Chapter 3
Vegetation Community Indicators

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Introduction

Vegetation sampling has been conducted in Great Lakes coastal wetlands for the purposes of classification, identification of important wetlands for protection or acquisition, and characterization of wetlands for management. Sampling has often been conducted along transects with the purpose of identifying physical gradients and corresponding biological gradients or zones. It is recognized that relatively discrete vegetation zones occur at most coastal wetland sites due to differences in water depth and substrate, and that wave energy also effects wetland vegetation diversity. A classification of coastal wetlands, developed by the Great Lakes Wetland Consortium, is present on the Consortium's web page.

In the initial phases of this project, data were collected across four regional areas of lakes Erie, Ontario and Huron, in an attempt to develop a Great Lakes-wide plant index of biotic integrity (IBI). Studies were being conducted in other parts of the Great Lakes as well in attempts to create a multimetric plant index. These attempts have not been clearly successful for several reasons, including extreme water level fluctuations, as well as the complex array of disturbance factors that occur at different spatial scales and in different spatial configurations around the Great Lakes. Differences in prevailing wind direction, shoreline configuration and wetland size all combine to make direct comparisons of neighboring wetlands nonproductive.

Because of the limited success at developing a Great Lakes-wide IBI with plants, this study suggests a more limited approach to evaluating coastal wetland degradation, one focusing on those factors agreed on by the plant ecologists studying Great Lakes coastal wetlands and participating in the Great Lakes Coastal Wetlands Consortium. These factors include 1) the coverage and distribution of invasive plants, 2) the coverage and diversity of submergent and floating plants, and 3) computing the Floristic Quality Index (FQI) and comparing it to regional FQI scores.

In the Great Lakes, the expansion of invasive plants into wetlands is the result of disturbances that alter the upper, seasonally wet edge of the wetland or disturbances that alter the permanently flooded portion of the wetland. The wet meadow and inner emergent marsh zones are typically degraded by alterations of the hydrology caused by ditching or the physical disturbance of sediments, resulting in the introduction of invasives. In contrast, changes to the outer emergent marsh and the submergent marsh zones are the result of disturbances to the flooded portion of the marsh by dredging, the addition of nutrients in the form of fertilizer or animal waste, or the addition of fine sediment as the result of intensive agriculture. It is recommended that these zones be monitored separately to identify sources of degradation, and thus allow solutions to be identified for each zone.

Alterations of the wet meadow or upper emergent zone result in drier conditions and bare exposed sediments, allowing small-seeded invasive species to establish and rapidly expand by rhizomes or stolons. Many invasives are tall perennials that shade out native plants. A list of invasive species is provided.

The submergent and flooded emergent marsh zones are degraded by fine sediments and organic nutrients from either agriculture or urban areas, resulting in high turbidity and resultant reduced photosynthesis and regeneration by seed for many submergent plants. Added nutrients and sediments provide habitat for Eurasian carp – large, aggressive bottom feeders which uproot many aquatic plants. Some of the species most tolerant of high nutrient and turbidity levels are invasive species that form dense weed beds of reduced habitat value to fish and other aquatic fauna.

A successful approach to evaluating the intactness of plant communities is the computation of a floristic quality index, which utilizes all plant species present at a site to estimate the intactness of the plant community. Conservatism index scores, discussed below, are developed and applied regionally with upper and lower limits of 10 and zero. A mean conservatism score evaluates the intactness of the wetland habitat, based on all of the plant species at a site. The use of the mean conservatism index is recommended for monitoring changes to Great Lakes coastal wetland vegetation.

In summary, this monitoring protocol focuses on 1) identifying and quantifying those invasive plants that are considered indicators of degraded habitat, 2) identifying significant changes to the submergent and floating-leaved vegetation of emergent and submergent marsh zones, and 3) comparing regional Mean Conservatism Indices for Great Lakes coastal wetland types to the local site's Mean Conservatism Indices.

Vegetation Sampling

Extensive vegetation sampling has been conducted in Great Lakes coastal wetlands for the purpose of classification, identification of important wetlands for protection or acquisition, and characterization of wetlands for management. Much of the sampling has been conducted along transects placed perpendicular to the shoreline with the purpose of identifying physical gradients and corresponding biological gradients or zones. In general, it is recognized that relatively discrete zones of shrub, wet meadow, emergent and sometimes submergent vegetation occur at most coastal wetland sites, and that these zones are related to differences in water depth, as well as associated differences in substrate. Frequency of inundation and wave energy increase with water depth in coastal wetlands directly connected to the Great Lakes. As wave energy increases, the amount of aquatic vegetation decreases; along high energy areas of the shoreline, the only coastal wetlands present are sheltered behind a barrier dune or beach ridge. See the classification of coastal wetlands on the Great Lakes Wetland Consortium web site for a more detailed description of coastal wetland types (Albert et al. 2003, Albert et al. 2005).

Evaluation of Great Lakes coastal wetlands quality and health

In the initial phases of this project, data were collected in more than 40 wetlands across four regional areas of lakes Erie, Ontario and Huron in an attempt to develop a Great Lakes-wide plant Index of Biotic Integrity (IBI), which would allow the ranking of all Great Lakes wetlands sites (Minc and Albert 2004). This attempt was not conducted in isolation, as other studies were being conducted as well, typically on a smaller scale (Albert and Minc 2004, Albert et al. 2006, Mack et al. in press, Simon and Rothrock 2006, Stewart et al. 2003, 1999, Wilcox et al. 2002). Attempts to create a multimetric plant index have not been clearly successful, for several reasons. Probably the greatest source of variability in Great Lakes wetland plant community composition is the extreme water level fluctuations that characterize the Great Lakes (Wilcox et al. 2002, Albert and Minc 2004, Albert et al. 2006, Hudon et al. 2006). Comparing the health of several wetlands of a single type or lake is complicated by the fact that each wetland is altered by a complex array of disturbance factors that occur at different spatial scales and in different spatial configurations. For example, winds along Saginaw Bay result in nutrient-rich organic sediments from the Saginaw River accumulating in a single wetland, contributing to the formation of dense algal mats nearly a meter thick at times. While other wetlands may receive similar amounts of organic sediments, they are not regularly concentrated to such a degree by the wind. Prevailing wind direction, shoreline configuration and wetland size all combine to make direct comparisons of neighboring wetlands nonproductive.

Because of the limited success in developing a Great Lakes-wide IBI for plants, we are suggesting a more limited approach to evaluating coastal wetland degradation, one focusing on those factors agreed on by the plant ecologists studying Great Lakes coastal wetlands and participating in the Great Lakes Coastal Wetlands Consortium. These wetland ecologists agreed that the most effective factors or approaches for evaluating wetland degradation were measuring 1) the coverage and distribution of invasive plants, 2) the coverage and diversity of submergent and floating plants, and 3) computing the Floristic Quality Index (FQI) and comparing it to regional FQI scores. A fourth and extremely important approach, determining the amount of wetland already lost or altered by comparing historic and recent aerial photos, is not the focus of the vegetation group.

In the Great Lakes, the expansion of invasive plants into wetlands is the result of two distinct types of disturbance: disturbances that alter the upper, seasonally wet edge of the wetland or disturbances that alter the permanently flooded portion of the wetland. The wet meadow and inner emergent marsh zones are only occasionally flooded and are typically degraded as the result of alterations of the hydrology caused by ditching or the physical disturbance of sediments. Major introductions of invasives into the wet meadow are often the result of such physical disturbances. In contrast, changes to the outer emergent marsh and the submergent marsh zones are the result of disturbances to the flooded portion of the marsh, either by dredging, the addition of nutrients in the form of fertilizer or animal waste, or the addition of fine sediment as the result of intensive agriculture. For this reason, we have separated the recommended monitoring into tracking these zones separately for the purpose of identifying the sources of the degradation, and thus potentially allowing solutions to be identified for each zone.

