2022 Lake Michigan Lake Trout Working Group Report [1,2]

This report provides a review on the progression of lake trout (*Salvelinus namaycush*) rehabilitation towards meeting 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). We also include lake trout stocking and mortality data to portray progress towards lake trout rehabilitation.

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 currently under review and will be publicly available in 2023 (https://doi.org/10.5066/P9XVOLR1). 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.

[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).

Methods: We drew from several data sources in preparing this report. Harvest information was supplied by the Lake Michigan extraction database (Redman 2023). Mortality rates were reported based on stock assessment model applications to the non-refuge waters of MM1/2/3 and to MM6/7 (Map 1). Trends in spring catch per unit effort (CPUE) were based on data from the spring (April – June) lakewide assessment plan (LWAP) gillnet survey that employs 2.5 - 6.0" graded nylon multifilament mesh or monofilament mesh, as described by Smith et al. (2022), at nine nearshore and two offshore locations distributed throughout the lake (Schneeberger et al. 1998; Maps 1 and 2). We also included data from spring surveys performed under the Fishery Independent Whitefish Survey (FIWS) protocols for the 1836 Treaty waters that employ 2.0 - 6.0" graded multifilament mesh in locations between Saugatuck and Manistique, Michigan (Smith et al. 2022). Fall adult CPUE was determined using data from 4.5 - 6.0" graded multifilament mesh spawner gillnet surveys completed at selected reefs during October – November. Data sources for wild lake trout recoveries included spring and fall gillnet assessment surveys and FWS Great Lakes Fish Tagging and Recovery Lab sport fishery surveys. In general, these surveys sampled several hundred lake trout annually in most management units, but we only report CPUE and proportions of wild fish from management units with sample sizes ≥ 30 lake trout recoveries in gillnet assessments or > 20 lake trout recoveries from the sport fishery survey. Prior to 2011, roughly 3% of stocked lake trout were released without a fin clip (Hanson et al. 2013) but since 2011 hatchery lake trout have been clipped and tagged in automated trailers and fewer than 1% of lake trout are stocked without a fin clip (Webster et al. 2020). We conservatively infer that natural recruitment is detectable when the percentage of unclipped fish exceeds 3% of all lake trout recoveries.

EVALUATION OF ATTAINMENT OF 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.*
>
> *Establish a self-sustaining lake trout population.*

Harvest: In 2022, total salmon and trout harvest was 2.76 million kg, thereby meeting the fish-community objective (FCO) harvest objective for the first time since 2014 (Figure 1). Lake trout harvest in 2022 was 0.57 million kg. Lake trout comprised 20.8% of the total salmonid harvest in 2022 (Figure 2). Thus, the FCO harvest objective of lake trout harvest representing 20-25% of the total salmonine harvest was met in 2022 (Figure 2). Lake trout harvest decreased between 2021 and 2022, whereas salmon harvest increased during this time period.

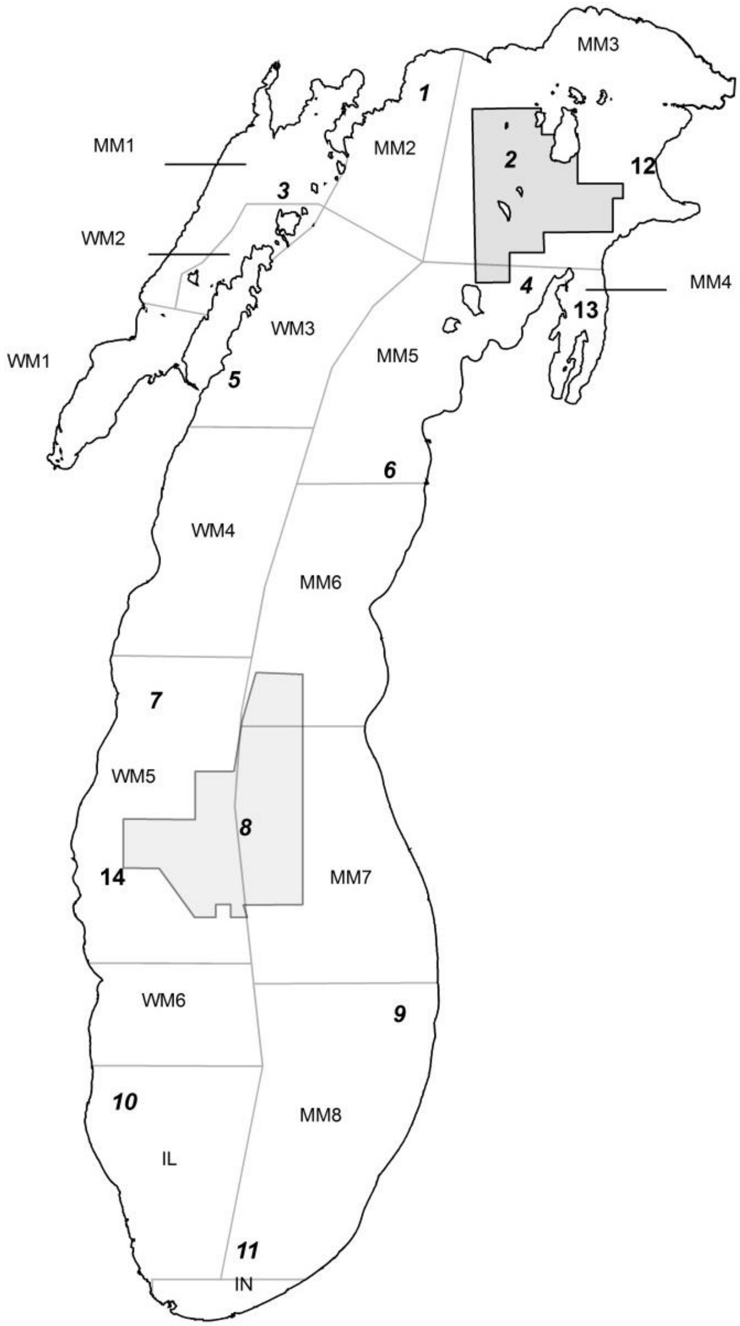
Data Reporting Stations for Spring and Fall Graded Mesh Gillnet Surveys

LWAP sites:

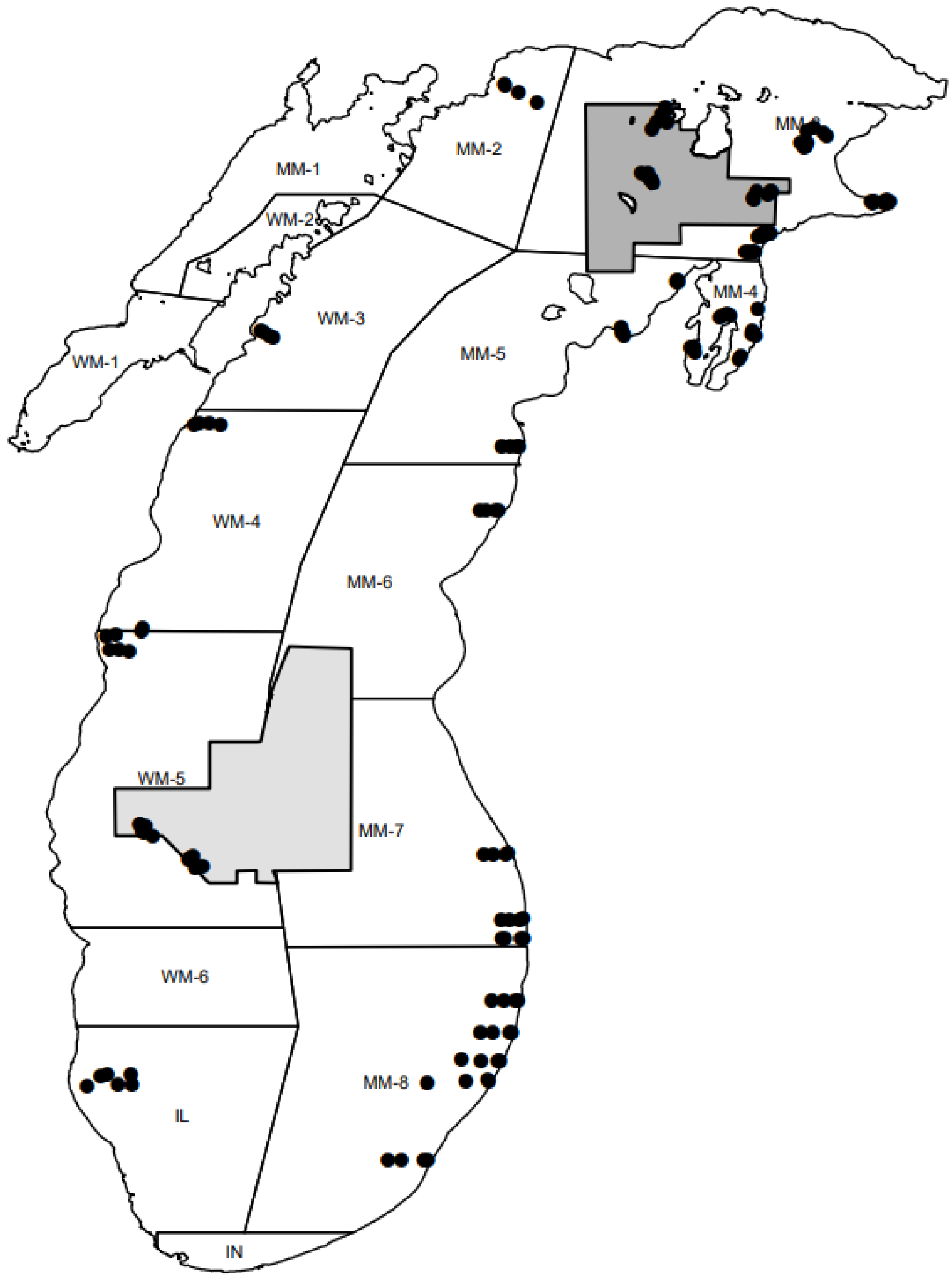
1. Manistique
2. Northern Refuge
3. Washington Island
4. Leland
5. Sturgeon Bay
6. Arcadia
7. Sheboygan
8. Southern Refuge
9. Saugatuck
10. Julian's Reef \ Waukegan
11. Michigan City

Supplemental sites:

12. Non-refuge Nearshore MM-3
13. Grand Traverse Bay
14. Milwaukee



Map 1. Reporting of spring and fall graded mesh gillnet data has been aggregated into the 11 LWAP sites and 3 supplemental sites. Generally, each reported lift is within 18 km of the site numerical label. Statistical district boundaries are outlined, and shading is used to outline the Northern and Southern refuges.



Map 2. Locations of assessment gillnet lifts during spring 2022. Statistical district boundaries are outlined with solid black lines, and shading is used to demarcate the Northern and Southern refuges.

