Standard Operating Procedure

Vegetation Sampling

Synopsis: A standardized method for collecting vegetation data according to Great Lakes Coastal Wetlands Consortium protocols

Last updated June 4, 2018

Contents:

1.0 EXECUTIVE SUMMARY

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.

This study utilizes an approach to evaluating coastal wetland degradation, 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 and comparing the Floristic Quality Index (FQI) to regional FQI scores.

In the Great Lakes, 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 by ditching or physical disturbance of sediments, resulting in 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, addition of nutrients in the form of fertilizer or animal waste, and addition of fine sediment as the result of intensive agriculture. The recommendation is made to monitor these zones separately to identify sources of degradation, and thus allow solutions to be identified for each zone.

Alteration 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 zone 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 provides 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.

An successful approach to evaluate the intactness of plant communities is computation of a Floristic Quality Index, which utilizes all plants present at a site to estimate the intactness of the plant community. Conservatism index scores are developed and applied regionally and have upper and lower limits of 10 and zero, respectively. A mean conservatism score evaluates the conservatism of all of the species at a site. We are using the mean conservatism index in 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 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.

2.0 INTRODUCTION

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 and 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 page for further detailed description of coastal wetland types (Albert et al. 2003, Albert et al. 2005).

3.0 EVALUATION OF GREAT LAKES COASTAL WETLAND QUALITY AND HEALTH

One of the greatest sources of variability in Great Lakes wetland plant community composition is that resulting from 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 to accumulate in a single wetland, contributing to the formation of dense algal mats nearly a meter thick at times. While other wetlands may receive similar 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 non-productive.

To reduce the need for direct comparison of neighboring wetlands for quality, we are utilizing an approach that evaluates coastal wetland degradation, 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 ecologists agree 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 and comparing the Floristic Quality Index (FQI) of an individual wetland 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, 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 they are typically degraded as the result of alterations of the hydrology by ditching or physical disturbance of sediments along the upper edge; major introductions of invasive plants 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, addition of nutrients in the form of fertilizer or animal waste, and addition of fine sediment as the result of intensive agriculture within the watershed. 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 result in both drier conditions and exposed sediments with no vegetation, a combination that allows small-seeded invasive species to establish 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 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, 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 provides 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 (see Table 1), which utilizes all plants 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 regarding plant species habitat fidelity. Conservatism index scores are developed and applied regionally and have upper and lower limits of 10 and zero, respectively. 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. The floristic quality index is more sensitive to sample size than the conservatism index, and it is also more sensitive to changes in species diversity resulting from water-level fluctuation. For that reason we are recommending use of the mean conservatism index in 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 region, as it was designed for use in Michigan, which encompasses most of the latitudinal gradient encountered in the Great Lakes. The FQA software is available through the Conservation Research Institute (Conservation Design Forum: **cdf@cdfinc.com**). Table 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 computer 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, with Mackinac Bay less disturbed than Presque Isle marsh on Lake Erie or Bradleyville marsh in Saginaw Bay (Table 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 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 RUSH
ELESMA	5	Eleocharis smallii	-5	OBL	Nt P-Sedge	SPIKE RUSH
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	VARIOUS 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
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 BULRUSH

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

SCHSUB	8	Schoenoplectus subterminalis	-5	OBL	Nt P-Sedge	BULRUSH
SCUGAL	5	Scutellaria galericulata	-5	OBL	Nt P-Forb	COMMON SKULLCAP
SIUSUA	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 ANGUSTIFOLIA	-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 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

4.0 MATERIALS AND METHODS

4.1 Equipment

Equipment needed for vegetation sampling is listed in Appendix I.

4.2 Special Training Requirements

All personnel responsible for sampling macrophytes will be trained and certified before sampling begins each year. Several of the regional team leaders (co-PIs) have permanent technicians and staff who have years of experience conducting aquatic sampling which will help to ensure that rigorous data quality standards are maintained throughout the project.

