Lake Ontario August gillnet survey and lake trout assessment, 2023

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Abstract

Lake Ontario lake trout (*Salvelinus namaycush*) rehabilitation has been annually assessed with fishery independent surveys since 1983, to evaluate program benchmarks and compare observations with management objectives. These surveys provide information on the abundance, strain composition, and condition of the adult lake trout stock, as well as information on levels of natural recruitment, sea lamprey (*Petromyzon marinus*) wounding rates, and abundance indices of other coldwater fish species (burbot *Lota lota*, cisco *Coregonus artedi*, and lake whitefish *C. clupeaformis*). In 2023, the catch per unit effort (CPUE) of total lake trout in gillnets was notably lower (12.1 fish/net) compared to recent survey years 2018–2022 (average = 17.3 ± 1.0 SD fish/net). CPUE of mature females fell below target levels. Wild-produced mature lake trout remain rare in the adult population (1.0% of adult catch). Strain composition of stocked fish indicated approximately half (51%) of all coded wire tagged lake trout captured in 2023 were from the Superior Klondike strain. Sea lamprey wounding rates decreased in 2023 and were near the target level (2.09 A1 wounds per 100 lake trout). Lake trout condition (predicted weight at length) remains high. Overall, the 2023 survey results suggest that lake trout indicators continue to meet some of the management objectives, however, recruitment of wild-produced offspring to the adult stock continues to be limited, and abundance of stocked fish may be decreasing relative to recent years in response to reduced stocking levels.

Introduction

Restoration of a self-sustaining lake trout (*Salvelinus namaycush*) population in Lake Ontario is a binational management objective (Lantry et al. 2014, Stewart et al. 2017). In Lake Ontario, lake trout were historically abundant prior to European settlement, and served as a native top predator in the coldwater fish community along with burbot (*Lota lota*) and Atlantic salmon (*Salmo salar*) (Smith 1995, Owens et al. 2003). By the mid-1950s, lake trout were considered extirpated in Lake Ontario, largely due to anthropogenic influences, and sea lamprey (*Petromyzon marinus*) predation; initial attempts to rehabilitate the population by stocking lake trout fry failed (Elrod et al. 1995). The advent of sea lamprey suppression programs in the 1970s coincided with resumed attempts to stock lake trout with annual yearling and fingerling stocking events. Since the 1970s, annual stocking rates in US waters have varied from approximately 1 million spring yearling equivalents per year during the 1980s, to approximately 300,000 per year since 2019 (Great Lakes Stocking database: http://fsis.glfc.org/). Managers have focused on stocking a diversity of genetically distinct strains, and more recently, broadening functional diversity by stocking a presumed deeper water morph (i.e., Lake Superior Klondike Reef [SKW] 'humper' strain). In their wild source populations, 'humper' strains, or more easily explained as an intermediate between 'lean' and 'deepwater' morphs, have higher fat content, deeper bodies, and tend to feed mainly on benthic prey than lean morphs which rely more on pelagic prey (Muir et al. 2012). In Lake Erie, stocked lake trout from Klondike Reef broodstock exhibited differences in diet, maturation, and survival, compared to strains derived from lean morphs (Rogers et al. 2019).

In this report, we summarized findings from the 2023 Lake Ontario August gillnet survey in context with long term trends from 1983 to 2023. We report on the status of the adult lake trout stock in US waters with an emphasis on indicators relevant to the most recent lake trout management strategy (Lantry et al. 2014). We also summarized abundance indices for other native coldwater fish species, specifically burbot, cisco (*Coregonus artedi)* and lake whitefish *(C. clupeaformis)*.

Methods

Gillnet Survey

During 1983-2021, the adult lake trout stock in US waters of Lake Ontario was assessed on an annual basis during September with gillnets fished along transects at randomly selected locations distributed across 17 geographic areas (Elrod et al. 1995). Not all 17 geographic areas are fished each year. During 1985–1995, eight to ten transects were also fished in Canadian waters at fixed locations. However, to standardize effort, all data and analyses presented in this report are based on US-only sites. Transects were fished perpendicular to shore, and the standard effort was typically three to four gillnets per transect. Survey design and gillnet construction (multi vs mono-filament netting) have changed through the years. For a description of survey history, including gear changes and corrections, see Elrod et al. (1995) and Owens et al. (2003). Since 1993, standard survey gillnets have consisted of monofilament netting with 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. Prior to 1993, standard survey gillnets were composed of multifilament netting with the same dimensions, except during 1990–1992 when one additional gillnet composed of monofilament netting was fished at each location for comparison.

During 2023, gillnets were fished from August-14 to August-24, marking the second consecutive survey year since the timing shift to August instead of September (Figure 1), to accommodate room for experimental trawling scheduled in September. Gillnets fished at the same site during August and again in September 2019 showed similar catches in terms of abundance, age distribution and strain composition. In 2023, gillnets were fished at 14 locations from as far west as the Port of Youngstown and as far to the northeast as just northwest of Galloo Island (Figure 2). At each location, two or four gillnets were set parallel to depth contours beginning at the 10°C isotherm and successively deeper at 10-m depth increments. At two sites in the eastern basin, near Galloo Island and near Stony Island, only two gillnets were fished because of depth-temperature constraints. Depths where gillnets were fished in the 2023 survey ranged from 17.5 to 79.4 m. Catches for each gillnet panel were sorted by species; total lengths (TL) and weights of individual fish were measured.

For all lake trout, prey items were identified and enumerated from stomach contents. Body size was recorded for intact prey species that were not highly digested. Sex and maturity were determined by visual inspection of gonads. Presence and types of fin clips were recorded, and when present, coded wire tags (CWTs) were removed and decoded to retrieve information on age and strain for recaptured fish of hatchery-origin. Sea lamprey wounds on lake trout were counted and graded according to King Jr. and Edsall (1979) and Ebener et al. (2006).

Because effort varied across locations and catch per net generally decreases with depth from the thermocline, a stratified catch per unit effort (CPUE) was calculated using four depth-based strata, representing net position from shallowest to deepest. Gillnets were fished for one night and the unit of effort was one overnight set per net. Survival of different year-classes and strains was estimated by taking the antilog slope from the linear regression of the natural logarithm (CPUE) as a function of age for fish ages 7 to 11 that received CWTs. We summarized demographic trends by sex and maturity, and for large (≥ 4,000 g) female lake trout. A condition index (predicted weight at a given length) was calculated using a linear regression based on length-weight data from all lake trout collected in the survey. Regression coefficients were used to predict the weight of a 700 mm TL lake trout each year. We calculated wounding rates from sea lamprey as the number of A1 wounds per 100 lake trout > 432 mm TL. For an index of natural reproduction, based on gillnet catches, we quantified the proportion of hatchery-origin lake trout (i.e., those with CWTs or fin clip marks) to putative-wild fish (i.e., unmarked fish).

Stocking information was compiled from annual correspondence with the managers of the USFWS Alleghany National Fish Hatchery (ANFH, Pennsylvania), USFWS Eisenhower National Fish Hatchery (ENFH, Vermont), the White River National Fish Hatchery (WRNFH, Vermont), and the NYSDEC Bath Fish Hatchery, as well as from summaries presented in Elrod et al. (1995), Eckert (2001), and Connerton and Moore (2024). For detailed descriptions of stocking during 1973-2020 see Lantry et al. (2021).

Results and Discussion

Stocking

In 2023, barge stocking occurred at four locations (Wilson, Oak Orchard, Oswego, and Stony Point, Figure 2). Strain totals of stocked lake trout in 2023 (2022 year class) included 161,664 Huron Parry Sound (HPW), 80,502 Lake Champlain (LC), and 80,412 Seneca Lake (SEN, Figure 3 and Table 1).

Abundance and Condition Indices

A total of 649 lake trout were caught in 52 gillnet sets from 14 sites during the August 2023 survey. Total lake trout CPUE was 12.1 (fish/net), which marks a decrease from values observed in recent years (Figure 4a). Mature male lake trout CPUE (6.5) was lower compared to the average over the last five years (9.2 ± 0.7 SD), and mature female CPUE (3.0) was the lowest observed since 2011 (Figure 4b-c). Total immature lake trout CPUE (2.7) was lower than in 2022 but overall similar to recent years. (Figure 4d). One hermaphroditic lake trout was sampled, having both female and male gonads present. The proportion of immature and mature lake trout in gillnet catches varied by location. A notably higher proportion of the catch was composed of immature lake trout at Youngstown relative to other locations (Figure 5). In 2023, CPUE (unstratified) of mature female lake trout ≥ 4,000 g was 1.6 fish/net (Figure 6) which was below the 2.0 fish/net target level established in lake trout management strategy (Schneider et al. 1998; Lantry et al. 2014). This marks the first time since 2012 that mature female lake trout of reproductive size has fallen below target. Overall, since 2010 the CPUE of mature females ≥ 4,000 g has generally remained near or above target after a period of below target during 2005–2009 (average CPUE = 1.4 ± 0.4). Condition, expressed as the predicted weight of a 700 mm TL lake trout, reached a high in 2022 and was lower in 2023 but remains relativewly high overall (predicted weight = 3,858 g at 700 mm TL; Figure 7). Since 1983, condition has shown an overall increase, and has remained consistently high > 3,700 g during recent survey years 2015–2023.

