Lake Trout Rehabilitation in Lake Ontario, 2018

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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. The catch per unit effort of adult lake trout in gill nets increased each year from 2008-2014, recovering from historic lows recorded during 2005-2007. Adult abundances declined each year from 2015 to 2017; and in 2017 were about 35% below the 2014 peak and 17% below the 1999-2004 mean. The 2018 adult abundance increased by 51% over the 2017 value. The 2018 rate of wounding by sea lamprey (Petromyzon marinus) on lake trout caught in gill nets (0.61 A1 wounds (fresh wound) per 100 lake trout) was below target (2 wounds per 100 lake trout). Estimates from the NYSDEC fishing boat survey indicated angler catch rate of lake trout was low in 2018 and among the lowest recorded for the time series. Condition values for an adult lake trout, indexed in September from the predicted weight for a 700mm lake trout from annual length-weight regressions and Fulton's K for age-6 males, were among the highest levels observed for the 1983-2018 time series. Condition of juvenile lake trout indexed from the predicted weight of a 400 mm individual and Fulton's K for age-2 fish increased sharply in 2017 from low values observed during 2015-2016 and remained relatively high in 2018. Reproductive potential for the adult stock indexed from the CPUE of mature females ≥ 4000g was again above the target in 2018 continuing a trend observed in nine of the last ten years. The 2018 catch of young native lake trout marked the 24th observation in the last 25 years, however the low numbers of native adults observed during that time period continues to indicate substantial restoration impediments still exist.

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], U.S. Geological Survey [USGS], U.S. Fish and Wildlife Service [USFWS], and Ontario Ministry of Natural Resources and Forestry [OMNRF]) developed the Joint Plan for Rehabilitation of Lake Trout in Lake Ontario (Schneider et al. 1983, 1997) which guided restoration efforts and evaluation through 2014. A revised document, *A Management Strategy for the Restoration of Lake Trout in Lake Ontario, 2014 Update* (Lantry et al. 2014), will guide future efforts. This report documents progress towards restoration by reporting on management plan targets and measures through 2018.

The Great Lakes Science Center (GLSC) is committed to complying with the Office of Management and Budget data release requirements and providing the public with high quality scientific data. The USGS research vessel data collected between 1958 and 2018 is publicly available from the GLSC website (http://doi.org/10.5066/F75M63X0). Please direct any immediate questions to our Information Technology Specialist, Scott Nelson, at snelson@usgs.gov. All USGS sampling and handling of fish during research are carried out in accordance with guidelines for the care and use of fishes by the American Fisheries Society (http://fisheries.org/docs/wp/Guidelines-for-Use-of-Fishes.pdf). Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Methods

Adult Gill Net Survey

During September 1983-2018, adult lake trout were collected with gill nets at random transects within each of 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 description of survey history including gear changes and corrections see Elrod et al. (1995).

During September 2018, NYSDEC R/V Seth Green fished standard monofilament gill nets for adult lake trout at 7 of the 14 geographic locations From Rochester to Cape Vincent along the U.S. shore in Lake Ontario. The USGS R/V Kaho was unavailable for most of the survey due to mechanical breakdowns, but was able to fish one location near Olcott, N.Y. at the western end of the U.S. shoreline. 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 the six sites in the lake's main basin, four survey nets were fished along randomly chosen transects, parallel to depth contours beginning at the 10ºC (50ºF) isotherm and proceeding deeper in 10-m (32.8-ft) increments. At two sites in the eastern basin, less than the standard four nets per site were fished due to thermocline depth. In the Black River Channel three nets were fished between 26 m and 42 m (85.3 – 437.8 ft); and in the St. Lawrence Channel three nets were fished between 32 to 51 m (105.0 – 167.3 ft).

For all lake trout captured, total lengths and weights were measured, body cavities were opened, and prey items were removed from stomachs, identified, and enumerated. Presence and types of fin clips were recorded, and when present, coded wire tags (CWTs) 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 depth-based strata, representing net position from shallowest to deepest. The unit of effort was one overnight set of one net. Depth stratification was used because effort was not equal among years and catch per net decreased uniformly with increasing depth below the thermocline (Elrod et al. 1995). 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 linear regression of ln(CPUE) on age for fish ages 7 to 11 that received coded wire tags. 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 and Prindle 2006).

Adult condition was indexed from both the predicted weights of a 700-mm (27.6 in) 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. Lake trout in those comparisons were of the lean morphotype, the only morphotype stocked into Lake Ontario until 2009. Since 2009, six year-classes of the Klondike (SKW) strain lake trout (2008, 2013-2017) were stocked into Lake Ontario. The SKW strain originated from a native, deep spawning "humper" morphotype of Lake Superior lake trout that are intermediate in fat content to lean and fat (siscowet) morphotypes with the potential to have a higher condition factor than the leans. When the first year-class (2008) of SKWs reached maturity in 2014, however, their age-6 Fulton's K value (1.07) was almost identical to Seneca Lake strain (SEN's;

1.08), one of the most prominent strains in the population. Thus, we included SKW in the population calculation of age-6 Fulton's K. No age-6 SKW were in the lake in 2018.

In past reports, population reproductive potential was estimated by calculating annual egg deposition indices (O'Gorman et al. 1998) from catches of mature females in September gill nets using length-fecundity relationships, and by accounting for observed differences in mortality rates among strains (Lantry et al. 2018). CPUE of mature females >3999g and egg indices were generally very well correlated from 1983-2017 (Figure 10, Lantry et al. 2018). In this year's report we used Pearson correlation to examine the correspondence between the two trends and only present female CPUE >3999 g to index reproductive potential.

Creel Survey

Catch and harvest by anglers fishing from boats on Lake Ontario 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 Harbor in the eastern basin (Connerton and Eckert 2019). The survey uses boat trips as the primary unit of effort. Boat counts are made at boat access locations and interviews are based on trips completed during April 15 - September 30, 1985-2018.

Juvenile Trawl Survey

From mid-July to early-August 1980-2017, 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 generally 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. In 2013, effort was reduced because no lake trout from the 2011 year-class were stocked in U.S. waters during 2012 (Lantry and Lantry 2013) and thus no U.S. stocked age-2 lake trout were present in 2013. Effort returned to routine levels in 2014 - 2017. In 2018, the R/V Kaho was unavailable and the R/V Seth Green only conducted trawling at 3 locations in the eastern portion of the lake during July 2 - 11. In this year's report, because of the greatly reduced survey effort, we report only on juvenile condition and the catch of naturally reproduced lake trout. For full description of survey design and changes see Lantry et al. (2018).