A multi-level training and certification program will be implemented to ensure accuracy of all data collection. A series of 2-day training workshops led by experts on each respective protocol will be held every spring/early summer before fieldwork begins at several locations across the basin to ensure good attendance by the majority of field crew staff in each area. The workshop agenda will include training on how to meet the data quality objectives for each element of the project, QAPP review, site verification procedures, hands-on training for each sampling protocol, procedures for entering data into the project database, record-keeping and archiving requirements, data auditing procedures, and certification/re-certification exams for each sampling protocol for all project personnel. All project co-PIs, field crew leaders, and as many summer staff as possible will participate in spring workshops and will be certified/re-certified on sampling protocols. When necessary, co-PIs and field crew chiefs will provide additional training and certification of staff members who are unable to participate in the spring workshop.

To be certified in a given protocol, individuals must pass a practical exam before sampling begins. Exams will be conducted in the field whenever possible and will be supplemented with photographs or audio recordings (e.g., bird and amphibian calls) when necessary. Passing the exams will certify the individual to perform the respective sampling protocol. Since not every individual will be conducting every sampling protocol, participants will be tested on the protocols for which they will be responsible. The majority of testing and certification will take place during the spring training workshops and additional certification will be administered by co-PIs as needed. Personnel who are not certified (e.g., part time technicians, new students, volunteers) will not be allowed to work independently nor to do any identification except under the direct supervision of certified staff members until they can pass the appropriate certification tests. The following paragraphs detail specific items to be covered during the training workshops each year. Preliminary certification criteria (minimum percent correct on certification exams) are also included. For some criteria, demonstrated proficiency during the field training workshops will be considered adequate for certification. Training and certification records for all participants will be collected by regional team leaders and copied to Dr. Don Uzarski at Central Michigan University. A summary of these records will be included in annual reports to EPA.

Site Selection and GPS Use—Field crews will be trained to consistently select sample locations within each pre-selected wetland and will be taught strategies to implement when pre-selected locations cannot be sampled due to insufficient water depth, unsuitable weather, inaccessibility, or safety concerns. Field crews will also receive training in proper GPS procedures, including equipment use and data entry. GPS training will include extensive instruction on navigating to waypoints, creating and properly naming waypoints, and determining levels of accuracy available. GPS training will be led by Dr. Terry Brown.

Certification Criteria:

- Identify circumstances in which a site can be rejected as unsampleable (90%)
- Identify vegetation zones for stratified sampling (90%)
- Proper use of a GPS to navigate to a waypoint (demonstrate proficiency)
- Determination of GPS accuracy (demonstrate proficiency)

Macrophytes—Macrophyte sampling training will be led by Drs. Albert (OSU) and Wilcox (SUNY Brockport), both of whom have years of experience with aquatic plant identification and coastal wetland sampling. Training will include proper transect establishment, location of random sample plots, aquatic vegetation taxonomy, protocols for dealing with problematic identifications, and when to take samples for QA/QC. The collaborators in this project have done extensive plant sampling in Great Lakes coastal wetlands, so our species lists and field data forms include most plants that will be encountered during the project. The species lists also include all of the major invasive plants known from coastal wetlands. Reference materials at university herbariums are available for comparison. Plant materials that cannot be positively identified in the field will be collected and pressed for later identification in the laboratory. Additionally, at QA sites, plants will be collected for QA checks later. One of the most difficult aspects of plant sampling in quadrats is accurate estimation of the percent coverage for plant species present. We will calibrate the estimation of plant coverage to the nearest percent as a group during training.

Certification Criteria:

- Transect and plot locations (demonstrate proficiency)
- Taxonomy (75% of 20 taxa in the field; 90% of 20 species, using appropriate macrophyte identification books in the lab.)
- Percent coverage of species within quadrats (sampling team estimate of coverage ±10% of expert's estimate 90% of the time, with evaluation being conducted on total plant coverage estimates within a plot)
- Determining when to collect voucher specimens for identification in the lab (demonstrate proficiency)
- Proper preservation procedure for specimens (demonstrate proficiency)
- Proper completion of field data sheets (demonstrate proficiency)

4.3 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 (Figure 1). Flooded portions of the emergent marsh zone typically contain abundant submergent and floating species, and these submergent plants can be analyzed if there is no submergent zone. If a deeper submergent zone is present, it can also be sampled and submergent plant metrics can be based on its plants.
2. Identify three potential sampling transects that will cross typical zones.

