sago Pondweed	1
		1	3	Hard-stemmed Bulrush	2
		1	3	Common Coontail	2
		1	3	Southern Wild Rice	5
		1	3	Curly-leaved Pondweed	2
		1	4	Sago Pondweed	2
		1	4	Hard-stemmed Bulrush	4
		1	4	Bushy Naiad	2
		1	4	Stonewort	8
		1	4	Red-based Spike-rush	1
		1	5	Tape-grass	5
		1	5	Bushy Naiad	3
		1	5	Tolypella	10
		1	5	Curly-leaved Pondweed	4
		1	X	Small's Spike-rush	O
		1	X	Bulrush	018
		1	X	Knotted Rush	O
		1	X	Tape-grass	O
		1	X	Hedge Bindweed	
		1	X	Common Reed	O
		1	X	Common Arrowhead	O
		1	X	Blue Vervain	O
		1	X	(T. angustifolia x T. latifolia)	O
		1	X	Pickerel-weed	O
		1	X	Fragrant Water-lily	O
		1	X	Water-milfoil	O
		1	X	Giant Bur-reed	O
		1	X	American Water-horehound	O
		1	X	Bullhead Lily	O
		1	X	Illinois Pondweed	O
		1	X	Boneset	O
		2	1	Knotted Rush	5
		2	1	Late Goldenrod	2
		2	1	Canada Blue-joint	5
		2	1	Shining Cyperus	4
		2	1	Red-based Spike-rush	2
		2	1	Canadian Rush	5
		2	1	Twig-rush	2
		2	1	Boneset	1

		2	1	Hard-stemmed Bulrush	2
		2	1	Needle Spike-rush	5
		2	1	Great Lobelia	2
		2	1	Hedge Bindweed	2
		2	2	Southern Wild Rice	6
		2	2	Stonewort	3
		2	2	Muskgrass	3
		2	2	Hard-stemmed Bulrush	5
		2	2	Bushy Naiad	10
		2	3	Stonewort	8
		2	3	Hard-stemmed Bulrush	3
		2	4	Muskgrass	+
		2	4	Sago Pondweed	4
		2	4	Tape-grass	3
		2	4	Bushy Naiad	9
		2	X	Bullhead Lily	O
		2	X	Blue Vervain	O
		2	X	Short-headed Rush	O
		2	X	Canada Thistle	O
		2	X	Marsh St. John's-wort	O
		2	X	American Water-horehound	O
		2	X	flower	R
		2	X	Floating Pondweed	O
		2	X	Curly-leaved Pondweed	O
		2	X	Willow-herb	R
		2	X	Variable-leaved Pondweed	O
		2	X	Whorled Water-milfoil	O
		2	X	Lady's-thumb	O
		2	X	Indian Hemp	R
		2	X	(T. angustifolia x T. latifolia)	O
		2	X	Water Smartweed	O
		2	X	Illinois Pondweed	O
		2	X	Common Arrowhead	O
		2	X	Water-milfoil	O
		2	X	Pickerel-weed	O
		2	X	Rice Cut Grass	O
		2	X	Small's Spike-rush	O
		3	1	Bullhead Lily	3
		3	1	Variable-leaved Pondweed	+
		3	1	Needle Spike-rush	5
		3	1	Olive-fruited Spike-rush	4
		3	1	Common Reed	3
		3	1	Rice Cut Grass	+
		3	1	Common Arrowhead	3
		3	1	Hard-stemmed Bulrush	5
		3	1	(T. angustifolia x T. latifolia)	3
		3	2	Variable-leaved Pondweed	2
		3	2	Southern Wild Rice	5
		3	2	Bullhead Lily	3
		3	2	Bushy Naiad	2
		3	2	Floating Pondweed	3

		3	3	Bullhead Lily	7
		3	3	Pickerel-weed	6
		3	3	Hard-stemmed Bulrush	5
		3	3	Bushy Naiad	4
		3	3	Muskgrass	9
		3	4	Southern Wild Rice	3
		3	4	Pickerel-weed	3
		3	4	Giant Bur-reed	3
		3	4	Bullhead Lily	6
		3	4	Hard-stemmed Bulrush	8
		3	X	Boneset	
		3	X	Small's Spike-rush	O
		3	X	Soft-stem Bulrush	O
		3	X	Twig-rush	O
		3	X	Common Bladderwort	O
		3	X	flower	R
		3	X	Stonewort	O
		3	X	Blue Vervain	O
		3	X	Water-milfoil	O
		3	X	Knotted Rush	O
		3	X	Canadian Rush	O
		3	X	Sago Pondweed	O
		3	X	Fragrant Water-lily	O
		3	X	Canada Blue-joint	O
		4	1	Fragrant Water-lily	3
		4	1	(T. angustifolia x T. latifolia)	7
		4	2	(T. angustifolia x T. latifolia)	5
		4	3	Giant Bur-reed	1
		4	3	Stonewort	10
		4	3	Hard-stemmed Bulrush	2
		4	3	Southern Wild Rice	4
		4	4	Muskgrass	5
		4	4	Stonewort	10
		4	4	Bushy Naiad	3
		4	4	Tape-grass	3
		4	X	Canadian Rush	O
		4	X	Whorled Water-milfoil	R
		4	X	Shining Cyperus	O
		4	X	Rice Cut Grass	O
		4	X	Bulrush	O
		4	X	Canada Thistle	R
		4	X	Smartweed	O
		4	X	Canada Blue-joint	O
		4	X	Tall Goldenrod	O
		4	X	Climbing Nightshade	O
		4	X	Threesquare	O
		4	X	Great Lobelia	R
		4	X	Sago Pondweed	O
		4	X	Water-milfoil	O
		4	X	Southern Blue-flag	O
		4	X	Boneset	O

		4	X	Indian Hemp	O
		4	X	Blue Vervain	O
		4	X	Red-rooted Cyperus	O
		4	X	Common Bladderwort	O
		4	X	Nodding Beggarticks	R
		4	X	Marsh Hedge-nettle	O
		4	X	Calico Aster	O
Colletta Bay	Crown Marsh	1	1	False-nettle	+
		1	1	Common Arrowhead	3
		1	1	Boneset	2
		1	1	Fragrant Water-lily	2
		1	1	Threesquare	6
		1	1	Olive-fruited Spike-rush	6
		1	1	Nodding Beggarticks	3
		1	1	Purple Loosestrife	3
		1	1	Variable-leaved Pondweed	3
		1	1	Southern Wild Rice	2
		1	2	Few-flowered Spike-rush	8
		1	2	Threesquare	3
		1	2	Stonewort	3
		1	3	Threesquare	4
		1	3	Few-flowered Spike-rush	7
		1	4	Stonewort	7
		1	4	Threesquare	5
		1	4	Few-flowered Spike-rush	2
		1	X	Greenish Sedge	O
		1	X	Small-flowered Willow-herb	R
		1	X	Rice Cut Grass	O
		1	X	Spotted Touch-me-not	O
		1	X	Knotted Rush	O
		1	X	Canada Thistle	O
		1	X	Stiff Arrowhead	O
		1	X	Short-headed Rush	O
		1	X	Short-headed Rush	O
		1	X	Common Reed	O
		1	X	Water-plantain	O
		1	X	Cottonwood	O
		1	X	Canada Blue-joint	O
		1	X	Bearded Sedge	O
		1	X	American Water-horehound	O
		1	X	Small's Spike-rush	O
		1	X	Spotted Water-hemlock	O
		1	X	Grass-leaved Goldenrod	O
		1	X	Frog's-bit	O
		1	X	(T. angustifolia x T. latifolia)	O
		2	1	(T. angustifolia x T. latifolia)	4
		2	1	Hedge Bindweed	+
		2	2	(T. angustifolia x T. latifolia)	5
		2	2	Spotted Touch-me-not	10
		2	3	Nodding Beggarticks	6