Sea Lamprey Predation

Rates of A1 sea lamprey marks on lake trout (fresh wounds where the sea lamprey has recently detached) were low in most years since the mid-1980s compared to high rates during 1975–1980 (Lantry et al. 2021; Figure 8). Wounding in 2023 was back to near-target levels at 2.09 A1 wounds per 100 lake trout > 432 mm TL, and down from a recent high point in 2022 likely because lampricide treatment has resumed at full scale following a pause during the COVID pandemic. Host CPUE (fish/net unstratified), expressed as the CPUE of lake trout > 432 mm TL was also lower at 12.0 fish/net and more like values pre-2018.

Strain Composition of Recaptured Fish

In total, 535 hatchery-origin lake trout with CWTs were recaptured in the 2023 gillnet survey (Figure 9). Strain composition based on CWT reads showed recaptured fish were mostly from the SKW strain (51%), followed by LC (19%), SEN (18%), and HPW (12%). Lake trout with CWTs recaptured in 2023 ranged from 2-33 years in age (Figure 10).

Angler Catch and Harvest

The NYSDEC fishing boat survey has been conducted each year from 1985 to 2023 (except 2020). We report on lake trout angler catch and harvest trends (Figure 11). Fishing regulations, lake trout population size, and availability of other trout and salmon species influenced angler harvest through time (Connerton et al. 2020). During 1988-1992, managers implemented a slot size limit to decrease harvest of mature lake trout and increase the number and ages of spawning adults in the population (Elrod et al. 1995). The slot limit from 1992 persisted through 2006, permitting a limit of three lake trout harvested outside of the protected length interval of 635 to 762 mm (25 to 30 inches). Effective October 1, 2006, the lake trout creel limit was reduced to two fish per day per angler, one of which could be within the 635 to 762 mm slot.

Annual angler catch and harvest of lake trout from US waters of Lake Ontario declined over 84% from 1991 to the early-2000s (Connerton et al. 2020). Angler catch and harvest further declined from the early- to mid-2000s, reaching 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 gillnet survey. Good fishing quality for other trout and salmon species may have also led to lower catch and harvest of lake trout during this period (Connerton et al. 2020). After 2007 however, catch and harvest and their rates increased for six consecutive years, then were relatively stable during 2013-2016 (Figure 11). 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. While angler catch and harvest totals have been low recently compared to the 1980s, harvest during 2013-2016 exceeded the US 10,000 lake trout target for restoration (Lantry et al. 2014). Catch rates of lake trout declined between 2016 and 2019, trending from 0.94 to 0.39 fish per boat trip, as did total catch, dropping from 36,336 fish in 2016 to 16,354 in 2019 (Connerton et al. 2020). The 2017-2019 declines in lake trout total catch, total harvest, and catch and harvest rates coincided with good to excellent fishing quality for other trout and salmon species, which may have reduced fishing effort directed at lake trout in those years. In 2023, estimated angler total catch (13,761) and angler harvest (8,122) of lake trout decreased slightly compared to estimates from 2022 (Figure 11). When summed, angler harvest (8,122) plus lake trout harvested from the survey in 2023 (649) remained below the management strategy harvest target level.

Adult Survival

Survival of SEN strain lake trout (ages 7 to 11) was consistently greater (20-51%) than that of Lake Superior (SUP) strain lake trout for the 1980-2003 year-classes (Table 2). Lower survival of SUP strain lake trout was likely due to higher mortality from sea lamprey predation (Schneider et al. 1996). Survival of both Jenny and Lewis Lake (JEN-LEW) strains (1984-1995 year-classes) were similar to the SUP strain, suggesting that those strains might also be highly vulnerable to sea lamprey. The Lake Ontario strain (ONT) was developed from egg collections of feral adults at a time when the composition of survey catches was predominantly SUP, SEN, and Clear Water Lake (CWL) strains (Elrod et al. 1995; Schneider et al. 1996); and the survival of 1983-1991 year-classes was intermediate to that of SENs and SUPs.

Population survival was based on catches for all strains combined for the 1983-1995 and 2003-2014 cohorts, as all fish stocked during those periods received coded wire tags. Population survival exceeded the management strategy target of 0.60 beginning with the 1984 year-class and remained above target for most year-classes thereafter. However, population survival from the 2013 and 2014 year-classes, which represents cohorts that have reached ages 7-10 in recent survey years, has fell below the target level (e.g., 0.52 for 2013 year-class; 0.53 for 2014 year-class).

The SUP strain was no longer available in 2006 and the Traverse Island strain (STW) and Apostle Island strain (SAW), also both of Lake Superior origin, replaced SUPs in stockings from 2007-2009 and in 2009 and 2013, respectively. For simplicity, we grouped all Lake Superior strains except for the Klondike Reef strain under the SUP strain category. Strains from Seneca Lake origins included feral and domestic Lake Champlain strains (LCW and LCD, respectively) beginning with the 2009 stockings. For simplicity, we grouped all Lake Champlain strains under the LC strain category. Survival for LC 2008-2010 and 2012 year-classes (60-71%) resembled their mostly SEN origins. Only one year-class of LCWs was stocked (2009) and its survival (not shown in Table 2) for ages 7-10 (73%) was also similar to SENs. Survival rates could not be calculated for the first large stocking of STWs (225,000 of the 2006 year-class) as they disappeared from survey catches after age 8. Survival for the 2007 (36%, ages 7-11) and the 2008 (41%, ages 7-11) year-classes of STWs was relatively low and similar to early values for SUPs. Survival rates for the SAW (53%, 2008 year-class grouped as SUP in Table 2) strain was also low and no 2008 SAWs were caught in 2018 or 2019. There were no SAWs stocked during 2010-2012 (2009-2011 year-classes), but the 2012 year-class of SAWs (stocked in 2013) observed in survey catches at ages 7-10 during 2019-2022 also experienced relatively low survival (61%).

The first stocking of Klondike Reef Strain from Lake Superior (SKW) occurred in 2009 (2008 year-class) which reached age 11 in 2019. SKW survival for the 2008 year-class was 82% (ages 7-11) and similar to SEN strain survival for the 2007 and 2008 year-classes, which were > 90%. Further stockings of SKWs occurred during 2014-2018, with the 2013 year-classes reaching age 10 in 2023. Survival of the 2013 year-class of SKWs age 7-10 (51%) was lower than the 2008 year-class. Notably low survival (35%) was observed for Lake Champlain domestic (LC in Table 2) 2013 year-class, which was approximately half of the survival rate when compared to the 2008-2012 Lake Champlain strain year-classes. The first stocking of Huron Parry Sound Strain from Lake Huron (HPW) occurred in 2015, and survival of the 2014 year-class of HPW age 7-9 (32%) was the lowest when compared to other strains in the 2014 year-class. In comparison, survival of 2012-2014 SEN year-classes have remained relatively higher than other strains (> 60%).

Percent Wild in Gillnet Catches

The main goal of the Lake Ontario lake trout restoration effort is to re-establish a self-sustaining population supported by natural reproduction. Young naturally reproduced lake trout have been detected in Lake Ontario bottom trawl surveys, however the percentage of putatively wild mature fish (i.e., not clipped and not tagged) in gillnet surveys has remained low (Figure 12). In 2023, five putatively wild mature adult lake trout were captured during the survey. The overall percentage of putatively wild mature adults in gillnet catches remained low at 0.99% in 2023.

Abundance Indices: Burbot, Cisco and Lake Whitefish

Burbot abundance (CPUE) in the gillnet survey generally increased from 1983 to the mid-1990s when a peak CPUE of 0.3 (N=17 burbot) was reached in 1998 (Figure 13). Since the mid-2000s, burbot have been rare in gillnet catches. During 2006–2023, burbot CPUE remained below 0.04, and burbot were absent from catches in 10 out of the past 20 survey years. No burbot were captured in the survey in 2023.

Cisco CPUE has been low throughout the time series likely because they are a pelagic species and may occupy warmer or shallower depths than those fished during the gillnet survey (Figure 13). Several back-to-back survey years exist where zero cisco have been captured, however, since 2015, cisco have been collected each year during the survey. In 2022, a total of 29 cisco were captured in the gillnet survey for a CPUE of 0.5, which represents the highest cisco CPUE during 1983–2023. In 2023, a total of four cisco were captured and cisco CPUE was lower than in 2022 (0.08), but still relatively high when compared to observations from the late 1990s through pre-2015.

Lake whitefish abundance has been low (CPUE < 0.2) but consistent across most survey years, with only two years in the time series where no lake whitefish were captured (Figure 13). In 2023, a total of seven lake whitefish were captured representing a CPUE of 0.13.

Evaluating lake trout restoration in Lake Ontario compared to other Great Lakes

Lake trout rehabilitation throughout the Great Lakes shares a common goal, that is to restore self-sustaining, naturally reproducing populations of lake trout that support fisheries (Bronte et al. 2022). This goal was met in Lake Superior by the mid-1990s (Schreiner and Schram 1997), and recent signs of increased natural recruitment are encouraging in lakes Huron and Michigan. However, natural recruitment is poor (i.e., <6%) in lakes Erie and Ontario, where stocking has been required to maintain adult stocks of lake trout.