5.0 FIELD SAMPLING

The primary data collection at the site will be the identification and quantification of all wetland plant species occurring in a specified number of sampling quadrats. Within wetlands, sampling will occur along three transects that run parallel to the gradient of increasing water depth and that therefore span the wetland vegetation zones present (varies depending on each particular wetland). Potential vegetation zones include wet meadow, emergent vegetation, and submergent vegetation. If a substantial submergent zone is present, it will also be sampled. The starting point of each transect will be randomly located along the upland or swamp forest edge, and the distance from this edge will be 1/6th the width of the vegetation zone from the wetland edge. Transect sampling can also be begun at the water's edge, using a random starting point. Vegetation will be surveyed in 1-m^2 quadrats at regular intervals along transects, for a total of 15-45 quadrats per wetland (15 quadrats per wetland zone). All survey quadrats will be placed 2 m right of the transect line to avoid trampling effects. The length of transect within a given plant zone will be measured, and if the plant zone is equal or greater than 11 meters wide, the length of the zone will be divided by 6 to determine the distance between sampling points. If the vegetation zone is less than 11 meters wide, a "narrow sampling" protocol will be used. In this protocol, the field crew will locate the midpoint of the narrow zone along the original transect. At this midpoint, an additional transect will be placed in the narrow vegetation zone perpendicular to the original transect. Survey plots along the perpendicular transect in the narrow zone will be located at -7, -3, 2, 7, and 12 meters from the zone midpoint along the original transect. Narrow transects are most likely to be encountered in either the wet meadow or submergent marsh zones.

A list of the most aggressive invasive plants was identified for the Great Lakes Coastal Wetlands Monitoring Plan (GLCWC 2008) and is included at the end of Table 2 of this protocol. An expanded list of most upland and wetland invasive species in the Great Lakes region is found in Michigan's Floristic Quality Assessment program (Herman et al. 2001). A thorough list of plants encountered in coastal wetlands of all of the Great Lakes states is found in Appendix 1 of this protocol, as recorded during inventories conducted with USEPA and USCZM funding from 1987 through 2004 (Albert et al. 1987, 1988, 1989; Minc 1997). Species lists from studies by GLEI, Dr. Douglas Wilcox, and other partners have been added to the species list (Appendix II).

Taxonomic descriptions will be cross-walked with the Flora of North America, which is available on-line (http://www.efloras.org/flora_page.aspx?flora_id=1). A new flora, *The Field Manual of Michigan Flora* (Voss and Reznicek 2012) from the University of Michigan Press, incorporates the most recent taxonomic treatments of the Flora of North America. However, local Great Lakes floras (Voss 1972, 1985, 1996), which are compatible with Michigan's FQA (Herman et al. 2001) will be used for field identification to facilitate rapid sampling. Other floras that may prove helpful for identification of difficult wetland plants include *A Manual of Aquatic Plants* (Fassett 1957), *Aquatic and Wetland Plants of Northeastern North America* (Crow et al. 2006) , and *Manual of Vascular Plants of Northeastern United States and Adjacent Canada* (Gleason and Cronquist 1991).

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 non-vascular plants.

Within each quadrat, all macrophyte species will be identified to lowest possible taxonomic unit (typically species). Plants that cannot be identified in the field will be collected and preserved for identification in the laboratory. Some sterile or immature species, including grasses, sedges, and willows, cannot be identified to species, and while these will be noted as present, they cannot be used in FQI analysis. Herbarium staff are typically not willing to identify sterile specimens, and thus sterile species will typically not be curated. Almost all invasive exotic species can be recognized, even when sterile, and will be included in analysis. Percent coverages will also be estimated for each vegetation type. Water depth and qualitative substrate composition will also be noted for each quadrat. Vegetation sampling data are considered critical for the majority of wetland sites (i.e., those not sampled only for birds and amphibians). At least 90% of the quadrats must be successfully sampled to consider the site effectively complete and to use the data in subsequent analysis. .