Data collection from trawl-captured lake trout was the same as that described above for fish captured with gill nets. 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 for 1981 – 2017 survey catches, we used the predicted weight of a 400-mm (15.8 in) fish caught in July bottom trawl surveys. A 400-mm fish would be age 2 or 3. Weights were estimated each year from length-weight regressions calculated from annual trawl catches of lake trout ranging in total length from 250 mm to 500 mm (9.8 in to 19.7 in); and from Fulton's K (Ricker 1975, Nash et al. 2006) for age-2 lake trout of both sexes. During 2018 only one age-2 lake trout was captured in the trawl survey. To index condition for 2018 juvenile lake trout, data from 54 fish 250-500mm TL caught in the September gillnet survey were used.

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 (1977 year-class) the USFWS Alleghany National Fish Hatchery (ANFH; Pennsylvania) was raising all lake trout stocked in U.S. waters of Lake Ontario and annual releases exceeded 0.60 million fish. In 1983, the first official Lake Ontario lake trout rehabilitation plan (Schneider et al. 1983) was formalized and it called for an annual U.S. stocking target of 1.25 million yearlings. 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, fishery managers reduced the lake trout stocking target to 500,000 yearlings because of a predator-prey imbalance in Lake Ontario and following recommendations from an international panel of scientists and extensive public review. Annual stockings were near the revised 1993 target level in 18 of 26 years during 1993-2018 (Figure 1). ANFH was closed in 2005 due to an outbreak of infectious pancreatic necrosis and remained closed for fish production through summer 2011. Completion of disinfection, renovation and disease trials permitted fish production to resume at ANFH in fall 2011. Lake trout stocked in 2006 were raised at the NYSDEC Bath Fish Hatchery. Lake trout for 2007 and 2008 stockings were raised at the USFWS Pittsford (the name was changed in 2009 to Eisenhower (ENFH)) and White River National Fish Hatcheries (WRNFH) in Vermont. In 2010, 94% of the stocked lake trout were raised at WRNFH and 6% were raised at NYSDEC Bath Fish Hatchery. All lake trout from stockings in 2009 and 2011 were raised at the USFWS WRNFH. In late August 2011, flooding of WRNFH from the adjacent White River during tropical storm Irene led to the USFWS decision to depopulate the hatchery over serious concerns of raceway contamination with didymo (*Didymosphenia geminate*) from the adjacent White River. As a result, no lake trout from the 2011 year-class were stocked into Lake Ontario in May 2012. Combined production of the 2012 year-class at ANFH and ENFH resulted in stocking of nearly 123,000 fall fingerlings and over 520,000 spring yearlings. During 2014, combined production of the 2013 year-class at ANFH and ENFH resulted in stockings of approximately 442,000 spring yearlings. That same year, fish managers increased the lake trout stocking target to 800,000 spring yearling equivalents (Lantry et al. 2014). Combined production of the 2014 year-class at ANFH and ENFH resulted in stocking of nearly 528,000 fall fingerlings and 521,000 spring yearlings (Connerton 2016). Combined ANFH and ENFH production of the 2015 year-class fish resulted in stocking of nearly 454,000 fall fingerlings and 384,000 spring yearlings (Connerton 2017). In fall 2016, fish managers reduced lake trout and Chinook salmon stocking targets to reduce predatory demand on alewife. The planned target stocking number of the 2016 year-class was 400,000 spring yearlings. No fall fingerling lake trout from the 2016 year-class were stocked. A mortality event at ANFH beginning in late fall 2016 further reduced the number of fish available for stocking, resulting in a combined ANFH and ENFH May 2017 stocking of 200,843 spring yearlings (Connerton 2018). The need to refresh broodstock at the Berkshire National Fish Hatchery also resulted in the release of 304 Klondike strain (SKW) adults from the 2012 year-class into the lake in December 2017.

Production targets for the 2017 year-class were met by stocking a combination of four strains of yearling lake trout in 2018 including 40,405 LCD produced at ENFH, and 119,227 SEN, 118,729 SKW, and 79,439 HPW from ANFH (Figure 1). Barge stocking was planned in 2018 at five sites, but bad weather forced shore stocking at Sodus and Olcott (Connerton 2019).

Abundance of Age-3 and Older Lake Trout

A total of 507 lake trout were captured in 30 nets during the September 2018 gill net survey, resulting in a total CPUE of mature adults of 13.83 (Figure 2). Catches of lake trout among sample locations were similar within years with the RSE for the CPUE of adult males and females (generally ≥ age 5) averaging only about 9.2% and 10.7% respectively, for the entire data series (Figure 3). The RSE for immature lake trout, however, rose by 115% between 2017 and 2018 due to the reduced numbers of nets fished, a higher mean CPUE, and an expanded range in catch totals that included the largest single catch of immature lake trout in one net (n = 32) since 1992. 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 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 1990s. After the 1998-1999 decline, the CPUE for mature lake trout remained relatively stable during 1999-2004 (mean = 11.1), appearing to reflect a new stable equilibrium established subsequent to the stocking reductions in 1993, but then abundance declined further (by 54%) in 2005. The 2005-2007 CPUEs of mature lake trout coincided with a nearly two-fold increase in the rate of wounding by sea lampreys on lake trout (Figure 6) and were similar to the 1983-1984 CPUEs which pre-dated effective sea lamprey control. The CPUE of mature lake trout increased each year during 2008-2014, but then declined during 2015-2017. Adult abundance in 2017 was 35% below the 2014 peak and 17% below 1999-2004 average. Results from the reduced effort deployed in the 2018 survey indicated adult abundance rose by 51% over 2017 values and was nearly equivalent to the prior peak observed in 2014. To examine whether the increase observed in 2018 was an artifact of fishing at only eight of the normal fourteen survey locations, we examined CPUEs calculated using data from only those eight sites (reduced design) for the 2011 to 2018 surveys. Comparisons indicated CPUE values and patterns were similar between the reduced and full survey datasets and the increased CPUE in 2018 was not solely due to decreased effort (Figure 2).

The CPUE for immature lake trout captured in gill nets (generally ages 2 to 5) declined by 64% between 1989-1993 (CPUE: 8.0) and 1995 (CPUE: 2.6) and remained at the lower level thereafter with a mean of 2.6 for 1995-2017. Similar to adult values, the 2018 CPUE for immature fish from the reduced 2018 survey increased by 1.7-fold over the 2017 full survey value. Comparisons between the reduced and full survey results for 2011-2018 again indicated that the CPUE values and patterns for both effort levels were similar.

Schneider et al. (1997) established a target gillnet CPUE of 2.0 for sexually mature female lake trout ≥ 4,000 g reflecting the level of abundance at which successful reproduction became detectable in the early 1990s. Building off observations in last year's report that the trends in the mature female CPUE and the egg deposition index were similar (Lantry et al. 2018), we ran Pearson correlations for the two time series and found strong positive correlation (Pearson $r = 0.741$). In this report, we only present the CPUE of mature females to index population reproductive potential. The CPUE for mature females reached the target value in 1989 and fluctuated about that value until 1992 (Figure 4). From 1992 until 2004, the CPUE exceeded the target, but fell below target during 2005 to 2009, coincident with the decline of the entire adult population. As the adult population abundance increased during 2008-2014, the CPUE of mature females ≥ 4,000 g also increased. During 2010-2018, CPUEs of mature females remained near or above target.