		2	3	Few-flowered Spike-rush	9
		2	3	(T. angustifolia x T. latifolia)	5
		2	3	Small-flowered Willow-herb	2
		2	4	Stonewort	2
		2	4	Few-flowered Spike-rush	2
		2	X	Marsh Hedge-nettle	O
		2	X	Pale Smartweed	O
		2	X	Common Arrowhead	R
		2	X	Bulb-bearing Water-hemlock	X
		2	X	Southern Wild Rice	O
		2	X	American Water-horehound	O
		2	X	Coarse Cyperus	O
		2	X	Canada Blue-joint	O
		2	X	Three-cleft Bedstraw	O
		2	X	Canada Thistle	O
		2	X	Smith's Club-rush	R
		2	X	Common Skullcap	O
		2	X	Lady's-thumb	O
		2	X	Marsh Yellow Cress	O
		2	X	Great Hairy Willow-herb	R
		2	X	Boneset	O
		2	X	Red-rooted Cyperus	O
Courtright Ridge	Helmer's Pond	1	1	Spotted Touch-me-not	2
		1	1	Lake Sedge	2
		1	1	Swamp Loosestrife	5
		1	1	Canada Blue-joint	2
		1	1	Narrow-leaved Cattail	5
		1	1	Marsh Fern	2
		1	2	Buttonbush	7
		1	2	Common Reed	3
		1	3	Narrow-leaved Cattail	5
		1	3	Common Reed	5
		1	4	Common Reed	8
		1	4	Narrow-leaved Cattail	4
		1	5	Bushy Naiad	7
		1	5	Sago Pondweed	1
		1	5	Water-milfoil	+
		1	5	Narrow-leaved Cattail	2
		1	5	Stonewort	2
		1	5	Bullhead Lily	4
		1	5	Southern Wild Rice	2
		1	X	Common Arrowhead	O
		1	X	Soft-stem Bulrush	O
		1	X	Variable-leaved Pondweed	0
		1	X	Bearded Sedge	R
		1	X	Smartweed	O
		1	X	Marsh Yellow Cress	R
		1	X	Tussock Sedge	O
		1	X	Water Smartweed	O
		1	X	Common Cattail	
		1	X	Rice Cut Grass	R

		1	X	False-nettle	R
		1	X	Common Coontail	O
		1	X	Common Skullcap	R
		1	X	Giant Bur-reed	R
		2	1	Spotted Touch-me-not	2
		2	1	Narrow-leaved Cattail	2
		2	1	Hedge Bindweed	4
		2	1	Common Reed	5
		2	2	Common Arrowhead	3
		2	2	Narrow-leaved Cattail	5
		2	2	Stiff Arrowhead	3
		2	2	Climbing Nightshade	2
		2	3	Bushy Naiad	6
		2	3	Sago Pondweed	6
		2	3	Southern Wild Rice	1
		2	3	Bullhead Lily	7
		2	3	Stonewort	8
		2	4	Bushy Naiad	9
		2	4	Stonewort	5
		2	4	Curly-leaved Pondweed	2
		2	4	Tape-grass	1
		2	5	Stiff Arrowhead	3
		2	5	Southern Wild Rice	3
		2	5	Sago Pondweed	3
		2	5	Bullhead Lily	8
		2	5	Stonewort	3
		2	X	(T. angustifolia x T. latifolia)	O
		2	X	Giant Bur-reed	O
		2	X	Hedge Bindweed	
		2	X	Common Arrowhead	O
		2	X	Soft-stem Bulrush	O
		2	X	Variable-leaved Pondweed	R
		2	X	Pickerel-weed	O
Causeway	Causeway[2]	1	1	Hedge Bindweed	9
		1	1	Spotted Touch-me-not	6
		1	1	(T. angustifolia x T. latifolia)	2
		1	1	European Stinging Nettle	3
		1	2	Common Coontail	8
		1	2	Stiff Arrowhead	4
		1	2	Pickerel-weed	4
		1	2	Giant Bur-reed	5
		1	2	Water-milfoil	2
		1	2	Frog's-bit	5
		1	2	Common Duckweed	+
		1	3	Common Coontail	4
		1	3	Tape-grass	3
		1	3	Curly-leaved Pondweed	4
		1	3	Common Duckweed	+
		1	3	Bullhead Lily	8
		1	3	Water net	5

		1	4	Common Duckweed	+
		1	4	Fragrant Water-lily	8
		1	4	Hard-stemmed Bulrush	5
		1	4	Common Coontail	8
		1	5	Water Star-grass	2
		1	5	Common Duckweed	+
		1	5	Water-milfoil	4
		1	5	Common Coontail	10
		1	5	Fragrant Water-lily	7
		1	5	Hard-stemmed Bulrush	5
		1	X	Late Goldenrod	O
		1	X	Common Cattail	O
		1	X	Climbing Nightshade	o
		1	X	Canada Thistle	O
		1	X	Sago Pondweed	O
		1	X	Field Mint	O
		1	X	flower	R
		1	X	American Water-horehound	O
		1	X	Canada Water-weed	O
		1	X	Calico Aster	O
		1	X	Great Water Dock	R
		1	X	Purple-leaved Willow-herb	R
		1	X	Rice Cut Grass	O
		1	X	Spotted Joe-Pye-weed	O
		1	X	Common Arrowhead	O
		1	X	Soft-stem Bulrush	O
		1	X	Common Reed	O
		1	X	Boneset	O
		1	X	Silky Dogwood	R
Hahn Marsh	Hahn Marsh	1	1	(T. angustifolia x T. latifolia)	4
		1	1	Giant Bur-reed	3
		1	1	Canada Blue-joint	8
		1	1	Common Arrowhead	6
		1	1	Hedge Bindweed	2
		1	1	Water Smartweed	4
		1	1	Mad-dog Skullcap	3
		1	1	Bulb-bearing Water-hemlock	3
		1	2	American Water-horehound	3
		1	2	Marsh Fern	8
		1	2	Water Smartweed	2
		1	2	Spotted Touch-me-not	4
		1	2	(T. angustifolia x T. latifolia)	6
		1	3	Marsh Cinquefoil	4
		1	3	(T. angustifolia x T. latifolia)	5
		1	3	Common Arrowhead	5
		1	3	Water Smartweed	5
		1	3	Canada Blue-joint	6
		1	3	Devil's Beggarticks	3
		1	4	Dotted Water-meal	4
		1	4	Common Duckweed	5

		1	4	Fragrant Water-lily	6
		1	4	Common Coontail	10
		1	X	Swamp Milkweed	O
		1	X	Mild Water-pepper	A
		1	X	Narrow-leaved Cattail	O
		1	X	Butter-and-eggs	O
		1	X	Soft-stem Bulrush	O
		1	X	Great Water Dock	O
		1	X	Climbing Nightshade	O
		1	X	Marsh Pea	O
		1	X	Marsh Bellflower	O
		1	X	Bullhead Lily	O
		1	X	Three-cleft Bedstraw	O
		1	X	Bugleweed	O
		1	X	Unidentified Moss	O
		1	X	Spotted Water-hemlock	O
		1	X	Common Skullcap	O
		1	X	Common Cattail	O
		2	1	Pale Smartweed	5
		2	1	(T. angustifolia x T. latifolia)	3
		2	1	Great Water Dock	3
		2	1	Canada Blue-joint	9
		2	1	Common Arrowhead	6
		2	1	Mild Water-pepper	1
		2	1	Unidentified Moss	9
		2	2	Pale Smartweed	5
		2	2	Common Arrowhead	4
		2	2	Giant Bur-reed	5
		2	2	(T. angustifolia x T. latifolia)	4
		2	3	Common Duckweed	3
		2	3	Few-flowered Spike-rush	1
		2	X	Virgin's-bower	O
		2	X	Spotted Water-hemlock	O
		2	X	Swamp Rose Mallow	R
		2	X	Water-plantain	O
		2	X	Boneset	O
		2	X	Red-osier Dogwood	R
		2	X	Red-rooted Cyperus	O
		2	X	Bulb-bearing Water-hemlock	O
		2	X	Swamp Loosestrife	O
		2	X	Marsh Pea	O
		2	X	Purple Loosestrife	O
		2	X	Common Skullcap	O
		2	X	Marsh Fern	O
		2	X	European Stinging Nettle	O
		2	X	Common Dodder	O
		2	X	American Water-horehound	O
		2	X	Field Mint	O
		2	X	Spotted Touch-me-not	O
		2	X	Flowering-rush	O
		2	X	Hedge Bindweed	O
		2	X	Cyperus-like Sedge	O