Data are recorded on a standardized plant sampling form (Figure 2) or on a short form that contains all of the abiotic sampling information at the top of the form (Figure 2) and a small number of the most commonly occurring species, with blank spaces for adding up to 60 additional species. The short form allows for much more efficient and rapid data collection. 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 over 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 2. 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.

Support facilities for vegetation crews include a laboratory or motel/hotel room with sinks and plant presses for preserving plant specimens. The plant curation site will be equipped with dissecting microscopes that magnify to 30x and at least the plant identification guides by E. G. Voss (1972, 1985, 1996) or by E. G. Voss and A. A. Reznicek (2012) mentioned above.

Supplemental data collection. It is also recommended that percent coverage of vegetation detritus or standing dead biomass be recorded for each vegetation quadrat – this is especially important for plots dominated by aggressive invasive plants. It is recommended that supplemental information on depths of organic sediments, water clarity, and underlying mineral soil texture by collected at each vegetation plot. Depths of organic soils (in centimeters) will be measured by forcing a 10 ft (3 m) length of ¾ inch (1.8 cm) aluminum conduit into the substrate until mineral soils are encountered. Water clarity will be simply noted in terms important for vegetation: is the bottom visible or not. In highly turbid waters where the bottom is not visible, submergent and floating plants are typically absent. Mineral substrate is broken into classes that include 1) silt/clay, 2) sand, 3) gravel/cobble, and 4) bedrock, based solely on rapid field evaluation with the conduit probe used for measuring organic soil depth. Presence of two-storied soils, such as a thin veneer of sand over clay can also be noted in the comment field, and can be significant for understanding sediment dynamics within a wetland.

6.0 SAMPLING HANDLING AND CUSTODY

A numbered label will be attached to each unidentified plant and noted on the field form. Each sample will be coded by site location, transect and plot number, and date to facilitate future entering of plant identities on the sample forms and in digital data files. These plants will be placed in Ziploc bags for either identification in the laboratory or by herbarium staff. Plants requiring identification by herbarium staff will be placed in a plant press for drying and storage. There are few difficult-to-identify rare plants in Great Lakes coastal wetlands, so unknown plants can be collected without jeopardizing rare or endangered species.

Collected plants will be placed in a cooler or refrigerator upon return from the wetland, in preparation for pressing within 24 hours. Pressed plants will be dried either with heat or with a fan whenever possible. Plant samples will be destroyed following identification, except for those of interest for the herbarium's collections, or samples kept as short-term identification aids to assist in training new personnel or as vouchers. A long term voucher collection will not be made as part of this project.

6.1 Analytical Methods Requirements

Performance criteria: Most specimens collected in the field will be identified to the species level during the evening of collection using identification keys and a magnifying glass. Specimens not identifiable to species because of lack of characteristic features (flowers, fruits, etc.) will be identified to the lowest taxonomic levels possible. Specimens of questionable identity will be pressed and returned to the laboratory. If fertile, unknown and unusual specimens will be sent to appropriate taxonomic experts for confirmation or refinement of taxonomic identity. Sterile or immature plants will be identified when possible. Target turnaround time for plant identifications is 3 months after the end of sampling.

Macrophyte data will include a) identifying and quantifying invasive plants that are considered indicators of degraded habitat (Albert and Minc 2004), b) quantifying baseline coverages of submergent and floating-leaved vegetation, and c) comparing local site mean Conservatism (mean C) values to regional mean C values (Herman et al. 2001).

One of the most difficult aspects of plant sampling in quadrats is accurate estimation of the percent coverage for plant species present. Thus, during indicator calculations, we will use a protocol that is not strongly dependent on accurate plant coverage estimates, but instead during the final stage of analysis converts percent cover to broad coverage classes of 0-25%, 25-50%, 50-75%, or greater than 75% for development of metrics. For both aggressive invasive species and submergent and floating plants that tolerate or respond to nutrient enrichment or sediment loading, these coarse cover classes are adequate for monitoring wetland quality changes.

