Sub-Indicator: Lake Trout

Overall Assessment

Status: Fair

10-Year Trend (2014-2023): Improving

Long-term Trend (1975-2023): Improving

Rationale: Natural reproduction is sustained and ubiquitous only in lakes Superior and Huron, is minimal in lakes Michigan and Ontario, and recently detected in Lake Erie. Continued stocking, harvest regulation, and Sea Lamprey (*Petromyzon marinus*) control are needed for continued restoration. High predator consumption and oligotrophication is reducing alewives (*Alosa pseudoharengus*) to their lowest levels, especially in Lakes Michigan and Huron. Diminished numbers of alewives in these lakes may be releasing Lake Trout from the hypothesized bottlenecks of thiamine deficiency and fry predation perceived to be caused by alewives, which may explain increases in wild recruitment. Lake Trout, being opportunistic feeders, now consume round gobies, a high-density nearshore energy and nutrient subsidy, which has likely increased survival of both stocked and wild recruits. Managers have decided to reduce Lake Trout stocking in some lakes to preserve the residual forage base for other predators that support the sport fishery. The relationship to alewife as forage is less critical in Lake Erie where alewife densities, though increasing recently, are relatively low and where Rainbow Smelt and Round Goby are the primary forage for Lake Trout.

Lake-by-Lake Assessment

Lake Superior

Status: Good

10-Year Trend (2014-2023): Improving

Long-term Trend (1987-2023): Improving

Rationale: Wild lean Lake Trout abundance has increased 50% in the last 10 years and 70% since 1987. Lake Superior Lake Trout have been rehabilitated and are considered in a conservation status in most areas. Offshore Lake Trout populations of all ecotypes including siscowets, humpers, and redfins are also considered to be healthy. Total annual mortality rates for lean Lake Trout populations have been low (< 35%) and mostly below the management target maximum range between 42% and 45%. Despite sustained control efforts, Sea Lamprey predation continues to be the major source of manageable mortality for Lake Trout populations. Fishery harvest of Lake Trout has generally been well-managed by natural resource agencies.

Lake Michigan

Status: Fair

10-Year Trend (2014-2023): Improving

Long-term Trend (1998-2023): Improving

Rationale: Wild fish continue to be observed in fisheries and fishery independent surveys but at low levels and mostly in the southern portion of the lake where mortality is low and adult stocks are more developed. Northern Lake Michigan experiences high fishing mortality but Sea Lamprey mortality has been reduced in recent years. Major concerns lie in the will of fisheries management agencies to stay the course of rehabilitation over concerns of angling public that favor non-native salmonines over Lake Trout in the face of a declining forage base, and the need to support fishery extraction.

Lake Huron

Status: Fair

10-Year Trend (2014-2023): Unchanging

Long-term Trend (1977-2023): Improving

Rationale: Adult (> 533 mm) catch-per-unit-effort (CPUE) from the fishery independent spring gillnetting surveys was below the target of 20 (13-26) per kilometer, which was achieved during the late 1990s and early 2000s, although the spawning stock included many consecutive year-classes and more than 50% of wild Lake Trout. Juvenile contribution to total survey catch was mostly below 20%, and juvenile wild percentage varied in a wide range from more than 80% to less than 40% in recent years.

Lake Erie

Status: Fair

10-Year Trend (2014-2023): Improving

Long-term Trend (1992-2023): Improving

Rationale: Stocking levels over the past decade, combined with an emphasis on introducing strains less susceptible to Sea Lamprey attacks and mortality (Seneca and Lake Champlain strains), has increased adult stocks to levels near or above targets. The rehabilitation plan was revised in 2021 to capitalize on successes, and the implementation of refined management actions since then (e.g., increased numbers stocked, exclusive use of preferred strains, expanded and pulsed stocking locations) is expected to further augment the population. The adult stock is now consistently comprised of over ten age groups. The primary source of assessment information, a bi-national gillnet survey, was redesigned in 2021, and results since have supported or improved upon previous positive estimates of status. Recent indexes of Sea Lamprey predation are near time series lows. Early life history assessments since 2020 have annually revealed successful reproduction to the fry stage though any wild contributions to the adult population are still below detectable levels. Fishing mortality is low despite increased recreational angler effort in recent years. All agencies remain committed to further rehabilitation and conservation through the rehabilitation plan.

Lake Ontario

Status: Fair

10-Year Trend (2014-2023): Improving

Long-term Trend (1983-2023): Improving

Rationale: Adult abundance is at values expected based on stocking and assessment history, conditions for natural reproduction are improving and the numbers of natural recruits has increased but remains low.

Status Assessment Definitions

Good: Relative abundance, harvest, or absolute abundance at or exceeding target levels. Wild fish making up 50% or more of population and increasing. Parental stock made up of many year classes beyond age of full cohort maturity.

Fair: Relative abundance, harvest, or absolute abundance below target levels. Wild fish making up between 15-49% of population. Parental stock made up of few year classes beyond age of full cohort maturity.

Poor: Relative abundance, harvest, or absolute abundance declining and below target levels. Wild fish making up less than 15% of the population. Parental stock made up of no or few age groups beyond age of full cohort maturity.

Undetermined: Data are not available or insufficient to assess conditions of the ecosystem components.

Trend Assessment Definitions

Improving: Relative or absolute abundance of wild Lake Trout, and wild and hatchery-reared adults are increasing, and the adult age composition is expanding.

