A test of the variability and usefulness of SOLEC environmental indicators in the coastal wetlands of eastern Lake Ontario

Final report

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ABSTRACT

Great Lakes coastal wetlands are an integral part of the Great Lakes ecosystem. They are indicators for progress in maintaining a healthier Great Lakes environment. Currently there are individual data sets on well-studied wetlands, yet few basin-wide and binational data are available for research use and management applications. Over the last six years, increasing attention has been focused on developing indicators that will lead to effective monitoring of coastal wetland quantity and quality. These indicators will be tested as part of a three-year study to develop a sustainable, long-term basin-wide monitoring plan for Great Lakes coastal wetlands. A near term goal is the creation and synthesis of basin-wide data sets from both the United States and Canada needed for the development of an effective, functional monitoring plan.

In this study, we addressed the near term goal by collecting and analyzing data in conjunction with other Great Lakes projects, including the Lake Ontario Biocomplexity project, to help define a long-term basin-wide monitoring plan. A series of indicators were studied in a set of co-located, hydrologically unique wetlands. The indicators included several methods for invertebrate data collection, several for fish data collection, submerged and emergent wetland plant identification, water chemistry, water levels, sediment flow, and landscape attribute assessment. We further augmented our data by performing collections in all study waters multiple times over the summer season to gain a better understanding of temporal changes of indicators within wetlands.

Preliminary analysis of the data from this study show that sweep netting yielded the most taxa rich samples with no appreciable increase in processing time over activity traps and Hester-Dendy sampling methods. Median species richness of fish samples was highest with electrofishing gear, closely followed by fyke net sampling. Temporally, invertebrate taxa richness and fish species richness were greatest in early to mid summer. Emergent wetland plant assessments, unlike submerged assessments, were costly and involved significant time commitment, however, both provided valuable information. Sediment flow data were easy to collect but questionable in quality. Water level data was inexpensive to obtain and low in effort to analyze. Water chemistry information was also easy to collect in the field but technical laboratory knowledge was required to accomplish water chemistry analysis. STORET data, by comparison, is low in cost and effort but may not cover the needed regions. Site attribution using both field and GIS analysis were effective and low in cost and effort. The resulting data sets will be further analyzed in consort with data from other Great Lakes wetland sites to determine the degree to which these techniques can be used to make comparisons of indicator tests and to develop a basinwide monitoring plan.

INTRODUCTION

Great Lakes coastal wetlands are an integral part of the Great Lakes ecosystems. They are indicators for progress in maintaining a healthier Great Lakes environment. Currently there are individual data sets on well-studied wetlands, yet few basin-wide and binational data are available for research use and management applications.

Over the last six years, increasing attention has been focused on developing indicators that will lead to effective monitoring of coastal wetland quantity and quality. Development of indicators of “ecosystem health” for the Great Lakes was recognized as a major need and was the emphasis of the State-of-the-Lakes Ecosystem Conferences (SOLEC) held in 1998 in Buffalo, New York and in 2000 in Hamilton, Ontario (Great Lakes Commission 2002). Authors at the conference concluded that Great Lakes coastal wetlands are a valuable resource, but that we currently have no system in place to consistently measure or monitor the status of coastal wetlands either in terms of wetlands loss or degradation.

Out of this need grew the establishment of the Great Lakes Coastal Wetland Consortium, a group of scientists, policy makers, and other parties dedicated to monitoring the condition of Great Lakes coastal wetlands. The goal of the Consortium is to develop and implement a sustainable, long-term basin-wide monitoring plan for Great Lakes coastal wetlands. A near term goal of the consortium is the creation and synthesis of basin-wide data sets from both the United States and Canada needed for the development of an effective, functional monitoring plan.

Objectives

The objective of this study was to test biotic indicators of wetland ecological health that could be employed in a monitoring program by federal, state and local agencies to detect effects of anthropogenic disturbance on the biotic integrity of Great Lakes coastal wetlands. Our study addressed these objectives by collecting and analyzing data in conjunction with other Great Lakes projects, including the Lake Ontario Biocomplexity project, to ultimately help in forming a long-term basin-wide monitoring plan. We set the stage for efficient and effective testing of environmental indicators by selecting a set of co-located, wetland-rich study waters having very different hydrologic settings. Indicators sensitive to changes in wetland conditions should show different values across our study waters. A series of indicators were studied including several methods for invertebrate data collection, several for fish data collection, submerged and emergent wetland plant assessment, water chemistry analysis, water level analysis, sediment flow, and site attribute assessment. We further augmented our data by performing collections in all study waters multiple times over the summer season to gain an understanding of temporal changes of indicators within wetlands. The resulting data analysis presented in this report can be used to determine the degree to which these techniques can be used to make basinwide comparisons and to develop a monitoring plan. Our extensive data has been made available for other Consortium indicator tests and evaluations in the context of well characterized wetland systems.

Biotic indicators employed in this study were evaluated on their usefulness in a monitoring program based on the seven criteria set forth in the original RFP from the Great Lakes Commission. These criteria are:

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

Detailed descriptions of each criterion are given below:

1. Cost

Total labor and equipment costs were tracked for each biotic indicator and are summarized within the results section of this report. Note that several pieces of equipment (i.e., boat, batteries, field supplies) were shared among sampling tasks. These are separated into a cost table titled general equipment. Boat equipment, due to the fact that the maintenance on a boat is cost intensive, is separated into its own cost category and is included under fish in the results section. Information is included for each supply on: cost, whether it is consumable, and whether it was already owned by our laboratory. Costs of supplies not already owned were obtained from the internet or estimated.

2. Measurability

Recommendations regarding the level of expertise and training required to implement each of the methodologies are reported in the results section.

3. Basin-wide Applicability and Sampling by Wetland Type

Recommendations regarding basin-wide applicability and sampling by wetland type are limited in this study due to the fact that all sampling was done in one wetland type, protected bays, and in the same general location of Lake Ontario. Since little information about basin-wide applicability can be discerned from our data, we will defer judgment on this criterion to studies that engaged in more widespread data collection.

4. Availability of Complementary Existing Research or Data

Where applicable, data collected from common coastal wetland study sites was utilized for the purposes of this project and was so noted within the methods section. The Lake Ontario Biocomplexity study was a large contributor of data to this project.

5. Indicator Sensitivity to Wetland Condition Changes

Data were collected on a variety of coastal wetland biotic indicators. The level of degradation of each site can be quantified for each coastal wetland study site from site attribution data. Indicator sensitivities to wetland condition changes can thus be estimated using the data collected from this and other studies.

6. Ability to Set Endpoint or Attainment Levels

The collection of anthropogenic disturbance variables at all study sites and compilation of databases by other investigators allowed ranking of human disturbance levels and identification of minimally impacted or reference wetland sites. Though not done in this study, metric values obtained within these sites can be used to establish appropriate attainment levels and identify if there is a requirement to set different endpoints within different basins and/or wetland types.

7. Statistical Approach

Biotic integrity metric development and testing is being undertaken for invertebrates by the Michigan research team and for birds and amphibians by Bird Studies Canada using data collected on this and other projects. Biotic integrity metric development was not a part of this study and will not be addressed in this report.

SITE SELECTION

Wetland sites for this project were chosen to overlap with areas already in use by the Lake Ontario biocomplexity project along the southeast coast of Lake Ontario. Two general locations were used which we call the western study sites and the eastern study sites (Figure 1). Two bays comprise the western study sites, namely Blind Sodus Bay and Little Sodus Bay. We sampled in two wetland locations in Blind Sodus Bay and one in Little Sodus Bay. Each of the wetland locations in the western study sites has two plant communities (Figure 2, Table 1).

Three bays comprise the eastern study sites, namely Floodwood, South Colwell and North Sandy Pond. We sampled in one wetland location in Floodwood, one in South Colwell, and three in North Sandy Pond. All wetland locations in the eastern sites have two plant communities each (Figure 3, Table 1).

The eastern bays are mostly separated from open Lake Ontario by a barrier composed mainly of sand. The western bays are separated from Lake Ontario by gravel and cobble barriers with some reinforced and roaded sections. All study sites reside in protected embayments. Detailed information on attributes of the wetlands and bays can be found in the site attribute data (Table 6).

Lake Ontario is the fourteenth largest lake in the world and the smallest of the Great Lakes in surface area at 18,960 km^2 (7,340 square miles; U.S. EPA 2002a). Lake Ontario has the highest ratio of watershed area to lake surface area with a basin that is largely rural, with many scenic resort areas on both the United States and Canadian sides. The climate consists of cold snowy winters and warm dry summers (Smith 1985). The annual precipitation in the area of the western sites is approximately 105 cm with mean Fahrenheit temperatures ranging from the upper 20s during the winter to the upper 60s during the summer (Weather.com 2003). The annual precipitation at the eastern sites is approximately 81 cm with mean Fahrenheit temperatures ranging from the upper teens during the winter to the upper 60s during the summer (Weather.com 2003).

METHODS

Our field investigations at the Lake Ontario coastal wetland sites began in 2001 with the assembling of basic information on the sites and was completed in the summer of 2002 with extensive sampling of fish and invertebrates, wetland plants, water chemistry, sediment flow, water levels and site attribute information (Figure 4). Our work will provide data of direct use in comparing indicator performance among our sites, and with some additional analysis, will substantially expand the comparability of our efforts with Consortium indicator evaluation goals. Below are descriptions of the sampling procedures in more detail. Details of the methods used were summarized in Table 2.

INVERTEBRATES

We used three sampling methods for assessing invertebrate populations in the study wetlands. Two of these methods, activity traps and sweep netting, were repeated three times for all sites throughout the summer. The third method, Hester-Dendy samplers, were set in May with data checks in June and July, thus yielding only two samples per site.

Activity traps

Activity traps were used to collect mobile organisms at the edge of the emergent vegetation. The traps were built following the protocols set forth in the U.S. Environmental Protection Agency's report titled "Methods for evaluating wetland condition: developing an invertebrate index of biological integrity for wetlands" (U.S. EPA 2002b) and personal communication with Don Wik whose company Protofab designed the soda-bottle activity trap. The traps were built with PVC pipe using a 3/4" outer diameter stick about 4 feet tall to hold the trap, a 4" inner diameter ring about 1.5" in width to hold the soda bottle, and a 1.5" width semicircle of PVC for the piece that holds the bottle ring to the stick. PVC pieces were held together with 3/8" bolts and wingnuts made of brass for corrosion resistance. Two liter soda bottles, without labels, were used as the actual traps. On these, the tops were cut off and inverted to form a funnel through which aquatic invertebrates could swim in but not leave (Figure 5).

We set activity traps with no bait near the edge of the emergent vegetation for a time period of 24 hours. Traps were placed horizontally in the mid-water column. One to two activity traps were set in each plant community for a total of three activity traps per wetland. Activity traps were generally set in the same locations as minnow traps. At collection time, the contents of the each of the traps were poured through a sieve then flushed with ethanol into a container and stored for later enumeration and identification to family at the Cornell University aquatic laboratory.

Sweep netting

We used sweep netting to capture organisms from within the flooded emergent vegetation in all plant zones at the site (Figure 5). The nets we used were D-frame with 500-micron mesh. We did sweeps throughout the water column at the surface, mid-water and just above the sediment to ensure that a variety of microhabitats were sampled as defined by Burton (1999). At most sites, three replicate samples were collected per plant zone, but occasionally if only two people were working, we would do two replicates instead. Invertebrates from sweeps were placed in gridded white enamel pans. Invertebrates were subsampled by picking all specimens from one randomly determined area of the grid before moving on to the next grid area. Special consideration was made to ensure that small organisms were not missed, avoiding bias towards larger, more mobile individuals. Plant detritus was sorted for a few additional minutes to ensure that cryptic species were included in the sample. As a means of semi-quantifying samples, picking of specimens was timed. Individual replicates were picked for one-half-person-hour, after which, if 150 specimens had not been obtained, organisms were tallied and picking continued to the next multiple of 50. If 150 organisms were picked in less than one-half-person-hour, picking was terminated. Specimens were preserved in ethanol in the field and later enumerated and identified to family at the Cornell University aquatic laboratory.

Hester-Dendy samplers

Hester-Dendy samplers were used to collect information on organisms which colonize on artificial substrate (Hester and Dendy 1962). The samplers were built following the procedures listed in the New Hampshire Department of Environmental Services' Biomonitoring Program Protocols report (2002), the USGS methods for collection and analysis of Aquatic biological and microbiological samples (Britton and Greeson 1989) and Acorn Naturalists' website (2002). Each sampler had three multiplate units. Each unit contained 14 disks made of masonite. The disks were 3" in diameter for a total of 0.13 square meters in area per multiplate unit. The bottom 5 disks were spaced 3/16" apart and the top 9 were spaced 1/8" apart. The three multiplate units were attached to a 30 pound paving stone with eye bolts so that the samplers would stay just above the bottom substrate (Figure 5). One sampler was placed in each plant community at the edge of the emergent vegetation and marked with a buoy. The Hester-Dendy samplers were left out for a month. The first set of samplers were placed in late May and samples were collected twice thereafter in late June and late July. Mesh bags were placed over the multiplate units at collection time so that no organisms could escape when the sampler was brought to the surface. Each unit was then scrubbed with an old toothbrush and all contents were stored in ethanol to later be identified to family and enumerated in the Cornell University aquatic laboratory.

FISH

We used four methods for assessing fish populations in the study wetlands. Two of these methods, minnow traps and fyke nets, were repeated three times for all sites (except North Sandy Pond which was only sampled twice) throughout the summer of 2002. The third method, electrofishing, was performed once in late July 2002. The last method, gill netting, was performed in late June and early July 2002.

Fyke nets

Two size fyke nets (Figure 5) were used in the study waters. The large fyke nets were Alaska-type trap nets with a 0.9 m x 1.8 m opening, two throats in the crib, a 15.2 m leader, and two 6.1 m wings. The small fyke nets had 36" x 18" openings, two throats and five hoop frames, a 50 ft leader, and two 12 ft wings. Fyke nets were set with the opening facing the emergent vegetation. The two wings were set at 45 degree angles to the net opening and the leader was extended into the emergent vegetation to optimize fish community sampling in those areas. The fyke nets were set for a period of 24 hours in water at least 25-75 cm deep for the small nets and at least 75-125 cm deep for the large nets making sure to have the funnels under water. A large fyke net and a small fyke net were set in each wetland, one in each plant community. The placement of the small and large nets in plant communities was swapped with each visit. For instance, if a shrub plant community had a small net in May, it would have a large net in June, and a small net again in July. All captured fish were identified to species, measured in mm and released. Counts of deformities, eroded fins, lesions, and tumors (following the DELT protocol of Sanders et al. 1999) were noted during fish identification.

Minnow traps

Minnow traps (Figure 5) were used to sample fish in areas too shallow for fyke nets. We set minnow traps near the edge of the emergent vegetation for a time period of 24 hours with no bait. They were set in at least a foot of water so that the opening of the minnow trap was under water. One to two minnow traps were set in each plant community for a total of three minnow traps per wetland. Fish handling was accomplished in the same manner as that for fyke nets as stated above.

Electrofishing

Electrofishing was preformed in late July 2002 from a 16ft boat with booms for 15 minutes in each wetland, therefore approximately 7.5 minutes per plant community. A 5,000 Watt generator was used with a Smith Root type VIA transformer unit at 120 pulses per second DC with a voltage of 354 DC. The pulse width varied between 3-5 milliseconds. A circular pattern was followed in water less than 4 m deep around a central buoy. Four depths were taken per area fished. Eight sites were sampled: one each in Blind Sodus Bay and Little Sodus Bay, one in Floodwood, two in South Colwell and three in North Sandy Pond. Two plant communities were sampled in all places except

Blind Sodus Bay and the three North Sandy Pond sites. Fish handling again was accomplished as stated above. All electrofishing data was provided to us by Kristi Arend of the Biocomplexity project at Cornell University.

Gill netting

Gill netting in late June and early July of 2002 was performed with 1”, 2” and 4” mesh nets, all 1.83 m in height. Four bays were sampled: Blind Sodus Bay, Little Sodus Bay, North Sandy Pond, and South Colwell. At Blind Sodus Bay 9.14 m and 32 m net lengths were employed while at Little Sodus Bay and North Sandy Pond, 9.14 m and 22.9 m net lengths were used. At South Colwell, only 9.14 m nets were set. Nets were deployed in 1.6 – 4.6 m of water and were set for approximately two hours. Start time, geographic coordinates, and net parameters were recorded as well as standard fish length and species data as stated above. Counts of deformities, eroded fins, lesions, and tumors were not noted formally during fish identification for this sampling method. Gill nets were set in fairly shallow water near the edges of the bays but not particularly in wetland locations or near emergent vegetation. All gill netting data was provided to us by Kristi Arend of the Biocomplexity project at Cornell University.

WETLAND PLANTS

Emergent wetland plants

Information was collected on both herbaceous and woody vegetation and submerged aquatic vegetation for the bays in which fish and invertebrate sampling occurred. Data on herbaceous and woody vegetation in wetlands was collected from the five study embayments during the summer of 2001. A systematic sampling design was employed using a grid of plots on parallel transects, with random placement of the first transect and of the first plot on each transect. The distance between transects and between plots along transects was determined independently for each embayment, resulting in varying numbers of transects and plots per embayment. At fixed intervals along each transect we sampled herbaceous vegetation in 0.25-m^2 square plots and, when present, woody vegetation in 5-m^2 square plots. In each plot we identified all species and recorded percent cover and stem density. Along the length of each transect we measured the line-intercept of community type as graminoid herbaceous, non-graminoid herbaceous, shrub, tree, or water. From these data, species richness, species relative importance values [(%frequency + %density +%dominance)/3], and the percentages of each community type present on a site were calculated. All emergent wetland plants data was provided to us by Don Leopold and Nicole Hotaling of the Biocomplexity project at SUNY ESF.

Submerged aquatic plants

Submerged aquatic plants were sampled in July of 2002 with the rake-toss method three times per plot. Percent cover was measured using point sampling observations (Madsen et al. 1996; Madsen 1999). Vegetation was identified to the species level and percent composition calculated for each rake toss. The three replicate rake toss values were averaged for each species to gain relative abundance values for the vegetation at each plot. Nine locations were sampled: three in North Sandy, two in Blind Sodus and Little Sodus and one each in Floodwood and South Colwell. This sampling method provides the extent of aquatic vegetation and the assemblage composition by common species. All submerged aquatic vegetation data was provided to us by Robert Johnson of the Biocomplexity project at Cornell University.

WATER LEVELS

Sampling for this pilot project was done on the eastern shores of Lake Ontario therefore daily mean water level data was obtained from the nearby Oswego, New York gauging station on Lake Ontario. Water level data for the Oswego station was downloaded from the National Ocean and Atmospheric Administration (NOAA) website (NOAA 2003). Maximum and minimum monthly means were calculated for 2002, the year of field sampling. Historical data was also retrieved from the Oswego gauging station for 1970 – 2003 and daily average, mean monthly maximum and minimum values were calculated.