The beginning and end quadrats of each transect will be marked using GPS, as will the middle quadrat point for vegetation zones less than 11 meters long. In case of GPS equipment failure, the vegetation crew will borrow a GPS from the fish and invert crew to finish the site when possible, and will return to their regional laboratory for a replacement GPS unit when possible. In cases where no GPS unit is available for replacement of failed equipment, start and end points will be marked with flagging, and these points will be returned to at a later time for exact GPS location of transects. Crew leaders will explain all equipment failures and the implications of this for the data on the data sheets and transfer this information, along with appropriate error codes, to the database during data input.

In many coastal wetlands along the southern Great Lakes, invasive *Phragmites australis* has formed a dense monoculture more than 200 m wide. With increased water levels in Lakes Huron and Michigan beginning in 2014, sampling across this entire zone has greatly increased crew effort, reduced efficiency, and increased the likelihood of crew injury. To mitigate these issues without reducing data quality, sampling will be conducted as needed within this zone at 5, 10, 15, 20, and 25 m from the *Phragmites* bed edge (either shoreward or lakeward edge, depending on accessibility), rather than spacing sampling points across the entire width of the zone. The actual width of the zone will be calculated from the most recent year's Google photos. Correlations between Google image interpretation and field surveys are high, and difficulty maintaining a straight transect line in *Phragmites* typically results in reduced accuracy from the field transects. Prior experience and data analysis show virtually no variability in vegetation composition within the *Phragmites* zone, indicating that there will be minimal loss of information by spatially restricting *Phragmites* sampling. When this modified protocol is used, it will be referenced in the comment box and recorded in the database. The direction of entry into the *Phragmites* beds, either from the upland shoreline or from the water, will also be noted.

Several worksheets developed as part of the Great Lakes Coastal Wetlands Monitoring Plan will be used to calculate macrophyte IBIs. These include 1) a table of wetland quality based on aquatic macrophyte sampling, 2) a flow chart for determining quality rating of submergent marsh zone or submergent component of an emergent marsh zone, 3) a table of species tolerant of nutrient enrichment, sedimentation, or increased turbidity, and 4) a combined standardized score based on 1-3 above.

Software for the calculation of Conservatism coefficients and associated metrics are contained within the FQI software for Michigan (Herman et al. 2001). The Michigan FQI software has been used in prior Great-Lakes-wide coastal wetland plant sampling projects, and has been found to contain almost all wetland plants growing in the Great Lakes. One of the advantages to the use of FQI and mean Conservatism scores is that they are based on the entire flora, not just a few indicator species. For this reason, the lack of a Conservatism score for one or two species at a site does not greatly alter the FQI or mean Conservatism scores.

7.0 QUALITY CONTROL REQUIREMENTS

Precision: For vegetation samples, each regional team will collect duplicate quadrat information at 2 sites per year. All taxa encountered in the resampling of quadrats will be identified in the field but then preserved and returned to the lab for identification by an expert as a second QC check.

Accuracy: The systematic difference from a reference standard or an expert. This will be assessed during the mid-year QC check (see below, this section).

Bias: Systematic bias by a crew or method. Bias will be assessed during the mid-year QC check by observing transect and quadrat placement and percent cover estimates, and by cross-validating difficult-to-ID taxa that are preserved. The quadrat method of sampling makes detection of uncommon taxa less likely than some other methods, and may result in lower taxa counts than other methods that cover more of the site (see sensitivity). This is a deliberate trade-off made to sample more sites rather than fewer sites more intensely.

Completeness: Calculated as % complete = (# useable sample pts)/(# planned pts) x 100. Sampling completeness will be calculated for all sites.

Representativeness: How well sites were sampled will be determined by plotting all sample points for each site on aerial photographs of the site and by checking the field sheets and database for problems, notes, and flags. This will be done for all sites.

Comparability: Data comparability among crews within the project and to other non-project data will be achieved by using standard, accepted methods; creating metadata explaining the methods; and having strict training and QA/QC for all crews and personnel.

