Executive Summary:
Developing a Cooperative Monitoring Strategy for Lake Ontario

Results of the Lake Ontario 2008 Intensive Sampling Year Workshop
Kingston, Ontario
October 23 – 24, 2006

A workshop convened by the Lake Ontario Lakewide Management Plan (LaMP) and the Great Lakes Fishery Commission's Lake Ontario Committee (LOC) and supported by the International Joint Commission (IJC) was held on October 23 - 24, 2006 in Kingston, Ontario with the goal of developing a strategy for sampling the Lake Ontario lower food web and fishery in 2008. Participants included academic, government researchers, and lake managers from both the United States and Canada. The workshop focused on the coordination of U.S. and Canadian lower food web monitoring and fishery assessment efforts in order to meet the information needs of environmental and natural resource managers. Funding was provided by the IJC with additional support from the Ontario Ministry of the Environment. A white paper was developed in support of workshop goals and is available on line at http://www.ijc.org. The paper, distributed to workshop participants, contains information on ten topic areas that were important to the development of a sampling plan for Lake Ontario in 2008. Each section was co-authored by a Canadian and U.S. workshop participant.

The State of Lake Ontario. The Lake Ontario food web has been permanently altered by invasive species and continues to undergo ecosystem change and ecological disruption. Ecological disruptions have been common in Lake Ontario over the past two centuries, but the pace at which these disruptions have occurred has increased over the past three decades. The sea lamprey and alewife have been associated with ecological disruptions since the late 1800s, but numerous other management actions, socio-political influences, and unplanned events have changed the Lake Ontario ecosystem since the 1970s. These include low phosphorus levels in the offshore, the identification of the microbial food web as an essential pathway of energy transfer to zooplankton, increased presence of cyanobacteria and the potential for toxic algal blooms, increased dominance of quagga mussels and round gobies, a progressive decline of the native amphipod *Diporeia*, the establishment of two predatory invasive cladoceran zooplankton, and a resurgence of fish-eating birds.

Scientists continue to chase ecological change in the Lake Ontario ecosystem, and food web disruptions continue to challenge our understanding of the system. For example, the LOLA 2003 study confirmed that the offshore ecosystem had changed dramatically with the following key findings:

1) Ecosystem breakdown, native amphipod *Diporeia* spp. at risk of extirpation.

2) Invasive quagga mussels causing food web disruption

3) Nutrient-limited offshore food web

4) Impaired food supply for zooplankton

Scientists are charged by society to provide answers to questions concerning ecological impacts of these disruptions and methods of mitigation. One way to help scientists provide such "answers" is to develop and maintain long-term datasets that view ecosystems both spatially and temporally. The Lake Ontario 2008 Intensive Sampling Year will build upon earlier lake-wide efforts and contribute significantly to defining the current and future state of Lake Ontario. In addition, monitoring efforts in 2008 will provide a scientific basis for understanding how ecological processes are linked spatially along gradients from the nearshore to offshore and coupled between pelagic and benthic habitats.

The importance of understanding fluxes between ecosystem compartments in Lake Ontario was a recurring theme in workshop discussions, particularly with respect to energy transfer between benthic and pelagic habitats as well as between shoreline, nearshore, and offshore habitats. Changes in total phosphorus concentration from the shore to the offshore provides an excellent illustration of a nutrient gradient in Lake Ontario, shifting from a phosphorus-rich environment in shallow shoreline waters to a phosphorus starved offshore (Figure 1). Understanding the current structure of these gradients and how they compare with historical trends provides the basis for monitoring and assessment of the Lake Ontario Intensive Year in 2008. To address questions associated with benthic/pelagic and nearshore/offshore gradients, a well-coordinated sampling plan for Lake Ontario in 2008 will require efficient use of sampling platforms and ship time, core funding, and a team effort.

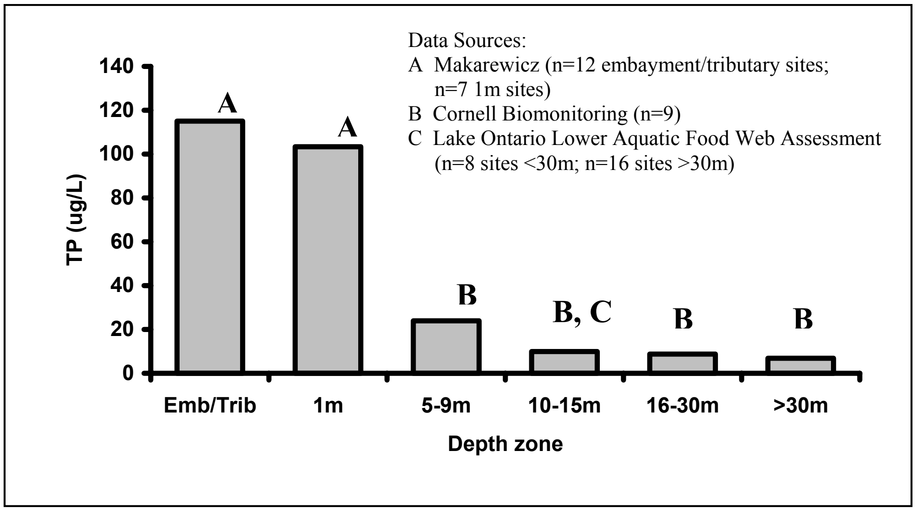

Figure 1. Mean total phosphorus (TP) concentrations in Lake Ontario, spring – fall 2003.