PHOSPHORUS AND TOTAL NITRATES

Field water chemistry sampling

Three water quality samples (Figure 5) were collected from each plant community within each wetland. Samples were collected once during each visit in late May, late June and late July. Water samples were collected in whirl paks from the boat while taking care not to disturb the sediment. Samples were stored in a cooler with ice packs and transferred to a freezer when we returned to Cornell University. In August, samples were moved to a freezer at Syracuse University where analysis was completed for total nitrogen and total phosphorus following procedures described in the Quality Assurance Project Plan (QAPP) submitted to the Environmental Protection Agency upon project initiation. When enough volume was present, the samples were also analyzed for ammonium and ortho-phosphate (samples were unfiltered). Unfortunately, the seams on several whirl paks opened due to repeated freezing and thawing thus causing many samples to lose volume and a few samples to be lost entirely. Where possible, samples collected at the same site and plant community on the same date were combined to yield enough volume for at least total nitrogen and total phosphorus analysis.

To supplement this data, additional water quality information was obtained from Charles Driscoll (at Syracuse University) who is collecting and analyzing water samples for the related Biocomplexity study. Nineteen locations in Blind Sodus Bay, North Sandy Pond, South Colwell, Little Sodus Bay, Floodwood and Lake Ontario itself were sampled approximately monthly from April 2001 – April 2002 for the following parameters: pH, Na, K, Ca, Mg, NH4, SiO2, Cl, NO3, SO4, F, DIC, DOC, TN, TP, and ANC. The sampling was accomplished by collecting samples so as not to disturb the sediments or contaminate the samples and bottles. Powder-free gloves were worn when collecting samples for phosphorus analysis. Samples were stored in a cooler with ice packs. This information will be included in the data files but will not be analyzed in this report.

STORET water chemistry data

STORET water chemistry data was obtained from a website operated by the United States Environmental Protection Agency (U.S. EPA 2002c). Over 400 records were obtained from 1964 through 1997 with water chemistry information from watersheds within our study area. Information on the following water chemistry parameters was downloaded: temperature (°C), dissolved oxygen (mg/l), pH lab, total alkalinity (CaCo3), dissolved nitrogen (nh3nh4; mg/l), dissolved nitrogen (no2no3; mg/l), total phosphorus (mg/L), and total hardness (mg/l). The data were classified by watershed and percent exceedence values were calculated for each parameter in each watershed. The criteria cutoffs were determined from the American Fisheries Society publication titled "Aquatic Habitat Assessment: Common Methods" (Bain 1999) and are the following:

Parameter	**Criterion (values inside range = poor quality)**
Temperature	>26 degrees C
Dissolved oxygen	<5 mg/l
pH and pH lab	<6.5 and >8.5
Total alkalinity	<20 mg/l
NH3NH4	>.02 mg/l
NO2NO3	>10 mg/l
Total Phosphorus	>.1 mg/l
Total hardness	<27 and >157 mg/l

SEDIMENT FLOW

Turbidity measurements were taken from each plant community within each wetland during the first and last site visits in late May/early June and late July/early August 2002. For the late May/early June turbidity measurements, a turbidimeter was borrowed and measurements were conducted in the field. For the late July/early August turbidity measurements, the turbidimeter was not available so water samples were collected in whirl paks and turbidity measurements were determined using a turbidimeter in the lab.

SITE ATTRIBUTION

Field site attribution

Field site attribute information forms were filled out while in a boat in the middle of each wetland area. Observations were applied to land immediately adjacent to the wetland. Site attribution features were determined by consensus among the six Great Lakes wetlands sampling project participants. Features identified were: dewatering in or near wetland, point source inlet, installed outlet/weir, ditch inlet, tile inlet, unnatural connection to other waters, presence of barriers (dams or waterfalls), tree removal, tree plantations, mowing or grazing, shrub removal, coarse woody debris removal, removal of emergent vegetation, presence of livestock hooves, presence of vehicle use, presence of grading/bulldozing, presence of filling, presence of dredging, sediment input (from inflow or erosional), areas of land in high public use, proximity to navigable channels, proximity to recreational boating activity, proximity to roadways that receive regular/daily traffic, number of dwellings, number of industries, number of 'other' buildings, number of boat docks, number of paved parking lots, number of dirt parking lots, number of boat launches, % hardened shoreline, % eroding shoreline, % shoreline containing a visible dirt road, % shoreline containing a visible paved road, habitat types adjacent to wetland, land uses adjacent to wetland, construction sites or obvious sedimentation, highway/rail/levees/berms/boardwalks or other such structures built in or around wetland including hydrologic restriction, categorical degree and type of human activity, and general comments.

GIS site attribution

Geographical information systems (GIS) software was used to model the area around the wetlands. Sources, originator, date of data, and source website are located in Table 3. Three types of GIS data were developed: 1) basic data on study area embayments such as area, ecoregion, elevation and location; 2) landscape disturbance data for study area embayments and individual sites; and 3) chemical pollution data for study area embayments. The development processes for each of these types of data are described below.

Development of basic GIS data for study area embayments

Wetland areas were calculated using National Wetlands Inventory data to determine the outline of the watersheds. Bay area was calculated using the total area of the bathymetry GIS data layers created by the Lake Ontario Biocomplexity group. Watershed outlines were determined by drawing the drainage basin for the watershed using digital elevation data. The watershed area was determined by calculating the area within the drainage basin polygon. Percent of wetland in bay was calculated by dividing the wetland area by the bay area. Percent of bay in the watershed was calculated by dividing the bay area by the watershed area. Likewise, percent of wetland in watershed was calculated by dividing the wetland area by watershed area. The length of streams in the watershed was calculated using the stream lengths in the GIS database and the outline of the watershed. All streams that fell within the watershed were tallied. The highest and lowest elevations in the watershed were determined using digital elevation model data. Latitude and longitude were determined from a point at a central location within the bay. Ecoregion was determined using Omernik's ecoregional maps.

Development of GIS landscape disturbance data for study area embayments and individual sites

There are five embayments in the study area. Land uses in the watersheds surrounding each embayment were classified into one of the following categories: water, low intensity residential, high intensity residential, commercial, bare ground, transitional, deciduous forest, evergreen forest, mixed forest, pasture/hay, row crops, urban grasses, woody wetlands, emergent herbaceous wetlands. The area of each type of land use in watershed was tallied from the GIS MRLC data. Total area of the wetland was also determined. Then the percent of area in the following major land use categories was determined by dividing the appropriate land uses by the total area: % agriculture, % forest, % urban, % barren, and % wetland. For instance, pasture/hay and row crops were added together and divided by total area to arrive at % agriculture. Deciduous, evergreen and fixed forest were used for % forest; woody wetland and emergent herbaceous wetlands were used for % wetlands; transitional and bare ground were used for % barren; and low intensity residential, high intensity residential and commercial were used for % urban. The density of roads was determined by selecting all roads within the watershed and summing their lengths. Likewise for density of railroads. Hydrologic soil groups were determined using the STATSGO soils database. All soils within the database are classified into one of four hydrologic soil groups A, B, C, D as follows:

Hydrologic soil group A - Lowest runoff potential. Includes deep sands with very little silt and clay; also deep, rapidly permeable loess.

Hydrologic soil group B - Moderately low runoff potential. Mostly sandy soils less deep than A, and loess less deep or less aggregated than A, but the group as a while has above average infiltration after thorough wetting.

Hydrologic soil group C - Moderately high runoff potential. Comprises shallow soils and soils containing considerable clay and colloids, though less than those of group D. The group has below-average infiltration after saturation.

Hydrologic soil group D - Highest runoff potential. Includes mostly clays of high swelling percent, but the group also includes some shallow soils with nearly impermeable subhorizons near the surface.

The area of each hydrologic soil group was tallied for each watershed. Similarly, a digital land ownership dataset was found and the area and percent of private land was determined as was public land. All methods were repeated using a 500 m buffer around the sixteen plant communities instead of the watershed boundary.

Development of GIS chemical pollution data for study area embayments

EPA BASINS data was used for determination of the number of industrial facilities discharge sites, number of hazardous waste sites, number of sites listed in the toxic release inventory, and the number of permitted wastewater facilities. The number of sites within each watershed were tallied.

RESULTS

INVERTEBRATES

Figure 6 shows that sweep netting yielded greater values for median taxa richness (6 families per sample) than either activity traps (1 family) or Hester-Dendy samplers (1 family). Taxa richness was highest (4 families per sample) in early summer and lowest (2 families) in the following two months (Figure 6). No trends were evident in invertebrate taxa richness between plant communities or bays. The number of individuals captured per sample were highest using sweep netting techniques and in late summer.

Activity traps

All activity trap data when combined yielded a total of 37 families in the following orders: Coleoptera, Collembola, Diptera, Ephemeroptera, Hemiptera, Odonata, and Trichoptera (Figure 7). Diptera had the most individuals (216). Hemiptera and Odonata were also well represented. Collembola was only found once. The file glc-inverts.xls has the full dataset with detailed information on all individuals caught. Most mollusks found in the activity trap samples were zebra mussels.

Sweep netting

Sweep netting sample data yielded a total of 68 families, the most diversity shown by the three methods tested. The following orders were represented: Coleoptera, Collembola, Diptera, Ephemeroptera, Hemiptera, Neuroptera, Odonata, Plecoptera, and Trichoptera (Figure 7). Hemiptera had the highest number of individuals (1218). Diptera, Odonata and Ephemeroptera also had high numbers of individuals. Neuroptera and Plecoptera were represented by only 1 and 3 individuals, respectively. The file glc-inverts.xls has the full dataset with detailed information on all individuals caught.

Hester-Dendy samplers

Hester-Dendy samplers had an overall diversity of 30 families. The following orders were represented: Coleoptera, Collembola, Diptera, Ephemeroptera, Hemiptera, Odonata, and Trichoptera (Figure 7). Diptera was by far the most dominant order with 752 individuals. The rest of the orders all had 86 or fewer individuals. Coleoptera, Collembola and Ephemeroptera all were represented by only a few individuals. The file glc-inverts.xls has the full dataset with detailed information on all individuals caught.

Costs

Table A1 shows the cost of invertebrate data collection three times during the summer of 2002 at 16 coastal wetland sites. The values are for all 16 wetland sites combined since the costs did not differ appreciably by site. In addition to cost, indicators for consumption (consumable/non-consumable) and ownership (previously owned by this project/bought for this project) are listed for each item. Invertebrate sampling gear is relatively inexpensive, however field and laboratory personnel costs can be high as sorting and identification of samples requires considerable time and effort.

Invertebrate collection was done in tandem with fish collection at the coastal wetland sites. Sweep netting in the field took approximately 1.25 hours per site, while activity trap sampling took 1 minute to place and 10 minutes to retrieve. Hester-Dendy samplers (sampled twice in 2002) took approximately 5 minutes to place and 30 minutes to retrieve. Processing of sweep netting samples in the lab took ~45 minutes per sample, Hester-Dendy samples took ~30 minutes, and activity trap samples took the longest amount of time at ~90 minutes per sample, due to their higher sediment content. In terms of personnel requirements in the field, sweep netting required 3 people, activity trap sampling 1 person and Hester-Dendy sampling 2 people. Table A2 presents personnel costs for invertebrate sampling for all methods combined.

Table A2. Field and lab personnel costs for invertebrate sampling using activity traps, sweep nets and Hester-Dendy gear.

Invertebrate sampling labor costs	**Cost**
Field (3 people, 16 sites, 3 samplings)	10,084
Lab (322 samples)	4,901

Measurability

Identification and sorting of invertebrates by taxonomic group requires skilled technicians trained and familiar with aquatic invertebrate identification. Prior experience with aquatic invertebrates will produce more uniform and standardized field collection techniques which will better capture the taxonomic diversity of the communities present in Great Lakes coastal wetlands.

Recommendations on methodology

Due to the frequency of water level changes at the edge of the wetland vegetation and the resulting emergence of Hester-Dendy samplers from the water, this methodology seems likely only to be useful in select areas. Activity trap sampling was very efficient, however, collected samples required increased time for processing and an overall lower taxa diversity. The method producing the highest diversity for a reasonable effort and cost was sweep netting. The biggest drawback with sweep netting, however, is the increased upfront time needed in the field for sample collection. Provision of data sheets, protocol materials and equipment lists will help to standardize the data collection of diverse sampling groups for whatever method is chosen by the Project Management Team.

Table A1. Costs required to conduct invertebrate sampling at 16 coastal wetland sample locations (Y = Consumable, N = Non-consumable; Y = Already owned, N = Bought for this project).

ACTIVITY TRAP GEAR	**Cost**	**Consumable**	**Already owned**
Activity trap soda bottles	7	N	N
PVC pipe	10	N	N
Bricks	15	N	N
Floats	5	N	N
Rope for attaching buoys	15	Y	N
Buoys	5	N	N
Sieves	10	N	Y
HESTER-DENDY GEAR			
Masonite sheeting	78	N	N
Hester-Dendy bolts and screws	22	N	N
Paving tiles	61	N	N
Toothbrushes	8	Y	N
Mesh netting for bags	18	N	N
Nalgene squirt bottles	8	N	N
SWEEP NETTING GEAR			
Dframe sweep nets (3)	305	N	Y
Shallow pans (3)	24	N	Y
GENERAL INVERTEBRATES			
Funnel	2	N	Y
Tweezers (3)	21	N	N
Eye droppers (3)	1	N	Y
Bottles for bug collection	70	N	N
Clicker counters (3)	27	N	Y
Petri dishes	10	N	Y
Scintillation vials (1500)	227	N	N
Wrenches	10	N	N
Invertebrate identification books (2)	150	N	Y
Dissecting microscope (2)	2,940	N	Y
Light sources for scope (2)	100	N	Y
Ethanol	120	Y	N
Total cost of invertebrate sampling	**4,268**		

FISH

Figure 8 is a comparison of median species richness for each of the four fish gear sampling types: fyke nets, minnow traps, electrofishing and gill netting. Median species richness was highest with electrofishing at 5 species per sample, closely followed by fyke nets with a median of 3 species per sample. A total of 68 fish species were identified over the 29 days of sampling independent of method. Analysis of fish from different times periods (also Figure 8) indicates that species richness of fish was slightly higher in the early part of the summer. No trends were evident in fish species richness between plant communities or bays. Deformities, erosions, lesions and tumors were found in 1% of the fish caught in minnow traps and fyke nets.

Fyke nets

Fyke net sampling produced a total richness of 24 species (Figure 9), the highest of all the gear types. The most common fish caught (1061 individuals; 52%) was brown bullhead (*Ameiurus nebulosus*) though it was not at all sites. Bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibbosus*) and largemouth bass (*Micropterus salmoides*) were also prevalent, though five times less likely to be caught in fyke nets. Species where only one individual was caught were: bluntnose minnow (*Pimephales notatus*), comely shiner (*Notropis amoenus*), creek chub (*Semotilus atromaculatus*), golden shiner (*Notemigonus crysoleucas*), northern pike (*Esox lucius*) and white sucker (*Catostomus commersoni*). Fish were largely between 50-180 mm in length (Figure 10). Only a few individuals were larger than 290 mm. The largest, at 700 mm, was a bowfin (*Amia calva*). The file glc-fyke.xls has the full dataset with information on all individuals caught.

Minnow traps

Minnow trap sampling focused on smaller individuals than fyke net sampling and produced a lower total richness of 17 species (Figure 9). The most common fish found in minnow traps was again brown bullhead (467 individuals; 58%). Chain pickerel (*Esox niger*), common carp (*Cyprinus carpio carpio*), and fathead minnow (*Pimephales promelas*) were found in very low numbers. Fish were entirely between 20 and 140 mm with the highest numbers of individuals around 50 mm (Figure 11). The file glc-minnow.xls has the full dataset with information on all individuals caught.

Electrofishing

Electrofishing sampling caught between 7 and 60 fish per site. The most common fish caught were largemouth bass and yellow perch (*Perca flavescens*). The least common fish were central mudminnow (*Umbra limi*), chain pickerel, creek chub and grass pickerel (*Esox americanus vermiculatus*) with two or fewer individuals captured at all sites. No fish species was caught at every site. Median species diversity of all sites was five species with individual sites ranging from three species (Little Sodus Bay shrubs) to ten species (South Colwell bur reeds) and overall diversity at fifteen species (Figure 8). Figure 12 shows the length frequency distribution of the fish caught using electrofishing gear. Fish were primarily between 40 and 230 mm with two large individuals at 680 mm (northern pike and bowfin). The file glc-electro.xls has the full dataset with information on all individuals caught.

Gill netting

The most diverse site in the gill netting data collection was Blind Sodus Bay with a total of 11 species found. North Sandy Pond had the next highest diversity with nine species and Little Sodus Bay was similar with eight species. South Colwell gill netting only yielded two species. Overall fish diversity with gill nets was sixteen species (Figure 8). The most common fish caught and the only fish caught at every site was yellow perch. Northern pike, smallmouth bass (*Micropterus dolomieui*) and white sucker were only caught at Blind Sodus Bay and green sunfish (*Lepomis cyanellus*) and rock bass (*Ambloplites rupestris*) were only found at North Sandy Pond. Fish caught with gill netting gear were primarily between 90-220 mm (Figure 13) with a few large northern pike. The file glc-gillnet02.xls has the full dataset.

Costs

Tables B1 and B2 show the costs of boat maintenance and fish data collection for three sampling events during the summer of 2002 at 16 coastal wetland sites. The values are for all 16 wetland sites combined since the costs did not differ appreciably by site. In addition to cost, indicators for consumption (consumable/non-consumable) and ownership (previously owned by this project/bought for this project) are listed for each item. Fyke netting and electrofishing gear (boat, transformer, etc) account for the highest costs involved in fish sampling. Boat maintenance costs should be included when evaluating the cost of electrofishing and gill netting.

Fish collection was done in tandem with invertebrate collection at all coastal wetland sites. Sampling using fyke nets required 2 people and took approximately 15 minutes to place and another 15 to retrieve. Minnow traps required only 1 person to place and retrieve but generally benefited from having two people to identify the catch. Electrofishing was performed for 15 minutes at each site by three people. In the above methods identification times ran up to 1.5 hours depending on catch size (with larger catch sizes later in the season). Gill net setting required two people and took 1 minute while retrieval and processing took between 5 minutes to 2 hours. The following table (Table B3) presents personnel costs for fish sampling for all methods combined.

Table B3. Personnel costs for fish sampling using fyke nets, minnow traps, electrofishing and gill netting gear.

