2023 Lake Michigan Lake Trout Working Group Report [1,2]

The Lake Michigan Lake Trout Working Group (LMLTWG)

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[1] The U. S. Geological Survey (USGS) data associated with this report are publicly available (Madenjian, Dieter, and Dabrowski 2024; Northern Lake Michigan gillnet assessment 1998-2023, U.S. Geological Survey data release, https://doi.org/10.5066/P13YOF5Y). Please direct questions to our Data Management Librarian, Sofia Dabrowski, at sdabrowski@usgs.gov.

[2] All USGS Great Lakes Science Center 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).

Background

Herein we provide a review of progress made to meet rehabilitation goals for lake trout (*Salvelinus namaycush*) in Lake Michigan as established in the Salmonine Fish Community Objectives (FCOs) for Lake Michigan (Eshenroder et al. 1995) and the interim goal and evaluation objectives articulated in *A Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan* (hereafter the "*Strategy*"; Dexter et al. 2011).

Spatial unit allocations

This report is designed to incorporate the current understanding of stock assessment units, which are reflective of a biological understanding of the behavior and distribution of lake trout and incorporate other political and policy decisions. Modeled population statistics and harvest policies are established within Stock Assessment Unit boundaries (A below). Notice that we made two stock assessments for the WM345 region, one with (WM345 with Southern Refuge) and one without the Southern Refuge included (WM345 no Southern Refuge). The main reason for two assessments was to try to separate populations of the Klondike strain from those of the other strains. Klondikes are a deepwater strain that display different movement patterns. They remained offshore and within the Southern Refuge to a much greater degree than the other strains, and thus were less vulnerable to the fisheries. Spring surveys (LWAP) are reported by Data Reporting Unit within each stock assessment unit (B below). Stocking is described within designated statistical districts (Figure 4). Fall survey information is reported by the spawning location assessed. Thiamine information similarly is associated with the capture location.

A. Stock Assessment Units:

- MM123 with Northern Refuge
- MM4
- MM5
- MM67
- WM345 with Southern Refuge
- WM345 no Southern Refuge
- WIIM (IL, IN, WM6, MM8)

B. Data Reporting Units (finer spatial scale, but respecting delineation of Stock Assessment Units):

- MM123-Northern Refuge
- MM123 no Northern Refuge
- MM4
- MM5
- MM67
- WM345-Southern Refuge
- WM345 no Southern Refuge
- WIIM-east (IN, MM8)
- WIIM-west (IL, WM6)

Abstract:

Data were compiled from several sources in preparing this report. Harvest information was supplied by the Lake Michigan extraction database (Redman 2024). Mortality rates were reported from agency run stock assessment models. Stocking information was recovered from the GLFC, Fish Stocking database available at: Stocking Events (glfc.org). Lamprey marking rates, CPUE, and age information were reported from the spring Lake-Wide Assessment Plan (LWAP) gillnet survey and from fall gillnet surveys conducted on spawning reefs (data obtained from Ted Treska, GLFC). Sex ratios and eggs for thiamine analysis were obtained from the fall gillnet surveys. Thiamine analysis and reporting are provided by Jacques Rinchard, SUNY Brockport. The proportion of unmarked fish are reported from biological sampling conducted in statewide creel programs, from the U.S. Fish and Wildlife Service biotech fishery monitoring program and from bottom trawl surveys conducted by the U.S. Geological Survey.

Fish community objectives related to harvest were met in 2023: total salmon and trout harvest was 2.7 million kg, and lake trout comprised 20% of the annual lakewide harvest. Three genetic strains (all lean ecomorphs) of lake trout were stocked in 2023 and numbers stocked into southern and nearshore waters remain low. Catch rates in spring LWAP surveys remained below target levels in lake trout stock assessment units except for Grand Traverse Bay and the Southern Refuge. Mortality rates were higher in northern stock assessment units, but generally trended downward in all units in 2023. Sea lamprey marking rates remained low lakewide in 2023. Egg thiamine concentrations in Lake Michigan have remained slightly above the threshold level of 4 nmol/g in most regions of Lake Michigan during 2023. Spawning populations of lake trout are being established at locations where they are stocked. Spawning stock biomass estimates are trending upward in southern Lake Michigan, and in the Southern Refuge. Measures of percent females were variable across sampling locations and were likely dependent on sampling date. There were spatial differences in the occurrence of older mature lake trout (age groups >7) in Lake Michigan. The oldest stocks of lake trout occurred in WM345 and MM67. Older age groups of lake trout were more prevalent in WIIM east in the spring and in WIIM west in the fall. Increasing levels of natural recruitment were apparent in both creel and USFWS biotech surveys in all stock assessment units except for northern Lake Michigan and MM5.

Fish Community Objectives

Salmonine (Salmon and Trout) Objectives for Lake Michigan (Eshenroder et al. 1995):

Establish a diverse Salmonine community capable of sustaining an annual harvest of 2.7 to 6.8 million kg, of which 20-25% is lake trout.

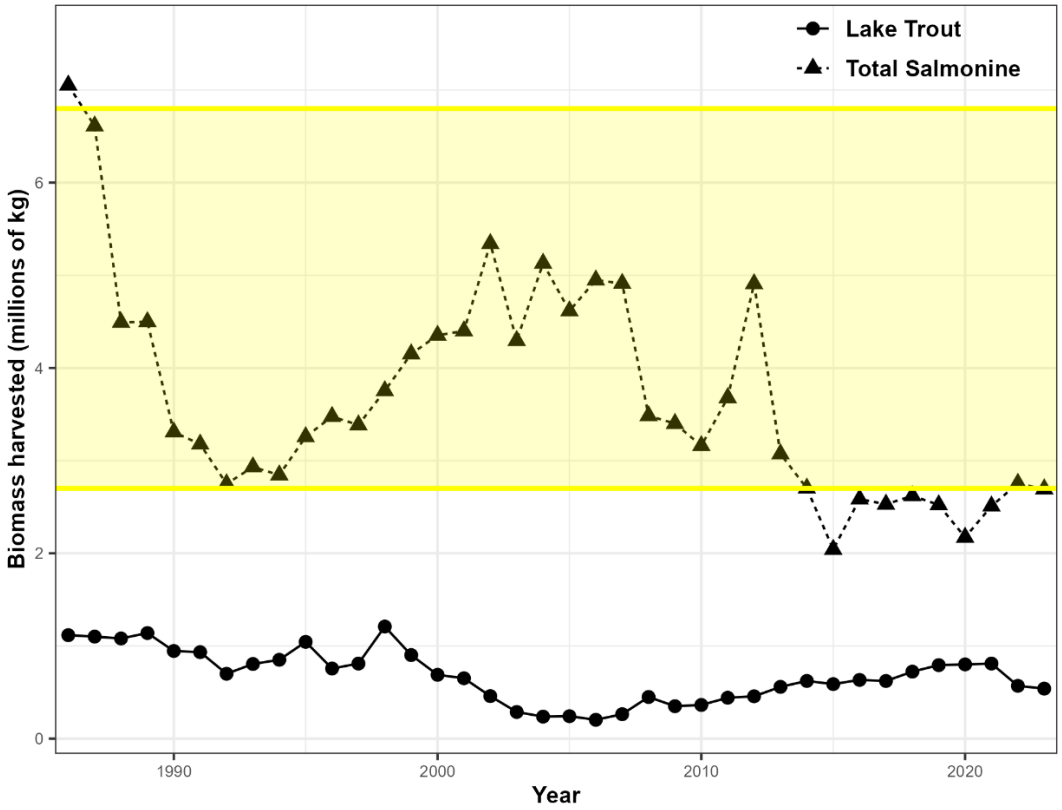

Figure 1. Lake Michigan total harvest (1985-2023) for lake trout (circles) and for all species of salmon and trout combined (triangles). Yellow shading depicts the targeted range of salmon and trout harvest that meets the fish-community objective (FCO).

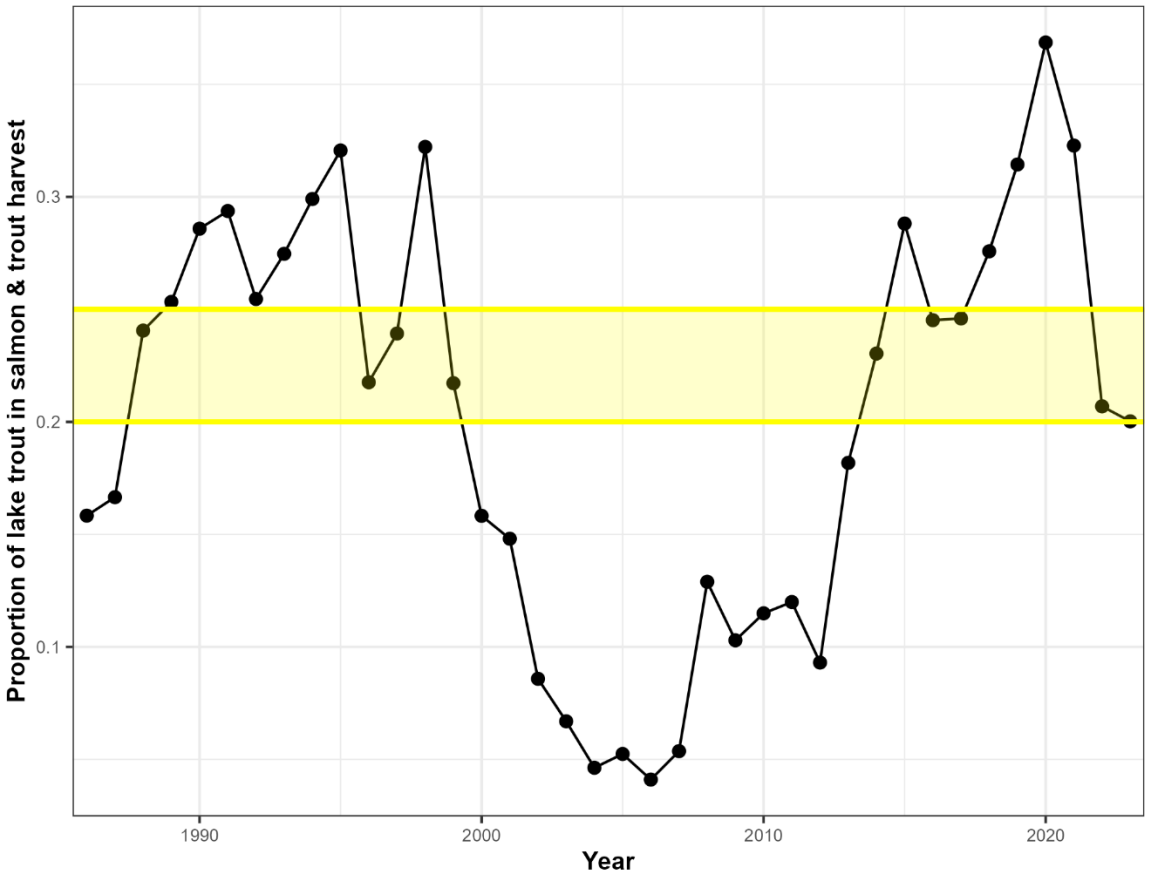

Figure 2. The proportion of salmon and trout harvest comprised of lake trout; yellow shading represents the 20 to 25% specified in the fish-community objectives (FCOs).

