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2008 Lake Ontario Lakewide Fishery Assessment

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2008 Lake Ontario Lakewide Fishery Assessment

Final Study Completion Report
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Rationale

The U.S.-Canada Lake Ontario Lakewide Management Plan (LaMP) uses the status of lake trout, a keystone native species, as one indicator of the relative "health" of the aquatic ecosystem. A bi-national program to restore lake trout to Lake Ontario has been on-going for more than 35 years. A cooperative New York State Department of Environmental Conservation (NYSDEC) and U.S. Geological Survey (USGS) gill net survey targeting lake trout has been conducted in U.S. waters each September since 1980 and with cooperation of Ontario Ministry of Natural Resources (OMNR) was undertaken in Canadian waters during 1985-1995. The program provides science support for natural resource managers by investigating the factors that contribute to the restoration and conservation of lake trout; develops research and technology tools for developing and evaluating adaptive management strategies to sustain stocked and naturalized lake trout populations; and enhances research capabilities to provide support and technical assistance to Federal and State government agencies and non-governmental organizations for natural resource management problem solving and decision making

Project Objective

Examine the lakewide status of the lake trout population in Lake Ontario. Examine how ecosystem changes have affected the relative health and reproductive potential of lake trout in the presence of a new prey species, round goby. While appearing to lack thiaminase, round gobies consume invasive dreissenids and therefore may be linked to a variety of nutritional consequences spanning the spectrum from new connections for ecosystem energy flow to transfer of harmful contaminants and potentially lethal pathogens.

Project Cooperators

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Project Funding Sources

In addition to agency funding to conduct the survey and process samples (USGS, OMNR, NYSDEC), supplementary funding was provided by: EPA, Canada Ontario Agreement, OMNR, and the University of Windsor.

Products:

- First whole lake fall gill net assessment completed since 1995 facilitating comparison of demographic patterns over dramatic changes in ecosystem status and management approaches.
- Tissues samples collected from 481 lake trout encompassing different strains, ages, and geographic locations.
- Ongoing tissue sample analyses include stable isotopes, fatty acids, and thiamine content.
- Samples from historic lake trout tissue archives (DFO/EC) will be analyzed to see if current patterns (strain, age, location) and overall health has changed through time.
- Ongoing tissue analyses include samples from preyfish collected in 2008-2010 and samples from historical archives.
- Results of demographic sampling and tissue analyses will be used to relate the health and nutritional composition of a top predator to its diet using a state-of-the-art diet assessment that combines short term (stomach contents) and long term (stable isotopes) indicators.

Introduction

Historically, lake trout (*Salvelinus namaycush*) were the most abundant native deepwater predators in the offshore waters of Lake Ontario. By the 1950s they were extirpated due to over-fishing and sea lamprey (*Petromyzon marinus*) predation. Restoration of a naturally reproducing population of lake trout 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 cooperating agencies (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 (Schneider et al. 1983, 1997). The bi-national program to restore lake trout to Lake Ontario has been on-going for more than 35 years. The Lake Ontario LaMP has adopted the lake trout targets developed through this process and articulated in the 1997 restoration plan:

- 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;

- 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;

- lamprey wounding should be no more than 2.0 A1 wounds per 100 lake trout >433 mm.

To measure progress, a cooperative state (NYSDEC) and federal (USGS) gill net survey targeting lake trout has been conducted in U S waters each September since 1980. During 1985 to 1995, in cooperation with Ontario Ministry of Natural Resources, Canadian waters were surveyed using the same standardized procedures and at the same time as U.S. waters. The Canadian sites were dropped from the survey in 1996 due to financial constraints. Since that time, limited catches of lake trout from OMNR community index sampling, not designed to target lake trout, have been used to gauge progress towards restoration in Canadian waters and to compare with trends from the still ongoing standard lake trout survey in U.S. waters. The scattered low catches from the Canadian nets have exhibited trends in important population characteristics (e.g., abundance and condition) that often diverged from those observed from the standard U. S. survey designed to target lake trout. Data from both surveys, however, clearly show that survival of stocked yearling lake trout has been very low since 1992 and that numbers of mature fish declined dramatically in 1999 and again in 2005. Current abundance of mature lake trout is far below restoration objectives (Objective 1, Schneider et al. 1997) and the reason for poor survival of stocked fish remains unexplained.

In addition to agency restoration objectives, the U.S.-Canada Lake Ontario Lakewide Management Plan (LaMP) uses the status of lake trout, a keystone native species, as one indicator of the relative "health" of the aquatic ecosystem. The USGS mission for the index gill netting program is to provide science support for natural resource managers by investigating the factors that contribute to the conservation and recovery of native lake trout; develops research and technology tools for developing and evaluating adaptive management strategies to sustain stocked and naturalized lake trout populations; and to enhance research capabilities to provide support and technical assistance to DOI bureaus and other Federal and State government agencies and non-governmental organizations for natural resource management problem solving and decision making.

The "Lake Ontario 2008 Intensive Sampling/Cooperative Monitoring Year" organized by EPA Region 2 in cooperation with USGS, USFWS, NYSDEC, OMNR, DFO, Ontario Ministry of the Environment, and several universities sought a focused intensive examination of the Lake Ontario ecosystem, an ecosystem where lake trout was once the historical top predator and was sustained through natural reproduction. The Intensive Monitoring Year coupled with the changing state of the ecosystem and the depressed lake trout population, presented an ideal opportunity to reinstitute the whole lake standard lake trout survey. During September 2008 USGS, NYSDEC and OMNR participated in the first whole lake survey since 1995. During this survey all U.S. shore locations that have been sampled annually since 1980 were again sampled by USGS and NYSDEC. The USGS used their vessel, the RV Kaho, to sample the four locations on the Canadian western shore not reachable by OMNR vessels and OMNR sampled the remaining locations along the central and eastern north shore. In the furtherance of EPA Region 2's and USGS's shared Great Lakes fishery restoration goals and objectives to guide future fishery-related management decisions, EPA and USGS entered into this cooperation Interagency Agreement (IA), which provided $11,140 in EPA resources and $38,191 in USGS resources towards the Lake Ontario fishery assessment project.

EPA and the USGS are both keenly interested in determining the status of Lake Ontario's fishery, in particular the status of lake trout which is considered to be the most important native top level predator fish. The U.S.-Canada Lake Ontario Lakewide Management Plan uses the Great Lakes Fishery Commission, Lake Ontario Committee's lake trout restoration objectives and indicators (Schneider et al. 1983, 1997) to evaluate the status of lake trout populations. EPA is the U.S. federal lead for the Lake Ontario LaMP and will be using the information collected by the 2008 whole-lake assessment in future LaMP reports. The USGS will incorporate this information into their routine fishery assessment reports that are part of their ongoing mission.

Methods

During September 2008, the first whole-lake trout assessment was accomplished using research vessels (RV) from the USGS Lake Ontario Biological Station, the NYSDEC Cape Vincent Fisheries Research Station, and the OMNR Glenora Fisheries Research Station. The USGS R/V Kaho sampled eleven sites, seven in U.S. and four in Canadian waters; the NYSDEC R/V Seth Green sampled nine sites in U.S. waters; and the OMNR RV Steelcraft sampled six sites in Canadian waters (Figure 1). Survey gill nets consisted of nine, 15.2- x 2.4-m (50 x 8 ft) panels of 51- to 151-mm (2- to 6-in stretched measure) mesh in 12.5-mm (0.5-in) increments. Standard survey design consisted of deploying four survey nets along randomly chosen transects, parallel to contours beginning with the first net set at the 10 ºC isotherm and proceeding deeper with each set in 10-m (32.8-ft) increments. At two sites in U.S. waters of the eastern basin, a total of six nets were fished covering two or three sequentially deeper locations per site and ranging in depth from 20 to 50 m. At four locations in Canadian waters of the Kingston Basin sites were added to extend the geographic spread and range of depths of the standard ongoing Community Index survey sets made late in August, and the combined data from those samples were used to index the sites that were fished during the 1985-1995 historical combined survey.

In addition to the standard survey net sets, deep sets were fished at four locations (2 U.S. and 2 Can.) to determine if lake trout depth distributions had shifted deeper into the lake beyond the range of our standard net sets. At Sodus and Oak Orchard along the U.S. shore the RV Kaho deployed nets according to the standard protocol and the RV Seth Green set nets at four sequentially 10 m deeper depths than the deepest set by the RV Kaho. At Port Hope and Point Traverse along the Canadian shore the OMNR RV Steelcraft added four deep sets to the standard sets, the first three at 20m intervals beyond the last regular set, the fourth set at 140m.

For all lake trout captured, total lengths and weights were measured, stomachs were emptied and prey items enumerated, fin clips were recorded, and coded wire tags (CWT's) were removed when present. Sex and maturity of lake trout were determined by visual inspection of gonads. Sea lamprey wounds on lake trout were counted and graded according to King and Edsall (1979) and Ebener et al. (2006). In addition to standard measurements, two tissue samples were collected from each fish by slicing off 25 mm cubes of dorsal muscle tissue just anterior of the dorsal fin. Tissue samples were immediately sealed in 500 ml Whirl-Paks® and preserved by freezing on dry ice for later analyses of stable isotopes, fatty acids and thiamine concentration.

Demographic analyses included: an index of population abundance in the form of catch per unit effort (CPUE); cohort specific survival calculations for fish marked with coded wire tags; an index of adult condition calculated from both the predicted weights of a 700-mm fish from annual length-weight regressions and from "Fulton's K" (Ricker 1975, Nash et al. 2006) for age-6 males; an index of population reproductive potential estimated by calculating annual egg deposition indices from catches of mature females; and an index of the intensity of sea lamprey predation on lake trout. A complete description of the methods and results for the above analyses (Lantry and Lantry 2009) is provided in Appendix 1.

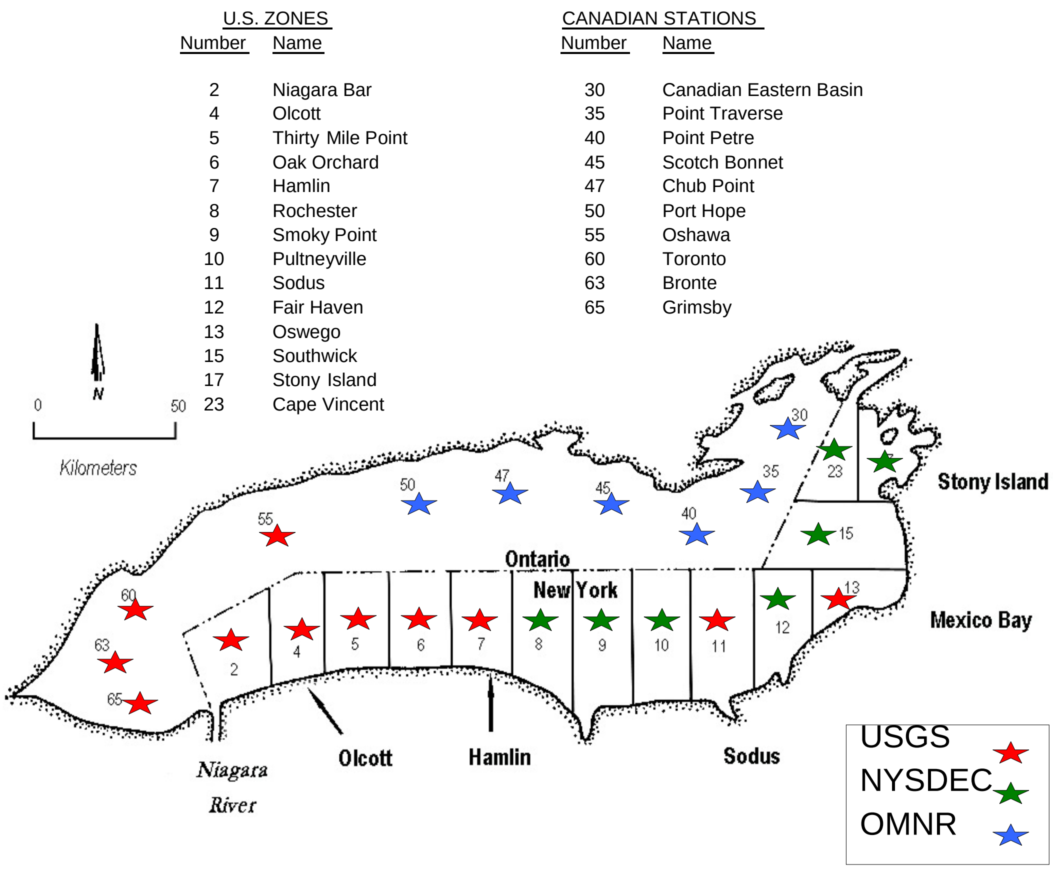


Figure 1. Sites sampled during the 2008 whole-lake lake trout assessment.

