CHAPTER 3 ECOSYSTEM GOALS, OBJECTIVES AND INDICATORS

3.1 Summary

This chapter evaluates the status of the Lake Ontario LaMP's ecosystem indicators based on reports and information provided by government monitoring programs as of the beginning of 2006. The key findings of these studies are presented in each of the indicator assessments. The reader should refer to original source reports for complete findings as well as details on monitoring techniques.

3.2 Development of Lake Ontario Ecosystem Goals and Objectives

After several years of work, the LaMP adopted ecosystem goals, objectives and indicators to help measure progress in restoring and maintaining the health of the Lake Ontario ecosystem. The selected indicators reflect lakewide conditions and are sensitive to a number of stressors. For example, healthy populations of bald eagles and mink, both native predators, indicate the presence of suitable habitat, healthy populations of prey organisms, and low levels of environmental contaminants. Healthy populations of eagles and mink also reflect our society's commitment to responsible stewardship in protecting habitat, limiting harvests and reducing levels of contaminants in the environment.

3.2.1 Ecosystem Goals for Lake Ontario

Work first began on Lake Ontario ecosystem goals, objectives and indicators as part of the Lake Ontario Toxics Management Plan (LOTMP) in the late 1980s. U.S. and Canadian monitoring experts brought together by LOTMP developed ecosystem goals and objectives for the lake. The LaMP has adopted these goals, which provide a vision for the future of Lake Ontario and the role human society should play:

- The Lake Ontario ecosystem should be maintained and, as necessary, restored or enhanced to support self-reproducing and diverse biological communities.
- The presence of contaminants shall not limit uses of fish, wildlife and waters of the Lake Ontario basin by humans, and shall not cause adverse health effects in plants and animals.
- We, as a society, shall recognize our capacity to cause great changes in the ecosystem and we shall conduct our activities with responsible stewardship for the Lake Ontario basin.

3.2.2 Ecosystem Objectives for Lake Ontario

The LaMP also adopted the LOTMP's five ecosystem objectives that describe the conditions necessary to achieve LaMP ecosystem goals:

- Aquatic Communities: The waters of Lake Ontario shall support diverse and healthy reproducing and self-sustaining communities in dynamic equilibrium, with an emphasis on native species.
- Wildlife: The perpetuation of a healthy, diverse and self-sustaining wildlife community that utilizes the lake habitat and/or food shall be ensured by attaining and sustaining the waters, coastal wetlands, and upland habitats of the Lake Ontario basin in sufficient quantity and quality.
- Human Health: The waters, plants and animals of Lake Ontario shall be free from contaminants and organisms resulting from human activities at levels that affect human health or aesthetic factors, such as tainting, odour and turbidity.
- Habitat: Lake Ontario offshore and nearshore zones surrounding tributary, wetland and upland habitats shall be of sufficient quality and quantity to support ecosystem objectives for the health, productivity and distribution of plants and animals in and adjacent to Lake Ontario.
- Stewardship: Human activities and decisions shall embrace environmental ethics and a commitment to responsible stewardship.

3.3 Ecosystem Indicators

Annex 11 of the Great Lakes Water Quality Agreement (GLWQA) describes the surveillance and monitoring activities that the parties will carry out in order to assist in evaluating the attainment of specific water quality objectives listed in Annex 1 of the GLWQA. These activities include the development of ecosystem health indicators for each of the Great Lakes.

Indicators proposed by the LOTMP and the State of the Lakes Ecosystem Conferences (SOLEC) served as a starting point for the LaMP's selection process. SOLEC has provided a forum for Great Lakes monitoring and ecosystem indicator issues. Data collected and reported by U.S. and Canadian monitoring programs were reviewed to identify what types of information, collected on a regular basis, could be used to measure long-term trends. The LaMP used six criteria to select appropriate ecosystem indicators that are:

- well-recognized by monitoring experts;
- supported by historical data available for comparison purposes;
- consistent with SOLEC and LOTMP indicator recommendations;
- easily understood by the general public;
- supported by data available from existing monitoring programs; and
- reflective of general "ecosystem health" on a lakewide scale.

The eleven indicators selected provide a good characterization of ecosystem health across the food web. The selected indicators can be divided into three groups:

1) Critical Pollutant Indicators: which measure concentrations of critical pollutants in water, young of the year fish, herring gull eggs and lake trout, and compare this information against existing guidelines?
2) Lower Food web Indicators: which track the status of nutrients, zooplankton and prey fish (such as alewife and smelt). These indicators reflect the ability of the ecosystem to support higher level organisms (such as lake trout and waterbirds); and
3) Upper Food web Indicators: which monitor the health of herring gull, lake trout, bald eagle, mink and otter populations. These top-level predators are dependent on quality habitat and sufficient prey populations, free of problematic contaminant levels.

The indicators were presented at SOLEC, RAP meetings, the Finger Lakes-Lake Ontario Watershed Protection Alliance Conference and in the LaMP 2001 Update Report. In general, the indicators have been well received by the public. The LaMP adopted the indicators in 2001.

The process of fine-tuning and reporting on these indicators fosters closer working relationships between U.S. and Canadian monitoring programs and will promote better binational coordination. Additional indicators, measures and/or targets will be considered, as necessary, to help guide LaMP restoration activities. The status of each indicator based on recent monitoring information is provided below. Some proposed improvements to indicator reporting are also discussed.

3.3.1 Critical Pollutant Indicators

Critical pollutant indicators measure concentrations of critical pollutants in water, young of the year (YoY) fish, herring gull eggs and lake trout, and compare this information against existing guidelines.

Critical Pollutants in Offshore Waters

Objective: critical pollutants in open waters should not pose a threat to human, animal and aquatic life
Measure: concentration of critical pollutants in offshore waters
Purpose: to measure priority toxic chemicals in offshore waters and to assess the potential impacts of toxic chemicals on human health and the aquatic ecosystem and the progress of contaminant reduction efforts
Target: concentrations of critical pollutants in offshore waters are below standards and criteria designed to protect the health of human, animal and aquatic life

Status: Environment Canada (EC) operates the only long-term Lake Ontario surface water contaminant monitoring program and will serve as the primary source of information to evaluate this indicator. Information from other special surface water investigations will also be considered as new information becomes available. EC has developed a new measurement technique and has invested in the construction of an ultra-clean laboratory in order to measure trace concentrations of pollutants in the surface waters of the Great Lakes. In 2004, a pilot project to measure organic contaminants in the surface waters in the western portion of Lake Ontario was initiated; full coverage of the lake was obtained in 2005. The 2005 data are not yet available, but the 2004 data show that concentrations of many organic compounds and metals are present in only trace amounts, and some are below available water quality objectives (Table 3.1). Concentrations of most critical pollutants (PCBs and mercury concentrations using comparable measurement techniques were not available prior to 2004) were similar in 2001 and 2004. Sampling and analytical problems have made it difficult to develop reliable estimates of dioxins and furans for offshore surface waters.

Some differences with earlier measurements in 1999, 2001, 2002 and 2003[1, 36, 37] are noted in these recent data. However, these apparent differences are not considered to be great, especially considering the generally low values obtained in these studies. In addition, differences in methods, volumes of waters sampled, and time of year, could result in differing values. Seasonal changes in water concentrations, in particular, may contribute to the differences between studies. Contaminant concentrations may be higher early in the season, when low temperatures and winter ice cover may limit volatilization of contaminants from the water to the atmosphere.

Collectively, the data for Lake Ontario offshore surface waters indicate that PCB levels are up to 140 times higher, and dieldrin up to 245 times higher than the most stringent ambient water quality guidelines designed to protect humans who consume fish (Table 3.1).

Table 3.1 Concentrations of critical pollutants (pg/L) compared to NYSDEC ambient water quality guidelines.

Critical Pollutant	Fall 1999[1]	Spring 2001[2]	Average of 2002 & 2003[3]	Spring 2004[4]	Most Stringent NYSDEC Ambient Water Quality Guideline	Basis Code[5]
Dieldrin	3 - 6	176		147	0.6	H (FC)
p,p'-DDE	0 - 2	19	4	14	7	H (FC)
p,p'-DDD	1 - 3	31		21	80	H (FC)
p,p'-DDT	0.54- 0.95	<43		<43	10	H (FC)
Total DDT	3 - 6	<43		<43	11	W
Photomirex	<0.02 – 0.3	<40		<40	No guideline	-
Mirex	0.15 – 0.30	<14		<14	1	H (FC)
Total PCB	26 – 46	NA	93	144	1	H (FC)
Dissolved Mercury (ng/L)	NA	NA	0.16 – 0.30	0.62[6]	0.7	H (FC)

Notes:

1) organic contaminant values are whole-water concentrations from NYSDEC, autumn 1999, using large volume samples (>400 L), filters and resin

2) values are dissolved concentration MLE (maximum likelihood estimates) from Environment Canada, spring 2001, offshore locations, using large volume samples (50 L), ship-based Goulden extraction.

3) organic contaminant values are average values for three large volume (~400 L) XAD resin and filter sampling events collected as part of the Clarkson University LOADs project.

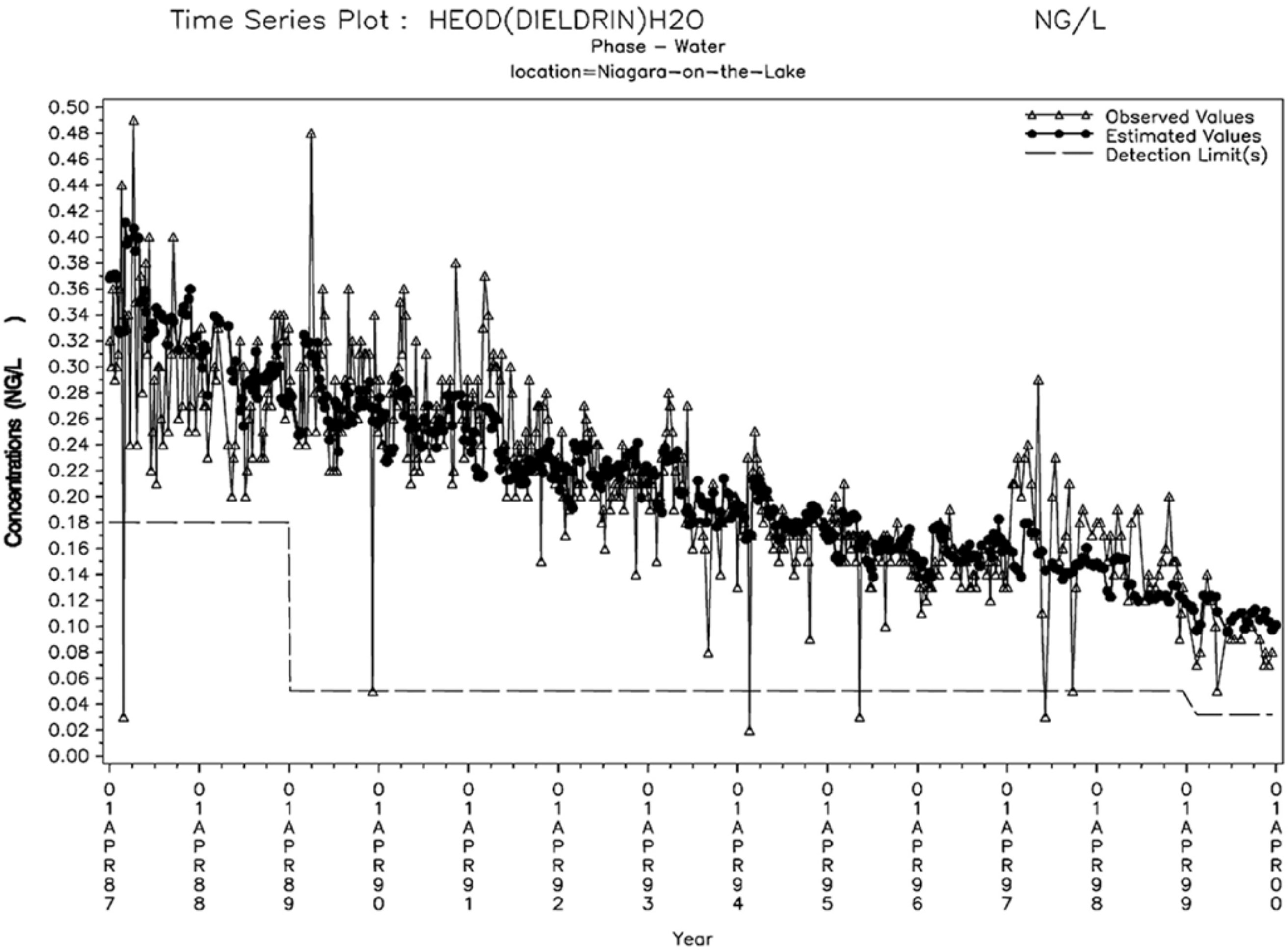
4) values are dissolved concentration MLE (maximum likelihood estimates) from Environment Canada, spring 2004, using 16 L samples, Goulden extraction in clean lab. Data are from offshore locations in the western portion of Lake Ontario only. PCB values are corrected for laboratory blanks.