Unchanging: Relative or absolute abundance of wild Lake Trout, and wild and hatchery-reared adults are stable, and the adult age composition is not expanding.

No Trend: The trend is not Improving or Deteriorating due to high variability in the data.

Deteriorating: Relative or absolute abundance of wild Lake Trout, and wild and hatchery-reared adults are decreasing, and the adult age composition is collasping.

Undetermined: A sufficient amount of data are not available to report on a trend.

Note: Adult = fish that are sexually mature, wild or stocked.

Endpoints and/or Targets

The goal of Lake Trout rehabilitation, as established by the Fish Community Objectives (FCOs) and Goals drafted by the Great Lakes Fishery Commission (GLFC), is self-sustaining, naturally reproducing populations that support fisheries. Appropriate quantitative measures of abundance, yield, or biomass should be established as reference values for self-sustaining populations of Lake Trout in the cold-water habitats of the Great Lakes. The sub-indicator target(s) for Lake Trout are based on the values provided in the Great Lakes Fishery Commission's rehabilitation plans for Lake Trout for each lake and/or for desired value(s) gained from analysis of the range and distribution of measures above compared to the ecosystem conditions.

Lake Superior

Achieve and maintain genetically diverse self-sustaining populations of Lake Trout that are similar to those found in the lake prior to 1940, with lean Lake Trout being the dominant form in nearshore waters, siscowet Lake Trout the dominant form in offshore waters, and humper Lake Trout a common form in eastern waters and around Isle Royale (Horns et al., 2003).

Lake Michigan

In targeted rehabilitation areas, re-establish genetically diverse populations of Lake Trout composed predominately

of wild fish able to sustain fisheries. (Bronte et al. 2008).

Objective 1 – Increase genetic diversity: increase the genetic diversity of Lake Trout by introducing morphotypes adapted to survive and reproduce in deep-water offshore habitats while continuing to stock a variety of shallow-water morphotypes.

Objective 2 – Increase overall abundance: by 2014, increase Lake Trout population densities in targeted rehabilitation areas to levels observed in other Great Lakes locations where recruitment of wild fish to the adult population has occurred. To achieve this objective, catch-per-unit-effort (CPUE) in spring assessments should consistently exceed 25 Lake Trout/1,000 feet of graded mesh gillnet (2.5-6.0-inch mesh).

Objective 3 – Increase adult abundance: by 2020, increase densities of spawning adult Lake Trout in targeted rehabilitation areas to that observed in other Great Lakes locations where recruitment of wild fish to the adult population has occurred. To achieve this objective, CPUE in fall assessments should consistently exceed 50 Lake Trout/1,000 feet of graded-mesh gillnet (4.5- 6.0-inch mesh).

Objective 4 – Detect deposition of viable eggs: by 2021, detect a minimum density of 500 viable eggs/m^2 (eggs with thiamine concentrations >4 nmol/g) in targeted rehabilitation areas stocked prior to 2008. This milestone should be achieved by 2025 in areas newly stocked.

Objective 5 – Build spawning populations: by 2024, spawning populations in targeted rehabilitation areas stocked prior to 2008 should be at least 25% female and contain 10 or more age groups older than age 7. These milestones should be achieved by 2032 in areas stocked after 2008.

Objective 6 – Detect recruitment of wild fish: Consistent recruitment of wild Lake Trout in targeted rehabilitation areas should occur as follows: by 2022, detect age-1 fish in bottom trawls; by 2025, detect age-3 fish in spring graded-mesh-gillnet assessments; and, by 2028, detect sub-adults in gillnet assessments.

Objective 7 – Achieve rehabilitation: By 2037, 75% or more of the Lake Trout in targeted rehabilitation areas should be age 10 or younger and of wild origin.

Interim targets were established by the Lake Michigan Committee in their strategic plan (Dexter et al. 2011) based on recommendations in Bronte et al. (2008). These are:

1. Increase the average CPUE to >25 Lake Trout/1000 feet of graded mesh gill net (2.5-6.0 inch) set overnight and lifted during spring stock assessments pursuant to the lakewide assessment in MM-3, WM-5, and at Julian's Reef by 2019. A reevaualtion is underway currently.

2. Increase the abundance of adults to a minimum catch-per-effort of >50 fish/1000 ft of graded large-mesh (4.5-6.0 inch) gill net fished on spawning reefs in MM-3, WM-5, and at Julian's Reef by 2019.

3. Significant progress should be achieved towards attaining spawning populations that are at least 25% females and contain 10 or more age groups older than age-7 in first priority areas stocked prior to 2007. These milestones should be achieved by 2032 in areas stocked after 2008.

4. Detect a minimum density of 500 viable eggs/m^2 (eggs with thiamine concentrations of >4 nmol/g) in previously stocked first priority areas. This milestone should be achieved by 2025 in newly stocked areas.

Lake Huron

The goal of Lake Trout rehabilitation in Lake Huron is to restore self-sustaining populations that are capable of yielding 1.4 to 1.8 million kg by the year 2020 (Desjardine et al. 1995; Ebener, 1998; OMNR, 1996).

Lake Erie

Establish a Lake Trout population consistent with a functional cold-water ecosystem that maintains a fishery in the eastern and central basins. Maintain viable adult spawning-stock biomass, as measured by survey catch per effort while maintaining and expanding existing fishing opportunities with a goal of documenting evidence of natural reproduction.