Results
A total of 492 lake trout were captured lakewide during the 2008 survey, 74 in Canadian waters and 418 in U.S. waters. Tissue samples were collected from 481 lake trout. Of the 418 lake trout caught in U.S. waters, 407 were caught in standard sets and 11 were caught in deep sets at areas 6 and 11. Of the 74 lake trout caught in Canadian waters 72 were caught in standard sets and 2 were caught in deep sets. Low catches in all deep sets did not support the idea that lake trout depth distribution had moved deeper in the lake.

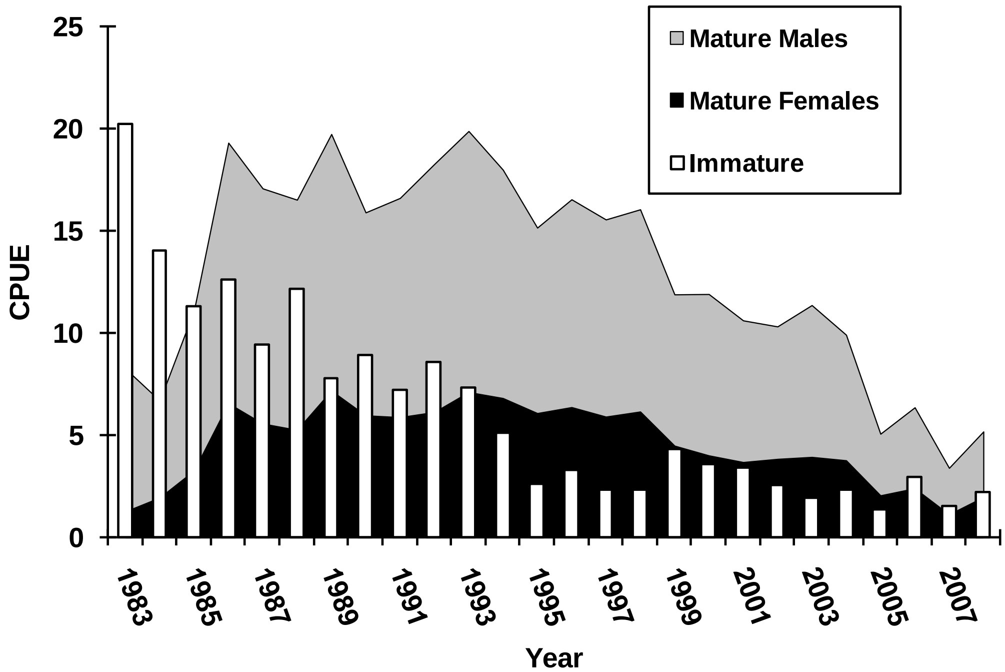
Demographic parameters for U.S. catches were reported in Lantry and Lantry (2009) (Appendix 1). The CPUE of adult lake trout in U.S. waters (5.2) declined by 70% below the average for 1985-1995 (17.1, Figure 2). The CPUE for adult lake trout captured at all Canadian sites (1.3) was 87% below the average observed during 1985-1995 (9.7).

During 1985-1995, U.S. catches were on average 1.9 times greater than Canadian catches likely due to greater numbers stocked in U.S. waters and a greater distance between depth contours on the Canadian side of the lake which would tend to spread fish out over greater distances and decrease catchability. In 2008 catches from U.S. waters exceeded catches from Canadian waters by about four times. This increase may be due to the change in stocking locations in Canadian waters following the 1993 reduction in lake wide stocking targets (i.e., abandonment of stocking locations along the central Canadian shoreline and concentration of stockings along the extreme eastern and western parts of the lake). Stocking locations and the proportions released at each location in U.S. waters were essentially unchanged.

Calculating the CPUE of lake trout at the three locations nearest the Canadian stocking sites in 2008 revealed nearly a 3-fold greater catch rate (3.5) than the average for all Canadian sites. The CPUE for those particular three Canadian sites was 64% below the 1985-1995 average for all Canadian sites which was less of a decline than experienced lakewide. The ratio of U.S. to Canadian catch for those three sites (1.5) was more similar to the mean ratio for 1985-1995 (1.9) than the 2008 value calculated using all Canadian sites (4.1). Movement of stocking sites on the Canadian side of the lake after 1993 was done in part to concentrate the reduced numbers being stocked near areas of known good spawning habitat and, given the preceding results, appears to have been somewhat successful. However, the change in stocking allocation has created an area devoid of lake trout along most of the central northern shore which, beyond issues of natural reproduction, has important implications for decreased potential for ecosystem stability related to the absence of a native top predator.

A total of 456 lake trout were examined for stomach contents. Examination of the relationship between predator and prey length indicated that the size of prey consumed increased substantially after lake trout reached 400mm so diet summaries were calculated separately for lake trout above and below this threshold. The percentage composition by weight of the diet of Lake trout <400mm consisted of 27.8% round goby (*Neogobius melanostomus*), 33.0% slimy sculpin (*Cottus cognatus*), 11.1% rainbow smelt (*Osmerus mordax*) and 28.1% *Mysis relicta*. The percentage composition by weight of the diet of lake trout ≥400mm consisted of 86.0% alewife (*Alosa pseudoharengus*), 7.1% round goby, 0.54% slimy sculpin, 5.3% rainbow smelt, 0.54% unidentified salmonids and 0.54% *Mysis relicta*.

a.



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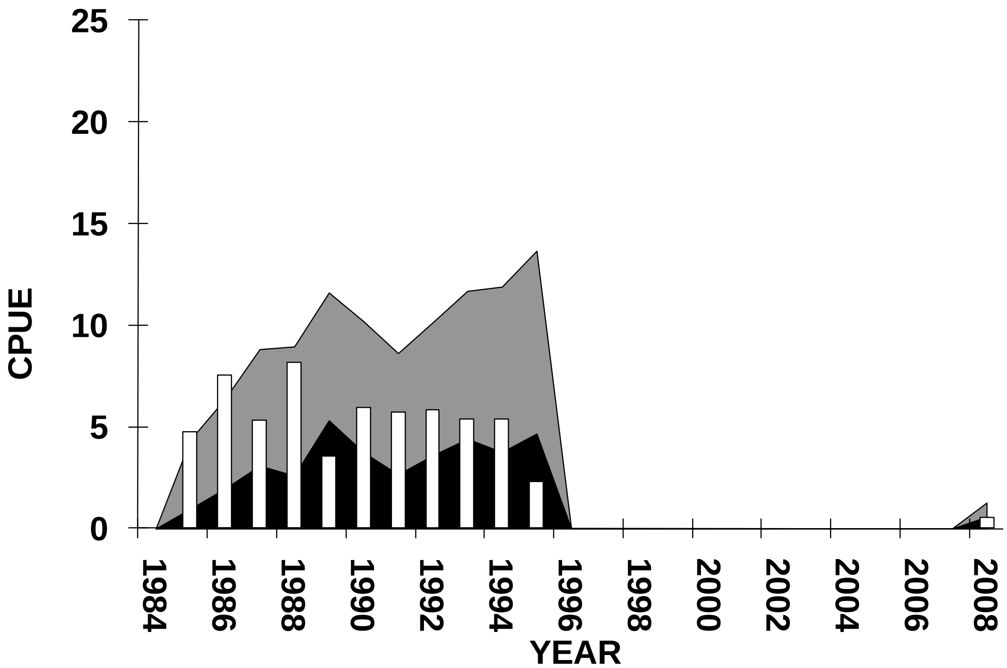

Figure 2. Abundance of mature and immature (sexes combined) lake trout calculated from catches made with gill nets set in U.S. (panel a) and Canadian (panel b) waters of Lake Ontario, during September 1983-2008. CPUE is catch per net. The survey was not performed in Canadian waters during 1996-2007and panel b provides no indication of CPUE for that time period.

Related Tissue Studies

The 2008 lakewide lake trout assessment provided a perfect opportunity to collect and provide tissue samples to researchers seeking to gain insights on lake trout feeding habits, productivity and reproductive health by studying lake trout fatty acids, stable isotopes and thiamine. Tissue analyses are being performed by a diverse group of cooperators with funding external to the EPA/USGS Interagency Agreement (IA No. DW14942144-01-1). Researchers cooperating on these analyses include: Aaron Fisk, Gord Paterson, Scott Rush, Ken Drouillard, and Doug Haffner at the University of Windsor, ON, Can.; Tim Johnson at OMNR, Picton, ON, Can.; Michael Arts at EC National Water Research Institute, Burlington, ON, Can.; Craig Hebert at EC National Wildlife Research Centre, Ottawa, ON, Can.; Dale Honeyfield at the USGS Northern Appalachian Research Laboratory, Wellsboro, PA; and John Fitzsimons at DFO Bayfield Institute, Burlington, ON, Can.

Tissue samples collected from 481 lake trout were grouped into age and size related pools representing four geographic delineations of the lake representing the Northeast, Northwest, Southeast and Southwest. From the initial pool of 481 samples, samples from 420 individuals (227 males, 191 females, and 2 of unknown sex) were analyzed for ratios of the stable isotopes of carbon (δ13C) and nitrogen (δ15N). Preliminary trends in depletion of the stable isotope of carbon as lake trout length increases is suggestive of depth related feeding differences or perhaps reductions in overall lake wide productivity.

Samples from 131 of the 420 individuals analyzed for stable isotopes are also being analyzed for fatty acids. Expected parallel trends in fish size, fat content and essential fatty acid composition have been observed thus far, but further results await completion of the analyses for the entire sample.

Ongoing analyses also include: muscle thiamine assays for tissues samples from approximately 80 lake trout; April/May 2010 collections of the primary prey for lake trout (alewife, rainbow smelt, slimy sculpin and round goby) at shallow and deep depths at sites along the southern shore for continued analyses of stable isotopes and fatty acids; and a retrospective analysis of lake trout and prey fish stable isotope and fatty acid composition from tissue samples archived by Environment Canada and Department of Fisheries and Oceans Canada.

Summary

By the mid-1990's most of the strategies and objectives set forth in the 1983 and 1990 restoration plans (Schneider et al. 1983, 1990) for adult annual survival (≥ 60%), average age of mature females in the population (7.5 years), sea lamprey predation (< 2.0 fresh wounds per 100 lake trout >433 mm), angler harvest (30,000 in U.S. and <10,000 in Canadian waters) and observations of naturally produced lake trout in assessment catches had been met. In 1997, the measures and tactics used to foster lake trout restoration were refined in a new restoration plan reflecting the success achieved since the previous plans and the appearance of age-0 and age-1 naturally reproduced lake trout in assessment catches. These measures were adopted in the Lake Ontario LaMP as indicators of health of the lake trout population. Ecosystem changes and lake trout stocking cuts in the early 1990s coincided with recruitment declines for stocked yearling lake trout. Low recruitment since that time resulted in a precipitous decline in adult abundance between 1998 and 1999 followed by another as yet unexplained decline in adult numbers between 2004 and 2005. Continued low recruitment and low adult numbers has lead to a substantial set back of lake trout restoration in Lake Ontario which is described below in terms of the five LaMP measures.

1) - Abundance of at least 2.0 mature female lake trout larger than 4,000 grams per standard gillnet.

Schneider et al. (1983, 1997) established target CPUEs of 2 and 1.1 for sexually mature female trout (≥ 4,000 g weight) in U.S. and Canadian waters, respectively. Those values reflected the level of abundance at which successful reproduction became detectable in the early 1990s. The CPUE for mature females in U. S. waters reached the target value (2) in 1989 and fluctuated about the value until 1992 (Figure 3). From 1992 until 2004, the CPUE exceeded the target, but fell below target during 2005 to 2008, coincident with the decline of the entire adult population. The 2008 CPUE for Canadian waters (0.3) was also below target.

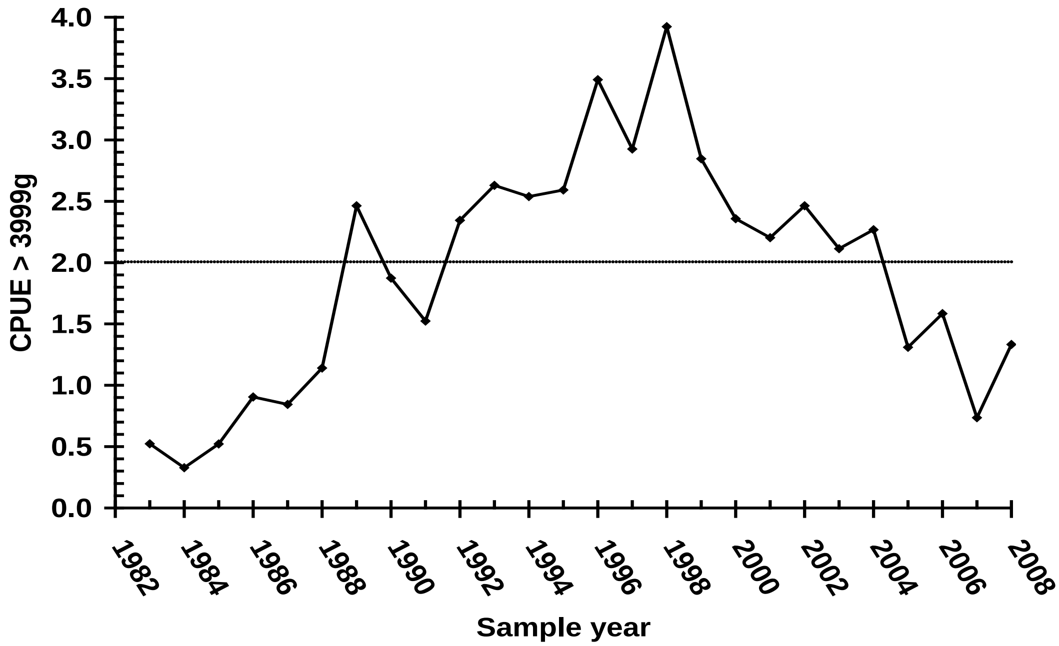

Figure 3. Abundance of mature female lake trout ≥ 4000g calculated from catches made with gill nets set in U.S. waters of Lake Ontario, during September 1983-2008. The dashed line represents the target CPUE from Schneider et al. (1997).