5) NYSDEC Value Basis Codes: H (FC) = Human Health Fish Consumption; W = Wildlife Protection

6) This particular result is for "total" mercury and therefore reflects a maximum potential value for dissolved mercury; since the total (dissolved plus particulate) is less than the dissolved NYSDEC criteria, the criteria is met.

The Niagara River Upstream-Downstream and the Wolfe Island St Lawrence River monitoring programs provide additional information on historical trends of some contaminants at sites entering and leaving Lake Ontario[2, 3]. For example, these programs show that concentrations of PCBs on suspended sediments and dissolved concentrations of dieldrin in Niagara River water entering Lake Ontario have been declining over the last two decades (Fig 3.1).

Figure 3.1 Dieldrin dissolved phase trends in Niagara River surface water at Niagara-on-the-Lake 1987-2000.



Critical Pollutants in Young-of-the-Year (YoY) Fish

Objective: critical pollutants should not pose a risk to fish-eating wildlife
Measure: concentration of critical pollutants in YoY fish
Purpose: to measure persistent toxic chemicals in YoY fish and to evaluate and measure potential harm to fish-eating wildlife
Target: concentrations of critical pollutants in YoY fish are below standards and criteria designed to protect fish-eating wildlife

Status: YoY fish PCB and mirex levels remain a concern at some locations.

New York State 1997 YoY fish sampling results[4] showed that PCBs and mirex exceed criteria designed to protect fish-eating wildlife at some locations (Figure 3.2). PCB levels in YoY fish collected from the Black River, Salmon River and Sodus Bay exceeded the GLWQA 100 ng/g criteria. PCB levels in YoY fish collected from U.S. AOCs were below the 100 ng/g criteria. Mirex was above the GLWQA criteria of "non-detect" at all locations except at the Black River and Sodus Bay. Mercury, dioxin, total DDT and dieldrin

YoY concentrations were below their respective criteria. Dieldrin was not detected at any location.

Mirex was at 2 ppb in YoY fish from Eighteenmile Creek and showed no change by 1997 but at the Oswego River site, the 1984 and 1987 means of 2.0 and 4.7 ppb decreased to less than detection in 1997. The mean mirex level of 8.5 ppb for Salmon River YoY fish represents a relatively small increase over means of 2 to 4 ppb measured in YoY fish from 1984-1986. Photomirex, a degradation product of mirex, was detected at low levels (mean = 3.7 ppb wet weight) in YoY fish only from the Salmon River. Low levels were last detected in young fish from the Salmon River, Oswego River and Black River Bay in 1984.

The results of more recent NYSDEC and OMOE studies will be reported here in future updates.

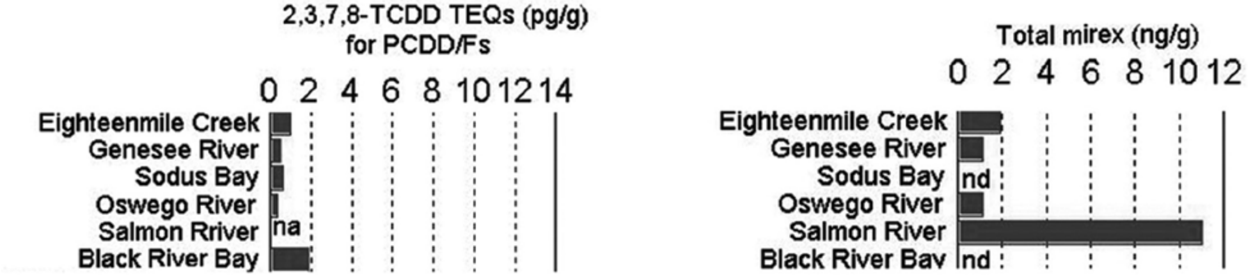
Critical Pollutants in Fish Tissue

Objective: consumption of fish should not be restricted due to contaminants of human origin
Measure: concentrations of pollutants in fish responsible for advisories
Purpose: to measure critical pollutants in fish and to evaluate the potential exposure of humans to these substances through fish consumption
Target: contaminants in fish tissue are below the existing standards and criteria designed to protect human health, as shown by the elimination of fish advisories

Status: PCBs, dioxins, mirex and mercury are still responsible for a number of lakewide fish consumption advisories.

Overall, the fish community has experienced a dramatic reduction in contaminant levels since the mid-1970s. One source of fish contaminant trend information is the U.S. EPA GLNPO fish contaminant monitoring program[5] (Fig. 3.3). Each year NYSDEC and USGS work together to provide EPA with lake trout for analysis. PCB concentrations have declined from >6 µg/g in 1978 to <2 µg/g in 2000. Trends are becoming increasingly more difficult to detect in the short term, controlling processes have half-lives on the order of a decade or two.

Figure 3.2 Contaminants in Young-of-the-Year Fish From Nearshore Areas of New York's Lake Ontario Basin, 1997[4].



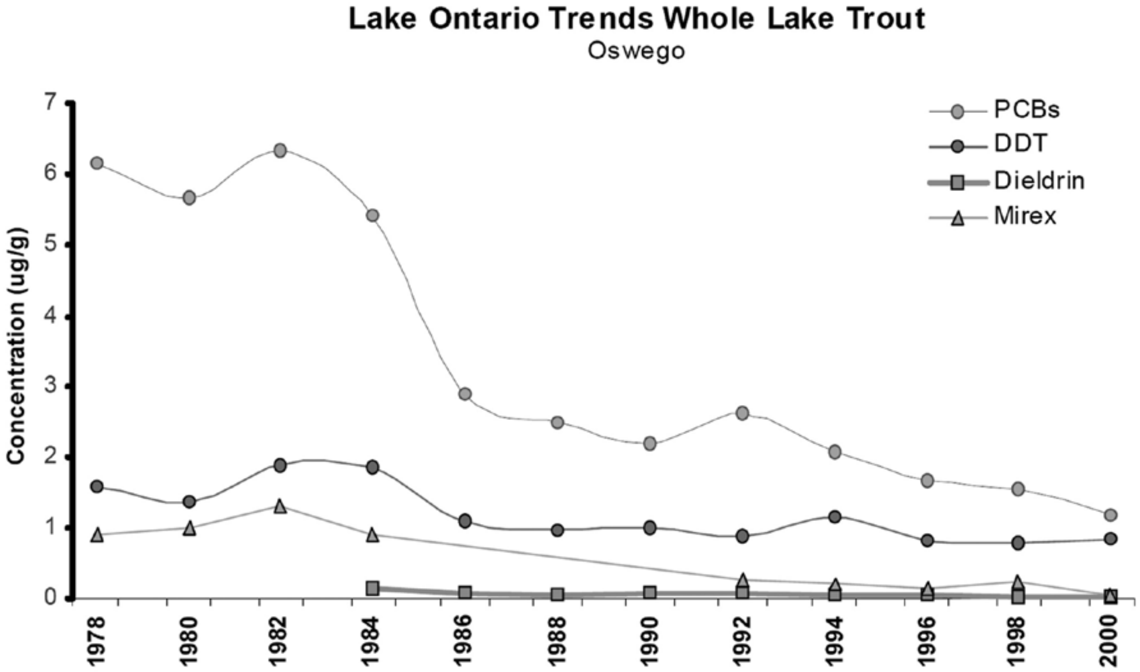
Criteria = 3 pg/g (NYSDEC)

Criteria = Non-detect (<2 ng/g) (GLWQA)

Criteria = 300 ng/g EPA recommended

Criteria = 100 ng/g (GLWQA)

Figure 3.3 Contaminant trends in Lake Ontario lake trout[5].



Canada has maintained a long-term, basin wide monitoring program that measures whole body concentrations of contaminants in lake trout and/or walleye [6]. The Canada Department of Fisheries and Oceans (DFO) had maintained this program for more than 25 years. This program was recently transferred to Environment Canada. Annual reports document contaminant burdens in similarly aged fish (4^+ - 6^+ range). Since the late 1970s, concentrations of historically regulated contaminants such as PCBs, DDT and Hg have generally declined in most monitored fish species. After a period of consistent decline total PCB levels have remained virtually unchanged since 1998. Over the past 6 years mean PCB levels were 1.27 µg/g which represent about 44% of the 1997 concentration. Total DDT concentrations continued a pattern of a steady decline since 1994. Whole fish concentrations have been consistently less than the Agreement Objective of 1.0 µg/g since 1995.

Long-term trends in contaminant concentrations are illustrated using data collected by the Ontario Ministry of Environment (OMOE) for 50-centimetre Coho salmon from the Credit River spawning run [7]. Coho salmon data are well suited to analysis of trends over time since they spend most of their time in the Lake and different individuals of similar age return to the same location each year to spawn. In the mid-1990s, Coho salmon stocks in the Credit River were low and no samples were obtained. Concentrations of total PCB, mirex, mercury, and total DDT in Credit River Coho salmon have been decreasing steadily since monitoring commenced in the late-1970s. Total PCB concentrations have decreased from greater than 1.5 ppm in late-1970s to approximately 0.5 ppm in 2000 (Figure 3.4). Over the same time period, concentrations of mirex have decreased from greater than 0.1 ppm to less than 0.05 ppm (Figure 3.5). Similar trends have been observed for mercury and DDT, as can be seen in Figures 3.6 and 3.7, respectively.

Both U.S. and Canadian fish tissue monitoring programs have been expanded to include some of the more recently recognized bioaccumulative contaminants such as polybrominated diphenyl ethers (PBDE). Future reporting on this indicator will include information on mercury levels in walleye. The identification of mercury as a lakewide critical pollutant is based on walleye advisories. Mercury is not a cause of lake trout or salmon consumption advisories.

Figure 3.4 PCBs in 65 cm Coho Salmon from Lake Ontario, 1976-2006.

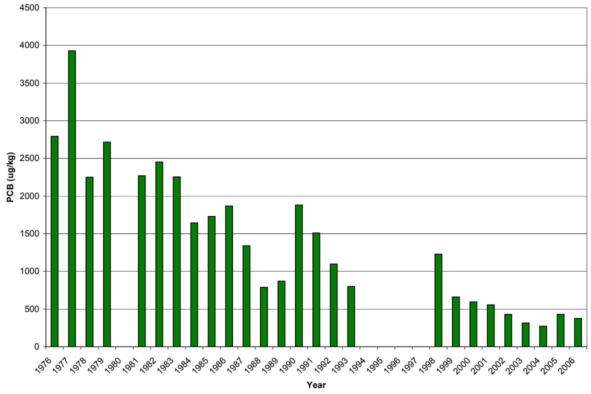


Figure 3.5 Mirex in 65 cm Coho Salmon from Lake Ontario, 1976-2006.

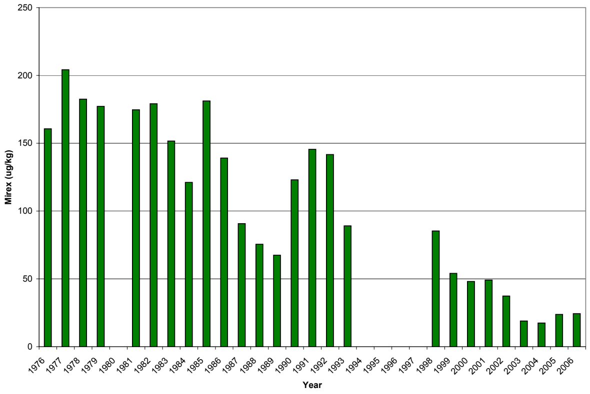


Figure 3.6 Mercury in 65 cm Coho Salmon from Lake Ontario, 1976-2006.

