Executive Summary

This document represents nearly seven years of work that has resulted in a long-term plan to monitor Great Lakes coastal wetlands using a scientifically validated sampling design and suite of indicators and metrics developed by many project partners. It includes a thorough cost analysis chapter that describes estimated costs associated with each element of the plan. The document should be of great value and benefit to agencies planning to incorporate coastal wetland monitoring into their overall monitoring strategy.

This document recommends multiple biological protocols and metrics for monitoring the condition of Great Lakes coastal wetlands – including those for plants, invertebrates, fish, amphibians, and birds. Also recommended is a design for sampling Great Lakes coastal wetlands that allows users to monitor condition of these wetlands on an annual basis. With a combination of repeated site visits and random sampling of other wetlands on an annual basis, users can establish status and trends (positive, negative, no change) of wetland condition for a given site, region, or for all Great Lakes coastal wetlands.

The objective of environmental monitoring is to establish the condition of ecosystems relative to reference conditions (the least impacted ecosystems in the area being monitored) and track changes in condition through time. Monitoring data are used to establish baseline conditions, temporal trends and compliance with regulatory requirements. Comprehensive monitoring is important to detect subtle changes to the environment that could have long-term negative consequences if not recognized and addressed.

The Great Lakes have benefited greatly from environmental monitoring. Decisions made by considering the results of effective monitoring programs have permitted the Great Lakes community to set fish consumption guidelines; better understand the health of Great Lakes fisheries; curb the loss of important wetlands; maintain safe air and drinking water; post public beach closings to avoid illness; control the introduction of invasive species through early detection; and maintain high water quality standards. These are just a few of the many benefits of maintaining a robust environmental monitoring regime in the Great Lakes basin (Great Lakes Commission, 2006).

In the 1990s, the need for environmental indicators measuring the integrity of Great Lakes coastal wetlands was identified, and many scientists and regulators around the Great Lakes began to work toward developing indicators that could be used to effectively monitor coastal wetland quantity and quality. In 1994, a seminal paper by The Nature Conservancy's Great Lakes Program titled *The Conservation of Biological Diversity in the Great Lakes Ecosystem: Issues and Opportunities*, called attention to Great Lakes coastal wetlands as "a system distinct to the Great Lakes." Further, the authors underlined the value of Great Lakes coastal wetlands to the Great Lakes as a whole in the following excerpts from the paper:

> *"They [Great Lakes coastal wetlands] are ecologically unique because they are dominated by large lake processes such as water level fluctuations, wave actions, and wind tides or "seiches." Spanning a diversity of types and the full geographic range, including freshwater estuaries, lagoons and deltas, Great Lakes coastal wetlands play a pivotal role in the aquatic ecosystem of the Great Lakes, storing and cycling nutrients and organic material from the land into the aquatic food web. They sustain large numbers of common or regionally rare bird, mammal, herptile and invertebrate species, including land-based species that feed from the highly productive wetlands. Most of the lakes' fish species depend upon them for some portion of their life cycles. Large populations of migratory birds rely on them for staging and feeding areas. Short- and long-term fluctuations in lake levels play a critical role in maintaining both wetland and shoreline systems. The processes of sediment inputs and longshore transport are important in maintaining bars and spits that shelter waters of many highly productive wetlands."*

Papers presented at the 1996 and 1998 State of the Lakes Ecosystem Conferences (SOLEC) reported on the status of Great Lakes coastal wetlands. Authors concluded that Great Lakes coastal wetlands were a valuable resource, but that no system was in place to determine their status or to track wetlands losses, degradation or improvements in condition. Furthermore, although many organizations focused resources on specific Great Lakes coastal wetlands and related issues, no one entity had responsibility for data collection and interpretation to determine basinwide status and trends and/or disseminate results.