2) - Abundance of naturally-produced mature female lake trout greater than 0.2 in U.S., and 0.1 in Canadian waters per standard gillnet.

Lake trout without fin clips or tags are currently being caught in assessments, however, techniques to differentiate between adult lake trout of naturally reproduced origin and adults of stocked origin that were not properly marked are not currently available. Reliable techniques to differentiate between stocked and naturally reproduced fish based on otolith stable isotopes are currently being tested (Schaner et al. 2007). Preliminary results show great promise and indicate that this technique should permit assessment of this objective in the future.

3) - Harvest of lake trout not to exceed 30,000 fish per nation.

The annual harvest of lake trout from U.S. waters of Lake Ontario declined over 90% since restrictive angling regulations were instated in 1992 in U.S. waters (Lantry and Eckert 2009; Figure 4) and in 2008 both U.S. and Canadian harvest remain well below the target.

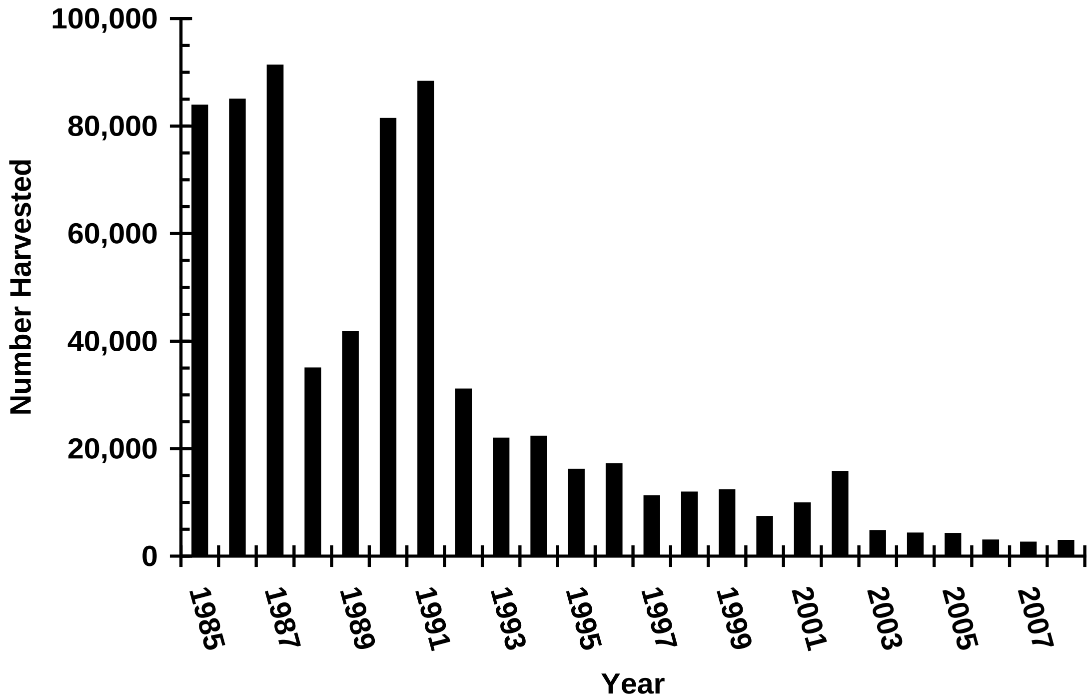

Figure 4. Estimated numbers of lake trout harvested by boat anglers from U.S. waters of Lake Ontario, 1985 – 2008 (Lantry and Eckert 2009).

4) - An abundance of naturally produced age 2 lake trout of at least 26 individuals from July bottom trawls in U.S. waters and increased over current levels in Canadian waters.

In 2008, only one naturally produced (wild) age-2 lake trout (278 mm, 10.9 in) was caught from all USGS and NYSDEC assessment surveys. Survival of naturally produced lake trout to the fingerling stage in summer and fall occurred each year during 1993-2006 (Figure 5) representing production of 14 consecutive year classes. We caught no wild yearling lake trout during 2005-2008 and have no evidence of a naturally produced year class in 2007. Low numbers of small (<100 mm, 3.9 in), wild fish captured in recent years (1997-2008) may be due in part to a change in our trawl gear that was necessary to avoid abundant dreissenid mussels. Our new bottom trawls do not fish as hard on bottom as the old gear and are not as efficient at capturing small benthic fishes.

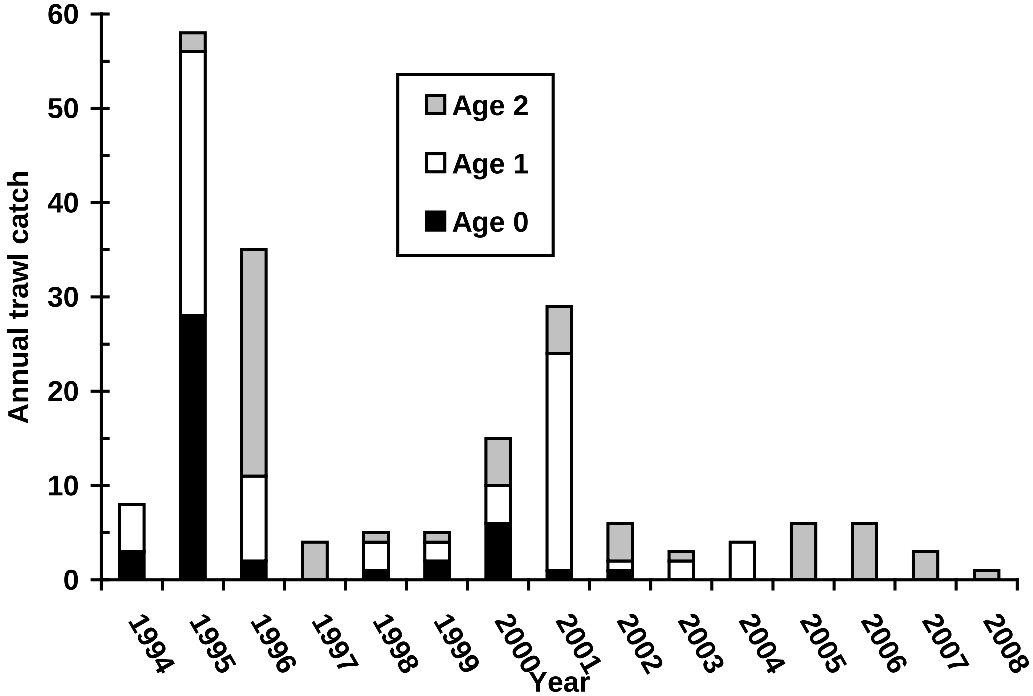

Figure 5. Numbers and ages of naturally produced (wild) lake trout captured with bottom trawls in Lake Ontario by NYSDEC and USGS, 1994-2008. During 1980-1993, only one naturally produced lake trout was captured with bottom trawls.

5) - Sea lamprey wounding should be no more than 2.0 A1 wounds per 100 lake trout over 433 mm.

In 2007, the A1 wounding rate for U.S. waters was 2.35 times above the target level, but by 2008 wounding fell below the target level to 1.47 wounds per 100 lake trout. Wounding was also low in Canadian waters in 2008 where there were no fresh wounds observed on any of the 74 lake trout collected. Wounding rates are related to sea lamprey abundance, host density, and lake trout strain composition. Variation in A1 wounding rates was likely more related to changes in lake trout abundance during 1993-2002 as estimates of sea lamprey abundance appeared to be near target levels. Sea lamprey abundance seemed to play a greater role in wounding rates during 2003-2008 when sea lamprey abundance rose above target levels during 2003-2005 and again in 2007, and fell back to target levels in 2006 and 2008.

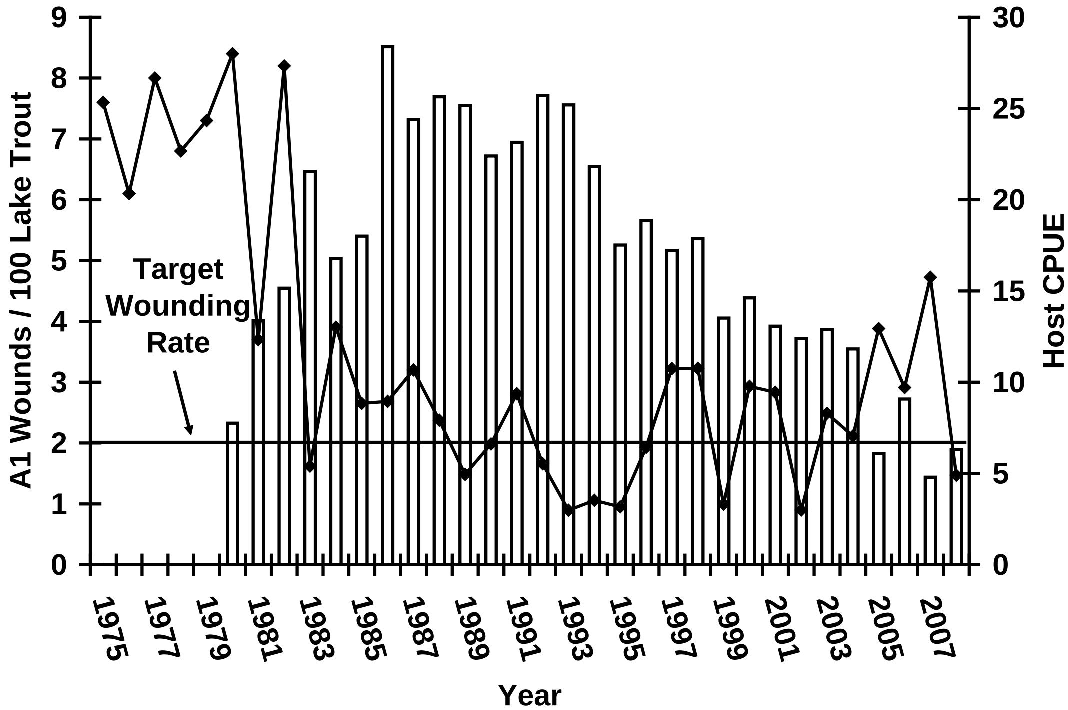

Figure 6. Wounding rates (A1 wounds per 100 lake trout, line) inflicted by sea lamprey on lake trout longer than 433 mm (17.1 in) TL and the CPUE of lake trout hosts (> 433 mm TL, bars) collected from Lake Ontario in fall, 1975 – 2008.

In addition to recent setbacks in the demographic measures of restoration success, the continued colonization of Lake Ontario with invasive species presents un-resolved implications for restoration. One such invasive, the round goby, was first reported from western Lake Ontario in 1998 but did not become abundant enough to show up in agency assessment trawling until 2002. The results of diet analyses for the 2008 whole-lake survey, however, indicated that round gobies have become important food for lake trout currently making up about 27.8% and 7.1% of the September diets of small and large lake trout, respectively. While these September diet estimates show the potential importance of this new prey fish to lake trout in autumn the results of ongoing stable isotope and fatty acid analyses will help to show how important round gobies are to lake trout year round. Preliminary information for thiaminase determinations for round gobies indicated that they are relatively low in this destructive enzyme when compared to alewives. The ongoing thiamine determinations for lake trout tissue samples collected in this study will help determine whether inclusion of this new prey in lake trout diets may improve their reproductive health and further restoration goals towards natural reproduction.