Summary: In 2023, total salmon and trout harvest was 2.69 million kg, thereby meeting the fish-community objective (FCO) harvest objective for the second consecutive year after below-objective levels from 2015 – 2021 (Figure 1). Lake trout harvest in 2023 was 0.54 million kg, and thus comprised 20% of the total salmonid harvest in 2023 (Figure 2). Thus, the FCO harvest objective of lake trout harvest representing 20-25% of the total salmonine harvest was met in 2023 (Figure 2). Lake trout harvest decreased between 2021 and 2023, whereas salmon harvest increased during this period.

Establish a self-sustaining lake trout population.

- Specific metrics are reported below within the lake trout impediments assessment review.

Lake trout impediments assessment

Goal (LMC Restoration Strategy; Dexter et al. 2011): Reestablish in targeted high-priority areas and refuges of Lake Michigan a diversity of primarily lean lake trout populations predominately supported by natural reproduction that provide sustainable yields to recreational, commercial, and subsistence fisheries.

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.

Strains stocked

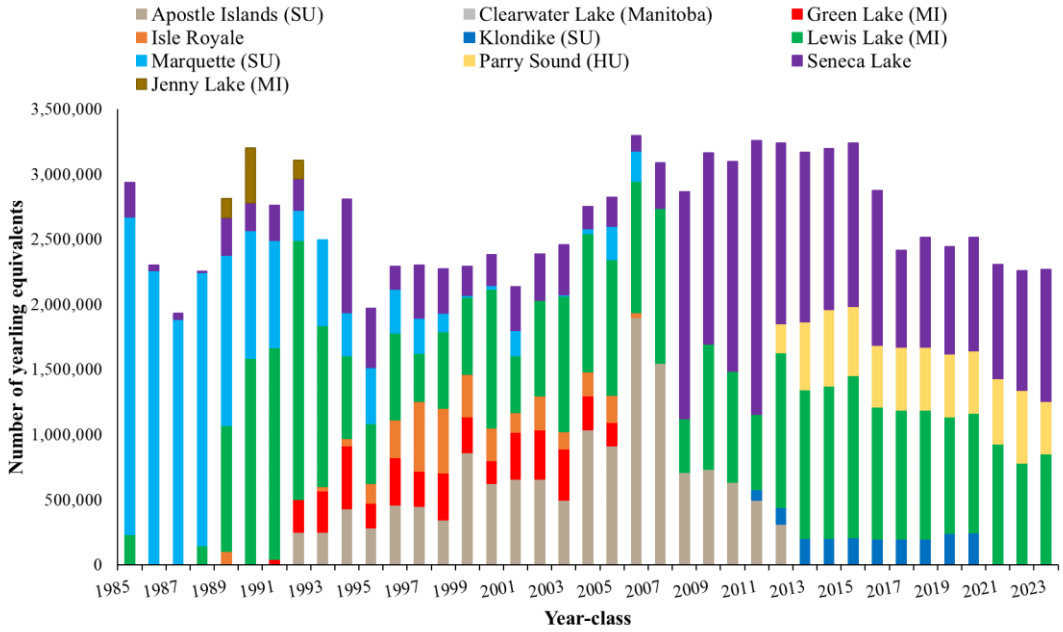

Figure 3. Numbers of yearling equivalent lake trout stocked by strain in Lake Michigan from 1985-2023.

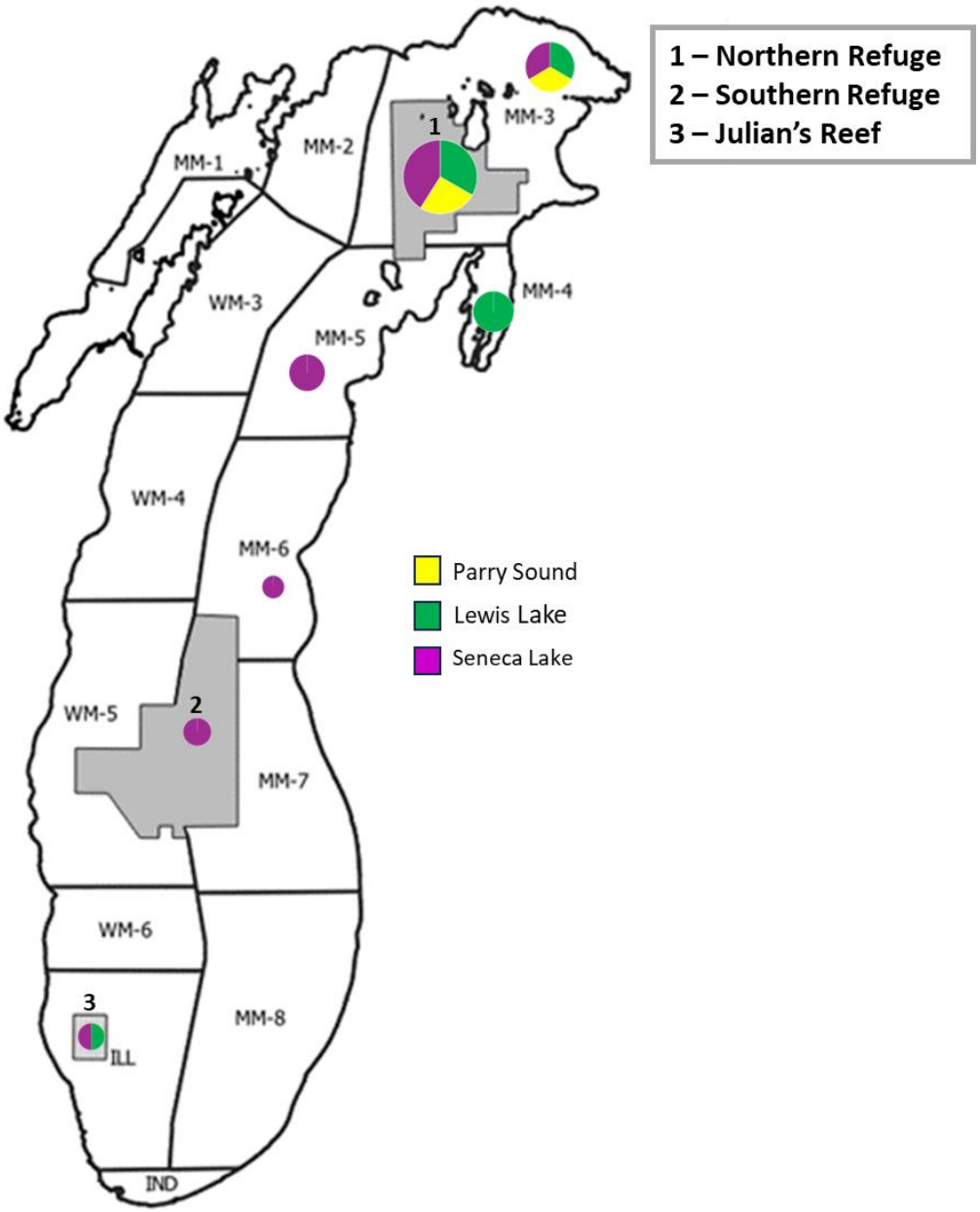

Figure 4. Yearling equivalents of each strain stocked into each statistical district and refuge location in Lake Michigan during 2023.

Table 1. Number of lake trout of each strain stocked into non-refuge statistical districts and delineated refuge areas 2023.

Statistical District	Strain			Total
	Lewis Lake	Parry Sound	Seneca Lake	
ILL	60,599		60,660	121,259
IND				0
Northern Refuge	347,348	267,953	428,805	1,044,106
MM3	133,694	134,173	134,628	402,495
MM4	311,939			311,393
MM5			200,378	200,378
MM6			70,562	70,562
MM7				0
MM8				0
Southern Refuge			116,334	116,334
WM3				0
WM4				0
WM5				0
WM6				0
Total	853,580	402,126	1,011,367	2,266,527

Summary: Throughout the 1990s and early 2000s as many as six different strains of lean lake trout were stocked into Lake Michigan (Figure 3). From 2011-2020, an intermediate non-lean form of lake trout, the Klondike strain (humper ecomorphotype), was stocked into the Southern Refuge. These Klondike strain lake trout appear to have survived well and continue to return in large numbers in survey nets set in the Southern Refuge. As of 2021, three lean strains of lake trout were stocked into Lake Michigan (Seneca Lake, Lewis Lake and Parry Sound). In 2023, 45% of stocked lake trout were Seneca Lake strain, 38% were Lewis Lake strain and 18% were Parry Sound strain (Table 1 & Figure 4). In 2023, lake trout stocking was concentrated in northern Lake Michigan (MM3, 4 & 5; 86% of all lake trout stocked) and 49% of lake trout stocked in the southern basin were released offshore away from recreational fisheries in the Southern Refuge (Figure 4, 5 & Table 1). Additional details on the strains of lake trout stocked into Lake Michigan and their history can be found in Jonas et al., 2023.

Objective 2 (Increase overall abundance): 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. The stocking strategy prescribed by the LMC calls for 3.53 million yearling equivalents placed in priority rehabilitation areas and in key locations to support fisheries lakewide. To meet abundance targets, catch-per-unit-effort (CPUE) rates in spring assessments should consistently exceed 25 lake trout/1,000 feet of graded-mesh gillnet (2.5-6.0-inch mesh).