		2	X	Coarse Cyperus	O
		2	X	Bugleweed	O
		2	X	Great Hairy Willow-herb	O
		2	X	Nodding Beggarticks	O
		2	X	Redtop	O
		2	X	Rice Cut Grass	O
		2	X	Swamp Rose	O
		2	X	Blue Vervain	O
		2	X	Swamp Milkweed	O
		2	X	Buttonbush	O
		3	1	Common Arrowhead	8
		3	1	Pale Smartweed	2
		3	1	Bulb-bearing Water-hemlock	4
		3	1	Canada Blue-joint	8
		3	1	Common Cattail	6
		3	2	Common Arrowhead	1
		3	2	Pale Smartweed	5
		3	2	Canada Blue-joint	10
		3	2	Spotted Touch-me-not	6
		3	3	Pale Smartweed	2
		3	3	Common Arrowhead	9
		3	3	Canada Blue-joint	8
		3	3	Spotted Touch-me-not	5
		3	4	Common Duckweed	3
		3	4	Bullhead Lily	9
		3	X	Lake Sedge	O
		3	X	Swamp Milkweed	O
		3	X	Common Skullcap	O
		3	X	Water Dock	O
		3	X	Great Water Dock	O
		3	X	Giant Bur-reed	O
		3	X	Three-cleft Bedstraw	O
		3	X	American Water-horehound	O
		3	X	Water Smartweed	O
		3	X	Devil's Beggarticks	O
		3	X	Marsh Bedstraw	O
		3	X	Mad-dog Skullcap	O
		3	X	Flowering-rush	O
		3	X	Water-plantain	O
		4	1	Devil's Beggarticks	3
		4	1	Common Skullcap	4
		4	1	(T. angustifolia x T. latifolia)	7
		4	1	Bugleweed	3
		4	1	Water Smartweed	7
		4	1	Canada Blue-joint	3
		4	2	False-nettle	2
		4	2	Bugleweed	2
		4	2	Marsh Cinquefoil	4
		4	2	Lake Sedge	3
		4	2	Spotted Touch-me-not	2
		4	2	Water Smartweed	3
		4	2	Common Arrowhead	4

		4	2	Canada Blue-joint	10
		4	3	Nodding Beggarticks	3
		4	3	Canada Blue-joint	10
		4	3	Pale Smartweed	2
		4	3	Common Arrowhead	5
		4	3	Devil's Beggarticks	3
		4	4	Dotted Water-meal	5
		4	4	Common Duckweed	6
		4	4	Common Coontail	5
		4	4	Mild Water-pepper	4
		4	X	Reed Canary Grass	O
		4	X	Swamp Loosestrife	O
		4	X	Giant Bur-reed	O
		4	X	Marsh Bellflower	O
		4	X	Three-cleft Bedstraw	O
		4	X	Climbing Nightshade	O
		4	X	Water-plantain	O
		4	X	Swamp Milkweed	O
		4	X	Hedge Bindweed	O
		4	X	Water-parsnip	O
		4	X	Unidentified Moss	O
		4	X	Coarse Cyperus	O
		4	X	European Stinging Nettle	R
		4	X	Red-based Spike-rush	O
		4	X	Great Water Dock	O
		4	X	Bulb-bearing Water-hemlock	O
		4	X	Rice Cut Grass	O
		4	X	Fragrant Water-lily	O
		4	X	Southern Blue-flag	O
		4	X	Marsh Pea	O
		4	X	Mad-dog Skullcap	O
		4	X	Soft-stem Bulrush	O
Helmer's Pond	Helmer's Pond	1	1	Narrow-leaved Cattail	2
		1	1	(T. angustifolia x T. latifolia)	6
		1	1	White Grass	2
		1	2	Bulrush	2
		1	2	Spotted Touch-me-not	3
		1	2	(T. angustifolia x T. latifolia)	5
		1	3	Spotted Touch-me-not	8
		1	3	Water Smartweed	4
		1	3	(T. angustifolia x T. latifolia)	5
		1	4	Bulrush	9
		1	4	Canada Blue-joint	+
		1	4	(T. angustifolia x T. latifolia)	2
		1	4	Common Arrowhead	3
		1	4	Spotted Touch-me-not	+
		1	5	Variable-leaved Pondweed	4
		1	5	Small's Spike-rush	2
		1	5	Soft-stem Bulrush	2
		1	5	Pickerel-weed	3

		1	5	Bulrush	4
		1	5	(T. angustifolia x T. latifolia)	2
		1	5	Twig-rush	2
		1	5	Rice Cut Grass	2
		1	5	Common Arrowhead	5
		1	5	Fragrant Water-lily	6
		1	X	Reed Canary Grass	R
		1	X	Marsh Hedge-nettle	R02
		1	X	Late Goldenrod	O
		1	X	Nodding Beggarticks	R
		1	X	European Stinging Nettle	R
		1	X	Southern Blue-flag	R
		1	X	Southern Wild Rice	R
		1	X	Swamp Loosestrife	O
		1	X	Canada Blue-joint	O
		1	X	Canadian Rush	O
		1	X	Knotted Rush	
		1	X	Giant Bur-reed	O
		1	X	False-nettle	R
		1	X	Blue Vervain	O
		1	X	Canada Thistle	O
		1	X	Hedge Bindweed	O
Lower Big Creek	Big Creek	1	1	Common Skullcap	+
		1	1	Spotted Touch-me-not	+
		1	1	(T. angustifolia x T. latifolia)	7
		1	2	(T. angustifolia x T. latifolia)	7
		1	2	Spotted Touch-me-not	7
		1	3	Canada Blue-joint	3
		1	3	(T. angustifolia x T. latifolia)	6
		1	3	European Stinging Nettle	6
		1	3	Blue Vervain	6
		1	4	Common Skullcap	2
		1	4	(T. angustifolia x T. latifolia)	5
		1	4	Pilewort	2
		1	4	Smartweed	10
		1	4	Canada Blue-joint	5
		1	4	False-nettle	5
		1	5	Marsh Bedstraw	2
		1	5	Common Skullcap	2
		1	5	Canada Blue-joint	1
		1	5	Swamp Loosestrife	10
		1	5	Unidentified Moss	2
		1	5	Blue Vervain	2
		1	5	Rice Cut Grass	1
		1	X	Pale Touch-me-not	O
		1	X	Climbing Nightshade	O
		1	X	Water Smartweed	O
		1	X	Common Arrowhead	R
		1	X	Spiny-leaved Sow-thistle	O
		1	X	Canada Thistle	O

		1	X	American Water-horehound	O
		1	X	Narrow-leaved Cattail	O
		1	X	Common Dodder	O
		1	X	Virginia Creeper	O
		1	X	Black-seeded Clearweed	O
		1	X	Marsh Bellflower	O
		2	1	Unidentified Moss	2
		2	1	Canada Blue-joint	9
		2	1	Swamp Loosestrife	5
		2	1	Common Cattail	3
		2	1	Mad-dog Skullcap	3
		2	1	Common Skullcap	2
		2	2	Common Arrowhead	3
		2	2	Canada Blue-joint	9
		2	2	Rice Cut Grass	2
		2	2	Mad-dog Skullcap	3
		2	2	Giant Bur-reed	2
		2	3	Water-pepper	5
		2	3	Marsh St. John's-wort	2
		2	3	Rice Cut Grass	6
		2	3	Hedge Bindweed	2
		2	3	Canada Blue-joint	3
		2	3	American Water-horehound	2
		2	3	Canada Thistle	3
		2	3	Water Sedge	3
		2	3	Common Arrowhead	2
		2	3	Spotted Touch-me-not	+
		2	3	Common Skullcap	1
		2	4	Fragrant Water-lily	8
		2	4	Giant Bur-reed	7
		2	5	Small's Spike-rush	1
		2	5	Common Arrowhead	4
		2	5	Soft-stem Bulrush	2
		2	5	Common Duckweed	1
		2	5	Giant Bur-reed	8
		2	X	Water Smartweed	O
		2	X	Blue Vervain	O
		2	X	Common Mullein	O
		2	X	Bulb-bearing Water-hemlock	O
		2	X	Common Ragweed	O
		2	X	Hairy Yellow Evening-primrose	O
		2	X	Bushy Naiad	O
		2	X	Stonewort	O
		2	X	Reed Canary Grass	O
		2	X	Swamp Milkweed	O
		2	X	Water-milfoil	O
		2	X	Pilewort	O
		2	X	Great Hairy Willow-herb	R
		2	X	Sago Pondweed	O
		2	X	Stiff Arrowhead	O
		2	X	Frog's-bit	O