Alteration of the wet meadow or upper emergent zone often results in both drier conditions and exposed sediments with no vegetation, a combination that allows small-seeded invasive species to become established in large numbers. Once established, many of the invasive plants in this zone are able to rapidly expand by rhizomes or stolons. Many of these invasives are also tall perennials that rapidly shade out and replace shorter native plants. A list of these invasive species is provided in the footnotes of Table 3.1 below.

The submergent marsh zone and the flooded portion of the emergent marsh zone are often degraded by the addition of fine sediments and organic nutrients from either agriculture or urban areas, resulting in high turbidity. High turbidity levels reduce the ability of many submergent plants to photosynthesize effectively. In addition, the deposition of suspended particulates on submergent plants may affect gas exchange with the environment. The combination of high turbidity and deposition of fine sediments on the bottom also reduces the ability of many submergent and floating plants to reproduce from seed, resulting in reduced plant reproduction. These additions of nutrients and sediments also provide excellent habitat for Eurasian carp (*Cyprinus carpio*), which are large, aggressive bottom feeders. Carp disturb the sediment, resulting in the resuspension of sediments and the uprooting of many aquatic plants. While minor levels of nutrient enrichment result in increased growth of many submergent and floating plants, further increases in nutrient enrichment are followed by rapid loss of plant coverage and/or diversity as turbidity increases beyond a critical point. Some of the species most tolerant of high nutrient and turbidity levels are invasive species. These invasives typically form dense weed beds that are of reduced habitat value to fish and other aquatic fauna and may create localized nocturnal anoxia.

An approach that has been used successfully to evaluate the intactness of plant communities is computation of a floristic quality index using a floristic quality assessment (FQA) program, which utilizes all plant species present at a site to estimate the intactness of the plant community and the site. FQAs are used to develop several indices, including the widely used *conservatism index* (*C*) and the *floristic quality index*. Each species is assigned a conservatism index based upon the specificity of a plant to a specific habitat. Species that can occupy a broad range of habitats are assigned low conservatism index scores, while those that are very restricted in their habitat are assigned high scores. Conservatism index scores are assigned through consensus by groups of plant ecologists with expert knowledge of plant species habitat fidelity. Conservatism index scores are developed and applied regionally and have upper and lower limits of 10 and zero. A mean conservatism score evaluates the conservatism of all of the species at a site. The floristic quality index is based on the square of the number of species times the conservatism index and is therefore influenced more by the number of species collected at a site than is the mean conservatism index. Floristic quality index scores are overly sensitive to sample size and water-level fluctuation, thus resulting in potentially large year-to-year score changes that do not reflect real changes in wetland quality. For that reason, the use of the mean conservatism (Mean C) is recommended for monitoring changes to Great Lakes coastal wetland vegetation.

Use of the Michigan Floristic Quality Assessment program (Herman et al. 2001) is recommended for the Great Lakes basin, as it was designed for use in Michigan, which encompasses most of the latitudinal gradient encountered in the Great Lakes. Alternative FQIs for Ohio, Indiana, Wisconsin, and southern Ontario do not adequately reflect the diverse flora found in Great Lakes wetlands. The FQA software is available through the Conservation Research Institute (Conservation Design Forum: cdf@cdfinc.com). Table 3-1 shows the standard output from FQA analyses for Mackinac Bay, a northern Lake Huron protected embayment. Standard indices computed with the software include FQI score, Mean C score, and Wetland Index (W). Each of these are computed for native species and for the total flora at a site, including adventive species. For this study, the Mean C for native species and total flora are being used. For Mackinac Bay, there are 44 native species and only one adventive species. As a result, the Mean C for native species (6.1) and total species (6.0) are very similar. For more disturbed sites, the difference between native and total Mean C scores can be much greater (Table 3-2).

In summary, this monitoring protocol focuses on 1) identifying and quantifying those invasive plants that are considered indicators of degraded habitat, 2) identifying significant changes to the submergent and floating-leaved vegetation of the emergent and submergent marsh zones, and 3) comparing regional mean conservatism indices for Great Lakes coastal wetland types to the local site's mean conservatism indices.

Table 3-1. Floristic Quality Assessment output for Mackinac Bay, Lake Huron.

Site:	Mackinac Bay 1999			By: D. Albert			
FLORISTIC QUALITY DATA		Native	44	97.80%	Adventive	1	2.20%
44	NATIVE SPECIES	Tree	0	0.00%	Tree	0	0.00%
45	Total Species	Shrub	3	6.70%	Shrub	0	0.00%
6.1	NATIVE MEAN C	W-Vine	0	0.00%	W-Vine	0	0.00%
6	W/Adventives	H-Vine	0	0.00%	H-Vine	0	0.00%
40.7	NATIVE FQI	P-Forb	28	62.20%	P-Forb	1	2.20%
40.2	W/Adventives	B-Forb	0	0.00%	B-Forb	0	0.00%
-4.7	NATIVE MEAN W	A-Forb	2	4.40%	A-Forb	0	0.00%
-4.7	W/Adventives	P-Grass	2	4.40%	P-Grass	0	0.00%
AVG:	Obl. Wetland	A-Grass	1	2.20%	A-Grass	0	0.00%
		P-Sedge	7	15.60%	P-Sedge	0	0.00%
		A-Sedge	0	0.00%	A-Sedge	0	0.00%
		Fern	1	2.20%			

ACRONYM	C	SCIENTIFIC NAME	W	WETNESS	PHYSIOGNOMY	COMMON NAME
AGRHYE	4	Agrostis hyemalis	1	FAC-	Nt P-Grass	TICKLEGRASS
ASTPUN	5	Aster puniceus	-5	OBL	Nt P-Forb	SWAMP ASTER
BIDCER	3	Bidens cernuus	-5	OBL	Nt A-Forb	NODDING BUR MARIGOLD
CALCAN	3	Calamagrostis canadensis	-5	OBL	Nt P-Grass	BLUE JOINT GRASS
CAMAPR	7	Campanula aparinoides	-5	OBL	Nt P-Forb	MARSH BELLFLOWER
CXAQUA	7	Carex aquatilis	-5	OBL	Nt P-Sedge	SEDGE
CXLASI	8	Carex lasiocarpa	-5	OBL	Nt P-Sedge	SEDGE
CXSTRI	4	Carex stricta	-5	OBL	Nt P-Sedge	SEDGE
ELEACI	7	Eleocharis acicularis	-5	OBL	Nt P-Sedge	SPIKE RU.S.H
ELESMA	5	Eleocharis smallii	-5	OBL	Nt P-Sedge	SPIKE RU.S.H
EQUFLU	7	Equisetum fluviatile	-5	OBL	Nt Fern Ally	WATER HORSETAIL
GALTRD	6	Galium trifidum	-4	FACW+	Nt P-Forb	SMALL BEDSTRAW
HETDUB	6	Heteranthera dubia	-5	OBL	Nt P-Forb	WATER STAR GRASS
HIPVUL	10	Hippuris vulgaris	-5	OBL	Nt P-Forb	MARE'S TAIL
IRIVER	5	Iris versicolor	-5	OBL	Nt P-Forb	WILD BLUE FLAG
LATPAL	7	Lathyrus palustris	-3	FACW	Nt P-Forb	MARSH PEA
LYCUNI	2	Lycopus uniflorus	-5	OBL	Nt P-Forb	NORTHERN BUGLE WEED
LYSTHY	6	Lysimachia thyrsiflora	-5	OBL	Nt P-Forb	TUFTED LOOSESTRIFE
MYRGAL	6	Myrica gale	-5	OBL	Nt Shrub	SWEET GALE
MYREXA	10	Myriophyllum exalbescens	-5	OBL	Nt P-Forb	SPIKED WATER MILFOIL
MYRHET	6	Myriophyllum heterophyllum	-5	OBL	Nt P-Forb	VARIOU.S. LEAVED WATER MILFOIL
NAJFLE	5	Najas flexilis	-5	OBL	Nt A-Forb	SLENDER NAIAD
NUPVAR	7	Nuphar variegata	-5	OBL	Nt P-Forb	YELLOW POND LILY
POLAMP	6	Polygonum amphibium	-5	OBL	Nt P-Forb	WATER SMARTWEED
PONCOR	8	Pontederia cordata	-5	OBL	Nt P-Forb	PICKEREL WEED
POTAMP	6	Potamogeton amplifolius	-5	OBL	Nt P-Forb	LARGE LEAVED PONDWEED
POTGRM	5	Potamogeton gramineus	-5	OBL	Nt P-Forb	PONDWEED
POTNAT	5	Potamogeton natans	-5	OBL	Nt P-Forb	PONDWEED
POTPAL	7	Potentilla palustris	-5	OBL	Nt P-Forb	MARSH CINQUEFOIL