Objectives – Maintain a spawning-stock abundance that results in an average catch rate of 2 adult (age 5+) Lake Trout per lift in a standardized gillnet survey designed to assess August coldwater habitat in all jurisdictional waters. Maintain an adult population that is comprised of at least 10 age classes.

Lake Ontario

Restore a self-sustaining population of Lake Trout in Lake Ontario (Lantry et al. 2014).

Objective 1 – Increase abundance of stocked Lake Trout to a level allowing for significant natural reproduction defined as the catch of mature females > 4000g greater than 15 and 8 fish per kilometer of standard assessment gill net set for 24 hours in U.S and Canadian waters, respectively.

Objective 2 – Increase populations of wild Lake Trout across a range of groups (measureable increase in catches of wild juveniles and adults in assessment catches, with values exceeding those observed during 1994-2011).

Management Strategy 1: Stock 800,000 spring yearling equivalents per year in U.S. waters and 500,000 spring yearlings per year in Canadian waters.

Management Strategy 2: Minimize stocking and juvenile mortality by optimizing stage, size, and condition at stocking; stocking methods; stocking locations (measures: U.S.: adjusted catch rate of age-2 fish per 500,000 stocked > 200 fish per standard survey; Canada: adjusted catch rate of age-3 fish per standard gillnet per 500,000 stocked > 1.5 fish per standard gillnet set).

Management Strategy 3: Maintain high survival of older fish by controlling Sea Lamprey and fishing mortality measures: Yearly survival of adult fish >60%; maintain the Sea Lamprey wounding rate in fall gillnetting at <2 A1 wounds per 100 Lake Trout >432 mm total length; maintain annual harvest to <10,000 fish in U.S. waters and <5,000 fish in Canadian waters.

Management Strategy 4: Emphasize stocking strains that show the best combination of low post-stocking, juvenile, and adult mortality.

Management Strategy 5: Emphasize stocking strains that are successfully producing a measureable level of wild recruits.

Management Strategy 6: Protect naturally produced fish.

Management Strategy 7: Continue efforts to restore populations of native prey for Lake Trout.

The Lake Trout is a valued species that supports recreational and (where permitted) commercial fisheries, and harvest or yield reference values established for self-sustaining populations probably represent an attempt to fully utilize annual production; as a result, harvest or yield reference values for these populations can be taken as surrogates for production reference values.

Sub-Indicator Purpose

- To estimate the relative abundance of both stocked and wild (naturally reproduced) Lake Trout.

- To measure the success of rehabilitation through catch rates of wild Lake Trout.
- To infer the control measures on fishing and Sea Lamprey predation by measuring the age structure and abundance of mature Lake Trout.
- To infer the basic structure of the cold-water predator community and the general health of the ecosystem.

Ecosystem Objective

This sub-indicator best supports work towards General Objective #5 of the 2012 Great Lakes Water Quality Agreement (GLWQA) which states that the waters of the Great Lakes should "support healthy and productive wetlands and other habitats to sustain resilient populations of native species."

More specfic ecoysystem objectives include maintaining a balanced, stable, and productive ecosystem with self-sustaining Lake Trout populations as a major top predator in the cold-water regions of the Great Lakes and maintaining self-sustaining populations by natural reproduction versus addition of stocked Lake Trout.

Self-sustaining, naturally reproducing populations that support target yields to fisheries is the goal of the Lake Trout rehabilitation program. Maximum potential yields approximate historical levels of Lake Trout harvest or levels presumed to be sustainable, were adjusted to accommodate stocked naturalized introduced predators such as Pacific salmon. These reference points were guiding benchmarks established by individual Lake Committees of the Great Lakes Fishery Commission in Fish Community Objectives for lakes Huron, Michigan, Erie, and Ontario (Eshenroder et al. 1999, DesJardin et al. 1995, Francis et al. 2021, Stewart et al. 1999), and are revised periodically. These targets are 1.1 million kg (2.5 million pounds) from Lake Michigan, and 0.9 million kg (2.0 million pounds) from Lake Huron. Lake Ontario has no specific yield objective but has a population objective of 0.5 to 1.0 million adult fish that produce 100,000 yearling recruits annually through natural reproduction. Lake Erie has no yield or population size goals. Lake Superior did not use a yield-based benchmark, rather a suite of population demographic and ecosystem indicators that achieved recovery and are used to maintain self-sustaining populations (Hansen 1996; Sitar et al., 2024). The desired state will be for Lake Trout to serve as the primary top predator in Lake Superior and share this status with other native and established non-native predators in lakes Michigan, Huron, Erie and Ontario.

Methods

This sub-indicator will measure absolute abundance, relative abundance, harvest, and self-sustainability through natural reproduction of Lake Trout (wild and stocked) in cold-water habitats of the Great Lakes.
For each lake, a graph with Lake Trout metrics including various lake-relevant measures of relative abundance (overall; adult; juvenile; wild) on the y-axis and year on the x-axis will be presented. Sampling method for each measure should be standardized at least within each lake, and if possible across lakes.