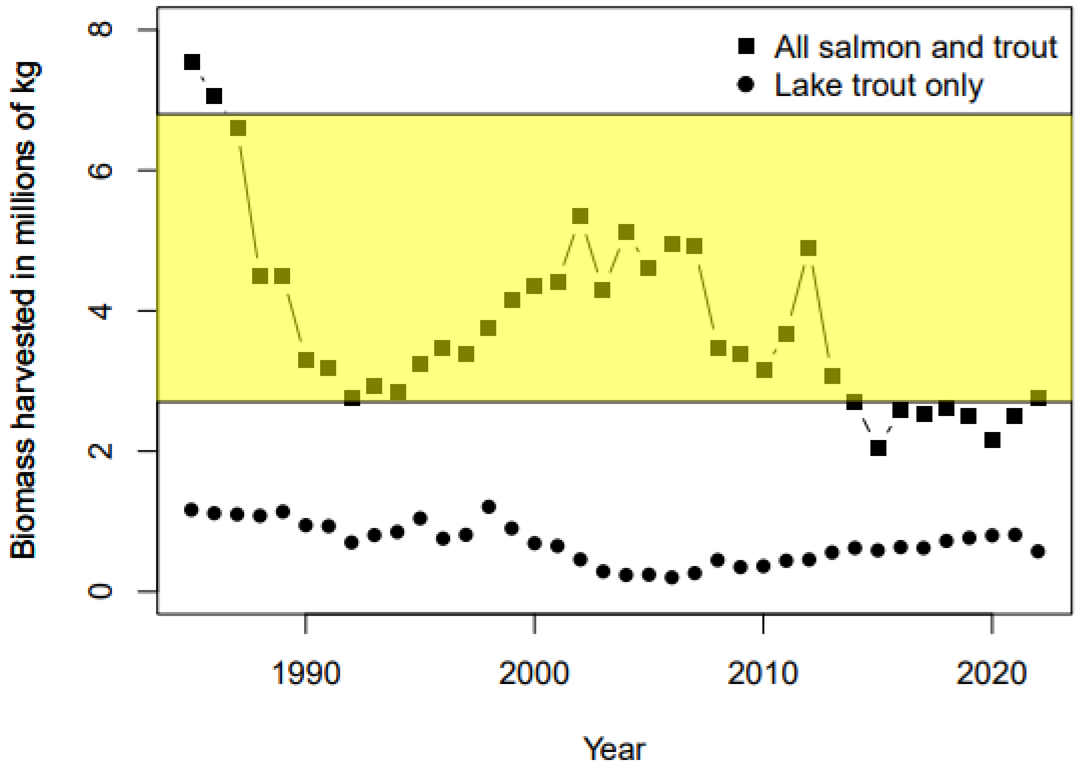


Figure 1: Lake Michigan total harvest (1985-2022) for lake trout (circles) and for all species of salmon and trout combined (squares). Yellow shading depicts the targeted range of salmon and trout harvest that meets the fish-community objective (FCO).

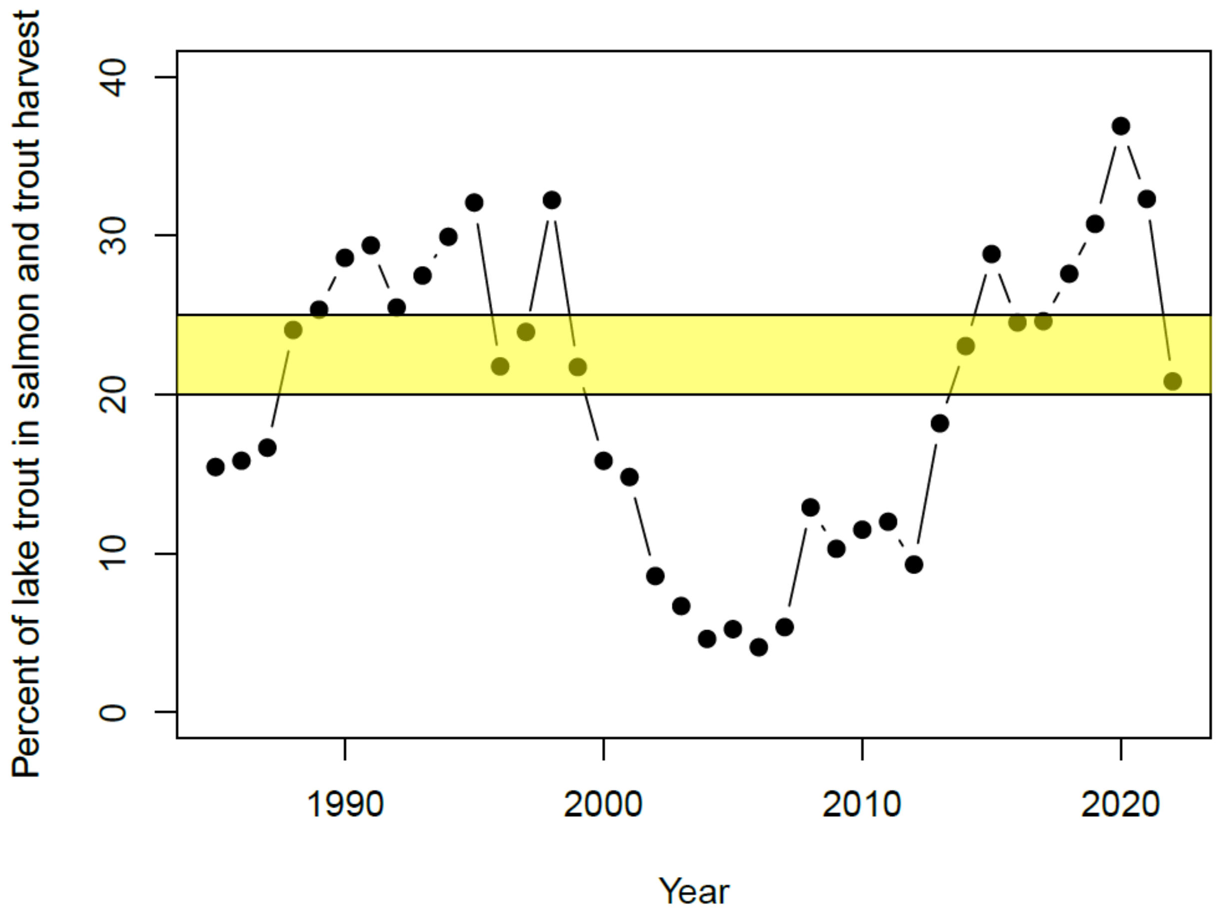


Figure 2: The percentage of salmon and trout harvest comprised of lake trout; yellow shading represents the 20 to 25% specified in the fish-community objectives (FCOs).

Establish a Self-sustaining Population (Natural Reproduction):

Catch Rates- Results from both the spring LWAP survey and the fall spawner survey indicated that lake trout natural recruitment in Lake Michigan increased between 2005 and 2022 after decades of near-zero recruitment. Because all lake trout stocked into Lake Michigan are presumed to be fin clipped (Webster et al. 2020), CPUE of unclipped lake trout represents an index of wild lake trout abundance. Averaging across the entire lake, wild fish CPUE based on the spring gillnet survey increased from 0.12 fish per 1000 feet of net in 2005 to 1.5 fish per 1000 feet of net in 2022. The increase was more pronounced in many of the fall gillnet surveys on spawning reefs, with average wild fish CPUE increasing from 0.83 fish per 1000 feet of net in 2005 to 18.0 fish per 1000 feet of net in 2022. The increase in natural recruitment coincided with reduced alewife (*Alosa pseudoharengus*) abundance in Lake Michigan that has remained low since 2004 (Tingley et al. 2023). Alewives can interfere with natural reproduction by lake trout in two ways: (1) alewives have been shown to feed on lake trout fry (Krueger et al. 1995), and (2) alewives can serve as a vector for thiamine deficiency complex (TDC) that may result in poor swim-up survival of lake trout fry (Honeyfield et al. 2005).

The magnitude of the increase in wild fish CPUE from 2005-2022 varied by region. For the spring gillnet survey, the greatest increase in wild fish CPUE occurred at Arcadia, where wild fish CPUE increased from 0.07 fish per 1000 feet of net in 2005 to 4.6 fish per 1000 feet of net in 2022 (Figure 3). To a lesser extent, increases in wild fish CPUE were also observed at Waukegan, Grand Traverse Bay, Michigan City, and Saugatuck (Figure 3). The increase in fall gillnet survey CPUE of wild fish was greatest in Illinois waters where 1.5 fish per 1000 feet of net was observed in 2005 rising to 75.6 fish per 1000 feet of net in 2019, remaining above 35 fish per 1000 feet of net thereafter (Figure 4). In fall gill net surveys, catch rates of hatchery and wild fish combined have been consistently above the 50 fish per 1000 feet threshold at most western and southern locations in Lake Michigan. During the recent 5 years (2018-2022), CPUEs were above 50 fish per 1000 feet of net at most spawning locations surveyed. CPUEs of wild fish (not including stocked fish) rapidly increased in the fall of 2022 in Grand Traverse Bay and in the Milwaukee/Sheboygan region, where CPUEs exceeded 20 fish per 1000 feet of net (Figure 4). More recently, wild fish CPUEs have approached the threshold of 50 fish per 1000 feet at spawning survey locations in the Southern Refuge, Illinois and in Sturgeon Bay (Figure 4).

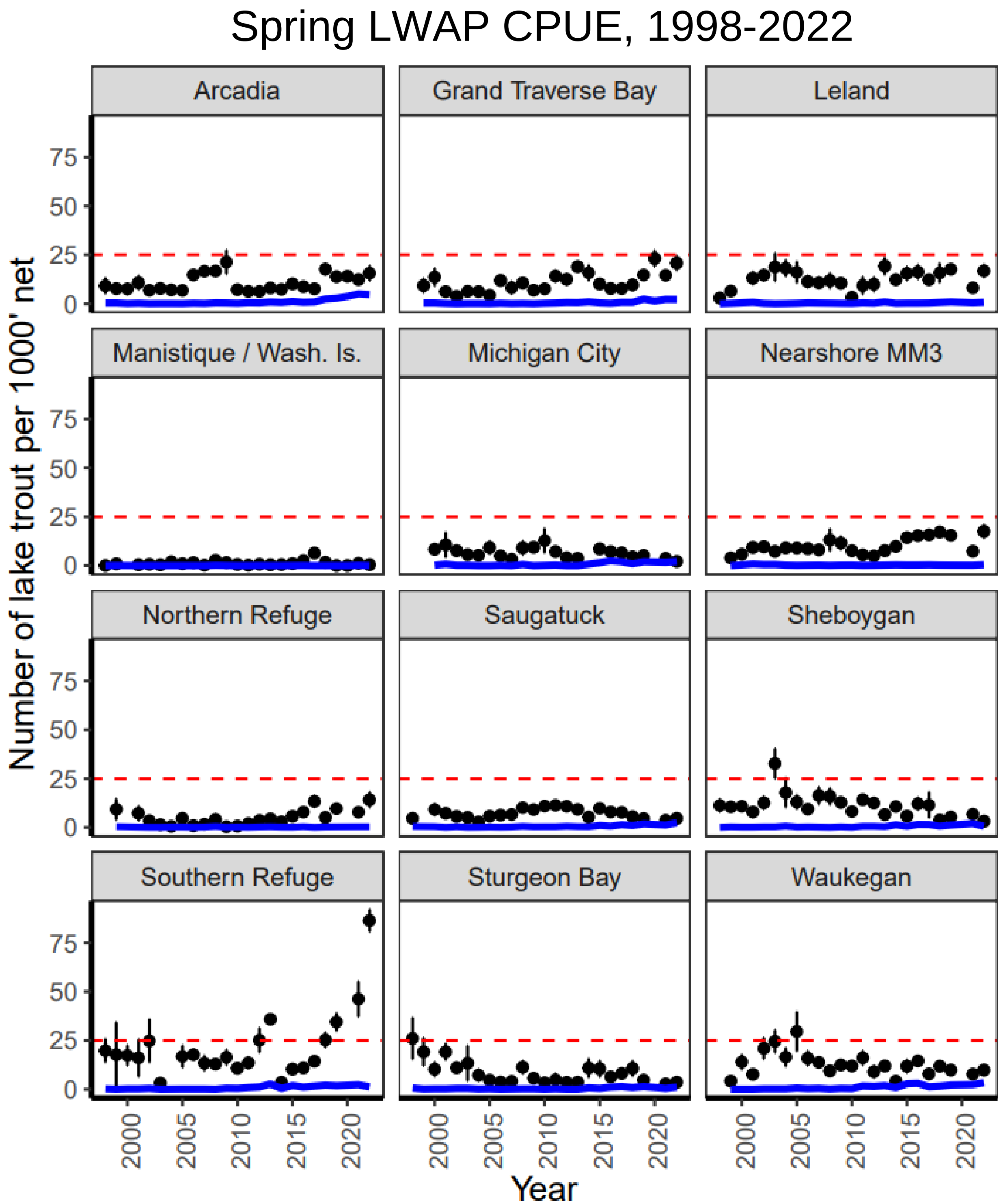


Figure 3: Time series of spring survey lake trout catch per effort (mean number of fish/1000 ft of graded mesh gill net) for the 11 LWAP sites plus 2 supplemental sites with comparable data (Grand Traverse Bay and non-Refuge nearshore MM3 waters). The black circles portray catch per unit effort (CPUE) of all lake trout (hatchery and wild fish pooled) whereas blue lines show the CPUE of wild lake trout. Vertical bars represent ± 1 SE and the horizontal red line shows the spring CPUE (hatchery and wild combined) benchmark of 25 fish per 1000'.

