Lake Trout Rehabilitation in Lake Ontario, 2005

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Abstract

Each year we report on the progress toward rehabilitation of the Lake Ontario lake trout population covering 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 2005, the number of yearling lake trout stocked in May was 45% below the target level of 500,000. During the juvenile lake trout bottom trawling survey the total catch of age-2 lake trout declined by 87% from 2004 and was the second lowest catch on record. During the adult lake trout gill net survey CPUE was 47% lower than in 2004 and 73% below the 1986-98 average. The rate of wounding by sea lampreys on lake trout caught in gill nets was above the target level suggesting that host density was affecting wounding rates. Estimates from the NYSDEC fishing boat census indicated that while effort aimed at trout and salmon increased by 23% from the low set in 2003, angler harvest of lake trout reached a new record low. The condition of adult lake trout, indexed from annual length – weight regressions, was the lowest observed in 14 years. Despite continued low abundance of age-2 lake trout, the condition of juvenile lake trout remained low and was similar to values observed through the 1980's. Reproductive potential for the adult stock from the annual egg deposition index declined by 40% from the 2001-2004 mean and was 64% below the average for 1993 to 1998. Age-2 naturally produced lake trout were present in survey catches, but for the first time in seven years age-1s were not suggesting little or no natural reproduction during 2004.

Introduction

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), identifying a goal, interim objectives, and strategies. The present report documents progress towards restoration through 2005.

Methods

<u>Adult Gill Net Survey:</u>
During September 2005, 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 four survey nets were fished along randomly chosen transects, parallel to contours beginning at the 10 C (50 F) isotherm and proceeding deeper in 10 m (32.8 ft) increments. At the two eastern basin sites, seven nets were fished at fixed sites covering 3-4 sequentially deeper locations per site ranging in depth from 20 to 50 m. For a complete description of survey history including gear changes and corrections see Elrod et al. (1995).

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 between years and catch per net decreased uniformly with increasing depth below the thermocline. Survival of various year classes and strains was estimated by taking the antilog of the slope of the regression of $\log_e$ CPUE on age, for ages 7-11. 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* (Fulton 1911) for age-6 males where:

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

and WT is weight (g) and TL is total length (mm). Potential population egg deposition was indexed from age specific fecundities and strain specific survivorships (O'Gorman et al. 1998).

<u>Creel Census:</u>
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 2006a). The survey used boat trips as the primary unit of effort; boat counts were made at boat access locations and interviews were based on completed trips.

<u>Juvenile Trawl Survey:</u>
From mid-July to early-August 1980-2005, 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 13 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 (20.4-m or 66.9-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 4, 2005, trawling was conducted at all 14 locations.

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 caught in this 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. Data obtained on the 1995 year class were not adjusted for strain or stocking location because of poor retention rates of coded wire tags (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 coded wire tags (CWT's). Catches of the 1995 through 2003 year-classes were, however, adjusted for numbers stocked. Most fish stocked since 1997 without CWT's 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 fish that had CWT's. Juvenile condition was indexed from both the predicted weights of a 400-mm TL fish calculated from annual length-weight regressions based on lake trout 250-500 mm and from Fulton's *K* (Fulton 1911) for age-2 individuals.

Results and Discussion

Stocking:

From 1973 to 1977 lake trout stocked in Lake Ontario were raised at a mix of 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 calling 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 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 13 years since the stocking cuts (1992-2004 year classes), the annual stockings were at the target level in seven and below it in six.

A total of 224,150 yearling lake trout were stocked at one site, Stony Point, in the U.S. eastern basin waters of Lake Ontario on May 24 and 25, 2005 (Figure 1). The strain composition was estimated to be 76% Seneca Lake wild (SEN) and 24% Lake Superior domestic (SMD). All fish were stocked from a landing craft, offshore, over waters 35 m (115 ft) deep. Detailed stocking information appears in Eckert (2006b), section 1 of this volume.