Angler Catch and Harvest

Fishing regulations, lake trout population size, and availability of other trout and salmon species influenced angler harvest through time (Lantry and Eckert 2018). Since 1988, managers instituted a slot size limit to decrease harvest of mature fish and increase the number and ages of spawning adults. In 1992, the regulation permitted a limit of three lake trout harvested outside of the protected length interval of 635 to 762 mm (25 to 30 in). Effective October 1, 2006, the lake trout creel limit was reduced to two fish per day per angler, only one of which could be within the 635 to 762 mm slot.

Annual catch and harvest of lake trout from U.S. waters of Lake Ontario (Figure 5) declined over 84% from 1991 to the early-2000s (Lantry and Eckert 2018). Catch and harvest declined further from the early to the mid-2000s reaching the lowest levels in the NYSDEC Fishing Boat Survey data series in 2007. Harvest at that time was more than 97% below the 1991 estimate. This low point in harvest coincided with lower adult abundance in the index gillnetting survey (Figure 2). Good fishing quality for other salmonids (i.e., anglers targeted other salmonids more frequently) may also have led to lower catch and harvest of lake trout during this period (Lantry and Eckert 2018). After 2007, however, catch and harvest rates and total catch and harvest increased for six consecutive years, then were relatively stable 2013-2016. Increases from 2007 through 2016 followed the October 2006 regulation change and coincided with an increase in lake trout abundance and anecdotal reports of anglers targeting lake trout more frequently during 2013-2016. Catch and harvest rates declined in 2017 and declined further in 2018 to 0.25 and 0.10 fish per boat trip, respectively resulting in lower total catch (12,205) and harvest (4,949) in 2018. Total harvest in 2018 was well below NY target harvest levels (i.e., <10,000 per year) set forth in the management strategy to maintain adequate adult survival (Lantry et al 2014). While catch and harvest totals have been low recently, relative to the late 1980s, catch and harvest rates increased to relatively high levels in 2015 and 2016 (e.g., catch rates were over 7.5 times higher than the 2007 record low). Catch rate in 2018 declined 73% from 2016; and was among the lowest recorded (7th lowest on record); however, it was still about 2 times higher than the lows observed in 2007 (Connerton and Eckert 2019). The 2017-2018 declines in lake trout catch, harvest, and catch and harvest rates coincided with good to excellent fishing quality for other trout and salmon species (especially Chinook salmon) which may have reduced fishing effort directed at lake trout in those years.

Sea Lamprey Predation

Percentage of A1 sea lamprey marks on lake trout (fresh wounds where the sea lamprey has recently detached) has remained low since the mid-1980s, however, wounding rates (Figure 6) in 9 out of 11 years between 1997 and 2007 were above the target level of 2 wounds per 100 fish ≥433 mm (17.1 in). Wounding rate rose well above target in 2005, reaching a maximum of 4.7 wounds in 2007 which was 2.35 times the target level. Wounding rates fell below target again in 2008 (1.47) and remained there through 2011 (0.62). While the rate was slightly above target again in 2012 (2.41) and 2013 (2.26), it fell below target in 2014 again thereafter and the 2017 and 2018 wounding rates (0.50 and 0.61, respectively) were the lowest for the data series.

Adult Survival

Survival of SEN strain lake trout (ages 7 to 11) was consistently greater (20-51%) than that of the SUP strain for the 1980-1990 year-classes (Table 1). Lower survival of SUP strain lake trout was likely due to higher mortality from sea lamprey (Schneider et al. 1996). Survival of both Jenny (JEN) and Lewis (LEW) strains were similar to the SUP strain, suggesting that those strains may also be highly vulnerable to sea lamprey. Ontario strain (ONT) lake trout were progeny of SEN and SUP strains (Appendix 1) and their survival was intermediate to that of their parent strains.

Survival for all strains combined (hereafter referred to as population survival) was based on all fish captured for the 1983-1995 and 2003-2009 cohorts as all fish stocked during those periods received coded wire tags. Population survival generally increased with successive cohorts through the 1985 year-class, exceeded the restoration plan target value of 0.60 beginning with the 1984 year-class, and remained above the target for most year-classes thereafter. Population survival of the 2003-2008 were all above target and survival for the 2009 year-class was at target (0.60). The SEN strain survival and the population survival for the 2004 and 2005 year-classes are above target and are identical because the stockings for both year-classes were predominantly SEN. Stockings for both of those year-classes were also far below the 500K target with all 224K of the 2004 year-class being stocked at one site in the eastern basin and all 118K of the 2005 year-class released at one site in the western part of the lake. The SUP strain was no longer available in 2006 and while stockings for the 2006 to 2008 year-classes were back near the 500K target and more evenly distributed between SEN and SUP-like strains, those strains from Lake Superior were now Traverse Island strain (STW) and Apostle Island strain (SAW). Strains from Seneca Lake origins now included SENs and feral (LCW) and domestic Lake Champlain strains (LCD). Survival for SENs (2006-2009 year-classes) continued to be high (≥74%) and survival for 2008 year-class of LCDs (73%, ages 7 to 10) resembled their mostly SEN origins. Only one year-class of LCWs was stocked (2009) and seems to be experiencing lower survival (47%, age7-9) than the LCDs. Survival rates could not be calculated for the first large stocking of STWs (225K of the 2006 year-class) which disappeared from survey catches after age 8. Survival for the 2007 (36%, ages7-11) and the 2008 (45%, ages 7-10) year classes of STWs appear low and similar to the early values for SUPs. Survival rates for SAW (53%, 2008 year-class, age 7-9 only) strains were also low and no SAWs were caught in 2018. The first stocking of Klondikes (SKW) occurred in 2009 with the release of the 2008 year-class which reached age-10 in 2018. SKW survival increased substantially from 64% (age 7-9) in 2017 to 72 % (ages 7-10) in 2018. Similarly, survival of SENs from the 2007 and 2008 year-classes increased from 81% and 76% in 2017 to 91 and 92% in 2018. Catches across most ages of SKWs and SENs increased substantially from 2017 to 2018 which seems to indicate there may have been a change in catchability rather than population abundance. This trend makes the survival increases for SKWs and SENs suspect with upcoming 2019 survey results needed to help explain these changes.