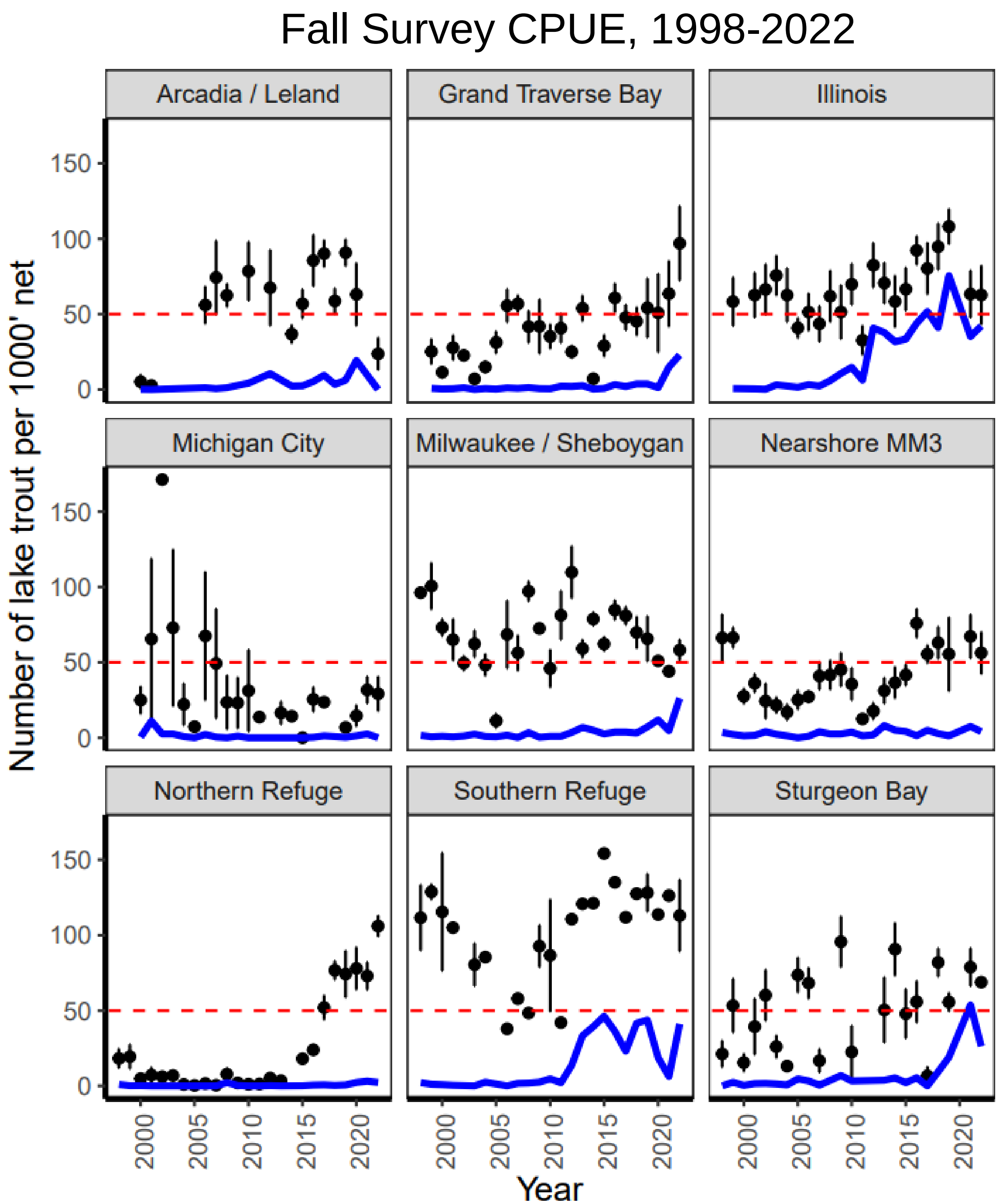


Figure 4: Time series of fall lake trout spawner survey catch per effort (mean number of fish/1000 ft of graded mesh gill net) for reefs within or near the LWAP stations. The black circles portray catch per unit effort (CPUE) of all lake trout (hatchery and wild fish pooled) whereas blue lines show the CPUE of wild lake trout. Vertical bars represent ± 1 SE and the horizontal red line shows the fall CPUE (hatchery and wild combined) benchmark of 50 fish per 1000'.

Proportions: The percentage of wild fish statistic is useful in gauging broad-scale patterns of emerging natural recruitment. However, wild fish CPUE is the more appropriate metric for tracking trends in wild fish 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. A decrease in hatchery fish abundance could be attributable to a reduction in stocking rate over time, declining survival of hatchery fish or both. In some sections of Lake Michigan, stocking rate reductions occurred during 2005-2009 and 2015-2022. Lakewide, 20.2% of the lake trout (N=7,814) collected in all surveys (sport-fishery (N=1,343), fall spawn (N=1,999), and spring gillnet (N=4,472)) were unclipped and presumed to be of wild origin in 2022. Selectivity differences would be expected among the three survey types. The sport fishery is dependent on angled fish that are harvested and not released, is focused in areas with high angler effort, and does not represent offshore refuge populations where angling is prohibited. Gillnet assessments require fish to swim into and become entangled in nets and mesh size can influence the size of fish captured. Spring and fall gillnet surveys target different segments of the lake trout population, utilize different mesh size configurations, and employ different criteria for selecting sampling locations. Lake trout populations are assumed to be more mixed in the spring than in fall when surveys target aggregations of mature spawners. Many additional factors, including the location, number, and strains of lake trout stocked, as well as characteristics of harvest strategies and of other mortality sources have the potential to influence the proportion of wild fish estimated in each survey.

Below we summarize the percentages of wild fish reported in 2022 by statistical district(s) and compare three survey types, each of which has distinct attributes (timing, spatial coverage, proximity to stocking locations, gear characteristics, etc.) that could influence the patterns observed. In northern Lake Michigan (MM3), the proportion of wild fish in 2022 was similar for the three survey types and remained low at <3% in the spring survey, 3% in the fall gillnet survey, and was 7% in the sport fishery (Figure 5). In Grand Traverse Bay (MM4), the percentage of wild fish increased in all surveys during the past 5 years, estimates ranged from 8 to 24% in 2022. Proportions of wild fish in the mid-latitude districts of MM5/6 and WM3/4 have generally increased since 2010 and 2015, respectively (Figure 5). In 2022, estimates of percent wild fish in MM5/6 were 37%, 0% and 36% in the spring LWAP, fall spawner, and sport fishery surveys, respectively, while percent wild estimates in WM3/4 were 29%, 38%, and 48% in the spring LWAP, fall spawner, and sport fishery surveys, respectively. In southern Lake Michigan (ILL, IND, MM7/8, and WM5/6) during 2022, wild lake trout comprised more than half (55 to 64%) of the sport fishery catch, highest proportions from fall surveys (67%) were observed in Illinois waters, and highest proportions from spring surveys (54%) were observed in MM7/8. Estimates of percent wild were more variable in southern regions particularly in the fall survey.

It is important to note that the higher percent wild values in southern Lake Michigan districts are driven at least in part by stocking reductions from 2005 – 2009 and again from 2015 – 2022. In addition, increased stocking of Klondike (humper) lake trout in place of a portion of lean lake trout on the Southern Refuge from 2012 – 2019 also contributed to a reduction in the catch of hatchery lake trout in some districts because the Klondike strain was far less likely to migrate from the refuge into adjacent nearshore units.

Overall, the proportion of wild fish in most districts of Lake Michigan increased during 2005-2022, as evidenced by results from all three survey types (Figure 5). Percent wild fish tended to be higher in southern and southwestern districts, although relatively high proportions of wild fish have recently been observed in MM5/6 and WM3/4 as well. In some sections of Lake Michigan, the increase in proportion of wild fish over time was not only attributable to increased natural recruitment but also to a marked decrease in hatchery fish abundance (Figure 6). Specifically, hatchery lake trout CPUE in the sport fishery survey decreased at the locations of WM5/6, MM5/6, MM7/8, and Indiana during 2014-2022 (Figure 6). Similarly, hatchery lake trout CPUE in the spring gillnet survey declined during 2014-2022 at the locations of

Saugatuck, Sheboygan, Sturgeon Bay, and Leland (Figure 3). Lake trout stocking rate decreased in some southern and western areas of Lake Michigan during 2005-2019 (Figure 7).

In some areas of Lake Michigan and for some survey types, increases in the proportion of wild fish over time were largely driven by increases in wild CPUE. In Illinois waters, the estimate of percent wild fish in the fall gillnet survey increased to a value greater than 50% in 2012 (Figures 4 and 5). Hatchery fish CPUE trended neither significantly upward nor significantly downward in the fall spawner survey in Illinois waters during 2005-2022, whereas the CPUE of wild fish showed a marked increase during that time. Similarly in the Southern Refuge and Sturgeon Bay, catch rates in fall surveys were variable and estimates of proportions of wild fish increased as did CPUEs of wild fish (Figures 4 and 5 (WM5/6 panel)). In Grand Traverse Bay, where stocking practices have remained relatively consistent, increases in wild fish CPUEs were accompanied by increases in total CPUE, and an increase in proportion wild in recent years.