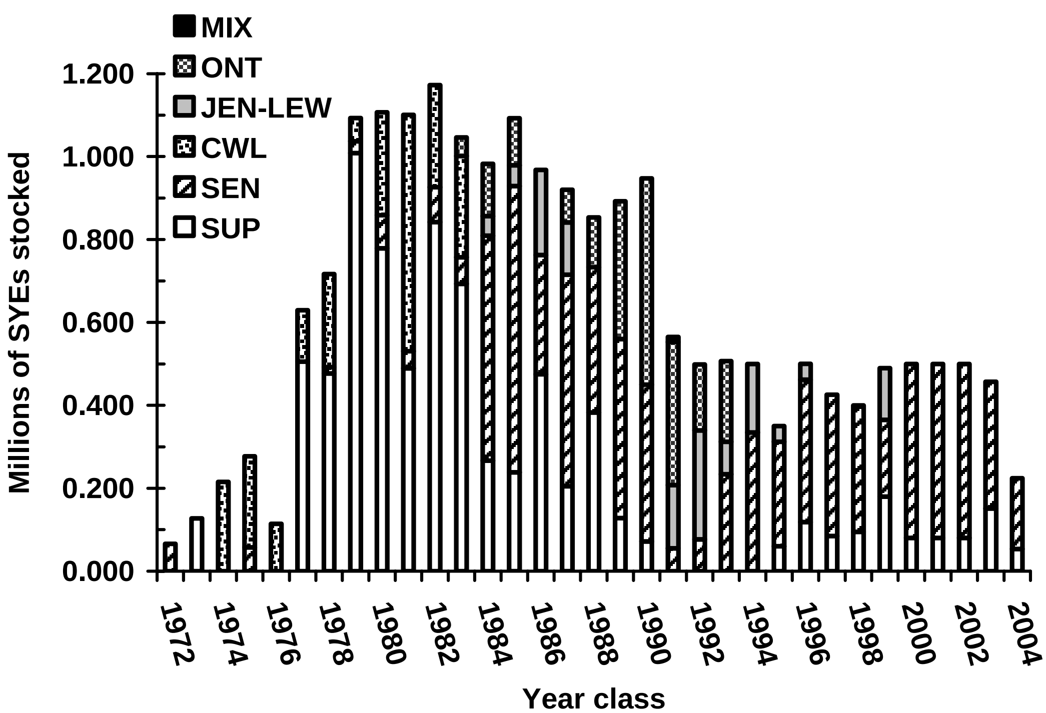

Figure 1. Total spring yearling equivalents (SYE) of lake trout stocked in U.S. waters of Lake Ontario for the 1972 – 2004 year classes. A yearling equivalent was equal to 1 spring yearling or 2.4 fall fingerlings for 1973 – 1991(Elrod et al. 1988). Fall fingerlings were not stocked after 1991. (About 0.27 million fish from the stocking of the 1990 year class were in poor condition at stocking and experiencing elevated mortality in transit.)

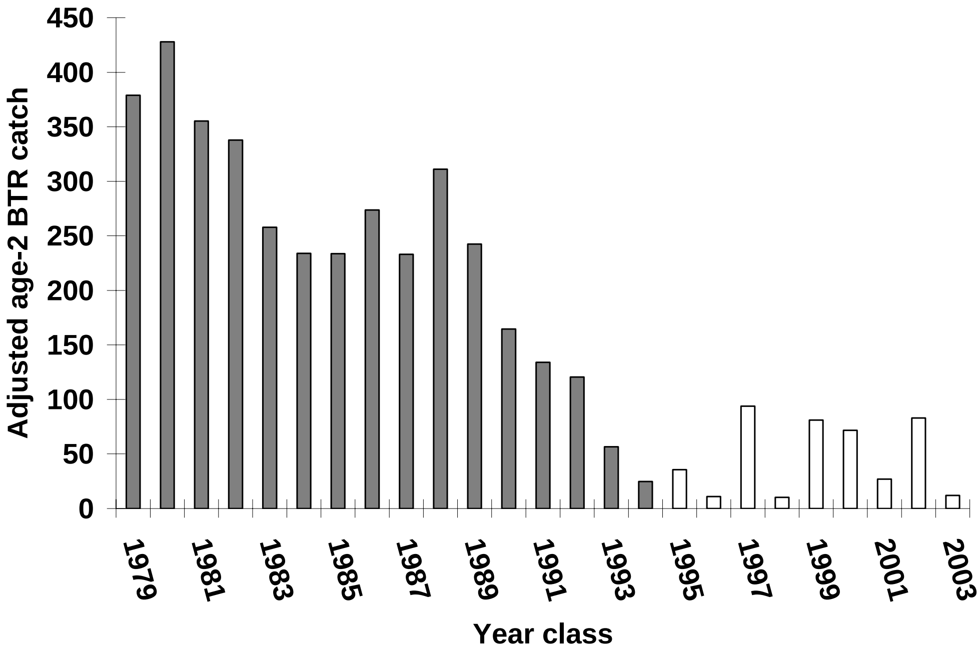

Figure 2. Survival indices for age-2 lake trout stocked as yearlings in U.S. waters of Lake Ontario in 1980 – 2004. Survival was indexed as the total catch per 500,000 fish stocked at age 2 from bottom trawls fished in July-August (Note: White bars represent trawl data collected with the new trawl configuration which did not fish as hard on the lake bottom as the old trawl).

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. First-year survival declined further for the 1990 year class and continued to decline for the 1991-1996 year classes. Survival indices for age-2 lake trout caught in trawl surveys declined to an all time low during the period from 1996 to 1998. 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. In 2005 the total catch (11) was the second lowest recorded and survival index was 96% below the average for the 1983-1989 year classes. In four out of the last six years the survival (for the 1997, 1999, 2000, and 2002 year classes) was about 3.5 times higher than the lows seen for the 1994–1996 year classes. Although this modest increase in the survival index was encouraging, it has not persisted and nearly all of the age-2 fish caught in those years were from sites near the western end of the lake suggesting that yearling survival in western Lake Ontario is higher than in eastern Lake Ontario.

Abundance of age-3 and older lake trout:

A total of 355 lake trout were captured in the September 2005 gill net survey (Figure 3). Catches of lake trout among sample locations has been similar within years with the relative standard error (RSE = 100 * {standard error / mean}) for the CPUE of adult males and females (age-5 and older) averaging only about 8.5 and 9.9%, 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 30% 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 1998-99 decline, the CPUE for mature lake trout remained relatively stable during 1999-2004 (mean = 11.0), but then declined in 2005 from that previous mean by 54%. The 2005 mature lake trout CPUE (5.1) was 71% lower than the 1986-98 mean. The CPUE for immature lake trout (ages 2-5) followed trends similar to the trawl catches of age-2 fish, but lagged ahead in time by three to four years. The average CPUE