Growth and Condition

The predicted weight of a 700-mm lake trout (from length-weight regressions) decreased during 1983 to 1986 but increased irregularly from 1986 to 1996 and remained relatively constant through 1999 (Figure 7). Predicted mean weight declined by 158.8 g (5.6 oz) between 1999 and 2006 but increased again in

2007 and remained high through 2015. Predicted mean weight rose sharply after 2015 so that 2016-2018 mean (3814.9 g, 8.4 lb) was at the highest level for the data series. The trend of improving condition through 1996 and from 2007 to 2018 corresponded to periods when the abundance of older lake trout in the population was increasing. Our data suggested that for lake trout of similar length, older fish were heavier. To examine whether age was the primary driver of recent condition changes we calculated annual means for Fulton's K for age-6 mature male lake trout which removed the effects of age and sex, (Figure 7). Values of K for age-6 males, however, followed a similar trend as predicted weights and indicated that age alone was not the sole determinant of condition for this population. While both predicted weight and condition generally remained at a high level during 2007-2015, a declining trend from 2011 to 2015 was apparent. That trend reversed in 2016 with the second highest Fulton's K value recorded since the time series began in 1983. No value was calculated in 2017 as no fish were stocked from the 2011 year-class. The 2018 K value exceeded the 2016 value and now was the second highest for the data series.

Similar trends occurred for the predicted weight of 400-mm lake trout and Fulton's K for an age-2 lake trout (Figure 8). The 1999 -2018 mean values for both were below the 1978-1998 means. Both also experienced a decline in the means after 1999 and the 1999-2008 pattern seemed to coincide with changes in the foodweb. The mean for predicted weight during 1999-2016 declined by 15.4g below the 1979-1998 mean, paralleling declines in native benthic prey resources (Weidel et al. 2014). Predicted weight increased for a brief period during 2006-2008 paralleling increases in round goby (*Neogobius melanostomus*) abundance (Weidel et al. 2014), which are now common in lake trout diets. Predicted weight fell again in 2009 (591.3 g, 1.3 lb.) and in most years during 2010-2016, remained at values that were among the lowest for the time series, however values were relatively high in 2014 (620.0 g, 1.4 lb), 2017 (617.5 g, 1.4 lb) and 2018 (600.3 g, 1.3 lb).

Natural Reproduction

Evidence of survival of naturally produced lake trout past the fall fingerling stage occurred in each year during 1993-2018 (Figure 9) except 2008, representing production of 24 year-classes. Numbers reported in previous reports represented the total capture of age-0 to age-2 unclipped and untagged lake trout from the entire annual bottom trawl catch from four surveys occurring during April-October (for a description of the surveys see O'Gorman et al. 2000 and Owens et al. 2003). Catch was not corrected for effort due to the low catch in most years and a relatively constant level of effort expended within the depth range (20m -100m) where age-0 to age-2 naturally reproduced lake trout are most often encountered in Lake Ontario. Changes in recent annual survey design necessitated a change in the way we report the catch. In 2013 effort in the July juvenile lake trout survey was reduced and only 9 of 14 trawling locations were fished because no yearling lake trout were stocked in 2012. Effort returned to normal for the July survey during 2014-2017, but was once again reduced in 2018 due to the RV Kaho not being available for the survey. In 2015, the June bottom trawl survey was discontinued, and the annual April survey was broadened which resulted in a net decrease in annual trawling effort in U.S. waters of approximately 60 tows (Weidel et al. 2016). In the current report we converted total catch to catch-per-unit-effort (CPUE) to account for recent changes in effort. We present the data for five lake regions along the southern shore from the Niagara River in the west to the mouth of the St Lawrence River in the eastern basin, grouping them by geographic location and patterns in catch through the years that we suspect is related to the proximity to suitable spawning habitat. The regions from west to east were two sites near the mouth of the Niagara River (region 1), four sites located between Olcott and Rochester (region 2), four sites between Smoky Point and Fair Haven (region 3), three sites between Oswego and Southwick (region 4), and two sites in the eastern outlet basin (region 5).

The distribution of catches of wild fish suggests that lake trout are reproducing throughout New York waters of Lake Ontario with the greatest concentrations near the mouth of the Niagara River (region 1) and in the eastern portion of the lake (regions 4 and 5; Figure 9). The four largest catches of the 24-year time-series occurred during 2014-2017 with 47 age-1 (93-186 mm, 3.7-7.3 in) and 70 age-2 wild lake trout (176-291 mm, 6.9-11.5 in) caught in 2014; 24 age-1 (94-147 mm, 3.7-5.8 in) and 48 age-2 (167-262 mm, 6.6-10.3 in) caught in 2015; 21 age-1 (87-169 mm, 3.5-6.6 in) and 30 age-2 (178-245 mm, 7.0-9.6 in) caught in 2016; and 8 age-1 (90-133 mm, 3.5-5.2 in) and 62 age-2 (148-265 mm, 5.8-10.4 in) caught in 2017. The relatively low catch (3 age-1 and 3 age-2) near the Niagara River in 2018 is, in part, due to the two sites there not being fished during July when most wild lake trout were encountered in the past. The small age-0 lake trout (<100 mm, 3.9 in) observed early in the time series disappeared from catches by the early 2000s and may have been due, in part, to a change in our trawl gear that was necessary to avoid abundant dreissenid mussels. The wild yearlings captured in 2010-2018 were the first wild yearlings caught since 2005.

Catches from at least 24 cohorts of wild lake trout since 1994 and survival of those year-classes to older ages implies feasibility of lake trout rehabilitation in Lake Ontario (Schneider et al. 1997). The recent large catches of wild lake trout off the mouth of the Niagara River are encouraging, but those occurred in only one portion of the lake. Achieving the goal of a self-sustaining population requires consistent production of relatively large wild year-classes across the range of spawning habitat and survival of those fish to reproductive ages. Lack of a similar trend of expanding production of wild lake trout near the reputed spawning habitat in the eastern basin indicates that drivers of local spawning success (e.g., spawning habitat) need to be further explored.

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Appendix 1.

Strain Descriptions

SEN - Lake trout descended from a native population that coexisted with sea lamprey in Seneca Lake, NY. A captive brood stock was maintained at the USFWS Alleghany National Fish Hatchery (ANFH) which reared lake trout for stocking in Lakes Erie and Ontario beginning with the 1978 year-class. Through 1997, eggs were collected directly from fish in Seneca Lake and used to supplement SEN brood stocks at the USFWS Alleghany National Fish Hatchery (ANFH) and USFWS Sullivan Creek National Fish Hatchery (SCNFH). Beginning in 1998, SEN strain broodstocks at ANFH and SCNFH were supplemented using eggs collected from both Seneca and Cayuga Lakes. Since 2003 eggs to supplement broodstocks were collected exclusively from Cayuga Lake.