Numbers stocked

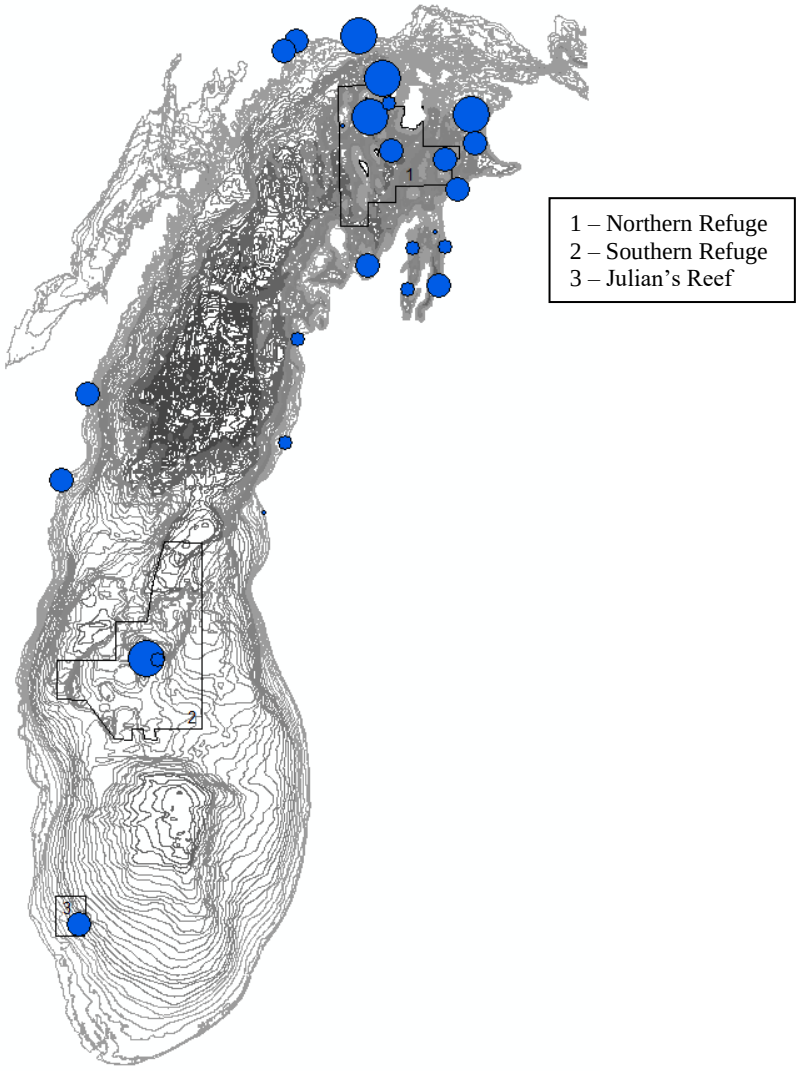

Figure 5. Bubble plot of stocking densities (average number stocked from 2019-2023) of yearling equivalent lake trout in Lake Michigan by location stocked. Results are displayed over grey scale bathymetry map of Lake Michigan (NOAA, Centers for Environmental Information). Note: During 2020 and 2021 lake trout were stocked into atypical nearshore areas due to COVID19 pandemic restrictions.

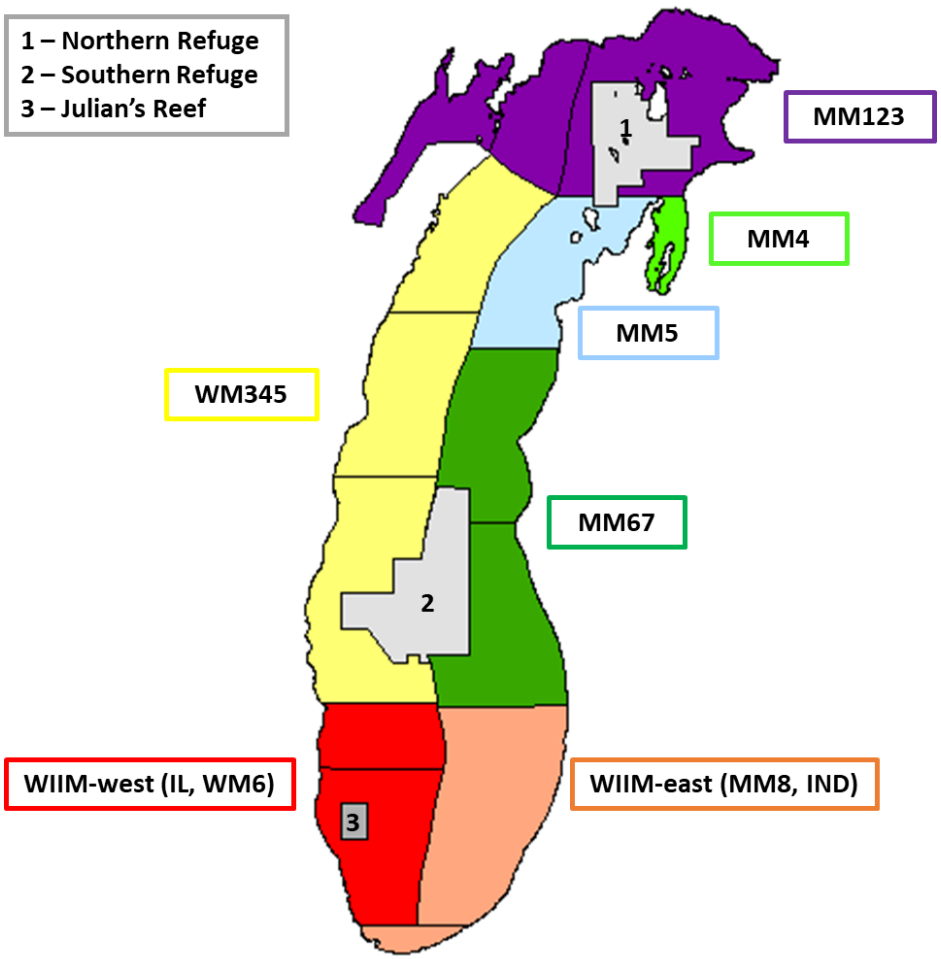

Figure 6. Delineated lake trout Stock Assessment and Data Reporting Units. Julian's Reef, the Northern Refuge, and Southern Refuge areas are identified as grey shaded areas.

Spring Survey (LWAP) CPUE

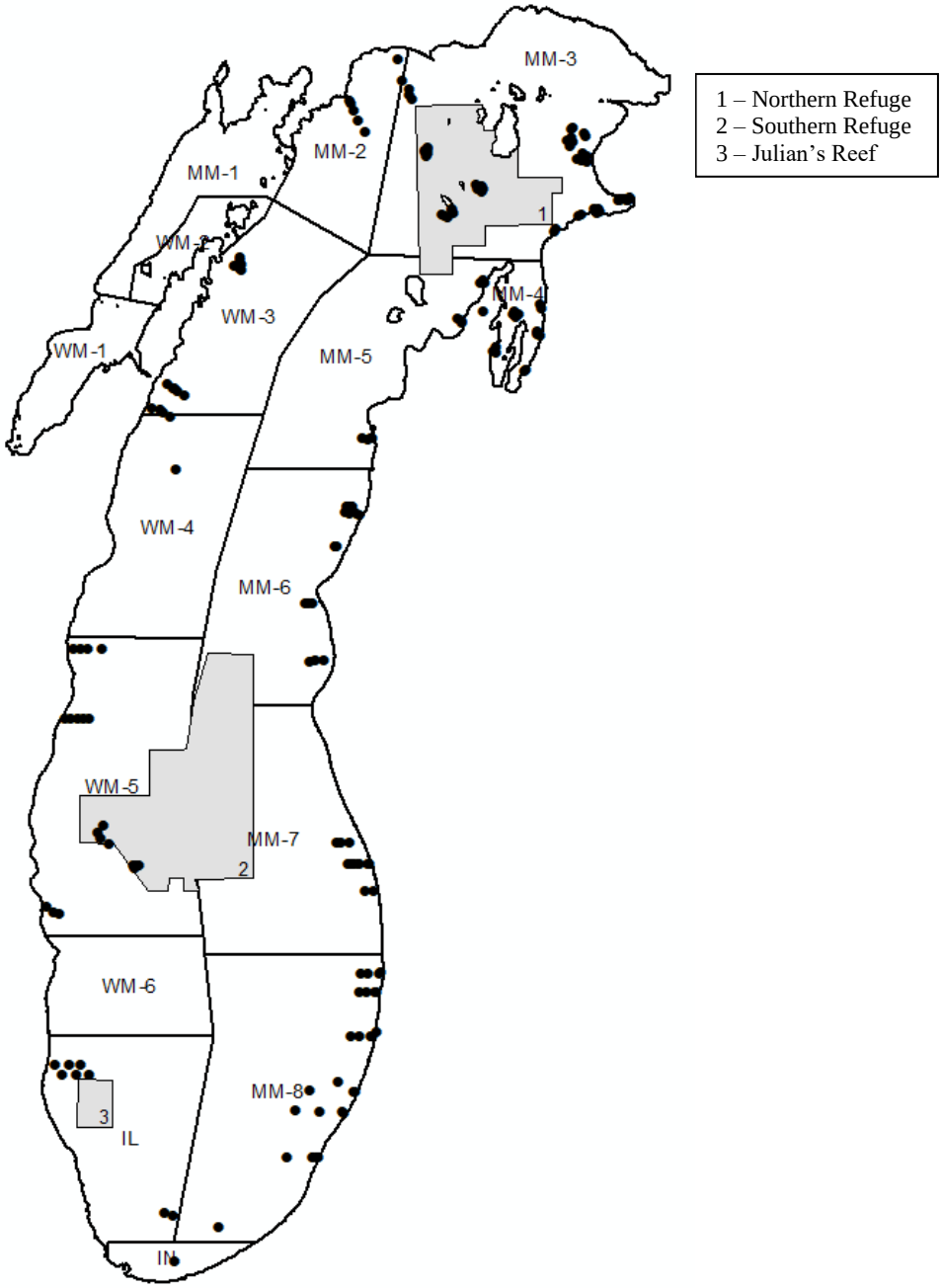

Figure 7. Locations where assessment gillnet lifts occurred during the spring of 2023. Statistical district boundaries are outlined with solid black lines, and shading is used to demarcate the Northern Refuge, Southern Refuge, and Julian's Reef.