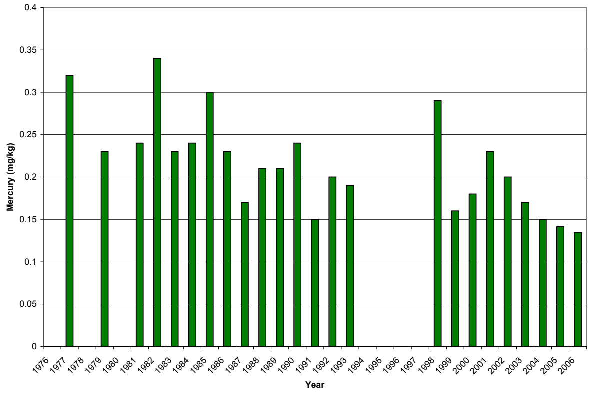
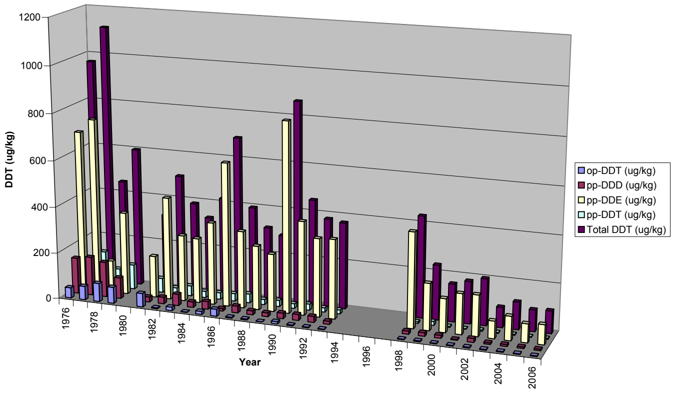


Figure 3.7 Total DDT and metabolites in 65 cm Coho Salmon from Lake Ontario, 1976-2006.



Critical Pollutants in Herring Gull Eggs

Objective: the health and reproductive success of waterbirds should not be impaired by contaminants present in the aquatic food web
Measure: annual concentrations of persistent toxic chemicals in herring gull eggs from colonies
Purpose: to measure critical pollutants in herring gull eggs from colonies that reflect general lakewide conditions and to compare contaminant concentrations to criteria designed to protect waterbirds
Target: contaminant levels in colonial nesting waterbird eggs are similar to those of unaffected reference sites or are below existing standards or criteria designed to protect colonial waterbirds

Status: Critical pollutant concentrations in gull eggs are continuing to decrease.

The herring gull is the most widespread colonial waterbird nesting on the Great Lakes. As a native, non-migratory species that relies heavily on aquatic prey organisms, the herring gull provides an excellent indicator species. The Canadian Wildlife Service's herring gull egg contaminant monitoring program has provided an excellent means to track environmental trends in persistent toxic chemicals[8-12, 26-28].

The long-term decline in concentrations of critical pollutants in eggs of Great Lakes and Lake Ontario herring gulls is well documented. Rates of decline of several organochlorine contaminants in herring gull eggs from the 1970s through the 1990s are available[8-12, 26- 28]. More recent changes in Lake Ontario herring gull egg concentrations for the critical pollutants DDE, dieldrin, mirex, PCBs, and Hg (2000-2005) and TCDD and TCDF (2000-2003), are as follows: DDE has declined 67.6 – 82.8%, dieldrin: 58.4 – 84.2%, mirex: 68.7 – 82.8%, PCBs: -12.6 – 41.8%, Hg: 36.0 – 38.0%, 2378-TCDD: -55.0 – 9.3%, 2378-TCDF: 12.7 – 93.1%30 . Trends for critical pollutants in gull eggs are illustrated in Figures 3.8 – 3.13. Similar decreases have been seen in other pollutants such as hexachlorobenzene (HCB) (Figure 3.14).

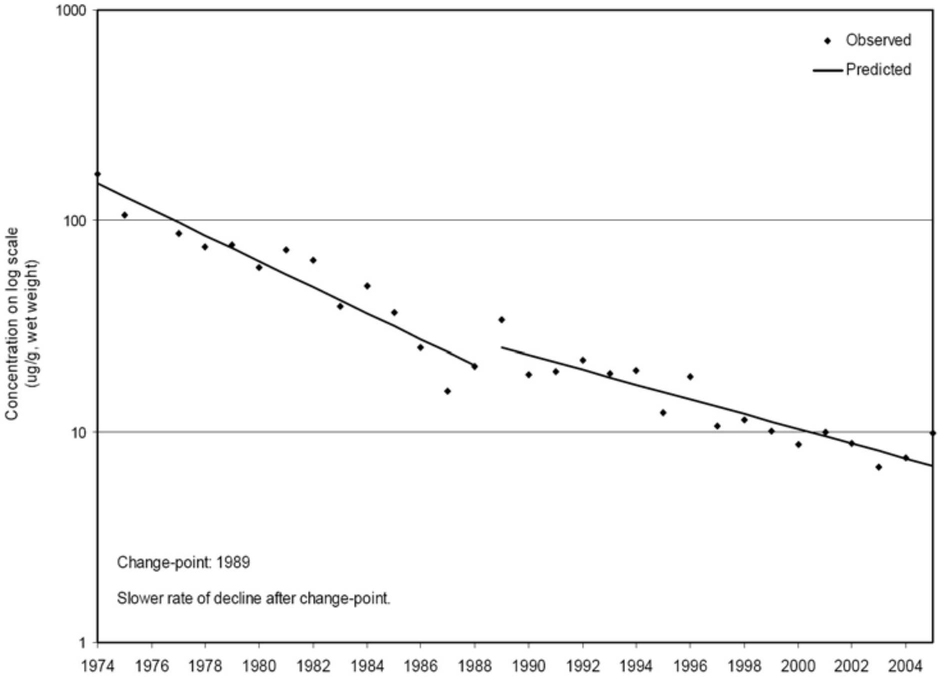
Data for PBDEs in herring gull eggs from the only Lake Ontario site where temporal data are available are shown in Figure 3.15. Concentrations increased dramatically from 1981 through 1999 but appear to have declined slowly since then[29, 30].

Future work on this indicator could include the development of specific target concentrations for critical pollutants in gull eggs. Although many of the obvious signs of toxic contamination are no longer apparent, the Canadian Wildlife Service is continuing its research to better understand the potential for more subtle effects of environmental contaminants on fish-eating birds and other wildlife on Lake Ontario.

Since the 1970s, the levels of most chlorinated hydrocarbons have decreased significantly at the majority of colonies on the Great Lakes. Change-point regression analysis continues to show that most contaminant levels at most sites (72.4%) are declining as fast as or faster now than they did in the past. This is particularly evident for dieldrin and DDE. The rates of decline have slowed for some compound-site comparisons particularly PCBs and mirex.

Figure 3.8 PCB Trends in Lake Ontario Herring Gull Eggs. "PCB 1:1" indicates that total PCBs have been quantified assuming a one to one ratio of PCB aroclors 1254 and 1260. Note that the vertical scale is logarithmic.

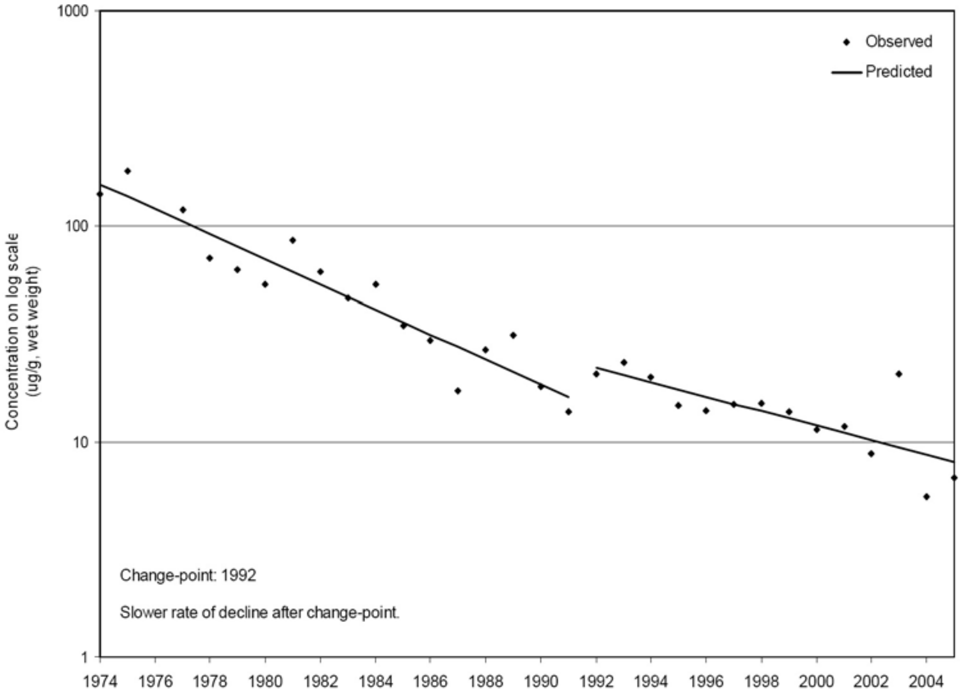
PCB 1:1 in Herring Gull eggs, Toronto, 1974-2005



Change-point: 1989

Slower rate of decline after change-point.

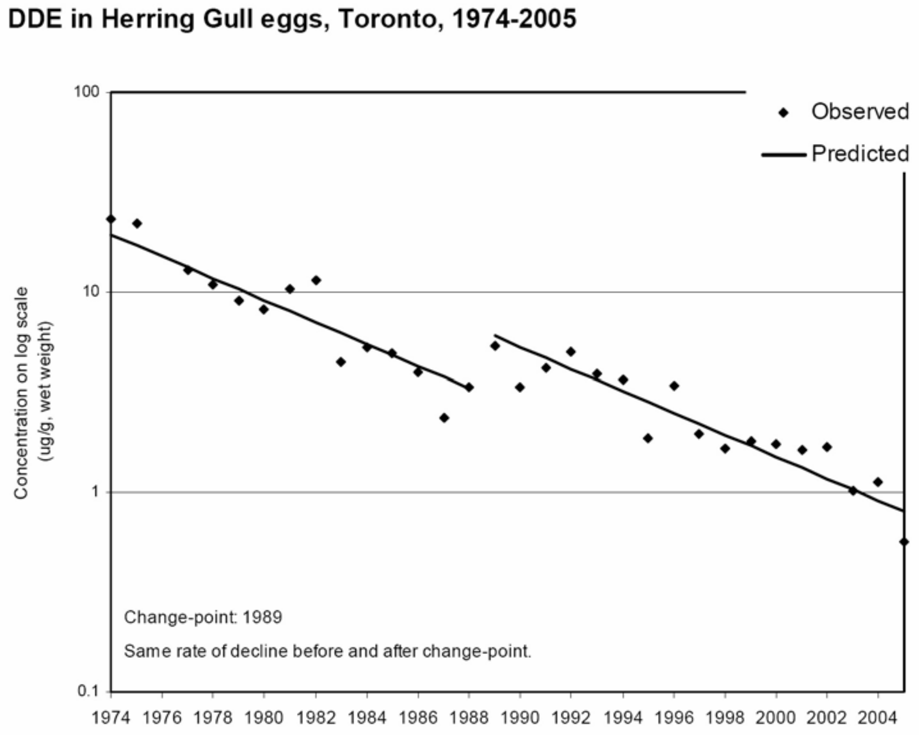
PCB 1:1 in Herring Gull eggs, Snake Island, 1974-2005



Change-point: 1992

Slower rate of decline after change-point.

Figure 3.9 DDE Trends in Lake Ontario Herring Gull Eggs.