Discussion

Trends in the relative abundance of stocked lean Lake Trout in Lakes Huron, Michigan, Erie and Ontario, and wild lean Lake Trout in Lakes Superior and Huron are displayed in Figure 1. Targets are set for most populations of lean Lake Trout as these are perceived to be biologically important for increasing the probability of natural reproduction in Lakes Huron, Michigan, Erie and Ontario and to maintain wild populations in Lake Superior. Target values are measured and expressed as relative abundances of all or a portion of the population in multiagency gill net surveys

that are standardized within each lake. These measures are superior to harvest objectives, which are harder to evaluate and represent desired states that cannot be easily tested for sustainability. Lake Trout abundance dramatically increased in all the Great Lakes after initiation of Sea Lamprey control, and after the stocking and harvest control of Lake Trout. Success in achieving population targets and ultimately self-sustaining, naturally reproducing populations has been mixed among the lakes. Successful Lake Trout recovery has been achieved in Lake Superior populations now in a conservation state (Sitar et al., 2024). Stocking rates of Lake Trout in lakes Michigan and Ontario were reduced due to concern over predatory consumption of declining alewife populations; these reductions may hamper rehabilitation potential. In Lake Huron, the 2003 alewife population collapse led to major decline in Lake Trout growth and body condition (He and Bence 2007; He et al. 2008; Riley et al. 2008), but the decline did not continue. Lake Trout growth and body condition have stabilized at a healthy level as adult Lake Trout switched to feed on Round Goby (He et al 2015, 2016; Happel et al. 2018).

Since the last report, more wild recruitment is being seen in Lakes Michigan and Huron, and Sea Lamprey numbers have been reduced to target levels basin-wide. Sustained, modest recruitment has continued in southern Lake Michigan where populations are stable but below density targets. Parental stocks seem adequate in most areas except for northern Lake Michigan where there is high Sea Lamprey and fishing mortality. Natural reproduction to the fry stage has been observed annually since 2021 in Lake Erie. In lakes Erie and Ontario, status and trends are similar to those reported in 2022. Lake Superior saw a slight improvement in Lake Trout abundance since the last report. In southern Lake Huron, total abundance of Lake Trout declined (Lenart et al. 2020), although management agencies did not reach a consensus on relative importance of changes in recruitment and mortality contributing to the apparent decline.

Desired states are populations that are self-sustaining through natural reproduction with minimal or no hatchery supplementation required, which support a sustainable harvest, and serve as a top predator. The resulting population size and sustainable yield compared to historical levels will likely be lower in most lakes since this apex trophic level is now shared by naturalized non-native predators that support a multi-billion dollar fishery.

Background

Historically Lake Trout were the keystone salmonine predator in most of the Great Lakes. Overfishing and predation by non-native Sea Lamprey, and to a limited extent other factors, destroyed nearshore lean populations and deep-water siscowet Lake Trout populations, but many populations survived in Lake Superior and a few lean Lake Trout populations survived in Lake Huron (Lawrie and Rahrer 1972, Berst and Spangler 1972, Wells and McLain 1972, Hartman 1972, Christie 1972). Rehabilitation efforts through stocking and controls on fisheries and Sea Lamprey have been ongoing since the early 1960s (Hansen et al. 1995, Eshenroder et al. 1995, Holey et al. 1995, Cornelius et al. 1995, Elrod et al. 1995). Lake Trout require cold, well-oxygenated water, and nearshore and offshore rocky substrates for spawning in the fall. They are opportunistic omnivores and can live in variety of prey environments that range from plankton to fish. Although there has been some physical habitat loss in the Great Lakes, especially in Lake Ontario, habitat loss is not generally considered a significant impediment to restoration elsewhere in the Great Lakes.

Status of Lake Trout

Lake Superior

Wild lean Lake Trout populations recovered from collapse in the 1950s due to an aggressive rehabilitation program employing Sea Lamprey suppression, stocking of hatchery-reared fish, and fishery restrictions (Hansen et al. 1995; Bronte et al. 2003). Recovery began with the buildup of large populations of hatchery-reared Lake Trout, which were superseded by wild fish (Hansen et al. 1995; Wilberg et al. 2003; Sitar et al., 2024). The transition to wild Lake Trout dominance began in the 1980s in Michigan waters and was subsequently followed in Wisconsin,

then most recently in Minnesota. During the same period, central and western Ontario populations also recovered and have healthy wild Lake Trout populations supported by natural reproduction. In Michigan waters, abundance and recruitment of most Lake Trout populations are near historic high levels with some indications of density-dependent growth declines (Wilberg et al. 2003; Richards et al. 2004; Sitar et al. 2010). The latest progress in recovery was the cessation of most stocking in Minnesota waters. Although Lake Trout populations in most areas are healthy, there are some populations that are of concern due to high or excessive fishery exploitation. Little or no recovery has been observed in the Whitefish Bay region of southeastern Lake Superior due to excessive commercial fishery harvest, hence Lake Trout stocking has been deferred in this area. In eastern Wisconsin and western Michigan waters, recovered Lake Trout stocks experience high levels of fishery harvest. Recognizing this issue, restrictions on harvest have been implemented by agencies to reverse this trend (Sitar et al., 2024).

Siscowet, a deep-water morphotype, is the most abundant form of Lake Trout in Lake Superior occupying deep water areas and have recovered from depressed levels in the 1940s (Bronte and Sitar 2008; Ebener et al. 2010). Recent harvest has been low, though emerging but fleeting industrial interest in extracting omega-3 fatty acid from Siscowet may develop a demand. Sea Lamprey wounding rates on Siscowet are high, though the mortality inflicted may not be higher than that experienced by lean Lake Trout (Moody et al. 2010; Goldsworthy et al., 2024). Similar to lean Lake Trout, Siscowet are at high population levels and experiencing density-dependent declines in abundance.