Table 3-1. Floristic Quality Assessment output for Mackinac Bay, Lake Huron, Continued.
Site: Mackinac Bay 1999 By: D. Albert

SAGLAT	1	Sagittaria latifolia	-5	OBL	Nt P-Forb	COMMON ARROWHEAD
SALCAN	9	Salix candida	-5	OBL	Nt Shrub	HOARY WILLOW
SCHACU	5	Schoenoplectus acutus	-5	OBL	Nt P-Sedge	HARDSTEM BULRU.S.H
SCHSUB	8	Schoenoplectus subterminalis	-5	OBL	Nt P-Sedge	BULRU.S.H
SCUGAL	5	Scutellaria galericulata	-5	OBL	Nt P-Forb	COMMON SKULLCAP
SIU.S.UA	5	Sium suave	-5	OBL	Nt P-Forb	WATER PARSNIP
SPAMIN	8	Sparganium minimum	-5	OBL	Nt P-Forb	SMALL BUR REED
SPIALB	4	Spiraea alba	-4	FACW+	Nt Shrub	MEADOWSWEET
TEUCAN	4	Teucrium canadense	-2	FACW-	Nt P-Forb	WOOD SAGE
TRIFRA	6	Triadenum fraseri	-5	OBL	Nt P-Forb	MARSH ST. JOHN'S WORT
TYPANG	0	TYPHA ANGU.S.TIFOLIA	-5	OBL	Ad P-Forb	NARROW LEAVED CATTAIL
UTRINT	10	Utricularia intermedia	-5	OBL	Nt P-Forb	FLAT LEAVED BLADDERWORT
UTRMIN	10	Utricularia minor	-5	OBL	Nt P-Forb	SMALL BLADDERWORT
UTRVUL	6	Utricularia vulgaris	-5	OBL	Nt P-Forb	GREAT BLADDERWORT
VALAME	7	Vallisneria americana	-5	OBL	Nt P-Forb	EEL GRASS
ZIZAQU	9	Zizania aquatica var. aquatica	-5	OBL	Nt A-Grass	WILD RICE

Table 3-2. Comparison of Native Mean C and Total Mean C scores for three Great Lakes Marshes on lakes Huron and Erie.

Marsh Name	Mean C Score	
	Native	Total (Native + Adventive)
Mackinac Bay, Lake Huron	6.1	6.0
Presque Isle Bay, Lake Erie	4.8	4.4
Bradleyville, Saginaw Bay, Lake Huron	3.9	3.3

Materials and Methods

Protocol for Great Lakes Marsh Aquatic Macrophyte Sampling

Mapping to identify sampling transects or random sampling points:

1. Using aerial photos, map wetland to be sampled, identifying major zones: wet meadow, emergent, and possibly submergent (Figures 3-1 and 3-2). Flooded portions of the emergent marsh zone typically contain abundant submergent and floating species, and these submergent plants can be analyzed rather than collecting data for the deeper submergent zone.
2. Overlay a random grid or identify three potential sampling transects that will cross typical zones.
3. If there are obvious monoculture (uniform) patches on the photos, these should be sampled, as these uniform areas are often areas of invasive plants. Large, dense areas of invasive plants should be mapped with GPS units or identified on aerial photos or satellite imagery to track the long-term expansion of these invasive patches.

Field Sampling:

1. In each zone, place 15 sample quadrats along transects or randomly, each quadrat with an area of 1.0 m^2. Limit sampling to two zones; 1) the wet meadow zone and dry portion of the emergent zone, and 2) the

flooded portion of the emergent zone and the submergent zone (Figures 3-1 and 3-2). Sampling points can be located along three transects (Figure 3-1) or randomly located using a GIS mapping program (Figure 3-2). Establishing points along transects requires less time than sampling random points and may be preferred for monitoring programs that have small budgets. For wetlands with narrow zones, sampling points may need to be located along a transect that is not perpendicular to the drainage gradient of the wetland (see Insert B on Figure 3.1). In some wetlands there is a submergent marsh zone that contains only floating or submergent plants. Typically, it is not necessary to sample this zone, as the flooded portion of the emergent zone will contain most of the plants in the deeper submergent zone and the emergent zone can be sampled much more rapidly.

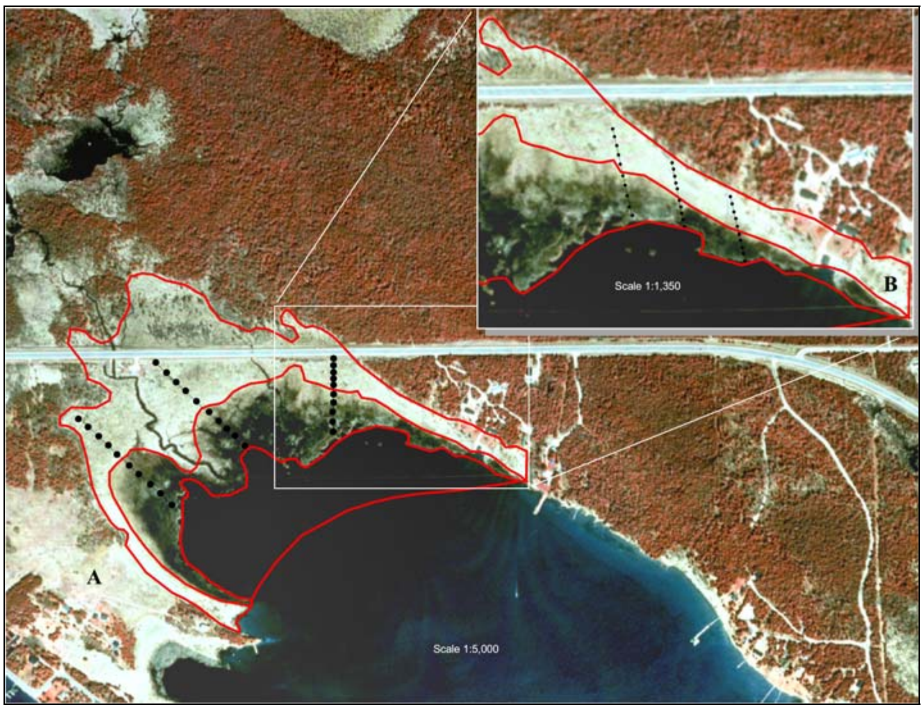

Figure 3-1. This aerial photo view of a wetland along northern Lake Huron shows the location of three transects, each beginning at the upland edge of the wetland and continuing south across the meadow zone (white) and the emergent/submergent zone (dark). The transects end at the edge of the emergent zone, even though there may be continued vegetation in a more open submergent zone. This open vegetation cannot typically be seen easily on aerial photos. Photo A shows 15 sampling points in each of the two zones. Photo insert B shows that if a narrow portion of this wetland, or a wetland that was narrow along its entire length, were being sampled, that the transects would need to be configured at an angle to the wetland's slope to allow for all 30 points to be placed. Locating the points along transects allows for more rapid sampling than the random sampling shown in Figure 3-2.

