2021 Lake Michigan Lake Trout Working Group Report [1,2]

This report provides a review on the progression of lake trout 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 have not received final approval by the agency and are currently under review. The Great Lakes Science Center is committed to complying with the Office of Management and Budget data release requirements and providing the public with high quality scientific data. We plan to release all USGS research vessel data collected between 1958 and 2021 and make those publicly available. Please direct questions to our Information Technology Specialist, Scott Nelson, at snelson@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).

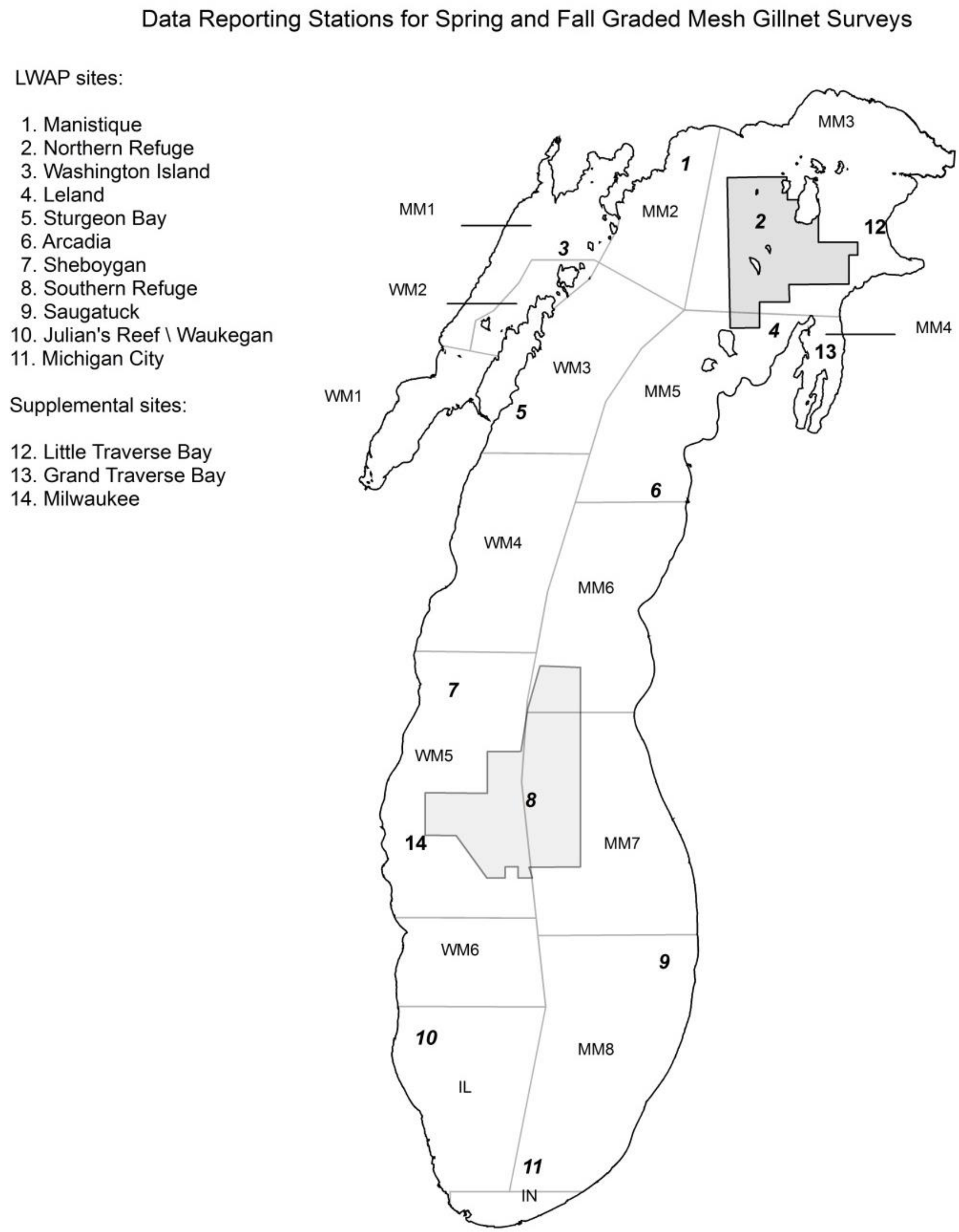
Methods: We drew from several data sources in preparing this report. Harvest information was supplied by the Lake Michigan extraction database. More detailed reporting of harvest and mortality within 1836 Treaty Waters of Lake Michigan was based on stock assessment models for northern and eastern Lake Michigan management units to approximate harvest and mortality in the proximate southern rehabilitation priority areas. Trends in spring catch-per-unit-effort (CPUE) were based on the spring (April – June) lakewide assessment plan (LWAP) gillnet survey that employs 2.5 - 6.0" graded nylon multifilament mesh, or monofilament as described by Smith et al. (2022), at nine nearshore and two offshore locations distributed throughout the lake (Schneeberger et al. 1998; Map 1). We also included 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. Fall adult CPUE was determined from the 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 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. 2019). We conservatively infer natural reproduction 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 2021, total salmon and trout harvest was 2.51 million kg and for the seventh consecutive year was below the 2.7 million kg minimum threshold of the FCO harvest objective (Figure 1). Lake trout harvest in 2021 was 0.81 million kg. The lake trout harvest objective (0.54-1.70 million kg) was met from 1985 to 2001 and from 2013 to 2021 (Figure 1). Lake trout comprised 32.3% of the total salmonid harvest in 2021 and thus exceeded the FCO harvest objective of 20-25% (Figure 2). Higher percentages of lake trout harvest over the last decade are largely driven by reduced salmon harvest since 2012, whereas lake trout harvest has remained relatively stable through the time series.