To continue development of indicators and coordinate efforts leading to future Great Lakes coastal wetland monitoring, the U.S. Environmental Protection Agency Great Lakes National Program Office (U.S. EPA-GLNPO) sent out a request for proposals (RFP) in spring 2000 for consortia to design an implementable, long-term program to monitor Great Lakes coastal wetlands. The U.S. EPA-GLNPO considered the creation of a consortium, an approach that could meet these purposes and capitalize on the existing mandates and authorities of the organizations already working on Great Lakes coastal wetlands. The Great Lakes Commission submitted a proposal in response to the RFP and was awarded a grant to begin this work.

Thus, the Great Lakes Coastal Wetlands Consortium (Consortium) was formed in 2000 with the goal of producing a cohesive, long-term plan to monitor Great Lakes coastal wetlands. The Great Lakes Commission served as secretariat for the Consortium and, through the efforts of many partners, this plan has been completed. Since inception of the Consortium, more than 50 organizations have contributed to this plan from initial pilot studies, to development of a Great Lakes coastal wetlands inventory and classification system, drafting of final coastal wetlands monitoring protocols, to the design of a publicly accessible international database. The partners included scientific and policy experts drawn from key U.S. and Canadian federal, state and provincial agencies, nongovernmental organizations, academia, and members of other interest groups with responsibility for coastal wetlands monitoring.

The following are summaries of each aspect of the plan. The details of the plan have been included in the individual chapters that follow:

Statistical Design

The sampling design specifies how wetlands should be selected and the number, type and location (spatial and/or temporal) of wetland sampling units that are assessed. The paramount purpose of sampling designs within the context of the Consortium's recommendations for monitoring is to ensure that data collected are representative of an area and are of adequate scope to support defensible (statistical) inference. This permits one to draw logical conclusions about wetlands in federal, tribal, regional, state and provincial areas of responsibility while maintaining the standardized sampling protocols necessary to draw conclusions regarding wetlands at the entire basin level. Deciding how to sample is often difficult because one must consider trade-offs between costs and benefits of the amount and type of sampling undertaken. Thus, any sampling design represents a balance between the study objectives and the constraints of cost, time, logistics, safety and existing technology.

Many aspects of statistical design (in italics below) are addressed in this chapter, including those involving target populations and sampling frames (Figure 1-1), allocation and arrangement of samples (*membership design*), frequency of sampling occasions (*revisit design*), measurements to be taken at sampling locations (*response design*), and the number of samples required to meet stated objectives (*sample size*).

Chemical/Physical and Land Use/Cover Measurements

Basic chemical/physical parameters should be measured, and on-site observation of disturbance should be recorded at the same time that biological sampling is undertaken. These data will be used as covariates, helping to account for some of the statistical variability encountered during data analysis as well as providing the necessary information to develop additional metrics for quantifying ecosystem health. Sampling and analytical procedures should follow those recommended in Standard Methods for the Examination of Water and Wastewater (APHA 1998) or accepted U.S. EPA, U.S. Geological Survey, Environment Canada, or other operating procedures as dictated by local agencies. It is understood that logistic constraints may preclude the collection of some of these data, but it is essential that as many as possible are collected.

This chapter discusses several elements related to chemical/physical and land use/cover measurements that are important considerations for a coastal wetlands monitoring program. These elements include:

- Ensuring use of properly serviced and calibrated equipment and detailed check-box field data sheets;
- Which parameters should be considered and included in the sampling design if deemed relevant and budgets allow;
- Quality assurance/quality control procedures;
- Site assessment protocols; and
- General Interpretation of Covariates.

Vegetation Community Indicators

Emergent and submergent plants have been sampled in Great Lakes coastal wetlands for the purposes of classification, identification of wetlands important 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. Relatively discrete vegetation zones occur at most coastal wetland sites due to differences in water depth, substrate, and exposure to wind and wave energy. Wave energy also affects wetland vegetation diversity. Plant sampling should be conducted in a way that insures that major plant zones are included at each site. Sites should also be subdivided by major coastal wetland type (riverine, drowned rivermouth, open embayment, closed embayment). A classification of coastal wetlands was developed by the Consortium (Appendix A at the end of this document) and is also available on the Consortium's web page at www.glc.org/wetlands.