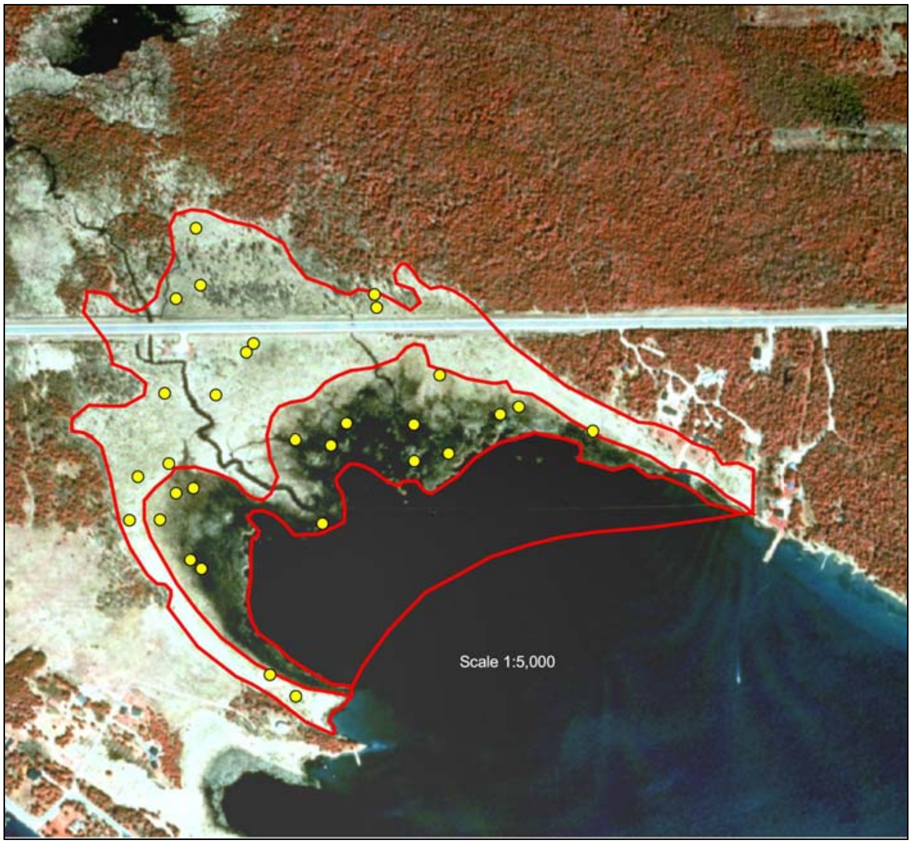

Figure 3-2. Random sampling of the wetland shown in figure 1. Random sampling can be configured utilizing GIS software, or by physically (or electronically) placing a grid over the photo and randomly choosing sampling points.

2. If transects are used, the starting point for each transect is randomly placed within 25 meters of the upland edge of the wet meadow zone, with sampling points established 25 meters apart. The location of each sampling quadrat around a sampling point is selected randomly using compass bearings and distances from one to nine meters. Percent cover is estimated for each plant species in the sample quadrat; coverage is estimated for all emergent, floating and submergent species. Substrate, organic depth, water depth and water clarity (using Secchi disk) are recorded. Depths of shallow organic soils can be measured with forcing a sharpened 4' x 3" (1.2 m x 8 cm) clear Plexiglas tube into the substrate until mineral soils are encountered and then forcing a rubber stopper into the top of the tube to create a vacuum, and then extracting the tube and reading the depth of the organic material in it. For deeper organic materials, as often encountered in barrier-enclosed or riverine wetlands, a 10-foot (3 m) length of ¾ inch (1.8 cm) aluminum conduit provides an inexpensive measuring pole. In each sample plot, list the species present along with approximate coverage value. Use values of 1%, 3%, 5%, 10% and so on, increasing by increments of 5% for higher coverage values. Note that cumulative areal coverage of all species can exceed 100% because more than one species can occupy the same space in a 2-dimensional plane. In addition, if it is not possible to place the quadrat close to the ground (i.e., in dense *Typha*), surveyors should be mindful of parallax and not include areas outside of the quadrat frame in their areal coverage estimates.

Although only vascular macrophytes are used in the mean conservatism indices, surveyors should record all aquatic macrophytes (e.g., *Chara*, *Nitella*, *Riccia*, *Ricciocarpos*). This may allow for further analyses in the future, including potential development of FQI indices for nonvascular plants. We are suggesting that plant taxonomic nomenclature be based on that found in the Michigan Flora (Voss 1972, 1985, 1996 and Herman et al. 2001). This will allow easy utilization of the FQA program, which contains almost all of the Great Lakes wetland flora. Another web-based flora of North America has been recommended (http://www.itis.gov), because it covers the entire flora of the continent, but taxonomic differences between this program and the FQA program are significant and will require the development of a crosswalk between ITIS and the FQA nomenclature.

Data are recorded on a standardized plant sampling form (Figure 3-3). This form provides the scientific names of the most commonly occurring aquatic macrophytes, with spaces provided for unknown species or species not listed on the form. For some genera with many species, such as *Carex* or *Potamogeton*, spaces are provided to fill in additional species within the genus. Since there are more than 600 species of aquatic macrophyte within Great Lakes coastal wetlands, only the most common are listed on the form. A more complete list of species is provided in Appendix 1. While this is a more complete list, no wetland tree species are included, although they might establish briefly during low-water conditions or they may be present at the edges of the open coastal wetland.

Worksheets

The worksheets utilized for the plant protocols include **Table 3-3:** Wetland quality based on aquatic macrophyte sampling; **Table 3-5:** Flow chart for determining quality rating of submergent marsh zone or submergent component of an emergent marsh zone; **Table 3-6:** Species tolerant of nutrient enrichment, sedimentation, or increased turbidity; and **Table 3-7:** Combined standardized score from Table 3-3, Rows A-I. Tables 3-1, 3-2, 3-4, and 3-8 provide additional examples and information, but are not required for computer marsh quality scores. **Figure 3-3:** Great Lakes Marsh Sampling Form, is utilized for collecting plant data in the wetland.

Checklists

One checklist is included: **Appendix 3-1**, a list of the most common wetland plants encountered in Great Lakes coastal wetlands.

Site selection/number of sites/stratification

Project-wide site selection, number of sites, and stratification is based on recommendations in the Statistical Design chapter of the report by Otieno and Uzarski. Overall statistical analysis selects and stratifies sites on the basis of ecoregions (Omernik 2000) and lake. For individual administrative units (state or province), it is recommended that hydrogeomorphic type (Albert and Simonson 2004) be noted, as the hydrogeomorphic types are important for understanding floristic differences.

As noted above, 15 sampling points are located in each zone of the wetlands chosen for sampling. Species areas curves leveled off after 12 to 15 sampling points in each marsh zone for most of the U.S. and Canadian wetlands studied, demonstrating that overall plant diversity was adequately sampled.

Analysis of quadrat data (use Table 3.3):

1. Compute overall INVASIVE COVER for the **entire site** by summing the coverage values for all invasive plants and dividing by the number of quadrats. This is the INVASIVE COVER score for the entire site and can be used to estimate the site quality; see Table 3-3-A for quality classes (High, Medium, Low, Very Low) and the equivalent numeric scores (5, 3, 1, 0).

2. Compute overall INVASIVE FREQUENCY for the **entire site** by summing the number of quadrats containing invasive species and dividing by the total number of quadrats. See Table 3-3-B for quality classes based on INVASIVE FREQUENCY.

3. Compute the MEAN CONSERVATISM INDEX for the **entire site** by totaling the conservatism score for each species and dividing by the number of species. This can be rapidly computed using the Michigan FQA software (Herman et al. 2001). The mean conservatism index for all species (total) is divided by the mean conservatism index for native species (native) and the ratio is compared (See Table 3-3, Row C for quality scores). Low scores (0.79 or lower) reflect large numbers of exotic species and degraded conditions. Table 3-4 provides average regional mean conservatism index scores for each of the Great Lakes and for each of the hydrogeomorphic types. The scores in Table 3.4 are not used in computing the quality of the wetland, but provide a regional perspective to wetland quality in different lakes and hydrogeomorphic types.