		2	X	Swamp Rose	O
		2	X	Marsh Bellflower	O
		2	X	Late Goldenrod	O
		2	X	Garden Asparagus	R
		2	X	Marsh Yellow Cress	O
		2	X	Canada Water-weed	O
		3	1	Common Arrowhead	4
		3	1	Common Skullcap	3
		3	1	Swamp Loosestrife	5
		3	2	Common Arrowhead	8
		3	2	Pilewort	4
		3	2	Swamp Loosestrife	4
		3	2	Canada Blue-joint	4
		3	2	Common Skullcap	3
		3	2	Marsh Yellow Cress	3
		3	2	Great Hairy Willow-herb	3
		3	2	Bugleweed	3
		3	3	Canada Blue-joint	5
		3	3	Marsh Cinquefoil	1
		3	3	Tussock Sedge	2
		3	3	Swamp Loosestrife	8
		3	4	Common Arrowhead	6
		3	5	Bushy Naiad	9
		3	5	Bullhead Lily	5
		3	X	Canada Thistle	O
		3	X	Field Mint	O
		3	X	Fragrant Water-lily	O
		3	X	Southern Wild Rice	R
		3	X	Giant Bur-reed	O
		3	X	Marsh Fern	O
		3	X	Climbing Nightshade	O
		3	X	Red-based Spike-rush	O
		3	X	Spotted Touch-me-not	O
		3	X	Soft-stem Bulrush	O
		3	X	Marsh St. John's-wort	O
		3	X	Common Coontail	O
		3	X	Pale Touch-me-not	
		3	X	Nodding Beggarticks	R
		3	X	American Water-horehound	O
		3	X	Water-milfoil	O
		3	X	Common Duckweed	O
		3	X	Lake Sedge	O
		3	X	Swamp Rose	
		3	X	Bulb-bearing Water-hemlock	R
		3	X	Small's Spike-rush	O
		3	X	Water Sedge	O
		3	X	Canada Water-weed	O
		4	1	Reed Canary Grass	4
		4	1	Common Reed	3
		4	1	Spotted Touch-me-not	3
		4	1	Canada Blue-joint	8

		4	1	Common Arrowhead	3
		4	1	Swamp Loosestrife	4
		4	1	Rice Cut Grass	6
		4	2	Canada Blue-joint	6
		4	2	Common Skullcap	3
		4	2	Field Mint	4
		4	2	Marsh Hedge-nettle	7
		4	2	Canada Thistle	7
		4	2	(T. angustifolia x T. latifolia)	3
		4	3	Pale Touch-me-not	9
		4	3	(T. angustifolia x T. latifolia)	7
		4	3	Common Skullcap	1
		4	4	(T. angustifolia x T. latifolia)	6
		4	4	Common Skullcap	3
		4	4	Spotted Touch-me-not	5
		4	5	Canada Blue-joint	8
		4	5	Pilewort	5
		4	5	Unidentified Moss	2
		4	5	Common Skullcap	7
		4	5	Marsh Bedstraw	3
		4	X	Narrow-leaved Cattail	O
		4	X	Great Water Dock	O
		4	X	Blue Vervain	O
		4	X	Swamp Milkweed	O
		4	X	Climbing Nightshade	O
		4	X	Giant Bur-reed	O
		4	X	Bugleweed	O
		4	X	Tussock Sedge	O
		4	X	Water Smartweed	O
		4	X	Great Hairy Willow-herb	R
		4	X	Marsh Bellflower	O
		4	X	Water-pepper	O
		4	X	Hedge Bindweed	O
		4	X	Marsh Pea	O
		4	X	Butter-and-eggs	R
		4	X	European Stinging Nettle	O
		5	1	Spotted Touch-me-not	5
		5	1	Marsh Hedge-nettle	2
		5	1	Canada Thistle	9
		5	2	Marsh Hedge-nettle	2
		5	2	Water-pepper	6
		5	2	Giant Bur-reed	3
		5	2	Mad-dog Skullcap	2
		5	2	Common Cattail	5
		5	2	Water Smartweed	6
		5	2	Common Skullcap	9
		5	3	Water Smartweed	6
		5	3	Canada Blue-joint	8
		5	3	Bugleweed	1
		5	3	flower	2
		5	3	Redtop	2

		5	3	Common Arrowhead	3
		5	3	Swamp Milkweed	5
		5	3	Common Skullcap	6
		5	3	Great Hairy Willow-herb	3
		5	4	Swamp Milkweed	2
		5	4	Spotted Touch-me-not	9
		5	4	Water Smartweed	3
		5	4	Giant Bur-reed	2
		5	4	Common Skullcap	2
		5	4	(T. angustifolia x T. latifolia)	6
		5	4	Narrow-leaved Cattail	2
		5	4	Canada Blue-joint	3
		5	5	Marsh Bedstraw	1
		5	5	Water-pepper	2
		5	5	Common Skullcap	7
		5	5	Giant Bur-reed	7
		5	5	Bugleweed	1
		5	5	Canada Blue-joint	3
		5	5	Pilewort	2
		5	5	Unidentified Moss	2
		5	X	Great Water Dock	O
		5	X	Field Mint	R
		5	X	Late Goldenrod	O
		5	X	European Stinging Nettle	O
		5	X	Common Dodder	O
		5	X	Hedge Bindweed	O
		5	X	Common Reed	
		5	X	Boneset	O
		5	X	American Water-horehound	O
		5	X	Swamp Loosestrife	O
		5	X	Willow-herb	O
		5	X	Nodding Beggarticks	O
		5	X	Blue Vervain	O
		5	X	Devil's Beggarticks	R
		5	X	Marsh Bellflower	O
		5	X	Tussock Sedge	O
		5	X	Hairy Yellow Evening-primrose	R
Lee Brown Marsh	Lee Brown Marsh	1	1	Hairy-fruited Sedge	1
		1	1	Marsh Cinquefoil	3
		1	1	(T. angustifolia x T. latifolia)	5
		1	1	Tussock Sedge	6
		1	1	Creeping Sedge	2
		1	1	Lake Sedge	4
		1	2	Swamp Loosestrife	5
		1	2	Marsh Cinquefoil	5
		1	2	Creeping Sedge	6
		1	2	False-nettle	4
		1	2	Hairy-fruited Sedge	2
		1	2	Canada Blue-joint	5
		1	2	Tussock Sedge	2

		1	2	Giant Bur-reed	1
		1	2	Lake Sedge	3
		1	3	Swamp Loosestrife	5
		1	3	Common Duckweed	+
		1	3	Red-based Spike-rush	5
		1	3	Bullhead Lily	7
		1	3	Stonewort	7
		1	4	Unidentified Moss	3
		1	4	Wild Strawberry	2
		1	4	False-nettle	4
		1	4	Tussock Sedge	3
		1	4	Common Reed	2
		1	4	Hairy-fruited Sedge	5
		1	4	Marsh Cinquefoil	3
		1	4	Hard-stemmed Bulrush	2
		1	4	Marsh Fern	3
		1	4	Lake Sedge	3
		1	5	American Water-horehound	3
		1	5	Wild Strawberry	2
		1	5	Swamp Loosestrife	5
		1	5	Bugleweed	+
		1	5	Marsh Fern	6
		1	5	Devil's Beggarticks	+
		1	5	Tussock Sedge	5
		1	6	Swamp Loosestrife	7
		1	6	Boneset	2
		1	6	Calico Aster	+
		1	6	Marsh Fern	4
		1	6	Devil's Beggarticks	3
		1	6	Common Skullcap	3
		1	6	Tussock Sedge	8
		1	7	Common Duckweed	1
		1	7	Leafy Pondweed	3
		1	7	Common Coontail	7
		1	7	Dotted Water-meal	1
		1	7	Common Bladderwort	8
		1	X	Water Star-grass	R
		1	X	Southern Blue-flag	O
		1	X	Canada Water-weed	O
		1	X	Bulb-bearing Water-hemlock	O
		1	X	Common Arrowhead	O
		1	X	Pale Smartweed	O
		1	X	Swamp Rose	O
		1	X	Marsh Bellflower	O
		1	X	Water Smartweed	R
		1	X	Buttonbush	R
		1	X	Sago Pondweed	O
		1	X	Speckled Alder	R
		1	X	Southern Wild Rice	O
		1	X	Pickerel-weed	R
		1	X	Marsh St. John's-wort	0
		2	1	Marsh Fern	5