Fish sampling labor costs	**Cost**
Field (3 people, 16 sites, 3 samplings)	6,080

Measurability

In order to monitor fish community health using electrofishing and gill netting techniques, field monitoring personnel should have some prior knowledge and training in boat use and maintenance. Fyke and gill net sampling personnel should be familiar with the methods for properly checking, processing, repairing, monitoring and storing fyke and gill nets. All fishing techniques require knowledge by personnel in identification of freshwater fish (adult and young-of-the-year) to species, and of the methods employed in properly handling, holding, releasing and measuring morphology of fish.

Recommendation on methodology

Gill net and minnow trap sampling seemed the least feasible methods for fish community health assessment. Gill net sampling did not produce appreciably different abundance measures or species of fish from the other methods and is generally most effective when deployed in deeper water than is found near the emergent vegetation. Minnow trap sampling alone would not be effective at capturing a representative collection of fish as they only capture individuals up to ~130 mm (a size range also covered by fyke nets). The remaining two methods, electrofishing and fyke net sampling, yielded the highest diversity per sample. Electrofishing, however, requires a large upfront cost in the purchase of a suitable boat and may not be feasible at all sites due to accessibility issues for boats. Fyke nets also are expensive but do not require a boat to deploy. We recommend the use of electrofishing when gear is available and the site is accessible and fyke nets when otherwise. Several common species were not captured with any of the above methods. This absence will need to be addressed during indicator sensitivity analysis. Provision of data sheets, protocol materials and equipment lists will help to standardize the data collection of diverse sampling groups when using any of the above methodologies.

Table B1. Costs required to maintain our boat for electrofishing and gill netting (Y = Consumable, N = Non-consumable; Y = Already owned, N = Bought for this project).

BOAT GEAR	**Cost**	**Consumable**	**Already owned**
Fuel fitting	5	N	N
Boat grease	3	Y	N
Boat sponge	1	N	N
Drain plug	4	N	N
Cotter pin	1	N	N
Grease kit	10	N	N
Screwdrivers	5	N	N
Set of wrenches	10	N	N
Spare fuel line	33	N	N
Winch handle (2)	16	N	N
Propeller repair	47	N	N
Boat paddles (2)	30	N	N
Rachet tie down (2)	17	N	N
Boat engine repair	144	N	N
Boat trailer	860	N	Y
Oil for boat engine	5	Y	N
Spark plugs for boat engine	5	Y	N
Anchor	11	N	N
Fire extinguisher	15	N	N
Jerry can	5	N	N
Total cost of boat gear	1,228		

Table B2. Costs required to conduct fish sampling at 16 coastal wetland sample locations (Y = Consumable, N = Non-consumable; Y = Already owned, N = Bought for this project).

FYKE NETTING GEAR	**Cost**	**Consumable**	**Already owned**
Cable ties	9	Y	N
Fyke nets - 3 small	1,654	N	N
Fyke nets - 3 large	2,200	N	Y
3/4" PVC (8 per fyke net)	48	N	N
Buoys	5	N	N
Rope for attaching buoys	17	Y	N
MINNOW TRAP GEAR			
Minnow traps	24	N	Y
Buoys	5	N	N
Rope for attaching buoys	17	Y	N
Bricks	15	N	N
ELECTROFISHING GEAR			
16' flat bottomed boat outfitted for electrofishing	25,000	N	Y
Gas for outboard motor	40	Y	N
Insulated rubber gloves (3)	120	N	Y
Dip net with long pole	90	N	Y
Fuses for transformer	10	Y	N
GILL NETTING GEAR			
100m net (4)	800	N	Y
Buoys	5	N	N
Rope for attaching buoys	17	Y	N
GENERAL FISH			
Ethanol	25	Y	N
NYS fish ID books	60	N	N
Buckets for holding fish	10	N	Y
Fish measuring boards	10	N	Y
Small dip nets (3)	5	N	Y
Baking soda for putting out fish	2	Y	Y
Containers for keeping caught fish	15	N	Y
Total cost of fish sampling	30,202		

WETLAND PLANTS

Herbaceous and woody vegetation

Figures 13 and 14 show the distribution of plant community types and species richness at each site. Floodwood had the highest percentage of herbaceous vegetation with little tree-, shrub-, or graminoid-dominated area. Alternatively, Blind Sodus Bay was mainly dominated by tree and shrub communities and had the smallest proportion of herbaceous vegetation of the five sites. South Colwell had the highest proportion of graminoid community and the least open water, while Little Sodus Bay had no graminoid plants at all. Species richness per square meter was highest in Little Sodus Bay (8.04 spp/m^2) and Blind Sodus Bay (7.37 spp/m^2) and lowest at Floodwood (2.67 spp/m^2).

No broad-leaved emergent plants were found at every site though 34 species were sampled. Two narrow-leaved emergent plants, giant bur reed (*Sparganium eurycarpum*) and hybrid cattail (*Typha x glauca*), out of four were found at all sites sampled. Likewise, European frog's bit (*Hydrocharis morsus-ranae*), was one of three free-floating plants found at every site. No graminoids (11 species), shrubs (8) or mosses (2) were ubiquitous. The file glc-wetplants.xls has an additional table which lists all species encountered and indicates their presence by site.

Submerged aquatic plants

Diversity by plot location for the nine sampled sites is shown in Figure 16. Diversity was highest at South Colwell (21 species) and lowest at Floodwood (8 species). The most abundant plant species at South Colwell, Floodwood, Blind Sodus Bay plot 10 and Little Sodus Bay plot B was common hornwort (*Ceratophyllum demersum*). Fragrant water lily (*Nymphaea odorata*) was abundant at the other two plots in Blind Sodus Bay and Little Sodus Bay (plot 9 and A respectively). Each of the three plots in North Sandy Pond had different abundant species: Common waterweed (*Elodea Canadensis*) at plot 1, tape grass (*Vallisneria Americana*) at plot 2, and common bladderwort (*Utricularia vulgaris*) at plot 3. See file glc-sav.xls for figures and detailed information on the composition at each of these sites.

Costs

Table C1 shows the costs of wetland plant data collection during the summer of 2001 (for emergent plants) and 2002 (for submerged plants) at Lake Ontario coastal wetland sites. The values are for all 16 wetland sites combined since the costs did not differ appreciably by site. In addition to cost, indicators for consumption (consumable/non-consumable) and ownership (previously owned by this project/bought for this project) are listed for each item.

Table C1. Costs required to conduct wetland plant sampling at coastal wetland sites (Y = Consumable, N = Non-consumable; Y = Already owned, N = Bought for this project).

EMERGENT PLANT SAMPLING	Cost	Consumable	Already owned
Plant bags and tags	15	Y	N
Plant press and blotters	90	N	N
SUBMERGENT PLANT SAMPLING			
Rake (2)	20	N	N
Plant bags and tags	15	Y	N
Total cost of wetland plant sampling	140		

Wetland plant sampling was done separately from fish and invertebrate sampling. Sampling for emergent wetland plants at 139 sites required two graduate students and three temporary field assistants and took approximately three months of effort in 2001. Submerged aquatic plant sampling took approximately two days and two to three field assistants to sample and identify the plants at nine sites. The following table (Table B3) presents personnel costs for wetland plant sampling.

Table C2. Personnel costs for submerged and emergent wetland plant sampling.

Plant sampling labor costs	Cost
Emergent field (2 grad stud+3 temp, 139 survey points)	10,080
Submerged field (3 people, 9 sites)	480

Measurability

Skills in identification of submerged and emergent plants to species are required to accurately sample wetland plants. Knowledge of the procedures for specimen collection and preservation and sampling with transects and quadrats is also necessary to ensure that wetland plant communities in coastal wetlands are sampled using a standardized procedure. Further, it would be helpful if sampling personnel had experience in transect sampling through the use of air photo interpretation and mapping.

Recommendations on methodology

The sampling procedure used to assess emergent plant communities in coastal wetlands, unlike submerged communities, was expensive but both provided valuable information for a reasonable cost. Our recommendation for applying this indicator into a comprehensive coastal wetland monitoring scheme is to develop a mechanism that ensures standardization of these sampling techniques. Provision of data sheets, protocol materials and equipment lists will help to standardize the data collection of diverse sampling groups.

WATER LEVELS

Water level data from Lake Ontario's gauging station at Oswego, New York are displayed in Figure 17. This figure indicates that water levels for the year 2002 were highest in June and July and that Lake Ontario reached its highest daily mean value for the year (75.342 m) on June 17th of 2002. Fluctuation between minimum and maximum monthly means in 2002 was highest in August and lowest in June. Historically, the mean monthly maximums were highest from May through July and lowest in January. Water levels for 2002 followed the long-term cyclical pattern, but from June through August, water levels were above the long-term average. Therefore, water levels during the field sampling season were up to 20 cm higher than the long-term average. More detailed 2002 and historical data are presented in the file glc-waterlevels.xls.

Costs

Table D1 indicates the personnel costs in downloading and manipulating data on Lake Ontario water levels. No other costs were incurred in the processing of water level gauge data.

Table D1. Personnel costs for water level data manipulation.

Water levels labor costs	**Cost**
Lab (1 person, 2 hours)	40

Measurability

No special requirements beyond general data manipulation skills are necessary to assess water levels in coastal wetlands.

Recommendations on methodology

When possible, long-term historical data should be obtained to gain a perspective on extremism of current water levels with respect to long-term averages.

PHOSPHORUS AND TOTAL NITRATES

Field water chemistry sampling

Analysis of the water chemistry samples from the wetland sites (Figure 18) shows that Little Sodus Bay shrubs and North Sandy Pond North cattails dominated wetlands had the highest values for total nitrogen (287 and 220 umol/L respectively). Correspondingly high total phosphorus levels were found in the same locations, North Sandy Pond North cattails (588 ug/L) and Little Sodus Bay shrubs (206 ug/L). Both high measurements for total nitrogen and total phosphorus at North Sandy Pond North cattails were taken on the same day, August 19th, 2002. The high total nitrogen measurement in Little Sodus Bay shrubs was taken on July 29th, 2002, a day with low total phosphorus (19 ug/L) and a high total phosphorus measurement was taken on June 25th, 2002, a day with relatively low total nitrogen (79 umol/L). Both locations, according to collected and GIS-derived site attribute information, have extensive landscape alteration and from 8-25% agriculturally dominated land use within 500 m of the wetland which may account for the high levels of total nitrogen and phosphorus in the wetlands. The remaining wetlands have consistent and reasonable values for total nitrogen and phosphorus. Data on temperature can be found in the file glc-wq.xls.

Information obtained from the Biocomplexity group on water chemistry was not analyzed as most sites are not within wetlands. It is merely included as additional information if useful. The information is presented in the file glc-biocomwq.xls.

STORET water chemistry data

Comparison information from the EPA's STORET database is presented in Table 5. No information was available for the Blind Sodus Bay watershed. Data range in dates from 1971-1985 for the North Sandy Pond watershed, 1964-1997 for the Floodwood watershed, 1965-1984 for the Little Sodus Bay watershed and just 1984 for the South Colwell watershed. Most of the records of information were from the Floodwood watershed (419 records) with the remaining spread between Little Sodus Bay (41 records), North Sandy Pond (5 records), and South Colwell (1 record). Only two parameters, pH lab and temperature, were tested in the South Colwell watershed. Temperature was within the normal limits but the pH value was outside the acceptable range. In the five records at the North Sandy Pond watershed pH, pH lab, total alkalinity, NH3NH4, total phosphorus and total hardness were tested. Only the NH3NH4 value was outside the acceptable range when tested. All parameters were tested at the Floodwood watershed and all parameters except NO2NO3 had values which fell outside the acceptable ranges to some degree. Temperature values fell outside the range 4% of the time, DO 22%, pH 41%, pH lab 3%, total alkalinity 24%, NH3NH4 33%, total phosphorus 25%, and total hardness 67% of the time. All parameters except pH lab and NO2NO3 were tested at the Little Sodus Bay watershed. Of those, only values from DO (43%), pH (28%) and NH3NH4 (100%) fell outside the acceptable ranges. More detailed information on the individual water samples is presented in the file glc-wqstoret.xls.

Costs

Table E1 provides a breakdown of the cost of water chemistry data collection for three data collection events during the summer of 2002 at 16 coastal wetland sites. No additional costs were incurred for STORET data analysis. The values are for all 16 wetland sites combined since the costs did not differ appreciably by site. In addition to cost, indicators for consumption (consumable/non-consumable) and ownership (previously owned by this project/bought for this project) are listed for each item. Laboratory analysis accounts for the bulk of the cost so surveyors with access to low-cost or free laboratory facilities will find their water chemistry costs appreciably lower.

Table E1. Costs required to conduct water chemistry sampling at 16 coastal wetland sites (Y = Consumable, N = Non-consumable; Y = Already owned, N = Bought for this project).

WATER CHEMISTRY SAMPLING:	**Cost**	**Consumable**	**Already owned**
Cooler	8	N	Y
Ice packs	10	N	Y
Gloves	15	Y	N
Whirlpaks	4	Y	Y
Thermometer (2)	20	N	Y
Kimwipes	65	Y	Y
Paper towels	5	Y	Y
Goggles	13	N	Y
Calibration rack	66	N	Y
Sampling tubes	42	N	Y
Test-tube racks	98	N	Y
Nalgene bottles	20	N	Y
Standards (nutrients)	189	Y	Y
Phosver 3	52	Y	Y
Nitraver 3	67	Y	Y
Nitraver 5	59	Y	Y
Volumetric Flasks	37	N	Y
Graduated Cylinders	158	N	Y
Filters	63	Y	Y
Beakers	22	N	Y
Pipettes	231	N	Y
Pipette tips	103	Y	Y
Total cost of water chemistry sampling	1,346		

Water chemistry sampling was performed in tandem with fish and invertebrate sampling and took approximately 2 minutes per site to perform in the field. STORET data analysis took approximately one day of effort for one person. The following table (Table E2) presents the personnel costs for two methods of water chemistry data collection.

Table E2. Personnel costs for water chemistry field sampling and STORET data manipulation.

Water chemistry labor costs	**Cost**
Field (3 people, 16 sites, 3 samplings)	1,165
Laboratory analysis (100 samples)	2,000
GIS (1 person, 1 day)	160

Measurability

STORET data analysis requires some familiarity with data manipulation techniques. Water chemistry field sampling requires proper training and experience for complete and representative collections. Results from a highly qualified professional laboratory are only as good and representative as the field collection procedures employed. Field staff should have prior training in proper physical and chemical parameter collection procedures, and instrumentation and calibration of field equipment. To ensure that QC/QA objectives are met, personnel measuring nutrient parameters must be familiar with and have the means to complete standard curves, analyze blanks and duplicates, and be able to determine repeatability of sample results. Thus, samples should either be processed in an appropriate water chemistry laboratory by professional staff, or trained project personnel must be able to conduct QC/QA activities under improvised laboratory conditions.

Recommendations on methodology

Water chemistry data collection using the STORET database would be ideal if data were available over widespread areas, for a recent time period, and within wetlands. This was not the case for this pilot study and data is likely to be sparse and unavailable in other Great Lakes regions as well. I recommend, however, that surveyors evaluate STORET data availability for their region prior to undertaking water chemistry field sampling as use of such data may lower costs appreciably. If field sampling is necessary, samples should all be collected within a 24 to 48 hour period to minimize temporal variation in results. Provision of data sheets, protocol materials and equipment lists will help to standardize the data collection of diverse sampling groups.

SEDIMENT FLOW

Sediment flow in the wetlands was determined by evaluating turbidity at all the sites in late May/early June and in late July/early August. Figure 19 indicates that in all but one site (Floodwood graminoids), turbidity was higher in August than in June. This may have been a result of the fact that the late May/early June samples were taken in the field and the late July/early August samples were evaluated in the lab. More information on turbidity is available in the file glc-sediment.xls.

Costs

Table F1 details the cost of sediment flow data collection for two events during the summer of 2002 at 16 coastal wetland sites. Values are for all 16 wetland sites combined since the costs did not differ appreciably by site. In addition to cost, indicators for consumption (consumable/non-consumable) and ownership (previously owned by this project/bought for this project) are listed for each item. The turbidimeter represents the bulk of the cost so surveyors with access to a low-cost or free turbidimeter will find their sediment flow costs appreciably lower.

Table F1. Costs required to conduct sediment flow sampling at 16 coastal wetland sites (Y = Consumable, N = Non-consumable; Y = Already owned, N = Bought for this project).

SEDIMENT FLOW SAMPLING:	**Cost**	**Consumable**	**Already owned**
Whirlpaks	4	Y	Y
Turbidimeter	695	N	Y
Total cost of sediment flow sampling	699		

Sediment flow sampling was performed in tandem with fish and invertebrate sampling and took approximately 2 minutes per site to perform in the field. The following table (Table F2) presents personnel costs for sediment flow data collection.

Table F2. Personnel costs for sediment flow data collection.

Sediment flow labor costs	**Cost**
Field (3 people, 16 sites, 2 samplings)	580

Measurability

Sediment flow field sampling requires proper training and experience for complete and representative collections. Field staff should have prior training in proper sediment flow data collection procedures, and instrumentation and calibration of the field equipment.

Recommendations on methodology

The methodology employed for this indicator is time efficient, low in cost and effective at sediment flow assessment in Great Lakes coastal wetlands. Standardization of field sampling techniques, however, is important for this indicator. Provision of data sheets, protocol materials and equipment lists will help to standardize the data collection of diverse sampling groups..

SITE ATTRIBUTION

Field site attribution

Field site attribution was done for five categories: hydrologic alteration, landscape alteration - vegetation removal/disturbances, landscape alteration - substrate/soil disturbances, estimated values of human impact, and descriptive information (Table 6). Only three sites (South Colwell, Floodwood and North Sandy Pond-Renshaw) had any evidence of hydrologic alteration. The forms of hydrologic alteration evident at these sites were point source inlets, ditch inlets, and unnatural connection to other waters. There was some evidence of landscape alteration – vegetation removal/disturbance at all sites except Floodwood. All sites also had some evidence of landscape alteration – substrate/soil disturbance but North Sandy Pond South, North Sandy Pond-Renshaw and Little Sodus Bay showed the greatest degree of alteration. Estimated values describe how close human habitation is to the wetland sites. Little Sodus Bay and North Sandy Pond-North had higher ratings than less developed locations like Floodwood and South Colwell. Descriptive information reveals the types of land uses and degree of construction in the area. Again the results revealed that Floodwood and South Colwell were less developed than other places sampled. An easy to view table showing all of these results can be viewed in file glc-siteattributes.xls.