4. Compute overall INVASIVE COVER for the **wet meadow and dry emergent zone** by summing the coverage values for all INVASIVE plants in these zones and dividing by the number of quadrats in these zones. This is the INVASIVE COVER score for the wet meadow and dry emergent zone and can be used to estimate the zone quality; see Table 3-3, Row D for quality classes.

5. Compute overall INVASIVE FREQUENCY for the **wet meadow and dry emergent zone** by summing the number of quadrats (in these zones) containing INVASIVE species and dividing by the total number of quadrats in the wet meadow and dry emergent zones. See Table 3-3, Row E for quality classes of the wet meadow and dry emergent zone based on INVASIVE FREQUENCY.

6. Compute the MEAN CONSERVATISM INDEX for the **wet meadow and dry emergent zone** by totaling the conservatism score for each species in these zones and dividing by the number of species. This can be rapidly computed using the Michigan FQA software (Herman et al. 2001). The mean conservatism index for all species (total) in the **wet meadow and dry emergent zone** is divided by the mean conservatism index for native species (native) and the ratio is compared (See Table 3-3, Row F for quality scores). Table 3-4 provides average regional mean conservatism index scores **by zone** for most of the Great Lakes and hydrogeomorphic types.

7. Compute overall INVASIVE COVER for the **flooded emergent and submergent zone** by summing the coverage values for all invasive plants in these zones and dividing by the number of quadrats in these zones. This is the INVASIVE COVER score for the **flooded emergent and submergent zone** and can be used to estimate the zone quality; see Table 3-3, Row G for quality classes.

8. Compute overall INVASIVE FREQUENCY for the **flooded emergent and submergent zone** by dividing the number of quadrats (in these zones) containing invasive species and dividing by the total number of quadrats in the **flooded emergent and submergent zone**. See Table 3-3, Row H for quality classes of the wet meadow and dry emergent zone based on INVASIVE FREQUENCY.

9. Compute the MEAN CONSERVATISM INDEX for the **flooded emergent and submergent zone** by totaling the conservatism score for each species in these zones and dividing by the number of species. This can be rapidly computed using the Michigan FQA software (Herman et al. 2001). The mean conservatism index for all species (total) in the **flooded emergent and submergent zone** is divided by the conservatism index for native species (native) and the ratio is compared (See Table 3-3, Row I for quality scores). Table 3-4 provides average regional mean conservatism index scores by zone for most of the Great Lakes and hydrogeomorphic types.

Table 3-3. Wetland quality based on aquatic macrophyte sampling.

VARIABLE	QUALITY			
	HIGH (5)	MEDIUM (3)	LOW (1)	VERY LOW (0)
A: INVASIVE COVER (entire site)[1]	Absent	<25 %	25-50%	>50%
B: INVASIVE FREQ. (entire site)	Absent	<25 %	25-50%	>50%
C: Mean conservatism of entire site (native/total)	>0.95	0.8 -0.94	0.6-0.79	< 0.6
D: INVASIVE COVER (wet meadow and dry emergent zones)[2]	Absent	<25 %	25-50%	>50%
E: INVASIVE FREQ. (wet meadow and dry emergent zones)	Absent	<25 %	25-50%	>50%
F: Mean conservatism score of wet meadow and dry portion of emergent zones (native/total)	>0.95	0.8 -0.94	0.6-0.79	< 0.6
G: INVASIVE COVER (flooded emergent and submergent zone)[3]	Absent	<25 %	25-50%	>50%
H: INVASIVE FREQUENCY (flooded emergent and submergent zone)	Absent	<25 %	25-50%	>50%
I: Mean conservatism of flooded emergent and submergent zones (native/total)	>0.95	0.8 -0.94	0.6-0.79	< 0.6

[1]Invasive species of entire site to include in analysis: *Butomus umbellatus* (flowering rush), *Cirsium arvense* (Canadian thistle), *Cirsium palustre* (marsh thistle), *Cirsium vulgare* (bull thistle), *Glyceria maxima* (tall manna grass), *Hydrocharis morsus-ranae* (European frog's-bit), *Impatiens glandulifera* (touch-me-not), *Iris pseudacorus* (yellow flag), *Lythrum salicaria* (purple loosestrife), *Myriophyllum spicatum* (Eurasian water milfoil), *Phalaris* arundinacea (reed canary grass), *Phragmites australis* (tall reed), *Polygonum lapathifolium* (nodding smartweed), *Potamogeton crispus* (curly pondweed), *Rorippa amphibia* (yellow cress), *Rumex crispus* (curly dock), *Typha angustifolia* (narrow-leaved cattail), *Typha* X *glauca* (hybrid cattail).

[2]Invasive species of wet meadow and dry emergent marsh: *Cirsium arvense*, *Cirsium palustre*, *Cirsium vulgare*, *Impatiens glandulifera, Iris pseudoacorus*, *Lythrum salicaria*, *Phalaris arundinacea*, *Phragmites australis*, *Polygonum lapathifolium*, *Rorippa amphibian, Rumex crispus*, *Typha angustifolia*, *Typha X glauca*.

[3]Invasive species of flooded emergent and submergent zone to include in analysis: *Butomus umbellatus*, *Hydrocharis morsus-ranae*, *Lythrum salicaria*, *Myriophyllum spicatum*, *Phalaris arundinacea*, *Phragmites australis*, *Potamogeton crispus*, *Typha angustifolia*, *Typha X glauca*.

Reference conditions for Regional Wetland Types

Several regional wetland types were identified through cluster analysis and Twinspan ordinations (Hill 1973, 1979) of vegetation data collected across the Great Lakes, including the connecting rivers (Minc 1997). Mean conservatism indices were computed for each of the regional wetland types (Table 3.2). For most of the wetland types, the indices were computed from the list of species that were present in more than 1% of the sampling points during inventories conducted in 1987, 1988, 1989, 1994, and 1995 (Albert et al. 1987, 1988, 1989; Minc 1997). For Georgian Bay protected embayments and Lake Erie sandspit embayments, the indices were computed from unpublished data collected in 2003 and 2004 (D. Albert). For the Lake Huron, Lake Michigan and Lake Superior swale complexes (barrier enclosed), scores were summarized from studies of swale complexes in Michigan (Comer et al. 1991, 1993). The Lake Ontario protected embayment and drowned river mouth sites are summarized from data collected by the Canadian Wildlife Service of Environment Canada in 2002 and 2003.

Table 3-4. Mean Conservatism Scores for each regional marsh type.

LAKE or REGIONAL MARSH TYPE	MEAN CONSERVATISM SCORE BY ZONE		
	MEADOW ZONE	EMERGENT ZONE	TOTAL MARSH
Lake Erie Open Embayments**	3.1 (4.6)	3.8 (5.3)	3.7 (5.3)
Lake Erie Sand-spit Embayments	4.3 (4.5)	4.4 (6.1)	4.5 (4.8)
Georgian Bay Protected Embayments *	5.1 (6.5)	6.4 (7.2)	5.8 (6.8)
Lake Huron (northern) protected Embayments	5.1	5.6	5.6
Lake Huron (northern) Open Embayments (Rich Fens)	5.5	4.5	5.1
Lake Huron's Saginaw Bay Open Embayment	3.2	4.5	3.9
Lake Huron Swale Complex (Barrier Enclosed)	-	-	4.9 (6.4)
Lake Michigan Drowned River Mouths	4.0	4.9	4.5
Lakes Michigan (northern) Open Embayments (Rich Fens)	5.5	4.5	5.1
Lake Michigan (northern) Protected Embayments	5.1	5.6	5.6
Lake Michigan Swale Complex (Barrier Enclosed)	-	-	5.3 (6.3)
Lake Ontario Barrier Beach Lagoons	5.0	5.7	5.3
Lake Ontario Drowned River Mouths	4.2	4.3	4.2
Lake Ontario Protected Embayments*	4.7 (6.4)	3.9 (5.8)	4.5 (6.3)
Lake St. Clair Open Embayments**	3.1	3.8	3.7
Lake Superior Barrier Beach Lagoons & Riverine Wetlands	6.3	6.7	6.4
Lake Superior Swale Complex (Barrier Enclosed)	-	-	5.9 (6.9)
St. Clair River Delta	4.2	5.5	4.7
St. Lawrence River Drowned River Mouths	4.4	5.5	5.0
St. Marys River Connecting Channel	5.1	5.6	5.6

* For Lake Ontario and Georgian Bay protected wetlands the mean scores for each zone are based on the scores of several wetlands rather than on a mean coverage value for all of the marshes studies. The maximum score of a single wetland for each zone is shown in parenthesis when the data is available ( ).
** For Lake Erie, mean C scores from historic data collected in high quality wetland at Perry's Victory Monument (Stuckey 1975) is shown in parenthesis ().