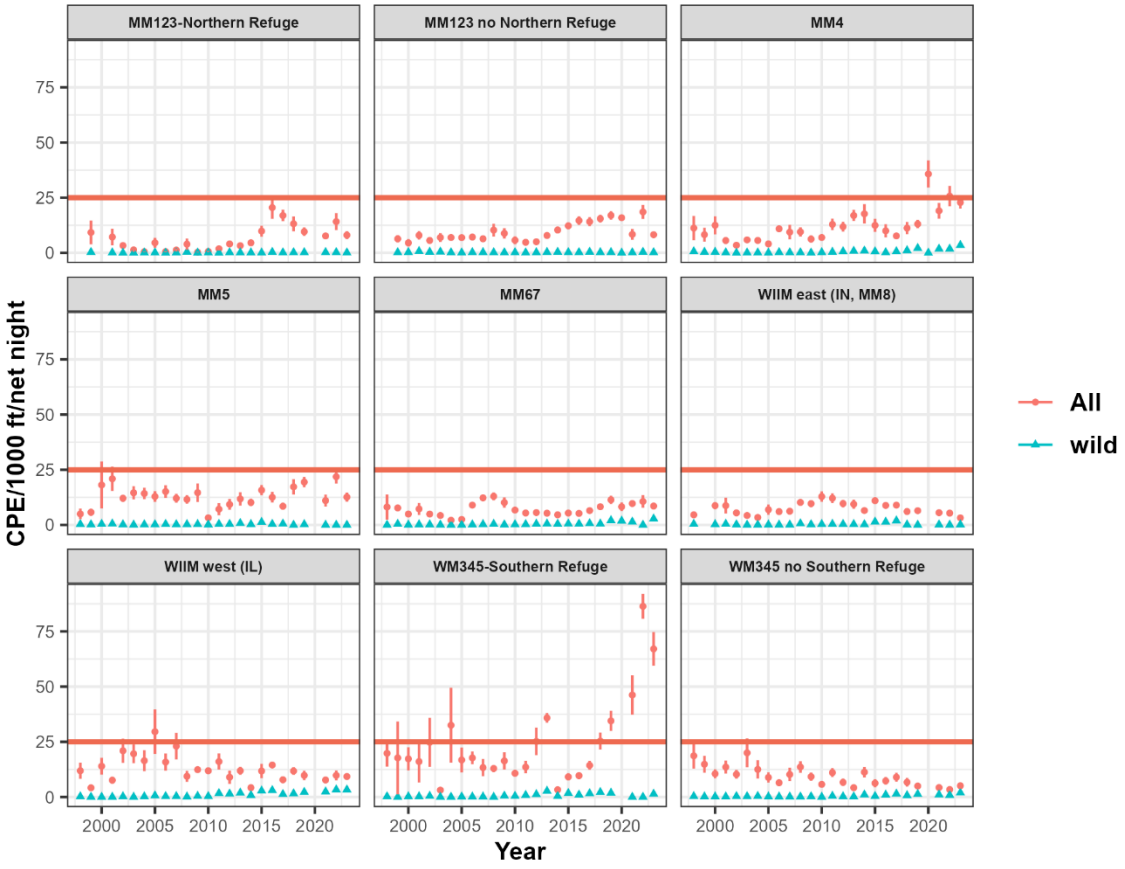

Figure 8. Time series of spring survey lake trout catch per effort (mean number of fish/1000 ft of graded mesh gill net) data reporting units. The coral diamonds portray catch per unit effort (CPUE) of all lake trout (hatchery and wild fish pooled) whereas the aqua triangles show the CPUE of wild lake trout. Vertical bars represent ± 1 SE and the horizontal coral line shows the spring CPUE (hatchery and wild combined) benchmark of 25 fish per 1000' of net.

Summary:

In 2023, 201 gillnet lifts were completed in Lake Michigan which met the LWAP sampling protocol (Figure 7).

On a lakewide basis, the objective has not been met, however, progress is being made in two reporting units. In the Southern Refuge catch rates have progressively increased since 2014 and have exceeded 25 fish per 1000 feet since 2018. In Grand Traverse Bay catch rates have met or exceeded target levels in 2020 and 2022.

In most other units, spring lake trout CPUEs have remained steady or have declined since 2017 (Figure 8). Stocking was discontinued at most nearshore locations in central and southern Lake Michigan in 2016. The removal of stocking as a reliable source of recruitment likely contributed to observed declining trends in CPUE.

In non-refuge waters of MM123, CPUEs rose to just over 18.2 lake trout per 1000 feet in 2022 and declined to 9.6 in 2023. Catches in the Northern Refuge area of MM123 were highest in 2016 at 20.5 lake trout per 1000 feet, and similar to non-refuge waters only 8 lake trout were caught per

1000 feet of net in 2023. Catches in Grand Traverse Bay have been steadily increasing since 2019. A small increase in wild fish CPUE in Grand Traverse Bay has also been observed, with the wild fish CPUE reaching 3.5 lake trout per 1000 feet of net in 2023.

In MM67, a slight increase in wild fish CPUE has been observed in recent years. Catches of wild fish in the eastern WIIM region have been low, whereas in the western portion of WIIM (Illinois waters), which includes Julian's Reef, wild fish CPUEs have remained around 3.3 wild lake trout per 1000 feet of net for the past 3 years.

In western Lake Michigan (WM345) nearshore and offshore waters show different trends. The steep increase in CPUE on the Southern Refuge from 9.7 in 2017 to 67 in 2023 can largely be attributed to stocking of the Klondike Reef strain of lake trout. Klondike strain lake trout have remained on the refuge rather than moving nearshore and appear to have survived well. Of the 659 coded-wire tagged (CWT) lake trout processed in the Southern Refuge LWAP survey in 2023, 98% were Klondike strain. In nearshore waters of WM345, CPUE declined, coinciding with reduced stocking levels which changed as management priorities shifted towards stocking northern waters and the offshore refuges. While CPUE target levels were met in the early 2000s, this region falls far below the target in recent years.

Results from the spring LWAP survey indicate that lake trout natural recruitment has increased in many areas of Lake Michigan, ", though levels of wild fish abundance as measured by the spring LWAP survey remain well below the benchmark level of 18.75 wild fish (75% of 25) per 1000 feet of net at all locations. There is no indication of progress in catch rates of wild lake trout in MM123, MM5 or eastern WIIM (MM-8 and Indiana waters), but most other units are experiencing increases in recent years. Lakewide average wild fish CPUEs based on the spring survey increased from 0.12 fish per 1000 feet of net in 2005 to 1.32 fish per 1000 feet of net in 2023.

Stock size and mortality

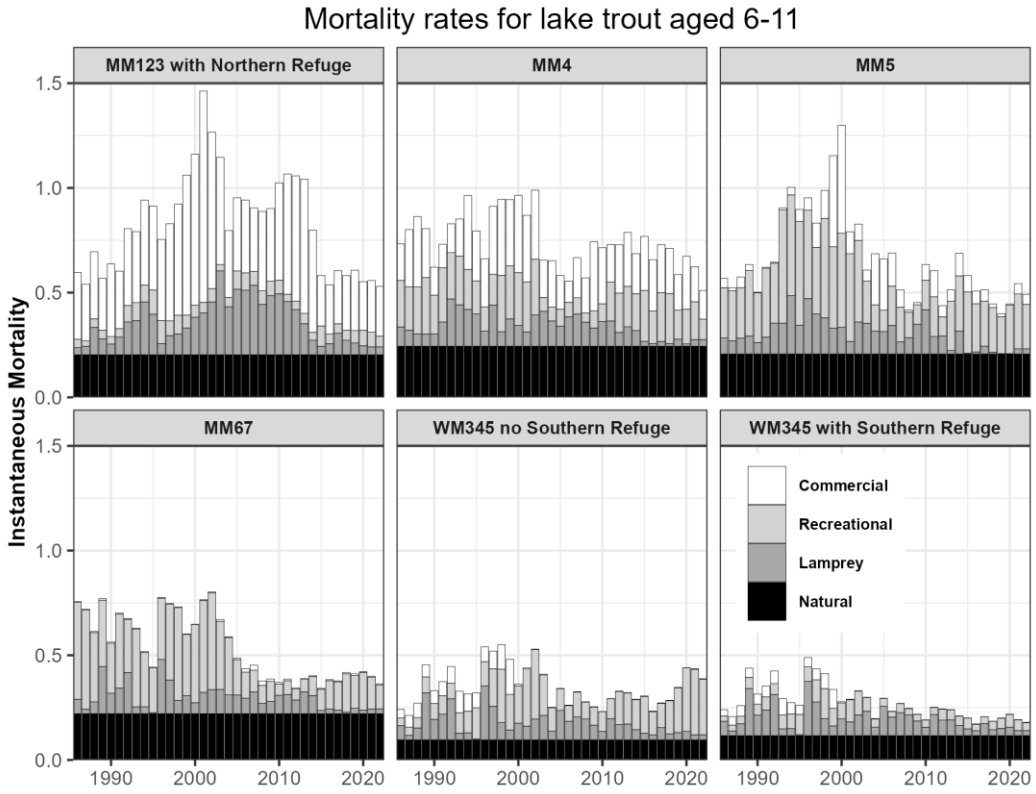

Figure 9. Annual estimates of instantaneous mortality by source (Natural, Commercial, Recreational, Lamprey) for five of the lake trout stock assessment units from catch-at-age models. Note that the WM345 assessment unit is shown with and without the Southern Refuge due to ongoing discussion on whether or not to model it as a separate unit.

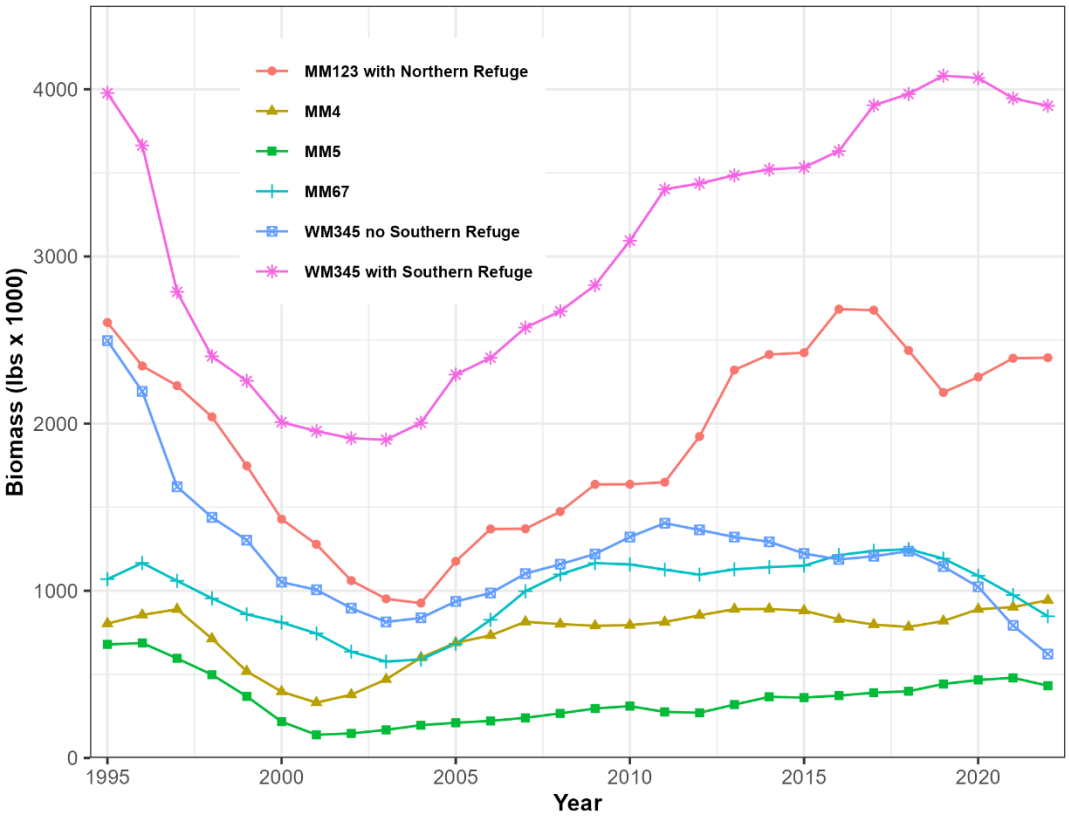

Figure 10. Annual estimates of lake trout biomass (lbs) in five of the six stock assessment units.