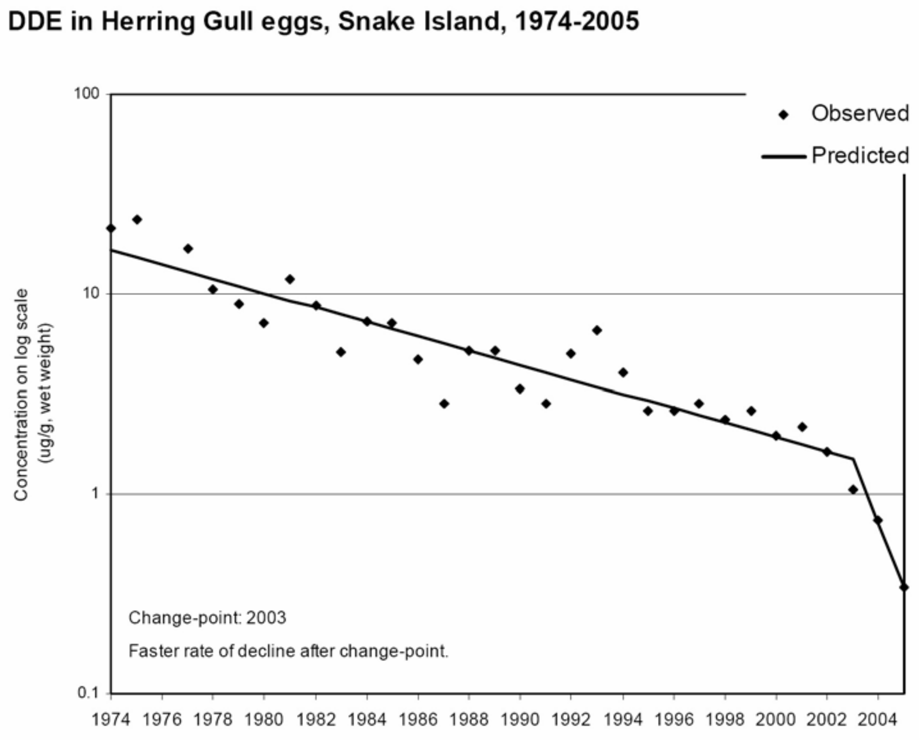
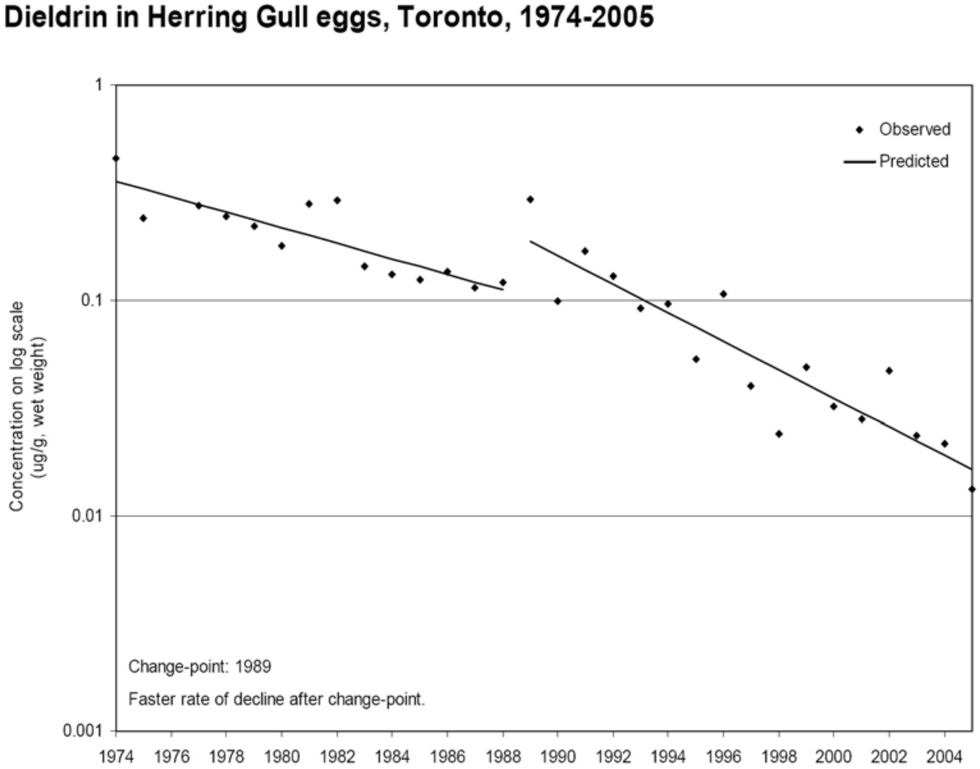


Figure 3.10 Dieldrin Trends in Lake Ontario Herring Gull Eggs.



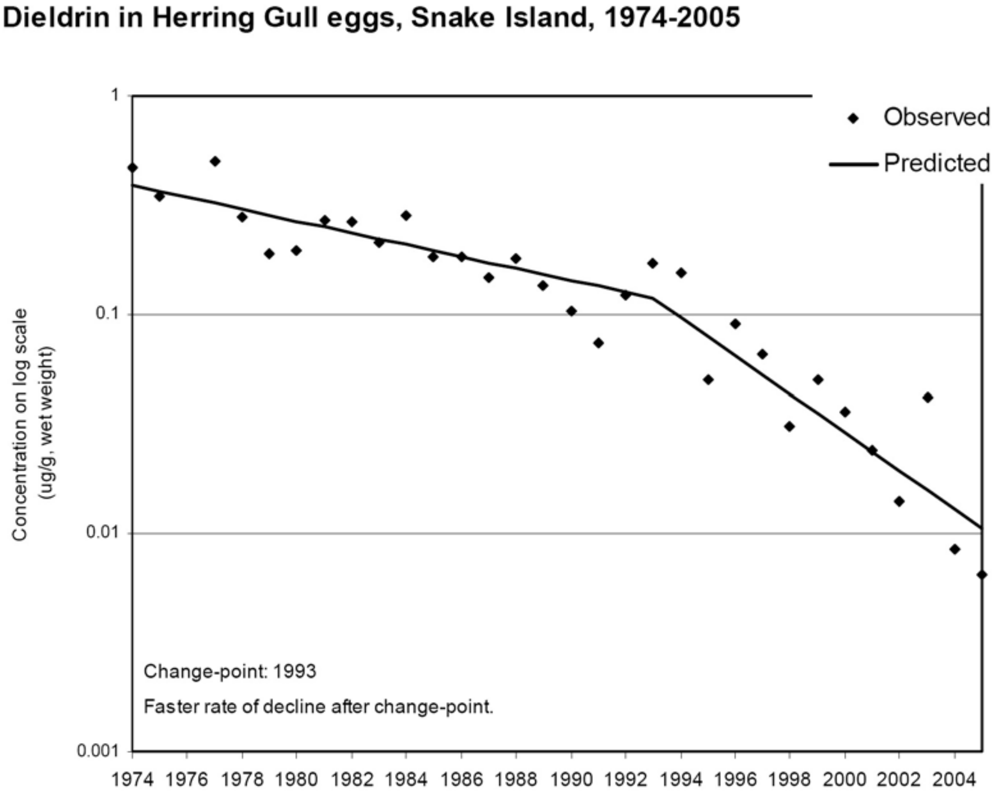
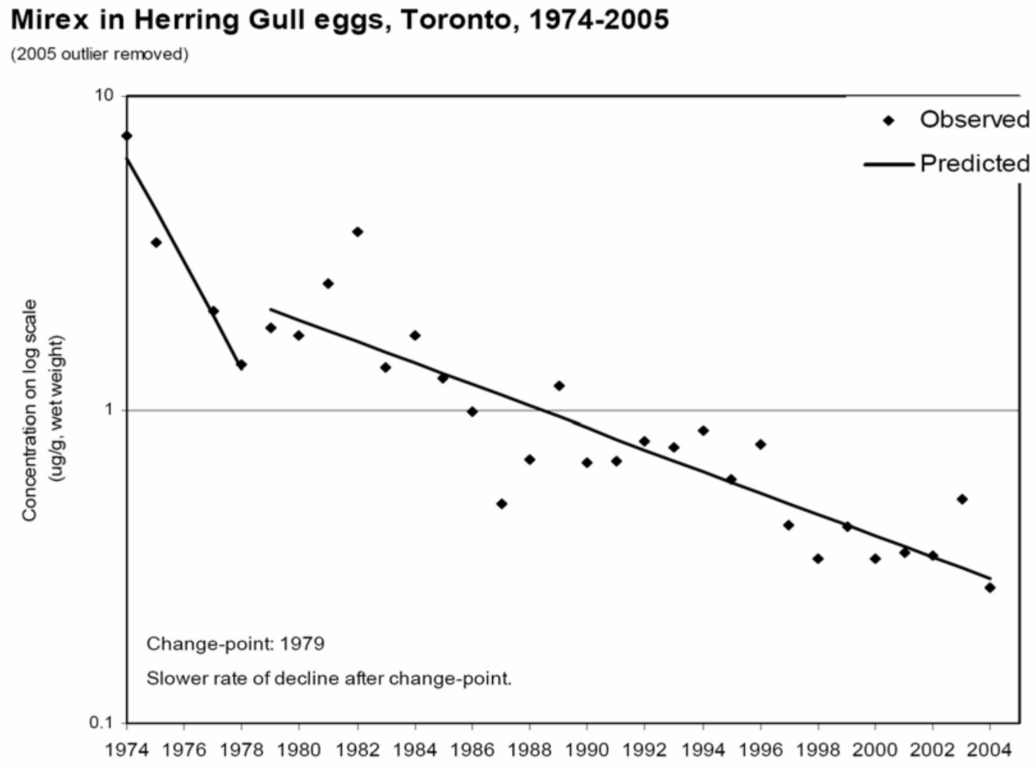


Figure 3.11 Mirex Trends in Lake Ontario Herring Gull Eggs.


Mirex in Herring Gull eggs, Toronto, 1974-2005

(2005 outlier removed)

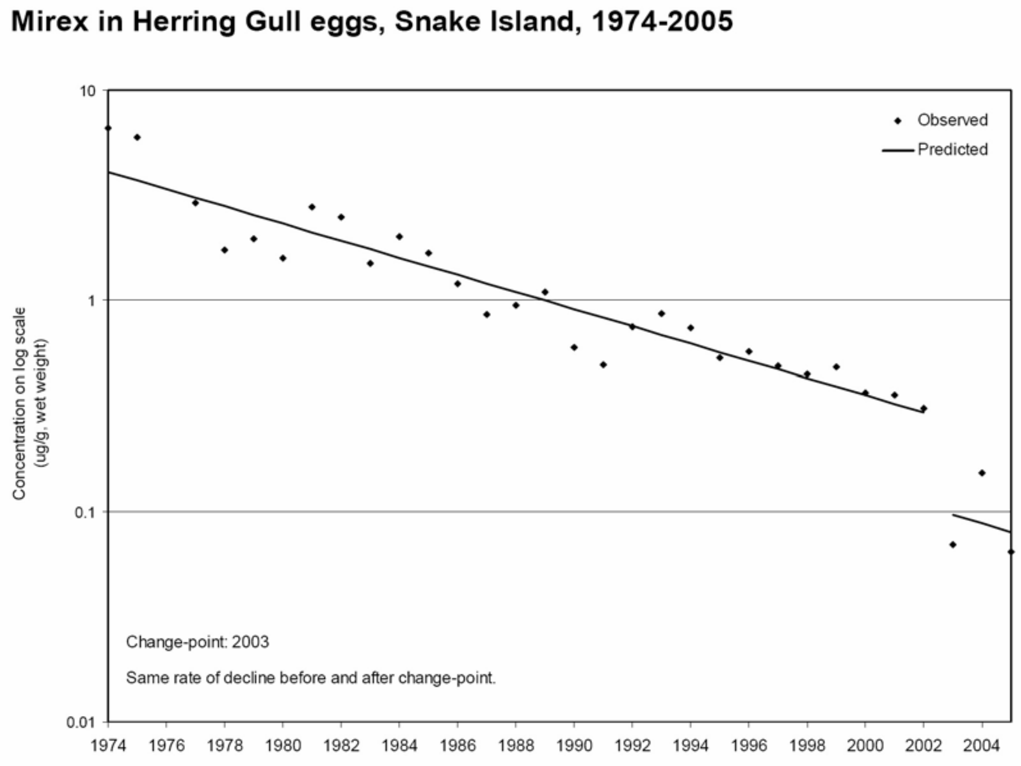
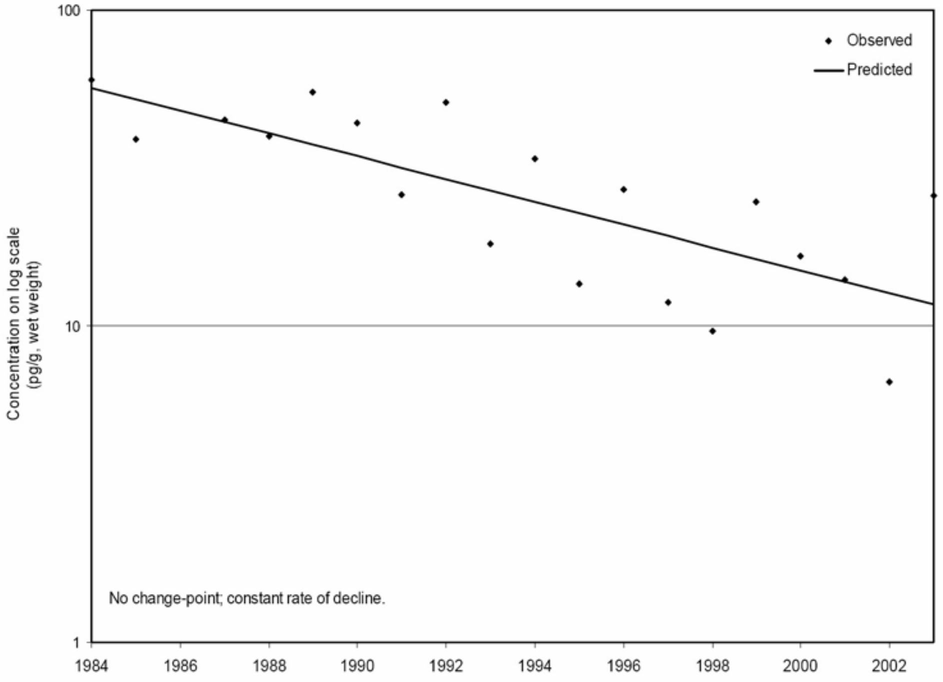

Mirex in Herring Gull eggs, Snake Island, 1974-2005

Figure 3.12 2,3,7,8-Dioxin Trends in Lake Ontario Herring Gull Eggs. Note that the vertical scale is logarithmic.