Wild lean Lake Trout abundance has steadily increased since 2000 and remains stable and on par with the prior State of the Great Lakes reporting period and has been trending upward since the 1970s. Fishing mortality has been controlled in most areas of Lake Superior through regulations. Despite continued Sea Lamprey management, wounding rates on Lake Trout in some areas have increased above target levels since 1995 (Pratt et al. 2016) but have been brought under control recently. In the near-term, slight declines in Lake Trout abundance in some areas may occur due to density-dependent declines in growth and recruitment, but overall populations in Lake Superior are stable (Sitar et al., 2024).

Lake Michigan

Stocking continues in all jurisdictions but has been reduced since 2017 in nearshore waters of Wisconsin to address angler concerns about excessive alewife predation by Lake Trout. Lake Trout densities measured by spring assessment surveys remain below target in most areas and lakewide. More wild fish, especially in southern areas were recovered in assessment surveys in the last 10 years (Lake Trout Task Group 2023) than previously, which indicates that natural reproduction has been increasing but overall remains low. Illinois, Indiana, and southern Wisconsin waters with advanced age compositions and higher densities of Lake Trout show some evidence of sustained natural reproduction (Hanson et al. 2012; Lake Trout Task Group 2023). Northern Lake Michigan experiences high fishing mortality but Sea Lamprey mortality has been reduced in recent years. Sustained levels of excessive mortality have resulted in very low spawning stock biomass in the Northern Refuge, hence few if any wild are detected. Increased stocking in the north has led to increases in overall densities but mature fish densities remain lower than desired. Lake Trout appear to be able to cope with the changing forage base with declining alewives by consuming more abundant round gobies. There is currently angler pressure to maintain or increase Chinook salmon stocking numbers, which has resulted in the stocking of fewer Lake Trout in Wisconsin waters.

Recommendations to advance recovery include minimizing adult Lake Trout mortality from fishing and Sea Lamprey, focus hatchery production in refuge areas, restore a native forage base of coregonines and recast FCOs for desired population characteristics rather than past harvest levels that are likely unattainable given the lower overall lake productivity and low prey fish biomass.

Lake Huron

The increases in wild recruitment and decreases in post-release survival of hatchery-reared fish in the last 10 years

have led to the management decision to cease stocking in Canadian waters of the main basin, and in U.S. waters of the southern Lake Huron, and reduce the stocking by 50% in U.S. waters of northern Lake Huron. Adult biomass increased rapidly during the 1990s and peaked in the early 2000s (He et al. 2015, 2020). The abundance of wild adults has increased since 2010 and wild Lake Trout now make up more than 50% of the assessment catch and fishery harvest. In Canadian waters of the main basin and North Channel, the proportion of wild Lake Trout has exceeded 80% of all fish sampled. The wild proportion of Lake Trout in Georgian Bay remains lower at 20 to 30%.

In the main basin of Lake Huron, Sea Lamprey-induced mortality on Lake Trout has been controlled below 5% since the end of 1990s (He et al. 2020; Nowicki et al. 2021). Lamprey wounding rates have declined in the last ten years in both the North Channel and Georgian Bay, with recent rates approaching the target levels in both basins. Lake Trout total mortality has been controlled far below the 40% target in the main basin (He et al. 2022, 2023a).

Prior to 2000, in addition to Sea Lamprey predation, Lake Trout rehabilitation was impeded mostly by the interference of Alewives with natural reproduction of Lake Trout (He 2024a). Alewives have adverse effects on reproduction via Thiamine Deficiency Syndrome and predation on Lake Trout eggs and fry (Madenjian et al. 2008: Fitzsimons et al. 2010). Since 2000, along with large declines in the alewife abundance, wild recruitment of Lake Trout in the main basin has continued for many consecutive years (Riley et al. 2007; He et al. 2012; Johnson et al. 2015), although the increases in wild recruitment might not fully offset declines in post-stocking survival of hatchery yearlings (Lenart et al. 2020; He et al. 2023b). After the 2003 collapse of Alewives, Lake Trout size-at-age and body condition first declined to a very low level but then recovered and stabilized, although the new level was not as high as that in the pre-2003 time-period with abundant Rainbow Smelt (*Osmerus mordax*) and Alewives (He 2024b; He and Bence 2007, 2023; He et al. 2008, 2016).

Lake Erie

Directed efforts to restore Lake Trout populations in Lake Erie began in 1982. Recruitment of stocked fish was good but their survival to adulthood was poor due to excessive Sea Lamprey predation. Adoption of the original Lake Trout rehabilitation plan in 1985 (Lake Trout Task Group 1985) brought higher annual stocking targets, Sea Lamprey control, and standardized assessment programs to monitor the population. Lake Trout responded quickly to the implementation of Sea Lamprey suppression and increased stocking, building a large population by 1990. However, these accomplishments were short-lived as stocking numbers were reduced in 1996 due to concerns about a shortage of forage fishes (Einhouse et al. 1999) while at the same time Sea Lamprey control was relaxed (Sullivan et al. 2003). Adult Lake Trout abundance was quickly reduced to low levels by 2000.

Overall, Lake Trout abundance in Lake Erie has increased due to adoption of a revised rehabilitation plan (Markham et al. 2008) that increased stocking numbers back to their original level. Further refinements to the plan, in particular those relating to stocking numbers and sites, were implemented recently (Lake Erie Committee, 2021).

Analysis of strain survival and stocking success in all three lake basins resulted in a decision to exclusively stock strains most resistant to Sea Lamprey attacks and mortality (Seneca and Lake Champlain strains) and to annually rotate stocking between promising locations in the eastern and central basins.