Sensitivity: In this case sensitivity refers both to the lowest taxonomic levels achievable, and to the ability to detect uncommon taxa. Identification will depend on the life-stage of the plants and the condition of the plants, which is primarily controlled by the time of year of sampling. Our sampling is timed so that the most species will be most identifiable when field crews are sampling. Uncommon taxa will not be particularly detectable because of the small percentage of each site that can be sampled even with 30-45 quadrats. Again, this is a deliberate trade-off made to sample more sites rather than fewer sites more intensely.

QA/QC specifics: Members of the project team responsible for vegetation sampling will receive rigorous taxonomic training prior to field sampling. Accurate plant identification is the most important component of vegetation monitoring. During the sampling season, representative specimens that cannot be identified in the field will be returned to the laboratory for identification, with assistance from botanical experts when necessary. A collection of difficult-

to-identify species will be maintained to assist with future identifications. This can be especially useful for commonly encountered plants that are often found in non-flowering condition. The project team will maintain an ongoing dialogue to ensure accurate and consistent identifications.
Field teams will ‘calibrate’ their percent cover estimates with each other during the yearly field training. Field teams will concur with each other on percent coverage estimates for each quadrat. Plant metrics are designed to be robust, so that small errors in percent-coverage estimates will not result in wetland quality ranking errors. Re-measurement of quadrats at a site will be conducted during training to calibrate individual sampler estimates of vegetation cover. The important test for this re-measurement is not the specific coverage value estimates, but the final conversion of the coverage values into the site metrics. The metrics are designed to be robust enough that slight differences in individual plant coverage values will not alter the metrics or the overall site quality ranking. Field team members will correspond with each other on percent coverage estimates for each quadrat; discrepancies in cover estimates exceeding 10% between individuals in a field team will trigger a re-sampling of the quadrats in that vegetation zone.

Individuals Responsible For Vegetation QA/QC:

Western Great Lakes	Nick Danz
Central Great Lakes (US side)	Dennis Albert
Central Great Lakes (CA side)	Jan Ciborowski/Joseph Gathman
Eastern Great Lakes (US side)	Doug Wilcox
Eastern Great Lakes (CA side)	Jan Ciborowski/Greg Grabas

Mid-Year QA/QC Checks:
Coverage estimates—Training and testing/certification for macrophyte coverage estimation will be conducted during the early summer training workshop. Additional mid-year QA/QC checks will also be implemented to ensure data quality. The project macrophyte experts (Dennis Albert, Oregon State University; Nick Danz, University of Wisconsin-Superior; Doug Wilcox, SUNY Brockport) or other individuals whom they designate will estimate coverages in 5% of each participant’s plots. Deviations in coverage estimates exceeding 10% will trigger re-sampling of the plot and additional corrective action.

Species Identification—The project macrophyte experts (Dennis Albert, Oregon State University; Nick Danz, University of Wisconsin-Superior; Doug Wilcox, SUNY Brockport) or other individuals whom they designate will verify the identity of 90% of species (not samples or plots) identified by each participant who is working independently. The performance criteria for this QA/QC step will be 90% accuracy of fertile plants or plants that can typically be identified in sterile condition. This QA/QC step will be based on a combination of field and laboratory identification. Preserved specimens or digital photographs are standardly used as part of the identification process.. This QA/QC evaluation will occur once per year during the sampling period. After verification, the macrophyte experts will record the species identified correctly or incorrectly by each participant, which will serve as a performance record for each participating individual. The macrophyte experts will also distribute a list of particularly difficult taxa that require preservation and lab verification when they are encountered. Corrections will be made to the macrophyte database when identification errors are found.

The project QA manager and assistant manager will provide guidance during the checks, provide oversight on the checks, and receive the QC reports from the macrophyte experts.

7.1 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Dissecting scopes, used for plant identification, will be cleaned and inspected annually. Boat motors will also be tuned up as necessary for safe operation. Crews will carry at least one spare quadrat. Boat repairs are also often necessary. Most towns around the Great Lakes have boat repair shops, which will be used by field crews as necessary. Appropriate spare parts will be carried by crews for boats and trailers.. Spare batteries will be carried for the GPS units and cameras. No other equipment used by the vegetation sampling crews requires equipment testing.