		2	1	Lake Sedge	6
		2	1	Marsh Cinquefoil	4
		2	1	Marsh Pea	2
		2	1	Common Arrowhead	5
		2	1	Canada Blue-joint	9
		2	1	Devil's Beggarticks	4
		2	1	Marsh Bellflower	2
		2	2	Marsh Cinquefoil	6
		2	2	Bugleweed	3
		2	2	Common Arrowhead	5
		2	2	Devil's Beggarticks	4
		2	2	Canada Blue-joint	3
		2	2	Tussock Sedge	3
		2	2	Unidentified Moss	7
		2	2	Swamp Loosestrife	5
		2	3	Water Smartweed	4
		2	3	Lake Sedge	4
		2	3	(T. angustifolia x T. latifolia)	6
		2	3	Canada Blue-joint	7
		2	3	Marsh Bellflower	3
		2	4	Lake Sedge	5
		2	4	(T. angustifolia x T. latifolia)	3
		2	4	Spotted Touch-me-not	4
		2	4	Canada Blue-joint	9
		2	4	Hedge Bindweed	3
		2	4	Marsh Bellflower	3
		2	5	Water-milfoil	10
		2	5	Water Star-grass	3
		2	5	Bullhead Lily	2
		2	5	Bushy Naiad	2
		2	X	Common Cattail	O
		2	X	Giant Bur-reed	O
		2	X	Pickerel-weed	O
		2	X	Rice Cut Grass	O
		2	X	Bulb-bearing Water-hemlock	O
		2	X	Stiff Arrowhead	O
		2	X	Common Reed	O
		2	X	Climbing Nightshade	O
		2	X	Nodding Beggarticks	O
		2	X	Red-osier Dogwood	R
		2	X	Common Skullcap	O
		2	X	Water-shield	O
		3	1	Common Skullcap	1
		3	1	Canada Blue-joint	7
		3	1	Common Arrowhead	4
		3	1	Marsh Bellflower	3
		3	1	Unidentified Moss	8
		3	1	Devil's Beggarticks	2
		3	1	Swamp Loosestrife	3
		3	1	(T. angustifolia x T. latifolia)	5
		3	2	Tufted Loosestrife	2
		3	2	Canada Blue-joint	8
		3	2	Marsh Bellflower	3

		3	2	Common Arrowhead	3
		3	2	(T. angustifolia x T. latifolia)	4
		3	2	Tussock Sedge	3
		3	3	Bulb-bearing Water-hemlock	1
		3	3	Canada Blue-joint	10
		3	3	Common Skullcap	2
		3	3	Common Arrowhead	5
		3	3	Giant Bur-reed	2
		3	3	Devil's Beggarticks	3
		3	3	Common Reed	4
		3	4	Water Star-grass	2
		3	4	Water-milfoil	7
		3	4	Canada Water-weed	3
		3	4	Bullhead Lily	9
		3	4	Mild Water-pepper	2
		3	5	Aquatic Beggarticks	2
		3	5	Water Star-grass	4
		3	5	Sago Pondweed	3
		3	5	Common Coontail	2
		3	5	Fragrant Water-lily	7
		3	5	Stonewort	4
		3	5	Water-milfoil	9
		3	5	Canada Water-weed	3
		3	X	Hard-stemmed Bulrush	O
		3	X	Spotted Touch-me-not	O
		3	X	Marsh Pea	O
		3	X	Lake Sedge	O
		3	X	Mad-dog Skullcap	O
		3	X	Water-shield	O
		3	X	False-nettle	R
		3	X	American Water-horehound	O
		3	X	Marsh Cinquefoil	O
		3	X	Marsh Fern	O
		3	X	Water Smartweed	O
		3	X	Willow-herb	R
		3	X	Swamp Milkweed	R
		3	X	Pickerel-weed	O
		4	1	Narrow-leaved Willow-herb	2
		4	1	Common Skullcap	2
		4	1	Swamp Rose	6
		4	1	Marsh Fern	3
		4	1	Tussock Sedge	8
		4	1	Devil's Beggarticks	3
		4	1	Lake Sedge	5
		4	2	Nodding Beggarticks	2
		4	2	Marsh Cinquefoil	3
		4	2	Lake Sedge	3
		4	2	Spotted Touch-me-not	+
		4	2	Canada Blue-joint	3
		4	2	Marsh St. John's-wort	2
		4	2	Tussock Sedge	7
		4	3	Giant Bur-reed	O
		4	3	Sago Pondweed	3

		4	3	Common Coontail	P
		4	3	Swamp Loosestrife	O
		4	3	Water-milfoil	4
		4	3	Common Skullcap	O
		4	3	Canada Water-weed	3
		4	3	Three-cleft Bedstraw	O
		4	3	Bulb-bearing Water-hemlock	O
		4	3	Stonewort	5
		4	3	Devil's Beggarticks	O
		4	3	Hairy-fruited Sedge	O
		4	3	Large-leaved Pondweed	O
		4	X	Red-osier Dogwood	O
		4	X	Common Bladderwort	O
		4	X	Common Reed	A
		4	X	Loesel's Twayblade	R
		4	X	Common Arrowhead	O
		4	X	Star Duckweed	R
		4	X	Bullhead Lily	O
		4	X	Aquatic Beggarticks	R
		4	X	Water Star-grass	O
		4	X	False-nettle	O
		4	X	Bugleweed	O
		4	X	Pickerel-weed	O
		5	1	Common Arrowhead	5
		5	1	Spotted Touch-me-not	2
		5	1	Bugleweed	3
		5	1	Canada Blue-joint	10
		5	1	Devil's Beggarticks	4
		5	2	Canada Blue-joint	7
		5	2	Spotted Touch-me-not	1
		5	2	Common Arrowhead	4
		5	2	(T. angustifolia x T. latifolia)	3
		5	2	American Water-horehound	2
		5	2	Devil's Beggarticks	4
		5	2	Marsh Bellflower	2
		5	3	Rice Cut Grass	1
		5	3	Red-based Spike-rush	4
		5	3	Dotted Water-meal	5
		5	3	Fragrant Water-lily	5
		5	3	Mild Water-pepper	3
		5	3	Common Duckweed	5
		5	3	Water-purslane	9
		5	3	Swamp Loosestrife	5
		5	4	Dotted Water-meal	3
		5	4	Canada Water-weed	3
		5	4	Water-meal	3
		5	4	Common Duckweed	3
		5	4	Common Coontail	8
		5	X	Small's Spike-rush	O
		5	X	Southern Blue-flag	O
		5	X	Stiff Arrowhead	O
		5	X	European Stinging Nettle	O

		5	X	Marsh Pea	O
		5	X	Swamp Milkweed	O
		5	X	Hedge Bindweed	
		5	X	Grey Dogwood	O
		5	X	Soft-stem Bulrush	O
		5	X	False-nettle	O
		5	X	Giant Bur-reed	O
		5	X	Great Water Dock	O
		5	X	Marsh Fern	O
		5	X	Water Smartweed	O
		5	X	Lake Sedge	
		5	X	Common Cattail	O
		5	X	Nodding Beggarticks	O
		5	X	Cyperus-like Sedge	O
		5	X	Bulb-bearing Water-hemlock	O
		5	X	Common Skullcap	O
		5	X	Marsh Yellow Cress	O
Long Point Provincial Park	Long Point Provincial Park	1	1	Hard-stemmed Bulrush	3
		1	1	Canada Blue-joint	3
		1	1	Narrow-leaved Cattail	4
		1	2	Jointed Rush	3
		1	2	Narrow-leaved Cattail	5
		1	2	Small's Spike-rush	2
		1	2	Few-flowered Spike-rush	5
		1	2	Variable-leaved Pondweed	5
		1	2	Stiff Arrowhead	3
		1	3	Soft-stem Bulrush	3
		1	3	Smith's Club-rush	1
		1	3	Needle Spike-rush	6
		1	3	Stiff Arrowhead	+
		1	3	Variable-leaved Pondweed	6
		1	3	Knotted Rush	5
		1	3	Bushy Naiad	7
		1	4	Giant Bur-reed	3
		1	4	Soft-stem Bulrush	4
		1	4	Four-angled Spike-rush	2
		1	4	Stonewort	7
		1	4	Stiff Arrowhead	3
		1	4	Bullhead Lily	6
		1	4	Pickerel-weed	4
		1	4	Bushy Naiad	+
		1	5	(T. angustifolia x T. latifolia)	4
		1	5	Common Bladderwort	5
		1	5	Floating Pondweed	5
		1	5	Pickerel-weed	3
		1	5	Bushy Naiad	3
		1	6	Giant Bur-reed	3
		1	6	Frog's-bit	9
		1	6	(T. angustifolia x T. latifolia)	8
		1	7	Southern Wild Rice	3
		1	7	(T. angustifolia x T. latifolia)	5