Recruitment of stocked fish has declined since 2012 but adult (age 5+) abundance has increased and is at or near targets established in the rehabilitation plan. The adult population is consistently comprised of over ten age groups and abundance of age-10 and older Lake Trout is increasing.

Since 2021, indicators of Sea Lamprey abundance (Adult Index and Lake Trout wounding rates) have declined to levels near or below targets. While encouraging, lamprey remain a potential threat and continued consistent suppression through lampricide treatments is critical to achieving Lake Trout rehabilitation goals for Lake Erie. Despite recent observations of natural reproduction to the fry stage, wild Lake Trout have not been found at significant detectable levels in Lake Erie. Fishing mortality remains low despite a recent increase in angler effort.

An acoustic telemetry project was initiated in 2016 to determine locations and habitat used by Lake Trout in Lake Erie during spawning in order to gain a better understanding of the factors limiting natural reproduction (Markham et al. 2022). This research has successfully identified some areas and specific habitats being used by spawning Lake Trout and will guide the next phase of rehabilitation activities.

Lake Ontario

Prior to 1996, Lake Trout were monitored with a targeted binational lake-wide netting program that has continued in U.S. waters. Since 1996, Lake Trout targets in Canadian waters have been evaluated based on catches in the Kingston Basin only. In U.S. waters, the abundance of hatchery-reared adult Lake Trout was relatively high during 1986-1998, but declined by more than 30% in 1999 due to reduced stocking and declines in survival of stocked yearlings since the early 1990s (Elrod et al. 1995, Lantry et al. 2020). Adult abundance remained relatively stable during 1999-2004, but again declined by 54% in 2005 likely due to ongoing poor recruitment and increased mortality from Sea Lamprey predation. Enhanced control of Sea Lamprey and subsequent decreases in wounding on Lake Trout during 2008-2019 led to sharp recovery in adult Lake Trout numbers, which by 2010-2014 rose to levels similar to those observed during 1999-2004. Subsequent abundances trended downward during 2015-2017, in part due to stocking levels in U.S. waters that were at about 66% below normal in 2010 and absent in 2012. Abundance increased again in 2018 returning to levels similar to 2014 and has remained relatively high through 2023 (Lantry et al. 2020). Within the Kingston Basin Lake Trout abundance has followed a similar trend of decline through the early 1990s and a recovery in stocks since 2005. Abundance within the Kingston Basin has been stable since 2013 albeit remains much lower than the 1990s and suggests a change in the ecosystem capacity to support Lake Trout in the post-dreissenid era.

Although the abundance of adults reached a peak in 1986, and evidence of natural reproduction was documented starting in 1986, appearance of naturally recruited Lake Trout in surveys occurred later, after the abundance of large adult females exceeded target levels in 1992 (Lantry et al. 2018). Despite widespread catches of small numbers of wild recruits nearly every year during 1993-2023, a failure to achieve self-sustaining stocks has been attributed to several factors: abundant population of Alewife in Lake Ontario, which may prey on Lake Trout fry and cause thiamine deficiency in adults and eggs; the absence of suitable alternative deepwater prey fishes; and the colonization of spawning reefs by invasive round gobies (Fitzsimons et al. 2003, Lantry et al. 2003, Schneider et al. 1997, Walsh et al. 2015) and dreissenid mussels (Furgal et al. 2019). Recent predictions for restoration success have improved due to a number of changes: the recovery of the adult stock from the collapse experienced in 2005-2007; the reappearance of deepwater sculpin, which have steadily increased during 2002-2023 (Lantry et al. 2007, Weidel et al. 2019, O'Malley et al. 2024); the international efforts to re-establish bloater; and the addition of round gobies in Lake Trout diets (Dietrich et al. 2006; Rush et al. 2012). Signs of improving conditions for natural reproduction were substantiated during 2014-2017 where there was a mean wild contribution of 17% (11-31%) with assessment catches of wild age-1 and-2 Lake Trout rising sharply to a level nearly 10-fold greater than the 1994-2013 mean of 2% (2-8%) (Lantry et al. 2020). Small numbers of wild young-of-year Lake Trout were also observed in Kingston Basin trawl surveys during this period.

As encouraging as trends currently are, there is some cause for concern. The high levels of wild Lake Trout observed during 2014-2017 have not resulted in higher amounts of wild adult Lake Trout in surveys during 2020-2023 (8.5-10.5% in the Kingston Basin; 1-3% in US waters). There is potential for Lake Trout diets to become more diverse with the inclusion of Round Goby and lake-wide declines in Alewife abundance (Weidel et al. 2019) has not fully played out as adult diets continue to be dominated by Alewife (Narwocki et al. 2020). Moreover, since 2020, Alewife biomass density has been relatively high, with exceptionally strong year classes (Weidel et al. 2024). Spawning habitat degradation appears to be ongoing as recent studies concentrating on historical habitat at Stony Island reef have demonstrated the potential for dreissenid mussel shell debris to completely infill interstitial habitat (Furgal et al. 2019). In addition, stocking reductions designed to decrease predator abundance and their

impacts on declining Alewife stocks have reduced Lake Trout stocking targets from 1,250,000 (in U.S. waters) to 500,000 in 1993, to 400,000 for 2017 and to 320,000 for 2020. Some of the current and proposed research to address impediments includes using acoustic telemetry to describe habitat use and spawning aggregations, basin-scale and fine-scale spawning habitat characterization, investigating potential for spawning habitat remediation, assessment of egg and larval survival, and current and retrospective studies of Lake Trout reproductive health (Lake Ontario Lake Trout Working Group 2022).