GIS site attribution

Site attribution using geographic information systems (GIS) was done for all wetlands by gathering information on basic data such as area, ecoregion, elevation and location; landscape disturbance; and chemical pollution (Table 7). Basic data analysis on area revealed that while North Sandy Pond has the largest bay and the most wetlands associated with that bay, Floodwood has the largest watershed although the least area in wetlands. Floodwood also has the most streams and Little Sodus Bay the least. Landscape disturbance analysis for the watershed of each embayment indicated that Little Sodus Bay has the most urban watershed (8%) of the embayments and North Sandy Pond has the highest percentage of forested area (68%). All watersheds had some degree of agricultural land ranging from 18% at South Colwell to 37% in Blind Sodus Bay. The watershed for Blind Sodus Bay is entirely under private ownership while all but 15% of South Colwell's watershed is public land.

Landscape disturbance was also evaluated for a 500 m buffer around each wetland sampling location. All buffered watersheds had over 32% forested area with some (Blind Sodus Bay east and west) with as much as 70%. No site had more than 12% urban area. All sites had some agricultural area ranging between 5% (Blind Sodus Bay west) and 25% (Little Sodus Bay). Most land in the 500 m buffer was under private ownership with only the study sites at South Colwell (70-92%) and Floodwood (100%) under public ownership.

Analysis of chemical pollution data indicated that the North Sandy Bay embayment had the most industrial facilities discharge sites and the highest number of permitted wastewater facilities. This is in comparison with watersheds like South Colwell which has no waste, discharge or toxic release sites in its watershed at all. More information on all of these GIS site attributes can be found in a table in the file called glc-siteattributes.xls.

Costs

Table G1 details the cost of site attribution data collection for one event during the summer of 2002 at 16 coastal wetland sites. Costs for site attribution in the field were low as data collection was done in tandem with fish and invertebrate testing and materials were limited to paper, writing implements and binoculars. GIS analysis required access to a server running high level GIS software. The cost of this access is $10/hour.

Table G1. Costs required to conduct sediment flow sampling at 16 coastal wetland sites (Y = Consumable, N = Non-consumable; Y = Already owned, N = Bought for this project).

SITE ATTRIBUTION SAMPLING:	Cost	Consumable	Already owned
Rite-in-the-rain paper	10	Y	N
China markers	6	Y	N
Binoculars	300	N	Y
Air photos	0 (from web)	N	N
Total cost of site attribution sampling	316		
SITE ATTRIBUTION GIS ANALYSIS:	**Cost**	**Consumable**	**Already owned**
Network access ($10/hr for 3 days)	240	Y	N
Total cost of site attribution GIS analysis	240		

Site attribution data collection in the field was performed in tandem with fish and invertebrate sampling and took approximately 20 minutes per site to perform. GIS data analysis took approximately three days of effort for one person. The following table (Table G2) presents personnel costs for the two methods of site attribution data collection.

Table G2. Personnel costs for site attribution data collection in the field and using GIS.

Landscape measures labor costs	Cost
Field (3 people, 16 sites, 1 sampling)	580
GIS (1 person, 3 days)	480

Measurability

Personnel should be able to identify and distinguish between all hydrologic and landscape alterations surrounding wetland sites, and should have some understanding of various anthropogenic processes (i.e., dredging, filling, deforestation, sedimentation, point source pollution, etc.). Considerable spatial analytical skills are required for personnel employing GIS techniques, in particular the ability to manipulate geographically referenced data and digitized spatial datasets.

Recommendations on methodology

The objective is to collect precise and accurate surrounding disturbance information, therefore efforts must be made to observe all land surrounding a wetland either on foot or from spatially referenced digital data. Most site attributes can be easily measured in the field, however quantification of surrounding land cover and point sources can be subjective, time consuming or completely infeasible. Site attribution using GIS techniques provides a standardized methodology for assessing wetland disturbance and can be performed from largely available data. We highly recommend that this method be used for any future wetland monitoring in place of or in addition to subjective field recordings from selected focal points within the wetlands.

Miscellaneous costs

Several costs were not accounted for in the above indicators since they were used across indicators (i.e. pens, camera, etc) or were necessary but unused (i.e. first aid supplies, etc). These costs are enumerated below in Table H1.

Table H2 displays a breakdown of personnel costs not associated with an individual wetland indicator but for tasks required as part of this project.

Table H2. Personnel costs for tasks not belonging to any particular wetland indicator.

Travel costs (car rental + gas)	3,630
Data review	2,330
Administration	1,864
Report writing	4,660

Table H1. Costs of general equipment used for multiple indicators or for items necessary but rarely used.

GENERAL EQUIPMENT	Cost	Consumable	Already owned
PFDs (4)	174	N	Y
Waders (3)	150	N	N
Depth stick	40	N	Y
Tape measure - 50 m	42	N	Y
Tool box	20	N	Y
Sandbags for truck	15	N	N
NYS gazetteer	20	N	Y
Camera	200	N	Y
Camera film	16	Y	N
Slide developing	3	Y	N
Extra batteries for camera	16	Y	N
Rite-in-the-rain paper	10	Y	N
Clipboards	5	N	Y
Field paperwork organizers	5	N	N
Flagging	2	Y	Y
Stickers for labeling bottles of samples	5	Y	Y
Tape	2	Y	N
Scissors	2	N	Y
Rope	56	N	N
China markers	6	Y	N
Spare keys	31	N	N
CDs	15	Y	N
GPS unit	120	N	Y
GPS batteries	16	Y	N
VHF radio	143	N	Y
Batteries for field equipment	21	Y	N
Red cross certification	180	N	N
Sunblock	20	Y	N
Bandaids	3	Y	N
Asprin	6	Y	N
Antiseptic solution	7	Y	N
Canoe	870	N	Y
Canoe paddles (2)	30	N	N
Phone line	303	Y	N
Data line	422	Y	N
Photocopying	42	Y	N
Total cost of general supplies	3,017		

DISCUSSION

Comparison of the methods used in invertebrate sampling shows that sweep netting was far greater in family richness both per sample and with all data for each gear type combined. Sweep netting requires a greater time commitment in the field but substantially less time in the lab. Activity trap samples were often muddy and sediment rich, requiring 2-3 times as long to pick and identify as sweep netting samples. Further activity trap richness was generally only one family per sample, much lower than the median of five families found in each sweep net sample. Hester-Dendy samplers required little labor both out in the field and in the lab, however the quality of their use as an indicator method is questionable. Many of the samples had no invertebrates and the fluctuation of water levels in the wetlands rendered some of the samplers emergent when checked one month after placement. Several hypotheses were suggested for the cases in which the samplers were under water but with no invertebrates present. The first is that the masonite disks expanded in the water thereby blocking access to much of the available surface for colonization. Another hypothesis is that the invertebrates would more likely colonize on aquatic plants if available than the samplers. This latter hypothesis is further supported by the fact that similarly built Hester-Dendy samplers used by the Biocomplexity project and placed in the center of the bays away from vegetation were rich in numbers of individuals when checked one month after placement. Therefore, overall sweep netting seems most reliable, time efficient and effective.

Comparison of the methods used in fish sampling shows that electrofishing yielded higher median species richness than minnow traps, fyke nets and gill netting. These results were adjusted for effort by taking each sample collection as a unit. However, the minnow trap sets corresponded directly with the fyke net sets as they were placed in the same locations and for the same time period. Since the range of sizes of fish captured in fyke nets overlapped with those caught in minnow traps and the species of fish caught in minnow traps were also caught in fyke nets, it may be possible to eliminate minnow trap sampling from the protocol. Both electrofishing and gill netting yielded fish species that were not found in fyke net sampling. Blackchin shiner was found during electrofishing and alewife, gizzard shad and longnose gar were captured with gill netting. This may somewhat be explained by the fact that gill netting was done somewhat further from the emergent edge of the wetlands and may have captured some wandering pelagic fish species, namely alewife and gizzard shad. Electrofishing may not be a suitable substitute for fyke netting due to the cost for a specialized electrofishing boat, transportation and labor (three people needed as opposed to two in fyke netting). The gain in electrofishing and gill netting over fyke netting is the fact that the sites only need to be visited once instead of twice as is necessary for a 24 hour fyke net set. Temporal analysis indicates that early and mid summer may yield the best results in terms of diversity which corresponds nicely with the time period for higher diversity from invertebrate sampling. A further temporal analysis may be worthwhile if only one visit is scheduled per wetland to maximize the quality of the fish and invertebrate information collected.

Information on wetland plants (submerged and emergent), sediment flow, and water levels was only done using one method therefore no comparison analysis about method efficiency can be performed. The emergent wetland plant survey was a lengthy and expensive task however it yielded much useful information, as did the submerged aquatic vegetation analysis. Less extensive emergent vegetation sampling may be considered for future sampling. Sediment flow analysis was easy and quick and was done while already at the site. There seems to be no drawback to performing the sediment flow analysis. A time comparison between June and August sampling showed that the August samples were almost always higher which may be accounted for by the difference in taking measurements in the field verses in the lab. Further temporal and lab verses field gear analysis may be worthwhile to test the importance of timing when scheduling sediment flow data collection. Water level information is quick to obtain and low in cost to assess.

Water samples for total phosphorus and nitrogen sampling were easy to collect but took some time to have analyzed as working equipment and trained laboratory technicians with available time were limiting. The STORET data is much less time consuming and labor intensive, however, the national database is somewhat deficient, often only having a small handful of entries for a particular region and perhaps none in a particular watershed or wetland (as in Blind Sodus Bay). For this project, we looked at sites which were found in the watershed of the bay encompassing the wetland. This designation may be too broad to actually give an accurate understanding of the water quality of a particular wetland of concern. Therefore, though easier and cheaper to use and with widespread data throughout the United States side of the Great Lakes basin, the STORET database may not be applicable as an indicator method.

Site attribution both in the field and with GIS were easy to perform. Data collected at the site provided pertinent information related to human impacts. Data derived using GIS focused more on land use patterns surrounding the wetland and upper watershed. With minimal effort, much information can be collected through both methods and can be used together effectively to give a better understanding of the quality of the wetland.

In conclusion, we found that sweep netting for invertebrates and electrofishing (if equipment and people are available; fyke net sampling if otherwise) for fish were the methods to yield the most taxa rich samples per site. Temporally, invertebrate taxa richness and fish species richness were greatest in early to mid summer. Emergent wetland plant assessments, unlike submerged assessments, were costly and involved significant time commitment, however, both provided valuable information. Sediment flow and water level data were easy to collect but questionable in quality. Water chemistry information was also easy to collect in the field but required technical laboratory knowledge to accomplish water chemistry analysis. STORET data, by comparison, is low in time and labor but may not cover the needed regions. Site attribution using both field and GIS analysis were effective and low in cost and effort. The resulting data sets will be further analyzed in consort with data from other Great Lakes wetland sites to determine the degree to which these techniques can be used to make comparisons of indicator tests and to develop a basinwide monitoring plan.

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Table 1. Fish, invertebrate, sediment, water quality, site attribute, sample sites in Lake Ontario wetlands (2002).

Location	Bay	Wetland	Site	Plant Community type
Lake Ontario West	Blind Sodus	BSW	BSWS	Shrubs
Lake Ontario West	Blind Sodus	BSW	BSWC	Cattails
Lake Ontario West	Blind Sodus	BSE	BSES	Shrubs
Lake Ontario West	Blind Sodus	BSE	BSEC	Cattails
Lake Ontario West	Little Sodus	LS	LSS	Shrubs
Lake Ontario West	Little Sodus	LS	LSC	Cattails
Lake Ontario East	North Sandy	NSR	NSRBL	Bulrushes
Lake Ontario East	North Sandy	NSR	NSRBR	Bur reed
Lake Ontario East	North Sandy	NSN	NSNG	Grasses
Lake Ontario East	North Sandy	NSN	NSNC	Cattails
Lake Ontario East	North Sandy	NSS	NSSLS	Purple loosestrife
Lake Ontario East	North Sandy	NSS	NSSC	Cattails
Lake Ontario East	Floodwood	FL	FLC	Cattails
Lake Ontario East	Floodwood	FL	FLG	Grasses
Lake Ontario East	South Colwell	SC	SCBR	Bur reed
Lake Ontario East	South Colwell	SC	SCC	Cattails

TABLE 2. Details of methods used in wetland indicator analysis.

INDICATOR	METHOD	NUMBER & LOCATION	SEASONAL TIMING	FREQUENCY	NOTES
Invert-ebrates	Activity traps	1-2 activity traps per plant zone for a total of 3 traps per wetland; placement at edge of emergent vegetation.	3 visits in June, July and August 2002	2 consecutive days with 24 hour intervals between checks	Soda bottle style activity traps. No bait. Horizontal placement in mid water column. Samples stored in ethanol and identified to family in the lab.
Invert-ebrates	Sweep nets	Generally 3 sweeps per plant zone; sweeps done in flooded vegetation at the bottom, mid and surface of the water column.	3 visits in June, July and August 2002	Once per visit	Standard 0.5mm mesh, D-frame dip nets. Samples processed in field with gridded white enamel pans. Replicates picked for 1/2 person-hour, after which, if 150 specimens have not been obtained, picking continues to the next multiple of 50 (Burton et al. 1999). Samples ID to family in lab.
Invert-ebrates	Hester-Dendy samplers	One sampler per plant zone in each wetland; placement at edge of emergent vegetation.	Placement in late May; reset in late June and removed late July 2002	4 week intervals	Three multi-plate units per Hester-Dendy sampler. Samples stored in ethanol and identified to family in the lab.
Fish	Minnow traps	1-2 minnow traps per plant zone for a total of 3 traps per wetland; placement at edge of emergent vegetation.	3 visits in June, July and August 2002	2 consecutive days with 24 hour intervals between checks	No bait. Fish identified to species, measured in mm & released; counts of deformities, eroded fins, lesions, and tumors recorded (DELT protocol) followed during fish identification.
Fish	Fyke nets	One fyke net per plant zone, alternating big and small net with each visit. Nets placed with long axes perpendicular to dominant leading edges of vegetation, with the leads going into emergent zones.	3 visits in June, July and August 2002	2 consecutive days with 24 hour intervals between checks	Big nets are Alaskan-style nets with .9x18m openings, 2 throats in crib, detachable 15.2 leader, and 2 6.2m wings. Small nets are 36" x 18" in height, with 2 steel square throat frames and 5 hoop frames, 1/4" nylon mesh dyed green, 24lb. Lead and wings are 18" high, 24" between square frames and after last hoop, 18" between hoops, funnels on the 1st and 3rd hoop. Fish ID to species, measured in mm & released; DELT recorded.
Fish	Electrofishing	Circular pattern followed around a central buoy in each wetland for 15 minutes. In wetlands with two distinct plant communities, each plant community was fished for 7.5 minutes.	Late July 2002	Once per summer	Fish identified to species, measured in mm & released; counts of deformities, eroded fins, lesions, and tumors recorded (DELT protocol) followed during fish identification.
Fish	Gill netting	One set of nets were set for at least two hours in the deepest water possible without setting in an anoxic zone. All nets were 1.83 m deep and when stretched were 1", 2" and 4" in mesh size.	Summer 2002	Approximately 2 hours between checks	Total time of employment was noted as was time set and net length used. At Blind Sodus 9.14 m and 32 m net lengths were employed, Little Sodus and North Sandy, 9.14 m and 22.9 m net lengths were used, South Colwell only 9.14 m nets were set. Nets were deployed in 1.6 – 4.6 m of water. Fish identified to species, measured in mm & released; counts of deformities, eroded fins, lesions, and tumors recorded (DELT protocol) followed during fish identification.

TABLE 2 cont. Details of methods used in wetland indicator analysis.

INDICATOR	METHOD	NUMBER & LOCATION	SEASONAL TIMING	FREQUENCY	NOTES
Plants	Herbaceous and woody vegetation	Wetland community composition determined by estimating cover of plant species and counting number of stems along systematically placed transects extending from upland to aquatic plants.	Summer 2001	Once per site per summer	Stem density and percent cover of each vascular plant species were recorded for plots (0.25m^2 herbaceous, 5m^2 woody) systematically placed along transects and the line-intercept of community types (graminoid herbaceous, non-graminoid herbaceous, shrub, tree, water) along each transect. From these data species richness and calculated species relative importance values [(%frequency + %density +%dominance)/3] and the percentages of each community type present on a site were calculated.
Plants	Submerged aquatic plants	Rake-toss method. 3x/plot.	Mid July 2002	Once per site per summer	Aquatic plants were sampled with grabs for identification and percent cover measured using point sampling observations. Sampling provides the extent of aquatic vegetation and the assemblage composition by common species. Community metrics such as percent dominant vegetation types, percent invasive types, percent native taxa, can be esimated etc;
Water levels	Stream discharge surveys	Discharge measured with Marsh-McBirney (wadable) or orange toss (unwadable) methods.	All year	Once per month	Measurements and predictions of stream volumes for all inflows.
Phos-phorus & total nitrates	Water quality samples	Water samples collected, 3 collections per plant community.	3 visits in June, July and August 2002	Once per visit	Analyzed for total nitrogen and total phosphorus; also included data from 2001 biocomplexity water chemistry collections and samples
Phos-phorus & total nitrates	Storet data	GIS data from EPA STORET site	Study period - late May through late August 2002	Once	Data will be obtained for the period of the study for all waters in and near the wetland study sites.
Sedi-ment flow	Turbidity	Turbidimeter used at sites where water and wetland come together under calm/mixed conditions	Twice in late May and late July 2002	2 times per summer	Turbidity taken in conjunction with water quality sampling. Late May samples were done with turbidimeter in the field; late July samples were done with turbidimeter in the lab.
Land-scape meas-ures	GIS analysis	GIS data from MRLC landuse, roads, railroads, hydrologic soil groups, land ownership, national wetlands inventory, bathymetry, industrial facilities discharge sites, toxic release inventory, hazardous waste sites, permitted wastewater facilities, ecoregions, hydrology, and elevation.	Once	Once	Basic GIS (area and % of wetland, bay, and watershed; length of streams; latitude/longitude; elevations; ecoregion). Landscape GIS attributes (area and % of each landuse; density of roads and railroads; area of each hydrologic soil group; land ownership). Chemical GIS attributes (# of industrial facilities discharge sites, # of hazardous waste sites, # of sites listed in the toxic release inventory, and the # of permitted wastewater facilities). Done for 500m buffer around each wetland and entire watershed.
Land-scape meas-ures	Field based inspections based on habitat	Site attribute protocol agreed upon by group	Late May 2002	Once per summer	Features identified were in the following categories: hydrologic alteration, landscape Alteration - vegetation removal/disturbances, landscape Alteration - substrate/soil disturbances, estimated values of human impact, and descriptive information.