Management Implications and Future Research

Lake trout abundance in Lake Ontario is now at a low level that has not been observed since modern restoration efforts began in the 1970s. However, the continued observations of small numbers of naturally spawned age-2 lake trout in assessment surveys and the appearance of mature lake trout of suspected natural origin, despite low abundance of the stocked population, is encouraging. Changes in stocking policy for Canadian waters in the early 1990s has produced a situation where lake trout along the north shore are concentrated in the west and east and suggests that the lakewide indicators of restoration progress used in the past for this part of the lake are in need of re-evaluation. In addition, this absence of lake trout along the central northern shore may be decreasing ecosystem stability and resistance to invasive species affects. Low lake trout abundance also seems to have positive implications for native preyfish recovery. Concurrent with lake trout declines, native deepwater sculpin (*Myoxocephalus thompansonii*) have reappeared (Lantry et al. 2007) and their recovery may indicate an enhanced opportunity exists for restoration of extirpated native deepwater coregonines. The results from this study thus far indicate that it would be beneficial to periodically repeat the whole lake survey and the five year interval of the EPA/EC Great Lakes cooperative monitoring cycle seems adequate and presents an ideal opportunity for researchers from this and other programs to share data and sampling infrastructure. Periodic lakewide lake trout assessments will extend annual monitoring of the condition of the lake trout population for the southern and north eastern areas of the lake to the whole lake and provide opportunity for assessment along the north shore. The whole lake surveys will also provide opportunities to calibrate between the annual USGS/NYSDEC standard lake trout assessments along the south shore and the OMNR community index netting occurring in the northeast portion of the lake; and an opportunity for collection of tissue samples for periodic examination of dietary trends and reproductive health.

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Appendix 1

Lake Trout Rehabilitation in Lake Ontario, 2008

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Abstract

Each year we report on the progress toward rehabilitation of the Lake Ontario lake trout Salvelinus namaycush *population, including the results of stocking, annual assessment surveys, creel surveys, and evidence of natural reproduction observed from all standard surveys performed by USGS and NYSDEC. During 2008, the number of yearling lake trout stocked in May (500,908) was at the target level of 500,000. The adjusted catch of age-2 lake trout with bottom trawls during the juvenile lake trout survey remained low and was 88% below the mean for the 1983-1989 year classes. Adult lake trout catch per unit effort from the gill net survey was 70% below the 1986-1998 average. The rate of wounding by sea lamprey* Petromyzon marinus *on lake trout caught in gill nets was 1.47 fresh (A1) wounds per 100 lake trout and was below target for the first time in six years. Estimates from the NYSDEC fishing boat survey indicated that, for the third consecutive year, angler catch, harvest, and harvest rate of lake trout remained near record lows. The condition of adult lake trout, indexed from annual length–weight regressions, increased from the reduced levels observed during 2004-2006 to a level equivalent to the high levels observed during 1996-1999. The improved condition for juvenile lake trout observed in 2006 and 2007 continued in 2008 and remained above the mean for the data series. Reproductive potential for the adult stock in 2008, determined from the annual egg deposition index, fell to a level 76% below the 1993-1998 mean. One age-2 naturally produced lake trout was collected in survey catches providing evidence of a 2006 year class, but age-1s were absent for the fourth consecutive year.*

Introduction

Restoration of a naturally reproducing population of lake trout (*Salvelinus namaycush*) 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 cooperating agencies (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 (Schneider et al. 1983, 1997), identifying a goal, interim objectives, and strategies. The present report documents progress towards restoration through 2008.

Methods

<u>Adult Gill Net Survey:</u>
During September 1983-2008, adult lake trout were collected with gill nets at random transects within 14 to 17 geographic areas distributed uniformly within U. S. waters of Lake Ontario. Survey design (size of geographic areas) and gill net construction (multi vs. mono-filament netting) has changed through the years. For a complete description of survey history including gear changes and corrections see Elrod et al. (1995).

During September 2008, USGS R/V *Kaho* and NYSDEC R/V *Seth Green* fished standard gill nets for adult lake trout at 14 geographic locations encompassing the entire U.S. shore in

Lake Ontario. Survey gill nets consisted of nine, 15.2- x 2.4-m (50 x 8 ft) panels of 51- to 151-mm (2- to 6-in stretched measure) mesh in 12.5-mm (0.5-in) increments. At 12 sites in the lake's main basin, four survey nets were fished along randomly chosen transects, parallel to contours beginning at the 10ºC (50ºF) isotherm and proceeding deeper in 10-m (32.8-ft) increments. At two sites in the eastern basin, a total of six nets were fished covering two or three sequentially deeper locations per site and ranging in depth from 20 to 50 m.

For all lake trout captured, total lengths and weights were measured, stomachs were emptied and prey items enumerated, fin clips were recorded, and, when present, coded wire tags (CWT's) were removed. Sex and maturity of lake trout were determined by visual inspection of gonads. Sea lamprey *Petromyzon marinus* wounds on lake trout were counted and graded according to King and Edsall (1979) and Ebener et al. (2006).

A stratified catch per unit effort (CPUE) was calculated using four strata based on net position from shallowest to deepest. Depth stratification was used because effort was not equal among years and catch per net decreased uniformly with increasing depth below the thermocline. To examine variability in CPUE between years, the relative standard error was calculated (RSE = 100% * {standard error / mean}).

Survival of various year classes and strains was estimated by taking the antilog of the slope of the regression of ln(CPUE) on age for fish that received coded wire tags of ages 7 to 11. Catches of age-12 and older lake trout were not used in calculations because survival often seemed to greatly increase after age 11 and catch rates were too low to have confidence in estimates using those ages (Lantry et al. 2006).

Adult condition was indexed from both the predicted weights of a 700-mm fish calculated from annual length-weight regressions based on all lake trout caught that were not deformed, and from "Fulton's *K*" (Ricker 1975, Nash et al. 2006) for age-6 males:

$K = (WT/ TL^3)*100,000$;

where WT is weight (g) and TL is total length (mm). We grouped data across strains because Elrod et al. (1996) found no difference between strains in the slopes or intercepts of annual length-weight regressions in 172 of 176 comparisons for the 1978 through 1993 surveys.

Population reproductive potential was estimated by calculating annual egg deposition indices from catches of mature females in September gill nets, length/age-fecundity relationships, and observed differences in mortality rates among strains. Appropriate length-fecundity relationships were determined from the fecundity of individual lake trout collected with gill nets in September and early October each year during 1977-1981 and in September 1994 (O'Gorman et al. 1998). During 1977-1981, fecundity-length relationships were not different among fish of various ages but in 1994, age-5 and age-6 fish had fewer eggs per unit length (P<0.003) than age-7 fish, and age-7 fish had fewer eggs per unit length (p<0.003) than fish of ages 8, 9, or 10. This suggests that at some point between the early 1980s and the mid 1990s, age began to influence fecundity. The lake trout population in the earlier period was small with few mature fish whereas the population in the 1990s was relatively large with many mature fish (Elrod et al. 1995).

Elrod et al. (1996) demonstrated that the weight of a 700-mm mature female lake trout was much greater during 1978-1981 than during 1982-1993 and they attributed the better condition during 1978-1981 to a lack of competition for food or space at low population levels. Therefore, we used the fecundity-length regression for 1977-1981 to calculate indices of egg deposition during 1980-1981 and the fecundity-length regressions for 1994 to calculate indices of age and size related egg deposition during 1982-2008. To account for sea lamprey induced mortality that occurred between September gill net sampling and November spawning, we reduced catches of mature females, other than Seneca strain fish, by $1 – e^{[-(ZSEN-ZSUP)]}$. Where ZSEN = instantaneous rate of total mortality for Seneca Lake strain, and ZSUP = instantaneous rate of total mortality for Lake Superior strain. Elrod et al. (1995) reported that mature SUP lake trout had a higher annual mortality rate than mature SEN fish. The difference was most likely due to the large numbers of SUP fish killed each fall by sea lamprey. Because SUP fish were present in large numbers throughout the study period, they were our standard for judging mortality rates of those lake trout strains susceptible to sea lamprey induced mortality.

Creel Survey:
Harvest by U.S. anglers fishing from boats is measured by a direct contact creel survey, which covers the open lake fishery from the Niagara River in the western end of the lake to Association Island near Henderson in the eastern basin. This survey is conducted during the months of April through September and measures about 85% of the total lake trout harvest (Eckert 2007). The survey uses boat trips as the primary unit of effort; boat counts are made at boat access locations and interviews are based on completed trips.

Juvenile Trawl Survey:
From mid-July to early-August 1980-2008, crews from USGS and NYSDEC used the R/V *Kaho* and the R/V *Seth Green* to capture juvenile lake trout (targeting age-2 fish) with bottom trawls. Trawling was conducted at 14 locations in U.S. waters distributed evenly along the southern shore and within the eastern basin and at one location in Canadian waters off the mouth of the Niagara River. A standard tow was 10 min long. From 1980 to 1996, trawling was conducted with a 12-m (39.4-ft, headrope) trawl at 5-m (16.4-ft) depth intervals, beginning at the metalimnion (15°C, 59°F isotherm) and progressing into deeper water until few or no lake trout were captured. Because of an abrupt shift in the depth distribution of juvenile lake trout to deeper waters in 1993 (O'Gorman et al. 2000) and fouling of the gear by dreissenid mussels in 1996, the sampling scheme and gear were changed. In 1997 the 12-m (39.4-ft) trawl was replaced with a 3-in-1 trawl (18-m or 59-ft headrope, 7.6-m or 24.9-ft spread) equipped with roller gear along the footrope. In addition, effort was decreased at depths < 55 m (180.4 ft) and increased at depths > 70 m (229.6 ft). For years after 1997, the sampling protocol was modified by alternating between odd and even depths (5-m or 16.4-ft increments) between adjacent sites and adjacent years. At four sites where depth did not exceed 60 m (196.8 ft), all 5-m (16.4-ft) contours at and below the 15°C (59°F) isotherm were fished. From July 7 to August 3, 2008, trawling was conducted at all 14 locations. Data collection from trawl captured lake trout was the same as that described above for gill net captured fish.
Trends were similar for the catch of age-2 lake trout caught in this survey and age-3 lake trout caught in the gill net survey. This indicated that recruitment of hatchery fish to the population was governed by survival during their first year in Lake Ontario. Therefore, survival indices were calculated from catches of age-2 lake trout that were stocked in U.S. waters and caught in the bottom trawl survey. For 1981 to 1996 (1979-1994 year classes), survival indices were calculated by adjusting CPUE for strain, stocking location, and to reflect a total of 500,000 spring yearlings stocked (CPUE * 500,000 / the number stocked). Data obtained on the 1995 year class were not adjusted for strain or stocking location because of poor retention rates of CWT's. Among the age-2 lake trout caught in trawls in 1997, 36% of adipose-fin clipped individuals did not have tags. Data for year classes stocked since 1997 were not adjusted for strain or stocking location because from 36% to 84% of fish in those year-classes did not receive CWT's. Catches of the 1995 through 2006 year classes were, however, adjusted for numbers stocked. Most untagged fish stocked since 1997 received paired fin clips that facilitated year class identification through at least age 4. The ages of unmarked fish and fish with poor clips were estimated with age-length plots developed from CWT tagged fish.

To assess the condition of juvenile lake trout, we used the weight of a 400-mm (15.8 in) total length fish (range: 250 mm to 500 mm, 9.8 in to 19.7 in) predicted from annual length-weight regressions. A 400-mm fish would be age 2 or age 3.

Results and Discussion

Stocking:
From 1973 to 1977 lake trout stocked in Lake Ontario were raised at several NYSDEC and USFWS (Michigan and Pennsylvania) hatcheries with annual releases ranging from 0.07 million for the 1973 year class to 0.28 million for the 1975 year class (Figure 1). By 1978 the USFWS Alleghany National Fish Hatchery (Pennsylvania) was raising all lake trout stocked in U.S. waters of Lake Ontario and annual releases exceeded 0.55 million fish. In 1983, the first official Lake Ontario lake trout rehabilitation plan (Schneider et al. 1983) was formalized and it called for a target of 1.25 million fish stocked annually in U.S. waters. The stockings of the 1979-1986 year classes

approached that level, averaging about 1.07 million annually. The number of yearling equivalents released declined by about 22% between the stockings of the 1981 and 1988 year classes. Stocking declined by 47% in 1992 (1991 year class) due to problems encountered at the hatchery. In 1993, because of a predator-prey imbalance in Lake Ontario, and following recommendations from an international panel of scientists and extensive public review, managers reduced the lake trout stocking target to the current level of 500,000 yearlings. In the 16 years since the stocking cuts (1992-2007 year classes), the annual stockings were near the target level in only nine years. The USFWS Alleghany National Fish Hatchery was closed in 2005 due to an outbreak of infectious pancreatic necrosis and will remain closed for fish production through at least 2010. Lake trout for 2007 and 2008 stockings were raised at that the USFWS Pittsford and White River Hatcheries in Vermont.

A total of 500,908 yearling lake trout were stocked into Lake Ontario during May 13 to 23, 2008 (Figure 1). The strain composition was 60% Seneca Lake wild (SEN) and 40% Lake Superior (from Traverse Island broodstock). All fish were stocked from a landing craft, offshore at five sites (Stony Point, Oswego, Sodus, Oak Orchard, and Olcott) over waters 55-m (180.4 ft) deep. Detailed stocking information appears in Connerton (2009).