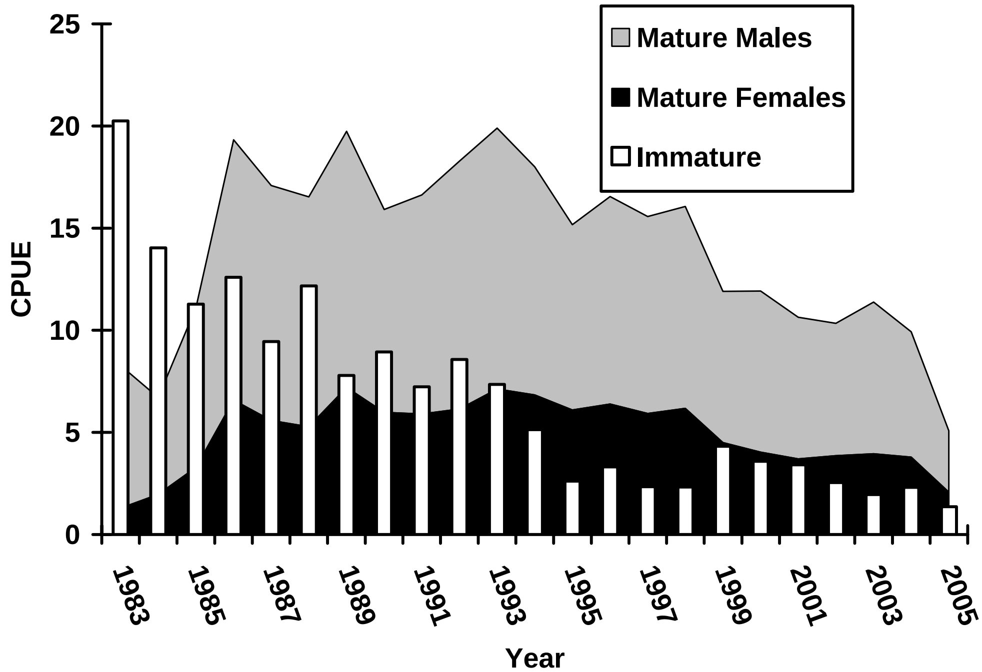

Figure 3. Abundance of mature and immature (sexes combined) lake trout calculated from catches made with gill nets set in U.S. waters of Lake Ontario, during September 1983 - 2005. CPUE was calculated based on 4 strata representing net position in relation to depth of the sets.

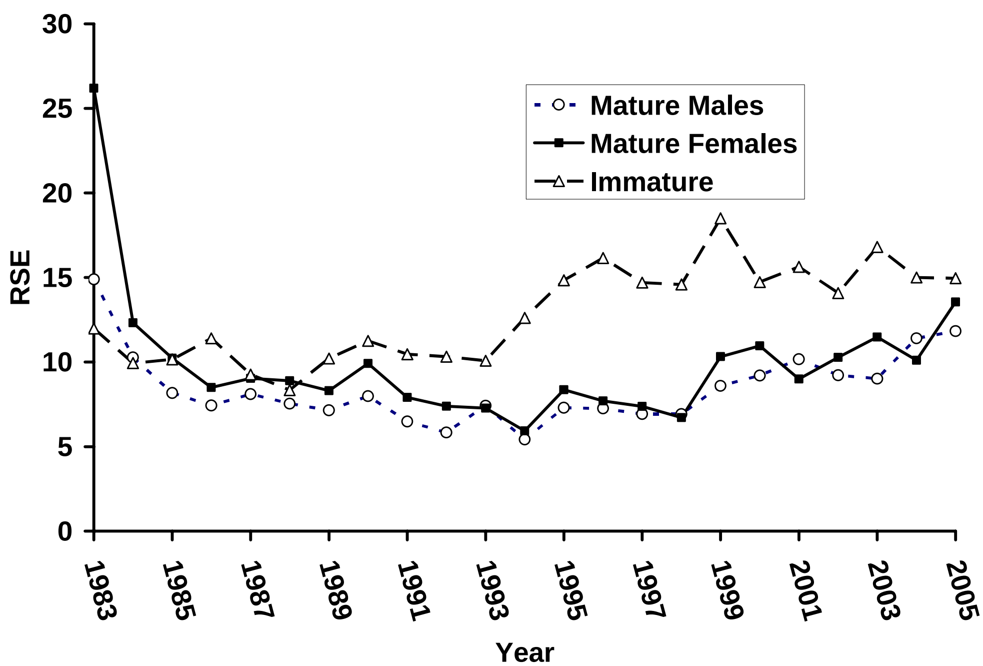

Figure 4. The relative standard error (RSE = {SE / Mean}*100) for the annual CPUE for mature and immature (sexes combined) lake trout caught with gill nets set in U.S. waters of Lake Ontario, during September 1983 – 2005.

of immature lake trout dropped by 64.0% between 1989-93 (8.0) and 1995-04 (2.9). The CPUE for 2005 (1.4) was 52.5% lower than the 1995-04 mean.

Angler Harvest:

The annual harvest of lake trout from U.S. waters of Lake Ontario (Figure 5) has been more than four times lower since the protected slot limit (635 - 762 mm, 25 - 30 in.) was re-instated in 1992, compared to previous years when no size limits were in effect (Eckert 2006a). Harvest was the lowest on record in 2005 at 4181 fish while total trout and salmon angling effort was up 23% from the low set in 2003. In 2005, lake trout catch and harvest rates also reached new record lows. The relatively poor fishing for lake trout may be related to the declines in adult population size since 1998, but also is likely related to good fishing for chinnok salmon (Eckert 2006a). While total harvest of lake trout fell with the development and institution of the slot limit (1988-1993), the portion of the harvest that was made up of large fish increased substantially. Previous to 1996, lake trout >762 mm (30in) on average made up only 5% or less of the annual total. During 1997-2004, lake trout >762 mm (30 in.) made up and average of 31% and during 2005 were 34% of the harvest. While targeted fishing for large fish may have influenced harvest size composition, availability of these large lake trout seems to of also have had an effect. Of fish caught in index gill nets during 1984 to 1994 less than 10% were >762 mm (30 in.), from 1997 to 2004 and average of 22% were above that size. In 2005, 51.8% fell within the size protected by the slot limit and 23.4% were above the protected slot size.