LC - Lake trout descended from a feral population in Lake Champlain. The brood stock (Lake Champlain Domestic; LCD) is maintained at the State of Vermont's Salisbury Fish Hatchery and is supplemented with eggs collected from feral Lake Champlain fish. Eggs taken directly from feral Lake Champlain fish (Lake Champlain Wild; LCW) were also reared and stocked.

SUP - Captive lake trout brood stocks derived from "lean" Lake Superior lake trout. Brood stock for the Lake Ontario stockings of the Marquette strain (initially developed at the USFWS Marquette Hatchery; stocked until 2005) was maintained at the USFWS Alleghany National Fish Hatchery until 2005. The Superior – Marquette strain is no longer available for Lake Ontario stockings. Lake Ontario stockings of "lean" strains of Lake Superior lake trout resumed in 2007 with Traverse Island strain fish (STW; 2006-2008 year-classes) and Apostle Island strain fish (SAW; 2008 and 2012 year-classes). Traverse Island strain originated from a restored "lean" Lake Superior stock. The STW brood stock was phased out of production at USFWS Iron River National Fish Hatchery (IRNFH) and is no longer be available as a source of eggs for future Great Lakes stockings. The Apostle Island strain was derived from a remnant "lean" Superior stock restored through stocking efforts, was phased out of production at USFWS Iron River National Fish Hatchery (IRNFH) and is no longer be available as a source of eggs for future Great Lakes stockings.

SKW - Originated from a native, deep spawning "humper" morphotype of Lake Superior lake trout that are intermediate in fat content to lean and fat (siscowet) morphotypes. Captive brood stocks have been held at the USFWS Sullivan Creek National Fish Hatchery and USFWS Iron River National Fish Hatchery. The USFWS Berkshire National Fish Hatchery developed a SKW brood stock to supply fertilized eggs to ANFH for rearing and stocking into Lake Ontario.

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

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 - 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 (see Elrod et al. 1995).

HPW - "Lean" lake trout strain originated from a self-sustaining remnant population located in Parry Sound on the Canadian side of Lake Huron in Georgian Bay. A captive HPW broodstock is maintained at the USFWS Sullivan Creek National Fish Hatchery and is the source of eggs for HPW reared at USFWS

Alleghany National Fish Hatchery in Warren, Pennsylvania for stocking into Lake Ontario. The first HPW lake trout stocking into Lake Ontario occurred in fall 2014.

For further discussion of the origin of strains used in Lake Ontario lake trout restoration see Krueger et al. (1983), Visscher, L. 1983, and Page et al. 2003.

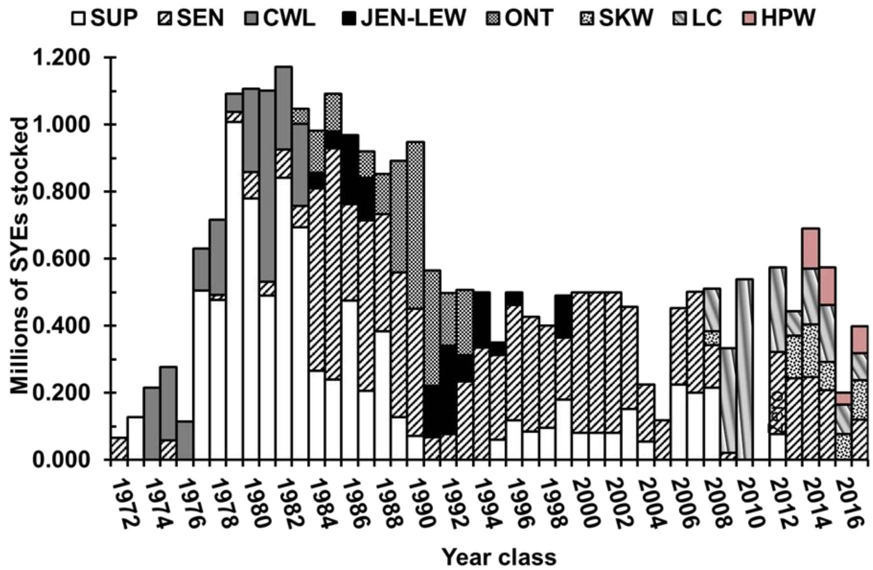

Figure 1. Total spring yearling equivalents (SYE) for lake trout strains (strain descriptions for ONT, JEN-LEW, CWL, SEN, LC, SUP, SKW, HPW appear in Appendix 1) stocked in U.S. waters of Lake Ontario for the 1972 – 2017 year-classes. For year-classes beginning in 2006, SUP refers to Lake Superior lean strains (SAW and STW) other than the Superior Marquette Domestics stocked prior to that time. SYE = 1 spring yearling or 2.4 fall fingerlings (Elrod et al. 1988). No lake trout from the 2011 year-class were stocked in 2012.

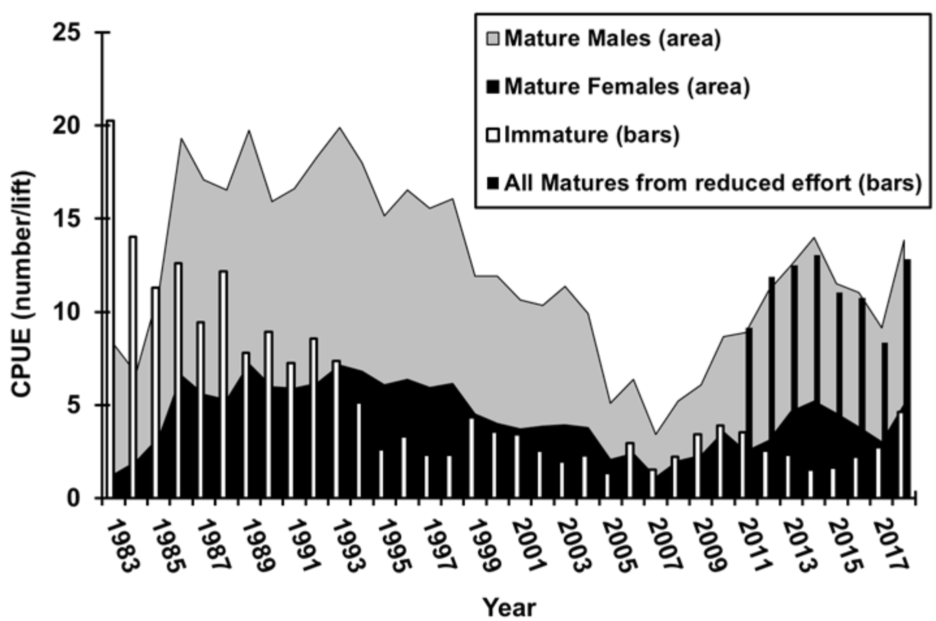

Figure 2. Abundance of mature (generally males ≥ age 5 and females ≥ age 6) and immature (sexes combined) lake trout calculated from catches made with gill nets set in U.S. waters of Lake Ontario, during September 1983-2018. CPUE (number/lift) was calculated based on four strata representing net position in relation to depth of the sets.