Note: A southern Lake Michigan model developed by MSU-QFC staff is under review by agencies contributing data and with local knowledge of the region. It is anticipated that values for the WIIM unit will be included in future reports.

Summary:

It is notable that there is a substantial difference in biomass estimates for unit WM345 when the Southern Refuge is included (pink line-asterisk symbol) compared to excluded (blue line-square symbol).

Sea lamprey – lake trout marking.

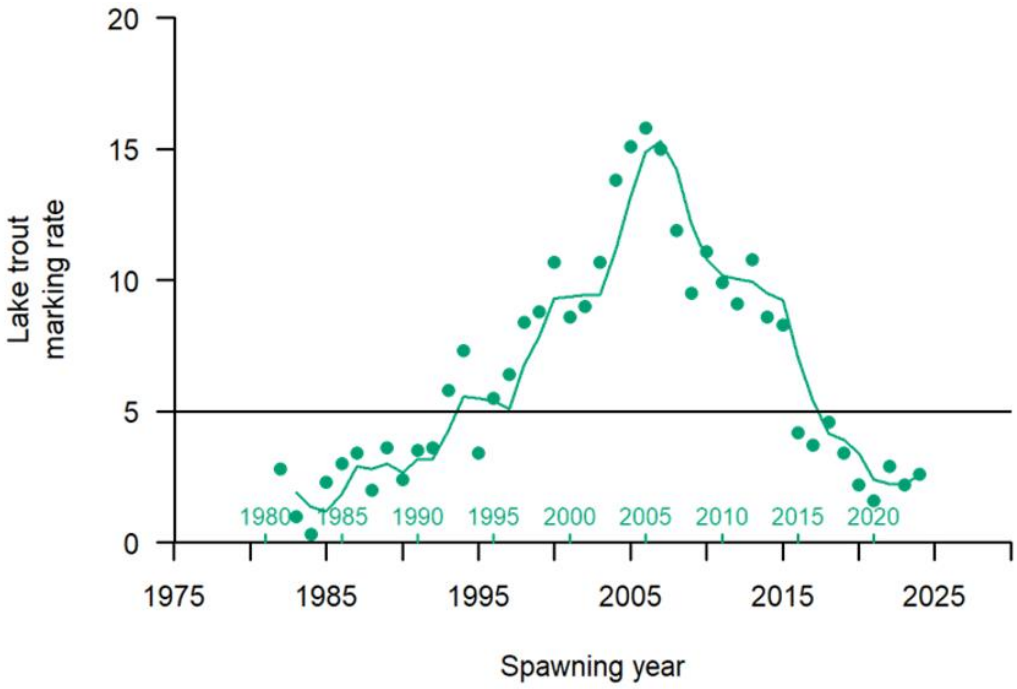

Figure 11. Number of A1-A3 marks per 100 lake trout > 532 mm from standardized assessments during August-November plotted against the sea lamprey spawning year, including the three-year moving average (line). The three-year (spawning years 2022-2024) average marking rate of 2.6 met the target of 5 A1-A3 marks per 100 lake trout >532 mm (horizontal line). A second x-axis shows the year the lake trout were surveyed.

Summary: Marking rates in Lake Michigan continue to be low.

Objective 3 (TDS): Lake trout egg thiamine concentrations >4 nmol/g in targeted rehabilitation areas.

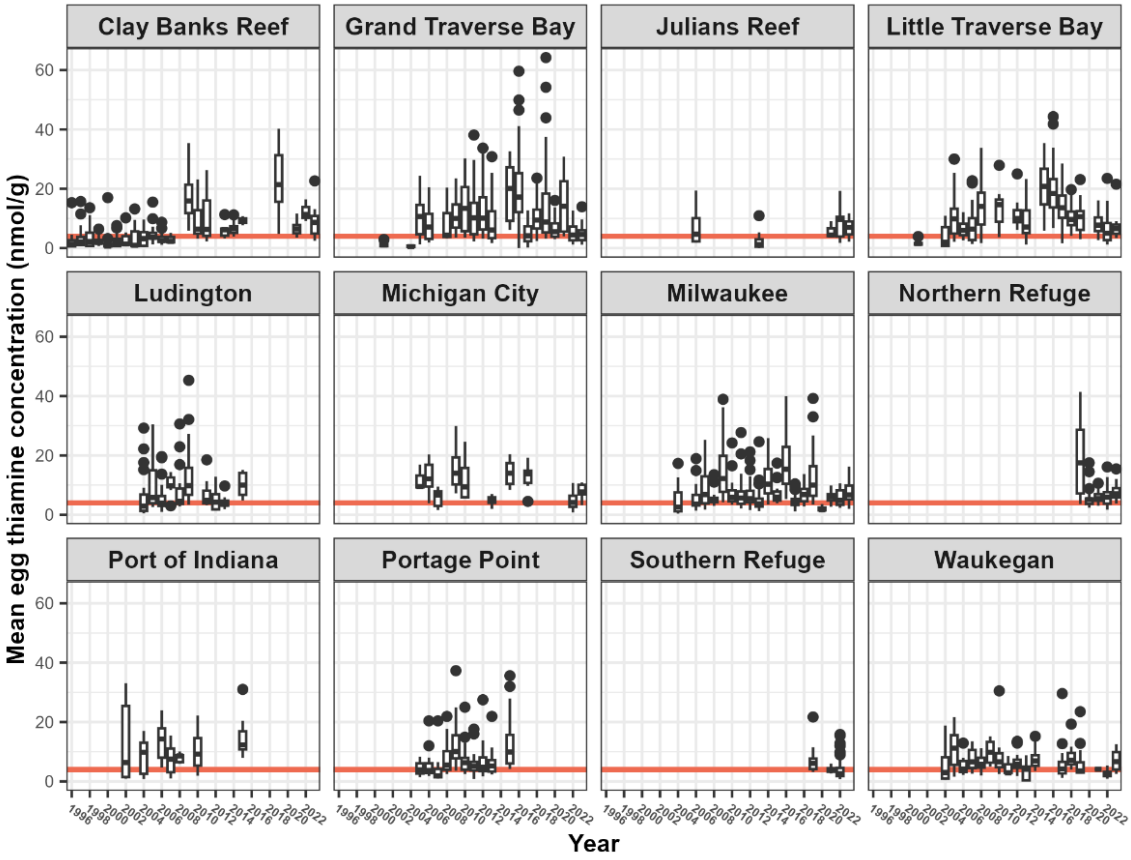

Figure 12. Mean egg thiamine concentrations (nmol/g) for ovulated lake trout females sampled in Lake Michigan fall spawner surveys, 1996-2023. Eggs with thiamine concentrations ≤ 4 nmol/g (horizontal coral line) are correlated with a higher probability of exhibiting thiamine deficiency syndrome (TDS). Data are provided by Jacques Rinchard, State University of New York at Brockport.

Summary: Egg thiamine concentrations in Lake Michigan have remained slightly above the threshold level of 4 nmol/g in most regions of Lake Michigan during 2023. In 2023, concentrations were lowest in Grand Traverse Bay (5.0±0.68 nmol/g; AVG±SE) and were highest at Clay Banks Reef (8.9±1.56 nmol/g).

Objective 4 (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. 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).

CPUE Fall spawning surveys

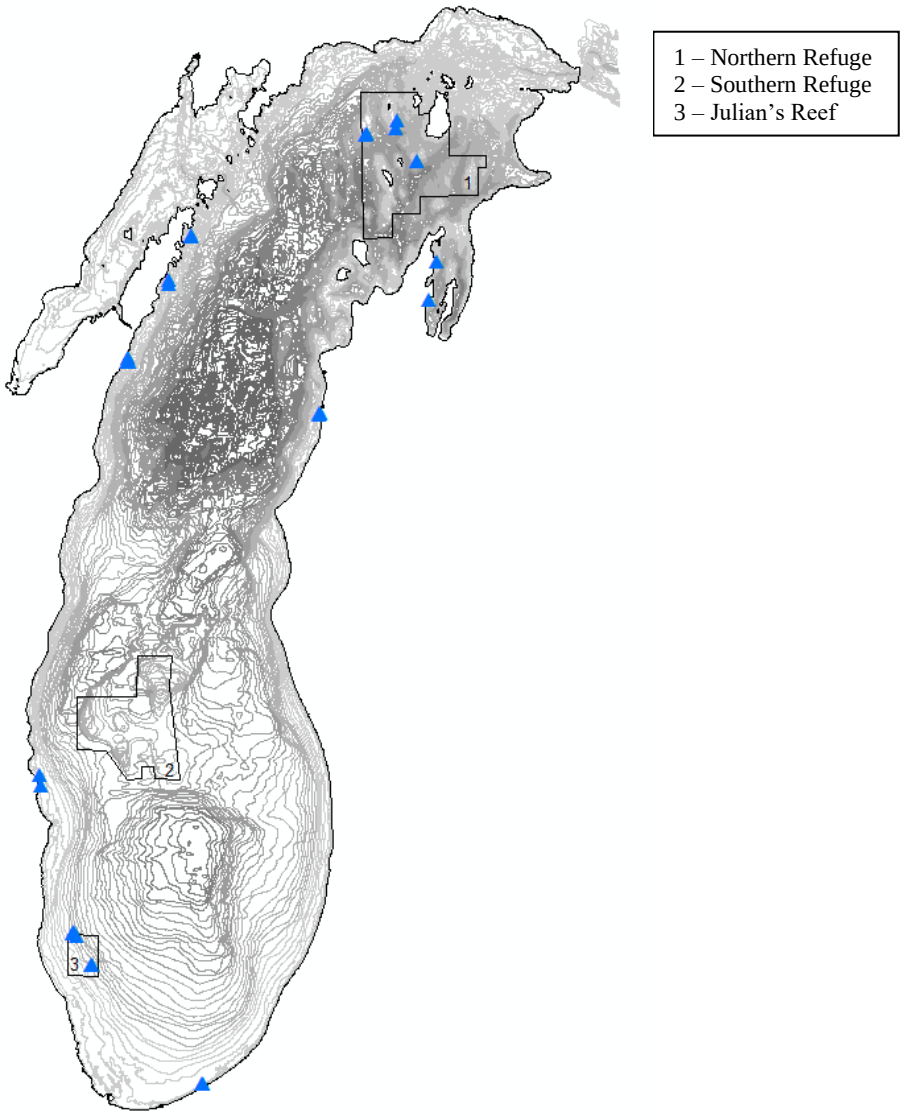

Figure 13. Locations of fall spawning survey gillnet lifts during the most recent year. Results are displayed over grey scale bathymetry map of Lake Michigan (NOAA, Centers for Environmental Information).