Sea Lamprey Predation:

Although percentage of fresh (A1) sea lamprey marks on lake trout has remained low since the mid 1980s, marking in seven out of eight years between 1997 and 2005 was higher than from 1992 to1996 (Figure 6). The 1997, 1998, 2000, 2001, 2003 and 2005 wounding rates were above the target level of 2 per 100 fish. The 1999 and 2002 wounding rates were below the target and similar to the 1992 to 1996 levels of about 1.0 wound per 100 fish. The 2005 A1 wounding rate of 3.9 wounds per 100 fish was nearly double the target level and the highest observed since 1984. The length of A1 marked fish in 2005 ranged from 539 to 955 mm (21.2 to 37.6 in, n = 13, mean = 773 mm or 30.4 in).

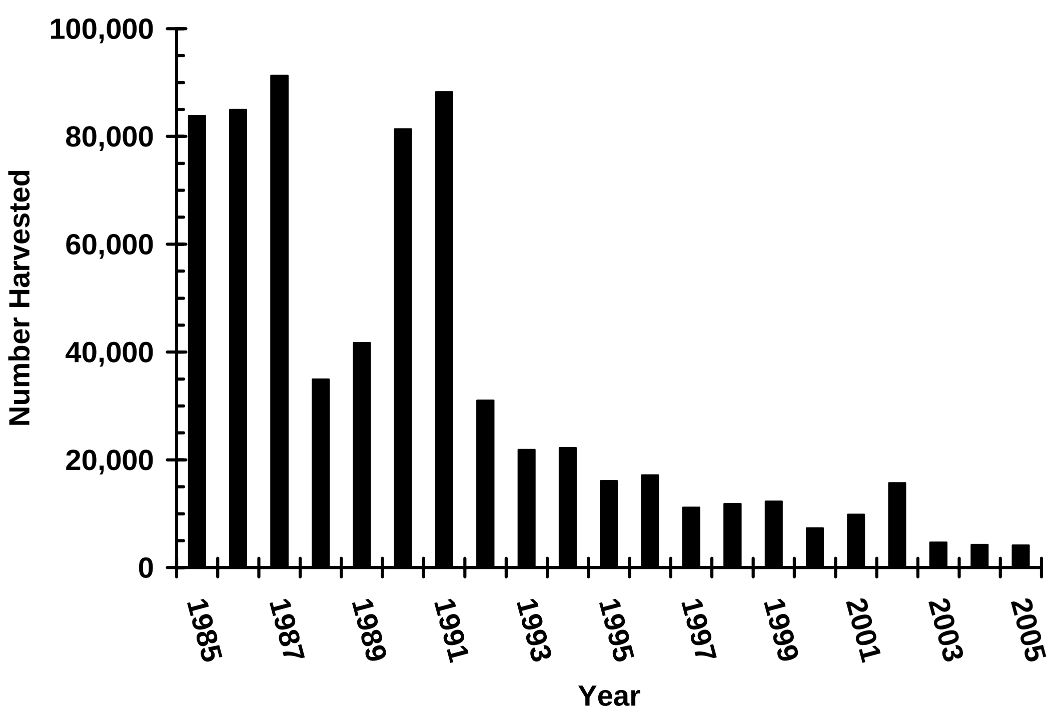

Figure 5. Estimated numbers of lake trout harvested by boat anglers from U.S. waters of Lake Ontario, 1985 - 2005.

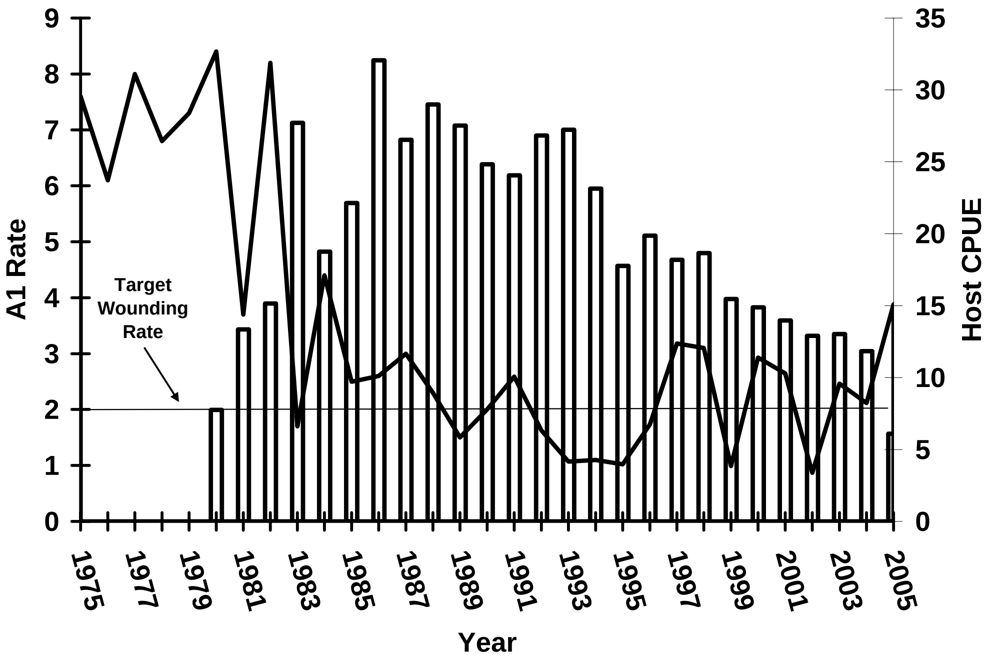

Figure 6. Wounding (A1 wounds per 100 host fish, line) inflicted by sea lamprey on lake trout longer than 433 mm (17.1 in) TL collected from Lake Ontario in fall, 1975 – 2005. The CPUE of lake trout hosts (>432mm TL, bars) was calculated from index gillnet catches in September.