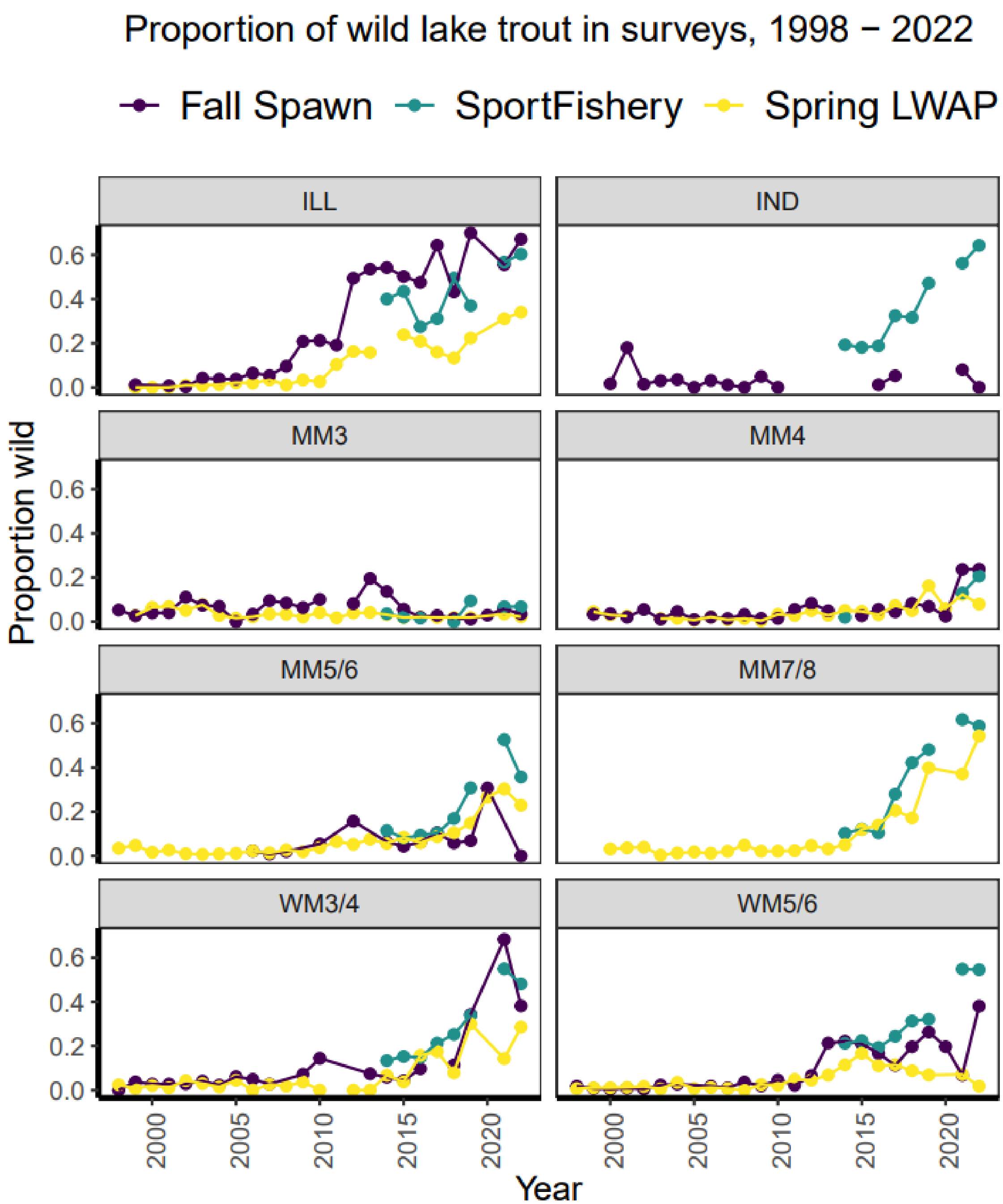


Figure 5: Proportion of wild (unclipped) lake trout captured in the sport fishery (teal), fall spawner gillnet (purple), and spring gillnet (yellow) surveys within each statistical district(s). Sport fishery data were provided by the Great Lakes Fish Tagging and Recovery Lab and gillnet data originated from multi-agency surveys described in the LWAP (Schneeberger et al. 1998). Data points are only included when at least 30 lake trout per year were examined for gillnet surveys and at least 20 fish for the sport fishery survey.

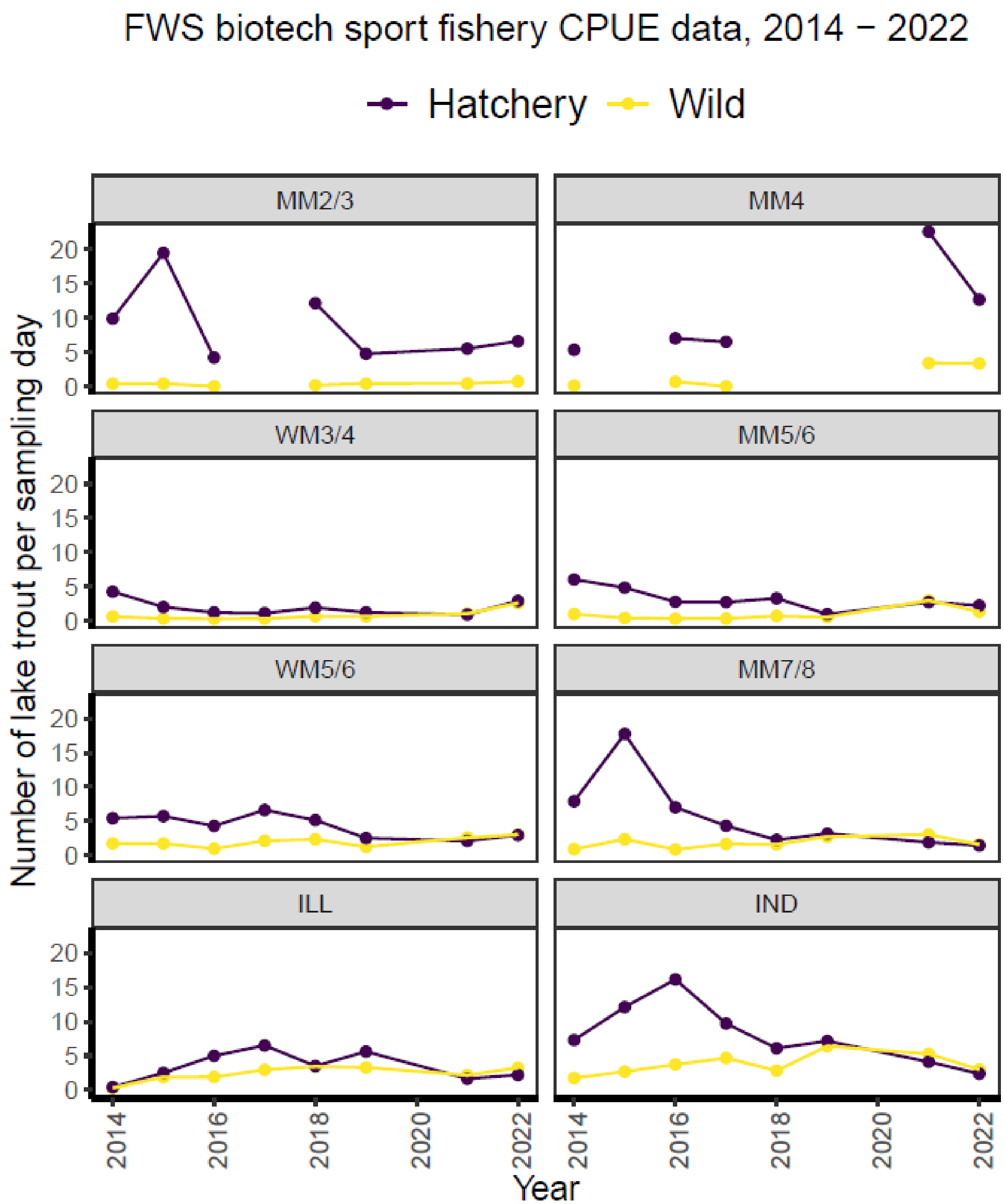


Figure 6: CPUE of hatchery (purple) and wild (yellow) lake trout based on the Great Lakes Fish Tagging and Recovery Lab survey of the recreational sport fishery, 2014-2022.

EVALUATION OF ATTAINMENT OF INTERIM STOCKING AND MORTALITY TARGETS, AND IMPLEMENTATION STRATEGY EVALUATION OBJECTIVES

<u>Fish Stocking:</u> Stocking hatchery-reared fish to achieve rehabilitation is the primary tool of the *Strategy*. Initially, the maximum stocking target was 3.31 million yearlings and 550,000 fall fingerlings, or 3.53 million yearling equivalents where one fall fingerling = 0.4 yearling equivalents (Elrod et al. 1988). However, based on feedback from angling groups, the Lake Michigan Committee adopted an interim stocking target not to exceed 2.74 million yearling equivalents when the strategy was approved (2011). Beginning in 2009, at least 2/3 of all lake trout were stocked in the Northern and Southern refuges with the remaining fish stocked at nearshore areas to support local fishing opportunities in addition to rehabilitation. The *Strategy* also called for an annual stocking of 200,000 individuals of the Klondike (humper) strain, an offshore reef spawning morphotype from Lake Superior. Klondike (humper) stocking was initiated at the Northeast Reef on the Southern Refuge in 2012 and continued through 2016, and the Sheboygan Reef was stocked from 2017-2019. The last year in which Klondike (humper) lake trout were stocked was 2020, due to the Covid-19 pandemic, these fish were stocked nearshore. In 2019, a bacterial infection (*Vagococcus salmoninarun*) resulted in the destruction of the Klondike (humper) strain broodstock at Iron River National Fish Hatchery. In 2017, the Lake Committee reduced the interim stocking target to 2.54 million fish and achieved this through the elimination of stocking at nearshore non-priority areas in southern Lake Michigan. Subsequently, the Lake Committee cancelled future requests for this strain, and annual stocking requests for other strains in the Southern Refuge were also decreased by 255,000 yearlings. Therefore, considerable changes to regional stocking patterns have occurred over the last decade. Annual stocking is now ~1.6 million lean lake trout in MM3 and the Northern Refuge and ~0.15 million in WM345 and the Southern Refuge. Stocking numbers have declined at sites in southern and central Lake Michigan (Figure 7). Due to personnel safety protocols enacted during Covid-19, there was an exception to this pattern whereby offshore stocking was cancelled at both refuge complexes in 2020 and only a portion of offshore stocking was achieved in 2021; fish intended for refuge complexes were instead shore-stocked in the nearby management units of MM2/3 and WM4 due to travel limitations. On a lakewide basis, the maximum stocking target of 3.53 million yearling equivalents was never exceeded during 1996-2022. Although the interim stocking target was exceeded during 2005-2017, the rate of stocking lake trout into Lake Michigan dropped below the interim stocking target in 2018 and has remained slightly below that level through 2022 (Figure 7).