		1	7	Common Bladderwort	5
		1	7	Frog's-bit	4
		1	7	Pickerel-weed	4
		1	7	Bullhead Lily	4
		1	7	Variable-leaved Pondweed	3
		1	8	Frog's-bit	4
		1	8	(T. angustifolia x T. latifolia)	5
		1	8	Canada Water-weed	3
		1	8	Bullhead Lily	4
		1	8	Pickerel-weed	3
		1	8	Water-milfoil	5
		1	8	Hard-stemmed Bulrush	3
		1	9	Needle Spike-rush	+
		1	9	Threesquare	3
		1	9	Bushy Naiad	+
		1	X	Common Arrowhead	O
		1	X	Common Reed	O
		1	X	Heart-leaved Willow	R
		2	1	Spotted Touch-me-not	5
		2	1	Narrow-leaved Cattail	3
		2	2	Canada Blue-joint	9
		2	2	Narrow-leaved Cattail	4
		2	3	Narrow-leaved Cattail	8
		2	4	Stonewort	2
		2	4	Hard-stemmed Bulrush	3
		2	5	Stonewort	8
		2	5	Hard-stemmed Bulrush	3
		2	6	Stonewort	8
		2	X	Reed Canary Grass	R
		2	X	Frog's-bit	R
		2	X	Greenish Sedge	O
		2	X	Common Arrowhead	R
		2	X	Common Skullcap	O
		2	X	Great Hairy Willow-herb	R
		2	X	Pickerel-weed	R
		2	X	Curly-leaved Pondweed	R
		2	X	Marsh Yellow Cress	R
		2	X	Bulb-bearing Water-hemlock	O
		2	X	Variable-leaved Pondweed	O
		2	X	Bearded Sedge	R
		2	X	Water-milfoil	O
		2	X	Tussock Sedge	R
		2	X	Knotted Rush	O
		2	X	Bullhead Lily	O
		2	X	Needle Spike-rush	O
		2	X	Common Bladderwort	O
		2	X	Four-angled Spike-rush	O
		2	X	Jointed Rush	O
		2	X	Canada Thistle	O
		3	1	Frog's-bit	8
		3	1	Common Duckweed	+
		3	1	Narrow-leaved Cattail	8

		3	2	Frog's-bit	2
		3	2	Narrow-leaved Cattail	8
		3	3	Narrow-leaved Cattail	8
		3	4	Narrow-leaved Cattail	8
		3	4	Water-milfoil	3
		3	4	Bushy Naiad	+
		3	5	Hard-stemmed Bulrush	+
		3	X	Climbing Nightshade	O
		3	X	Stonewort	O
		3	X	Spotted Water-hemlock	O
		3	X	American Water-horehound	O
		3	X	Boneset	O
		3	X	Nodding Beggarticks	O
		3	X	Bulb-bearing Water-hemlock	O
		3	X	Bullhead Lily	O
Little Rice Bay	Little Rice Bay	1	1	(T. angustifolia x T. latifolia)	6
		1	1	Spotted Touch-me-not	6
		1	2	Frog's-bit	3
		1	2	Narrow-leaved Cattail	6
		1	3	(T. angustifolia x T. latifolia)	5
		1	3	Southern Wild Rice	2
		1	3	Stonewort	10
		1	3	Sago Pondweed	4
		1	3	Common Bladderwort	2
		1	4	Muskgrass	10
		1	4	Southern Wild Rice	4
		1	4	Fragrant Water-lily	5
		1	5	Thread alga	4
		1	X	Water-milfoil	O
		1	X	Canada Water-weed	O
		1	X	Curly-leaved Pondweed	O
		1	X	Pickerel-weed	O
		1	X	Heart-leaved Willow	O
		1	X	Giant Bur-reed	O
		1	X	Bulrush	O
		1	X	Stiff Arrowhead	O
		1	X	Yellow Pond-lily	O
		1	X	Common Arrowhead	O
		1	X	Bushy Naiad	O
		2	1	(T. angustifolia x T. latifolia)	6
		2	1	Spotted Touch-me-not	3
		2	1	Narrow-leaved Cattail	3
		2	2	Bulrush	2
		2	2	Narrow-leaved Cattail	6
		2	2	Common Arrowhead	5
		2	3	Bulrush	3
		2	3	Common Arrowhead	3
		2	3	(T. angustifolia x T. latifolia)	5
		2	3	Spotted Touch-me-not	5
		2	4	Narrow-leaved Cattail	6

		2	4	Stiff Arrowhead	3
		2	5	Bushy Naiad	3
		2	5	Tape-grass	3
		2	5	Curly-leaved Pondweed	2
		2	5	Stonewort	9
		2	5	Hard-stemmed Bulrush	3
		2	6	Tape-grass	4
		2	6	Canada Water-weed	2
		2	6	Sago Pondweed	3
		2	6	Hard-stemmed Bulrush	2
		2	6	Curly-leaved Pondweed	6
		2	6	Bushy Naiad	9
		2	6	Water-milfoil	2
		2	X	Blue Vervain	O
		2	X	Southern Wild Rice	O
		2	X	Climbing Nightshade	O
		2	X	Bullhead Lily	O
		2	X	Boneset	O
		2	X	Marsh Hedge-nettle	O
		2	X	Hedge Bindweed	O
Port Rowan	Port Rowan	1	1	(T. angustifolia x T. latifolia)	2
		1	1	Reed Canary Grass	9
		1	1	Spotted Touch-me-not	3
		1	2	(T. angustifolia x T. latifolia)	8
		1	2	Spotted Touch-me-not	8
		1	3	(T. angustifolia x T. latifolia)	8
		1	3	Common Dodder	3
		1	3	Spotted Touch-me-not	9
		1	4	European Stinging Nettle	2
		1	4	(T. angustifolia x T. latifolia)	2
		1	4	Common Dodder	8
		1	4	Bulrush	3
		1	4	Pale Smartweed	4
		1	5	Water-milfoil	2
		1	5	Common Coontail	2
		1	5	Fragrant Water-lily	3
		1	5	Common Arrowhead	6
		1	5	Pickerel-weed	8
		1	6	Common Coontail	2
		1	6	Bullhead Lily	7
		1	6	Common Arrowhead	7
		1	6	Common Duckweed	+
		1	6	Water-milfoil	3
		1	7	Common Coontail	8
		1	7	Sago Pondweed	3
		1	7	Common Arrowhead	3
		1	7	Water-milfoil	6
		1	X	Wild Cucumber	R
		1	X	Tape-grass	O
		1	X	Canada Water-weed	O
		1	X	Hedge Bindweed	O

		3	3	Canada Water-weed	7	
		3	3	Sago Pondweed	3	
		3	4	Stiff Arrowhead	3	
		3	4	Sago Pondweed	10	
		3	4	Stonewort	3	
		3	5	Tape-grass	5	
		3	5	Stonewort	3	
		3	5	Water Star-grass	3	
		3	5	Canada Water-weed	5	
		3	X	Southern Wild Rice	R	
		3	X	Soft-stem Bulrush	O	
		3	X	Bullhead Lily	O	
		3	X	Giant Ragweed	R	
		3	X	Pale Smartweed	R	
		3	X	Curly-leaved Pondweed	R	
		3	X	(T. angustifolia x T. latifolia)	O	
		3	X	Canada Thistle	R	
		3	X	Spotted Touch-me-not	R	
		3	X	Reed Canary Grass	R	
		4	1	Bulrush	3	
		4	1	(T. angustifolia x T. latifolia)	9	
		4	1	Spotted Touch-me-not	4	
		4	2	Hedge Bindweed	3	
		4	2	Common Reed	9	
		4	2	Spotted Touch-me-not	3	
		4	3	Spotted Touch-me-not	7	
		4	3	Bulrush	4	
		4	3	Rice Cut Grass	8	
		4	3	Narrow-leaved Cattail	6	
		4	4	Stonewort	4	
		4	4	Water-milfoil	+	
		4	4	Stiff Arrowhead	7	
		4	4	Soft-stem Bulrush	3	
		4	5	Stonewort	6	
		4	5	Sago Pondweed	6	
		4	5	Stiff Arrowhead	7	
		4	5	Water-milfoil	3	
		4	6	Stiff Arrowhead	6	
		4	6	Curly-leaved Pondweed	2	
		4	6	Bushy Naiad	2	
		4	6	Water Star-grass	3	
		4	6	Muskgrass	2	
		4	6	Water-milfoil	4	
		4	X	Wild Cucumber	O	
		4	X	Bulb-bearing Water-hemlock	O	
		4	X	Nodding Beggarticks	O	
		4	X	Common Dodder	O	
		4	X	Coarse Cyperus	O	
		4	X	Canada Thistle	O	
		4	X	Red-rooted Cyperus	O	188
		4	X	Marsh Yellow Cress	O	
		4	X	Bullhead Lily	O	