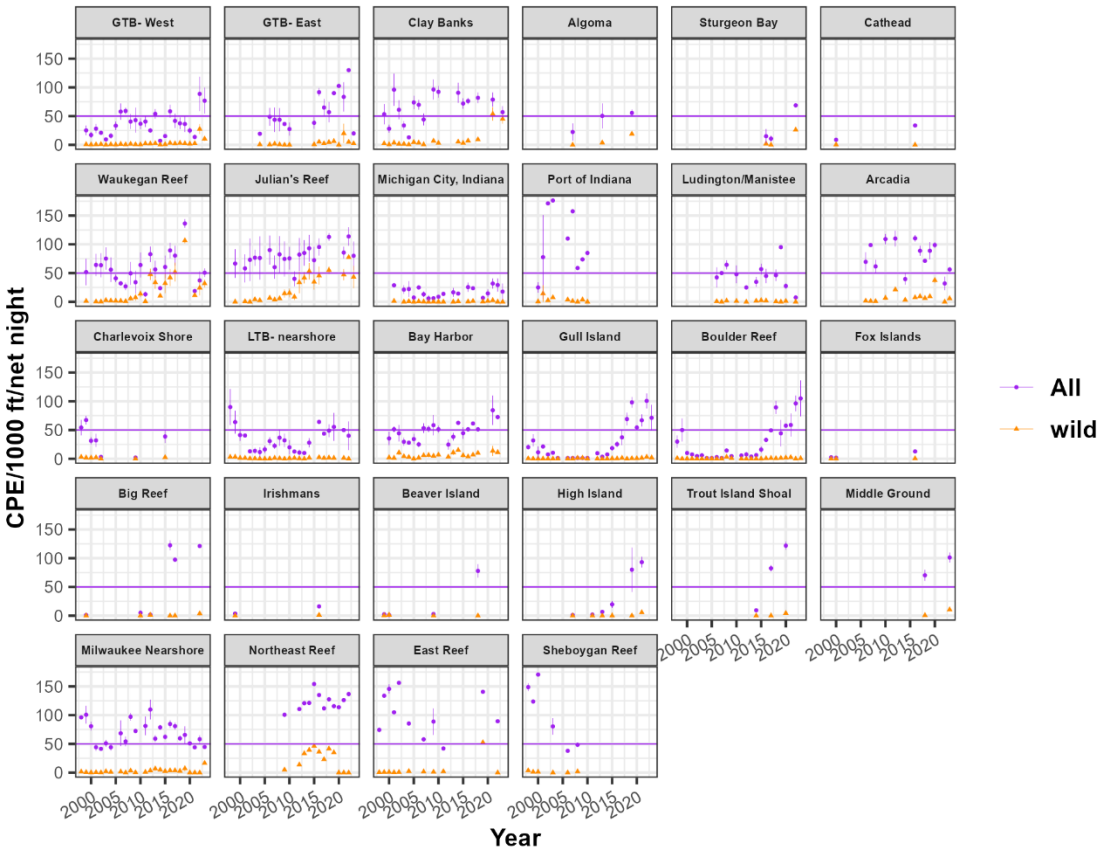

Figure 14. Time series of fall lake trout spawner survey catch per effort (mean number of fish/1000 ft of graded mesh gill net) for reefs with three or more years of sampling effort. The purple circles portray catch per unit effort (CPUE) of all lake trout (hatchery and wild fish pooled) whereas orange triangles show the CPUE of wild lake trout. Vertical bars represent $\pm$ 1 SE and the horizontal purple line shows the fall CPUE (hatchery and wild combined) benchmark of 50 fish per 1000'.

Spawning Stock Biomass

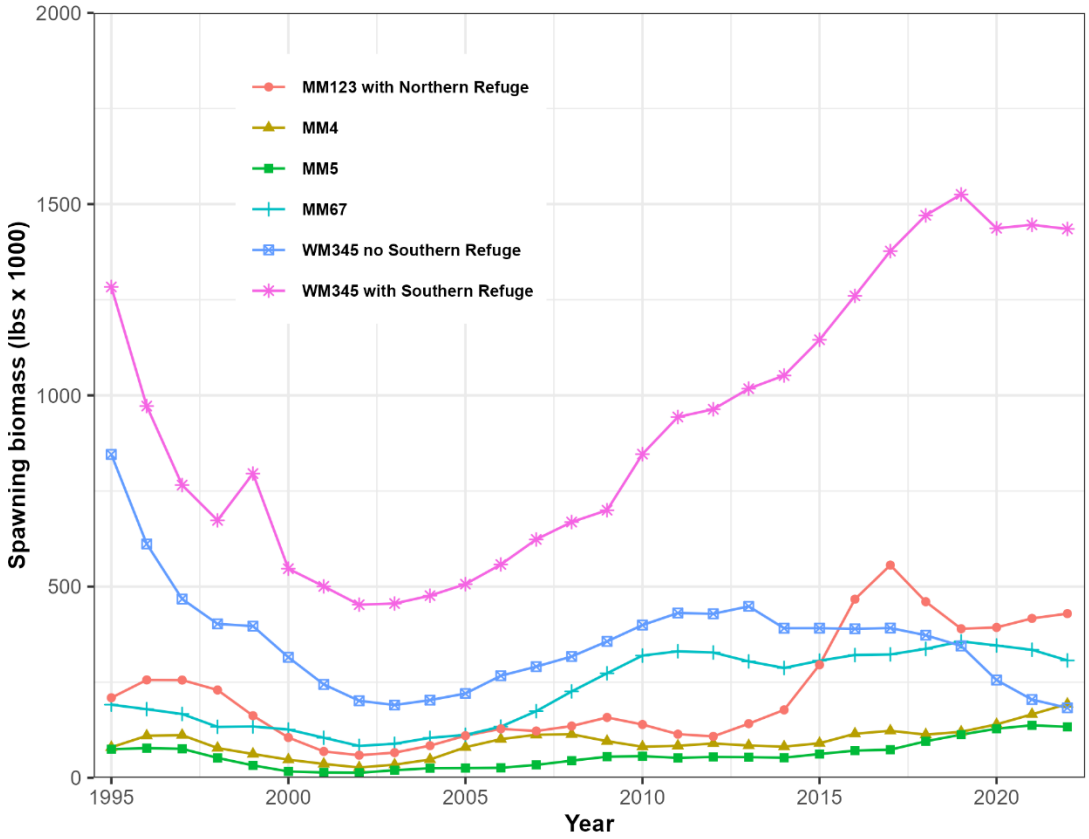

Figure 15. Annual estimates of female spawning stock biomass (lbs) in five of the six stock assessment units.

Note: A southern Lake Michigan model developed by MSU-QFC staff is under review by agencies contributing data and with local knowledge of the region. It is anticipated that values for the WIIM unit will be included in future reports.

Summary:

In 2023, 28 gillnet lifts were completed lakewide to assess the abundance of spawning lake trout on reefs (Figure 13). Most of the fall survey effort occurred in the Northern Refuge and Grand Traverse Bay. The Southern Refuge was not sampled in fall 2023 due to poor weather conditions.

CPUEs at targeted rehabilitation areas (Northern Refuge, Southern Refuge, and Julian's Reef) continue to meet the evaluation objective of ≥50 lake trout per 1000 feet of net.

Heavily stocked locations in northern Lake Michigan and Grand Traverse Bay continue to produce high catch rates of individuals returning to spawn. Spawning populations of lake trout are being established at locations where they are stocked. Spawning stock biomass estimates are trending upward in southern Lake Michigan, and in the Southern Refuge. A slight, less pronounced increase in spawning stock biomass is also occurring MM3.

Waukegan Reef and Julian's Reef in Illinois waters have shown promising signs with sustained high catch rates of wild fish since 2015.

In Wisconsin non-refuge waters, catches of both wild and hatchery lake trout remain high at Clay Banks Reef. Overall CPUE declined in 2023, but there was an increase in the CPUE of wild lake trout.

Within the Southern Refuge, CPEs of wild fish had shown promise on the Northeast Reef, but in recent years, catch rates of wild fish have declined.

Percent mature females

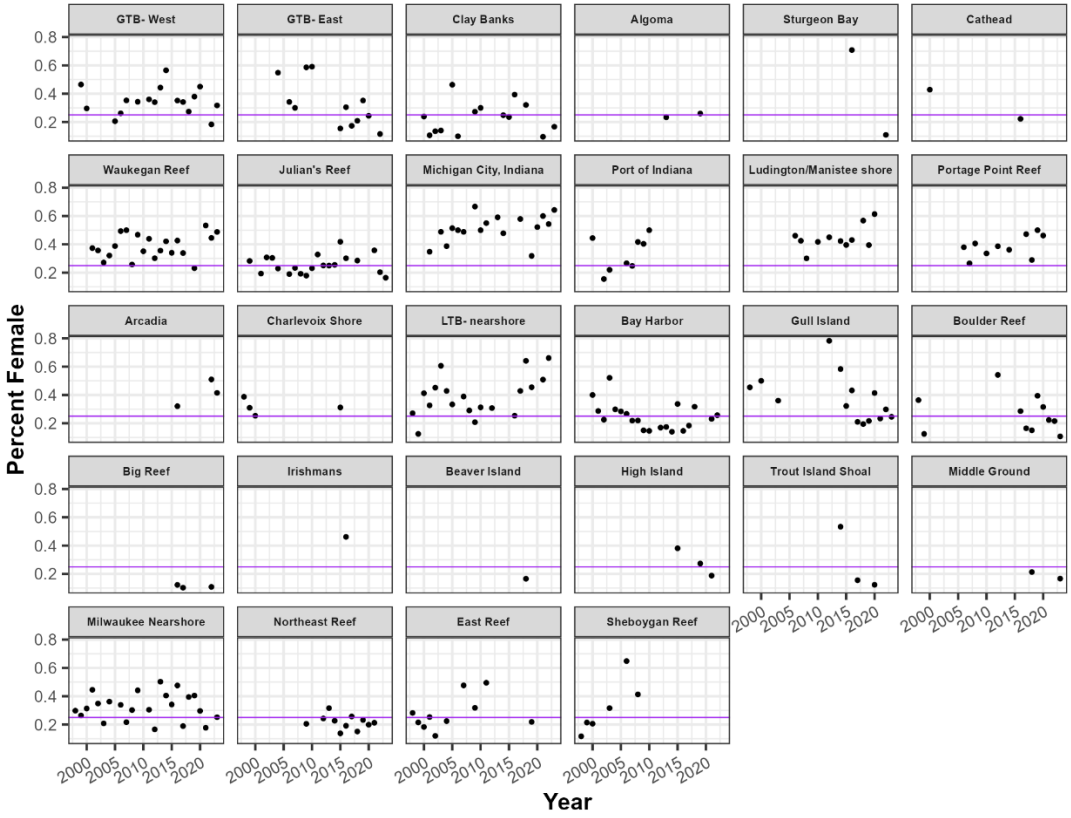

Figure 16: Percent of fish captured in fall surveys that are female. The solid purple line indicates the management benchmark of females accounting for ≥25% of mature fish in fall surveys. Information was included for sites and years' where more than 10 lake trout were collected and a minimum of 1 female was observed.