Evaluating wetland quality using submergent and floating plant species

Evaluating the quality of the portion of a wetland dominated by submergent or floating plants requires a multi-step process (Table 3-5), as several factors can influence the presence and density of these plants. Table 3.5 summarizes the ranks proposed for submergent or emergent zones using submergent and floating plants. It is common for submergent plants to cover only a portion of the bottom substrate in a marsh, so sparse submergent or floating vegetation does not necessarily indicate degraded conditions. High coverage (>75%) of submergent or floating vegetation, with a predominance (>50%) of nutrient-enrichment or sediment-and-increased-turbidity tolerant species (Table 3-6) typically indicates that either agriculture or urban development has resulted in increased nutrient, sediment, or turbidity in the lake waters (Index score = 1), but not to a level that would result in complete elimination of submergent or floating vegetation (Index score = 0). Under such conditions, other submergent and floating plants can be more common, in which case the wetland is considered less degraded (Index score = 3). Submergent and floating vegetation cover ranging from 25-75% is the typical condition for most emergent and submergent wetlands, and Index scores of 3 or 5 indicate this increased quality. Coverage values of less than 25% indicate degraded conditions if **only** nutrient-enrichment or sediment-and-increased-turbidity tolerant species are present, but are typical for other submergent or floating plant coverage values in many marshes (Index score = 5).

If submergent or floating plants are completely absent, it can indicate several conditions. In lower stream reaches (drowned river mouths, connecting rivers, or deltas), it can indicate that the stream velocity is too high for these plants to persist. Emergent plants may, however, be able to persist in these higher velocity regions of a stream. However, in protected bays or in slow-flowing lower reaches of streams, lack of submergent and floating vegetation typically indicates that sedimentation or turbidity is preventing plant establishment or persistence. When conditions are windy or when turbidity is the result of fine mineral or organic sediments, turbidity is often evident and can be directly linked to lack of wetland vegetation. However, when conditions are calm, surface waters can be clear, but thick, loose sediments will often be evident and easily stirred up during plant sampling. Another complication can be that strong winds may stir up sediment even though conditions are adequate for submergent and floating plants to occupy the wetland. In this case, the wetland would be judged on the basis of the vegetation present, **not** on the basis of the short-term turbidity.

Combined standardized score

A combined standardized score can be calculated by adding the wetland quality scores from Table 3-3 (Rows A-I) and Table 3-5. Each of these ten numeric scores ranges from zero to five, with a maximum total score of 50 and a minimum score of zero. The Combined numeric quality scores and their equivalent descriptive quality scores are shown in Table 3-7. Table 3-8 provides example scores for six riverine wetlands resulting from totaling the metrics in Table 3-3 and 3-5.

Table 3-5. Flow chart for determining quality rating of submergent marsh zone or submergent component of an emergent marsh zone.

	Plant Coverage	Type of submergent plants present	Index Score
Submergent or Floating Vascular Plant Species Present	>75%	>50% nutrient-enrichment tolerant species or sediment-and-increased-turbidity tolerant species	1 LOW
		<50% nutrient-enrichment tolerant species or sediment-and-increased-turbidity tolerant species	3 MODERATE
	25-75%	>50% nutrient-enrichment tolerant species or sediment-and-increased-turbidity tolerant species	3 MODERATE
		<50% nutrient-enrichment tolerant species or sediment-and-increased-turbidity tolerant species	5 HIGH
	<25%	>75% nutrient-enrichment tolerant species or sediment-and-increased-turbidity tolerant species	1 LOW
		<75% nutrient-enrichment tolerant species or sediment-and-increased-turbidity tolerant species	5 HIGH
Submergent or Floating Plant Species Absent	0%	Clear water in rapidly flowing streams or where bottom consists of cobbles or rock	? REQUIRES FURTHER ANALYSIS
		Highly turbid at time of survey, loose bottom sediments	0 VERY LOW
		Clear water, but thick, loose bottom sediments	0 VERY LOW
Only Algae Present			0 VERY LOW

Mapping of invasive species

If there are areas where invasive species have greater than 50% cover, these should be mapped. Boundaries of polygons should be identified on recent aerial photos and or mapped with a GPS unit. Mapping allows the agency managing the marsh to either initiate restoration activities or document the spread of invasive species in future monitoring periods. Further detailed sampling can be conducted in polygons dominated by invasives to meet the needs of the sampling agency. For example, five randomly located 1 m2 quadrats could be sampled in one or several large patches of invasive plants to document the species composition and relative coverage values (estimated to 5%) for long-term monitoring of change within the patches, either due to natural wetland changes or to active management. If there are several patches of invasive species, at least one polygon of each invasive-species type could be sampled.

Table 3-6. Species tolerant of nutrient enrichment, sedimentation, or increased turbidity.

Stress	Species
Nutrient Enrichment	*Ceratophyllum demersum*
	Elodea canadensis
	Lemna minor
	Myriophyllum spicatum
	Potamogeton crispus
	Potamogeton pectinatus
	Algae
Sedimentation and Increased Turbidity	*Butomus umbellatus*
	Ceratophyllum demersum
	Elodea Canadensis
	Heteranthera dubia
	Myriophyllum spicatum
	Potamogeton crispus
	P. foliosus
	P. pectinatus
	P. pusillus
	Ranunculus longirostris

Table 3-7. Combined standardized score from Table 3.3, Rows A-I and Table 3.5.

Combined Numeric Score	Combined Descriptive Scores
0-5	VERY LOW
6-20	LOW
21-40	MEDIUM
41-50	HIGH

Table 3-8. Examples of Combined Standardized Scores for five riverine wetlands

METRICS	SITES				
	Au Train, Mich.	Kalamazoo, Mich.	Kewaunee, Wis.	Fox, Wis.	Lineville, Wis.
Table 3A	5	3	3	0	1
Table 3B	5	0	3	0	0
Table 3C	5	3	3	0	3
Table 3D	5	3	3	0	0
Table 3E	5	3	1	0	0
Table 3F	5	3	3	0	3
Table 3G	5	5	3	0	1
Table 3H	5	3	3	0	0
Table 3I	5	3	3	0	3
Table 5	5	1	0	0	1
TOTAL SCORE	50 HIGH	27 MODERATE	25 MODERATE	0 VERY LOW	12 LOW

Interpretation of results

In the vegetation section, an attempt was made to incorporate interpretations of the results into a discussion of the protocols. For example, Table 3-4 (Mean conservatism scores for each regional marsh type) provides the scores derived from previous sampling of coastal wetlands that will allow state and provincial wetland monitors to compare their wetlands to the conditions encountered in each lake and hydrogeomorphic wetland type. Similarly, Table 3-8 (Examples of combined standardized scores for five riverine wetlands), shows the range of quality scores found for a given wetland type, in this case riverine wetlands along lakes Michigan and Superior. It is common for riverine wetlands in the northern portions of the Great Lakes to be of higher quality than those in the southern portion of the lakes, but it can be seen that even northern riverine wetlands (Kewaunee, Fox and a small stream at Lineville near the town of Green Bay) can be degraded by urban and agricultural land use.