The impact 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. Significant correlations between numbers of A1 wounds on Superior strain lake trout and carcass density (Schneider et al. 1996) in the past provided a basis for relating A1 wounds to sea lamprey induced mortality on lake trout and other salmonines. The current population, however, is dominated by Seneca strain fish which are attacked by sea lamprey less frequently than Superior strain fish. Additionally, poorly recruited lake trout year classes since 1993 were becoming vulnerable to attack by lampreys by 1997. Wounding rate increases during 1997 - 2005 occurred as lake trout host CPUE declined. Hence, changes in A1 rates may be attributable to either increased sea lamprey abundance or decreased host density.

Survival of Adults:

In past reports, survival was calculated for all ages of lake trout caught from the September gill nets surveys > age 7. Gradual creeping up of survival rates through the years as additional ages were added to cohort survival calculations caused us to reexamine estimation procedures. Plots of LnCPUE by age from gill net catches indicated that survival was not constant across all adult ages. In all cases survival was generally constant between ages 7 and 11. After age-11, in most cases survival greatly increased, however, catch rates were too low (often only one fish) to have confidence in those survival estimates. In this report, survival rates have been recalculated for only age 7-11.

Survival of Seneca strain lake trout (ages 7-11) has been consistently greater (20-45%) than that of the Superior strain for the 1984-1995 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; a portion were pure Seneca strain, some were pure Superior strain, and others were a Seneca x Superior cross. Survival of Ontario strain fish has been intermediate to that of the Seneca and Superior strain fish, perhaps because mortality from sea lampreys is high only among fish of the Ontario strain that were of pure Superior strain heritage. 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.

Table 1. Annual survival of various strains of lake trout, U.S. waters of Lake Ontario, 1985 - 2005. Note: the most recent cohorts (1995 and 1996) of SUP strain fish used data for ages 7 to 9. All other year classes were calculated with data from ages 7-11.

YEAR		STRAIN				
CLASS	AGES	SEN	ONT	SUP	JEN	LEW
78	7-10	-	-	0.40	-	-
79	7-11	-	-	0.49	-	-
80	7-11	-	-	0.58	-	-
81	7-11	-	-	0.45	-	-
82	7-11	-	-	0.44	-	-
83	7-11	-	-	0.53	-	-
84	7-11	0.70	0.60	0.48	-	-
85	7-11	0.76	0.75	0.46	-	-
86	7-11	0.89	-	0.45	0.58	-
87	7-11	0.83	-	0.51	0.51	-
88	7-11	0.73	-	0.64	-	-
89	7-11	0.85	0.79	0.60	-	-
90	7-11	0.79	0.64	0.60	-	-
91	7-11	0.69	0.62	-	-	0.57
92	7-11	0.82	-	-	-	0.51
93	7-11	0.71	-	-	-	0.67
94	7-11	0.46	-	-	-	0.73
95	7-10	0.69	-	-	-	
95	7-09	-	-	0.66	-	0.49
96	7-09	-	-	0.39	-	-
Mean		0.74	0.68	0.51	0.55	0.59

Growth and Condition:

To assess the condition of adult lake trout, we used the weight of a 700-mm (27.6 in) total length (TL) fish. Weights were calculated from length-weight regressions of all fish captured during the annual gill net surveys for lake trout. 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 to 1993 surveys. The weight of a 700-mm fish decreased from 1983 to 1986, but increased irregularly from 1986 to 1996 and remained relatively constant to 1999 (Figure 7). Mean weight declined by 164 g (5.8 oz) between 1999 and 2005. The 2005 value (3506.1 g, 7.7 lb) was unchanged from 2004, remaining at the lowest level recorded in the last 14 years.

The past trend of improving condition through 1996 corresponded to the build-up of older lake trout in the population. Our data suggest that for lake trout of similar length, older fish are heavier. Recent declines in condition since 1999, however, may be indicative of resource limitation. To remove the effects of age and sex, we also calculated annual means for Fulton's *K* for age-6, mature male lake trout (Figure 7a). The *K* for age-6 males followed a similar trend as the predicted weight above calculated 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. 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. Explaining the trend of increasing condition from 1986 to 1996 for both indices will require further analysis.

To assess the condition of juvenile lake trout, we used the weight of a 400-mm (15.8 in) TL fish (range: 250 mm to 500 mm, 9.8 in to 19.7 in) predicted from annual length-weight regressions (Figure 8). A 400-mm fish would be age 2 or age 3. Predicted weight was highest at the beginning of the data set for 1980 lake trout that were likely from stockings of the 1978 year class in 1979. That was the end of the early stockings (1973-1979) where numbers planted ranged from 66,000 to 728,240 yearling equivalents (Figure 1). Lake trout condition remained high through 1981. Stocking first exceeded 1,000,000 yearling equivalents in 1980 and between 1980 and 1981 the CPUE of