Workshop Recommendations

Offshore Sampling Needs & Approaches (Ora Johannsson, David Rockwell, and Steve Lozano)

In order to determine the state of Lake Ontario in 2008 and test for possible ecological changes, the sampling strategy and methods employed must be consistent with and build on those of the past, particularly LOLA 2003. Ideally, offshore sampling would include both spatial and temporal components in spring (ice out conditions), summer (stable stratified conditions), fall (prior to overturn) for all lower trophic levels, and late fall (after overturn) for mysids. Spring is the time of isothermal water temperatures and provides the initial chemical conditions for the year prior to significant uptake of nutrients by the biota. The spring survey provides a picture of the amounts of nutrients available for the biological activity that will occur during the year. Summer and fall surveys (August and September) characterize the summer and late summer zooplankton production and community structure. Mysid biomass and reproductive effort peak later than that of the zooplankton and is tracked by the late fall survey in November. Benthic sampling is not time sensitive so samples are collected during the summer-stratified period.

Assessment needs for the offshore habitat include characterization of both physical and chemical habitat and food web structure. Other key attributes to assess ecological change include use of stable isotopes to determine predator/prey relationships, the relative proportion and seasonal timing of the various taxonomic groups of algae and cyanobacteria, measures of seston stoichiometry and nutrient status, the relative balance between the microbial food web and the direct zooplankton grazing food chain, the diversity and abundance of predatory invertebrates relative to their herbivorous/detritivorous prey within both the zooplankton and the benthos, the proportion of biomass at each ‘trophic level’ that is composed of exotics, and the degree of benthic-pelagic coupling.

Given the assessment needs, an offshore monitoring program is recommended that combines key stations sampled at two week intervals annually from April-May until the end of October with spatial cruises in spring, summer and fall every fifth year. Moored instrumentation (thermistors, current meters) could be added at key stations to provide continuous measurements of some parameters. The key stations would provide the backbone of the biological data, estimates of inter-annual variability, seasonal context for the spatial surveys, and improved sensitivity to detect change. The seasonal spatial cruises should incorporate sampling of fixed sites with towed sensors. A zig-zag pattern (Figure 2) that loops between nearshore and offshore regions could be used to calibrate sensors with data collected at fixed stations that overlap with previous efforts (LOTT, LOLA). The eight EPA offshore sites, which are monitored twice a year (April and August) would provide data from the deepest region, especially if no key stations could be situated in that region, and would further supply information on inter-annual variation. The seasonal spatial cruises would define and track spatial patterns in the lake, link the nearshore and offshore, and provide the basis for whole lake estimates of biomass and production. A segmented sampling strategy using the minimum number of calibration stations needed to ensure the interpretability of the towed instrument data could be used in the event that the entire circumnavigation could not be completed.

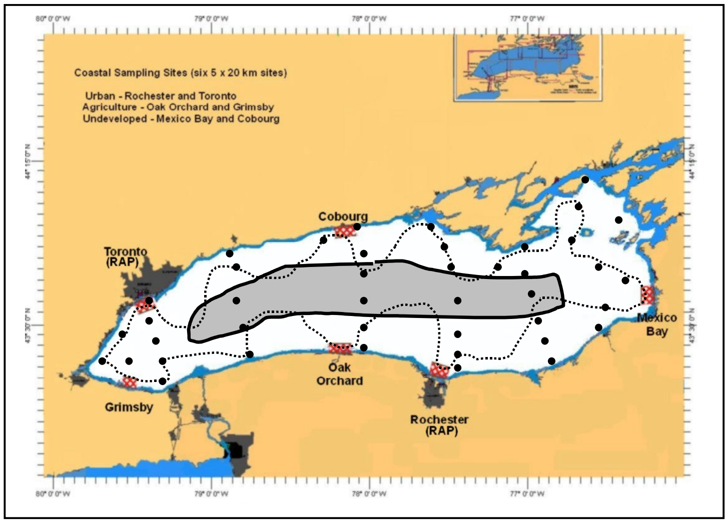

Figure 2. Proposed sampling strategy at nearshore and offshore sites for the LOLA 2008 Intensive Year.