TABLE 3. Sources of GIS site attribute information

DATA SET	ORIGINATOR	DATE	WEBSITE
MRLC Land use	EPA	1992	http://www.epa.gov/mrlc/
Roads	TIGER line files	1995	http://cugir.mannlib.cornell.edu/search_sim/search_sim.html
Railroads	TIGER line files	1995	http://cugir.mannlib.cornell.edu/search_sim/search_sim.html
Hydrologic soil groups	NRCS STATSGO	1994	http://www.essc.psu.edu/soil_info/index.cgi?soil_data&statsgo
Land ownership	USGS Gap Analysis	2001	http://www.gap.uidaho.edu/
National wetlands inventory	USFWS	1998	http://wetlands.fws.gov/
Bathymetry	Lake Ontario Biocomplexity	2001	http://ontario.cfe.cornell.edu/
Industrial facilities discharge sites	EPA BASINS 3	1998	http://www.epa.gov/ostwater/BASINS/
Toxic release inventory	EPA BASINS 3	1998	http://www.epa.gov/ostwater/BASINS/
Hazardous waste sites	EPA BASINS 3	1998	http://www.epa.gov/ostwater/BASINS/
Permitted wastewater facilities	EPA BASINS 3	1998	http://www.epa.gov/ostwater/BASINS/
Ecoregions - Omernik	EPA BASINS 3	1998	http://www.epa.gov/ostwater/BASINS/
Hydrology - RF3	EPA BASINS 3	1998	http://www.epa.gov/ostwater/BASINS/
Elevation	EPA BASINS 3	1998	http://www.epa.gov/ostwater/BASINS/

TABLE 4. Overview of time commitment and costs for methods used in wetland indicator analysis.

INDICATOR	METHOD	TIME COMMITMENT	LABOR COMMITMENT	EQUIP-MENT COST	PERSON NEL COST
Invertebrates	Activity traps	1 minute in placement; 10 minutes in retreival; ~90 minutes to ID each sample	1 person to place & retrieve; 1 person to identify	$67 + $2,738 general costs	Field $10,084 + lab $4,901
Invertebrates	Sweep nets	1 1/4 hours to sweep and pick 3 samples; ~45 minutes to ID each sample	3 people to sweep and pick; 1 person to identify	$194 + $2,738 general costs	Field $10,084 + lab $4,901
Invertebrates	Hester-Dendy samplers	5 minutes in placement; 30 minutes in retrieval; ~30 minutes to ID each sample	2 people to place and retrieve; 1 person to ID	$329 + $2,738 general costs	Field $10,084 + lab $4,901
Fish	Minnow traps	1 minute in placement; 15 min - 1.5 hours in retrieval & processing	2 people	$61 + $127 general costs	$6,080
Fish	Fyke nets	15 minutes in placement; 15 min - 1.5 hours in retrieval & processing	2 people	$590 + $127 general costs	$6,080
Fish	Electrofishing	15 minutes per wetland (7.5 minutes per plant community)	3 people	$25260 + boat maintenance $1,228 + $127 general costs	$6,080
Fish	Gill netting	1 minute to set net; 5 minutes to two hours in retrieval and processing	2 people	$822 + boat maintenance $1,228 + $127 general costs	$6,080
Plants	Herbaceous and woody vegetation	3 months for all sites	2 grad students and 3 technicians for 1 summer	$105	$10,080
Plants	Submerged aquatic plants	2 days for all sites	2-3 people	$35	$460
Water levels	Gauging station data collection	2 hours for all data	1 person	$0	$40
Phosphorus & total nitrates	Water quality sampling	5 minutes to collect water; 2 days In lab	1 person	$37	Field $1,165 + lab $2,000
Phosphorus & total nitrates	Storet data	1 day to analyze and sort data	1 person	$0	$160
Sediment flow	Turbidity	5 minutes per site	1 person	$699	$580
Landscape measures	GIS analysis	3 days for all data	1 person	$240	$480
Landscape measures	Field based inspections based on habitat	20 minutes per site	1 person	$10	$580

TABLE 5. Percent exceedence for nine parameters from EPA's STORET water chemistry database for the five watersheds in the Lake Ontario study area.

Watershed	Total number of individual sites	Number of records of data	Number temp records	% temp exceedence	Number DO records	% DO exceedence	Number pH records	% pH exceedence	Number pH lab records	% pH lab exceedence
Criteria				**> 26 C**		**<5 mg/l**		**<6.5 and >8.5**		**<6.5 and >8.5**
SC	1	1	1	0.00	0	0.00	0	0.00	1	1.00
NS	4	5	0	0.00	0	0.00	1	0.00	4	0.00
FL	15	419	219	0.04	254	0.22	357	0.41	146	0.03
LS	4	41	20	0.00	23	0.43	29	0.28	0	0.00
BS	0	0	0	0.00	0	0.00	0	0.00	0	0.00

Watershed	Number T ALK records	% T ALK exceedence	Number NH3NH4 records	% NH3NH4 exceedence	Number NO2NO3 records	% NO2NO3 exceedence	Number Tphos records	% Tphos exceedence	Number Tot Hardness records	% Tot Hard exceedence
Criteria		**<20 mg/l**		**>.02 mg/l**		**>10 mg/l**		**>.1 mg/l**		**<27 and >157 mg/l**
SC	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
NS	1	0.00	1	1.00	0	0.00	1	0.00	1	0.00
FL	83	0.24	70	0.33	48	0.00	89	0.25	126	0.67
LS	7	0.00	13	1.00	0	0.00	1	0.00	1	0.00
BS	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

Table 6. Site attribute information collected while at wetland sites (2002). ***E indicates that the feature exists, NE indicates that the feature does not exist.***

Hydrologic Alteration							
Site ID	Dewatering in or near wetland	Point source inlet	Installed outlet, weir	Ditch inlet	Tile inlet	Unnatural connection to other waters	Presence of barriers (dams, waterfalls)
BSE	NE	NE	NE	NE	NE	NE	NE
BSW	NE	NE	NE	NE	NE	NE	NE
FL	NE	E	NE	E	NE	E	NE
LS	NE	NE	NE	NE	NE	NE	NE
NSN	NE	NE	NE	NE	NE	NE	NE
NSR	NE	NE	NE	E	NE	E	NE
NSS	NE	NE	NE	NE	NE	NE	NE
SC	NE	NE	NE	NE	NE	E	NE

Landscape Alteration - vegetation removal/disturbances						
Site ID	Tree removal	Tree plantations	Mowing or grazing	Shrub removal	Coarse woody debris removal	Removal of emergent vegetation
BSE	E	E	E	E	E	E
BSW	E	E	E	E	E	E
FL	NE	NE	NE	NE	NE	NE
LS	E	E	E	E	E	E
NSN	E	NE	E	E	E	E
NSR	E	NE	E	E	NE	E
NSS	E	E	E	E	E	E
SC	NE	NE	E	NE	NE	NE

Landscape Alteration - substrate/soil disturbances							
Site ID	Presence of livestock hooves	Presence of vehicle use	Presence of grading/bulldozing	Presence of filling	Presence of dredging	Sediment input (from inflow or erosional)	Areas of land in high public use
BSE	NE	E	NE	NE	NE	E	E
BSW	NE	E	NE	NE	NE	E	E
FL	NE	NE	NE	NE	E	E	E
LS	NE	E	NE	E	NE	E	E
NSN	NE	NE	E	NE	NE	NE	E
NSR	NE	E	E	E	E	NE	NE
NSS	NE	E	NE	NE	E	E	E
SC	NE	E	NE	NE	NE	E	E

Estimated values										
Site ID	navigable channels (est distance in	recreational boating activity (est	roadways that receive regular	# of dwellings	# of industries	# of 'other' buildings	# of boat docks	# of paved parking lots	# of dirt parking lots	# of boat launches
BSE	5	1000	500	9	0	1	7	0	0	0
BSW	5	5	100	4	0	0	1	0	1	0
FL	5	100	1000	0	0	0	0	0	0	0
LS	5	500	5	4	0	1	4	0	1	0
NSN	5	5	200	50	0	0	0	0	50	0
NSR	5	5	50	6	0	0	4	0	2	1
NSS	5	100	25	26	0	2 (garages)	50	0	10	3
SC	5	100	2500	0	0	0	0	0	1	1

Table 6 cont. Site attribute information collected while at wetland sites (2002).

	Estimated values				Descriptive information
Site ID	% hardened shoreline	% eroding shoreline	containing a visible dirt road	containing a visible paved road	Habitat types adjacent to wetland (est %, groundtruthing)
BSE	10	10	0	0	Forest (90%), graminoids (10%)
BSW	5	2	0	5	Forest (60%), lawn (10%), shrubs (30%)
FL	0	0	0	0	Cattails (93%), graminoids (7%)
LS	20	5	10	10	Forest (70%), graminoids (20%), shrubs (10%)
NSN	10	10	5	0	Graminoids with mixed purple loosestrife and cattails (70%), cattails (30%)
NSR	30	0	35	0	Deciduous forest (75%), water (15%), shrubs (10%)
NSS	10	5	10	40	Purple loosestrife (15%), cattails (55%), lawn (20%)
SC	0	0	0	0	Cattails (80%), rushes (20%)

	Descriptive information	Descriptive information
Site ID	Landuse classes adjacent to wetland (est %, groundtruthing)	Construction sites or obvious sedimentation
BSE	Forest (90%), residential (10%)	A little bit of sedimentation, but no construction sites, channel may have been dredged
BSW	Residential (15%), forest (80%), shrubs (5%)	Looks like it has been dredged, but homeowner says that it has not - they are applying for a permit to dredge though; sedimentation from tributary
FL	Grass (90%), forest (10%)	Some dredging evident
LS	Forest (65%), residential (25%), roads/urban (10%)	Piece of rusted construction equipment partially submerged next to shore.
NSN	Mobile home park (residential) 10%, tress and shrubs (90%)	Construction going on near wetland in mobile home park
NSR	Residential (35%), forest (65%)	Dredged channel immediately adjacent to site.
NSS	Residential (30%), forest (70%)	Sedimentation coming from tributary, construction on rt. 3 bridge causing some sedimentation
SC	Forest (20%) and shrubs (80%)	Sedimentation possible from tributary inlet

	Descriptive information
Site ID	Highway, rail, levees, berms, boardwalks or other such structures built in or around wetland including whether or not the structure appears to restrict hydrological connection
BSE	
BSW	Road doesn't restrict wetland function
FL	No structures
LS	Road (paved) next to wetland, does seem to restrict connection and has a pipe underneath. Road seems to be artificially raised.
NSN	None visible
NSR	Berm along western edge separating wetland from navigable dredged channel; does not restrict hydrological connection
NSS	Rt 3 bridge crosses over tributary - does not constrict hydrologic function. Boardwalk down inner part of tributary near bridge, does not constrict hydrological connection.
SC	None

	Descriptive information
Site ID	Categorical degree and type of direct human activity
BSE	Boating and residential both probable
BSW	Residential areas nearby, boat activity low
FL	No visible human activity
LS	Fairly frequent recreational boating, residential zones along shore
NSN	Construction near mobile home park, possible sewage from park, etc.
NSR	Boating activity in dredged channel, and residential areas neighbouring.
NSS	Dwellings, marina store with boat launch, lots of boat docks and summer home type places
SC	Boat launch activity

Table 6 cont. Site attribute information collected while at wetland sites (2002).

	Descriptive information
Site ID	Comments
BSE	Wetland is up a small channel; sites deeper into wetlands; residential locations at mouth of channel; some erosion but trees on banks; lots of wildlife (birds, mammals, amphibians present).
BSW	Houses with mowed lawns at deep end of wetland; channel continues up to tributary which has not been dredged according to landowner; lots of dead fish just outside wetland (6/14/02-after storm)
FL	No human habitation for miles; however, there is a fair bit of recreational boating activity - most times we see someone fishing, jet skiing or sea kayaking
LS	Abandoned house on island within wetland; tributary comes into wetland through culvert
NSN	Landscape alteration due to mobile home park on edge of wetland
NSR	Alder trees may alter nitrogen content
NSS	Local says water temperature is colder this year in North Sandy bay itself; tributary inlet
SC	Pipe in cove; car submerged in cove (possible contaminants?); dead fish in cove (6/3/02); alder trees may alter nitrogen content

Table 7. Site attribute information determined from GIS.

BASIC DATA

EMBAYMENT	ECOREGION	AREA OF WETLANDS ASSOCIATED WITH BAY (km2)	BAY AREA (km2)	WATERSHED AREA (km2)
Blind sodus	Erie/Ontario Lake Hills & Plain	0.18	0.95	34.46
Floodwood	Erie/Ontario Lake Hills & Plain and Northeastern Highlands	0.10	0.10	629.68
Little sodus	Erie/Ontario Lake Hills & Plain	0.91	2.98	11
North sandy	Erie/Ontario Lake Hills & Plain and Northeastern Highlands	1.70	9.27	234.97
South colwell	Erie/Ontario Lake Hills & Plain	0.46	0.46	1.72

EMBAYMENT	PERCENT OF WETLAND IN BAY	PERCENT OF BAY IN WATERSHED	PERCENT OF WETLAND IN WATERSHED	LENGTH OF STREAMS IN WATERSHED (m)
Blind sodus	0.19	0.03	0.01	30.49
Floodwood	1.00	0.00	0.00	778.6
Little sodus	0.30	0.27	0.08	0
North sandy	0.18	0.04	0.01	292.09
South colwell	1.00	0.27	0.27	0

EMBAYMENT	ELEVATION HIGH (m)	ELEVATION LOW (m)	LATITUDE (geographic, nad27)	LONGITUDE (geographic, nad27)
Blind sodus	137	75	43.3366	-76.7289
Floodwood	535	75	43.7231	-76.2
Little sodus	126	75	43.3302	-76.7083
North sandy	435	75	43.6556	-76.1807
South colwell	110	76	43.6982	-76.1942

LANDSCAPE DISTURBANCE: GIS site attributes for the watershed of each bay

EMBAYMENT	WATER (km2)	LOW INTENSITY RESIDENTIAL (km2)	HIGH INTENSITY R	COMMERCIAL (km2)
Blind sodus	1.01	0.01	0	0.01
Floodwood	2.43	1.77	0.4	2.52
Little sodus	2.72	0.78	0.03	0.11
North sandy	10.36	1	0.25	1.22
South colwell	0.42	0	0	0

EMBAYMENT	BARE GROUND (km2)	TRANSITIONAL (km2)	DECIDUOUS FOREST (km2)	EVERGREEN FOREST (km2)
Blind sodus	0	0	16.7	0.16
Floodwood	0.15	0.02	272.12	29.25
Little sodus	0	0	3.76	0.07
North sandy	0.43	0.04	109.67	11.92
South colwell	0	0	0.1	0.74

EMBAYMENT	MIXED FOREST (km2)	PASTURE/HAY (km2)	ROW CROPS (km2)	URBAN GRASSES (km2)	WOODY WETLANDS (km2)
Blind sodus	2.55	9.06	3.61	0.02	1.3
Floodwood	75.25	185.74	42.96	0.82	15.34
Little sodus	1.32	1.34	0.54	0.31	0.01
North sandy	38.47	50.23	6.68	0.56	3.49
South colwell	0.05	0.27	0.04	0	0.01

Table 7 cont. Site attribute information determined from GIS.

EMBAYMENT	EMERGENT HERBACEOUS WETLANDS (km2)	TOTAL AREA (km2)	% URBAN	% FOREST
Blind sodus	0.03	34.46	0.00	0.56
Floodwood	0.91	629.68	0.01	0.60
Little sodus	0	11	0.08	0.47
North sandy	0.67	234.97	0.01	0.68
South colwell	0.08	1.72	0.00	0.52

EMBAYMENT	% AGRICULTURAL	% BARREN	% WETLAND	RAILS (km)	ROADS (km)
Blind sodus	0.37	0.00	0.04	5.53	64.56
Floodwood	0.36	0.00	0.03	14.63	758.73
Little sodus	0.17	0.00	0.00	0.00	40.95
North sandy	0.24	0.00	0.02	18.17	343.96
South colwell	0.18	0.00	0.05	0.00	2.91

EMBAYMENT	HSG A (km2)	HSG B (km2)	HSG C (km2)	HSG D (km2)	PUBLIC (km2)	PRIVATE (km2)	% PUBLIC	% PRIVATE
Blind sodus	0.00	0.00	36.13	0.00	0.00	35.30	0.00	1.00
Floodwood	48.26	218.41	325.42	65.88	90.96	566.36	0.14	0.86
Little sodus	0.00	0.00	11.53	0.00	0.32	8.46	0.04	0.96
North sandy	24.01	33.51	33.51	0.00	26.77	199.65	0.12	0.88
South colwell	40.01	0.00	2.66	0.00	2.36	0.40	0.85	0.15

LANDSCAPE DISTURBANCE: GIS site attributes for the 500m buffer surrounding each sampling location

SITE	WATER (m2)	LOW INTENSITY RESIDENTIAL (m2)	HIGH INTENSITY RESIDENTIAL (m2)	COMMERCIAL (m2)
NSRBL	336	1	0	0
NSRBR	388	1	0	0
NSNG	373	24	0	22
NSNC	384	12	0	22
NSSLS	129	54	2	29
NSSC	126	56	2	28
SCBR	240	1	0	0
SCC	208	0	0	0
FLC	98	3	0	0
FLG	126	1	0	0
BSEC	17	1	0	1
BSES	17	1	0	1
BSWC	101	0	0	0
BSWS	157	0	1	0
LSC	77	75	0	11
LSS	197	81	0	12

SITE	BARE GROUND (m2)	TRANSITIONAL (m2)	DECIDUOUS FOREST (m2)	EVERGREEN FOREST (m2)
NSRBL	36	0	267	0
NSRBR	40	0	248	0
NSNG	0	0	162	1
NSNC	0	0	188	0
NSSLS	0	0	309	1
NSSC	0	0	277	0
SCBR	86	0	318	3
SCC	0	0	336	0
FLC	56	0	340	0
FLG	111	0	300	0
BSEC	0	0	476	0
BSES	0	0	469	0
BSWC	0	0	485	0
BSWS	0	0	463	3
LSC	0	0	276	3
LSS	0	0	188	3

SITE	MIXED FOREST (m2)	PASTURE/HAY (m2)	ROW CROPS (m2)	URBAN GRASSES (m2)	WOODY WETLANDS (m2)
NSRBL	45	45	4	0	85
NSRBR	30	23	4	0	85
NSNG	107	56	22	29	17
NSNC	104	48	17	23	13
NSSLS	38	32	39	63	3
NSSC	43	33	36	91	3
SCBR	46	86	19	0	20
SCC	42	145	43	0	8
FLC	22	1	102	0	15
FLG	22	0	70	0	15
BSEC	128	189	7	0	0
BSES	135	188	8	0	0
BSWC	105	61	14	0	53
BSWS	115	34	8	0	38
LSC	169	199	3	6	0
LSS	129	200	3	6	0

Table 7 cont. Site attribute information determined from GIS.