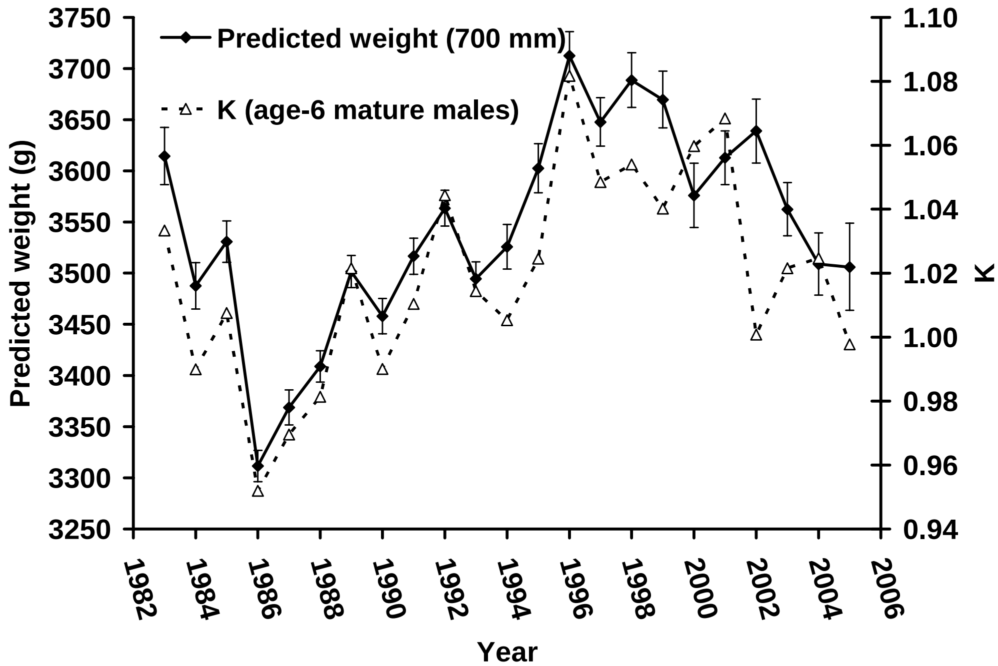

Figure 7. For Lake Ontario lake trout, condition (K) for age-6, mature males and predicted weight at 700-mm (27.6 in) TL from weight - length regressions calculated from all fish collected during each annual gill net survey, September 1983 – 2005. Error bars represent the regression confidence limits for each annual value.

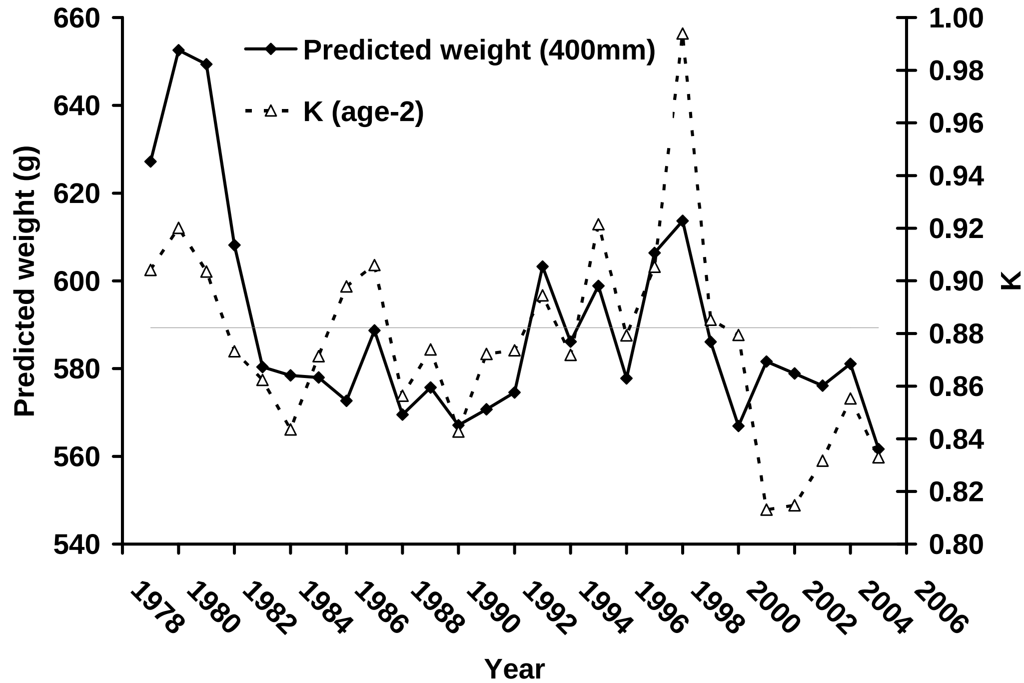

Figure 8. For Lake Ontario lake trout, condition (K) at age-2 and predicted weight at 400 mm (15.8 in) TL from annual weight-length regressions calculated from fish 250 mm - 500 mm (9.8 to 19.7 in). All lake trout were sampled from bottom trawls, July - August 1994 - 2005. For regressions, sample size varied from 39 to 934 except for 1997, 2000 and 2005 (n = 13 15 and 19, clear diamonds) and the horizontal line represents the mean of the predicted weight across all years.

immature lake trout from gill net catches doubled (Lantry et al. 2003). 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 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) and declined to its' current level (500,000 fish) in 1992 and has remained there or below through 2005. 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 related to reduced stocking rates, lower survival of juveniles, and the resultant low numbers of immature fish. This indicated that declines in survival of stocked fish were likely not due to resource limitation. After 1998, condition declined to a level similar to the mid-1980's and may reflect resource limitation.

Reproductive Potential:

Previously, we used the CPUE of mature females as a measure of reproductive potential of lake trout in Lake Ontario. The CPUE of mature females in September, however, 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.