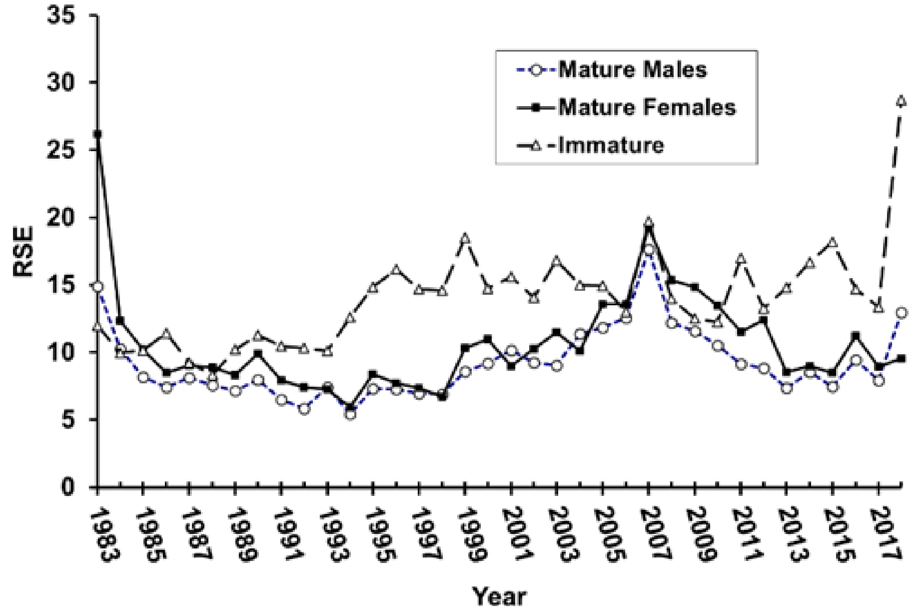

Figure 3. Relative standard error (RSE = {SE / Mean}*100) of the annual CPUE for mature males, mature females and immature (sexes combined) lake trout caught with gill nets set in U.S. waters of Lake Ontario, during September 1983-2018. RSE increases after 1993 are in part due to an effort reduction with the number of sites sampled declining from 17 to 14 in 1994. In 2018 there were only 8 sites sampled with a total of 30 nets fished compared to an average of 53 nets (range 42-58) fished for the 14 sites sampled during 1994-2017. The reduced effort in 2018 contributed to the increases in RSE for the 2018 CPUEs.

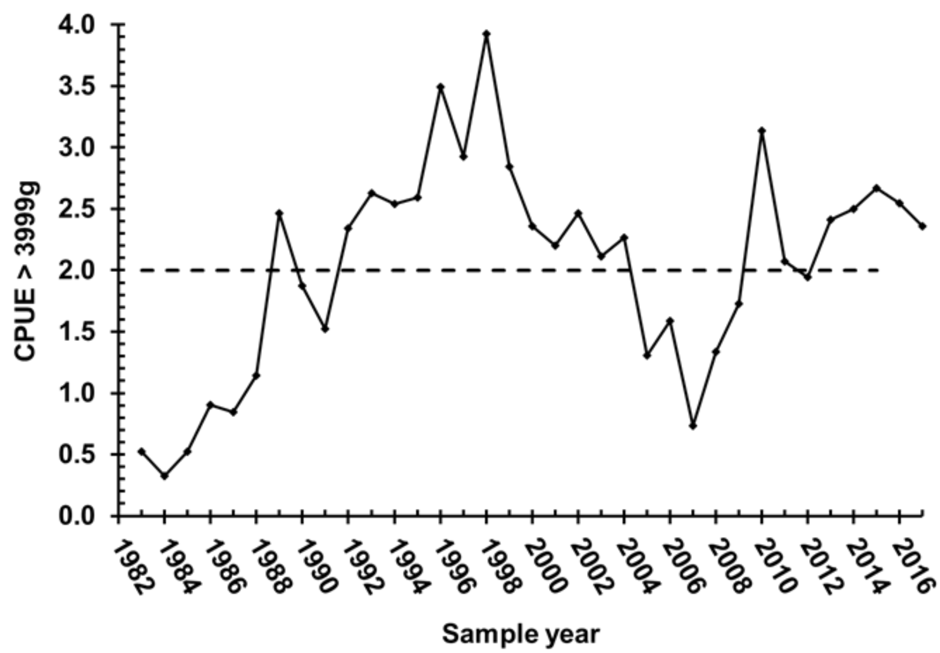

Figure 4. Abundance of mature female lake trout ≥4000g calculated from catches made with gill nets set in U.S. waters of Lake Ontario, during September 1983-2018. The dashed line represents the target CPUE from Schneider et al. (1997) and Lantry et al. (2014).

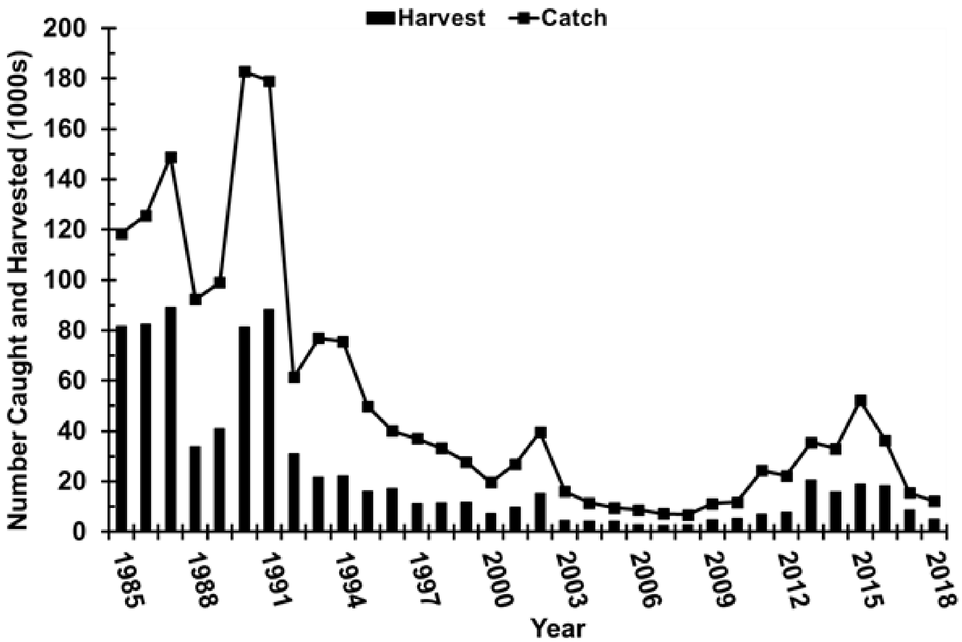

Figure 5. Estimated numbers of lake trout caught and harvested by boat anglers from U.S. waters of Lake Ontario, during April 15 – September 30, 1985-2018 (Connerton and Eckert 2019). Beginning with the 2012 report, all values have been reported reflecting a 5.5-month sampling interval. Prior reports were based on a 6-month sampling interval (April 1 – September 30).