2,3,7,8-dioxin in Herring Gull eggs, Toronto, 1984-2003



2,3,7,8-dioxin in Herring Gull eggs, Snake Island, 1984-2003

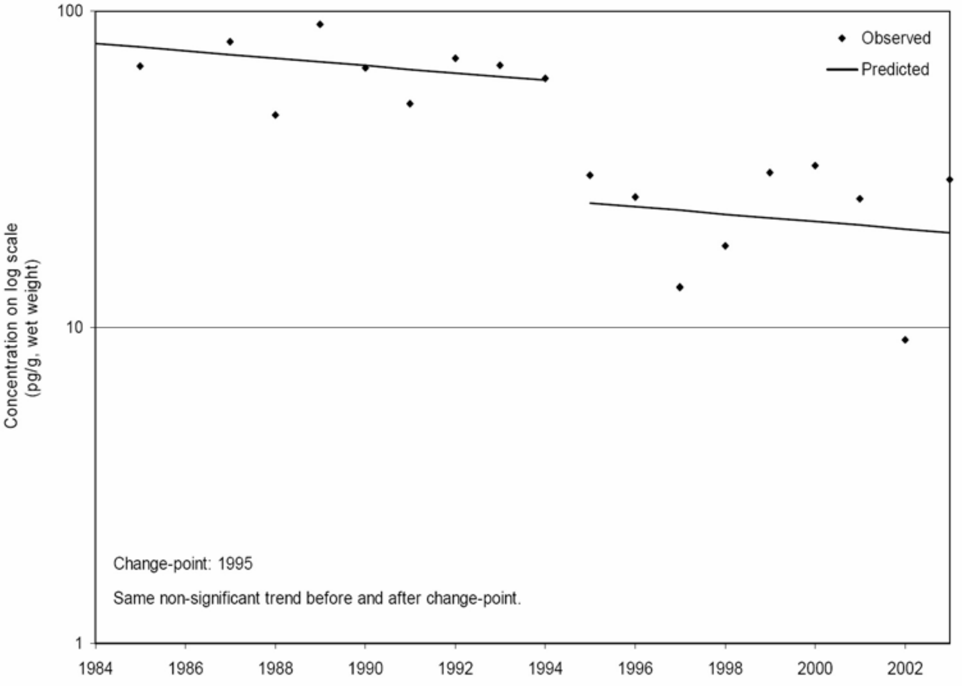
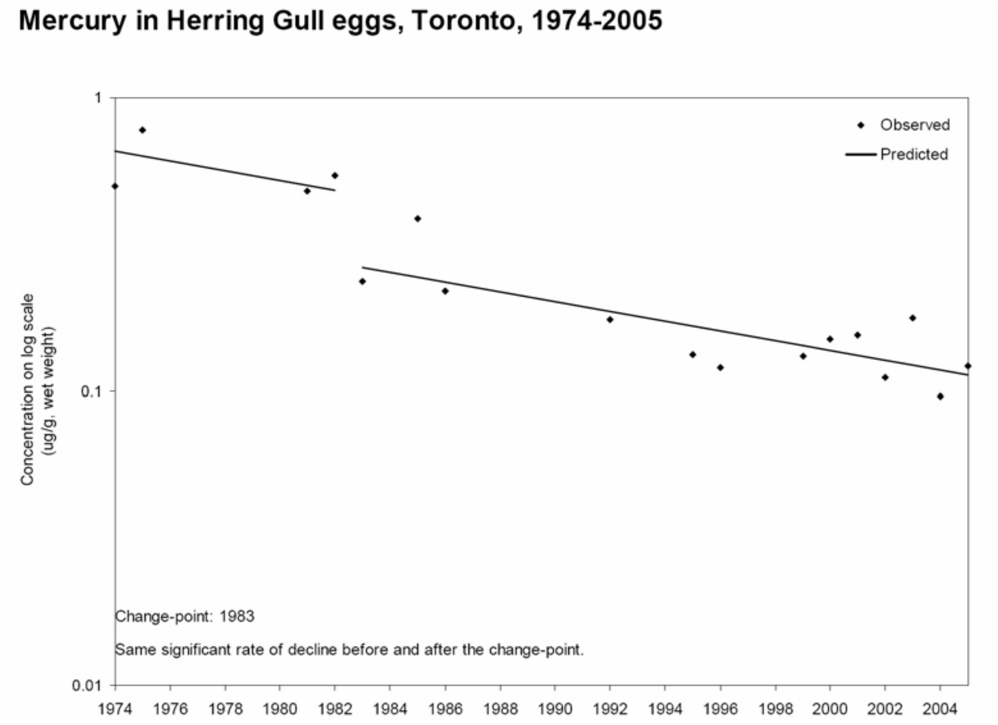


Figure 3.13 Mercury Trends in Lake Ontario Herring Gull Eggs, Toronto & Snake Island. Note that the vertical scale is logarithmic.



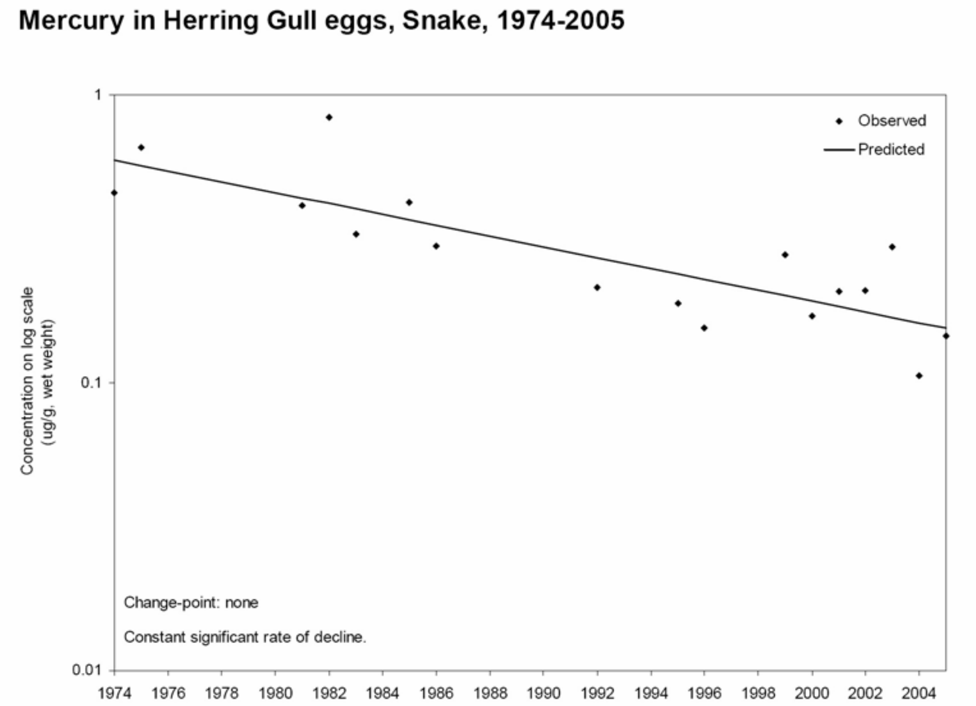
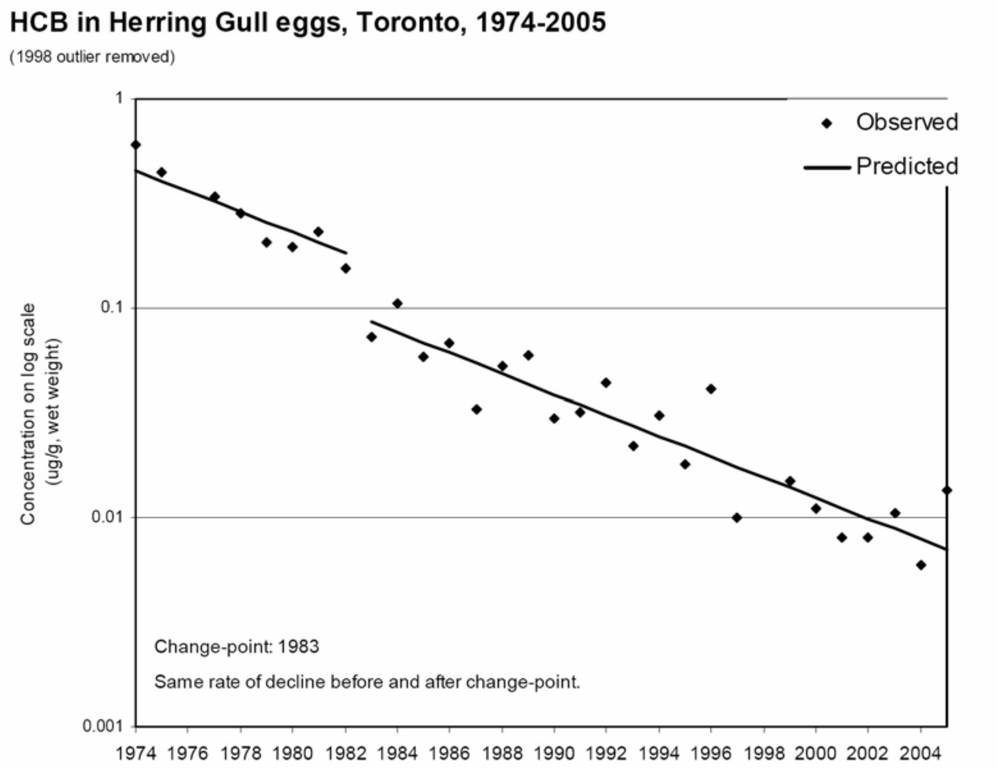
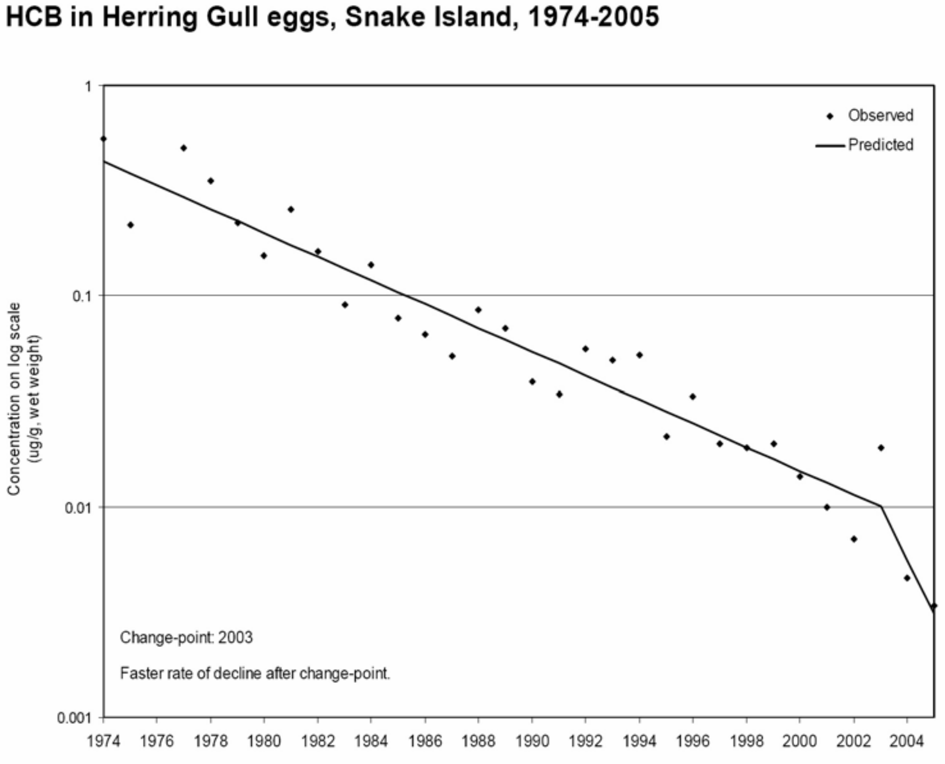


Figure 3.14 Hexachorobenzene (HCB) Trends in Lake Ontario Herring Gull Eggs. Note that the vertical scale is logarithmic.