To better gauge reproductive potential of the population, we calculated indices of egg deposition 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). In 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 ($P<0.003$) than age-7 fish, and age-7 fish had fewer eggs ($P<0.003$) 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 higher in 1978-1981 than in 1982-1993 and they attributed the better condition in 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 egg deposition during 1982-2002. 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 $1 - EXP[-(Z_{SEN}-Z_{SUP})]$. Where Z = instantaneous rate of mortality, EXP is the exponential of e, SEN = Seneca Lake strain, and SUP = 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 lampreys. 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.

Temporal changes in lake trout reproductive potential measured by the egg deposition index (Figure 9) differed considerably from those measured by the CPUE of mature females

(Figure 3). 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 1998. Strain composition of the eggs was mostly SUP during 1983-1990 and mostly SEN during 1991-2002. After 2002 it has become increasingly difficult to assess strain specific contribution to the egg deposition index because most fish stocked since 1997 were not marked with coded wire tags. In most years during the recent period SEN strain has predominated in the stockings and we assume that they continue to contribute the greatest proportion to the egg index. The reproductive potential of the lake trout population in Lake Ontario declined by 13% in 1999 from the mean 1993 - 1998 value. That decline was concurrent with a 31% decline in the CPUE of mature females. Although CPUE was constant from 1999 to 2000, reproductive potential dropped by 27% after 1999. The first predominantly untagged cohort since 1983 was stocked as spring yearlings in 1997 and began to show up in substantial numbers as mature females at age 5 in 2001. For the first two years (2001 and 2002, Fig. 11, Lantry et al. 2003) we adjusted up the strain-specific mean fecundities for the tagged population by proportioning numbers of untagged fish to the strain makeup of the tagged population. It became evident, however, that mean fecundities based on tagged fish represented values for substantially older individuals than those for untagged fish. Simply raising fecundity indexes based on tagged fish to account for the untagged proportion of the population was biasing population values high. In 2003 we began to calculate 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. The new calculations lowered the previous egg deposition index values for 2001 and 2002 by 12% and 26% respectively. The resulting 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 2001-04 mean and was the lowest observed since 1985.

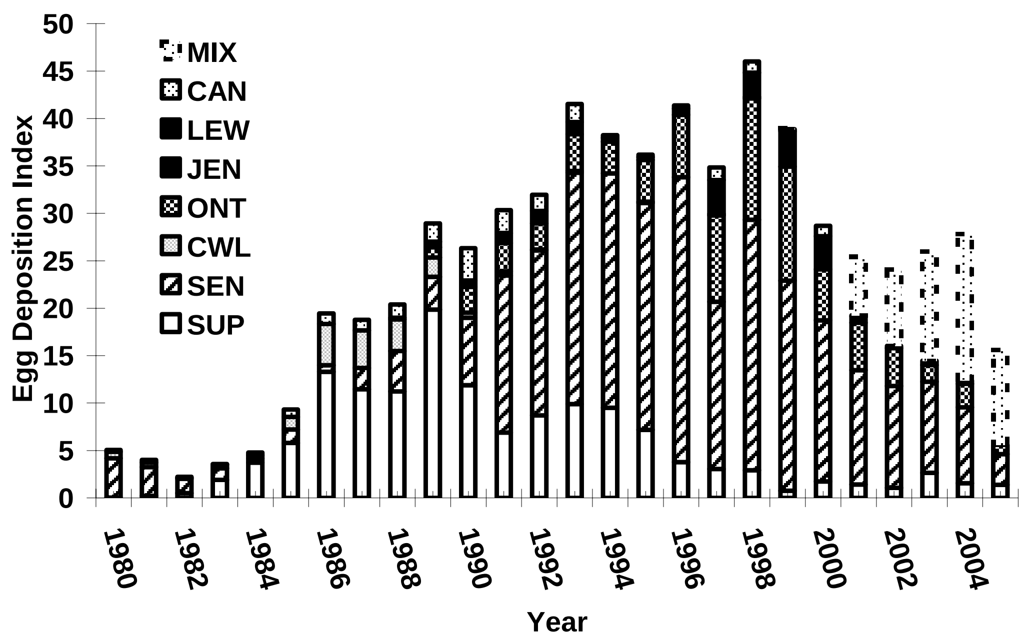

Figure 9. For lake trout in U.S. waters of Lake Ontario, egg deposition indices by strain 1980 - 2005. Mix represents the egg deposition index for untagged females stocked since 1997 for which strain could not be determined.

Natural Reproduction:

In 2005, six naturally produced (wild) age-2 (3) and age-3 (3) lake trout were caught with bottom trawls. They ranged in size from 179 to 269 mm (7.1 to 10.6 in.). Survival of naturally produced lake trout to the fingerling stage in summer and fall occurred each year during 1993-2003 (Figure 10) representing production of 11 consecutive year classes. We caught no wild yearling lake trout in 2005 and have no evidence of a 2004 year class. Catches from 11 consecutive cohorts of wild lake trout since 1994 and survival of those year classes to older ages, has been an important sign of successful natural reproduction meeting the plan objective to demonstrate the feasibility of lake trout rehabilitation in Lake Ontario (Schneider et. al. 1997). Low numbers of small wild fish (<100 mm, 3.9 in) captured in recent years (1997-2003) 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 good catches of age-1 wild fish near Oswego in 2001. Low catches during 2002 to 2005, however, may be related to increases in predation on young, changes in prey resources, and in 2005 to declines in adult abundance.