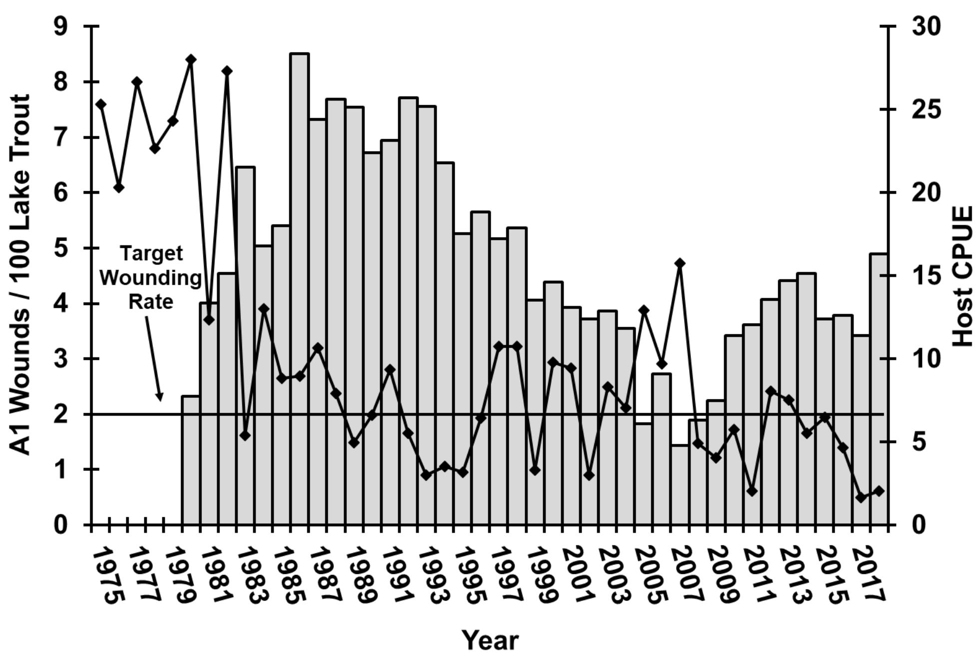

Figure 6. Wounding rates (A1 wounds per 100 lake trout, line) inflicted by sea lamprey on lake trout ≥ 433 mm (17.1 in) TL and the gill net CPUE of lake trout hosts (≥ 433 mm TL, bars) collected from Lake Ontario in fall, 1975-2018.

Table 1. Annual survival of various strains (strain descriptions appear in Appendix 1) of lake trout, sampled from U.S. waters of Lake Ontario, 1985-2018. Dashes represent missing values due to no or

low numbers of tagged lake trout stocked for the strain, or when the strain was not in the US federal hatchery system. ALL is population survival of all strains combined using only coded wire tagged fish. Values for ALL in some years are influenced by strains not included in the table because they only appeared in the lake for a short while (e.g., the 1991-1993 cohorts of OXS) or because they only occurred before successful sea lamprey control was established (1974-1983 cohorts of CWL).

YEAR		STRAIN									
CLASS	AGES	JEN	LEW	ONT	SUP	SAW	STW	SEN	LCD	SKW	ALL
1978	7-10	-	-	-	0.40	-	-	-	-	-	-
1979	7-11	-	-	-	0.52	-	-	-	-	-	-
1980	7-11	-	-	-	0.54	-	-	0.85	-	-	-
1981	7-11	-	-	-	0.45	-	-	0.92	-	-	-
1982	7-11	-	-	-	0.44	-	-	0.82	-	-	-
1983	7-11	-	-	0.61	0.54	-	-	0.90	-	-	0.57
1984	7-11	0.39	-	0.61	0.48	-	-	0.70	-	-	0.65
1985	7-11	-	-	0.80	0.47	-	-	0.77	-	-	0.73
1986	7-11	0.57	-	-	0.43	-	-	0.81	-	-	0.62
1987	7-11	0.50	-	-	0.50	-	-	0.80	-	-	0.73
1988	7-11	-	-	0.77	0.61	-	-	0.73	-	-	0.68
1989	7-11	-	-	0.78	0.59	-	-	0.86	-	-	0.81
1990	7-11	-	-	0.64	0.60	-	-	0.75	-	-	0.68
1991	7-11	-	0.56	0.62	-	-	-	0.70	-	-	0.70
1992	7-11	-	0.51	-	-	-	-	0.81	-	-	0.60
1993	7-11	-	0.64	-	-	-	-	0.72	-	-	0.71
1994	7-11	-	0.73	-	-	-	-	0.45	-	-	0.56
1995	7-11	-	0.50	-	-	-	-	0.76	-	-	0.72
1996	7-10	-	-	-	0.43	-	-	-	-	-	-
1999	7-11	-	-	-	-	-	-	0.84	-	-	-
2000	7-11	-	-	-	-	-	-	0.90	-	-	-
2001	7-11	-	-	-	-	-	-	0.73	-	-	-
2003	7-11	-	-	-	0.53	-	-	0.72	-	-	0.68
2004	7-11	-	-	-	-	-	-	0.78	-	-	0.78
2005	7-11	-	-	-	-	-	-	0.85	-	-	0.85
2006	7-11	-	-	-	-	-	-	0.74	-	-	0.72
2007	7-11	-	-	-	-	-	0.36	0.91	-	-	0.84
2008	7-10	-	-	-	-	0.53	0.45	0.92	0.73	0.72	0.73
2009	7-9							0.58	0.66		0.60