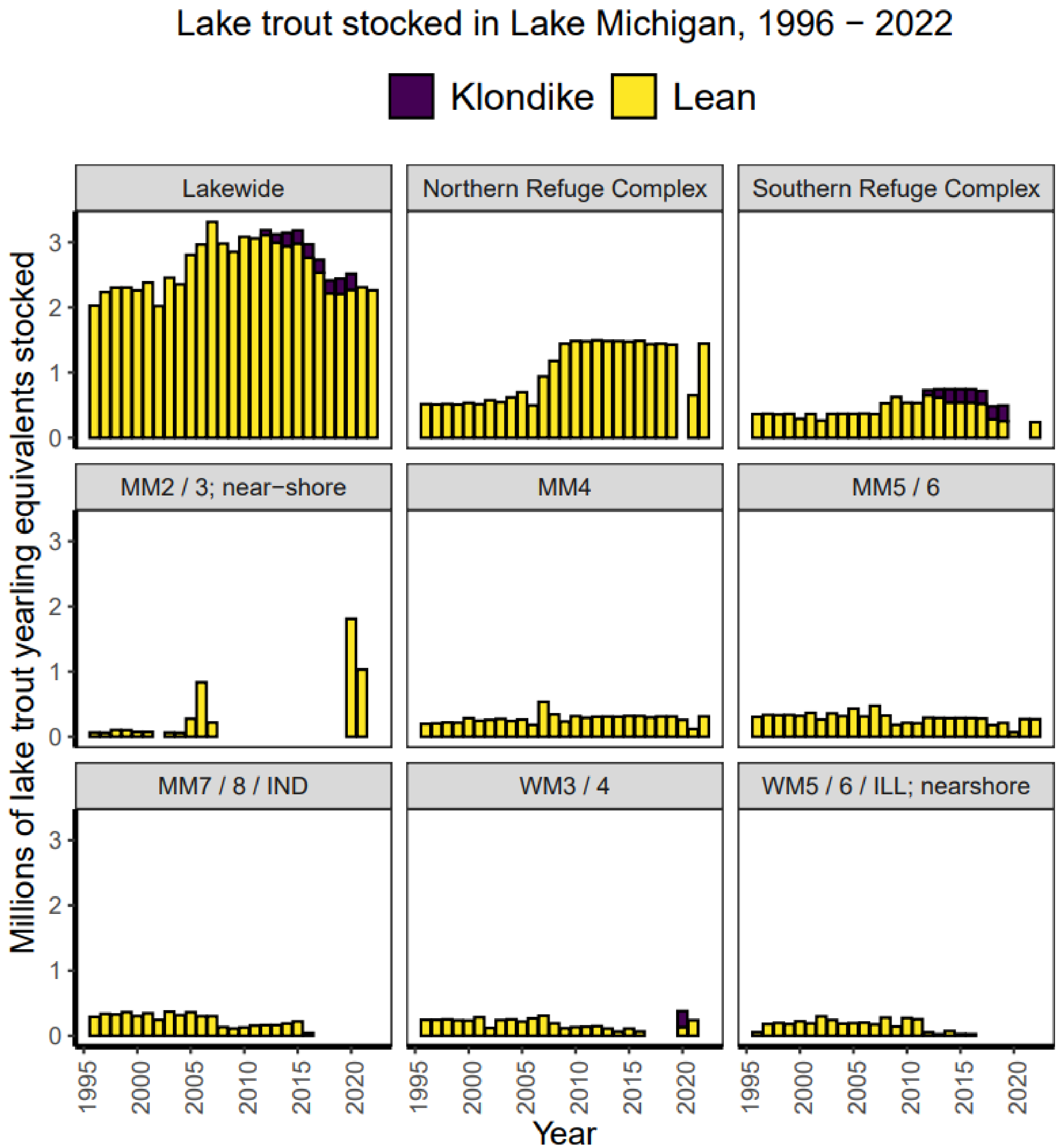
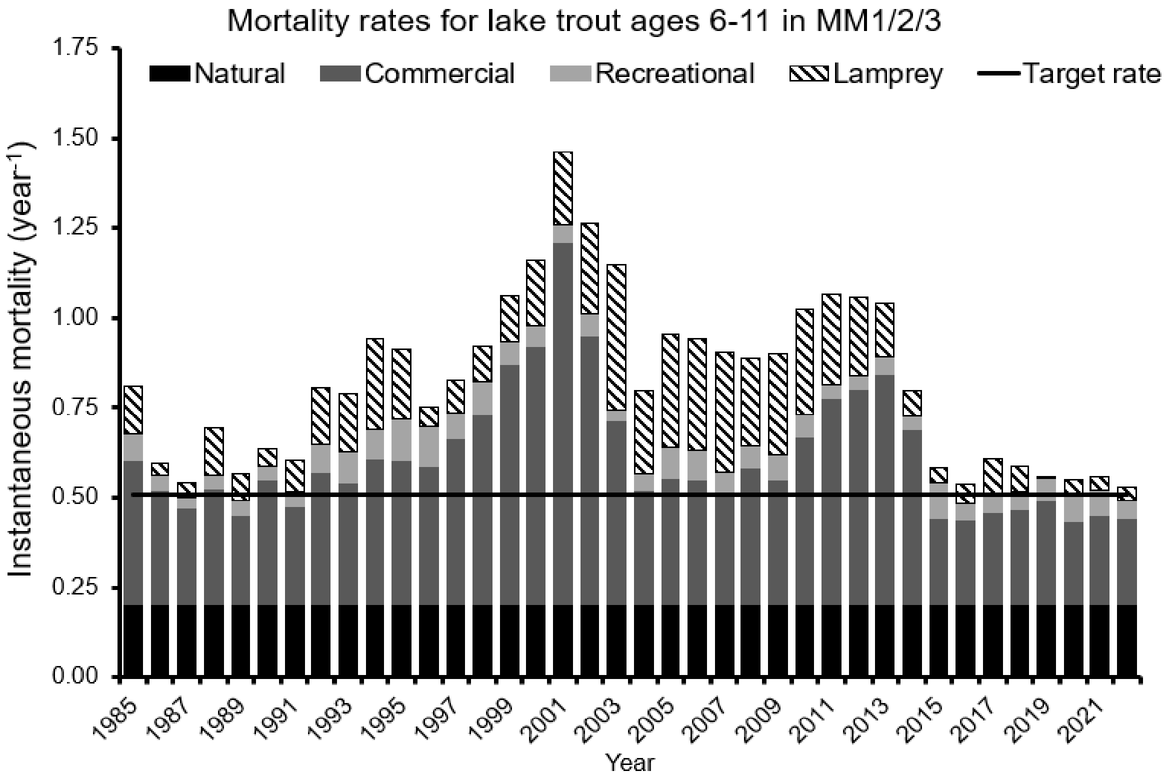


Figure 7: Number of lake trout (yearling equivalents) stocked in Lake Michigan by region, 1996-2022. Several lean strains of lake trout (yellow) have been stocked in Lake Michigan since 1996; the Klondike strain, a humper morphotype selected for deep-water reefs, is shown separately (purple), and was first stocked in 2012. The "Northern Refuge Complex" includes stocking sites that are both within the Northern Refuge boundary (i.e., Trout Island, High Island, Boulder Reef, Gull Island Shoal, Middle Ground, and Big Reef) and at nearshore sites outside of the refuge boundary that are still considered a part of the complex (i.e., Hog Island Reef, Ile Aux Galets, Dahila Shoal, and Irishmen's Ground). The "Southern Refuge Complex" includes East Reef, Northeast Reef, Milwaukee Reef, and Sheboygan Reef, all of which are within the Southern Refuge boundary.

Lake Trout Mortality: Mortality rate experienced by lake trout stocks is best estimated by stock assessments conducted using survey, sport, and commercial fishery data. These stock assessments involve application of statistical catch at age (SCA) population models. Total mortality is partitioned into natural mortality, sea lamprey induced mortality, and fishing (both recreational and commercial) mortality. The *Strategy* requires management agencies to "adjust local harvest regulations if appropriate when mortality rates exceed target levels", and the target annual mortality rate has been set to 40-45% (Bronte et al. 2008; Dexter et. al. 2011).

In the non-refuge waters of MM1/2/3 (Map 1), the total annual mortality rate estimate for lake trout ages 6-11 in 2022 was 41%, which was slightly lower than the 2021 estimate of 43% (Figure 8, upper panel; Technical Fisheries Committee: 2000 Consent Decree). In this northeastern section of the lake, commercial fishing is the primary source of mortality (Figure 8, upper panel). In the 2000s, there was an extended period of elevated sea lamprey induced mortality thought to be caused by additional recruitment of parasitic juveniles produced after sea lamprey spawners breached the dam on Manistique River and reached areas of the river not treated with lampricide. In recent years, lake trout mortality due to attacks by sea lamprey has dropped precipitously after several years of intensive lampricide treatments on the Manistique River and other Lake Michigan tributaries (Figure 9; Technical Fisheries Committee: 2000 Consent Decree). Even though the increased sea lamprey control was a contributing factor, the sharp decline in sea lamprey induced mortality in MM1/2/3 during 2012-2015 was also attributable to the stocking rate increase in the Northern Refuge complex during 2006-2010 (Figure 7; Madenjian et al. 2023). Increased stocking rate apparently led to a disproportionately greater increase in lake trout post-stocking recruitment. As these large year-classes recruited to the population of lake trout vulnerable to sea lamprey attacks during 2013-2015, the number of targets available to parasitic sea lamprey rapidly increased, and wounding rate correspondingly underwent a rapid decrease (Figures 8 and 9). This sharp decline in wounding rate during 2012-2015 did not coincide with the 72% decrease in the estimated lakewide abundance of sea lamprey in Lake Michigan that occurred during 2006-2012, but this sharp decline did coincide with the recruitment of the increased stocking rate year-classes (2006 and older) to the population of lake trout vulnerable to sea lamprey attacks during 2013-2015 (Madenjian et al. 2023).

In MM6/7, estimated total annual mortality rate has been below the target mortality rate of 40% since 2005 (Figure 8, bottom panel). Estimated total annual mortality rate averaged 32% during 2008-2022, and the 2022 estimate was 30%. Prior to 2005, recreational fishing was the main source of lake trout mortality in MM6/7. Natural mortality has been the single largest component of total mortality since 2005. As in northern Lake Michigan, sea lamprey induced mortality rate in MM6/7 was considerably lower during 2015-2022 than during the 2000s (Figure 9).



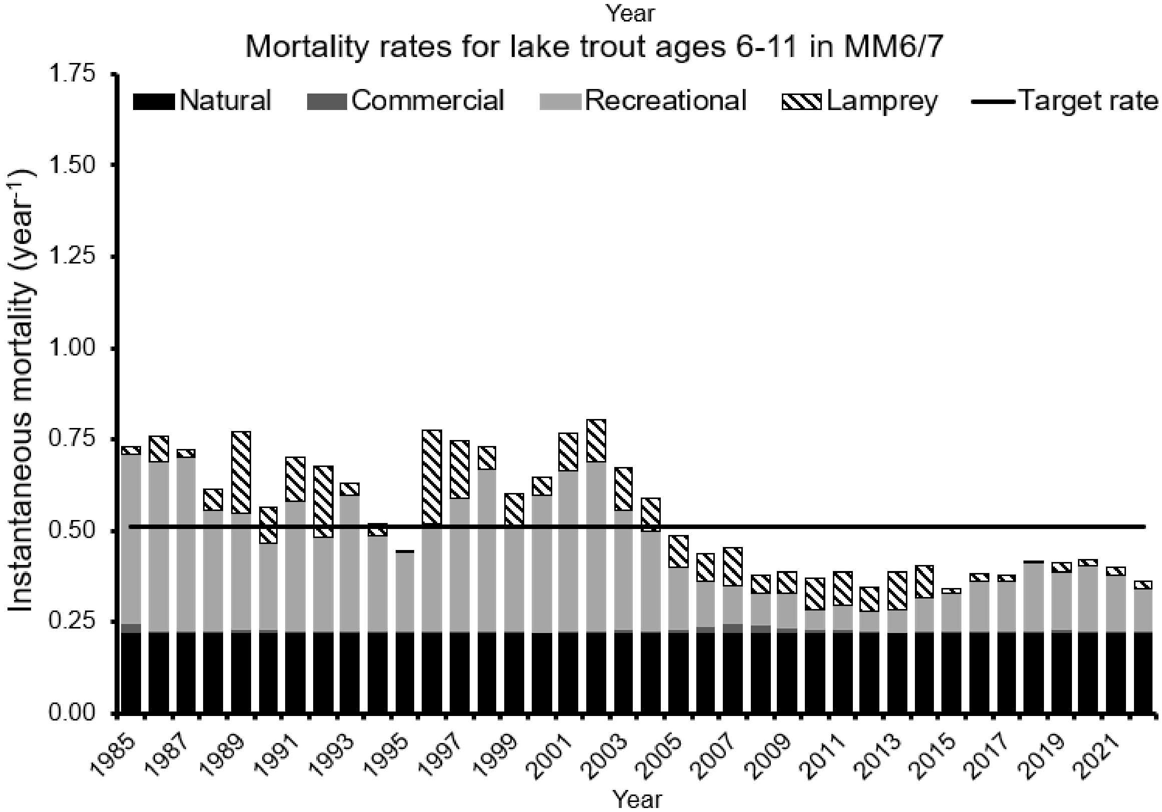


Figure 8: Model estimates of instantaneous mortality rates for lake trout ages 6-11 in non-refuge waters of northern Lake Michigan (MM1/2/3; top plot) and in MM6/7 (bottom plot). Horizontal black line represents an instantaneous mortality rate of 0.51 that is equivalent to a 40% annual mortality rate.