Plant community attributes that correlated with marsh condition for all five of the Great Lakes were based on (1) identifying and quantifying the distribution and coverage of invasive plants for major plant zones and overall; (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 a local site's Mean Conservatism Indices by plant zone and overall. These three attributes were incorporated into nine metrics by dividing plant zones into wet and dry portions of the plant zone. Protocols for collecting each set of data include a choice of using transects across the zones or using a sampling procedure with quadrats sampled by randomly selected locations within a randomly selected subset of grid elements.

Invertebrate Community Indicators

The invertebrate Index of Biotic Integrity (IBI) proposed and tested by Uzarski et al. (2004) appears to be the most appropriate and most broadly applicable means of assessing invertebrate community condition currently available for Great Lakes coastal wetlands. Other metrics are available for additional classes of wetlands, but they require data collected by field methods that differ slightly or substantially from those of Uzarski et al. (2004). These alternative methods are included where possible for comparison. Furthermore, because these alternative IBIs are either still in development or testing phase, or have not been quantitatively assessed against well-defined gradients of anthropogenic disturbance, it is premature to recommend their use. Thus, the Uzarski et al. protocol is recommended for sampling using the same protocol for all vegetation types and for all types of Great Lakes coastal wetlands. Metrics can be tested using data collected in the monitoring program and modified appropriately to extend to other wetland types not included in the Uzarski et al. publication. Alternative protocols can also be developed using procedures developed by others after they have been cross-tested against the Uzarski et al. protocol.

Fish Community Indicators

Great Lakes coastal wetlands provide critical habitat for more than 80 species of fish (Jude and Pappas 1992). More than 50 of these species depend upon wetlands while another 30+ migrate into and out of them during different periods in their life history (Jude and Pappas 1992, Wilcox 1995, Wei et al. 2004). An additional 30+ species of fish may be occasional visitors to coastal wetlands based on occurrence in adjacent habitats (Jude and Pappas 1992, Wei et al. 2004).

Fish have long been included as key indicators in assessment of biotic integrity in streams (e.g., Karr et al. 1986, Lyons and Wang 1996) and to a lesser degree in lakes (e.g., Fabrizio et al. 1995, Whittier 1998) and estuaries (e.g., Jordan et al.1991, Deegan et al. 1997). Fish had historically received little attention as indicators of wetland condition, but recognition of their ecological significance in Great Lakes coastal wetlands (Jude and Pappas 1992) generated considerable interest in using fish as indicators for these habitats (Wilcox et al. 2002, Timmermans and Craigie 2003, Environment Canada and Central Lake Ontario Conservation Authority 2004, Uzarski et al. 2005).

This chapter provides step-by-step detail of the Consortium-developed fish IBI, which is based on multiple metrics for *Typha* (cattail) & *Schoenoplectus* (bulrush)-dominated wetlands in relation to water quality and agricultural/urban land-use stresses (Uzarski et al. 2005). The chapter also compares the Consortium-developed monitoring protocols to alternative methods developed using fish as an indicator for coastal wetland health. The fish metrics have been tested for all five Great Lakes and can be utilized across the basin at present. These metrics can be modified and improved using data collected as the monitoring program is adopted basinwide.

Amphibian and Bird Community Indicators

Being directly associated with the Great Lakes hydrological influences, lacustrine or coastal wetlands are among the most important wetlands that occur within the Great Lakes basin. A high proportion of the Great Lakes basin's wildlife species inhabit wetlands during part of their life cycle, and numerous bird species federally listed as threatened or endangered in the United States or of conservation concern in Ontario are associated with wetlands. Although much is known about many landbird species of the Great Lakes, the ecology of most marsh-dependent birds has received much less attention, and relatively little is known about species such as rails and other secretive marsh birds.