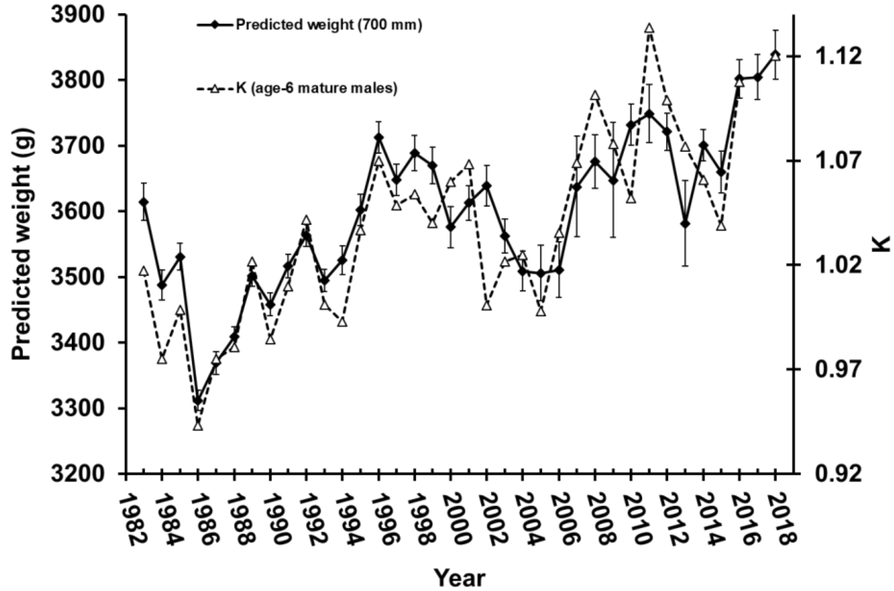

Figure 7. Lake Ontario lake trout condition (K) for age-6 mature males and predicted weight at 700-mm (27.6 in) TL from weight-length regressions calculated from all fish collected during each annual gill net survey, September 1983 – 2018. There were no fish stocked from the 2011 year-class in 2012 so age-6 K is not available in 2017. Error bars represent the regression confidence limits for each annual value.

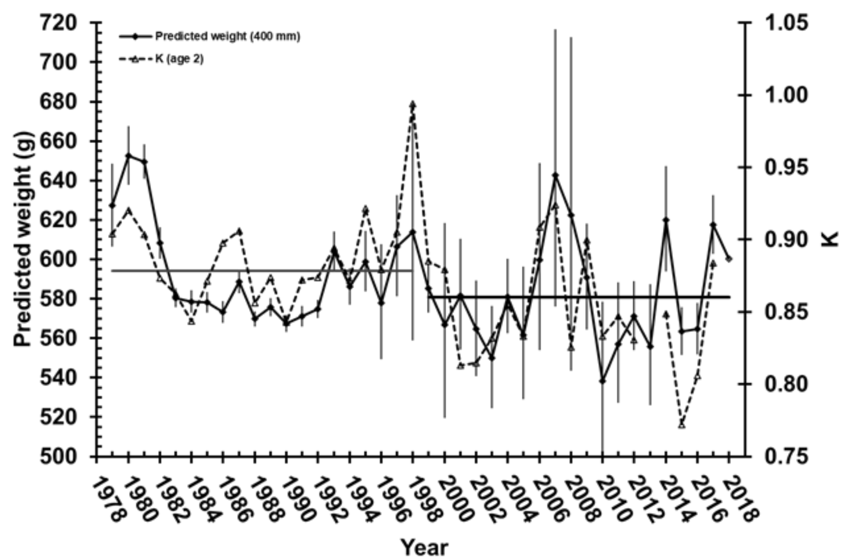

Figure 8. Lake Ontario lake trout condition (K) for age-2 coded wire tagged fish and predicted weight at 400-mm (15.8 in) TL from annual weight-length regressions calculated from fish 250 mm-500 mm (9.8 to 19.7 in). All lake trout were sampled from bottom trawls, July-August 1978-2017. The horizontal lines represent the mean predicted weights during 1979-1998 and during 1999-2017. Sample sizes for regressions were ≥ 39 except for 1997, 2000, 2005, 2006, 2007, 2008 and 2013 (n = 13, 15, 19, 11, 14, 20 and 12, respectively). There were no fish stocked from the 2011 year-class in 2012 so age-2 K is not available in 2013. The value for predicted weight in 2018 came from age-2 lake trout caught in gillnets during the September survey. Error bars represent the regression confidence limits for each annual value.

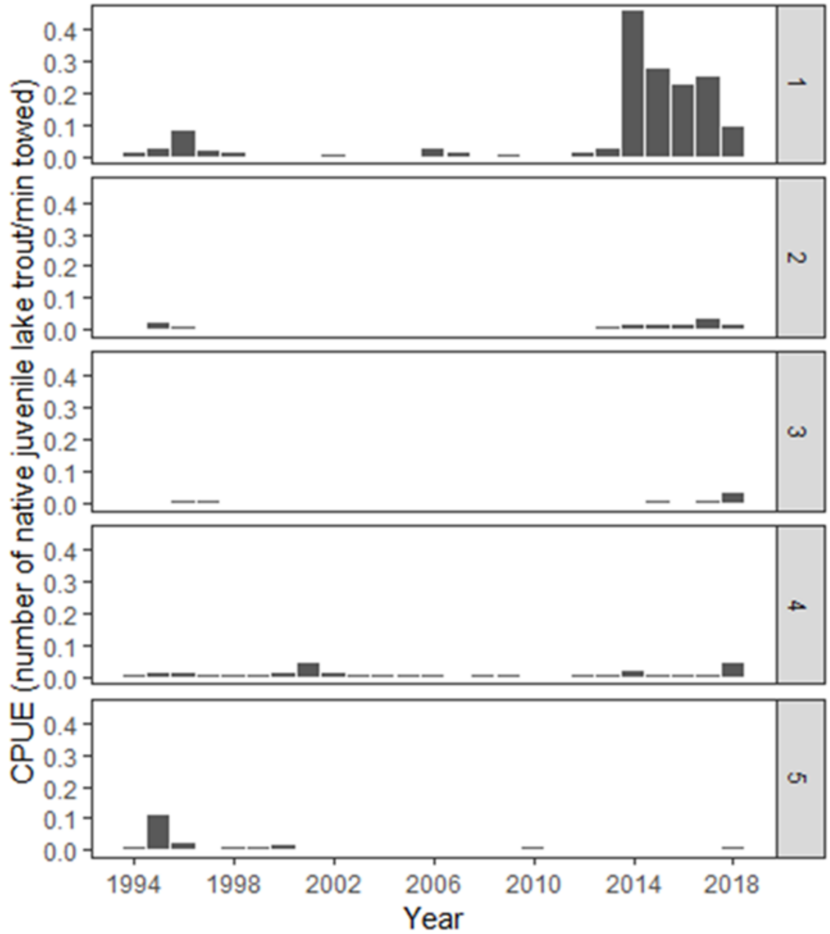

Figure 9. CPUE of naturally produced (wild) age-0 to age-2 lake trout captured with bottom trawls in Lake Ontario by NYSDEC and USGS, 1994-2018. Numbered panels represent regional groupings of bottom trawl locations proceeding from west to east: two sites near the mouth of the Niagara River (region 1), four sites located between Olcott and Rochester (region 2), four sites between Smoky Point and Fair Haven (region 3), three sites between Oswego and Southwick (region 4), and two sites in the eastern outlet basin (region 5).