Survival to age-2

First-year survival was relatively high for the 1979-1982 year classes but then declined by about 32% and fluctuated without trend for the 1983-1989 year-classes (Figure 2). First-year survival declined further for the 1990 year class and continued to decline for the 1991-1996 year classes. The average survival of the 1994-1996 year classes at age 2 was only 6% of the average for the 1979-1982 year classes and only 9% of the average for the 1983-1989 year classes. The 2008 survival index, while not as low as the record low observed in 2006, was still quite low and about 88% below the average for the 1983-1989 year classes.

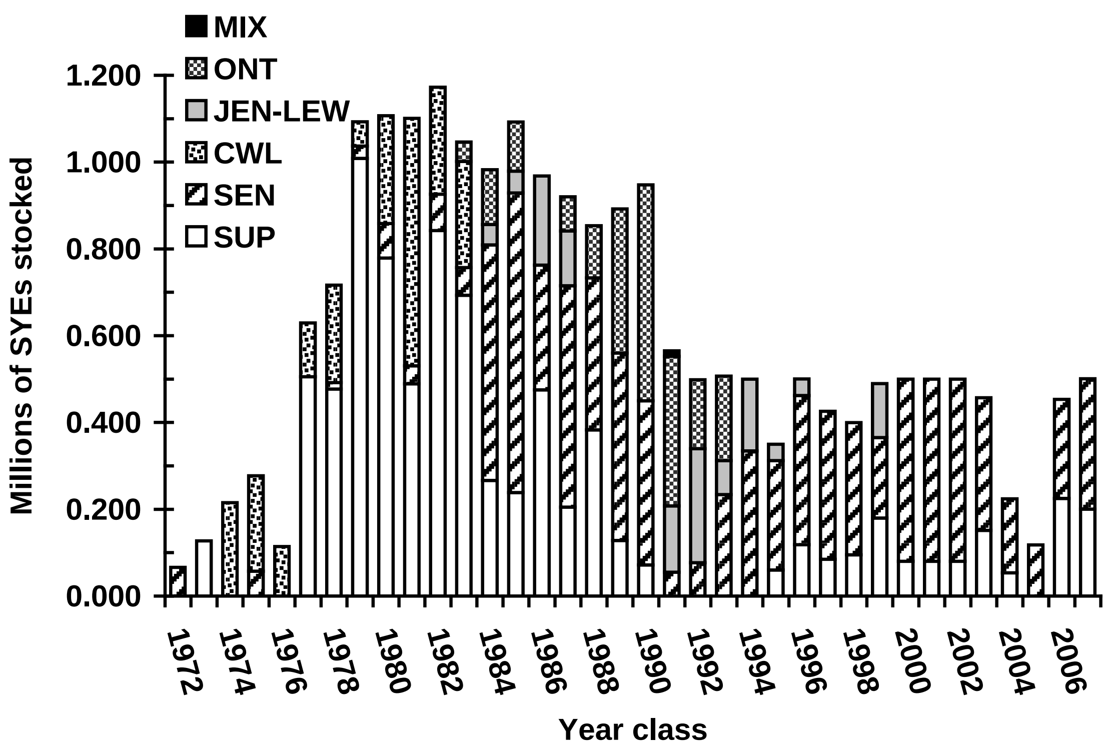

Figure 2. Total spring yearling equivalents (SYE) for lake trout strains (strain descriptions for ONT, JEN-LEW, CWL, SEN, and SUP appear in Appendix 1) stocked in U.S. waters of Lake Ontario for the 1972 – 2007 year classes. MIX were unknowns. SYE = 1 spring yearling or 2.4 fall fingerlings (Elrod et al. 1988). Fall fingerlings were not stocked after 1991.

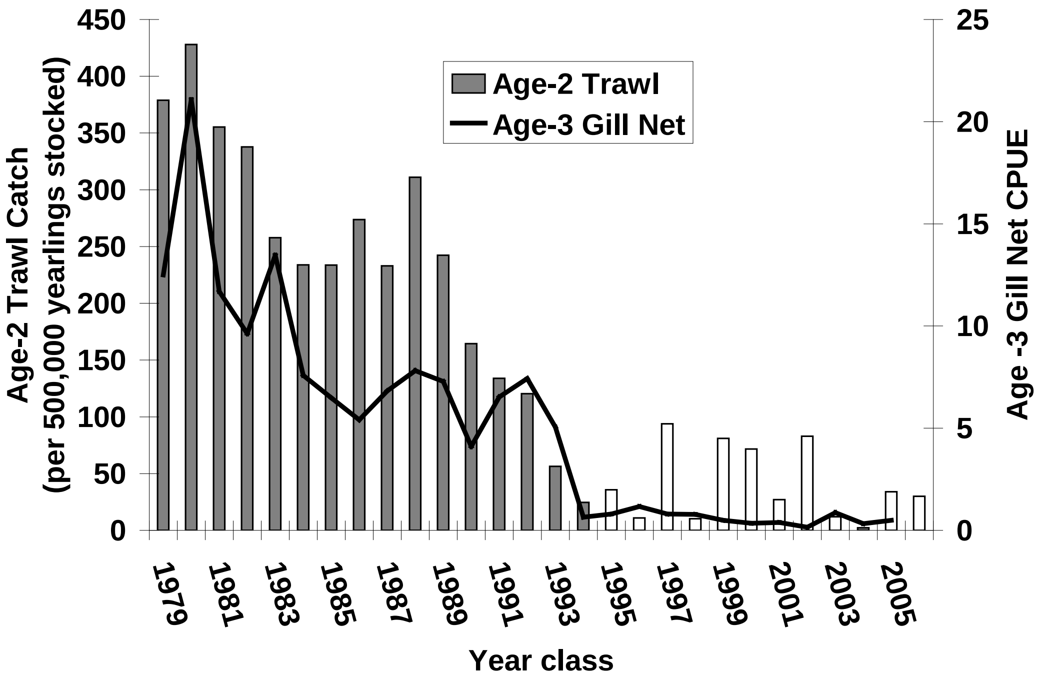

Figure 2. Survival indices for age-2 lake trout stocked as yearlings in U.S. waters of Lake Ontario in 1980 – 2007. Survival was indexed at age 2 as the total catch per 500,000 fish stocked from bottom trawls (BTR) fished in July-August (Note: White bars represent trawl data collected with the new trawl configuration which did not fish as hard on the lake bottom as the old trawl).

Abundance of age-3 and older lake trout:

A total of 407 lake trout were captured in the September 2008 gill net survey (Figure 3). Catches of lake trout among sample locations has been similar within years with the RSE for the CPUE of adult males and females (generally ages 5 and older) averaging only about 9.1 and 10.6%, respectively, for the entire data series (Figure 4). The CPUE of mature lake trout had remained relatively stable from 1986 to 1998, but then declined by 31% between 1998 and 1999 due to the poor recruitment of the weak 1993 year class. Declines in adult numbers after 1998 were likely due to poor survival of hatchery fish in their first year post-stocking and lower numbers of fish stocked since the early 1990's. After the 1998-1999 decline, the CPUE for mature lake trout remained relatively stable during 1999-2004 (mean = 11.0), but then declined by 54% in 2005. The CPUE of mature lake trout in 2008 (5.2) was 70% below the 1986-1998 mean and 53% below the 1999-2004 mean. The CPUE of mature lake trout in 2008 was similar to the 1983 - 1984 values which predated effective sea lamprey control and recruitment from the first large stockings in 1979. The CPUE for immature lake trout (generally ages 2 to 5) followed trends similar to the trawl catches of age-2 fish, but shifted ahead in time by three to four years (Figure 3). The average CPUE of immature lake trout dropped by 64% between the 1989-1993 interval (8.0) and the 1995-2004 interval (2.9). The CPUE in 2008 (2.21) was the second lowest observed and was 23% lower than the 1995-2004 mean.

Schneider et al. (1983, 1997) established a target CPUE of 2 for sexually mature female trout (≥ 4,000 g weight) reflecting the level of abundance at which successful reproduction became detectable in the early 1990s. The CPUE for mature females reached the target value (2) in 1989 and fluctuated about the value until 1992 (Figure 5). From 1992 until 2004, the CPUE exceeded the target, but fell below target during 2005 to 2008, coincident with the decline of the entire adult population.

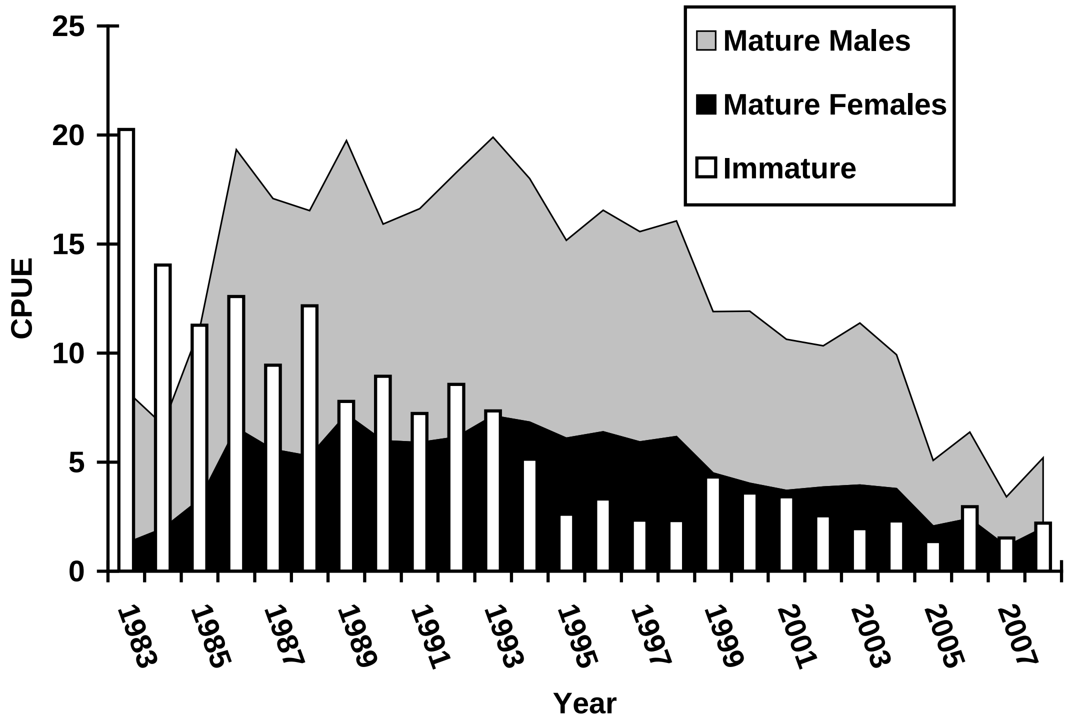

Figure 3. Abundance of mature and immature (sexes combined) lake trout calculated from catches made with gill nets set in U.S. waters of Lake Ontario, during September 1983-2008. CPUE was calculated based on four strata representing net position in relation to depth of the sets.

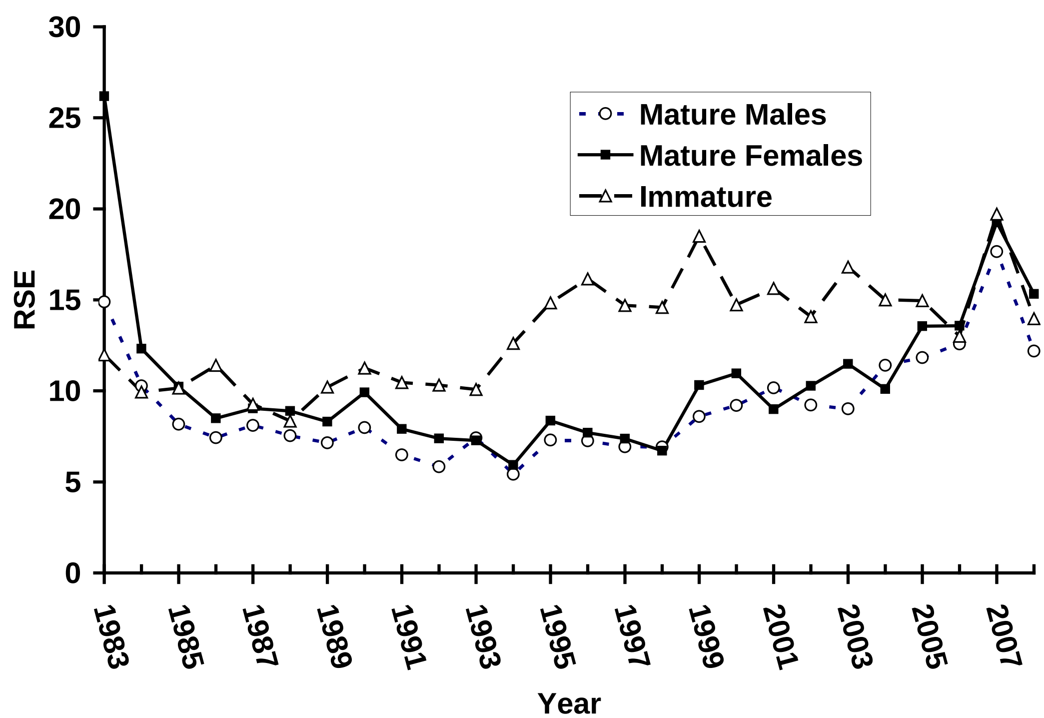

Figure 4. Relative standard error (RSE = {SE / Mean}*100%) of the annual CPUE for mature and immature (sexes combined) lake trout caught with gill nets set in U.S. waters of Lake Ontario, during September 1983 – 2008.