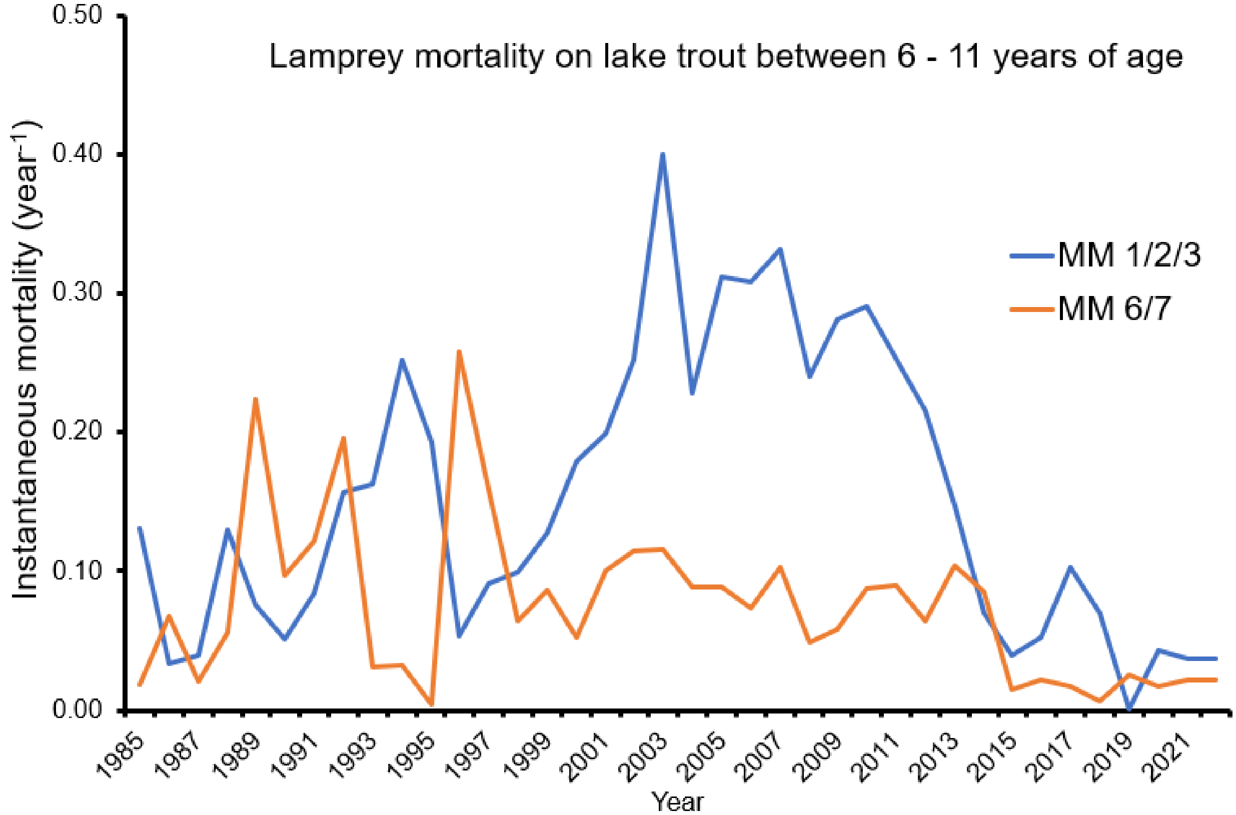


Figure 9: Estimated sea lamprey induced instantaneous mortality rates for lake trout ages 6-11 in non-refuge waters of MM1/2/3 and in MM6/7. Estimates were based on observed marking rates.

<u>Evaluation Objective 1:</u> **Increase the average catch-per-unit-effort (CPUE) to ≥25 lake trout per 1000 feet of graded mesh gill net (2.5-6.0 inch) in over-night sets lifted during spring assessments pursuant to the lakewide assessment in MM3, WM5, and at Julian's Reef by 2019.**

In 2022, 149 gillnet lifts were completed lakewide to assess spring lake trout abundance (Map 2). This included at least six lifts at each nearshore LWAP site, 11 lifts on the Southern Refuge, and 18 lifts on the Northern Refuge. We also report data from FIWS survey lifts and supplemental sites along the eastern shore (MM3 – MM8) (Maps 1 and 2); these data are aggregated with the nearest non-refuge LWAP site except for those lifts in MM3 that are reported under a new 'Nearshore MM3' site name (Figure 3).

On a lakewide basis, this evaluation objective has not been attained, as the Southern Refuge was the only site with a CPUE exceeding 25 fish per 1000 feet of net since 2020 (Figure 3). In general, trends in total (hatchery and wild combined) spring lake trout CPUE have been declining at many LWAP sites due to the elimination or reduction of stocking at most nearshore locations in central and southern Lake Michigan since 2017 (Figure 7). Along the eastern shore, the declining trend was particularly evident at Michigan City and Saugatuck, where the 2022 CPUEs ranged from 2.2 to 4.6 lake trout per 1000 feet of net, compared to CPUEs that averaged 6.7 to 7.2 lake trout per 1000 feet of net from 2014 – 2018. In northern Lake Michigan, sustained stocking levels have resulted in elevating densities at Northern Refuge and nearshore MM3 such that CPUEs reached 13.4 and 15.6 fish per 1000 feet of net, respectively, in 2017. However, CPUEs appeared to have leveled off since 2017 (Figure 3). Over years 2005-2022, CPUE showed an upward trend both in the Northern Refuge and nearshore MM3, and the increase in the Northern Refuge was more pronounced. Similarly, CPUE in Grand Traverse Bay clearly increased during 2005-2022. CPUE in the Southern Refuge showed an increasing trend during 2005-2022, with an especially steep increase that began in 2015 and reached its high point at 86.4 fish per 1000 feet of net in 2022 (Figure 3). This steep increase stemmed from the Klondike strain stockings that began in 2012. In 2022, 95% of the 950 coded wire tagged (CWT) lake trout processed in the Southern Refuge LWAP survey were Klondike strain. Klondike fish show a tendency to remain in the refuge compared with lean morphs, such as the Seneca Lake strain, which more frequently stray from the refuge. The Southern Refuge has met the evaluation objective of attaining a total lake trout CPUE ≥ 25 since 2018. In sum, spring lake trout CPUE has increased in both refuges, Grand Traverse Bay, and nearshore MM3 during 2005-2022, but CPUE decreased or was trendless during this period at all other spring LWAP locations. Since 2018, this evaluation objective has only been met in the Southern Refuge, but the evaluation objective has not been met on a lakewide basis at any time.

<u>Evaluation Objective 2:</u> **Increase the abundance of adults to a minimum catch-per-unit-effort of 50 fish per 1000 feet of graded mesh gill net (4.5-6.0 inch) fished on spawning reefs in MM3, WM5, and at Julian's Reef by 2019.**

On a lakewide basis, this evaluation objective has largely been attained (Figure 4). The only two sites in 2022 at which CPUE was below the benchmark level of 50 fish per 1000 feet of net were Arcadia/Leland and Michigan City. In 2022, we determined total spawner (wild and hatchery fish combined) CPUE based on 31 fall spawner survey lifts from nine locations. Each of these nine locations coincided with, or was in the vicinity of, an LWAP site or one of the supplemental sites. CPUEs at priority reefs in the Northern Refuge, nearshore MM3, Julian's Reef, and the Southern Refuge met the evaluation objective of ≥ 50 fish per 1000 feet of net. In fact, CPUEs greater than 100 fish per 1000 feet of net were observed in both refuges in 2022, an indication of abundant and building spawning stocks on stocked reefs. High fall spawner survey CPUEs of total lake trout spawner abundance have been accompanied by steep increases in wild fish CPUEs at some regions in fall (Figure 4). Wild fish densities in the 2022 spawner surveys were highest in Illinois waters (CPUE = 42.1 fish per 1000 feet of net), the Southern Refuge (CPUE = 41.1), at Sturgeon Bay (CPUE = 26.3), at Milwaukee/Sheboygan (CPUE = 26.3), and in Grand Traverse Bay (CPUE = 23.0).

<u>Evaluation Objective 3:</u> 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.

On a lakewide basis and averaging across all years, more than 25% of the lake trout caught in the fall gillnet surveys have been females (Figure 10). Since 1998, the percentage of females captured during the fall spawner survey has exceeded the 25% benchmark at most sites during most years. In 2022, the proportions of females caught in the Northern Refuge (18.3%), at Sturgeon Bay (5.5%), and in Grand Traverse Bay (13.4%) were below the 25% benchmark (Figure 10).

At this time, lake trout ages from fall spawner surveys are not reported for all hatchery and wild fish within first priority areas (refuge complexes) or nearshore management districts and we are unable to rigorously address the evaluation objective pertaining to "10 or more age groups older than age-7 in first priority areas stocked prior to 2007". The underlying crux of this objective roughly translates to older fish are larger and have greater fecundity, thereby enabling adequate egg deposition to support wild production. To this end, we used fish length from spawner surveys to infer lake trout age structure at a regional level (Figure 11). In 2022, mean total length of lake trout caught in the fall spawner surveys was greatest at Sturgeon Bay, where the modal length bin occurred at the 800-900 mm length interval. Correspondingly, age estimates of several of these lake trout spawners at Sturgeon Bay were 20 years or greater. For Arcadia/Leland, Illinois, Michigan City, the Northern Refuge, and nearshore waters of MM3, the modal length bin fell at the 700-800 length interval in 2022 (Figure 11). Figure 12 illustrates how this inferred age structure has changed at the Northern Refuge and the Southern Refuge over the last decade. In 2012, most fish caught in the Northern Refuge spawner surveys were small (500-600 mm total length), but the distribution has shifted to larger and presumably older adults over time. For the Southern Refuge, the modal length bin occurred at the 700-800 mm length interval during 2012 and 2017, but the modal length bin decreased to the 600-700 mm length interval in 2022. This decrease may have been due to an increase in the proportion of Klondike strain fish in the catch, as the Klondike strain lake trout have generally tended to be younger than lean lake trout caught in the gill nets set in the Southern Refuge and are known to reach maturity at smaller body sizes than lean strains in other lakes (Hansen et al. 2016; Rogers et al. 2019).

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In cases where age composition of the fall spawner survey catch (including both hatchery and wild fish) was fully determined, results indicated more than 10 age groups older than age-7 at Sturgeon Bay, but less than 10 age groups older than age-7 in the Northern Refuge, nearshore waters of MM3, and Grand Traverse Bay (LMLTWG 2016). In other cases where age composition of the fall spawner survey catch was determined based solely on CWT fish, results showed more than 10 age groups older than age-7 in the Southern Refuge and Illinois waters.

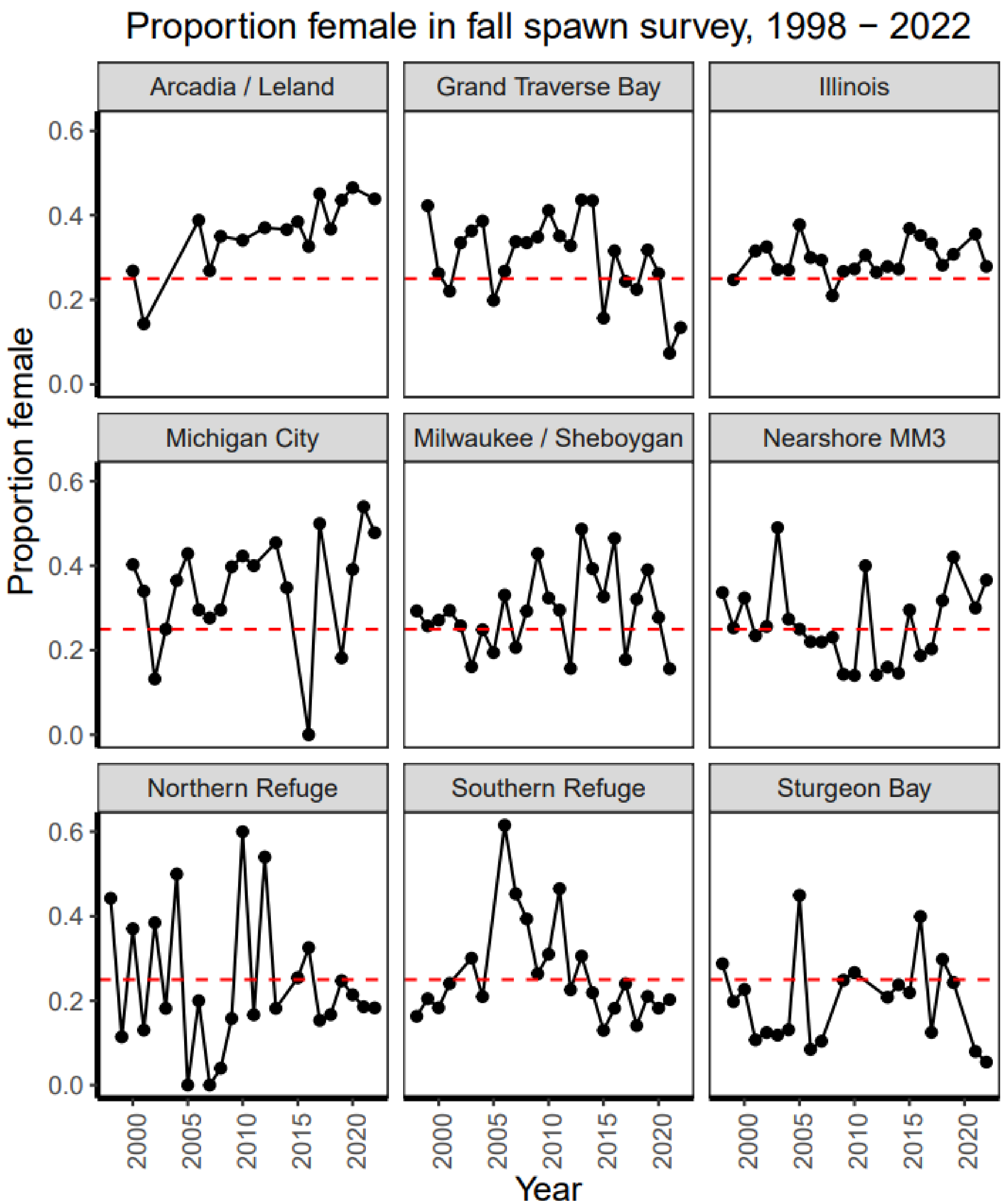

Figure 10: Proportion of fall spawner survey catches comprised of females; the horizontal red line portrays the Strategy evaluation objective of 25% females.