Lake Superior

In Lake Superior, natural recruitment is high, and has been higher than in any of the other Great Lakes on a whole-lake level, since at least as early as 1993 (Figure 14; Sitar 2021). In 1993, approximately 67% of fish captured in standard spring gillnet surveys were considered wild fish. This figure has risen consistently since then, and presently, wild fish comprise more than 90% of the lakewide lake trout population (Sitar 2021).

Lake Huron

Prior to 2010, the average percent wild adults (i.e., >533 mm TL) captured in the annual standardized spring gillnet survey in Lake Huron was approximately 8% (Figure 14; He 2019). Since about 2004, natural reproduction and survival of lake trout has been observed throughout Lake Huron (Riley et al. 2007; He et al. 2012; Scribner et al. 2018), and the percentage of wild adult lake trout captured during annual surveys has risen considerably. In 2018, nearly 60% of lake trout caught during the spring gillnetting survey were wild. Lake Huron has had the second highest level of percent wild since data has been available for all five lakes (i.e., 2000), and is currently more than double that of Lake Michigan, the Great Lake with next highest level of natural recruitment.

Lake Michigan

The percentage of wild fish captured in standard fall gillnet surveys on a lakewide basis between 1998 (the first year of data available) and 2009 was <6% (Figure 14; Madenjian et al. 2022). The percentage of wild fish captured during these surveys has risen in most years since, coinciding with declines in alewife abundance. In 2021, on a lakewide scale, approximately 24% of the lake trout caught in the fall gillnet survey were wild. However, it is important to note that there is considerable spatial variation in natural recruitment in Lake Michigan, which is high (55-62% wild in 2021) in the southern portion of the lake (IL, IN, MM7/8, WM5/6; Figure 15), but low in the northern areas of the lake (MM3 = 6-7% wild in 2021; Madenjian et al. 2022).

Lake Erie

Natural recruitment of lake trout in Lake Erie is poor (Figure 14). The percentage of adult wild lake trout captured in annual fall gillnet surveys has never exceeded 2.2%. In 2022, 1.5% of lake trout caught in the annual fall gillnet survey were considered wild (MacDougall et al. 2023). The first documentation of successful Lake Trout reproduction in Lake Erie occurred in 2021, when three free embryo lake trout were captured on Shorehaven Reef near Forsythe, New York. (Markham et al. 2022).

Lake Ontario

Like Lake Erie, Lake Ontario has consistently had limited levels of natural recruitment (Figure 14). The percentage of adult wild lake trout captured in annual U.S. fall gillnet surveys was at its highest in 2007, when 6% of the lake trout captured were wild. This number remains low and has averaged 1.3% from 2013 – 2023. However, during sampling for a lakewide lake trout telemetry study in 2023, 40.9% (n = 56 wild/137 total) of fish captured in Canadian waters were wild, whereas 3.3% (n = 6 wild/ 183 total) of fish captured in U.S. waters were wild (A. J. Gatch, unpublished data, USGS Great Lakes Science Center, March 2024). All fish sampled for this project were >512 mm, and fish were captured during spring 2023 using a combination of gillnets and angling. It is possible that natural recruitment is being underestimated in Lake Ontario on a lakewide basis if patterns of natural recruitment differ in Canadian waters.

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Data Release

The data associated with this report are currently under review and will be publicly available in 2023. Previous versions of the data may be accessed at U.S. Geological Survey, Great Lakes Science Center, 2019, Great Lakes Research Vessel Operations 1958-2018. (ver. 3.0, April 2019): U.S. Geological Survey data release, https://doi.org/10.5066/F75M63X0. Please direct questions to our Data Management Librarian, Sofia Dabrowski, at sdabrowski@usgs.gov.

References

Bronte, C.R., C. Davis, J.X. He, J. Holden, B.F. Lantry, J.L. Markham, S.P. Sitar. 2022 State of the Great Lakes 2022 Technical Report: Lake Trout Subindicator. Environment and Climate Change Canada and the U.S. Environmental Protection Agency. Available from: https://binational.net/wp-content/uploads/2023/11/State-of-the-Great-Lakes-2022-–-Technical-Report.pdf

Connerton, M. J. 2022. New York Lake Ontario and upper St. Lawrence River stocking program 2021. Pages 5–16. NYSDEC Lake Ontario Unit Annual Report.

Connerton, M.J., and R. J. Moore. 2024. Lake Ontario Fishing Boat Survey 1985-2023. Section 2 *In* NYSDEC 2023 Annual Report, Bureau of Fisheries, Lake Ontario Unit and St. Lawrence River Unit to the Great Lake Fishery Commission's Lake Ontario Committee.

Connerton, M.J.., N.V. Farese and R. J. Moore. 2020. Lake Ontario Fishing Boat Survey 1985-2019. Section 2 *In* NYSDEC 2019 Annual Report, Bureau of Fisheries, Lake Ontario Unit and St. Lawrence River Unit to the Great Lake Fishery Commission's Lake Ontario Committee.

Ebener, M. P., E. L. King Jr., and T. A. Edsall. 2006. Application of a dichotomous key to the classification of sea lamprey marks on great lakes fish. Great Lakes Fishery Commission Report.

Eckert, T. H. 2001. Lake Ontario stocking and mass marking program 2000. Pages 27–37. NYSDEC Lake Ontario Unity Annual Report.

Elrod, J. H., R. O'Gorman, C. P. Schneider, T. H. Eckert, T. Schaner, J. N. Bowlby, and L. P. Schleen. 1995. Lake Trout Rehabilitation in Lake Ontario. Journal of Great Lakes Research 21:83–107.

He, J. X. 2019. Regions and Sub-regions of Lake Trout in the Main Basin of Lake Huron. Journal of Aquatic Research and Marine Sciences 2(1):97-105.

He, J. X., M. P. Ebener, S. C. Riley, A. Cottrill, A. Kowalski, S. Koproski, L. Mohr, and J. E. Johnson. 2012. Lake Trout Status in the Main Basin of Lake Huron, 1973-2010. North American Journal of Fisheries Management 32:402-412.

King Jr., E. L., and T. A. Edsall. 1979. Illustrated field guide for the classification of sea lamprey attack marks on great lakes lake trout. Great Lakes Fishery Commission Report.

Lantry, B. F., B. C. Weidel, S. P. Minihkeim, M. J. Connerton, J. A. Goretzke, D. Gorsky, and C. Osborne. 2021. Lake trout rehabilitation in Lake Ontario, 2020. NYSDEC Lake Ontario Unit Annual Report.

Lantry, J., T. Schaner, and T. Copeland. 2014. A management strategy for the restoration of lake trout in Lake Ontario, 2014 update. Available from: http://www.glfc.org/pubs/lake_committees/ontario/Lake%20Ontario_Lake_Trout_Strategy_Nov_2014.pdf

MacDougall, T., G. Montague, J. Buskiewicz, J. Chiotti, A. Cook. C. Eilers, J. Markham, L. Sumner, J. Schmitt, J. Roberts, M. Haffley. 2023. 2022 Report of the Lake Erie Coldwater Task Group. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan.

Madenjian, C., C. Bronte, R. Clark, B. Dickinson, K. Donner, R. Gordon, D. Hanson, J. Janssen, J. Jonas, M. Kornis, S. Lenart, D. Makauskas, E. Olsen, R. Redman, J. Smith, L. Schmidt, T. Treska. 2022. 2021 Lake Michigan Lake Trout Working Group Report.

Markham, J. L., J. M. Robinson, C. C. Wilson, C. S. Vandergoot, P. D. Wilkins, R. C. Zimar, M. N. Cochrane. 2022. Evidence of Lake Trout (*Salvelinus namaycush*) natural reproduction in Lake Erie. Journal of Great Lakes Research 48:1728-1734.

Muir, A. M., C. C. Krueger, and M. J. Hansen. 2012. Re-Establishing Lake Trout in the Laurentian Great Lakes: Past, Present, and Future. Pages 533–588. 2nd ed. Michigan State University Press, East Lansing.

Owens, R. W., R. O'Gorman, T. H. Eckert, and B. F. Lantry. 2003. The offshore fish community in southern Lake Ontario 1972-1998. Pages 407-441 *In* (Ed.) Munawar State of Lake Ontario (SOLO) – Past, Present, and Future. Aquatic Ecosystem Health & Management Society.

Riley, S. C., J. X. He, J. E. Johnson, T. P. O’Brien, J. S. Schaeffer. 2007. Evidence of Widespread Natural Reproduction by Lake Trout *Salvelinus namaycush* in the Michigan Waters of Lake Huron. Journal of Great Lakes Research 33:917-921.

Rogers, M. W., J. L. Markham, T. MacDougall, C. Murray, and C. S. Vandergoot. 2019. Life history and ecological characteristics of humper and lean ecotypes of lake trout stocked in Lake Erie. Hydrobiologia 840:363–377.

Schneider, C. P., Owens, R. W., Bergstedt, R. A. and R. O'Gorman. 1996. Predation by sea lamprey (*Petromyzon marinus*) on lake trout (*Salvelinus namaycush*) in southern Lake Ontario, 1982-1992. Canadian Journal of Fisheries and Aquatic Science 53:1921-1932.

Schneider, C. P., T. Shaner, S. Orsatti, S. Lary, and D. Busch. 1998. A management strategy for Lake Ontario lake trout. Report to the Lake Ontario Committee.