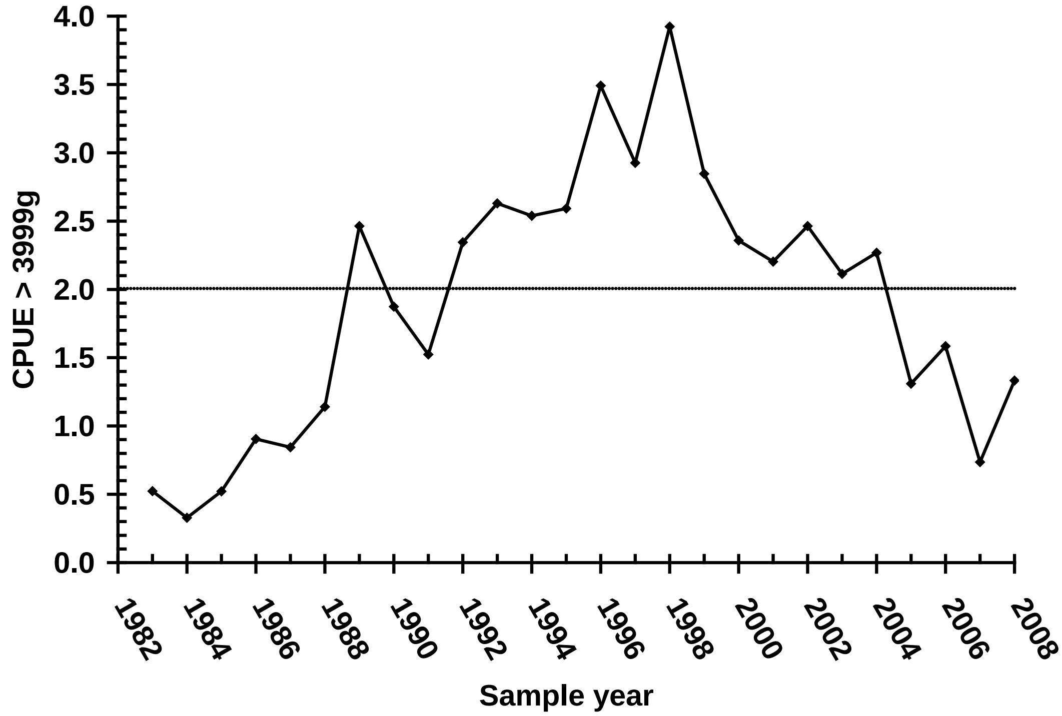

Figure 5 Abundance of mature female lake trout ≥ 4000g calculated from catches made with gill nets set in U.S. waters of Lake Ontario, during September 1983-2008. The dashed line represents the target CPUE from Schneider et al. (1997).

<u>Angler Harvest:</u>

The annual harvest of lake trout from U.S. waters of Lake Ontario (Figure 6) declined over four fold since the protected slot limit was re-instated in 1992 compared to years without size limits (Lantry and Eckert 2009). The protected slot regulation was a limit of 3 lake trout harvested outside of the protected length interval of 635 to 762 mm, or 25 to 30 in. In October 2006, a regulation change reduced the creel limit to two fish per angler and allowed for one of those fish to be within the 25 to 30 in slot. Despite the new “relaxed” slot limit lake trout harvest (2875) and harvest rate had the second lowest values recorded and catch (6757) was the lowest recorded. The relatively poor fishing for lake trout in 2008 was likely related to the declines in adult population size since 2004 and also to good fishing for Chinook salmon (*Onochorynchus tshawytscha*) (Lantry and Eckert 2009). Although total harvest of lake trout fell with the development and institution of the slot limit (1988-1993), the portion of the harvest that was larger than the upper limit of the protected slot increased substantially. Prior to 1993, lake trout >762 mm (30 in) made up only 5% or less of the annual total harvest. During 1997-2005, these fish made up an average of 32% of the harvest. In 2008 the proportion >762 mm harvested was 18.0%, the second lowest level since 1996 (Lantry and Eckert 2009). Since the October 2006 regulation change, the proportions of lake trout harvested within the slot were 41.5% (2007 and 3rd highest in the data series) and 40.0% (2008 and 4th highest in the data series).

Although targeted fishing for large fish during 1997-2008 may have influenced size composition of the harvest, availability of large lake trout seems to also have had an effect. Catches from our September gill netting survey give an index of the size distribution of adult lake trout. Of fish caught in index gill nets during 1984 to 1994, less than 10% were >762 mm (30 in) whereas during 1997-2006 an average of 22% were >762 mm. In 2008 18.9% of lake trout caught in survey gill nets were >762 mm (30 in).

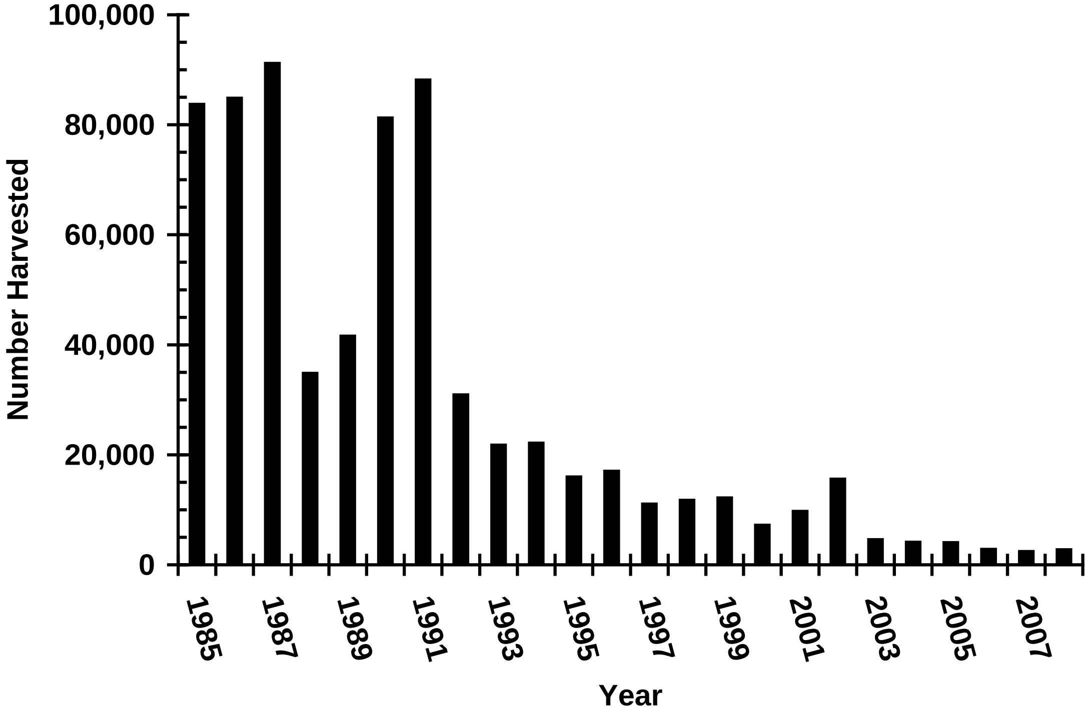

Figure 6. Estimated numbers of lake trout harvested by boat anglers from U.S. waters of Lake Ontario, 1985 – 2008 (Lantry and Eckert 2009).

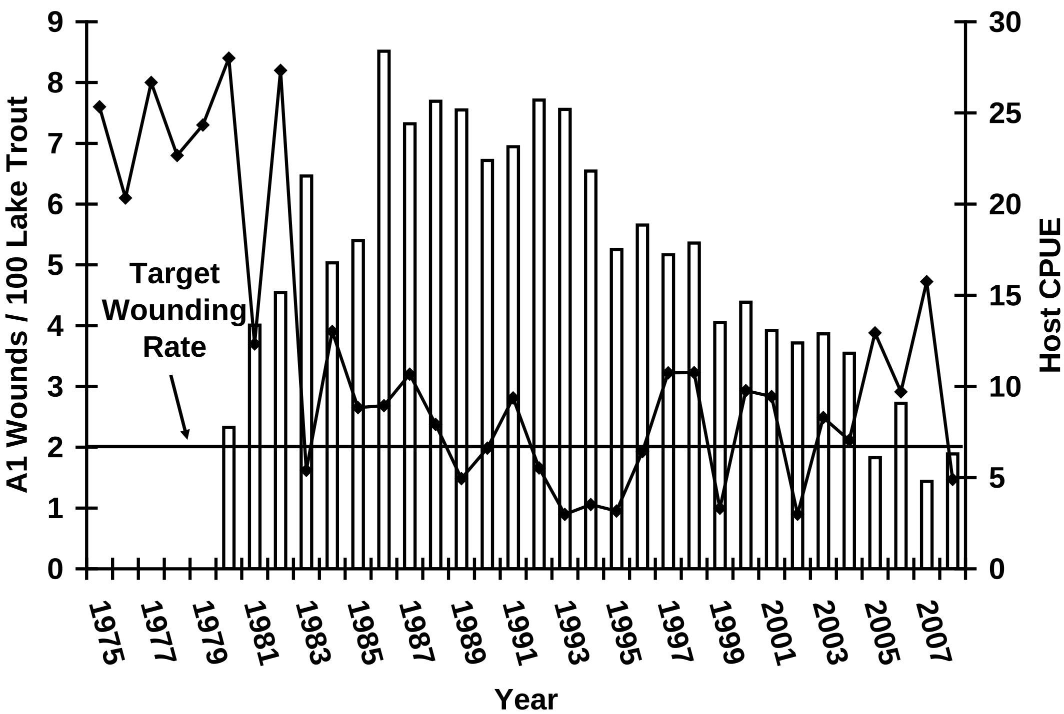

Figure 7. Wounding rates (A1 wounds per 100 lake trout, line) inflicted by sea lamprey on lake trout longer than 433 mm (17.1 in) TL and the CPUE of lake trout hosts (> 433 mm TL, bars) collected from Lake Ontario in fall, 1975 – 2008.

<u>Sea Lamprey Predation:</u>
Although percentage of fresh (A1) sea lamprey marks on lake trout has remained low since the mid 1980s, wounding rates (Figure 7) in eight

out of twelve years between 1997 and 2008 were above the target level of 2 per 100 fish >433 mm (17.1 in). The 1999 and 2002 wounding rates were below the target and similar to the 1992-1996 levels of about 1.0 wound per 100 fish. The 2007 A1 wounding rate of 4.7 wounds was 2.35 times the target level. The 2008 level fell below the target level to 1.47 wound per 100 lake trout. The length of A1 marked fish in 2008 ranged from 560 to 738 mm (22.1 to 29.1 in, n = 5, mean = 668 mm or 26.3 in).

The effect of the current wounding rate on the lake trout population is difficult to assess without measures of lake trout carcass density. Dreissenid mussels have made trawling for carcasses impossible since 1996. Wounding rates may be related to sea lamprey abundance, host density, lake trout strain composition, or changes in sea lamprey search behavior. In the past, significant correlations between numbers of A1 wounds on Superior strain lake trout and carcass density (Schneider et al. 1996) provided a basis for relating A1 wounds to sea lamprey-induced mortality on lake trout and other salmonines. However, the current population is dominated by Seneca strain fish which are attacked by sea lamprey less frequently than Superior strain fish (Schneider et al. 1996). Additionally, poorly recruited lake trout year classes since 1990 were becoming vulnerable to attack by sea lampreys by 1995. Wounding rate increases during 1997-2008 occurred as host CPUE (lake trout >433 mm) declined (Figure 7). Hence, changes in A1 wounding rates may be attributable to either increased sea lamprey abundance or decreased host density.