The distribution of catches of wild fish suggests that lake trout are reproducing throughout New York waters (Figure 11). Although these signs are encouraging, achieving the goal of a self-sustaining population require continued improvement in production of wild lake trout. Surviving members of the 1993-1998 year classes were likely sexually mature by the fall of 2005. As successive naturally reproduced year classes approach reproductive age over the next several years, greater catch rates of young, naturally reproduced lake trout would be an encouraging sign of restoration. The absence of this snowball effect on abundance of natural recruits may indicate that naturally reproduced fish are experiencing system pressures similar to those that have had a negative impact on stocked fish survival and reproduction.

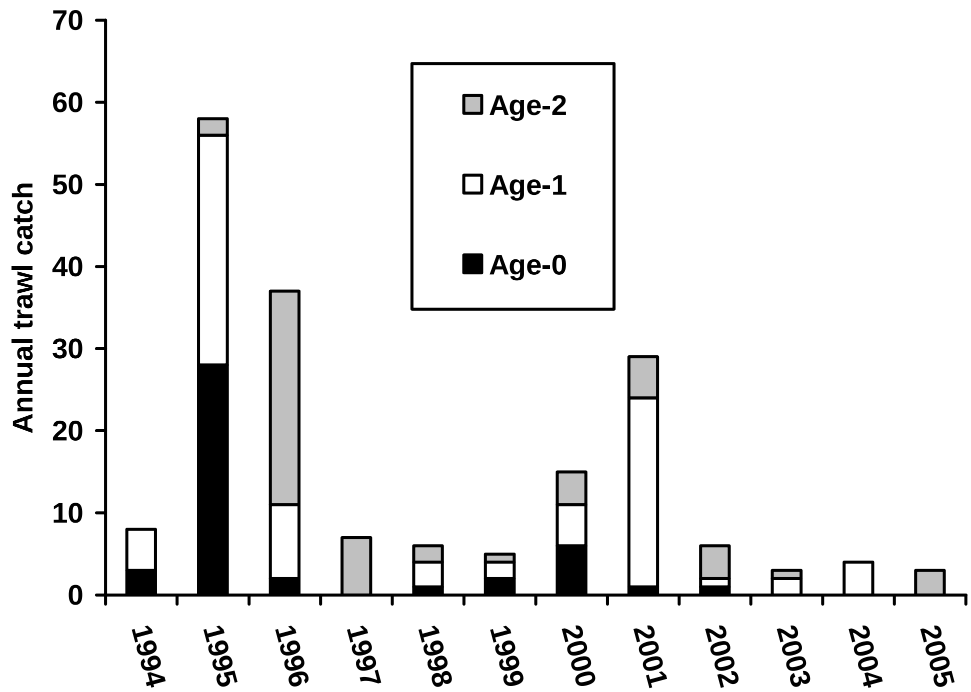

Figure 10. Numbers and lengths of naturally produced (wild) lake trout captured with bottom trawls in Lake Ontario by NYSDEC and USGS, 1994 - 2005.

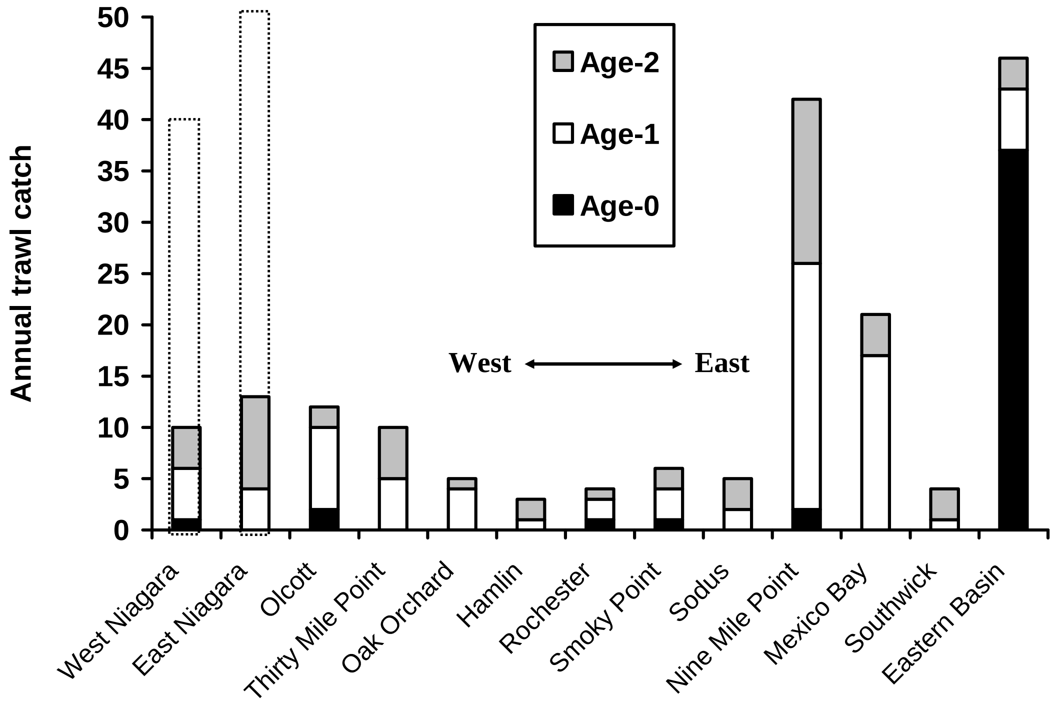

Figure 11. Numbers of wild lake trout (age 0 to 2) captured with bottom trawls at various locations in Lake Ontario by NYSDEC and USGS, 1994 - 2005. (Note: east and west Niagara are only sampled once per year whereas the other locations are usually sampled four times per year. Dashed lines show these catches adjusted for effort).

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