SITE	EMERGENT HERBACEOUS WETLANDS (m2)	TOTAL AREA (m2)	% URBAN	% FOREST
NSRBL	0	819	0.00	0.38
NSRBR	0	819	0.00	0.34
NSNG	6	819	0.06	0.33
NSNC	8	819	0.04	0.36
NSSLS	120	819	0.10	0.42
NSSC	124	819	0.11	0.39
SCBR	0	819	0.00	0.45
SCC	37	819	0.00	0.46
FLC	182	819	0.00	0.44
FLG	174	819	0.00	0.39
BSEC	0	819	0.00	0.74
BSES	0	819	0.00	0.74
BSWC	0	819	0.00	0.72
BSWS	0	819	0.00	0.71
LSC	0	819	0.11	0.55
LSS	0	819	0.11	0.39

SITE	% AGRICULTURAL	% BARREN	% WETLAND	RAILS (km)	ROADS (km)
NSRBL	0.06	0.04	0.10	0	2.48
NSRBR	0.03	0.05	0.10	0	3.99
NSNG	0.10	0.00	0.03	0	3.22
NSNC	0.08	0.00	0.03	0	3.22
NSSLS	0.09	0.00	0.15	0	5.32
NSSC	0.08	0.00	0.16	0	5.32
SCBR	0.13	0.11	0.02	0	1.14
SCC	0.23	0.00	0.05	0	0.80
FLC	0.13	0.07	0.24	0	0.26
FLG	0.09	0.14	0.23	0	0.00
BSEC	0.24	0.00	0.00	0	3.04
BSES	0.24	0.00	0.00	0	2.94
BSWC	0.09	0.00	0.06	0	1.63
BSWS	0.05	0.00	0.05	0	1.60
LSC	0.25	0.00	0.00	0	4.22
LSS	0.25	0.00	0.00	0	3.84

SITE	HSG A (km2)	HSG B (km2)	HSG C (km2)	HSG D (km2)	PUBLIC (km2)	PRIVATE (m2)	% PUBLIC	% PRIVATE
NSRBL	0.00	0.00	0.64	0.00	0.00	0.42	0.00	1.00
NSRBR	0.00	0.00	0.56	0.00	0.00	0.36	0.00	1.00
NSNG	0.08	0.00	0.61	0.00	0.00	0.46	0.00	1.00
NSNC	0.10	0.00	0.57	0.00	0.00	0.46	0.00	1.00
NSSLS	0.75	0.00	0.00	0.00	0.00	0.66	0.00	1.00
NSSC	0.76	0.00	0.00	0.00	0.00	0.67	0.00	1.00
SCBR	0.00	0.00	0.78	0.00	0.47	0.20	0.70	0.30
SCC	0.00	0.00	0.78	0.00	0.72	0.06	0.92	0.08
FLC	0.00	0.00	0.78	0.00	0.71	0.00	1.00	0.00
FLG	0.00	0.00	0.76	0.00	0.58	0.00	1.00	0.00
BSEC	0.00	0.00	0.78	0.00	0.00	0.76	0.00	1.00
BSES	0.00	0.00	0.78	0.00	0.00	0.76	0.00	1.00
BSWC	0.00	0.00	0.78	0.00	0.00	0.64	0.00	1.00
BSWS	0.00	0.00	0.78	0.00	0.00	0.56	0.00	1.00
LSC	0.00	0.00	0.78	0.00	0.00	0.72	0.00	1.00
LSS	0.00	0.00	0.78	0.00	0.00	0.66	0.00	1.00

CHEMICAL POLLUTION				
EMBAYMENT	NUMBER OF INDUSTRIAL FACILITIES DISCHARGE SITES	NUMBER OF SITES LISTED IN THE TOXIC RELEASE INVENTORY	NUMBER OF HAZARDOUS WASTE SITES	NUMBER OF PERMITTED WASTEWATER FACILITIES
Blind sodus	1	0	0	1
Floodwood	5	1	0	2
Little sodus	5	0	0	3
North sandy	7	0	0	4
South colwell	0	0	0	0

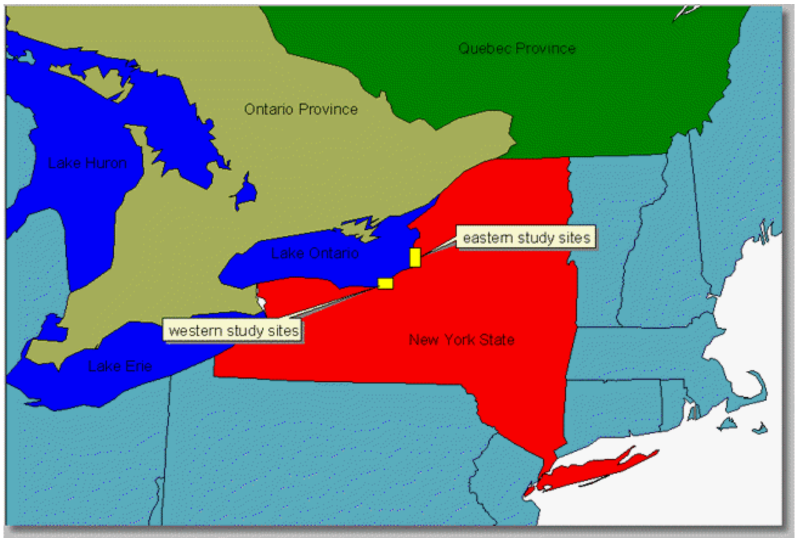


Figure 1. General study site locations on NY shore of Lake Ontario. Source: Biocomplexity website (2002).

Figure 2. Western fish, invertebrate, water quality, sediment and site attribute Lake Ontario study sites (2002).

Figure 3. Eastern fish, invertebrate, water quality, sediment and site attribute Lake Ontario study sites (2002).

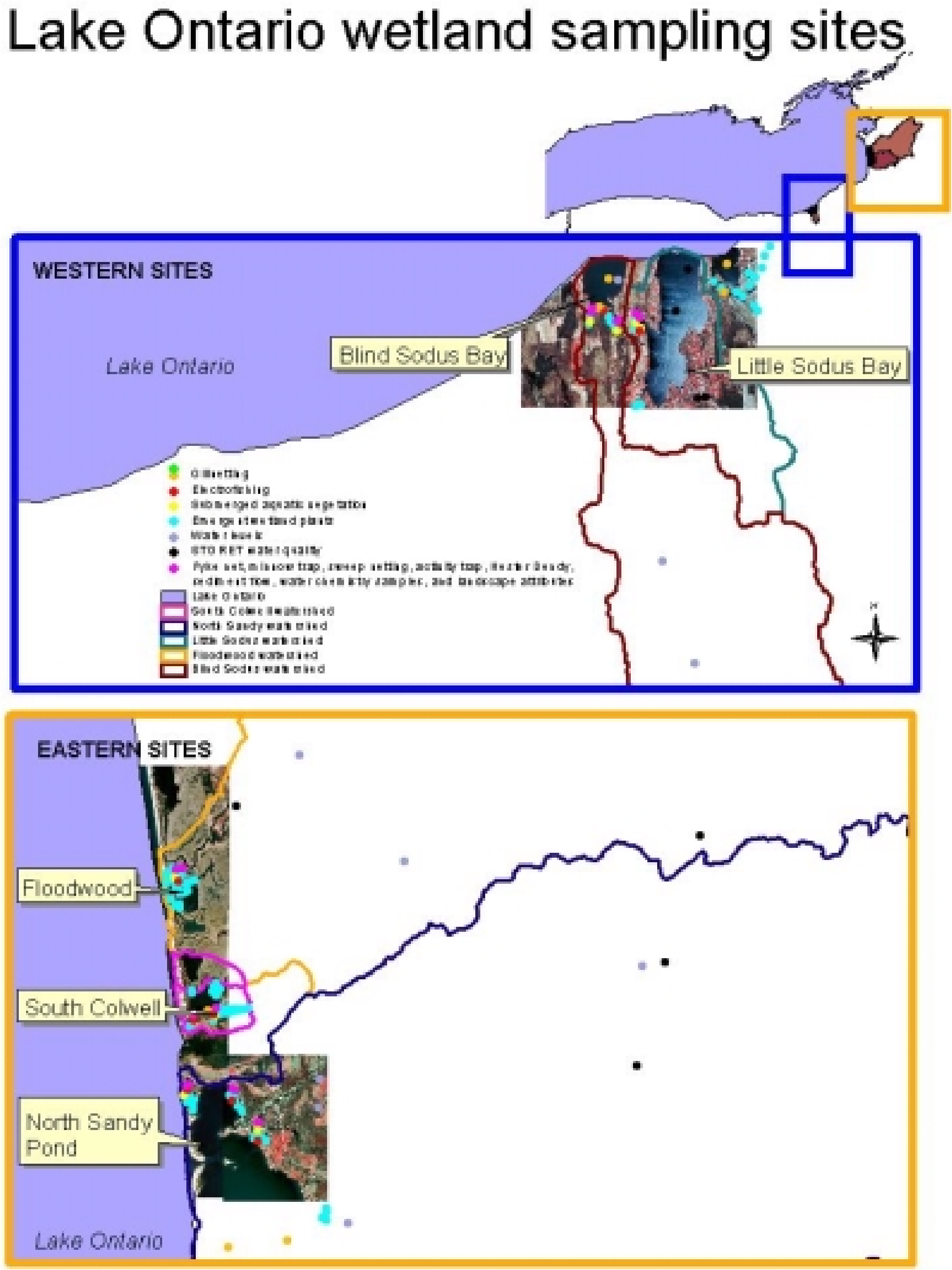
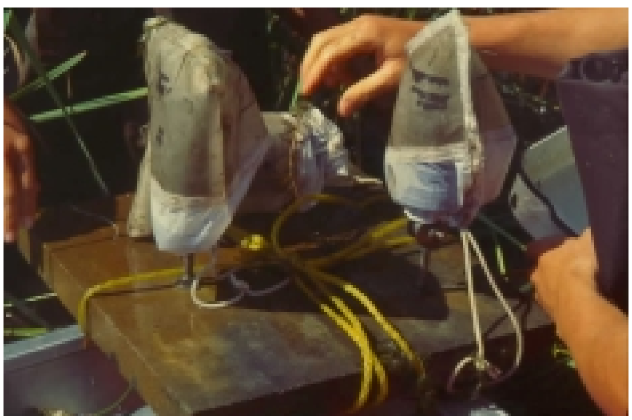


Figure 4. Sampling locations in and around wetlands in eastern Lake Ontario (2001 and 2002).

Fyke net

Minnow trap

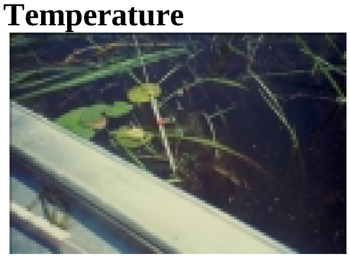


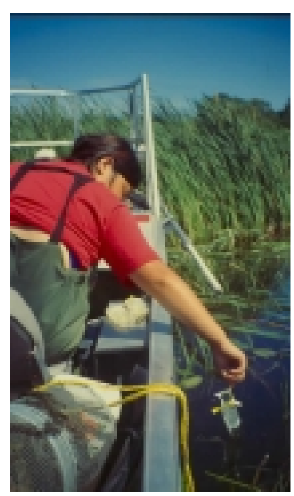
Hester-Dendy samplers

Sweep netting

Activity trap

Temperature





Water chemistry sampling

Figure 5. Selected fish, invertebrate and water chemistry sampling techniques in the field.

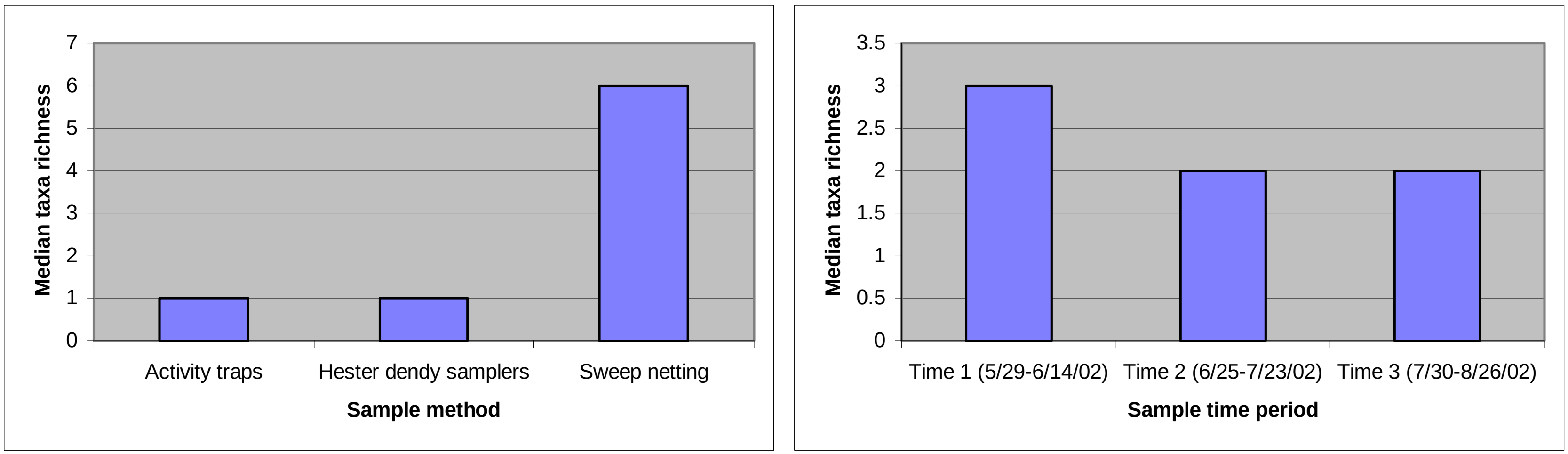
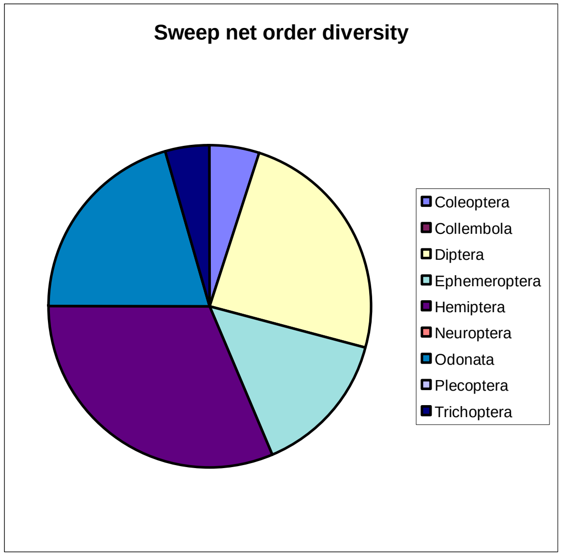
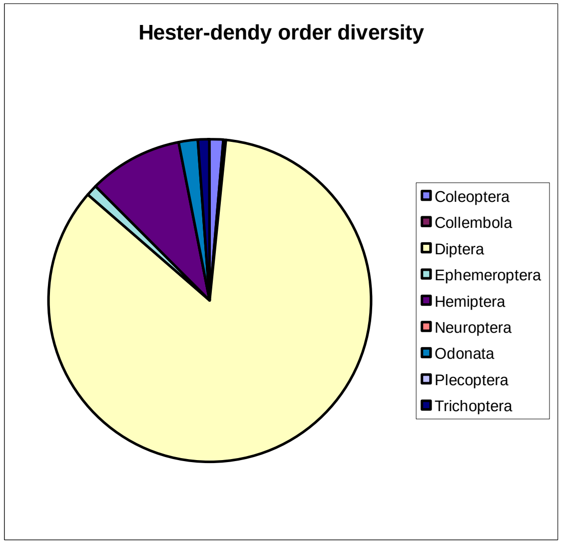


Figure 6. Median species richness per sample of aquatic invertebrates by gear type and by time period (2002).





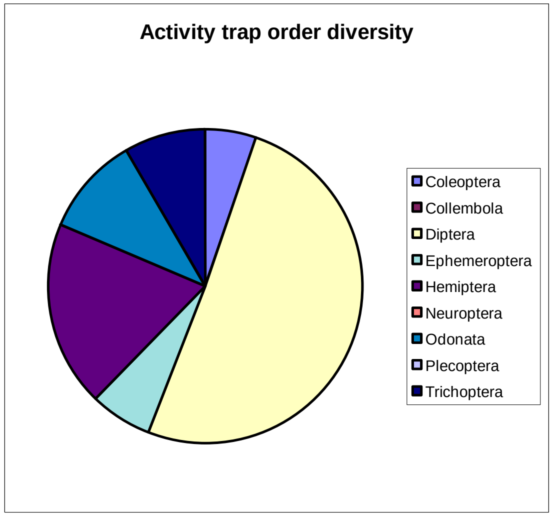


Figure 7. Invertebrate diversity by gear type (2002).

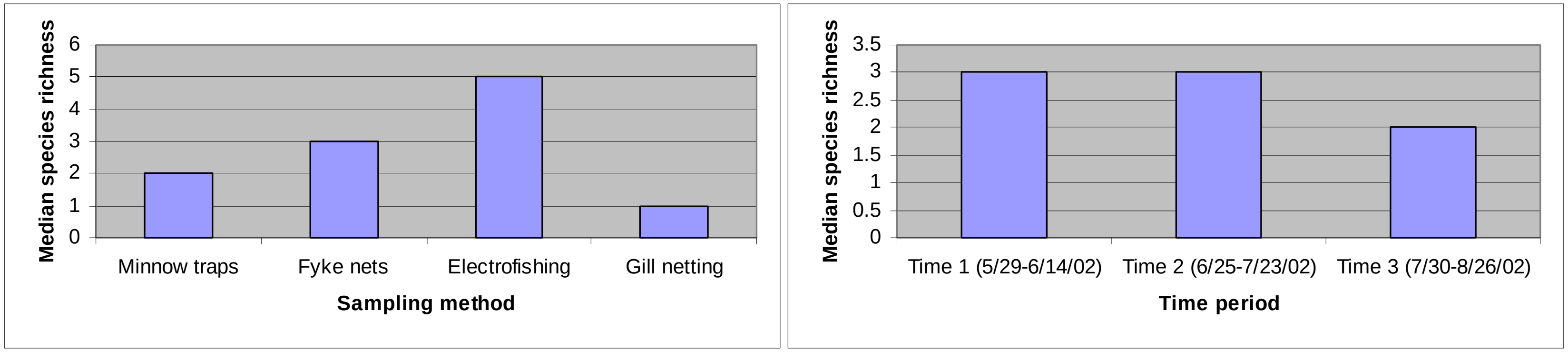


Figure 8. Median species richness per sample of fish by gear type and by time period (2002).