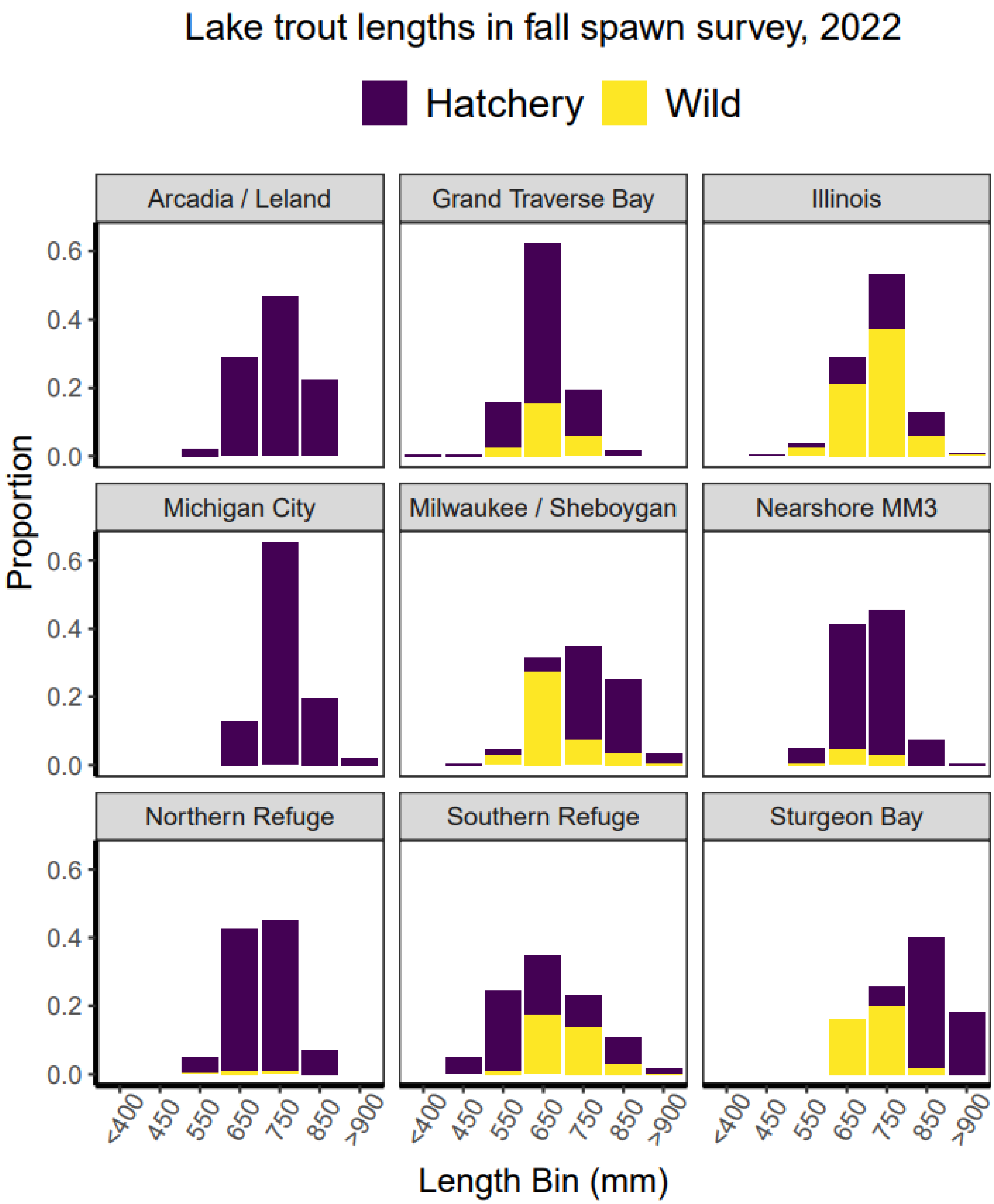

Figure 11: Proportion of lake trout captured in 2022 fall spawner survey within each 100 mm length bin.

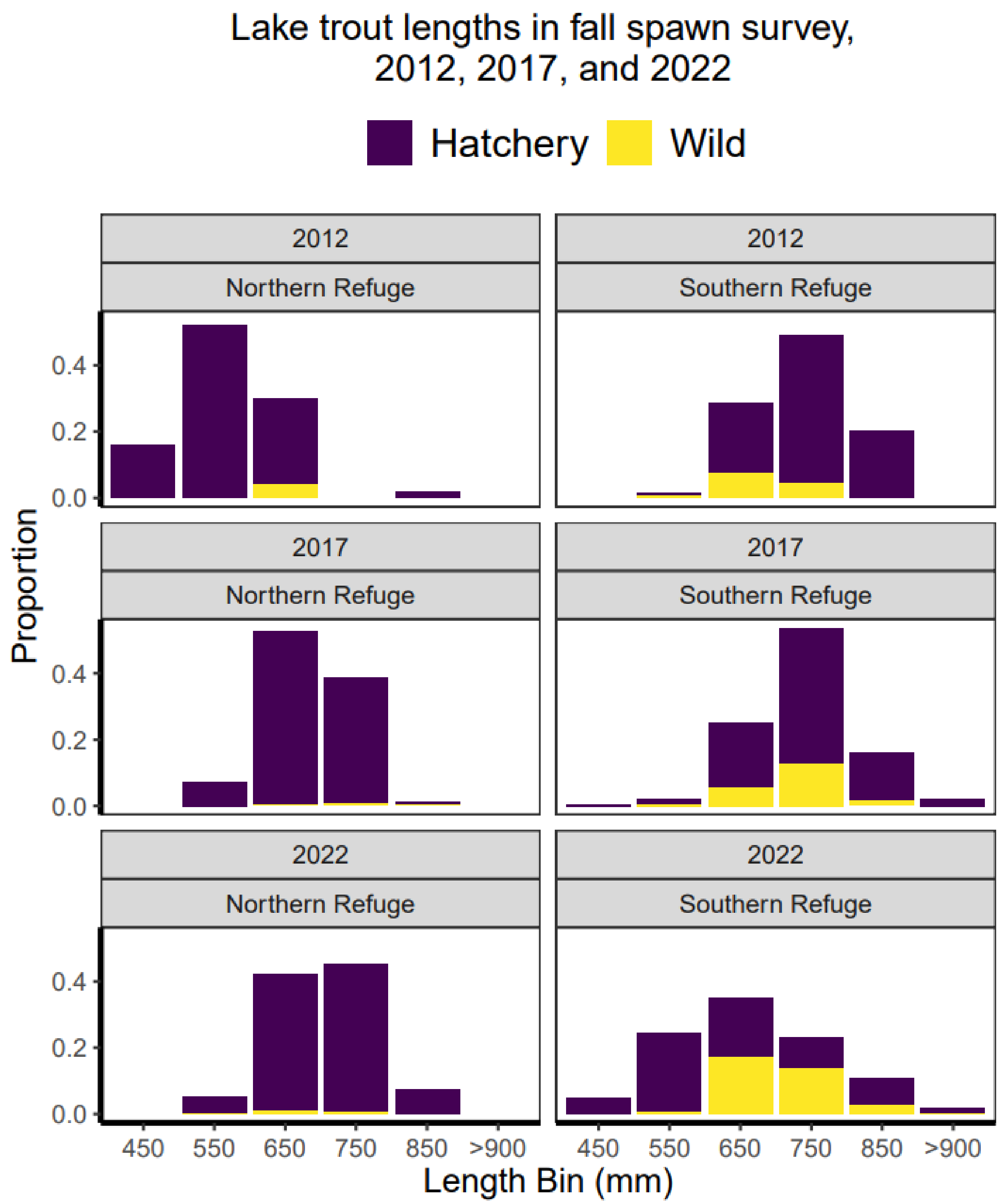

Figure 12: Proportion of lake trout captured in fall spawner survey within each 100 mm length bin for the Northern Refuge and Southern Refuge in 2012, 2017, and 2022.

<u>Evaluation Objective 4:</u> **Detect a minimum density of 500 viable eggs/m^2 ('viable' defined as 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.**

<u>Egg Deposition:</u> Egg deposition rates have remained below target densities at four sites in northern Lake Michigan during 2000-2022. In 2022, three sites were evaluated, and egg deposition ranged from ~7 to 12 eggs/m^2 (Figure 13). Estimates of egg deposition have been below the target of 500 eggs/m^2 throughout the time series.

<u>Egg Thiamine Concentration:</u> On a lakewide basis, egg thiamine concentrations exceeded 4 nmol/g during 2004-2022 (Figure 14). In contrast, egg thiamine concentrations were generally near or below the 4 nmol/g evaluation objective threshold during the late 1990s and early 2000s. Lakewide mean thiamine concentration in lake trout eggs increased from 2004 to 2016, but then declined (Figure 14).

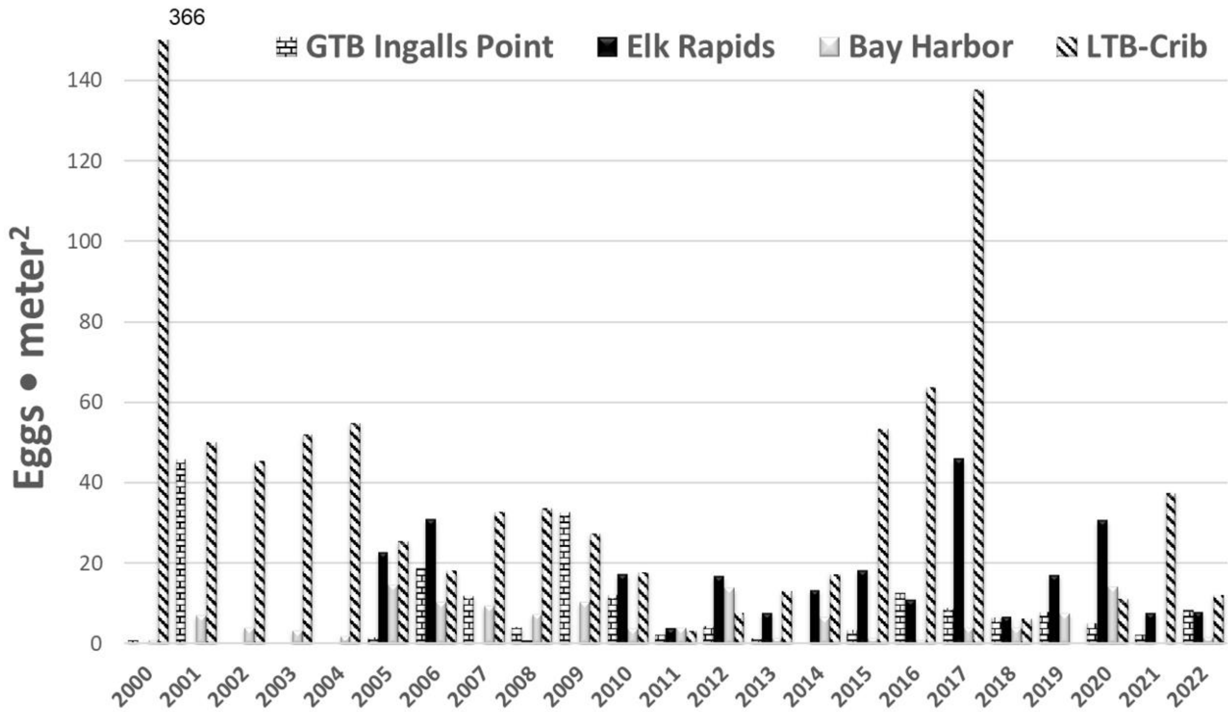

Figure 13: Numbers of lake trout eggs observed per square meter in northern Lake Michigan fall egg deposition surveys, 2000-2022. Egg deposition was measured using standard egg bag methodologies (Jonas et al. 2005). Abbreviations: GTB = Grand Traverse Bay; LTB = Little Traverse Bay.