7.2 Instrument Calibration and Frequency

Recreational GPS accuracy is sufficient for these data. GPS receivers will be tested prior to and after the field season by taking repeated readings at known localities, i.e., benchmarks. During the field season, field crews will be uploading GPS readings nearly daily. At least once per week, GIS personnel will plot GPS points onto aerial photographs of a sampled site and send the image to the field crew to verify that points appear to be reasonably accurate. Accuracy during the field season will also be checked *a posteriori* by comparing latitude/longitude at easily recognized localities (e.g., road stream crossings) with GPS readings. All tests and results will be logged and the logs kept with the appropriate GPS units.

8.0 WORKSHEETS

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

8.1 Checklists.

Two checklists are included, **Appendix I**, a list of equipment needed for sampling, and **Appendix II**, a list of the most common wetland plants encountered in Great Lakes coastal wetlands.

9.0 SITE SELECTION/NUMBER OF SITES/STRATIFICATION

Project-wide site selection, number of sites, and stratification is based on recommendations in the Statistical Design section of the report by Otieno, Uzarski, and the Landscape Committee. Overall statistical analysis selects and stratifies sites on the basis of Ecoregions 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 US and Canadian wetlands studied, demonstrating that overall plant diversity was adequately sampled.

9.1 Analysis of quadrat data (use Table 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-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 dividing the number of quadrats containing invasive species and dividing by the total number of quadrats. See Table 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-C for quality scores). Low scores (0.79 or lower) reflect large numbers of exotic species and degraded conditions. Table 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 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-D for quality classes.

5. Compute overall INVASIVE FREQUENCY for the **wet meadow and dry emergent zone** by dividing 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-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-F for quality scores). Table 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-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-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-I for quality scores). Table 4 provides average regional Mean Conservatism Index scores by zone for most of the Great Lakes and hydro-geomorphic types.

TABLE 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 percent	25-50%	>50%
B: INVASIVE FREQ. (entire site)	Absent	<25 percent	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 percent	25-50%	>50%
E: INVASIVE FREQ. (wet meadow and dry emergent zones)	Absent	<25 percent	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 percent	25-50%	>50%
H: INVASIVE FREQUENCY (flooded emergent and submergent zone)	Absent	<25 percent	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*.

10.0 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 2). For most of the wetland types, the indices were computed from the list of species that were present in more than one percent 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 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 ().

10.1 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 5), as several factors can influence the presence and density of these plants. Table 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 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 (A through I) and Table 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 7. Table 8 provides example scores for six riverine wetlands resulting from totaling the metrics in Table 3 and 5.

Table 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

Table 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 7. Combined standardized score from Table 3A-I and Table 5.	
Combined Numeric Score	Combined Descriptive Scores
0-5	VERY LOW
6-20	LOW
21-40	MEDIUM
41-50	HIGH

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

METRICS	SITES				
	Au Train, MI	Kalamazoo, MI	Kewaunee, WI	Fox, WI	Lineville, WI
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

11.0 INTERPRETATION OF RESULTS

In the vegetation section, an attempt was made to incorporate interpretations of the results into discussion of the protocols. For example, Table 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 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 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 has been discussed in the introduction. Probably the greatest challenge to evaluation of 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.

12.0 DATA HANDLING AND STORAGE

A data handling protocol is being developed by the Great Lakes Commission, who 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 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 develops. These future analyses may well provide us with adequate data to further test metrices and indices developed for wetlands in other parts of the Great Lakes region, and to develop a more robust set of Great-Lakes based plant metrices and indices.