Survival of Adults:

Survival of Seneca strain lake trout (ages 7 to 11) has been consistently greater (20 to 51%) than that of the Superior strain for the 1980-1995 year classes (Table 1). Lower survival of Superior strain lake trout was likely due to higher mortality from sea lampreys (Schneider et al. 1996). Lewis and Jenny Lake strain lake trout share a common genetic origin that can be traced back to native Lake Michigan fish. Survival of both of those strains was similar to the Superior strain, suggesting that Jenny and Lewis Lakes fish are also highly vulnerable to sea lampreys. Ontario strain lake trout are progeny of Seneca and Superior strains (Appendix 1) and their survival has been intermediate to that of their parent strains. In recent years survival of the remaining Ontario strain fish has approached that of the Seneca strain indicating many of the members of these cohorts that were highly vulnerable to sea lamprey predation have been removed from the population. Population survival for all strains combined generally increased with successive cohorts up through 1985 year class, exceeded the restoration plan target value of 0.60 first with 1984 year class, and remained above the target for most year classes thereafter. Survival values for the 1996-1998 cohorts could not be estimated for untagged SENs which made up 69-80% of those stockings. The survival value for 1996 cohort is for SUP strain fish only and is not representative of the true population value. The 1999, 2000 and 2001 cohorts of SEN lake trout were marked with CWT's as part of a stocking methods study (Lantry et al. 2007). The survival value for 1999 cohort is for SEN strain fish only which made up 38% of the stocking in 2000 along with 37% SUP (tagged, but low numbers recaptured) and 25% LLW (not tagged).

Table 1. Annual survival of various strains (strain descriptions appear in Appendix 1) of lake trout, U.S. waters of Lake Ontario, 1985-2008. Note: ALL is survival of all strains combined using only coded wire tagged fish.

YEAR		STRAIN					
CLASS	AGES	SEN	ONT	SUP	JEN	LEW	ALL
78	7-10	-	-	0.40	-	-	
79	7-11	-	-	0.52	-	-	0.52
80	7-11	0.85	-	0.54	-	-	0.58
81	7-11	0.92	-	0.45	-	-	0.48
82	7-11	0.82	-	0.44	-	-	0.50
83	7-11	0.90	0.61	0.54	-	-	0.57
84	7-11	0.70	0.61	0.48	0.39	-	0.65
85	7-11	0.77	0.80	0.47	-	-	0.73
86	7-11	0.81	-	0.43	0.57	-	0.62
87	7-11	0.80	-	0.50	0.50	-	0.73
88	7-11	0.73	0.77	0.61	-	-	0.68
89	7-11	0.86	0.78	0.59	-	-	0.81
90	7-11	0.75	0.64	0.60	-	-	0.68
91	7-11	0.70	0.62	-	-	0.56	0.70
92	7-11	0.81	-	-	-	0.51	0.60
93	7-11	0.72	-	-	-	0.64	0.71
94	7-11	0.45	-	-	-	0.73	0.56
95	7-11	0.76	-	-	-	0.50	0.72
96	7-10	-	-	0.43	-	-	0.43
99	7-09	0.60	-		-	-	0.58

Growth and Condition:

The predicted weight of a 700-mm lake trout (from length-weight regressions) decreased from 1983 to 1986, but increased irregularly from 1986 to 1996 and remained relatively constant through 1999 (Figure 8). Mean weight declined by 158.8 g (5.6 oz) between 1999 and 2006, but increased again in 2007 and by 2008 (3676.0 g, 8.1 lb) was equivalent to the 1996-1999 mean (3679.6 g, 8.1lb).

The past trend of improving condition through 1996 corresponded to increased abundance of older lake trout in the population. Our data suggest that for lake trout of similar length, older fish are heavier. However, declines in condition since 1999 may have been indicative of food limitation. To remove the effects of age and sex, we calculated annual means for "Fulton's *K*" for age-6 mature male lake trout (Figure 8). The *K* for age-6 males followed a similar trend as the predicted weight, which was calculated using data from all fish captured. The correspondence of these two trends indicates that the relation between condition, age, and resource availability for lake trout in Lake Ontario was more complex than was thought in the past (Lantry et al. 2005). Further analysis has indicated that trends in predicted weight were related both inversely to the proportion of juveniles to adults and directly to the slope of the length-weight regressions used to predict weights. This indicates that it is likely that differences in growth trajectories between juveniles and adults confuse the relation between predicted weight and resource availability. The *K* for age-6 mature males may yield a better picture of condition and resource availability; however, *K* has the same trend as predicted weight and increasing condition with increasing abundance between 1984 and 1999 is counterintuitive. Understanding the trend of increasing condition from 1986 to 1996 for both indices will require further analysis.

Predicted weight (from length-weight regressions based on bottom trawl catches) for a 400-mm lake trout was highest for trout caught in 1980 (these were likely from the 1979 stocking of the 1978 year class) (Figure 9). That was the end of the early stockings (1973-1979) where numbers planted ranged from66,000 to 728,240 yearling equivalents (Figure 1). Immature lake trout condition remained high through 1981. Stocking first exceeded 1,000,000

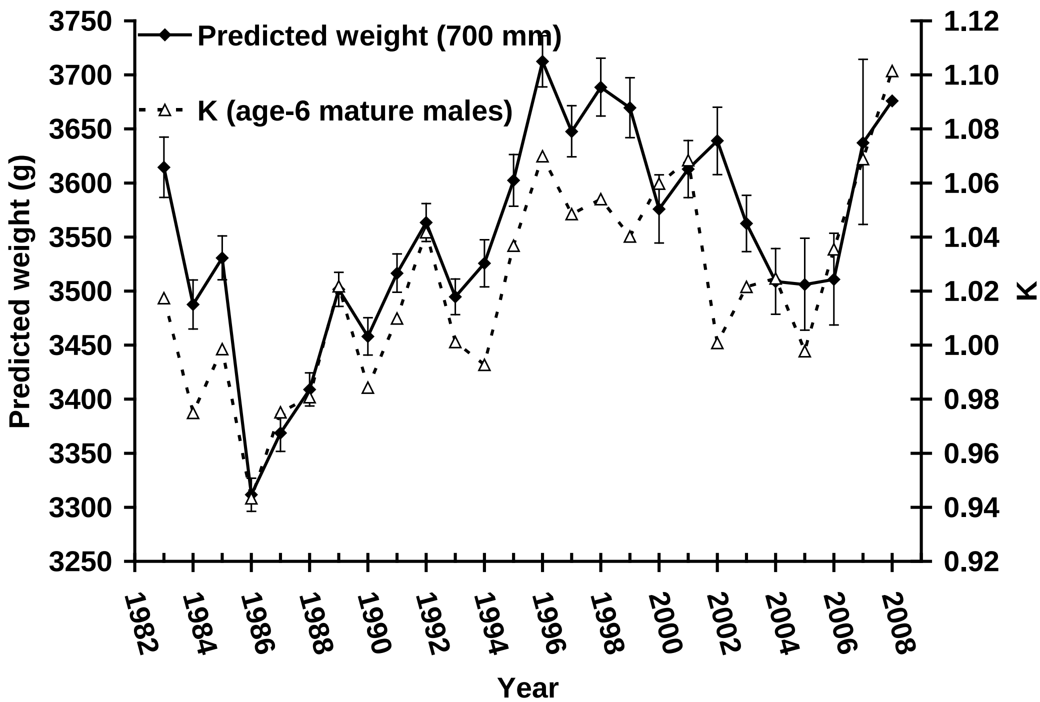

Figure 8. For Lake Ontario lake trout, condition (K) for age-6 mature males and predicted weight at 700-mm (27.6 in) TL from weight-length regressions calculated from all fish collected during each annual gill net survey, September 1983 – 2008. Error bars represent the regression confidence limits for each annual value.

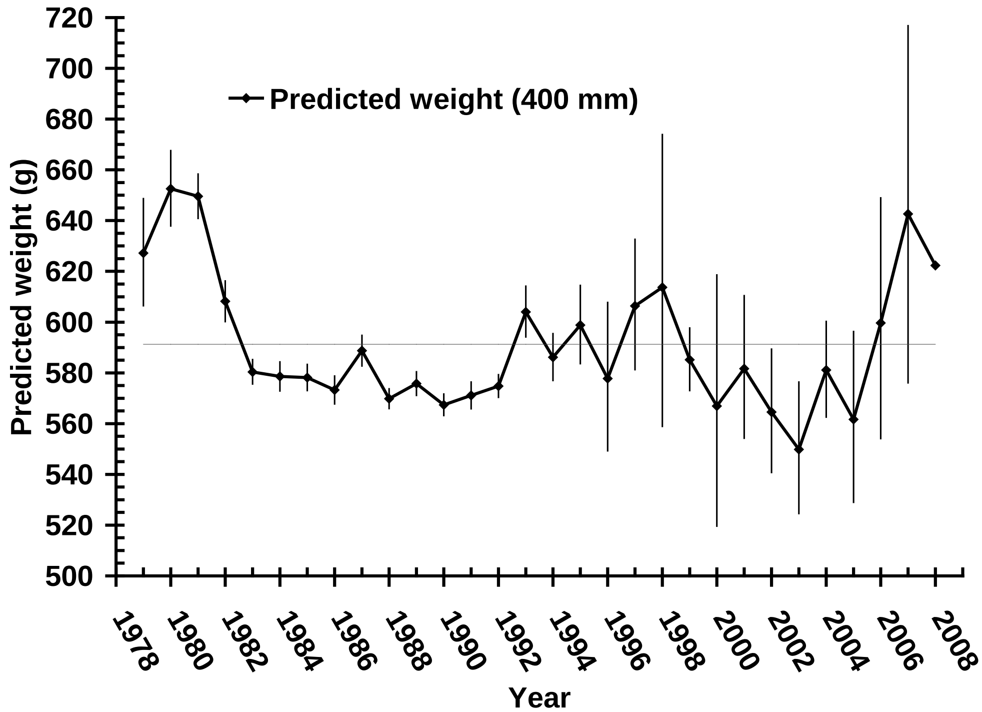

Figure 9. For Lake Ontario lake trout, predicted weight at 400-mm (15.8 in) TL from annual weight-length regressions calculated from fish 250 mm-500 mm (9.8 to 19.7 in). All lake trout were sampled from bottom trawls, July -August 1978 – 2008. The horizontal line represents the mean of the predicted weight across all years. Sample sizes for regressions were ≥ 39 except for 1997, 2000, 2005, 2006, 2007 and 2008 (n = 13, 15, 19, 11, 14 and 20, respectively). Error bars represent the regression confidence limits for each annual value.

yearling equivalents in 1980 and between 1980 and 1981 the CPUE of immature lake trout from gill net catches doubled. From 1981 to 1983 predicted weight fell by 69 g (2.4 oz) and remained relatively constant (mean = 576 g, 1.3 lb) through 1992.

Predicted weights of 400-mm lake trout (Figure 9) were inversely related to both total numbers stocked and the CPUE of immature fish captured with gill nets in September (Figures 1 and 3). Stocking remained at a relatively high rate from 1980 to 1991 (846,260 to 1,165,530 fish) then declined to its' current level (500,000 fish) in 1992. It has remained there or below through 2008. Predicted weight rose in 1993 and the 1993-1998 mean was 22 g (0.8 oz) higher than the mean for 1983-1992. Increased condition of young lake trout from 1993 to 1998 was likely due to poor survival of stocked fish and not due to changes in resource availability. During 1999-2005, condition declined to a level similar to the mid-1980's and may have reflected resource limitation. Predicted weight increased during 2005-2008. Predicted weight may have been somewhat influenced by the larger mean size of yearling lake trout at stocking during 2006 - 2008 or related to increases in round goby (*Neogobius melanostomus)* abundance (Walsh et al. 2008) which are beginning to appear in lake trout diets.

Reproductive Potential:

Previously, we used the CPUE of mature females as a measure of reproductive potential of lake trout in Lake Ontario. However, the CPUE of mature females in September is not a precise measure of reproductive potential because fecundity changes with age and length (O'Gorman et al. 1998), both of which have increased through the years. Also, sea lampreys kill mature lake trout each fall, mostly between our September assessment and November spawning (Bergstedt and Schneider 1988, Elrod et al. 1995). Furthermore, the numbers of lake trout killed have varied through time, and not all strains of lake trout are equally vulnerable to attack by sea lampreys or are as likely to succumb to an attack. Compared with Superior strain fish, Seneca strain lake trout were 0.41

times as likely to be attacked and they were much less likely to die from an attack (Schneider et al. 1996). Thus, change in age and strain composition of mature females has to be considered when judging reproductive potential from September gill net catches. Since 1996, potential population egg deposition has been indexed from age and size related fecundities and strain specific survivorships (O'Gorman et al. 1998).