Schreiner, D. R., and S. T. Schram. 1997. Lake Trout Rehabilitation in Lake Superior: Maintaining Our Progress. Fisheries 22(7):12-14.

Scribner, K., I. Tsehaye, T. Brenden, W. Stott, J. Kanefsky, and J. Bence. 2018. Hatchery Strain Contributions to Emerging Wild Lake Trout Populations in Lake Huron. Journal of Heredity 109:675-688.

Sitar, S. P. 2021 Status of Lake Trout in Lake Superior in 2017. *In* The state of Lake Superior in 2017. *Edited by* M.P. Ebener and T.C. Pratt [online]. Available from: http://www.glfc.org/pubs/SpecialPubs/Sp21_02.pdf

Smith, S. H. 1995. Early changes in the fish community of Lake Ontario. Great Lakes Fishery Commission Technical Report no. 60. 41 pp. Ann Arbor, MI.

Stewart, T. J., A. Toddy, and S. LaPan. 2017. Fish community objectives for Lake Ontario. Available from: http://glfc.int/pubs/lake_committees/ontario/LO-FCO-2013-Final.pdf#:~:text=This%20document%20updates%20the%201999%20goals%20and%20objectives,ecosystem%20evolves%20and%20our%20understanding%20of%20it%20improves.

Tables

Table 1. Lake trout strains stocked in Lake Ontario with abbreviated name.

Strain	Abbreviation
Clearwater Lake	CWL
Lake Huron-Parry Sound Wild	HPW
Jenny-Lewis Lakes	JEN-LEW
Lake Champlain	LC
Lake Ontario	ONT
Lake Superior Lean	SUP
Seneca Lake	SEN
Lake Superior Klondikes	SKW

Table 2. Annual survival of different lake trout strains sampled from US waters of Lake Ontario during the adult lake trout gillnet survey 1985-2023. Dashes represent missing values due to no or low numbers of tagged lake trout stocked for the strain, or when the strain was no in the US federal hatchery system. ALL is population survival of all strains combined using only coded wire tagged fishes. 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; the 2009 cohort of LCW) or because they only occurred before successful sea lamprey control was established (1974-1983 cohorts of CWL). Missing survival values for 1997, 1998, and 2002 year-classes were caused by low tagged proportions of total stockings and there were no lake trout stocked from the 2011 year-class. Reduced survey effort in 2020 contributed to missing values for the 2009 year-class of SENs at age 11.

		STRAIN										
Year-class	Ages	JEN	LEW	ONT	SUP	SAW	STW	SEN	LC	SKW	HPW	ALL
1978	7-10	-	-	-	0.40	-	-	-	-	-	-	-
1979	7-10	-	-	-	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	7-11	-	-	-	0.53	-	0.41	0.96	0.76	0.82	-	0.79
2009	7-11	-	-	-	-	-	-	0.74	0.71	-	-	0.66
2010	7-11	-	-	-	-	-	-	-	0.75	-	-	0.75
2012	7-11	-	-	-	0.61	-	-	0.67	0.58	-	-	0.67
2013	7-10	-	-	-	-	-	-	0.63	0.35	0.51	-	0.52
2014	7-9	-	-	-	-	-	-	0.71	0.53	0.46	0.32	0.53

Figures

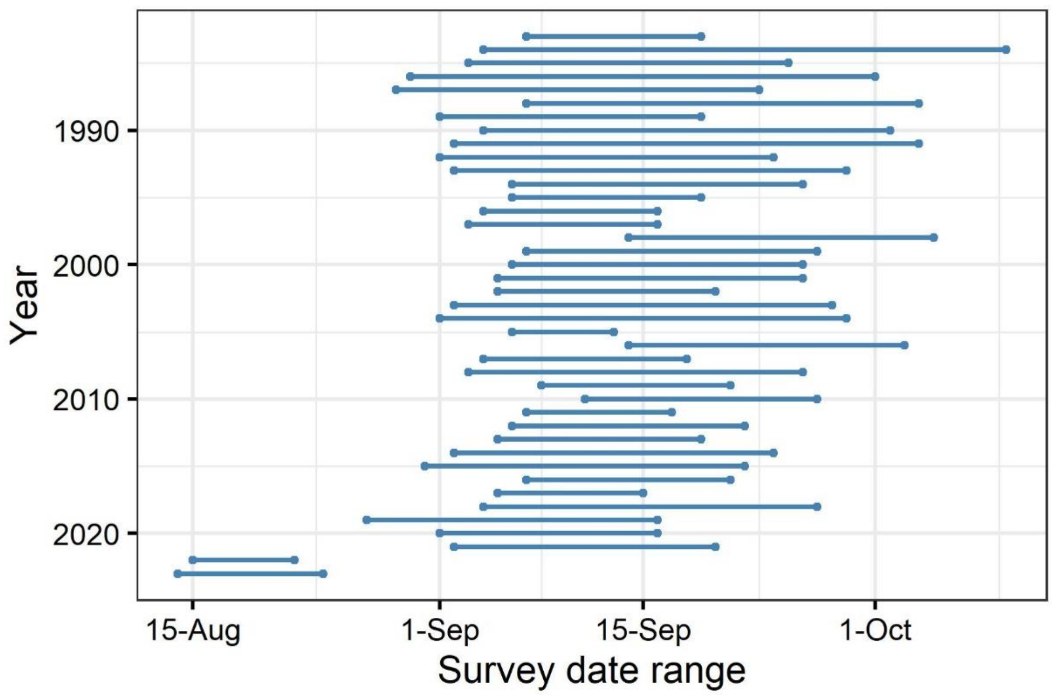

Figure 1. Calendar date range for the Lake Ontario August gillnet survey and lake trout assessment by sampling year 1983–2023.

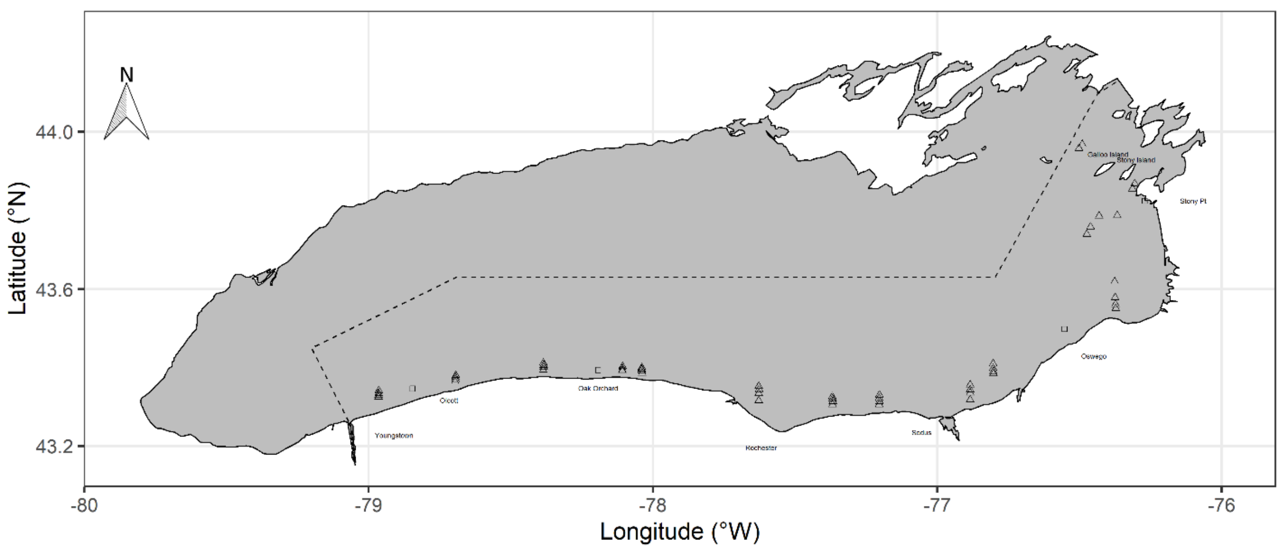

Figure 2. Map of Lake Ontario gillnet sets from the 2023 Lake Ontario August gillnet survey and lake trout assessment (triangles; N = 52), and approximate 2023 lake trout stocking locations (squares; N = 4). Dashed line indicates US-Canada international boundary.