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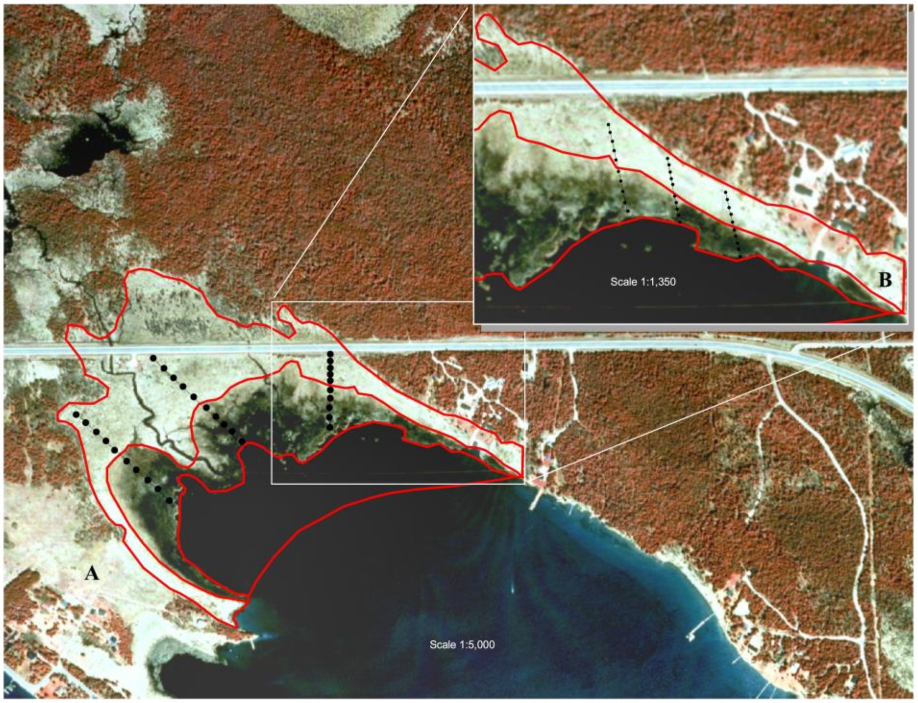

Figure 1. This aerial photo view of a wetland along northern Lake Huron shows the location of three transects, each beginning at the upland edge of the wetland and continuing south across the meadow zone (white) and the emergent/submergent zone (dark). The transects end at the edge of the emergent zone, 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 2.

FIGURE 2. GREAT LAKES WETLAND SAMPLING FORM		Date:	
Site ID:	Location:	Wetland name:	Crew code:
GPS:N E waypt:		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:	Crew chief name:	
Marsh zone: 1=meadow 2=emergent 3=submergent		Water clarity: Bottom Visible or Not Visible	

SUBSTRATE TYPE															
ORGANIC DEPTH (CM)															
DETRITUS (%)															
STANDING DEAD BIOMASS (%)															
WATER DEPTH (CM)															
WATER CLARITY: V or NV															
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															

Page 2, Site ID:	Samplers:								Date:						
SAMPLING POINT															
SPECIES															
Echinocloe walteri															
Eleocharis smallii															
Eleocharis															
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															

Page 3, Site ID:	Samplers:								Date:						
SAMPLING POINT															
SPECIES															
Myriophyllum															
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, Site ID:	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 I. Equipment needed for vegetation sampling (one set per team).

Canoe (not needed for all sites) including:
- Paddles (3 per boat)
- Life preservers (one per person in canoe)
- Motor (only for flat-backed canoe)
- Fire extinguisher (when using motor)
- Gas can (when using motor) with mix of gasoline and oil
- Rope
- Anchor
- Tie downs or rope for tie-down of canoe
- Flash light for night travel

Laptop with necessary software for data download
Cell Phone
GPS unit
Compass (magnetic)
Sampling quadrats (2 PVC – 1m X 1m)
Ten foot conduit marked in 5 cm intervals (2 per team)
Open reel fiberglass tape (50m)
Clip Board
Plant sampling forms (rite in rain paper)
Plastic one-gallon or two-gallon zip-lock plant sampling bags (50)
Aluminum or cloth plant labels
Magic markers (waterproof pens)
Pencils
Plant press, blotters, and cardboards, newspapers
Fan (for plant drying)
Plant identification manuals (Voss I-III) + others
Michigan Floristic Quality Assessment software and manual
Dissecting microscope
Camera
Dry bags
First aid kit
Sun glasses
Waders or boots
Rubbing alcohol
Suntan lotion (water resistant)
Hat (optional)
Extra sweaters/fleeces in plastic sealed bag