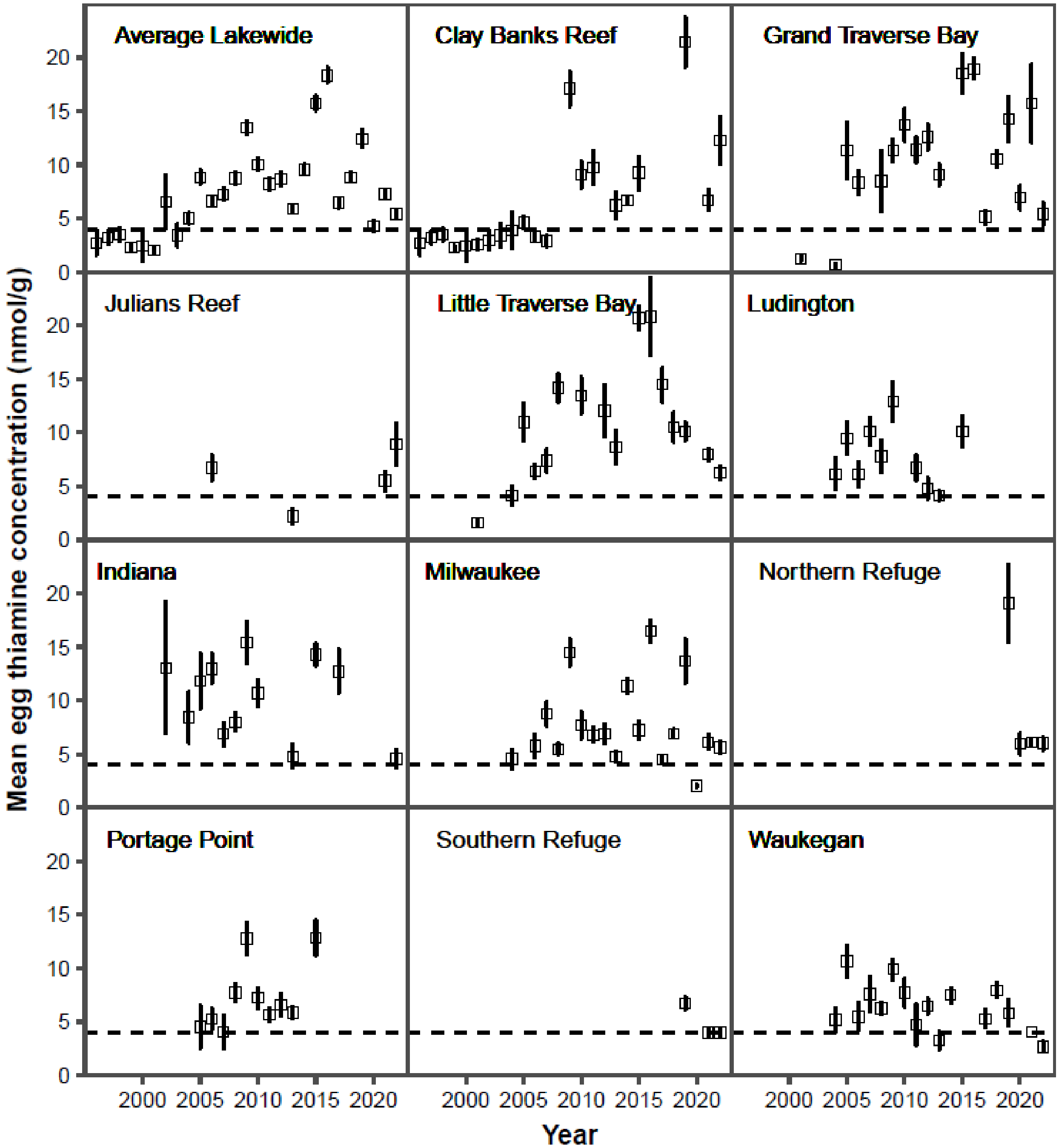

Figure 14: Mean egg thiamine concentrations (nmol/g) for ovulated lake trout females sampled in Lake Michigan fall spawner surveys, 1996-2022. Eggs with thiamine concentrations ≤ 4 nmol/g are correlated with a higher probability of exhibiting thiamine deficiency complex (TDC). Data are provided by Jacques Rinchard, State University of New York at Brockport.

<u>Conclusions</u>:

- **Harvest:** The harvest objective for lake trout in Lake Michigan was met in 2022. Total salmon and trout harvest was 2.76 million kg, and lake trout comprised 20.8% of the total.

- **Self-sustaining population:** The abundance of wild lake trout in Lake Michigan increased from 2005-2022. In spring surveys, average lakewide CPUEs of wild lake trout increased from near-zero in 2005 to modest levels (1.5 fish per 1000 feet of gill net). In fall surveys, wild lake trout CPUEs alone exceeded the total CPUE (hatchery and wild combined) benchmark of 50 fish per 1000 feet of gill net at Sturgeon Bay, Illinois, and Southern Refuge locations from 2005-2022.

  The proportion of wild fish, as estimated from the USFWS sport fishery, spring gillnet, and fall gillnet surveys has increased during 2005-2022. In some sections of Lake Michigan, a portion of this increase can be attributed to reductions in the numbers of fish stocked, as evidenced by corresponding decreases in CPUEs of hatchery fish.

- **Stocking:** The annual lake trout stocking rate exceeded the interim target level during 2005-2017 but remained slightly below this target level from 2018-2022. The effects of reductions in the number of stocked fish are being seen in certain areas of southern and central Lake Michigan. Managers can expect continued reductions in stock size and catch rates. Greater stocking levels in the north are helping to offset mortality and are having positive influences in progressing toward restoration targets.

- **Mortality:** Mortality targets are largely being met, albeit with higher mortality rates in the northern areas of the lake. In 2022, estimated annual mortality rate was 41% in the non-refuge waters of MM3. In MM6/7, annual mortality rate during 2005-2022 averaged 32%, which was below the target level of 40%. Sea lamprey induced mortality rate remained low throughout the lake in 2022.

- **Survey total CPUE:** The spring survey total CPUE target of ≥ 25 fish per 1000 feet of net was met only in the Southern Refuge area in 2022. The fall spawner total CPUE target of ≥ 50 fish per 1000 feet of net was met in 2022 at all spawning reef locations except for Arcadia/Leland and Michigan City.

- **Spawning population:** The percentage of females captured during the fall spawner survey has exceeded the 25% benchmark at most sites during most years. Based on the available age composition data, the benchmark of 10 or more age groups older that age-7 in the fall gillnet survey catch has been attained for Sturgeon Bay, the Southern Refuge, and Illinois waters. This benchmark has not been attained in the Northern Refuge, nearshore waters of MM3, and Grand Traverse Bay.

- **Egg deposition:** Egg densities remained low at nearshore spawning locations in the northern Lake Michigan where monitoring occurred.

- **Egg thiamine:** Egg thiamine concentrations were above the threshold level of 4 nmol/g at most locations in 2022.

Continued discussion and areas for evaluation:

Survey Methods

Year-classes may have different representation within each survey due to gear differences as well as the timing and location of the sampling event. Spring and fall gillnet assessments differed in the rate at which wild fish CPUE approached the benchmark value over time. Although benchmark values of 25 and 50 fish per 1000 feet of net were established for total CPUE (wild and hatchery) in the spring and fall gillnet surveys, respectively, we reference these benchmarks with respect to wild fish to provide discrete reference points for comparison of the relative magnitude of CPUE for wild fish. The rate at which spring gillnet CPUE of wild fish approached the benchmark value of 25 fish per 1000 feet of net was considerably slower than the rate at which fall gillnet CPUE of wild fish approached the benchmark value of 50 fish per 1000 feet of net. Additional discussion is needed to address specific restoration targets, refine the metrics, and refine the scale to which the metrics are applied. That said, temporal trends in lake trout abundance indices generally showed similar trajectories among our surveys at 2/3-3/4 of the eight survey regions over the past two decades. Lake trout population increases were also reflected in estimates of population size from statistical catch at age models which integrate multiple data sources.

One possible explanation for rising wild fish CPUE in fall at some sites would be that earlier year-classes of wild fish are now mature and exhibiting spawning site affinity to their natal reefs. The spring survey samples a regional population that is not focused on spawning activity, whereas fall surveys measure abundance of adults utilizing spawning habitat at the time of the survey. Wild fish CPUEs from the spawner survey, which assess areas that have been intensively managed by stocking, may reach target levels more rapidly. This explanation is consistent with fall spawn surveys providing an early signal of increased wild production, especially at reefs in Illinois and the Southern Refuge that are thought to be among the focal points of wild production in Lake Michigan.

Lake Trout Strains

Lake trout strain may further complicate the interaction between lake trout origin (hatchery versus wild) and survey season. As previously mentioned, hatchery and wild lake trout may vary in their spatial distribution across seasons. Previous research on lake trout of hatchery origin in the Great Lakes has shown that bathythermal distribution can vary across strains (Bergstedt et al. 2012). In addition, ontogeny (i.e., lake trout age or lake trout size) may also enter into an interaction with lake trout origin, season, and strain. For example, bathythermal habitat has been shown to vary across lake trout strains (Bergstedt et al. 2012), and the most frequent genetic origin of wild lake trout sampled from Lake Michigan has been the Seneca Lake strain (Larson et al. 2021). Perhaps the Seneca Lake fish are more catchable in the sport fishery and fall gillnet surveys than in the spring gillnet survey. Seneca Lake fish, especially at younger ages, may be either more pelagic or inhabit waters deeper than those sampled in the spring gillnet survey compared with other strains during the spring sampling. In this way, the Seneca Lake fish may have relatively low catchability in the spring gillnet survey. Untangling this potentially complicated interaction will require a considerable amount of additional research effort.

Hatchery versus Wild Lake Trout

Whether there are ecological differences between wild and hatchery lake trout is an underexplored research theme. Marsden et al. (2022) reported foraging differences in Lake Champlain between age 0 to 1 stocked juveniles versus their wild counterparts; differences were attributed to behavior learned in early rearing environments and increased size of hatchery fish. During months of thermal stratification, wild juveniles occupied shallower, warmer water relative to stocked fish; therefore, assessment of wild-to-hatchery proportions may be seasonally influenced (Wilkins and Marsden 2021). Clearly, more studies are needed on the ontogeny of habitat use for both hatchery and wild lake trout.

While trajectories in total CPUE were comparable among surveys, wild lake trout CPUE showed much more substantial increases in fall spawner surveys than during spring. A possible contributing factor to this discrepancy is that wild lake trout may be more catchable in the fall gillnet survey than in the spring gillnet survey. Perhaps this is a reflection of where surveys are being conducted in relationship to where naturalized fish were produced and likely to return to spawn.

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