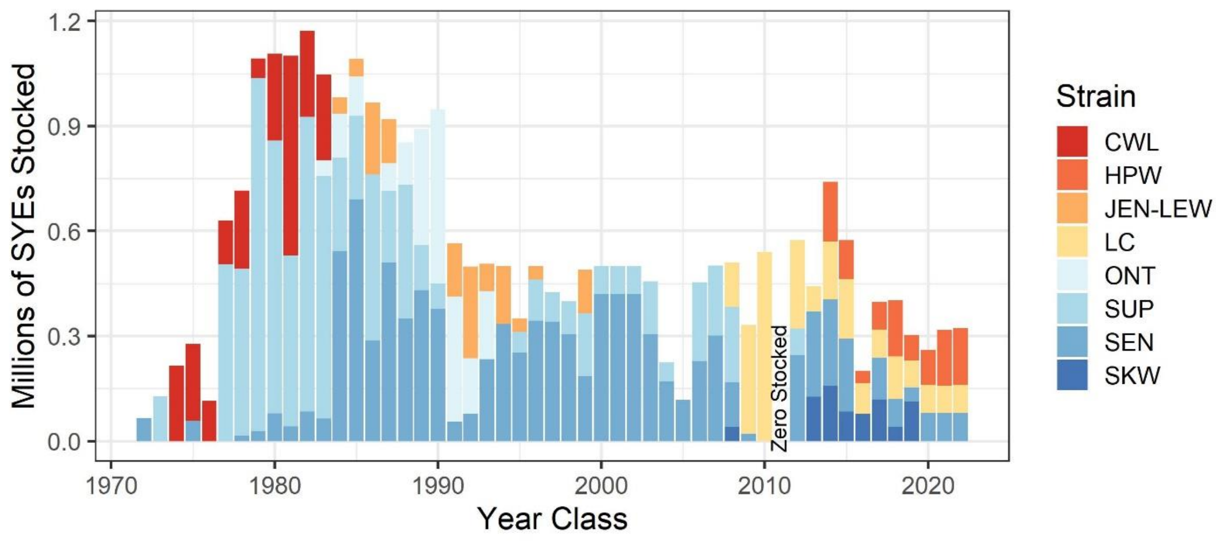

Figure 3. Total spring yearling equivalents (SYE) for lake trout strains (strain descriptions for ONT, JEN-LEW, CWL, SEN, LC, SUP, SKW, HPW appear in Table 1) stocked in U.S. waters of Lake Ontario for the 1972 – 2022 year-classes. For year-classes beginning in 2006, SUP refers to Lake Superior lean strains (SAW and STW) other than the Superior Marquette Domestics stocked prior to that time. SYE = 1 spring yearling or 2.4 fall fingerlings. No lake trout from the 2011 year-class were stocked in 2012.

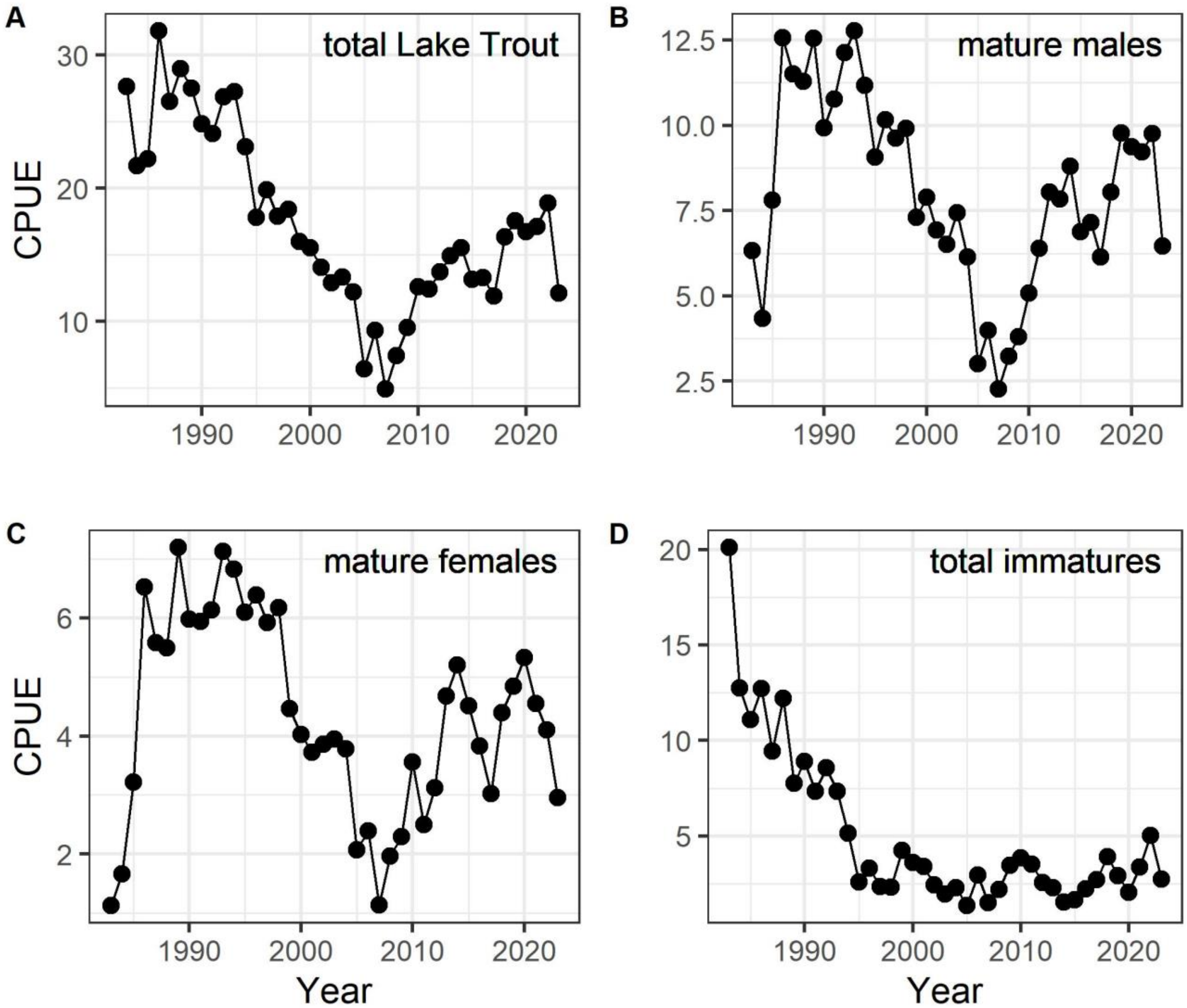

Figure 4. Abundance (stratified catch per unit effort, CPUE) of (A) total lake trout, (B) mature male lake trout, (C) mature female lake trout, and (d) total immature lake trout captured in the Lake Ontario August gillnet survey and lake trout assessment 1983–2023.

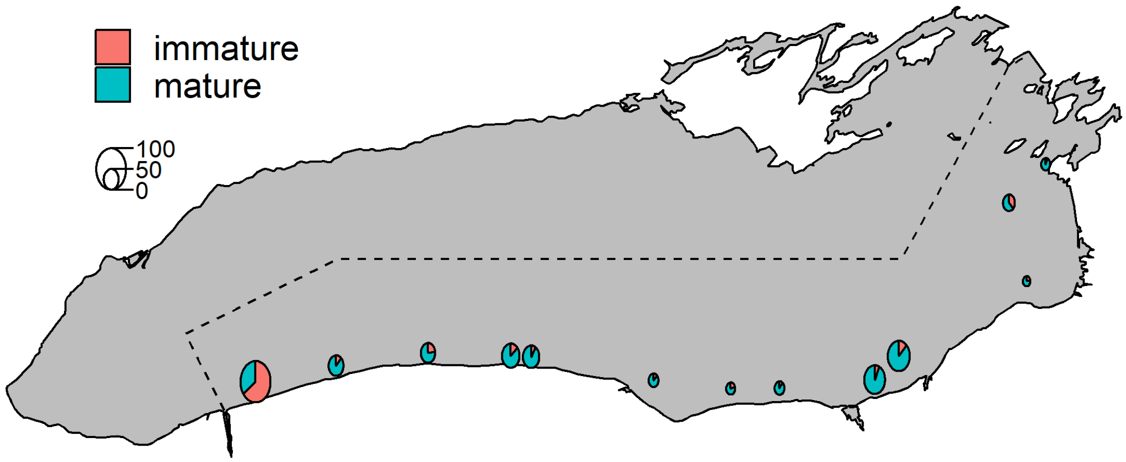

Figure 5. Spatial distribution of Lake Ontario lake trout catches summarized by port and maturity from the Lake Ontario August gillnet survey and lake trout assessment in 2023. Bubble size is scaled according to the total lake trout catch, not adjusted for effort. Note that the number of gillnets fished varies among sites (see methods). Only one lake trout was collected at Charity Island Trench, and it was a mature fish, shown as a small-sized point. Dashed line indicates US-Canada international boundary.

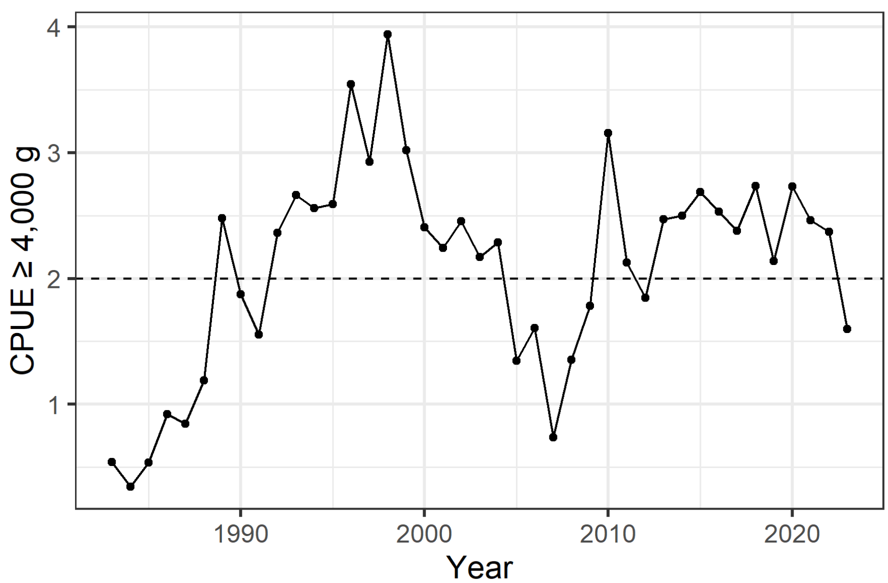

Figure 6. Abundance (CPUE unstratified) of mature female lake trout ≥ 4,000 g calculated from gillnet catches in the Lake Ontario August gillnet survey and lake trout assessment 1983-2023. The dashed line represents the target CPUE from Schneider et al. (1998) and Lantry et al. (2014).