Summary:

On a lakewide basis and averaging across all years, more than 25% of the lake trout caught in fall spawning surveys are female (Figure 16). Variations in the percent female lake trout captured in fall gill net surveys by site and year are likely more reflective of the timing of sample location than the actual ratio of females occupying a spawning location given a relatively low number of lifts, often only 1 per site. In 2023, the benchmark was met in Grand Traverse Bay, nearshore Ludington/Manistee, Portage Point Reef, Arcadia, nearshore Little Traverse Bay, nearshore Indiana, Waukegan, and nearshore Milwaukee.

Age groups >7 (target 10 or more)

Spring LWAP Survey

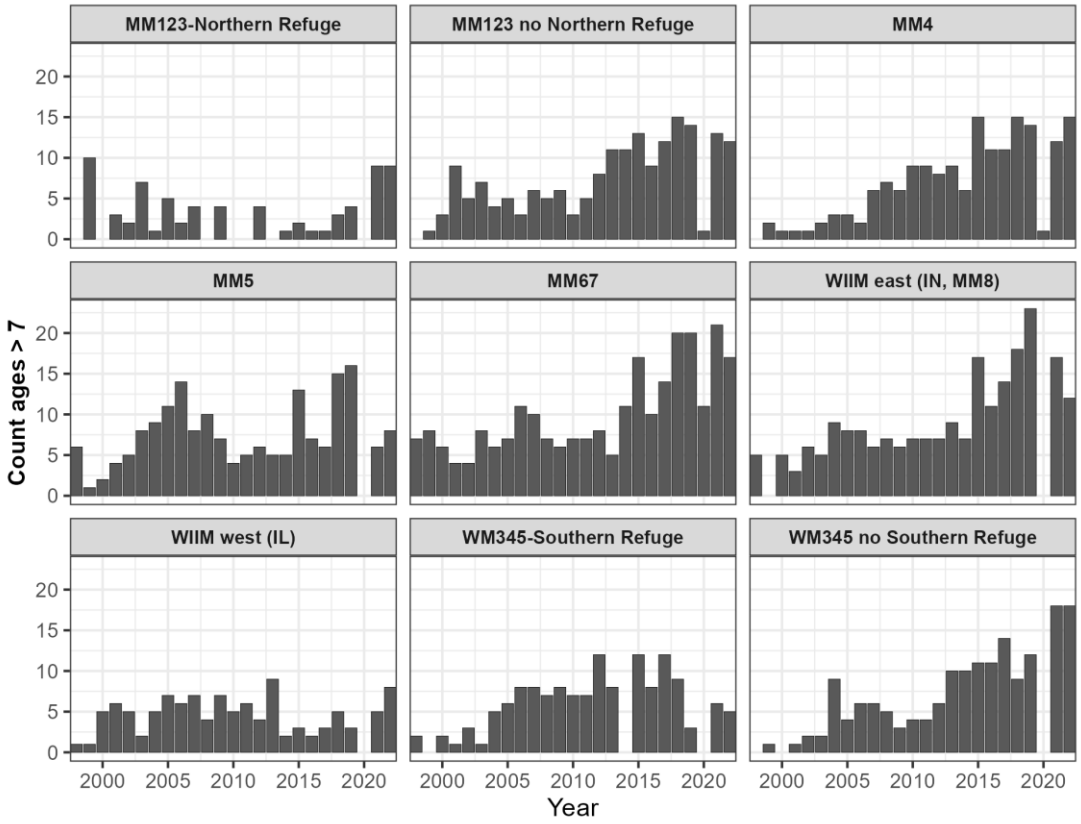

Figure 17. Number of age groups observed in LWAP gill net surveys in the spring that are greater than age 7, summarized by data reporting unit.

Fall Spawning Survey

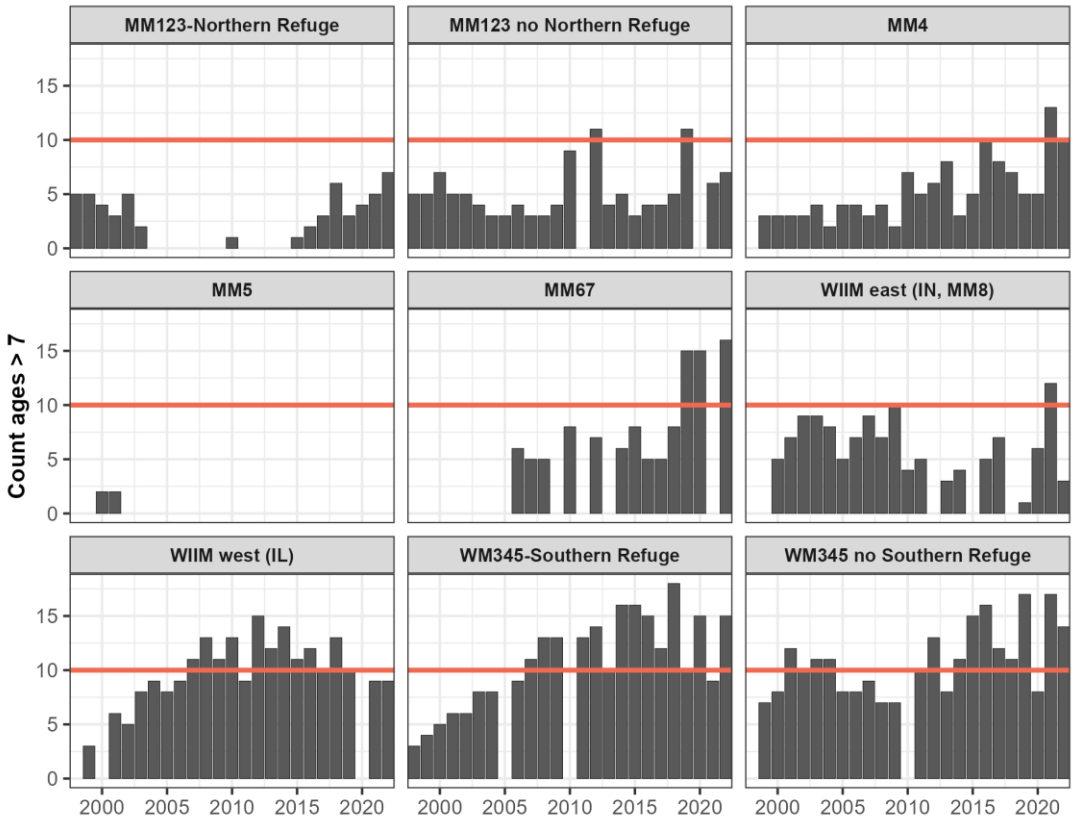

Figure 18. Number of age groups observed in fall gill net surveys that are greater than age 7, summarized by data reporting unit.

Summary:

More than 10 age groups > age 7 were observed in LWAP surveys in recent years in non-refuge waters of MM123, MM4, MM67, WIIM east and in non-refuge waters of WM345. Fall surveys conducted on targeted spawning reefs indicate the greatest number of age groups occurring in the Southern Refuge and non-refuge waters of WM345. MM67 and MM4 show promising trends in recent years. In spring LWAP surveys, older aged fish were more prevalent in WIIM east than in WIIM west. Whereas older age fish are much more prevalent in WIIM west (Illinois) in fall surveys. From 2007-2018 the number of age groups > age 7 had been increasing and promising in WIIM west, however in recent years older aged fish are less prevalent.

Objective 5 (Detect recruitment of wild fish): Consistent recruitment of wild lake trout in targeted rehabilitation areas, detect age-0 & 1 fish in bottom trawls; detect wild in gillnet assessments (LWAP & Fall spawning) and in recreational fisheries (state creel programs & USFWS biotech data).