Linkages

Linkages to other sub-indicators in the indicator suite include:

- Sea Lamprey – without sustained levels of Sea Lamprey control, Lake Trout stocking and building of parental stocks would not be possible.
- Preyfish Populations and Communities – oligotrophication is making zooplanton communities more suitable for native coregonines and their restoration, than for non-native alewife that have sustained salmonine predators since the 1960s.
- *Diporeia* – Lake Trout are among the fish species that are energetically linked to *Diporeia* as juvenile Lake Trout feed on sculpin, and sculpin feed heavily on *Diporeia*.
- *Mysis* - Lake Trout are among the fish species that are energetically linked to *Mysis*. Young Lake Trout feed on *Mysis* directly, while juvenile Lake Trout feed on sculpin, and sculpin feed heavily on *Mysis*.
- Changes in Phyiscal Conditions - Warmer temperatures are predicted to increase the warm thermal habitat of fishes in the water column with extended thermal stratification and reduced ice cover (Collingsworth et al. 2017). The effect on Lake Trout, which rely on the presence of cold thermal habitat, are bentho-pelagic in their foraging behavior and shown to be more thermally tolerant than previously realized (Sellers et al. 1998), is uncertain, however the lack of sustained ice cover during the egg incubation period may make more shallow shore oriented spawning habitat unsuitable for natural reproduction.
- Dreissenid Mussels - The degradation of Lake Trout spawning habitat due to colonization by Dreissenid mussels has been identified as a potential factor inhibiting wild recruitment of Lake Trout in Lake Ontario.

This sub-indicator also links directly to the other sub-indicators in the Food Web category. The rehabilitation of Lake Trout populations in the Great Lakes has linkages to Sea Lamprey, prey fish, and non-native species. Lake Trout stocking and building parental stocks would not be possible without sustained levels of Sea Lamprey control, as well as controls on fisheries. Non-indigenous alewives, while at lower levels now, still effect wild recruitment through predation on Lake Trout fry. Alewives also contain high levels of thiaminase that is thought to lower egg viability and fry survival in Lake Trout that consume mostly alewives. The lack of native pelagic and benthopelagic coregonines (whitefishes), lost to overfishing, habitat degradation and non-native invasions, is also hampering recovery as these lost species were conduits for energy transfer between offshore benthic and pelagic production and to the nearshore environment and to Lake Trout as prey.

Assessing Data Quality

Data Characteristics	Agree	Neutral or Unknown	Disagree	Not Applicable
Data are documented, validated, or quality-assured by a recognized agency or organization	X			
Data are from a known, reliable and respected generator of data and are traceable to original sources	X			
Geographic coverage and scale of data are appropriate to the Great Lakes Basin	X			
Data obtained from sources within the U.S. are comparable to those from Canada		X		
Uncertainty and variability in the data are documented and within acceptable limits for this sub-indicator report	X			
Data used in assessment are openly available and accessible	No			

Note: The data used in this report are from various sources, including state, federal, tribal, and provincial databases. Some sources may provide access to data if requested directly. Please contact the authors to inquire further.

Data Limitations

The sub-indicator is of greatest value in assessing ecosystem health in the oligotrophic, open-water portions of Lake Superior, where native species at all trophic levels dominate the fish community. Because the sub-indicator includes only a single species, it may not reliably diagnose ecosystem health in other parts of a lake or in the other Great Lakes. Also, because Lake Trout abundance can be easily reduced by overfishing and Sea Lamprey predation, harvest restrictions designed to promote sustained use and enhanced Sea Lamprey control is required if the species is to be used as an indicator of ecosystem health. Annual interagency stock assessments in U.S. waters are fishery-independent, and measure changes in relative abundance, size and age structure, survival, and extent of natural reproduction but do not provide direct feedback to yield goals. Assessment activities in Canadian waters are not as spatially or temporally comprehensive or are based on sampling of commercial fishery catches, which may be less robust than assessments in U. S. waters. Yield goals alone are inadequate to evaluate ecosystem health as they can vary dramatically dependent upon management induced quotas, user group preferences, market conditions, community structure, and system productivity.

Additional Information

Self-sustainability of Lake Trout populations is measured in lakewide assessment programs carried out annually in each lake. The historical dominance of Lake Trout in oligotrophic waters in all of the Great Lakes provides a good basis for a basin-wide evaluation of ecosystem health. Maintaining or re-establishing historical levels of

abundance, biomass, or production and re-establishing self-sustaining populations of Lake Trout throughout their native range in the basin will help ensure dominance in the ecosystem and the maintenance of a desirable aquatic community in oligotrophic, cold water habitats. The desired trend is increasing dominance of the indicator species to historical levels in cold water, oligotrophic habitats throughout the basin.

The oligotrophic fish community is associated with cold, clear, less productive, offshore waters. Oligotrophic communities, along with mesotrophic and eutrophic communities are found to varying degrees in all five of the Great Lakes with Lake Superior and more recently most parts of lakes Huron and Michigan, dominated by oligotrophic habitat.