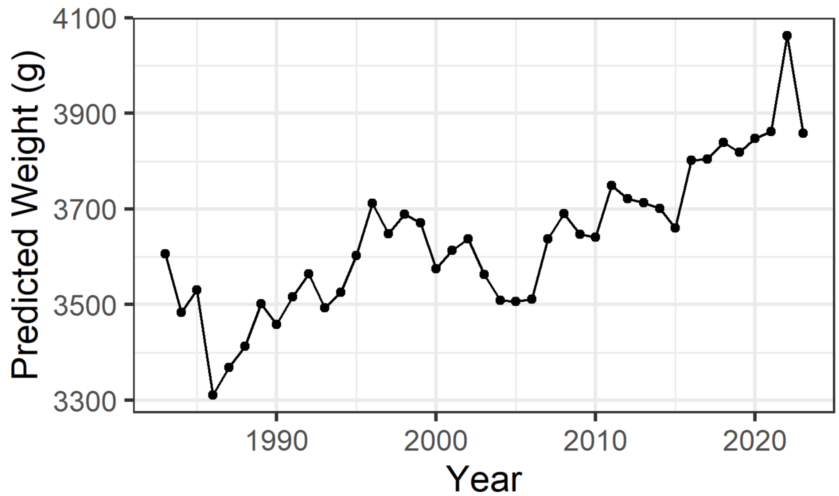

Figure 7. Lake Ontario lake trout condition expressed as the predicted weight (g) at 700 mm TL from length-weight regressions calculated from all fish collected during the Lake Ontario August gillnet survey and lake trout assessment by year.

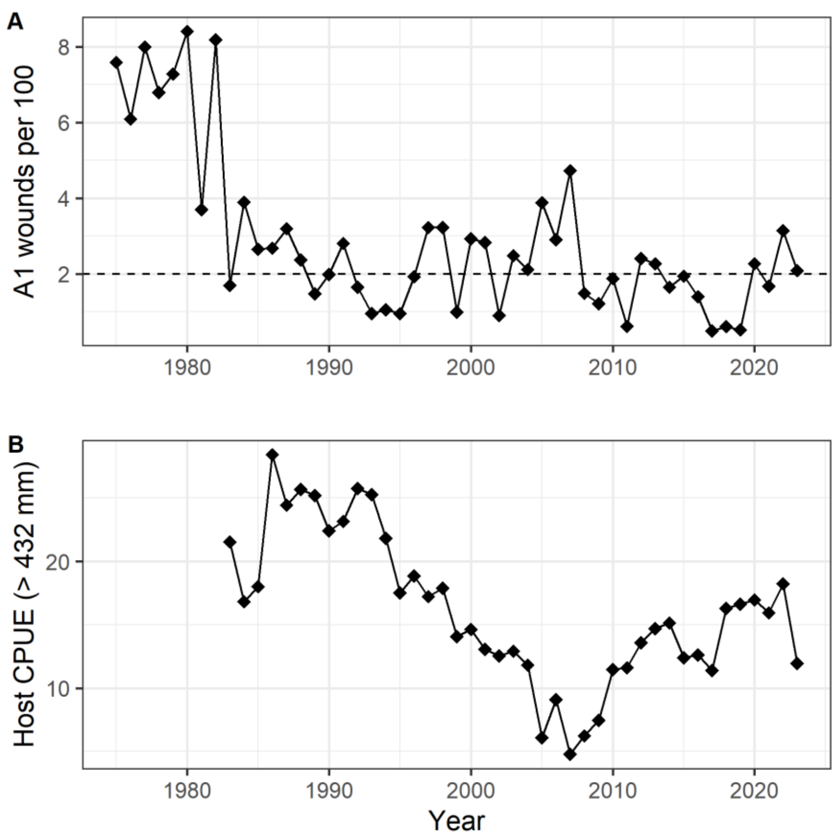

Figure 8. (A) Wounding rates (A1 wounds per 100 lake trout) inflicted by sea lamprey on fish > 432 mm TL and (B) the gillnet CPUE of lake trout hosts > 432 mm TL during 1983–2023. Data from 1975–1982 are from Lantry et al. (2021).

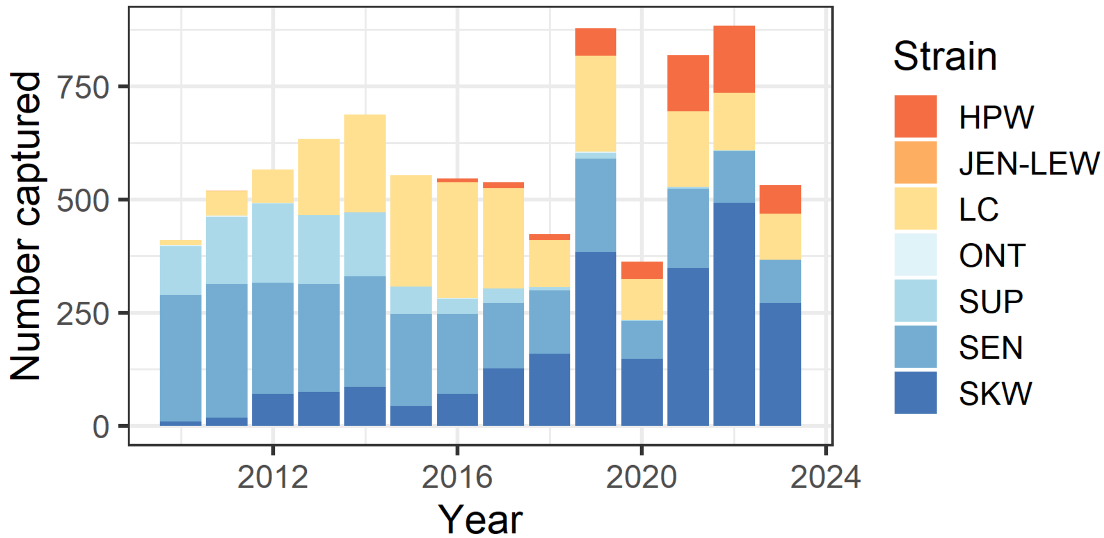

Figure 9. Strain composition of coded wire tagged lake trout captured during the Lake Ontario August gillnet survey and lake trout assessment since 2010 by survey year. For strain descriptions, see Lantry et al. (2021).

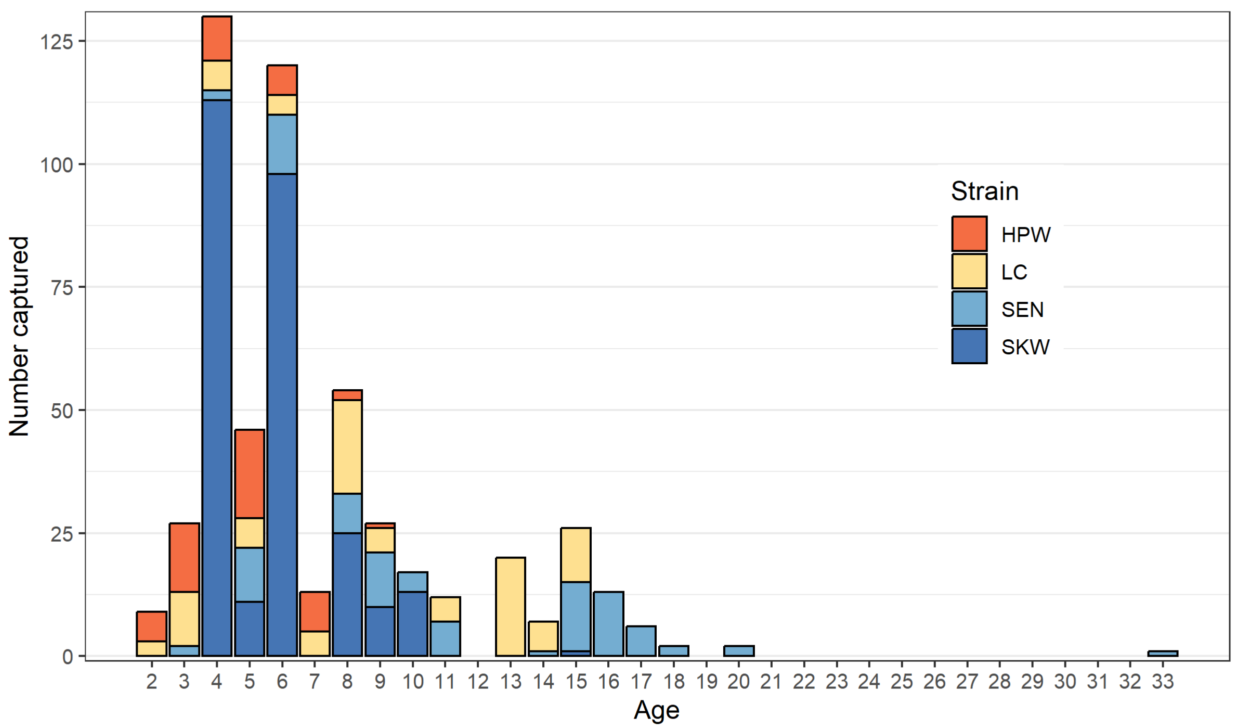

Figure 10. Age-strain distribution of coded wire tagged lake trout captured during the Lake Ontario August gillnet survey and lake trout assessment in 2023. For strain descriptions, see Lantry et al. (2021).