The effectiveness of vegetation data to detect wetland degradation was discussed in the introduction. Probably the greatest challenge in evaluating wetland degradation is presented by the response of wetland plant composition to water-level fluctuations. The use of a simplified set of metrics and indices was an acknowledgement that the number of effective plant metrics is greatly limited by natural plant response to water level fluctuation.

Data handling and storage

A data-handling protocol has been developed by the Great Lakes Commission, which will maintain long-term storage of the data collected for this project. The plant analyses have been simplified to utilize only the metrics (invasive species and species tolerant of nutrient enrichment and turbidity) and indices (mean conservatism, part of floristic quality assessment) agreed upon by the group of wetland plant ecologists meeting in Duluth, Minn. during the spring of 2007. As a result, the statistical analysis of the vegetation data is not complex. However, the data collected provides an opportunity to conduct future analyses as the long-term database is developed. These future analyses may well provide us with adequate data to further test metrics and indices developed for wetlands in other parts of the Great Lakes basin, and to develop a more robust set of Great-Lakes based plant metrics and indices.

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Appendix 3-1. Great Lakes Marsh Sampling Form

Marsh name:	Location:	Local Jurisdiction:	Date
GPS:N E		Samplers:	
GPS Pt - begin transect 1:		End 1:	
GPS Pt - begin transect 2:		End 2:	
GPS Pt - begin transect 3:		End 3:	
Lake:	Hydrogeomorphic Type:	Substrate (circle): sand silt clay gravel	
Marsh zone: 1=meadow 2=emergent 3=submergent		Secchi Disk Reading:	

SUBSTRATE TYPE															
ORGANIC DEPTH															
WATER DEPTH															
MARSH ZONE															
SAMPLING POINT															
SPECIES															
Agrostis hyemalis															
Algae sp.															
Alisma plantago-aquatica															
Alnus rugosa															
Aster puniceus															
Aster umbellatus															
Aster															
Bidens cernuus															
Bidens															
Boehmeria cylindrical															
Bolboschoenus fluviatilis															
Brasenia schreberi															
Butomus umbellatus															
Calamagrostis Canadensis															
Calla palustris															
Caltha palustris															
Campanula aparinoides															
Carex aquatilis															
Carex lacustris															
Carex stricta															
Carex															
Carex															
Cephalanthus occidentalis															
Ceratophyllum demersum															
Chara spp.															
Cicuta bulbifera															
Cirsium															
Cladium mariscoides															
Cornus stolonifera															
Cornus															
Cyperus															
Decodon verticillatus															
Drosera															
Dulichium arundinaceum															
Echinocloe walteri															
Eleocharis smallii															
Eleocharis															

Page 2, Marsh Name:	Samplers:								Date:						
SAMPLING POINT															
SPECIES															
Elodea Canadensis															
Epilobium															
Equisetum fluviatile															
Erechtites hieracifolia															
Erigeron philadelphicus															
Eriophorum															
Eupatorium maculatum															
Eupatorium perfoliatum															
Euthamia graminifolia															
Galium															
Galium trifidum															
Glyceria															
Heteranthera dubia															
Hippuris vulgaris															
Hydrocharis morsus-ranae															
Hypericum															
Ilex verticillata															
Impatiens capensis															
Iris															
Juncus															
Juncus alpinus															
Juncus balticus															
Juncus canadensis															
Juncus dudleyi															
Juncus nodosus															
Lathyrus palustris															
Leersia oryzoides															
Lemna minor															
Lemna trisulca															
Lobelia															
Ludwegia palustris															
Lycopus americanus															
Lycopus uniflorus															
Lysimachia															
Lysimachis terrestris															
Lysimachis thyrsiflora															
Lythrum salicaria															
Megalodonta beckii															
Mentha															
Menyanthes trifoliata															
Mimulus ringens															
Muhlenbergia glomerata															
Myosotis															
Myriophyllum exalbescens															
Myriophyllum spicatum															
Myriophyllum															

Page 3, Marsh Name:	Samplers:								Date:						
SAMPLING POINT															
SPECIES															
Najas flexilis															
Nitella spp.															
Nuphar advena															
Nuphar variegata															
Nymphaea odorata															
Onoclea sensibilis															
Osmunda															
Panicum															
Peltandra virginica															
Phalaris arundinacea															
Phragmites australis															
Poa															
Polygonum amphibium															
Polygonum lapathifolium															
Polygonum															
Pontederia cordata															
Potamogeton crispus															
Potamogeton gramineus															
Potamogeton illinoensis															
Potamogeton natans															
Potamogeton pectinatus															
Potamogeton richardsonii															
Potamogeton zosteriformis															
Potamogeton															
Potamogeton															
Potentilla palustris															
Ranunculus longirostris															
Ranunculus															
Rhamnus															
Rhynchospora															
Rorippa palustris															
Rosa palustris															
Rubus															
Rumex crispus															
Rumex orbiculatus															
Sagittaria latifolia															
Sagittaria															
Salix candida															
Salix exigua															
Salix															
Sarracenia purpurea															
Saururus cernuus															
Scheuchzeria palustris															
Schoenoplectus acutus															
Schoenoplectus pungens															
Schoenoplectus subterminalis															
Schoenoplectus tabernaemontani															

Page 4, Marsh Name:	Samplers:								Date:						
SAMPLING POINT															
SPECIES															
Scirpus															
Scutellaria galericulata															
Sium suave															
Solanum dulcamara															
Solidago															
Sparganium															
Sparganium chlorocarpum															
Sparganium eurycarpum															
Sparganium minimum															
Sphagnum spp.															
Spiraea alba															
Spirodela polyrhiza															
Teucrium canadense															
Thelypteris palustris															
Tofieldia glutinosa															
Triadenum															
Triglochin															
Typha angustifolia															
Typha latifolia															
Typha x glauca															
Urtica dioica															
Utricularia vulgaris															
Utricularia intermedia															
Utricularia															
Vaccinium															
Vallisneria americana															
Verbena hastata															
Veronica															
Viburnum lentago															
Viola cucullata															
Vitis riparia															
Wolffia columbiana															
Zannichellia palustris															
Zizania aquatica															

NOTES:

Appendix 3-2. Wetland plant species most commonly encountered in Great Lakes coastal wetlands.