		4	X	Common Arrowhead	O
		4	X	Heart-leaved Willow	O
		4	X	Pickerel-weed	O
		4	X	Pale Smartweed	O
		4	X	Blue Vervain	O
		4	X	Tape-grass	O
		4	X	European Stinging Nettle	O
		4	X	(T. angustifolia x T. latifolia)	O
		4	X	Giant Bur-reed	O
		4	X	American Water-horehound	O
Smith Marsh	Smith Marsh	1	1	European Stinging Nettle	3
		1	1	(T. angustifolia x T. latifolia)	3
		1	1	Spotted Touch-me-not	9
		1	1	Common Dodder	3
		1	2	Spotted Touch-me-not	8
		1	2	European Stinging Nettle	5
		1	2	(T. angustifolia x T. latifolia)	4
		1	3	Muskgrass	2
		1	3	Stiff Arrowhead	7
		1	3	Bullhead Lily	3
		1	3	Common Coontail	3
		1	4	Bushy Naiad	3
		1	4	Water-milfoil	4
		1	4	Muskgrass	8
		1	4	Stiff Arrowhead	4
		1	4	Soft-stem Bulrush	6
		1	5	Stonewort	10
		1	5	Tape-grass	6
		1	5	Curly-leaved Pondweed	3
		1	X	Canada Thistle	O
		1	X	Blue Vervain	O
		1	X	Sago Pondweed	O
		1	X	Hedge Bindweed	A
		1	X	Common Arrowhead	O
		1	X	Mermaid-weed	R
		1	X	Pale Smartweed	R
		1	X	Fragrant Water-lily	O
		1	X	Bulrush	O
Squire's Ridge	Helmer's Pond	1	1	Hedge Bindweed	4
		1	1	Field Horsetail	1
		1	1	Marsh Fern	9
		1	1	Tussock Sedge	2
		1	1	Pale Touch-me-not	+
		1	1	False-nettle	3
		1	1	Tall Goldenrod	5
		1	2	Unidentified Moss	6
		1	2	Marsh Bellflower	2
		1	2	Buttonbush	8
		1	2	Marsh Cinquefoil	3

		1	2	Marsh Fern	2
		1	2	Canada Blue-joint	3
		1	3	Marsh Bellflower	2
		1	3	Wild Strawberry	2
		1	3	Buttonbush	7
		1	3	Unidentified Moss	7
		1	3	Tussock Sedge	+
		1	3	Marsh Cinquefoil	6
		1	3	Common Skullcap	2
		1	3	Marsh Fern	3
		1	3	Common Arrowhead	3
		1	4	Unspecified Violet	+
		1	4	Marsh St. John's-wort	3
		1	4	Marsh Bellflower	3
		1	4	Tussock Sedge	5
		1	4	Canada Blue-joint	5
		1	4	False-nettle	3
		1	4	Spotted Touch-me-not	3
		1	4	Marsh Fern	4
		1	5	Bulb-bearing Water-hemlock	1
		1	5	Swamp Loosestrife	3
		1	5	Bogbean	4
		1	5	Calico Aster	3
		1	5	Buttonbush	3
		1	5	Tussock Sedge	4
		1	5	Marsh Cinquefoil	3
		1	5	Marsh Fern	8
		1	5	Canada Blue-joint	3
		1	5	Devil's Beggarticks	2
		1	5	False-nettle	3
		1	X	Tufted Loosestrife	O
		1	X	Mermaid-weed	O
		1	X	Swamp Rose	O
		1	X	Water Sedge	O
		1	X	Bebb's Sedge	0
		1	X	Basket Willow	R
		1	X	Common Scouring-rush	O
		1	X	Nodding Beggarticks	O
		1	X	Lake Sedge	O
		1	X	Water Smartweed	O
		1	X	Marsh Pea	O
		1	X	Southern Blue-flag	R
		1	X	Meadowsweet	O
		1	X	Twig-rush	R
		1	X	Canada Thistle	O
		2	1	Black-seeded Clearweed	5
		2	1	False-nettle	2
		2	1	Marsh Fern	3
		2	1	Canada Blue-joint	6
		2	1	Swamp Loosestrife	5
		2	1	Common Arrowhead	6
		2	1	Bugleweed	1

		2	1	Unidentified Moss	6
		2	1	Marsh Bedstraw	2
		2	1	Spotted Touch-me-not	2
		2	1	Marsh Bellflower	1
		2	2	False-nettle	4
		2	2	Marsh Fern	2
		2	2	Common Arrowhead	3
		2	2	Swamp Loosestrife	7
		2	2	Marsh Bellflower	3
		2	2	Canada Blue-joint	4
		2	2	Marsh Cinquefoil	3
		2	2	Bulb-bearing Water-hemlock	1
		2	2	Spotted Touch-me-not	1
		2	2	Unidentified Moss	2
		2	2	Marsh Pea	3
		2	3	Nodding Beggarticks	5
		2	3	Canada Blue-joint	5
		2	3	Marsh St. John's-wort	1
		2	3	Marsh Fern	5
		2	3	Spotted Touch-me-not	2
		2	3	Common Arrowhead	4
		2	3	Swamp Loosestrife	8
		2	3	Unidentified Moss	3
		2	4	Common Cattail	3
		2	4	Swamp Loosestrife	5
		2	4	Water Smartweed	+
		2	4	Canada Blue-joint	5
		2	4	Marsh Bellflower	2
		2	4	Unidentified Moss	3
		2	4	Spotted Touch-me-not	3
		2	5	False-nettle	2
		2	5	Common Arrowhead	3
		2	5	Canada Blue-joint	5
		2	5	Devil's Beggarticks	3
		2	5	Marsh Fern	3
		2	5	Spotted Touch-me-not	8
		2	X	Small's Spike-rush	O
		2	X	Pickerel-weed	O
		2	X	Common Skullcap	R
		2	X	Buttonbush	O
		2	X	Calico Aster	R
		2	X	Pilewort	R
		2	X	Hard-stemmed Bulrush	O
		2	X	Field Horsetail	R
		2	X	Fragrant Water-lily	O
		2	X	Water-milfoil	R
		2	X	Southern Blue-flag	O
		2	X	Horseweed	R
		3	1	(T. angustifolia x T. latifolia)	3
		3	1	Black-seeded Clearweed	2
		3	1	Water Smartweed	3

		3	1	Common Arrowhead	3
		3	1	Smartweed	1
		3	1	Bulb-bearing Water-hemlock	2
		3	1	False-nettle	7
		3	1	Giant Bur-reed	3
		3	1	Tufted Loosestrife	2
		3	1	Canada Blue-joint	5
		3	1	Devil's Beggarticks	3
		3	2	Buttonbush	5
		3	2	Common Reed	4
		3	3	Unidentified Moss	3
		3	3	Common Reed	8
		3	3	Buttonbush	3
		3	4	Common Reed	5
		3	4	Field Horsetail	5
		3	4	Trailing Wild Bean	4
		3	4	Late Goldenrod	7
		3	4	Buttonbush	
		3	5	Common Reed	5
		3	X	Bullhead Lily	O
		3	X	Tussock Sedge	O
		3	X	Marsh Cinquefoil	O
		3	X	Marsh Fern	o
		3	X	Narrow-leaved Cattail	O
		3	X	Swamp Loosestrife	O
		3	X	Heart-leaved Willow	O
		3	X	Canada Thistle	O
		3	X	Twig-rush	O
		3	X	Threesquare	O
		3	X	Fragrant Water-lily	O
Thoroughfare	Little Rice Bay	1	1	Nodding Beggarticks	2
		1	1	(T. angustifolia x T. latifolia)	3
		1	1	Common Arrowhead	2
		1	1	Narrow-leaved Cattail	6
		1	1	Frog's-bit	2
		1	1	Common Duckweed	2
		1	2	Nodding Beggarticks	2
		1	2	Spotted Touch-me-not	6
		1	2	Common Arrowhead	3
		1	2	(T. angustifolia x T. latifolia)	6
		1	2	Smartweed	3
		1	3	Nodding Beggarticks	3
		1	3	Hedge Bindweed	3
		1	3	(T. angustifolia x T. latifolia)	6
		1	4	Bushy Naiad	3
		1	4	Stonewort	3
		1	4	Hard-stemmed Bulrush	5
		1	4	Narrow-leaved Cattail	5
		1	4	Bullhead Lily	3
		1	5	Hard-stemmed Bulrush	6
		1	X	European Stinging Nettle	O
		1	X	Southern Wild Rice	R