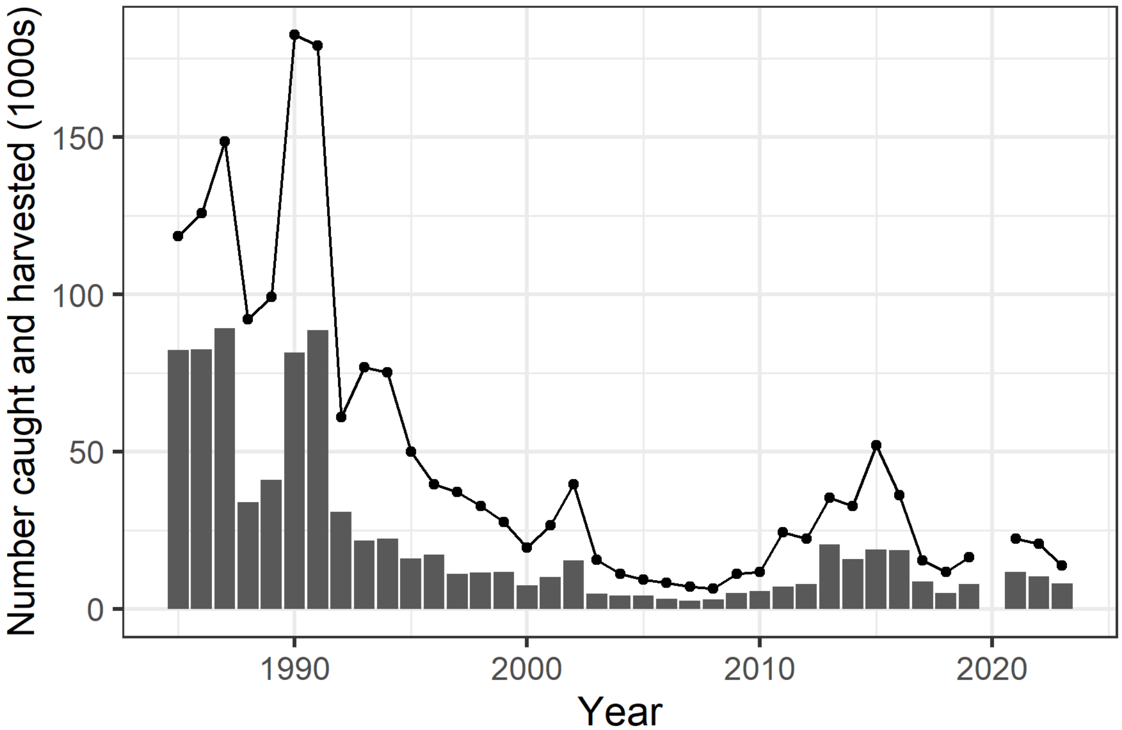

Figure 11. Estimated number (in thousands) of lake trout caught (points) and harvested (bars) by fishing boat anglers from US waters of Lake Ontario, during April 15 – September 30, 1985-2023 (Connerton and Moore 2024). Beginning in 2012, all values have been reported reflecting a 5.5-month sampling interval. Prior reports were based on a 6-month sampling interval.

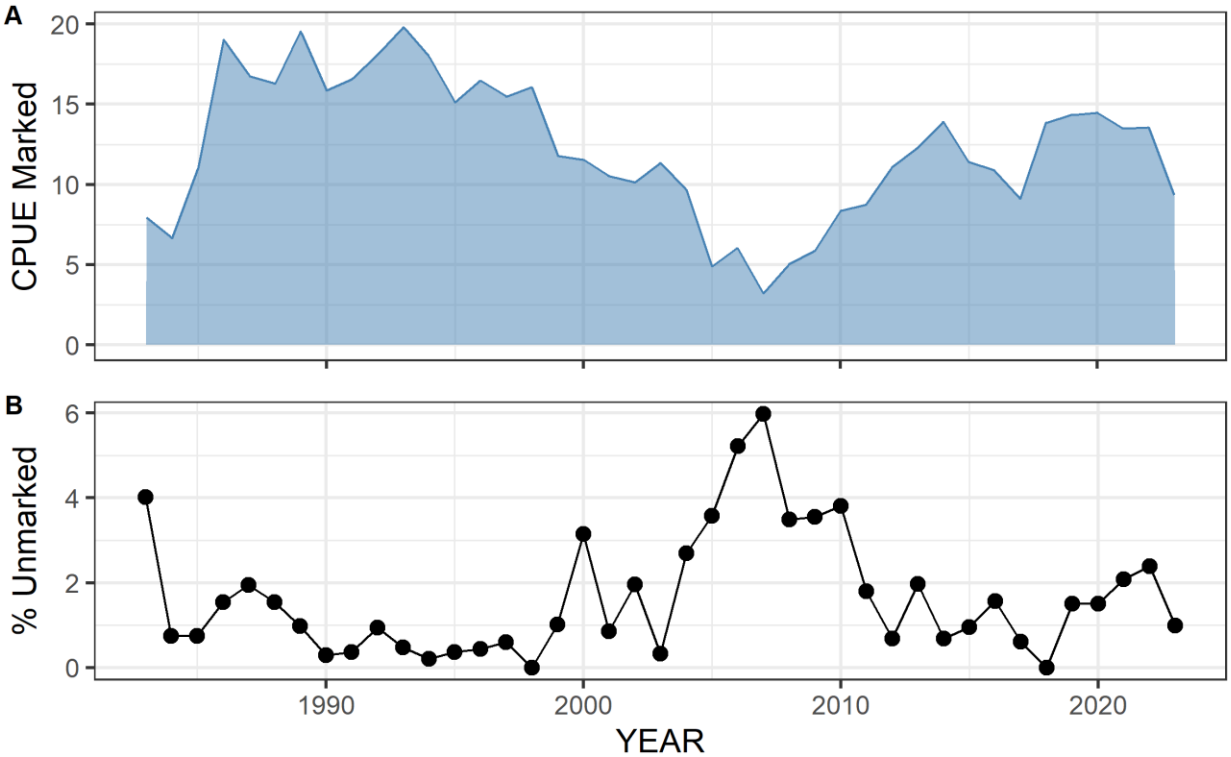

Figure 12. (A) CPUE of all mature lake trout and (B) the percentage of unmarked (no clips or tags) sexually mature lake trout, by year in the Lake Ontario August gillnet survey and lake trout assessment 1983–2023.

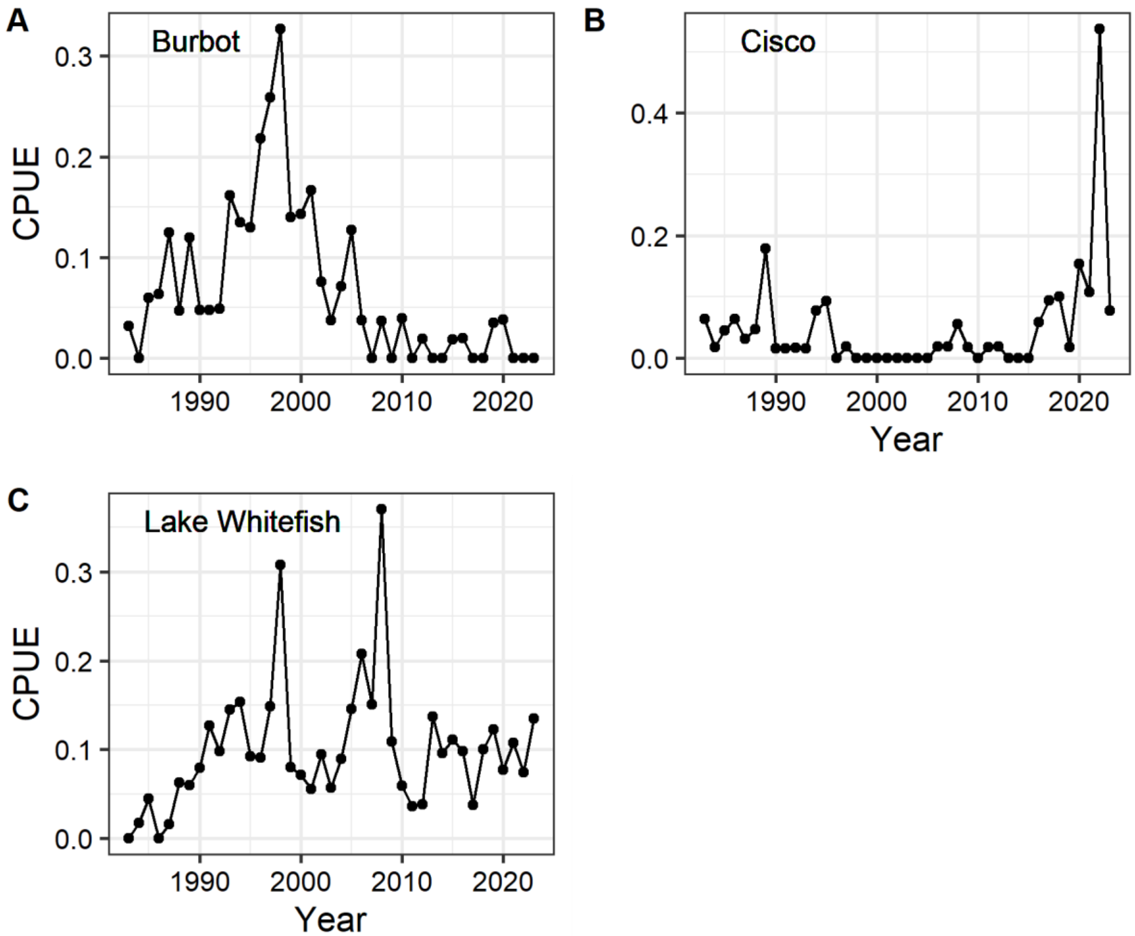

Figure 13. CPUE of (A) Burbot, (B) Cisco, and (C) Lake Whitefish, from the Lake Ontario August gillnet survey and lake trout assessment 1983–2023.