Temporal changes in lake trout reproductive potential measured by the egg deposition index (Figure 10) differed considerably from those measured by the CPUE of mature females (Figures 3 and 5). The CPUE of mature females suggests that reproductive potential quadrupled from 1983 to 1986 and then fluctuated around a high level through 1998. In contrast, the egg index suggests that reproductive potential quadrupled from 1985 to 1993 and then remained high through 1999. The CPUE of mature females declined by 31% between 1998 and 1999, yet a change in reproductive potential was delayed by one year dropping by 27% between 1999 and 2000. Strain composition of the eggs was mostly SUP during 1983-1990 and mostly SEN during 1991-2002. After 2002 it became increasingly difficult to assess strain specific contribution to the egg deposition index because many fish stocked since 1997 were not marked with coded wire tags. In most years during the recent period SEN strain dominated stockings and we assume that they continue to contribute the greatest proportion to the egg index. The first predominantly untagged cohort since 1983 was stocked as spring yearlings in 1997 and were first captured in substantial numbers as mature females at age 5 in 2001. For 2001 and later indices we calculated size and age-specific fecundities for untagged fish with paired fin clips that permitted aging. We then applied strain related mortality correction factors to those values by calculating the strain composition of untagged fish based on the strain composition for the specific cohorts at stocking.

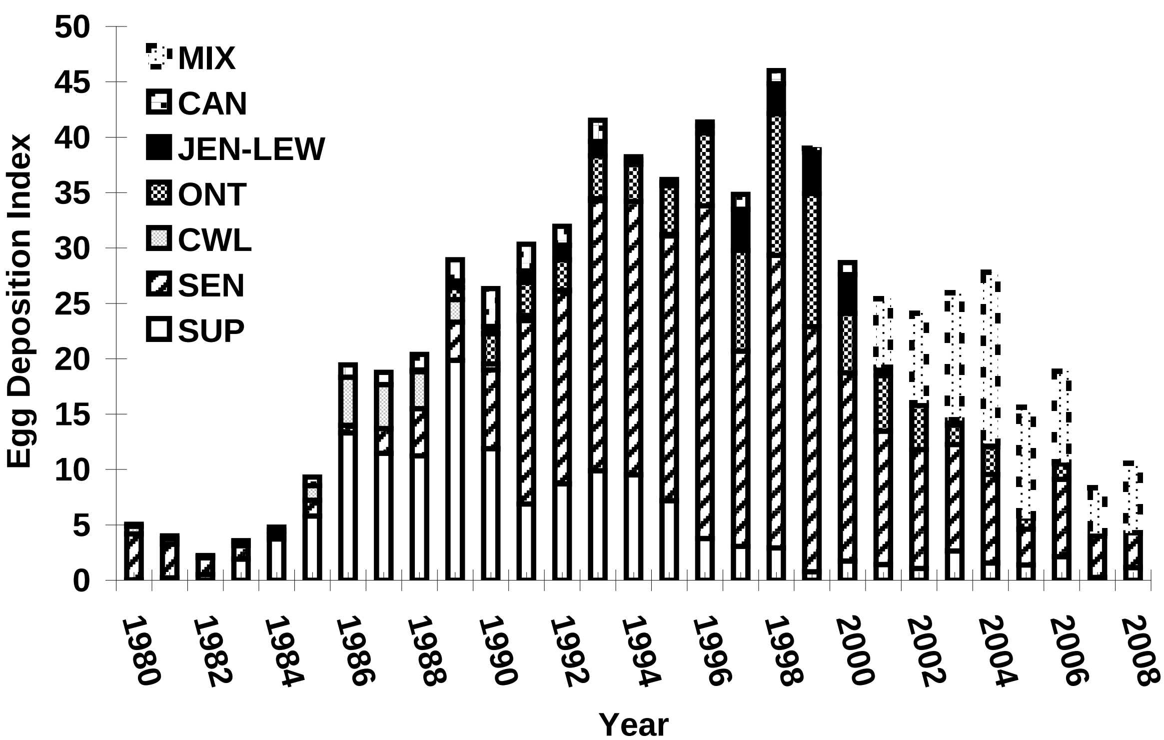

Figure 10. Egg deposition indices by strain (strain descriptions for ONT, JEN-LEW, CWL, SEN, and SUP appear in Appendix 1) for lake trout in U.S. waters of Lake Ontario during 1980-2008. CAN represents a mix of the strains stocked by OMNR and MIX represents values for untagged females stocked since 1997 for which strain could not be determined.

The egg deposition index changed little between 2001 and 2004 and the average for those years was 42% lower than the average for 1993 to 1999. In 2005, the index dropped to 40% below the 2001-2004 mean and was the lowest observed since 1985. The 2008 index value was 76.0% below the 1993-1999 mean.

Natural Reproduction:

In 2008, one naturally produced (wild) age-2 lake trout (278 mm, 10.9 in) was caught from bottom trawling. Survival of naturally produced lake trout to the fingerling stage in summer and fall occurred each year during 1993-2006 (Figure 11) representing production of 14 consecutive year classes. We caught no wild yearling lake trout during 2005-2008 and have no evidence of a naturally produced year class in 2007. Low numbers of small (<100 mm, 3.9 in), wild fish captured in recent years (1997-2008) may be due in part to a change in our trawl gear that was necessary to avoid abundant dreissenid mussels. Our new bottom trawls do not fish as hard on bottom as the old gear and are not as efficient at capturing small benthic fishes. We were encouraged by catches of age-1 wild fish near Oswego in 2001. However, low catches during 2002 to 2008 may have been related to increases in predation on young, changes in prey resources, and to declines in adult abundance.

The distribution of catches of wild fish suggests that lake trout are reproducing throughout New York waters (Figure 12). Catches from 14 consecutive cohorts of wild lake trout since 1994 and survival of those year classes to older ages, meets the plan objective to demonstrate the feasibility of lake trout rehabilitation in Lake Ontario (Schneider et. al. 1997). Although recent evidence of wild reproduction is encouraging, achieving the goal of a self-sustaining population requires improvement in production of wild lake trout. Surviving members of the 1993-1999 year classes would have begun to reach sexual maturity by the fall of 2000-2006 and greater catch rates of young, naturally reproduced lake trout would have been an encouraging sign of restoration. The absence of this snowball effect on abundance of natural recruits may indicate that naturally reproduced fish are experiencing pressures similar to those that have had a negative impact on stocked fish survival and reproduction.

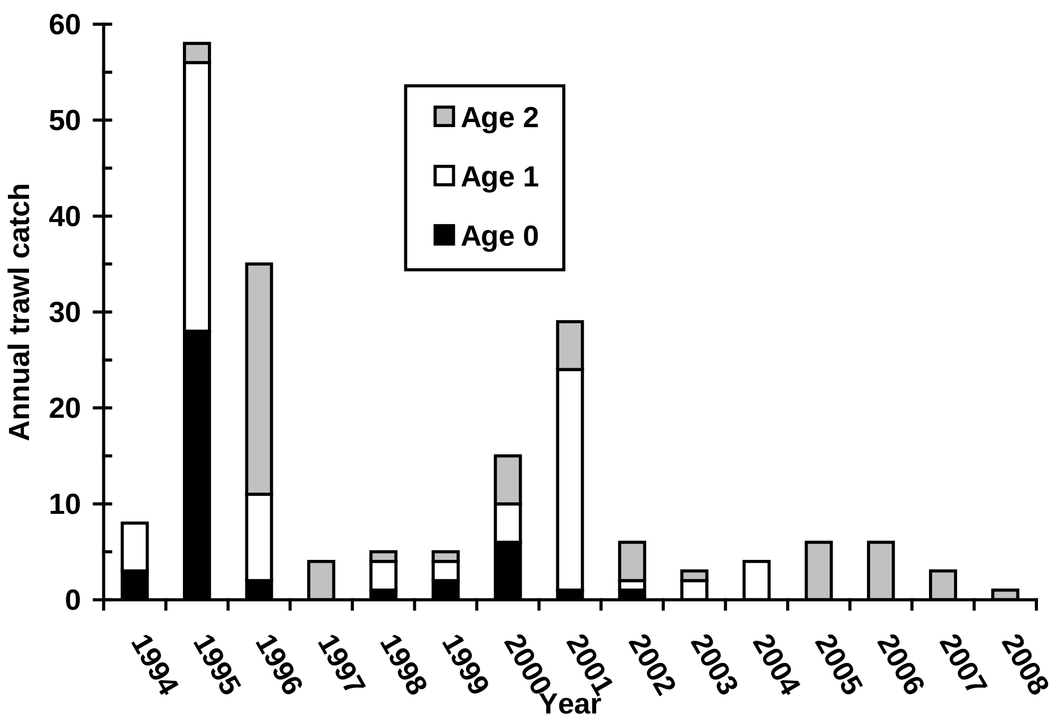

Figure 11. Numbers and ages of naturally produced (wild) lake trout captured with bottom trawls in Lake Ontario by NYSDEC and USGS, 1994-2008. During 1980-1993, only one naturally produced lake trout was captured with bottom trawls.

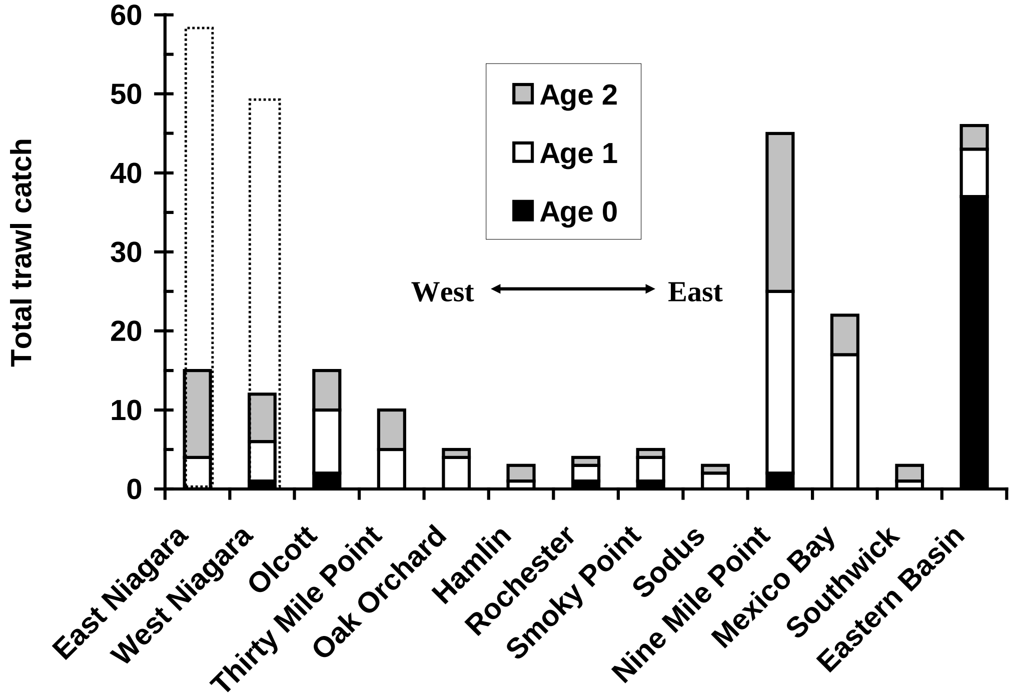

Figure 12. Numbers of wild lake trout (age 0 to 2) captured with bottom trawls at various locations in Lake Ontario by NYSDEC and USGS, 1994 – 2008. (Note: east and west Niagara are only sampled once per year whereas the other locations are usually sampled four times per year. Dashed lines show these catches adjusted for effort).

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Appendix 1.

<u>Strain Descriptions</u>
SEN – (Connerton 2009) Lake trout descended from a naturally sustained population that coexisted with sea lamprey in Seneca Lake, New York. In addition to eggs collected from the population in Seneca Lake, a captive broodstock was maintained at the Alleghany National Fish Hatchery in Warren, Pennsylvania until 2005.

SUP – (Connerton 2009) Captive lake trout broodstock initially developed at the Marquette (Michigan) State Hatchery and derived from restored lean, Lake Superior lake trout. Broodstock for Lake Ontario stockings was maintained at the Alleghany National Fish Hatchery in Warren, Pennsylvania until 2005. The 2006 year class of this strain was derived from Traverse Island broodstock and raised at the USFWS Pittsford and White River Hatcheries in Vermont.

CWL – (Elrod et al. 1995) Eggs collected from lake trout in Clearwater Lake, Manitoba, Canada and raised to fall fingerling and spring yearling stage at the Alleghany National Fish Hatchery in Warren, Pennsylvania.

JEN-LEW Northern Lake Michigan origin stocked as fall fingerlings into Lewis Lake, Wyoming in 1890. Jenny Lake is connected to Lewis Lake. The 1984-1987 year classes were from brood stock at the Jackson (Wyoming) National Fish Hatchery and the 1991-1992 year classes were from broodstock at the Saratoga (Wyoming) National Fish Hatchery

ONT – (Elrod et al. 1995) from mixed strains stocked into and surviving to maturity in Lake Ontario. The 1983-1987 year classes were from eggs collected in the eastern basin of Lake Ontario. The 1988-1990 year classes were from broodstock developed from the 1983 egg collections from Lake Ontario. Portions of the 1991-1992 year classes were from ONT strain broodstock only and portions were developed from crosses of ONT strain broodstock females and SEN males.