		1	X	Climbing Nightshade	O
		1	X	Bulb-bearing Water-hemlock	R
		1	X	Soft-stem Bulrush	O
		1	X	Threesquare	O
		1	X	Bulrush	O
		1	X	Spotted Water-hemlock	R
		1	X	Mild Water-pepper	O
		1	X	Curly-leaved Pondweed	0
		1	X	Common Reed	O
		1	X	Pickerel-weed	O
		2	1	Frog's-bit	2
		2	1	Bullhead Lily	2
		2	1	(T. angustifolia x T. latifolia)	5
		2	2	(T. angustifolia x T. latifolia)	7
		2	2	Bushy Naiad	2
		2	3	Curly-leaved Pondweed	2
		2	3	Small's Spike-rush	3
		2	3	Hard-stemmed Bulrush	2
		2	3	Stonewort	6
		2	4	Hard-stemmed Bulrush	3
		2	4	Stonewort	10
		2	5	Bushy Naiad	8
		2	5	Stonewort	7
		2	X	Sago Pondweed	O
		2	X	Southern Wild Rice	O
		2	X	Common Bladderwort	O
		2	X	Canada Water-weed	O
		2	X	Common Reed	O
		2	X	Illinois Pondweed	O
		3	1	Frog's-bit	2
		3	1	Bullhead Lily	4
		3	1	(T. angustifolia x T. latifolia)	7
		3	2	Frog's-bit	+
		3	2	(T. angustifolia x T. latifolia)	6
		3	3	(T. angustifolia x T. latifolia)	5
		3	3	Tape-grass	5
		3	3	Muskgrass	8
		3	4	Southern Wild Rice	5
		3	4	Water-milfoil	2
		3	4	Bullhead Lily	2
		3	4	Muskgrass	7
		3	4	Stonewort	9
		3	X	Aquatic Beggarticks	R
Upper Big Creek	Big Creek	1	1	Water-pepper	2
		1	1	Spotted Touch-me-not	4
		1	1	(S. alba X S. fragilis)	2
		1	1	(T. angustifolia x T. latifolia)	5
		1	2	Common Arrowhead	5
		1	2	Common Duckweed	2
		1	2	Soft-stem Bulrush	8
		1	2	Frog's-bit	5
		1	3	Common Duckweed	2

		1	3	Water net	9
		1	3	Sago Pondweed	6
		1	3	Common Arrowhead	7
		1	3	Soft-stem Bulrush	4
		1	4	(T. angustifolia x T. latifolia)	4
		1	4	Soft-stem Bulrush	5
		1	4	Common Arrowhead	9
		1	4	Common Duckweed	1
		1	5	Water net	8
		1	5	Canada Water-weed	3
		1	5	Sago Pondweed	4
		1	5	Water Star-grass	3
		1	X	European Stinging Nettle	O
		1	X	Common Coontail	o
		1	X	Bulb-bearing Water-hemlock	O
		1	X	Climbing Nightshade	O
		1	X	Common Reed	O
		1	X	Rice Cut Grass	O
		1	X	Small's Spike-rush	O
		1	X	Stiff Arrowhead	O
		1	X	Nodding Beggarticks	O
		1	X	Cursed Crowfoot	R
		1	X	Giant Bur-reed	O
Velocity Creek	Little Rice Bay	1	1	Jointed Rush	2
		1	1	Soft-stem Bulrush	3
		1	1	Variable-leaved Pondweed	2
		1	1	Marsh St. John's-wort	2
		1	1	Common Arrowhead	4
		1	1	Narrow-leaved Cattail	5
		1	2	Common Reed	4
		1	2	Stonewort	8
		1	2	Soft-stem Bulrush	4
		1	2	Water Sedge	5
		1	2	Spike-rush (unspecified)	+
		1	2	Variable-leaved Pondweed	5
		1	2	Canada Blue-joint	4
		1	3	Giant Bur-reed	3
		1	3	Stonewort	3
		1	3	Southern Wild Rice	3
		1	3	Soft-stem Bulrush	3
		1	3	Common Reed	5
		1	3	Variable-leaved Pondweed	7
		1	3	Creeping Sedge	4
		1	4	Stonewort	8
		1	4	Common Reed	3
		1	4	Variable-leaved Pondweed	4
		1	4	Bushy Naiad	5
		1	4	Stiff Arrowhead	4
		1	4	Water Sedge	3
		1	4	Narrow-leaved Cattail	
		1	5	Stonewort	10
		1	5	Common Reed	5

		1	5	Red-based Spike-rush	2
		1	5	Variable-leaved Pondweed	2
		1	5	Stiff Arrowhead	3
		1	6	Common Reed	+
		1	6	Large-leaved Pondweed	5
		1	6	Hard-stemmed Bulrush	5
		1	6	Muskgrass	6
		1	6	Variable-leaved Pondweed	2
		1	6	Stiff Arrowhead	4
		1	6	Common Bladderwort	3
		1	6	Stonewort	6
		1	7	Hard-stemmed Bulrush	4
		1	7	Muskgrass	4
		1	7	Muskgrass	3
		1	7	Common Reed	3
		1	7	Stonewort	10
		1	X	Canadian Rush	O
		1	X	Short-headed Rush	O
		1	X	Boneset	O
		1	X	Fragrant Water-lily	O
		1	X	Climbing Nightshade	O
		1	X	Four-angled Spike-rush	O
		1	X	Smith's Club-rush	R
		1	X	Knotted Rush	O
		1	X	Small's Spike-rush	O
		1	X	Floating Pondweed	O
		1	X	Sago Pondweed	O
		1	X	Cottonwood	O
		1	X	Blue Vervain	O
		1	X	Porcupine Sedge	R
		1	X	Illinois Pondweed	O
		1	X	Curly-leaved Pondweed	O
		1	X	Bullhead Lily	O
		1	X	Water Smartweed	R
		1	X	Few-flowered Spike-rush	O
		1	X	Lake Sedge	O
		1	X	Pickerel-weed	O
		2	1	Calico Aster	+
		2	1	Fragrant Water-lily	5
		2	1	River Horsetail	8
		2	1	Common Arrowhead	2
		2	1	Hard-stemmed Bulrush	5
		2	2	River Horsetail	3
		2	2	Common Reed	1
		2	2	Variable-leaved Pondweed	2
		2	2	Small's Spike-rush	3
		2	2	Canadian Rush	5
		2	2	Hard-stemmed Bulrush	4
		2	3	Common Reed	5
		2	3	Stonewort	10
		2	3	Cottonwood	5

		2	3	River Horsetail	2
		2	3	Soft-stem Bulrush	4
		2	3	Heart-leaved Willow	3
		2	3	Purple-leaved Willow-herb	2
		2	3	Stiff Arrowhead	3
		2	4	Variable-leaved Pondweed	8
		2	4	Stonewort	4
		2	4	Muskgrass	3
		2	4	Bushy Naiad	5
		2	4	Hard-stemmed Bulrush	1
		2	4	Stiff Arrowhead	3
		2	5	Bushy Naiad	5
		2	5	Stonewort	7
		2	5	Common Arrowhead	4
		2	5	Large-leaved Pondweed	5
		2	5	Soft-stem Bulrush	3
		2	5	Muskgrass	7
		2	X	Giant Bur-reed	O
		2	X	Few-flowered Spike-rush	O
		2	X	Southern Wild Rice	O
		2	X	Small's Spike-rush	O
		2	X	Three-way Sedge	R
		2	X	Fragrant Water-lily	O
		2	X	Sago Pondweed	O
		2	X	Boneset	R
		2	X	Water Sedge	O
		2	X	Creeping Sedge	R
		2	X	Muskgrass	O
		2	X	Red-based Spike-rush	O
		2	X	Pickerel-weed	R
		2	X	Red-osier Dogwood	R
		2	X	Bulrush	R
		2	X	Canada Blue-joint	O
		2	X	Climbing Nightshade	R
		3	1	Hard-stemmed Bulrush	4
		3	1	Narrow-leaved Cattail	5
		3	1	River Horsetail	4
		3	2	Fragrant Water-lily	2
		3	2	Frog's-bit	4
		3	2	Hard-stemmed Bulrush	4
		3	2	River Horsetail	6
		3	2	Small's Spike-rush	5
		3	2	Variable-leaved Pondweed	2
		3	3	Fragrant Water-lily	5
		3	3	Muskgrass	3
		3	3	Common Arrowhead	4
		3	3	Hard-stemmed Bulrush	3
		3	3	Small's Spike-rush	6
		3	3	Pickerel-weed	3
		3	4	Fragrant Water-lily	5
		3	4	Stonewort	6
		3	4	Southern Wild Rice	3

		3	4	Climbing Nightshade	2
		3	4	Small's Spike-rush	5
		3	4	Hard-stemmed Bulrush	2
		3	4	Common Arrowhead	2
		3	4	Common Reed	3
		3	4	Water Sedge	2
		3	4	Large-leaved Pondweed	3
		3	4	River Horsetail	5
		3	X	Jointed Rush	O
		3	X	Canada Thistle	O
		3	X	Four-angled Spike-rush	O
		3	X	Canada Blue-joint	O
		3	X	Great Hairy Willow-herb	R
		3	X	Marsh Cinquefoil	O
		3	X	Giant Bur-reed	O