3.3.2 Lower Foodweb Indicators

Lower food web indicators track the status of nutrients, zooplankton and prey fish (such as alewife and smelt). They reflect the ability of the ecosystem to support higher level organisms (such as lake trout and waterbirds). In Lake Ontario phosphorus levels have declined over the past 20 years, but this event has come at a time when demands for a salmonid sport fishery have increased, non-native species such as the alewife have exhibited highly variable population dynamics, pelagic zooplankton production has declined, oligotrophic fish stocks are recovering, and exotics such as the zebra mussel, quagga mussel and currently the predatory zooplankton *Cercopagis pengoi* have proliferated [13, 14, 15].

Nutrients in Open Waters

Objective: nutrient levels should be sufficient to support aquatic life without causing persistent water quality problems (such as the depletion of dissolved oxygen in bottom waters, nuisance algal blooms or accumulations, and decreased water clarity)
Measures: total spring phosphorus levels (micrograms per litre), chlorophyll-a, and water clarity
Purpose: to follow trends in open lake nutrients
Target: nutrient levels allow attainment of fishery management objectives without exceeding the GLWQA phosphorus-loading target for Lake Ontario.

Status: Concentration recommended to achieve the GLWQA target load for the lake has been met.

In response to binational phosphorus control programs, open lake phosphorus concentrations declined from a peak of about 25 µg/L in 1971 to the 10 µg/L concentration recommended to achieve the GLWQA target load to the lake by the mid 1980s [15, 16, 17]. Offshore phosphorus levels continued to decline through the 1990s and are now at approximately 5 – 7 µg/L (Fig 3.16) [16, 17].

Chlorophyll data from Environment Canada's Surveillance Program show that the trophic status of Lake Ontario has changed from a mesotrophic system in the 1970s and is now bordering on oligotrophy[18] (Figure 3.17). Monitoring in the summer of 2006 and beyond will assist in determining if this trend is continuing.

Water clarity, as measured by Secchi disc depth, has increased dramatically in Lake Ontario over time (Figure 3.18) [19]. Some of the improvement occurred concurrently with improved phosphorus discharge controls and the accompanying decline in nuisance algal biomass. However, the most dramatic changes in offshore waters have been apparent since about 1989, indicating that water clarity has increased due to the influence of zebra and quagga mussels filtering particles (including algae) from the water column.

Figure 3.15 Mean spring total phosphorus concentration in the open waters of Lake Ontario. Dashed line represents concentration recommended to achieve GLWQA target loads.

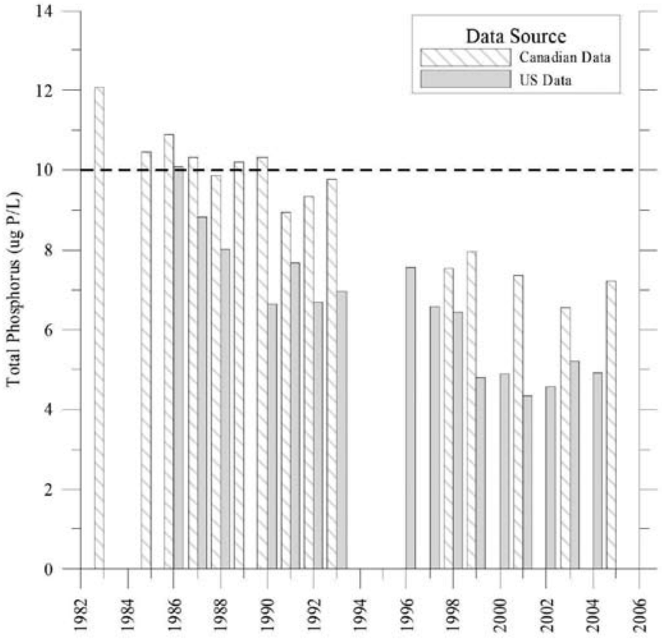


Figure 3.16 Corrected chlorophyll-a values in 0 – 20 m integrated samples, offshore waters (depth ≥ 100 m) in Lake Ontario, 1974 – 2003.

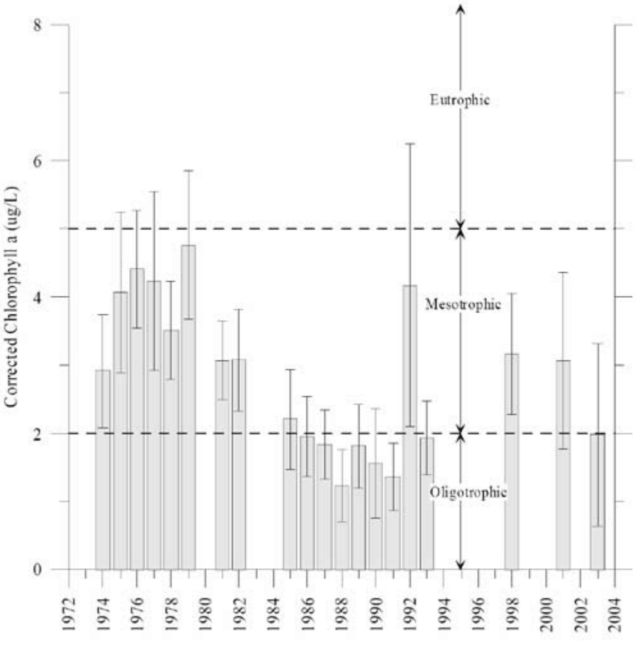
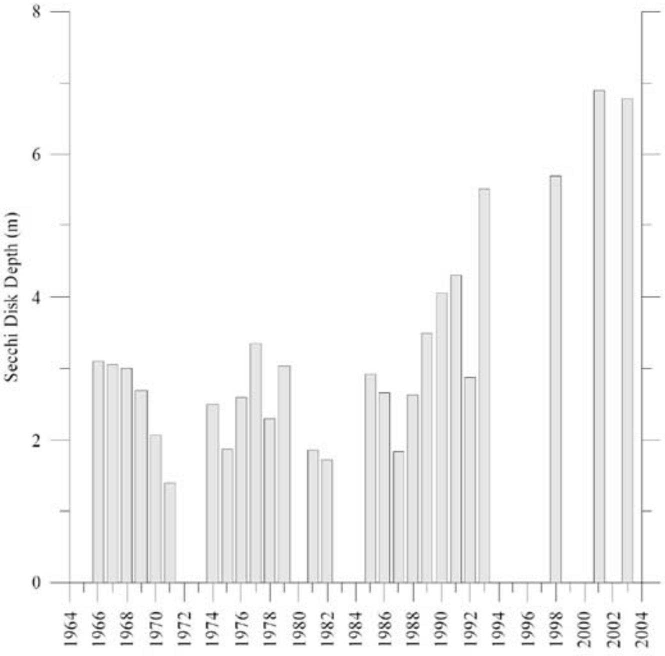


Figure 3.17 Summertime Secchi disc depths in Lake Ontario offshore waters (depth ≥ 100 m) 1966 – 2004.



Zooplankton Populations

Objective: zooplankton populations should be sufficient to support a healthy and diverse fishery
Measures: (1) mean individual size, and (2) biomass.
Purpose: to directly measure changes in mean individual size and biomass of zooplankton populations in order to indirectly measure changes in food-web dynamics due to: changes in vertebrate or invertebrate predation, changes in system productivity, the type and intensity of predation, and energy transfer within a system
Targets: zooplankton populations are sufficient to maintain prey and predator fish at levels consistent with existing binational fishery objectives; mean individual size of approximately 0.8 millimeters (mm) is generally considered an optimal size when the water column is sampled with a 153 micron mesh net; specific biomass targets will be developed as the state of knowledge permits

Status: 2004 mean offshore zooplankton body size was close to the target.

Mean zooplankton length can be used as an indicator of the balance between plankton eating fish and fish predators. Given the dependence of Lake Ontario adult alewife on zooplankton for food, the mean body size of offshore crustacean zooplankton of 0.74 mm, close to the 0.8 mm target, indicates that populations of predator fish are successfully controlling prey fish populations [20]. Mean body sizes much less than 0.8 mm, on the other hand, would indicate that there are insufficient numbers of predator fish to control prey fish populations [21].

Prey Fish

Objective: a diverse array of prey fish populations should be sufficient to support healthy, productive populations of predator fishes
Measures: abundance, age and size distribution of prey fish species (such as deepwater ciscoes, sculpins, lake herring, rainbow smelt and alewives)
Purpose: to directly measure the abundance and diversity of prey fish populations and to indirectly measure the stability of predator species necessary to maintain biological integrity
Target: given the rapid changes that have occurred in the Lake Ontario food web, a specific

target in terms of average annual biomass cannot be set at this time; a specific target will be set once fishery managers have a better understanding of prey fish dynamics

Status: The prognosis is poor for Lake Ontario alewife and rainbow smelt populations, the mainstays of the offshore food web for most pelagic predators. This indicator may need to be updated as round gobies have expanded their range well into the offshore in association with quagga mussels and these fish are gaining importance as diet items for fish like lake trout.

The following overview of the status of Lake Ontario prey fish is based on the collaborative work of New York State, Ontario Ministry of Natural Resources and the U.S. Geological Survey [22]:

Alewife - The process of food web disruption, mediated by exotic species, may well have eroded lower trophic level support for the Lake Ontario alewife population to below that of the early 1990s. With the carrying capacity of the lake reduced, the alewife population at a low level and made up of a high proportion of fish ≥ age 5 (44%), and environmental conditions unfavorable for production of age-1 alewives, measures of adult alewife abundance are anticipated to be at, or below, 2004 levels through 2006.

Rainbow Smelt - The mean weight of rainbow smelt caught during the June 2004 survey decreased to 2.4 g (0.08 oz) from 3.9 g (0.14 oz) in June 2003, because yearling rainbow smelt (the youngest age group in the catch) dominated the catch in 2004. In 2005, the number of yearlings caught declined significantly perhaps signaling a return to alternating strong and weak year classes. The paucity of large rainbow smelt during 1989-2005 was most likely due to heavy predation and, more recently, several consecutive weak year classes. In all likelihood, any rise in rainbow smelt abundance will be short lived without a relaxation of predation pressure.

Slimy sculpin - Assessment of slimy sculpin was done with a modified trawl in 2005. When compared with 2003 results, the number per trawl declined except for the largest size group (130 mm). Distribution of these fish remained similar across recent sampling years. However, the change in gear type in 2005, warrants some caution in interpretation at least until a few more years are added to the data set.

Deepwater Sculpin - During the alewife assessment in April 2004, one deepwater sculpin was caught and released and in 2005, 17 of various sizes were caught but young small sculpin represented 7 of these fish. Prior to 1998, the last documented record of a deepwater sculpin being captured in U.S. waters of Lake Ontario was over 50 years ago. Although 2005 is only a single year of sampling, these numbers have created some excitement among agencies. In Canadian waters, 1 small deep water sculpin was caught.

Round Goby – This non-native species has been caught in US waters off of Olcott since 2002. This is not surprising as it has been found in near shore waters since about 1998 in the Bay of Quinte. However, it has spread to 130 m deep in just 3 years from 0 in 2002 to 69 per 10 minute trawl in 2005. This species is fast becoming an important diet item for lake trout35 and many other fish species.

Restoring Deepwater Cisco -Historically Lake Ontario's fishery was dominated by benthic fish such as the deepwater Cisco. These fisheries were lost at the turn of the century and this ecological niche has remained vacant ever since. The Lake Ontario Committee of the GLFC has initiated process to reintroduce deep water Cisco to Lake Ontario using existing stocks from Lake Superior. The Chippewa Ottawa Resource Authority has assisted the Lake Ontario Committee in collecting Lake Superior Cisco brood stock and rearing eggs/fry at their facilities. As well, young Ciscoes were transported and are being raised at the U.S. Geological Survey's Northern Appalachian Research Laboratory in Wellsboro, PA in order to create a captive brood stock to support restoration efforts and to conduct disease testing. Concerns over introducing EED (Epizootic Epitheliotrophic Disease) virus to Lake Ontario from Lake Superior will require extensive stress testing of juvenile fish prior to stocking, which could hamper restoration efforts.

3.3.3 Upper Foodweb Indicators

Upper food web indicators monitor the health of herring gull, lake trout, bald eagle, mink and otter populations. These top level predators are dependent on quality habitat and sufficient prey populations, free of problematic contaminant levels.

Lake Trout

Objective: lake trout populations should be sustained through natural reproduction
Measures: (1) abundance of naturally produced fish, (2) number of mature females, and (3) number harvested
Purpose: to measure progress and identify obstacles to the successful rehabilitation of naturally reproducing populations of lake trout
Targets: abundance of at least 2.0 mature female lake trout larger than 4,000 grams per standard gillnet; abundance of naturally-produced mature females greater than 0.2 in U.S., and 0.1 in Canadian waters per standard gillnet; harvest not to exceed 30,000 fish per nation; and abundance of naturally produced age 2 fish of at least 26 juveniles from July bottom trawls in U.S. waters and increased over current levels in Canadian waters. In addition, to reduce mortality, lamprey wounding should be no more than 2.0 A1 wounds per 100 lake trout over 433 mm.