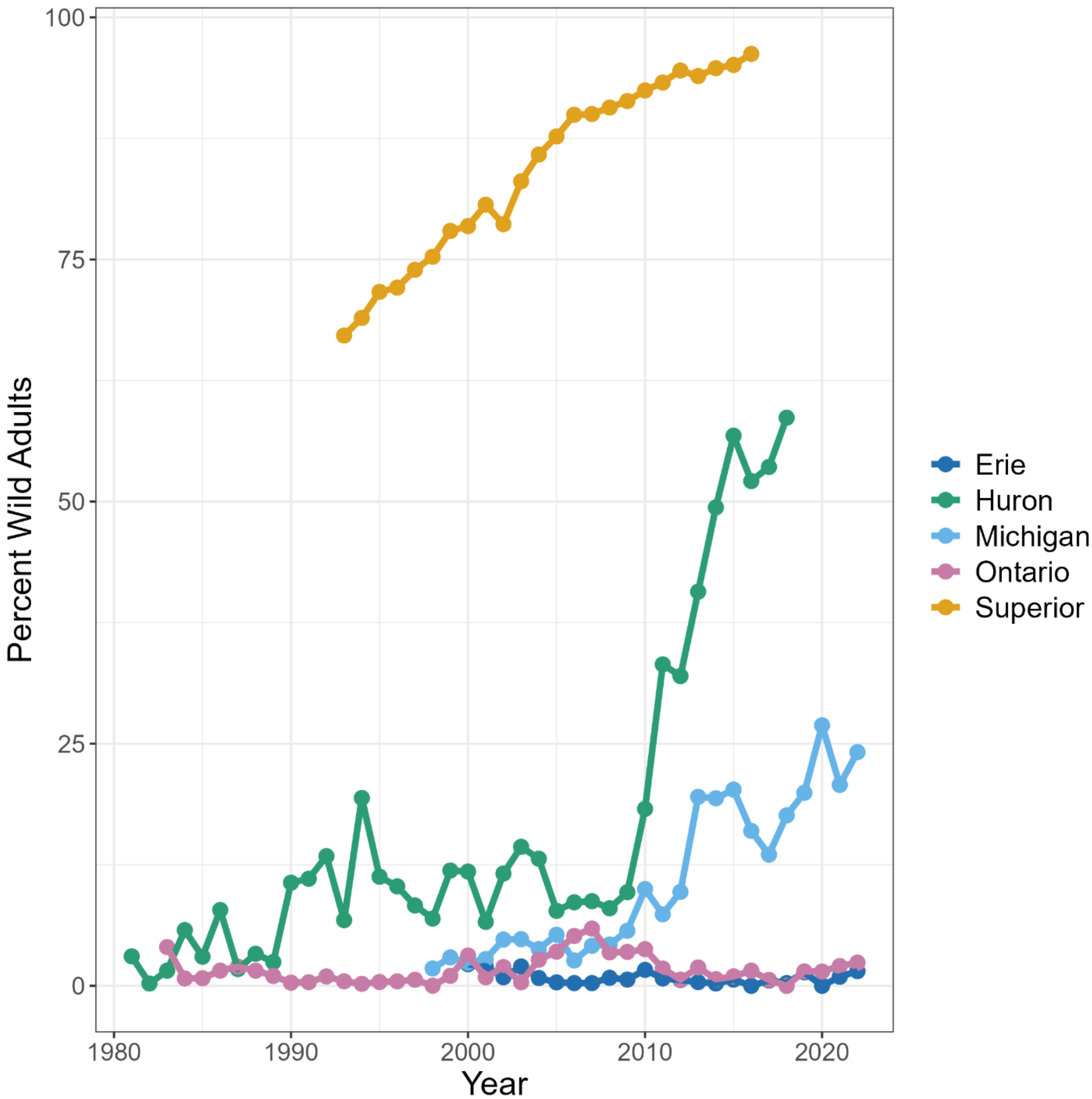

Figure 14. Average percent wild adults captured in annual standardized surveys. Sources: Lake Superior = Sitar (2021); Michigan = Madenjian et al. (2022); Huron = He (2019); Erie = Markham et al. (2022); Ontario = (this report). Surveys occurred during the spring in lakes Superior (1993 – 2016) and Huron (1981 – 2018), and in the fall for lakes Michigan (1998 – 2021), Erie (2000 – 2022), and Ontario (1983 – 2022). Note: data for lakes Superior, Michigan, and Huron were approximated from source material using WebPlotDigitizer.

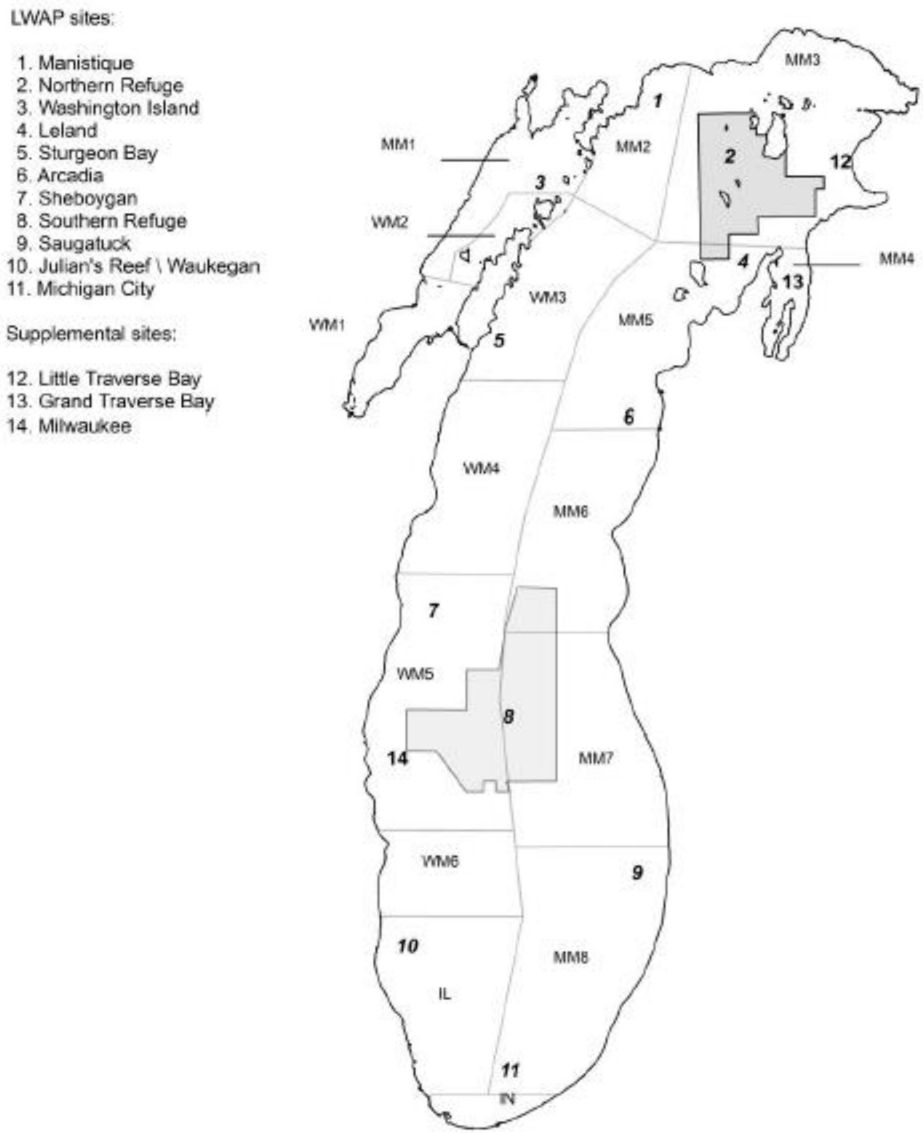

Figure 15. Lake Michigan statistical district boundaries. Shading represents the extant of the Northern and Southern refuges. From Madenjian et al. (2022).