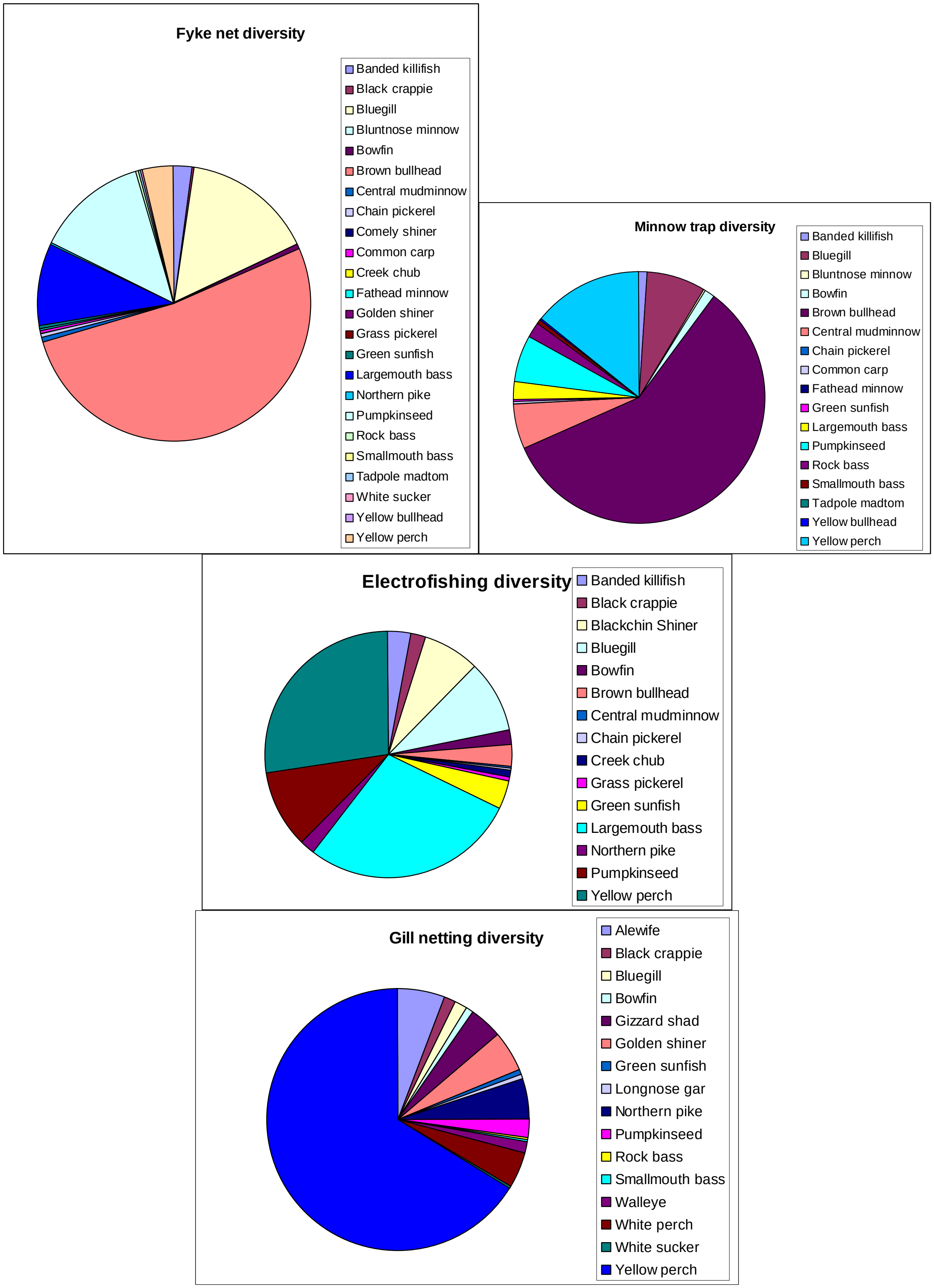


Figure 9. Fish diversity by gear type (2002).

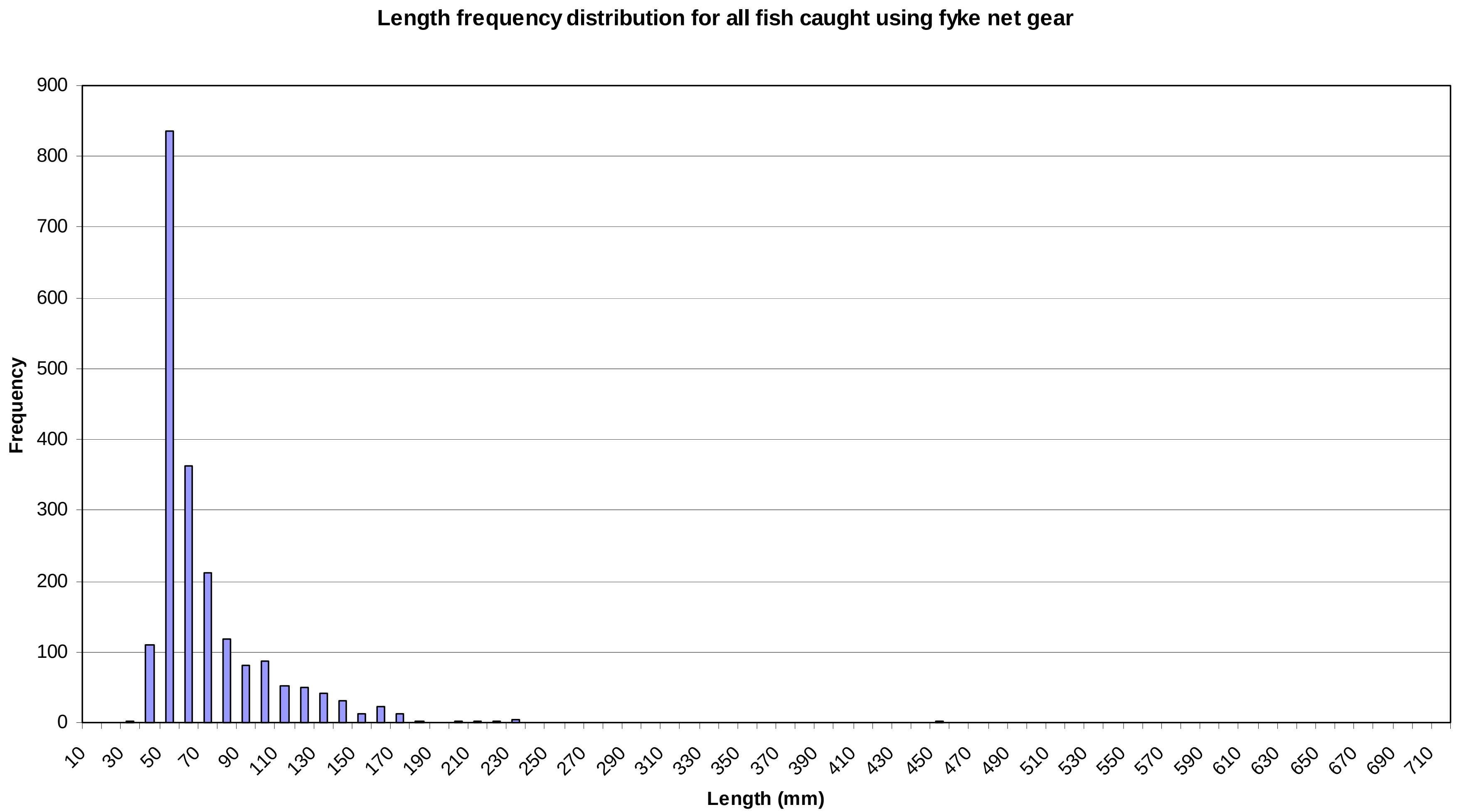


Figure 10. Length frequency disturbance for all fish caught using fyke net gear (2002).

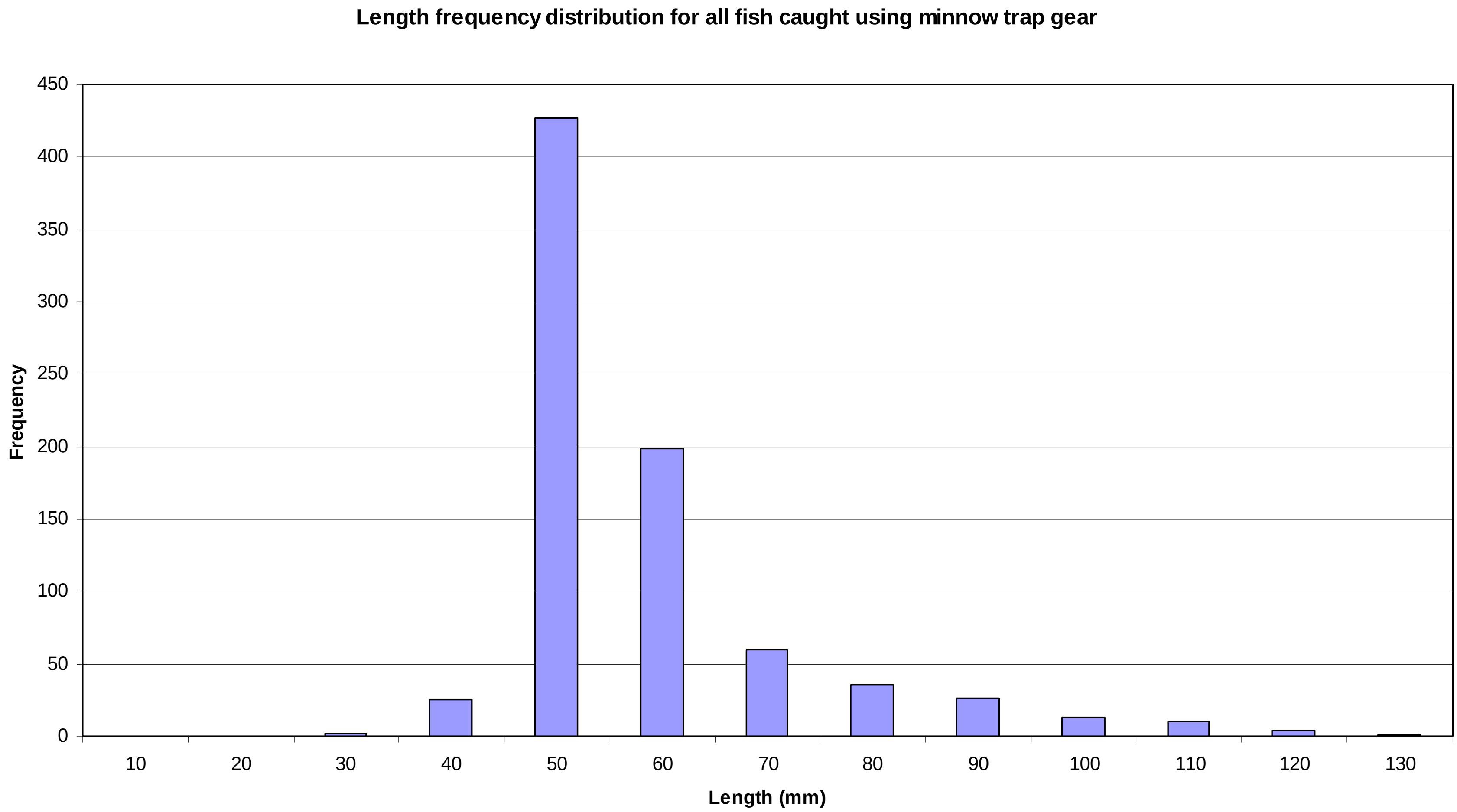


Figure 11. Length frequency for all fish caught using minnow trap (2002).

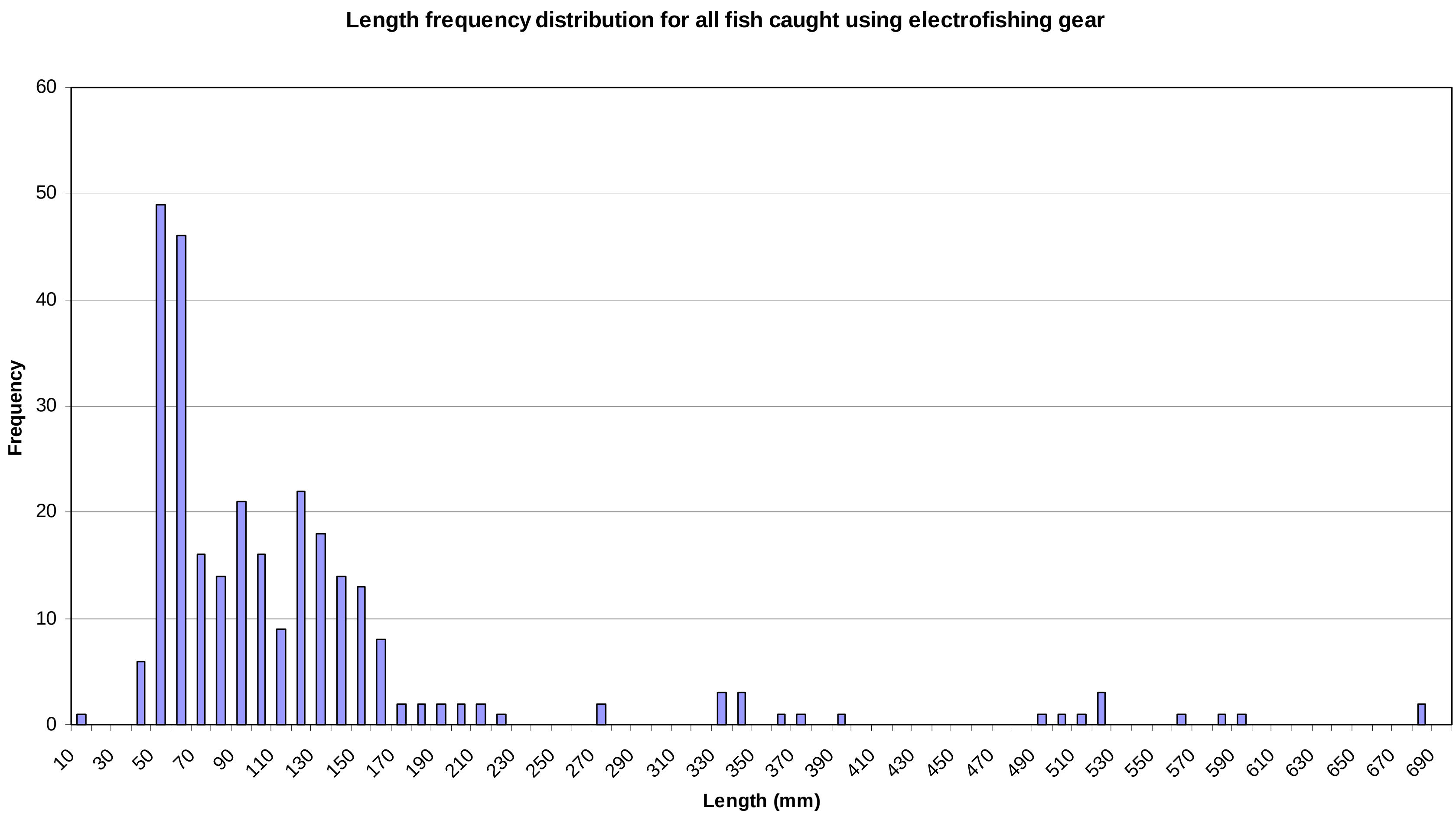


Figure 12. Length frequency for all fish caught using electrofishing gear (2002).

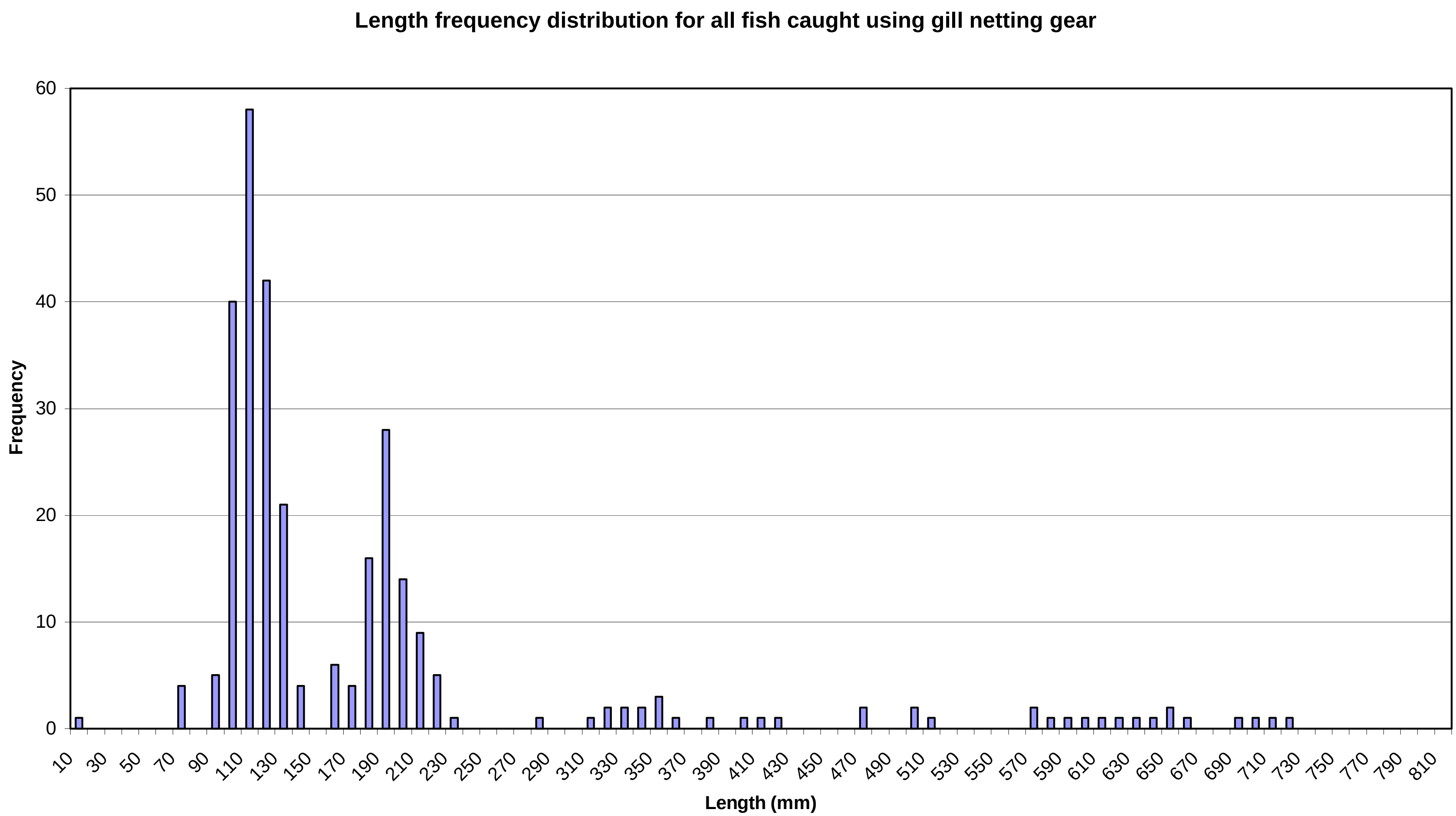


Figure 13. Length frequency distribution for all fish caught using gill netting gear (2002).