USGS Bottom Trawl Surveys

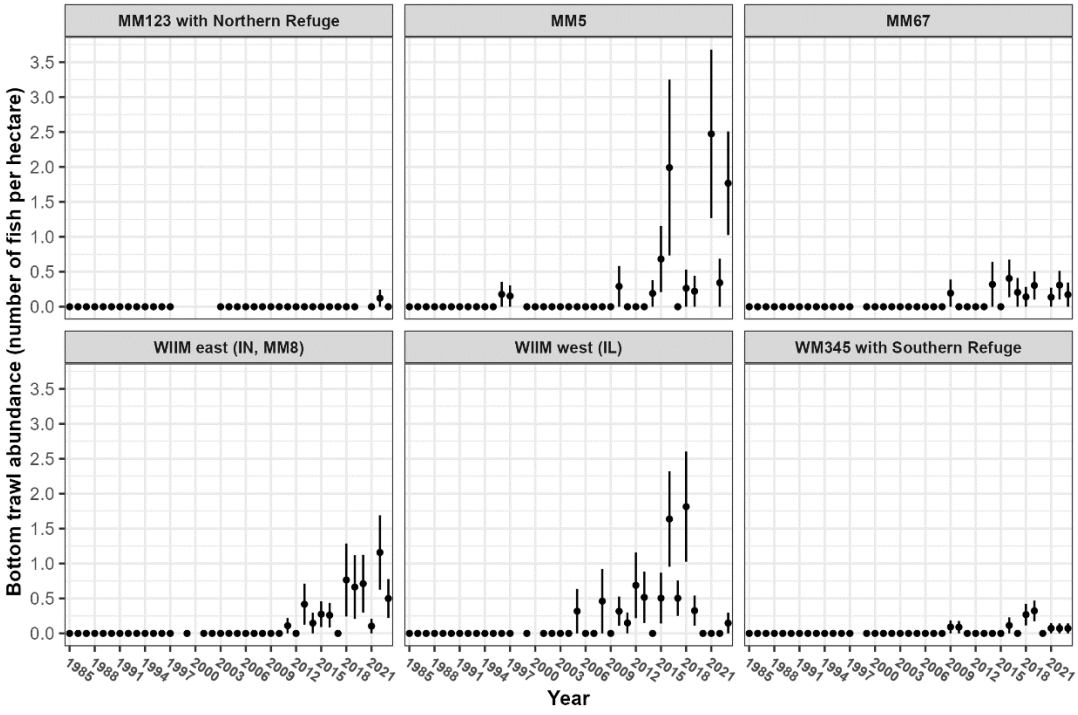

Figure 19. Estimated density of unclipped lake trout (number per hectare) captured annually in USGS bottom trawl surveys, summarized by data reporting unit. Transects are run off 7 ports (Frankfort, Ludington, Saugatuck, Waukegan, Port Washington, Sturgeon Bay, and Manistique) are performed. Along each transect, a set of 10-minute bottom trawl tows are performed. The trawl is towed along the depth contour.

State Creel Survey Biodata

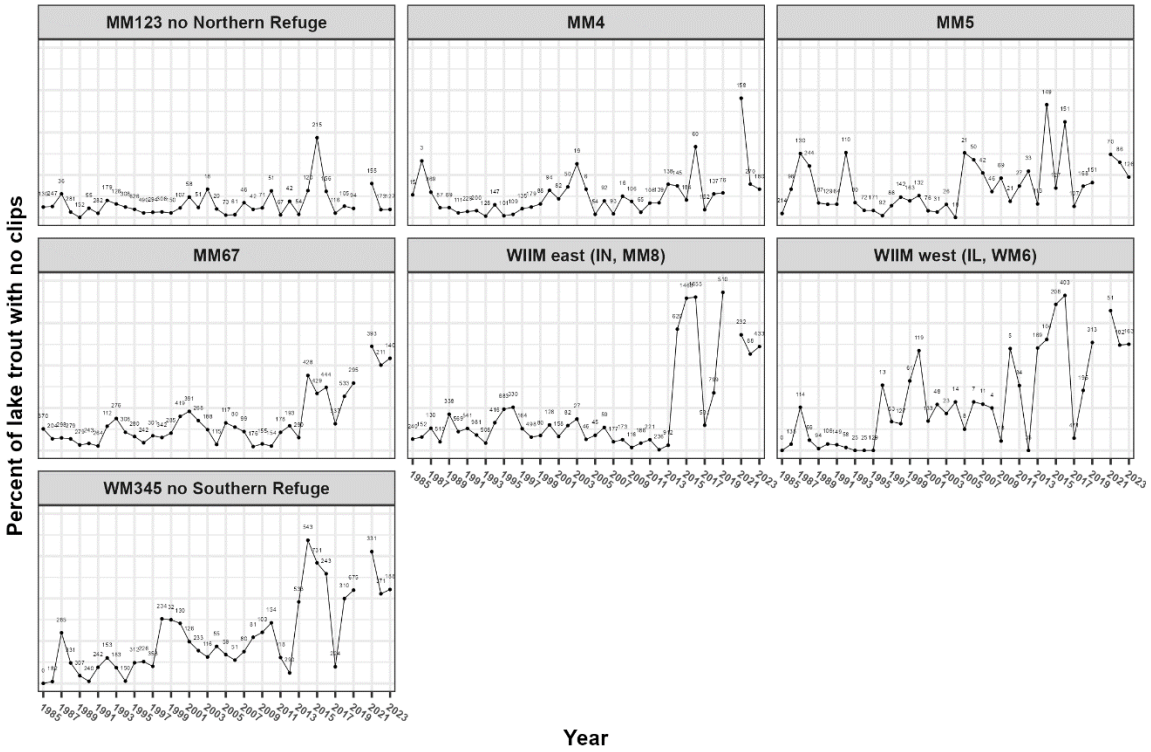

Figure 20. Percentage of unclipped lake trout observed in creel biodata samples collected from Lake Michigan recreational fisheries during the months of April – September in years 1985-2023, summarized by data reporting unit. In 2020 no samples were collected due to COVID-19 pandemic shut-downs. Sample sizes are provided for each observed data point. To avoid misuse of numeric data, we have not included numeric values on the y-axis. However, scaling among graphs is held consistent. The data as presented are intended for evaluation of trends or to assess interannual variability in concert with other more defensible metrics provided.

USFWS Biotech

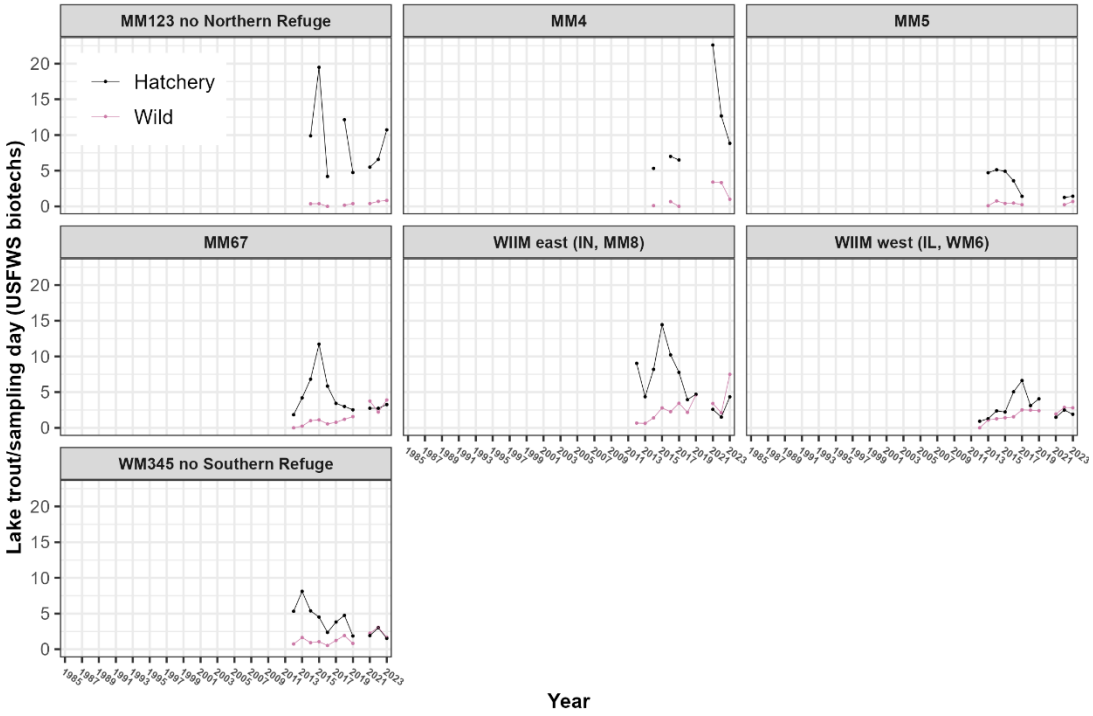

Figure 21. CPUE of hatchery (black) and wild (purple) lake trout based on the Great Lakes Fish Tagging and Recovery Lab survey of the recreational sport fishery, 2014-2023, summarized by data reporting unit.

Note: Sport fishery CPUE is measured in observations per sampling day and includes sampling from tournament and non-tournament events. There was no trend between sport fishery CPUE and angler effort (hours) within a unit; thus, angler hours were not included in sport fishery CPUE. Tournament days counted as 2.6 sampling days because there are, on average, 2.6 times more observations from tournaments than non-tournaments. Recent analysis demonstrated minimal differences among tournament and non-tournament samples when summarizing lake trout length, weight, maturity, sex ratio, proportion wild, proportion with a CWT, or age distributions (USFWS unpublished data presented to LMTC in July 2024). Sport fishery CPUE is thus thought to be a reasonable measure of changes in relative lake trout abundance despite potential bias in fishery-dependent data, a claim supported by similar trends between sport fishery and fishery-independent data sources.

Summary:

Bottom trawl catches of unmarked lake trout are increasing in MM5, and WIIM east. Catches were promisingly increasing in WIIM west but have dropped down to low levels approaching zero in the most recent 4 years. Catches in MM67 have been notably above zero for the last 10 years and are worth paying attention to. The proportion of unmarked fish have been increasing in non-refuge waters of WM345, in WIIM east, WIIM west and in MM67. It is worth noting that reduced stocking rates likely influence these estimates and caution should be used in interpretation. Though the time series is shorter, USFWS biotech encounter rates indicate that, similar to observations in creel surveys, numbers of unmarked lake trout have been increasing in non-refuge waters of WM345, WIIM east, WIIM west and in MM67.

Executive summary: All lake trout stocked into Lake Michigan are fin clipped and coded-wire tagged, with fin clip and tag success rates averaging 99.1% and 96.6% respectively (n = 469 tag lots; Webster et al. 2022). Given the low fin clip error of <1%, the CPUE of unclipped lake trout represents an index of wild lake trout abundance. An increasing trend in proportion of wild fish over time may not only be due to an increase in the abundance of wild fish but may also be due to a decrease in hatchery fish abundance over that period of time.

Upticks in CPUEs of natural lake trout in the LWAP survey are observed in all units except for northern Lake Michigan, including MM5 (eastern north mid-Lake Michigan), and in the southeast (WIIM-east).

In fall spawning surveys, Waukegan and Julian's Reef have shown promising signs with sustained high catch rates of wild fish since 2015. Additionally, in nearshore Wisconsin waters (Clay Banks Reef, Algoma, Sturgeon Bay), catch rates of wild lake trout have been notably increasing since 2019. In the past two years, minor increases in CPUEs of wild lake trout have occurred in Grand Traverse Bay and Milwaukee nearshore. It will be interesting to follow these sites in the future to see if these increases are sustained.

In state creel surveys, the proportion of lake trout without fin clips in biodata collections has been increasing in southern and mid-Lake Michigan (WIIM, WM345, and MM67). U.S. Fish and Wildlife Service biotech surveys are detecting similar patterns in CPUEs of wild fish. In both state creel and biotech surveys in Grand Traverse Bay, there were impressive returns of wild fish in 2021. It will be interesting to see if this trend returns in future years.

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