The Lake Trout is the native top predator in deep, open waters of all of the Great Lakes. Lake Trout is selected as an indicator because they represent a vital role in the original fish communities in the different habitats, they have value to the ecosystem and to fisheries, and they are the focus of fisheries management and restoration efforts. They have been subjected to the full range of other environmental effects as a result of human impacts on the Great Lakes including habitat loss, nutrient pollution, and toxic pollutants. While restoration efforts such as stocking can complicate interpretation of the status of native species, the successes of these species are indicative of progress toward the goals of the GLWQA.

Reporting frequency should be every five years, which is more appropriate given the rates of real change in population status of a long-lived species. Monitoring systems are in place, but in most lakes the measures do not directly relate to stated harvest objectives. Lake Trout population objectives should be redefined as endpoints in units measured by the monitoring activities, as they are relevant to population characteristics required for restoration to proceed and should be incorporated into restoration guides and plans. The data time series presented are based on important population targets that can be measured with current assessment activities.

Objectives for Lakes Superior and Huron are harvest-based on historical yields or desired harvest states. They are divorced from “target” population states (CPUE, age composition) and fishery-independent survey data or population model output that better track rehabilitation progress toward desired targets. This lack of feedback makes evaluations difficult. Harvest levels alone are dictated by a variety of factors that are not necessarily tied to population abundance or trajectory.

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Figure 1. Relative abundance of stocked Lake Trout (and wild fish where provided) in the Great Lakes from 1970 - 2023. Due to Covid-19, many surveys were not conducted in 2020. The measurements and time frame reported vary from lake to lake, as shown on the vertical and horizontal scales, and comparisons among lakes may be misleading. Overall trends over time provide information on relative abundances for all or part of the population. No targets have been specified for Lakes Superior and Huron.

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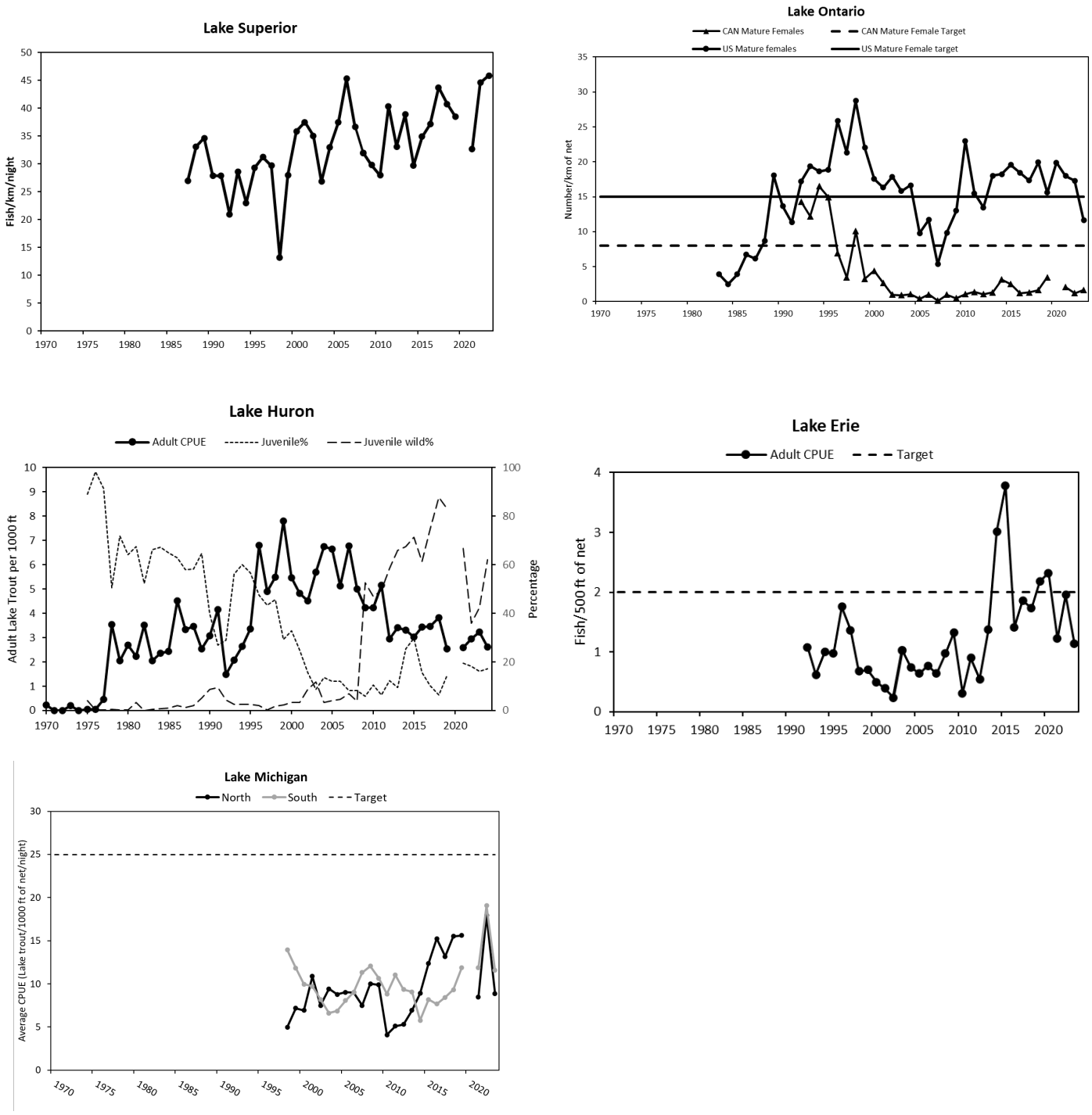

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