Data to be collected should include nutrients (TP, SRP, Si, TN, NO2, NO3, Ca, Fe), physical parameters (light, temperature and oxygen), and plankton (microbial food web components and zooplankton – supplemented with OPC, FluoroProbe, and calibration data). Benthos would be collected in summer and fall and mysids in the fall. Annually, key sampling locations, physical conditions, zooplankton, phytoplankton, rotifers, and the MFW would be sampled every two weeks from April-May until the end of October. Regular interpretation of satellite imagery should be employed to track changes in surface temperature and upwelling events as both parameters have strong effects on biota and are expected to shift with climate change.

Our ability to detect ecological change (response to management actions) is very low with a five-year monitoring strategy, especially for the biological parameters. Consequently, annual sampling of biological parameters is recommended. Measures of the larger biota (zooplankton and benthos) can be highly variable. Zooplankton biomass would have to decline by more than 27% -32% before a significant difference could be detected based on the LOLA 2003 data. Detection of change could be improved by increasing the number of samples collected per station and collating them before analysis. For instance, in two sets of eight replicate zooplankton samples from Lake Ontario (August 1986), the coefficient of variation (sd/mean) was reduced by approximately half when the data were collated for all possible sample pairs (Johannsson, unpublished data). This indicates that collating several samples at each station would reduce the total variability by reducing the component due to sampling variability.

Building a Nearshore Sampling Network including Shoreside and Embayments

(Joe Makarewicz and Todd Howell)

Despite significant water quality improvement in the open waters of the lake over the last three decades, the Lake Ontario coastal zone (shoreline and embayments—bays, river and creek mouths and their associated wetlands) suffers from several impairments that severely limit recreational use and ultimately affect economic development. Impairments include invasive species; habitat destruction; algae blooms; erosion, sedimentation and associated nutrient enrichment; turbidity; navigational impairments; beach closings, property loss; and fish consumption advisories due to toxicants. A decoupling of the nearshore to offshore movement of materials could explain these observations. A key question is to what extent has the retention (and accumulation) of nutrients and pollutants increased in the nearshore and, conversely, the supply to the offshore declined? This question is particularly relevant to phosphorus since much of the total phosphorus input to the lake are in particulate form, originate from the nearshore, and are now susceptible to being retained in the nearshore than prior to the establishment of the dreissenid mussels. There is substantial potential for dreissenid mussels to enhance benthic algal growth by increasing habitat availability through greater water clarity and by enhancing nutrient supply through excretion or indirectly through the accumulation of particulate material in mussel beds. More simply, the *Dreissena* and *Cladophora* beds could be acting as biological filters removing and retaining phosphorus in the coastal zone and thereby reducing the amount transported to the offshore.

A current understanding of the state of Lake Ontario must include an assessment of its coastal zone. Assessment efforts could focus on the working hypothesis that nutrients and particulate matter loaded to the coastal zone are being trapped/sequestered in the coastal zone by dreissenid mussels and *Cladophora.* Consequently, elevated levels of benthic algae, planktonic algae and nutrient levels in the nearshore are expected. With the disruption of the nearshore to offshore flow of nutrient and materials, lower than expected phosphorus concentrations in the offshore should result.

Intensive monitoring using fixed stations and towed sensor arrays will describe the nearshore to offshore gradient in three seasons (spring, summer and fall) at six sites (three Canadian and three U.S.) within the coastal zone of Lake Ontario. The six coastal sampling areas (20 km x 5 km) will be located adjacent to drainage areas dominated by the following land use patterns: urban, agricultural and undeveloped land.

Recommended key elements of the Lake Ontario Intensive year effort include the following spatial and temporal elements within the six sampling areas:

1. Describe the gradient from nearshore/offshore in regards to phosphorus, suspended solids, other nutrients and tracers of watershed input within the nearshore under the influence of three different land use patterns (urban, agriculture and undeveloped).

2. Estimate the abundance (biomass) of *Cladophora*, dreissenid mussels, cyanobacteria and round gobies.

3. Describe the thermal, light and nutrient regimes to the extent needed to support numerical modeling of *Cladophora* growth and other selected biological processes.

4. Describe the role of physical processes, such as prevailing coastal flow regimes, the spring thermal bar and hypolimnetic upwellings, on movement of materials from nearshore to the offshore.

5. Document the importance of tributaries (including smaller tributaries) locally to the nearshore zone by describing the inputs of nutrients and sediments to the nearshore.

6. Use these data in developing models of transport of materials from the nearshore to the offshore to evaluate the working hypothesis.