Status: In 2005, only 2 of the 5 targets were met; the abundance of naturally produced lake trout is well below its target and adult numbers of both wild and stocked fish are declining.

The rehabilitation of lake trout populations is the focus of a major international effort in Lake Ontario. Coordinated through the Lake Ontario Committee of the Great Lakes Fishery Commission, representatives from New York State Department of Environmental Conservation (NYSDEC), United States Geological Survey (USGS), United States Fish and Wildlife Service (USFWS) and Ontario Ministry of Natural Resources (OMNR) developed the Joint Plan for Rehabilitation of Lake Trout in Lake Ontario[23, 24], identifying a goal, interim objectives, and strategies. The following assessment is based on their most recent progress reports [25, 34].

2005 data showed that the target of a harvest rate of less than 30,000 in each of Canadian and US waters was met. Lake trout harvest continued to decline in 2005 in both countries and is likely due in part to increased angling effort directed at Chinook salmon and declining numbers of lake trout particularly in eastern Lake Ontario. The rate of wounding by sea lampreys on lake trout caught in gill nets increased to more than the target level. This change in wounding rates may be attributable to either increased lamprey abundance or decreased lake trout density.

In 2005, no naturally produced lake trout yearlings were caught showing a break in the 11 consecutive years of wild yearlings. The number of wild age-2 fish also declined dramatically and the condition of adult lake trout also declined to an all time low.

It appears that changes in the offshore ecosystem have rendered the current lake trout restoration strategy ineffective. Accordingly, NYSDEC and OMNR are currently revising the Lake Ontario lake trout management plan. In addition to new restoration strategies/tactics, new indices for assessing performance may also be developed. For example, the establishment of dense lake bottom populations of quagga mussels has forced lake trout monitoring programs to change their bottom trawling methods. These changes will require the lake trout indicator measures and targets to be adjusted to better fit current monitoring programs. The Lake Ontario LaMP will review this document and consider how the current LaMP objectives reflect this new plan.

Herring Gull Populations

Objective: Lake Ontario should support healthy populations of colonial waterbirds.
Measure: total number of active herring gull nests counted per year (with additional species counted, as necessary)
Purpose: to directly measure numbers of breeding gulls on Lake Ontario in order to detect changes in population status that may reflect stresses due to contaminants, disease or insufficient food supply
Target: reproduction and fledging rates of herring gulls are normal (that is, similar to unaffected background areas)

Status: Mixed but encouraging. Contaminants do not appear to be limiting herring gull or other colonial bird populations.

Lake Ontario is home to nearly 1,000,000 colonially nesting water birds[26,31]. Biologists from the Canadian Wildlife Service, the Ontario Ministry of Natural Resources and the New York State Department of Environmental Conservation have completed 3 Lake Ontario-wide census of nesting colonial water birds, a survey that is conducted approximately once every 10 years. Although herring gulls are the selected LaMP waterbird indicator, this section also includes information on species of colonial waterbirds in order to provide additional information on waterbird issues. Lake Ontario-wide surveys were conducted in 1976-1977, 1990-1991 and 1998-1999 for 6 species of colonial water birds: double-crested cormorant, ring-billed gull, herring gull, great black-backed gulls, common tern and Caspian tern.[26, 31] Selected species are monitored more frequently; their recent numbers are discussed and updated below.

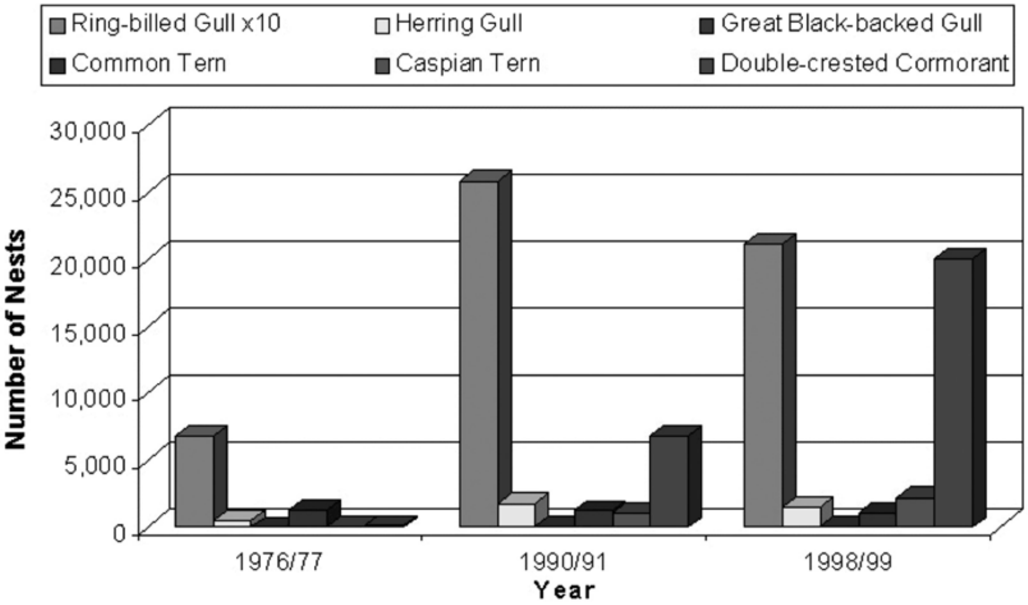
Herring Gull - The herring gull is the most widespread colonial waterbird nesting on the Great Lakes[26]. As a native non-migratory species that relies heavily on aquatic prey organisms, the herring gull serves as an excellent indicator species. From 1976/77 to 1990, the number of nests (=breeding pairs) of Herring Gulls on Lake Ontario increased from 522 to nearly 1800, a 242% increase. The number of nesting sites increased from 14 to 21. However, more recently, from 1990 to 2003, the number of breeding pairs decreased to approximately 1400 (when adjusted for uncensused sites), a decline of approximately 22%[26,31]. Declines in the numbers of breeding Herring Gulls have been most noticeable at sites where cormorants also nest. However, a cause and effect relationship has yet to be established.

Double-crested Cormorant – From 1977 to 1999 the Lake Ontario population of breeding cormorants increased from 96 pairs to over 20,000. In response to this increase and the cormorant's potential impacts to vegetation and co-occurring tree/shrub-nesting species, management actions were begun on Little Galloo Island (NY) in 1999 and at Presqu'Ile Provincial Park (ON) in 2003. These actions appear to have stabilized the number of nesting cormorants in the eastern basin of Lake Ontario (at approximately 9,000 pairs) and decreased it in the central basin to just over 5,000 26,31 (Fig. 3.21). However, the number of nesting pairs in Lake Ontario's western basin is now the greatest (9,000+ pairs) and appears to be still growing. Cormorants are reproducing very well.

Great black-backed Gull - Of the gulls and terns which commonly nest on Lake Ontario, the great black-backed gull is the least numerous. During the 1976-77 census, it was not found nesting anywhere on Lake Ontario. In 1990, a total of 15 nests were found on 3 sites and by 2004 this number had grown to 40 pairs. However, there was a severe botulism-induced die-off of various colonial waterbirds in Lake Ontario in the summer-fall of 2004 and several Lake Ontario-banded black-backed gulls were found dead. In the spring of 2005, the breeding numbers had declined to only 12 pairs.

The next Canadian Wildlife Service (CWS) Lake Ontario colonial waterbird population survey is planned for 2008.

Figure 3.18 Numbers of Gull, Tern and Cormorant Nests on Lake Ontario, 1976 – 1999.



Mink and River Otter

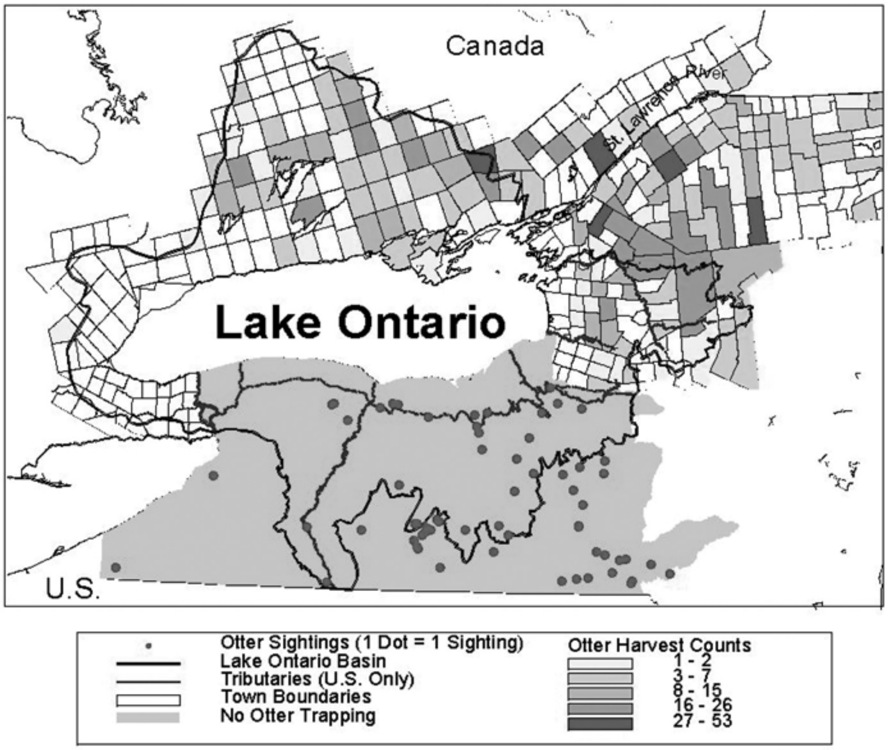
Objective: naturally reproducing populations of mink and river otter should be established throughout the Lake Ontario basin
Measure: number of tributaries and wetlands with established mink and river otter populations
Purpose: to evaluate mink and otter populations in the Lake Ontario basin
Target: all suitable habitats have established, healthy and naturally reproducing populations

Status: Sizeable populations of naturally reproducing mink and otter are present in the basin.

Mink and river otter are making a comeback in the Lake Ontario basin. Their populations were severely reduced in the 1800s due to habitat loss, water pollution and excessive trapping. Prior to these changes the river otter had the largest geographic range of any North American mammal. A review of trapping data showed that more than 5000 mink were trapped during the 1999-2000, harvest season. Although otter trapping is illegal in a large portion of the basin, over 1,200 otter were trapped in the remaining areas in the 1999-2000 season (Fig. 3.22). There were also a number of otter sightings in the portion of the Lake Ontario basin that is closed to otter trapping. The harvest counts found in the trapping records represent only a small percentage of the total populations of mink and otter in the Lake Ontario basin. This provides good evidence that significant numbers of these animals are present in the basin [32].

Mink are located throughout the basin and their populations are stable. River otter, found around the eastern end of Lake Ontario, in central Ontario and along the St. Lawrence River, are now moving into western and central New York as more and more abandoned agricultural land returns to natural conditions. Their expansion has been aided by initiatives like the New York River Otter project that released nearly 300 river otters at several locations in central and western New York.

Figure 3.19 Otter sightings and harvests in the Lake Ontario basin 1999-2000.



Bald Eagle

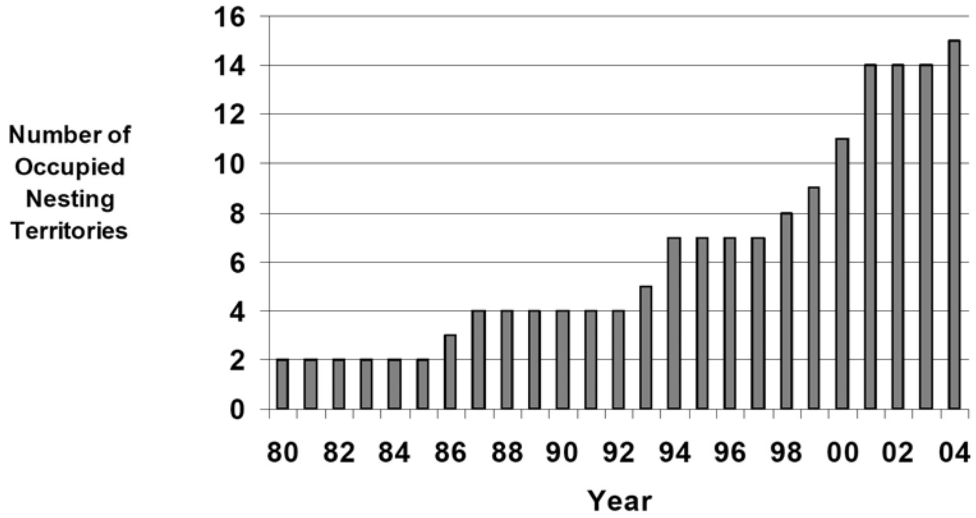
Objective: shoreline and inland bald eagle nesting territories should be established and sustained through natural reproduction throughout the basin
Measures: (1) total number of established bald eagle nesting territories within the Lake Ontario basin, (2) total number of established shoreline nesting territories (defined as those less than 7 kilometers from the lake), and (3) average number of eaglets per nest successfully produced.
Purpose: to measure trends in the recovery and reestablishment of bald eagles within the basin
Targets: all suitable habitat for bald eagle nesting is successfully utilized; average basinwide fledging rates per occupied territory are 1 eaglet per nest or greater.