Acorus calamus
Agrostis hyemalis
Algae sp.
Alisma plantago-aquatica
Alnus rugosa
Andromeda glaucophylla
Anemone canadensis
Apocynum sibiricum
Aronia melanocarpa
Asclepias incarnata
Aster borealis
Aster dumosus
Aster lanceolatus
Aster lateriflorus
Aster longifolius
Aster novae-angliae
Aster puniceus
Aster umbellatus
Betula pumila
Bidens cernuus
Bidens connatus
Bidens coronatus
Bidens frondosus
Boehmeria cylindrica
Bolboschoenus fluviatilis
Brasenia schreberi
Bromus ciliatus
Butomus umbellatus
Calamagrostis canadensis
Calamagrostis inexpansa
Calla palustris
Callitriche hermaphroditica
Calopogon tuberosus
Caltha palustris
Campanula aparinoides
Cardamine pensylvanica
Carex alata
Carex aquatilis
Carex atherodes
Carex bebbii
Carex bromoides
Carex buxbaumii
Carex canescens
Carex chordorrhiza
Carex comosa
Carex crinita
Carex cryptolepis
Carex diandra
Carex exilis
Carex flava
Carex hystericina
Carex interior
Carex intumescens
Carex lacustris
Carex lanuginosa
Carex lasiocarpa
Carex leptalea
Carex limosa
Carex livida
Carex michauxiana
Carex oligosperma
Carex pauciflora
Carex paupercula
Carex prairea
Carex pseudo-cyperus
Carex retrorsa
Carex rostrata
Carex sartwellii
Carex scoparia
Carex sterilis
Carex stipata
Carex stricta
Carex tenera
Carex vesicaria
Carex viridula
Carex vulpinoidea
Cephalanthus occidentalis
Ceratophyllum demersum
Chamaedaphne calyculata
Chara spp.
Chelone glabra
Cicuta bulbifera
Cinna arundinacea
Cirsium arvense
Cirsium muticum
Cladium mariscoides
Clematis virginiana
Cornus amomum
Cornus drummondii
Cornus foemina
Cornus racemosa
Cornus rugosa
Cornus stolonifera
Crataegus spp.
Cuscuta gronovii
Cyperus diandrus
Cyperus strigosus
Cypripedium calceolus
Cypripedium spp.
Cystopteris bulbifera
Decodon verticillatus
Deschampsia cespitosa
Drosera intermedia
Drosera rotundifolia
Dryopteris cristata
Dulichium arundinaceum
Echinocloe walteri
Eleocharis acicularis
Eleocharis elliptica
Eleocharis erythropoda
Eleocharis obtusa
Eleocharis rostellata
Eleocharis smallii
Elodea canadensis
Elodea nuttallii
Elymus virginicus
Epilobium ciliatum
Epilobium coloratum
Epilobium hirsutum
Epilobium leptophyllum
Equisetum fluviatile
Equisetum hyemale
Equisetum palustre
Equisetum variegatum
Erechtites hieracifolia
Erigeron philadelphicus
Eriocaulon septangulare
Eriophorum angustifolium
Eriophorum spissum
Eriophorum tenellum
Eriophorum virginiana
Eupatorium maculatum
Eupatorium perfoliatum
Euthamia graminifolia
Galium asprellum
Galium labradoricum
Galium palustre
Galium tinctorium
Galium trifidum
Gaylussacia baccata
Geum aleppicum
Geum canadense
Geum rivale
Glyceria borealis
Glyceria canadensis
Glyceria striata
Heteranthera dubia
Hibiscus palustris
Hippuris vulgaris
Hydrocharis morsus-ranae
Hydrocotyle americana
Hypericum boreale
Hypericum kalmianum
Hypericum majus
Ilex verticillata

Impatiens capensis
Iris versicolor
Iris virginica
Juncus alpinus
Juncus balticus
Juncus brevicaudatus
Juncus bufonius
Juncus canadensis
Juncus dudleyi
Juncus effusus
Juncus greenei
Juncus nodosus
Juncus pelocarpus
Juncus tenuis
Kalmia polifolia
Lathyrus palustris
Ledum groenlandicum
Leersia oryzoides
Lemna minor
Lemna trisulca
Liatris spicata
Lobelia dortmanna
Lobelia kalmii
Lobelia siphilitica
Lobelia spicata
Ludwegia palustris
Lycopus americanus
Lycopus uniflorus
Lysimachia ciliata
Lysimachia nummularia
Lysimachia quadriflora
Lysimachis terrestris
Lysimachis thyrsiflora
Lythrum alatum
Lythrum salicaria
Matteuccia struthiopteris
Megalodonta beckii
Mentha arvensis
Mentha piperita
Menyanthes trifoliata
Mimulus ringens
Muhlenbergia glomerata
Muhlenbergia unifloris
Myosotis laxa
Myosotis scorpioides
Myosoton aquaticum
Myrica gale
Myrica pensylvanica
Myriophyllum alterniflorum
Myriophyllum exalbescens
Myriophyllum
heterophyllum
Myriophyllum spicatum
Myriophyllum tenellum
Myriophyllum verticillatum
Najas flexilis
Najas minor
Nelumbo lutea
Nemopanthus mucronata
Nitella spp.
Nuphar advena
Nuphar variegata
Nymphaea odorata
Onoclea sensibilis
Osmunda cinnamomea
Osmunda regalis
Panicum lindheimeri
Panicum virgatum
Parnassia glauca
Peltandra virginica
Penthorum sedoides
Phalaris arundinacea
Phragmites australis
Physostegia virginiana
Pilea fontana
Pilea pumila
Platanthera clavellata
Poa palustris
Pogonia ophioglossoides
Polygonum amphibium
Polygonum
hydropiperoides
Polygonum lapathifolium
Polygonum pensylvanicum
Polygonum persicaria
Polygonum punctatum
Polygonum sagittatum
Pontederia cordata
Potamogeton alpinus
Potamogeton amplilfolius
Potamogeton berchtoldii
Potamogeton crispus
Potamogeton epihydrus
Potamogeton filiformis
Potamogeton foliosus
Potamogeton friesii
Potamogeton gramineus
Potamogeton illinoensis
Potamogeton natans
Potamogeton nodosus
Potamogeton obtusifolius
Potamogeton pectinatus
Potamogeton perfoliatus
Potamogeton praelongus
Potamogeton pusillus
Potamogeton richardsonii
Potamogeton robbinsii
Potamogeton spirillus
Potamogeton strictifolius
Potamogeton zosteriformis
Potentilla anserina
Potentilla fruticosa
Potentilla palustris
Prenanthes racemosa
Proserpinaca palustris
Pycnanthemum
virginianum
Ranunculus abortivus
Ranunculus longirostris
Ranunculus pensylvanicus
Ranunculus recurvatus
Ranunculus sceleratus
Rhamnus alnifolia
Rhamnus frangula
Rhynchospora alba
Rhynchospora capillacea
Rorippa palustris
Rosa palustris
Rubus hispidus
Rubus pubescens
Rubus strigosus
Rumex crispus
Rumex maritimus
Rumex orbiculatus
Sagittaria graminea
Sagittaria latifolia
Sagittaria montevidensis
Sagittaria rigida
Sagittaris cuneata
Salix amygdaloides
Salix bebbiana
Salix candida
Salix cordata
Salix discolor
Salix eriocephala
Salix exigua
Salix lucida
Salix myricoides
Salix pedicellaris
Salix petiolaris
Salix pyrifloia
Salix sericea
Salix serissima
Sarracenia purpurea
Saururus cernuus
Scheuchzeria palustris
Schoenoplectus acutus
Schoenoplectus pungens
Schoenoplectus
subterminalis
Schoenoplectus
tabernaemontani
Scirpus atrovirens
Scirpus cespitosus
Scirpus cyperinus
Scutellaria galericulata
Scutellaria lateriflora
Sium suave
Solanum dulcamara
Solidago gigantea
Solidago ohioensis

Solidago patula
Solidago rugosa
Solidago uliginosa
Sparganium americanum
Sparganium chlorocarpum
Sparganium eurycarpum
Sparganium fluctuans
Sparganium minimum
Spartina pectinata
Sphagnum spp.
Spiraea alba
Spiraea tomentosa
Spiranthes cernua
Spiranthes romanzoffiana
Spirodela polyrhiza
Stachys palustris
Stachys tenuifolia
Symplocarpus foetidus
Teucrium canadense
Thalictrum dasycarpum
Thelypteris palustris
Tofieldia glutinosa
Triadenum fraseri
Triadenum virginicum
Triglochin maritimum
Triglochin palustre
Typha angustifolia
Typha latifolia
Typha x glauca
Urtica dioica
Utricularia cornuta
Utricularia intermedia
Utricularia resupinatua
Utricularia vulgaris
Vaccinium corymbosum
Vaccinium macrocarpon
Vaccinium oxycoccos
Vallisneria americana
Verbena hastata
Veronica anagalis-aquatica
Veronica officinalis
Viburnum lentago
Viola cucullata
Vitis riparia
Wolffia columbiana
Wolffia punctata
Xyris montana
Zannichellia palustris
Zanthoxylum americanum
Zizania aquatica
Zizania aquatica var. aquatica