Lake-wide Lake Trout Assessment and Integration of Lower Food Web with Fish and Other Upper Trophic Level Biota

(Bob O'Gorman, Jana Lantry, and Ted Schaner)

Important fishes lacking sufficient assessment efforts are those that are difficult to capture (salmon in the open lake) and those for which catch data is difficult to interpret (nearshore fishes in the main lake basin). Adult lake trout are the one exception. Although there are regional lake trout assessments, there is a need for conducting an integrated, whole lake assessment such as was done during 1985-1995. Restoration of a self-sustaining lake trout population is a goal of New York and Ontario resource managers and gauging progress towards the goal should be done on a whole lake basis. Since the cessation of whole lake assessment, stocked lake trout have begun reproducing, and regional differences in occurrence of naturally produced juveniles have been documented. An important measure of progress towards restoration would be the proportion of naturally produced fish in the spawning population. A whole lake assessment, aside from collecting valuable demographic information, could also be used to collect information on the genetic makeup of naturally produced fish, thiamine status of mature females, and general population health.

Growing evidence indicates that not only food quantity, but also the nutritional quality (e.g. relative proportion of elemental components or chemical stochiometry) of the food can be of vital importance. Trophic transfers from phytoplankton to zooplankton and benthic invertebrates determine fatty acid composition and chemical stochiometry of fish and fish-eating birds. The composition of these essential fatty acids is important for fish osmoregulation, winter survival, and fish/wildlife health. Use of food web bio-marker (stable isotopes and fatty acids) analysis is advised to complement the lake trout/upper trophic level assessment.

Use of New Technologies (Kim Schulz and Steve Lozano)

Bioassessment programs should undergo periodic evaluation, not only to reconsider modifications to historic sampling regimes, but also to determine the appropriateness of new technologies. Technological advances have the potential to enhance bioassessment programs by reducing sampling costs and providing new and/or more comprehensive data. Monitoring the physical, chemical, and biological condition of the Lake Ontario ecosystem has traditionally been conducted by shipboard surveys. Advances in remote sensing technologies and computer storage and computation offer opportunities to add new information and expand spatial and temporal observations of environmental and biological community condition. Several technological advances related to the assessment of lower food webs of freshwater ecosystems have been developing over the past two decades. The following technological/mathematical tools are recommended for consideration in Lake Ontario in

2008. These include the laser optical plankton counter, hydroacoustics, fluorometry, FlowCAM imaging, satellite imagery, a computerized binational data repository, and ecological models. It is essential to ground truth these instruments using 'traditional sampling' and cross calibration.

Food web bio-markers including fatty acid and stable isotope analyses are recommended to meet goals of (1) estimating food web structure at key monitoring sites, (2) looking at benthic-pelagic coupling in the offshore, (3) linking condition in upper trophic level biota (e.g. lake trout, fish-eating birds) and diet monitoring, and (4) examining nearshore-offshore fluxes.

Data Needs and Management, and Model Development (Joe DePinto, Tom Stewart, and Tim Johnson)

Considerable research, monitoring, and modeling have been conducted in order to support water quality and fishery management in Lake Ontario. In most cases, those data-supported modeling efforts have led to rational and defensible management decisions; however, our quantitative understanding of the Lake Ontario ecosystem structure and functioning has not been able to keep pace with the latest stressor-induced changes that were not considered at the time management actions were taken for a specific issue. Given the significant ecological changes that have taken place in Lake Ontario over the past 10 – 15 years, a revision of conceptual and quantitative models of the Lake Ontario trophic structure and function is needed. Two basic goals of developing of a whole-system ecological model are to 1) provide a quantitative framework within which to synthesize and integrate the recent experimental and monitoring data on the Lake Ontario ecosystem; and 2) construct a model that can inform management decisions on how to move the Lake Ontario fishery toward a more healthy and diverse community in the face of the multiple stressors that act concurrently on this system.

Data compiled for large scale modeling efforts warrant special attention. A standardized data format needs to be employed, and data need to be condensed to meaningful units while maintaining the most raw form possible. There should be an all parties "publication guarantee" that ensures every contributor of data has the first right to publish it (either solely, or as a co-author) before other project partners (users of the database) can publish the information. All contributing parties must agree to the timely provision of making the data available through the database so that modeling and assessment efforts are not delayed. The database should include only information set out by the official LOLA II sampling plan and not include information supplemental to the project. The data collected should be rigorous enough to allow comparison between years and between other Great Lakes.

Building on the modeling that has already been conducted on Lake Ontario, a data collection program during 2008 year should help support the following refinements in a Lake Ontario ecosystem trophic transfer model that can support the above two goals:

1. Formulation of a fine-scale ecosystem model that is linked to a fine-scale hydrodynamic model.
2. Incorporation of Lake Ontario coastal wetlands into the model in terms of their contribution to fish spawning and recruitment.
3. *Dreissena* bioenergetics and their impact on nutrient cycling and energy flow should be built into the ecosystem model.
4. Incorporation of a *Cladophora* sub-model.
5. Develop a whole-system trophic transfer model.