Status: The number of bald eagle nesting territories within the Lake Ontario basin continues to increase and the 2004 fledging rate was above the 1 eaglet per nest target.

The Bald Eagle is considered by many to be one of the premier ecological indicators of the Great Lakes. In the 1970s there were no active Bald Eagle nesting territories in the Lake Ontario basin. Two eagle nesting territories were artificially established in the basin during the 1980s through the introduction of adult eagles captured in Alaska. Since that time the number of nesting territories has steadily increased. There are now 15 established nesting territories in the basin including 1 shoreline nest[33] (Fig. 3.23). The 2004 average successful reproduction rates for these nests was ~1.5 eaglets per nesting attempt. A minimum reproduction rate of 1.0 eaglet per occupied nesting territory is generally believed to be necessary to maintain stable Bald Eagle populations.

Although good to excellent bald eagle nesting habitat exists along the eastern shoreline of the lake, there were until quite recently no shoreline or island nests. Then in 2000 the first shoreline nesting territory was established and has fledged 1 to 2 eaglets each year since. More eagles are expected to occupy shoreline nesting sites as their numbers steadily increase. Human disturbance has slowed the return of eagles to the shoreline. A few years ago a young hunter shot and killed the female of a Bald Eagle pair engaged in nest building behavior along the lake shore west of Oswego, New York. Restoration of shoreline nesting territories will depend in part on protection of eagle nesting habitats and preventing further human disturbance. A binational eagle working group is developing specific eagle habitat conservation goals and objectives to be included in future reporting on this indicator.

Figure 3.20 Number of Occupied Bald Eagle Nesting Territories in the Lake Ontario basin.



3.4 Cooperative Monitoring Progress Towards Meeting LaMP Goals and Indicators

Having adopted ecosystem indicators, the LaMP has shifted attention to data collection and synthesis. Fortunately, much of this work is already being done through existing federal, state and provincial Great Lakes water quality, biomonitoring and fisheries programs and organizations, such as the Great Lakes Fishery Commission's Lake Ontario Lake Committee, consisting of New York and Ontario fishery managers.

Although the LaMP's primary focus is the development of strategies and actions designed to restore impaired lakewide uses, effective monitoring is required to track progress in achieving its goals. Whenever possible, the LaMP promotes cooperative U.S.-Canadian monitoring efforts in Lake Ontario's open waters, nearshore areas and tributaries. Increased communication and coordination of existing programs are encouraged. The LaMP's cooperative monitoring approach has 3 components: (1) promoting increased communication and coordination among monitoring programs; (2) developing special monitoring projects to answer specific LaMP-related questions; and (3) building on existing monitoring initiatives.

The LaMP is working to better coordinate U.S and Canadian monitoring related to LaMP beneficial uses and ecosystem indicator data needs. The LaMP's information needs can be classified into 4 general categories:

- evaluating the status of beneficial use impairments;
- monitoring environmental levels of critical pollutants;
- measuring progress through the use of ecosystem indicators; and
- providing input to mass balance modeling.

Existing U.S. and Canadian monitoring programs meet most of the LaMP's beneficial use and ecosystem indicator monitoring needs. The findings of these programs are highlighted in LaMP reports and will be used in reporting on selected ecosystem indicators. The LaMP is now working to promote and encourage existing U.S. and Canadian programs to coordinate their efforts, and where possible, expand their efforts as needed to develop a more complete lakewide assessment of current conditions. The LaMP will support these efforts by identifying available equipment, boats and other resources that can support these activities. Additional information regarding U.S. and Canadian tributary monitoring and sediment sampling is provided in Chapter 6.

Lake Ontario fishery researchers have a well-developed binational approach to monitoring and reporting through the efforts of the Great Lakes Fishery Commission's binational Lake Ontario Committee. NYSDEC and OMNR conduct joint hydro-acoustic surveys at key times of the year to evaluate the status of alewife and smelt populations. Binational investigations of eel populations are also being conducted. The findings of these studies, as well as other individual agency studies (such as warm water fish population monitoring and lake trout restoration) are presented at annual Lake Ontario Committee meetings. The Lake Ontario Technical Committee (LOTC) of U.S. and Canadian fishery researchers maintains close contact through an informal network that allows them to efficiently address monitoring issues.

Monitoring programs are often impacted by equipment failure, staffing and budgetary cuts, and/or severe weather events all of which can derail sampling plans. Similar to the LOTC, the LaMP is developing an informal network of contacts involved in monitoring critical pollutants in water, sediment and biota that may be able to assist each other when problems arise. Increased communication will also lead to a better understanding of each other's sampling methods and recognition of opportunities to collaborate. Binational reporting on LaMP ecosystem indicators will further promote communication between various monitoring programs.

Much of the monitoring done in Lake Ontario would not be possible without the support of U.S. and Canadian research vessels. Cooperative monitoring projects in 2003 were supported by:

- ***Lake Guardian*** (180 ft / 54 m)
  U.S. EPA Great Lakes National Program Office
- ***Limnos*** (148 ft / 45 m)
  Canadian Coast Guard
- ***Great Lakes Guardian*** (45 ft / 14 m)
  Ontario Ministry of the Environment
- ***Lake Explorer*** (82 ft / 25 m)
  U.S. EPA Office of Research & Development

3.5 Cooperative Monitoring Projects

The Lake Ontario Lakewide Management Plan has coordinated a number of binational cooperative monitoring efforts to improve our understanding of the Lake Ontario ecosystem. In addition to promoting projects that address key LaMP information needs, emphasis has been placed on improving communication and data sharing between US and Canadian monitoring programs. Often the hardest part of this type of work is pulling together key researchers to interpret the data and to effectively communicate the "big picture" to stakeholders. This type of coordination and data synthesis takes time and effort and the LaMP is committed to making this happen.

In promoting cooperative monitoring the LaMP has broadened its base of partners to help support and strengthen existing efforts. For example, the LaMP's partnership with the Great Lakes Fishery Commission (GLFC) has brought together water quality and fishery managers. The LaMP and the GLFC have identified common information needs that helped guide the development of this year's projects. This may be the first step in developing a long-term binational strategy for Lake Ontario that meets the needs of both water quality and fishery managers.

Three major binational cooperative monitoring projects are summarized in the following sections.

3.5.1 Lake Ontario Atmospheric Deposition Study (LOADS)

Understanding Sources of Atmospheric Contaminants

Atmospheric deposition is one of the important sources of critical pollutants entering Lake Ontario. This project is developing a more detailed understanding of atmospheric deposition processes within the Lake Ontario basin. The results of this study will support the development of contaminant loading mass balance models that are being used to predict how changes in contaminant loadings will impact contaminant levels in fish tissue.

The partners involved in this study include:

Clarkson University
Environment Canada
EC Meteorological Services Canada
New York State Department of Environmental Conservation
Ontario Ministry of the Environment
U.S. EPA Region 2
U.S. EPA Region 5
U.S. EPA Great Lakes National Program Office
U.S. EPA Office of Research & Development
Fredonia College
State University of New York, Oswego
University of Michigan

PCBs, pesticides, dioxins/furans and mercury were measured in air and wet and dry precipitations samples collected from sampling platforms on land and on the lake. Lake water samples were also being collected during 3 cruises. This work will give the LaMP a better understanding of how contaminants enter and leave the lake via atmospheric processes.

Some of the major questions being addressed by this study include:

- How important are the amounts of contaminants entering the lake via atmospheric deposition compared to other sources, such as upstream lakes and in-basin tributaries?
- Does the nature of atmospheric contaminant deposition differ between land and lake sampling locations?
- How significant are urban sources of atmospheric contamination?

Some of the data from the study is now available and summarized in Chapter 6 of this LaMP Status Report.

3.5.2 Lake Ontario Lower Aquatic Food web Assessment (LOLA)

Understanding Changes in a Post-Zebra Mussel Food web

This project developed a better understanding of the changes that are occurring in Lake Ontario's lower aquatic food web and its ability to support fish populations. The introduction of exotic species such as zebra & quagga mussels has changed the way nutrients are cycled through Lake Ontario's food web impacting the productivity of fisheries and threatening efforts to restore naturally reproducing populations of native fish. The effects of recently introduced exotic zooplankton which may also negatively impact native zooplankton communities is not well understood. The LaMP recently listed 2 new lakewide impairments, degraded benthos and degraded nearshore phytoplankton, probably related to the disruption of the food web by zebra and quagga mussels. The LaMP and the GLFC both agree that the need for better information on the lower food web is a high priority.

Partners involved in this project included:

Great Lakes Fishery Commission
National Oceanic & Atmospheric Administration
Cornell University
U.S. EPA Great Lakes National Program Office
U.S. EPA Office of Research & Development, Duluth
University of Toronto
State Univ. of New York, Environmental Sciences & Forestry
Lake Ontario LaMP Parties (EC, EPA R2, OMOE, OMNR, DFO, NYSDEC, USFWS)

4 sampling cruises (April, August, September & October) were conducted with the assistance of U.S. EPA's vessel Lake Guardian and the Canadian Coast Guard's vessel Limnos. Approximately 30 stations per cruise were sampled along 4 north-south transects. Nutrient, phytoplankton, zooplankton, mysid (a type of freshwater shrimp) and benthic samples were collected in order to characterize the status of Lake Ontario's lower food web. The use of optical plankton counters, a new remote sensing technology, was also explored as a tool to collect information on the status of zooplankton communities. Data interpretation and report writing is being coordinated among U.S. and Canadian partners. Pre-zebra mussel lower aquatic food web surveys conducted in the 1980s will provided a historical point of comparison for these results.

Some of the questions that were addressed include:

- What types of organisms make-up the lower aquatic food web?
- Have exotic species had negative impacts on native benthic organisms and zooplankton?
- Can the lower aquatic food web continue to support existing recreational and sport fisheries?

The project's findings and recommendations are being used to guide the development of better coordination between US and Canadian monitoring programs. The final report is available on U.S. EPA GLNPO's website.

3.5.3 Interagency Laboratory Comparison Study

Understanding Differences in Analytical & Sampling Methods

Accurately measuring extremely low (i.e. parts per trillion) concentrations of critical pollutants is very difficult. The use of different sampling methods and laboratory techniques may provide different results for the same sample due to slight differences in the ability of various methods to capture and measure contaminants. This project was designed to give the LaMP a better understanding of how well the analytical results produced by U.S. and Canadian monitoring programs compare with each other and will allow the LaMP agencies to combine their data sets with confidence to better characterize the lakewide environmental conditions.

Partners involved in this project include:

Environment Canada
U.S. EPA Region 2
Ontario Ministry of the Environment
New York State Department of Environmental Conservation

Samples containing PCBs, pesticides and PAHs were carefully prepared in the lab and split 4 ways and analyzed by laboratories that perform analytical work for the LaMP. The results are now being carefully reviewed to identify any data comparability issues. Later stages of this study will include the collection and analysis of actual field samples at Niagara-on-the-Lake.

Some of the major questions to be addressed through this study include:

- How well do analytical results produced by U.S. and Canadian laboratories compare?
- Does the use of different sampling methods produce similar results?

3.6 Other Indicator Initiatives

Work is on-going to develop habitat indicators. In particular the Great Lakes Wetlands Consortium is involved in a number of studies that will hopefully lead to the development of a set of wetland habitat indicators. The use of walleye or other selected nearshore fish species indicators may also be considered as part of future LaMP indicator development work.

3.7 Actions and Progress

This 2006 Chapter update is the first time that the LaMP is reporting out on the status of its selected ecosystem indicators. Given the rapid rate of unanticipated changes occurring in response to the disruption of the lower aquatic food web by non-native invasive species, the relevance of these selected indicators and targets will need to be periodically re-evaluated. The development and use of the LaMP's ecosystem indicators has helped to demonstrate the need to maintain strong Lake Ontario monitoring programs. The status of these indicators will continue to be reported on in future LaMP reports and public meetings.

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