Similarly, several frog and toad species are associated with wetlands of the Great Lakes basin. Amphibians rely heavily on aquatic environments for reproduction and other life sustaining purposes. Most amphibians inhabit wetland environments during most or part of their life cycle, and among the amphibian class, frogs and toads generally rely most heavily on wetland systems. Amphibians may also be the most sensitive vertebrates to aquatic and atmospheric pollution, and therefore may be deemed highly useful early warning indicators of wetland pollution and habitat degradation.

As recently as the 1990s, researchers began to realize that marsh bird and amphibian populations were declining in the Great Lakes basin. However, the magnitude and geographic extent of these declines was still uncertain. The uncertainty surrounding the nature of the declines was primarily due to lack of extensive, scientifically rigorous, consistently collected data, as well as a lack of detailed population information on localized metapopulations.

As a result of the loss and degradation of marsh habitats throughout the Great Lakes basin, there was increasing concern among citizens and scientists that continued stresses, including urban, industrial and agricultural development were negatively affecting marsh-dependent wildlife populations and other marsh functions such as water quality improvement. Consequently, Bird Studies Canada (BSC), in partnership with Environment Canada, developed the Marsh Monitoring Program (MMP) in Ontario in 1994. With substantial financial support from U.S.

EPA-GLNPO and the Great Lakes Protection Fund, the MMP was launched binationally throughout the Great Lakes basin in 1995 and has continued to operate annually since.

The methodological framework used to create coastal wetland indices of biotic integrity (IBI) relied on nine years of MMP data and was similar for both the bird and anuran communities. Within each community, attributes (e.g., species richness and abundance of marsh birds, species richness and presence/absence of anurans) that responded significantly to disturbance across sites were identified. The field-based values for responsive attributes (called metrics) were standardized. All metrics were then combined to give a quantitative measure of the condition of the community.

The marsh bird community IBI incorporated guilds that represent disturbance-sensitive marsh-nesting birds and general marsh-users. The metrics used were (1) abundance of non-aerial foragers, (2) abundance of marsh nesting obligates, and (3) species richness (number of species present in a sample) of area-sensitive marsh nesting obligates.

The amphibian community IBI also incorporated three metrics: (1) total species richness, (2) species richness of woodland species, and (3) probability of detecting a woodland species within the wetland.

The bird and amphibian IBIs were developed using sites in the Great Lakes basin within Ecoregion 8 (i.e., Southern lakes Huron and Michigan, all of lakes Ontario, Erie, St. Clair and connecting channels). Therefore, these IBIs should be limited to reporting on coastal wetland sites within this geographic area. Site size might also be a limiting factor for this approach, as there is evidence that suggests IBIs incorporating a guild approach might not provide accurate measures of marsh bird community condition in sites composed of less than 10 hectares of emergent marsh.

Landscape-Based Indicators

The Landscape chapter defines the role of landscape data in wetland monitoring, assesses landscape scale monitoring methods and data sources, and identifies an operational strategy for recurring assessment of the extent, composition and vigor of coastal wetland complexes and the surrounding landscape at a synoptic scale. The chapter provides background information on landscape methods to monitor coastal wetlands, and describes various remote sensing resources, tools and techniques. Because coastal wetland monitoring needs exist at the local, county, tribal, state, provincial and federal levels, the methods described are designed to provide flexibility in the sources of data used for landscape mapping and monitoring, as well as the ability to tailor them toward specific needs and budgets of each project. At the same time, it is important to provide some general protocols on classification schemes and landscape monitoring to keep the end products consistent enough for merging with adjacent maps created by other agencies, and for comparison to future maps.

The Landscape chapter describes the indicators and assessment and management programs that landscape metrics would inform. It also discusses details of landscape monitoring (e.g., sampling design, data sources and limitations, methodological innovations) and how they can be used to construct stressor gradients. Recommendations for a landscape monitoring protocol are provided. The chapter also describes and analyzes the Consortium's wetland inventory, which was assembled from various landscape data sources and is itself a spatial data set for intersecting with other landscape data layers.