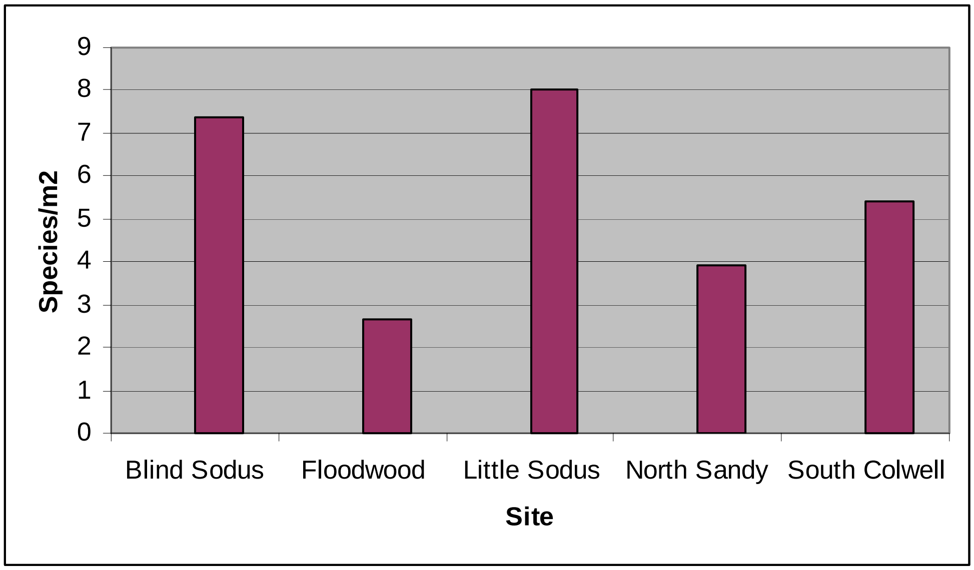


Figure 14. Species richness per square meter as sampled in 2001. Source: Nicole Hotaling and Don Leopold, SUNY ESF.

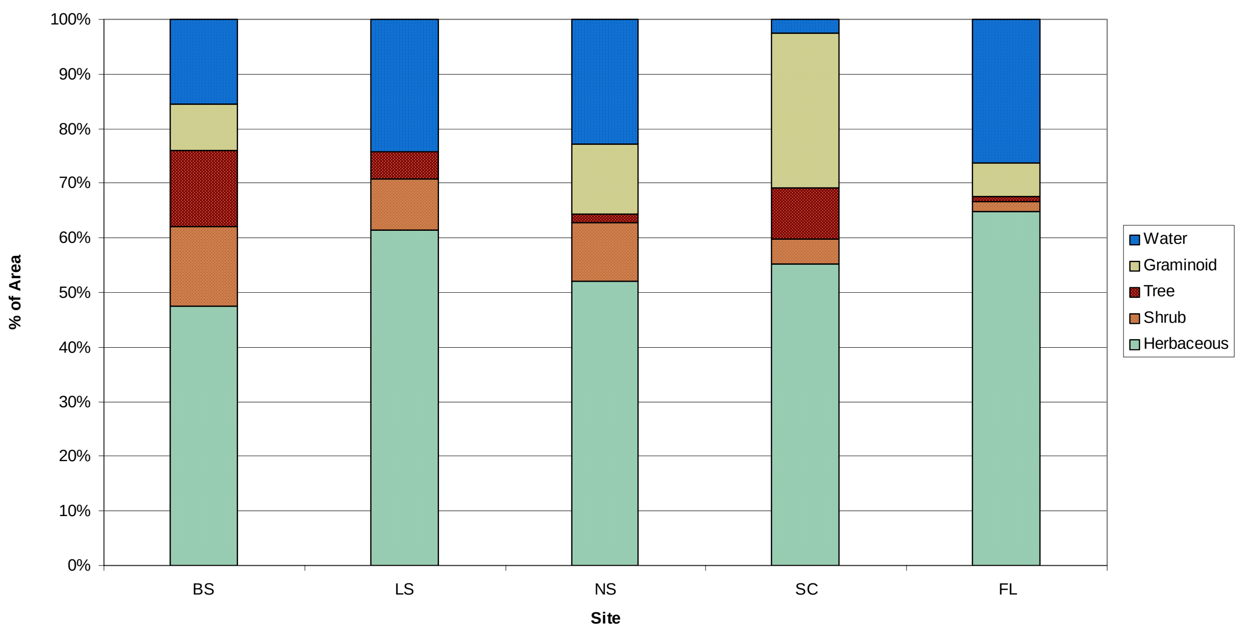


Figure 15. Comparison of sites by percentages of wetland vegetation community type (2001). Source: Nicole Hotaling and Don Leopold, SUNY ESF.

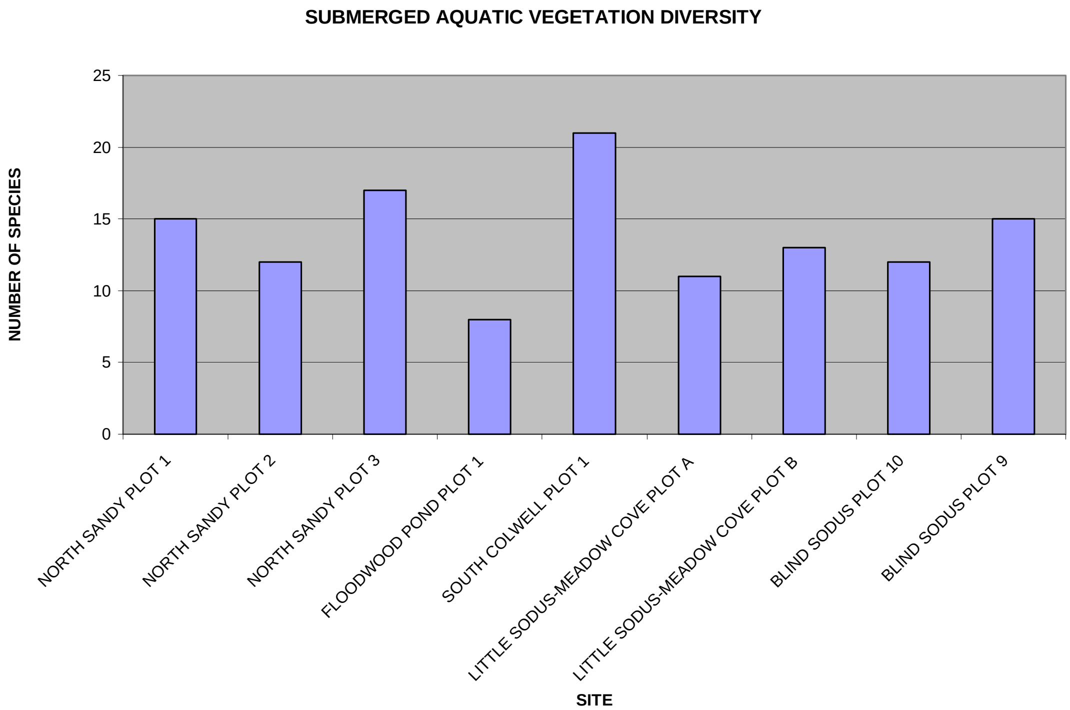


Figure 16. Study site locations and taxa richness of submerged aquatic vegetation on the east shore of Lake Ontario (2002). Source: Robert Johnson, Cornell University.

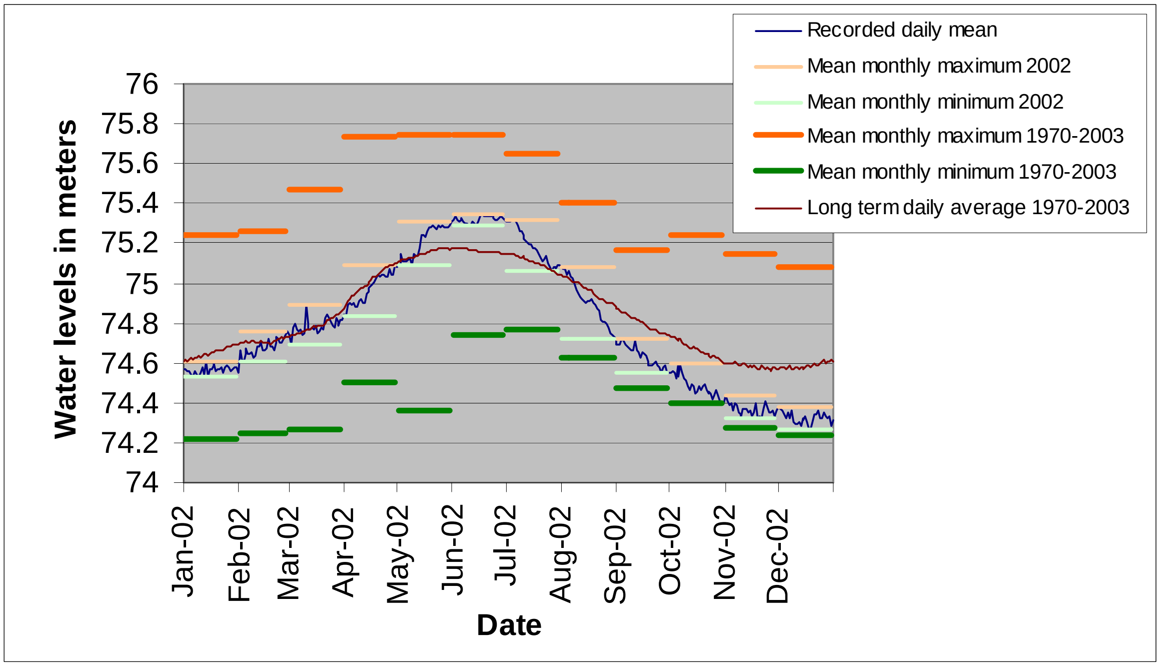
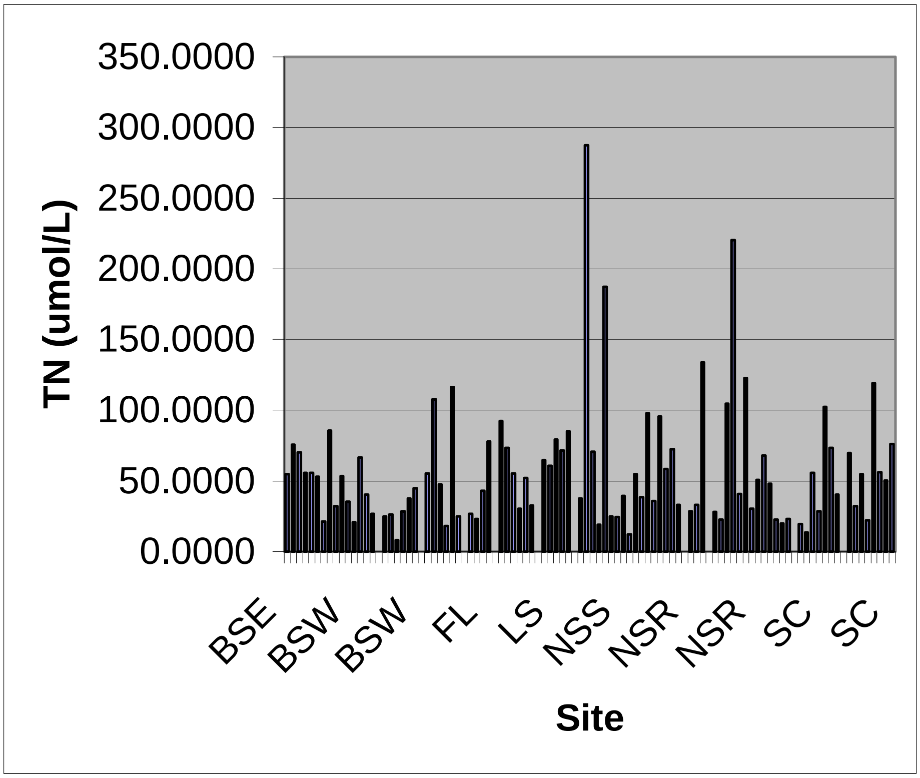


Figure 17. Actual and long-term Lake Ontario mean water levels from Oswego, New York during 2002. Source: National Ocean and Atmospheric Administration, 2003.



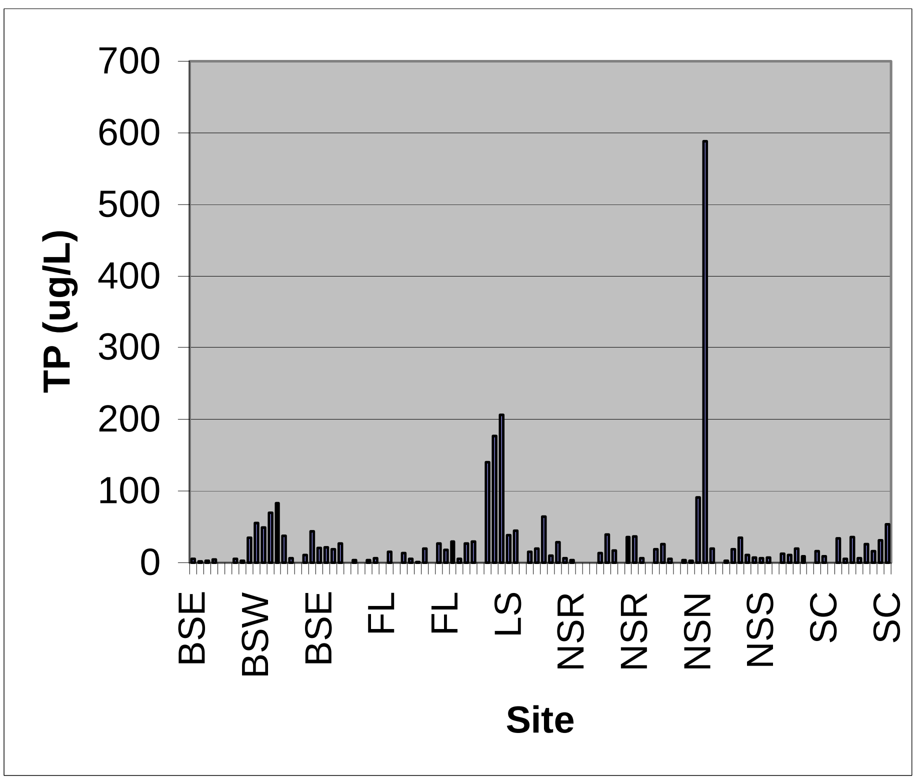


Figure 18. Total nitrogen (top) and total phosphorus (bottom) at all wetland sites (2002).

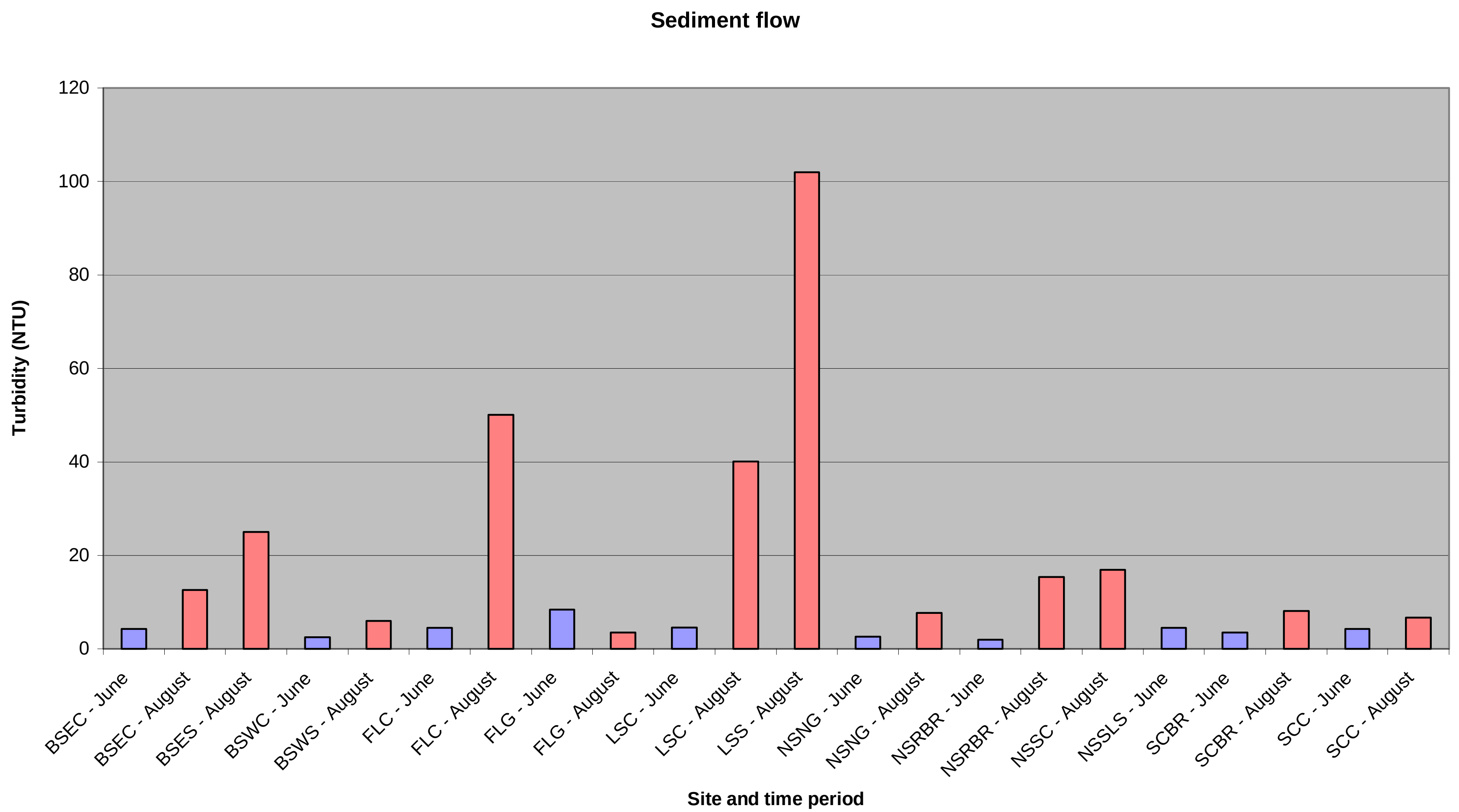


Figure 19. Sediment flow in Great Lakes embayments in June and August in 2002.