To support Great Lakes coastal wetland monitoring, assessment and management into the future, a two-tier wetland mapping system is recommended, combining (1) a moderate (30 m) resolution satellite-based mapping of the entire basin every five years; and (2) a high resolution (< 1 m) airborne or satellite-based map of one lake basin per year on a rotating basis. This two-tier approach would provide a consistent baseline map from synoptic data sources using semi-automated techniques at the regional scale every five years, as well as a fine resolution map allowing more detailed discrimination of wetland boundaries and landscape land use and land cover. Using satellite data allows for multi-temporal and multi-spectral analysis to map wetlands that are dynamic throughout the seasons and allows automated change detection techniques to be used to update existing maps such as those of the National Wetlands Inventory (NWI). Note that highly sensitive areas (e.g. wetlands in high population areas or areas of rapid land cover/land use change and those with aggressive invasive species) will need to be mapped at high resolution with greater frequency.

Coastal wetlands are impacted by both local factors and stressors acting at the watershed scale; hence assessment and monitoring should quantify stressors operating at both spatial scales. The protocols described in this chapter are designed to monitor key landscape indicators that quantify watershed-scale changes relevant to coastal wetlands. The basic strategy is to (1) identify data sources that are updated regularly across the basin; (2) define watershed-scale spatial summary units appropriate for coastal wetlands; (3) enumerate key landscape metrics for these units; and (4) describe a monitoring process that allows identification of trends in key landscape stressor variables across the basin. The techniques and information in this chapter can be used in conjunction with field-based indicators described in other chapters to evaluate relationships among the broader landscape conditions and the condition and functions of coastal wetlands. The use of remote sensing data allows for a repeatable and comprehensive view of broad spatial characteristics across the Great Lakes basin (e.g., to produce landscape metrics and indicators), providing opportunities to capture the instances and magnitude of disturbances, which may, in turn, affect – or already have affected – coastal wetland condition and functions.

Cost Analysis for Sampling Great Lakes Coastal Wetlands

Great Lakes coastal wetland monitoring involves many possible costs including paying and training staff, buying equipment, travel expenses, and processing of samples. Funding availability often determines how much sampling is feasible; therefore it is important to evaluate cost as a factor in developing a wetland monitoring program.

During the course of this project detailed cost estimates were assembled and analyzed for the following indicators: water chemistry, plants, invertebrates, fish, amphibians, birds, and landscape attributes. Cost estimates for each indicator included:

- each item of equipment needed to sample each indicator and whether it is likely to already be owned, if it is shared by several indicators, and if it is consumable;
- salaries for technicians and professionals involved in sampling;
- the length of time it takes each person to sample each wetland for each indicator;
- time needed to train staff in the protocols for sampling each indicator;
- external lab processing of water chemistry and invertebrate samples; and
- automobile and boat travel (per mile/kilometer).

These cost estimates formed the basis for the development of a spreadsheet-based Wetland Sampling Cost Estimator Tool. This tool presents cost information in a format most useful for monitoring agencies since it allows them to test an almost unlimited variety of scenarios and evaluate the relative differences in cost. Members of the Consortium evaluated and verified the Cost Estimator Tool and its underlying assumptions and cost formulas.

Data Management System

Because of the breadth of potential users of the Consortium's coastal wetlands monitoring plan, there is clearly a need for a mechanism to facilitate communication and data sharing. In response, the Consortium's data management group developed a standardized approach that could be applied across the region, allowing data to be easily shared by researchers and sponsoring agencies. A centralized, online Data Management System (DMS) has been implemented. The DMS described in the Data Management chapter of this document is designed to allow data to be recorded in standardized formats and placed in a data archive housed within the Consortium website.

The Consortium DMS is considered a first generation system and will be fine-tuned as problems arise during its use by managers, regulators and others. It accepts data files prepared using a standardized data template compatible with Microsoft Excel and other spreadsheet software and stores the data on the Consortium web site and data server. From there, files can be downloaded and used as needed. The data template approach was chosen during the DMS design phase because it allowed system development to take place while scientific subcommittees finalized protocol content. Future versions of the DMS will include the capacity to upload raw data and to select and retrieve data based on more refined criteria.

The DMS is housed within an online database programmed using standard php/MySQL software. The user interface consists of background information about the Consortium and the DMS, a log-in page, and data submission and retrieval forms. As a means of protecting the integrity of the database, users are required to register before they can upload data. Active members of the Consortium's development committees were registered when the system was created. New users must submit a registration request via the DMS log-in page. Individuals retrieving data are asked to register as a means of tracking the distribution of the Consortium's products.

Partnerships for Implementation

In 2001 and 2002, initial stakeholder meetings of the Consortium were held in the U.S. and Canada to raise awareness of and receive input toward developing a science-based, binational coastal wetland monitoring plan for the Great Lakes. Presentations and discussion groups were used to begin partner engagement. Since then, the Consortium has been a significant presence at SOLEC, where representatives from agencies and organizations from around the basin meet to discuss indicators that assess environmental condition of the Great Lakes. The biennial SOLEC conferences have offered a venue for presentation of Consortium monitoring protocols and results from pilot investigations.

From the beginning, it was clear that agencies and organizations wishing to adopt Consortium protocols would need assistance in implementing this monitoring plan and forming partnerships to optimize use of staff, funding and equipment resources. Consequently, the Consortium Partnerships for Implementation Committee (PIC) was formed to promote awareness of and execution of this plan.

The PIC identified agencies and organizations that conduct coastal wetland monitoring or other wetland monitoring activities in the Great Lakes basin. It used the Great Lakes Commission's 2006 report *Environmental Monitoring Inventory of the Great Lakes Basin*, which assessed gaps and overlaps in observing systems and monitoring programs. The gap analysis summarized monitoring efforts for 21 resource areas, highlighted potential gaps in monitoring coverage, and provided recommendations to address the gaps.

The PIC surveyed agencies and organizations that might benefit from adoption of the Consortium's basinwide, standardized monitoring protocols and assessed whether these entities would have the capacity to conduct this monitoring. Survey questions addressed aspects of current or former coastal wetland monitoring activities, staff or volunteer expertise, available equipment, funding mechanisms, and protocol training requirements.

Finally, the PIC developed an implementation strategy for presentation to potential partner agencies, in order that the process of adopting (or adapting) this plan would be less daunting for those that already lack sufficient resources. This strategy includes adaptive management techniques to make adoption of the plan more seamless.

Although implementing new programs can be difficult for many agencies due to funding, equipment, and staff limitations, the PIC found that a number of agencies and organizations throughout the Great Lakes basin are already conducting monitoring programs that, if willing, could fully or partially adopt or adapt Consortium protocols. In addition, the PIC identified a number of partnership opportunities that could assist in the implementation of this plan.

Adoption or adaptation of the Consortium coastal wetland monitoring protocols can aid agencies in satisfying monitoring mandates and contribute to the goals set forth in SOLEC, the Great Lakes Regional Collaboration (GLRC), the Great Lakes Water Quality Agreement (GLWQA), and other important cooperative efforts. The recruitment of agencies and the formation of partnerships among those agencies will lead to greater success when implementing this plan. Accurate, standardized monitoring data, of which this plan will produce when implemented, is in the best interest of many Great Lakes stakeholders.

Final Summary Recommendations

In this chapter, we recommend an integrated sampling program for the entire basin that includes plant, invertebrate and fish metrics, with time of sampling periods recommended that allows a small crew of three trained individuals to gather, analyze and interpret the required data for parts of the Great Lakes shoreline in a particular jurisdiction with aid from several seasonal workers. For large states and provinces such as Michigan and Ontario with responsibility for multiple lakes and many miles/kilometers of lake shore, two or more such crews would be needed. These individuals would also work with trained volunteers using MMP protocols to generate the amphibian and bird data.