Map 1. Reporting of spring and fall graded mesh gill net 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.

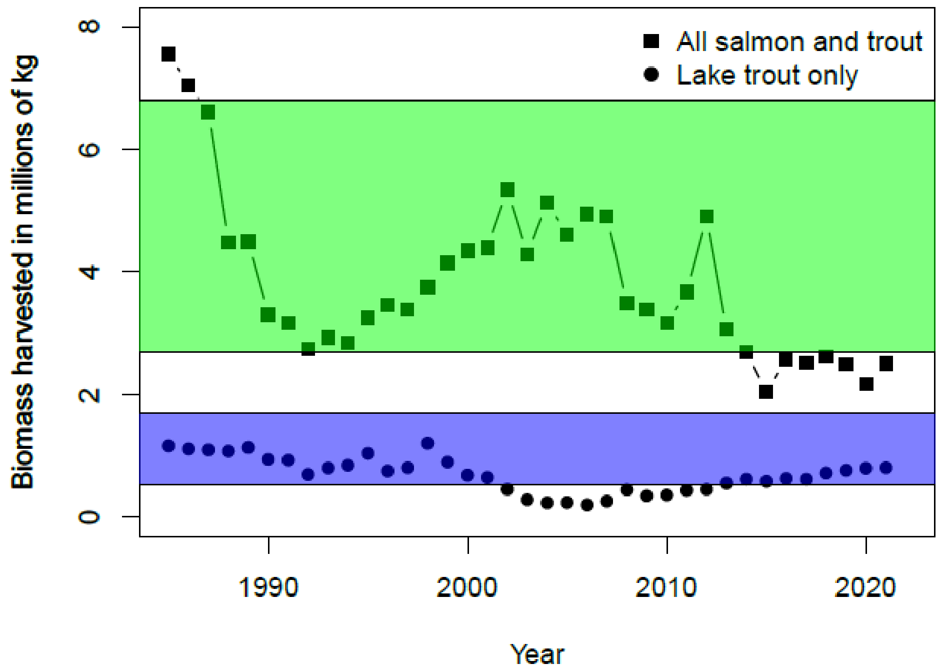


Figure 1: Lake Michigan total harvest (1985-2021) for lake trout (circles) and for all species of salmon and trout combined (squares); green-shading depicts the range of salmon and trout harvest in the FCO while blue-shading depicts the 20-25% range of salmon and trout harvest reserved for lake trout.

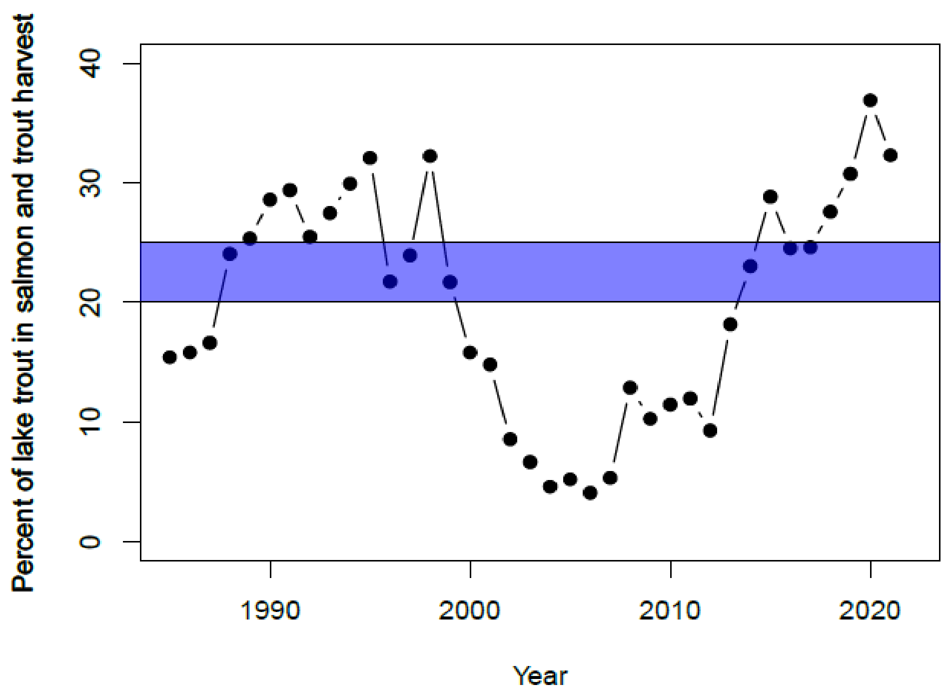


Figure 2: The percentage of salmon and trout harvest comprised of lake trout; blue shading represents the 20 to 25% specified in the FCO.

Natural Reproduction: Overall, 23.4% of the 5,826 lake trout representing the pooled catch from the 2021 sport-fishery, fall spawner, and spring gillnet surveys lacked a fin-clip and were presumed to be of wild origin. These surveys each provide a measure of proportion of wild lake trout within a management unit, but temporal and spatial differences in sampling methods may lead to contradictory survey-specific perceptions on the proportion of fish from natural origins within a unit. Specifically, the sport fishery survey is focused on areas of high angler effort, and this survey under-samples offshore waters, especially refuges where angling is not permitted. Gillnet assessments represent both nearshore and offshore sites, but spring versus fall surveys target different segments of the lake trout population (i.e., a population assumed to be mixed in spring and aggregations of mature spawners in fall). Therefore, many factors, including lake trout stocking patterns and seasonal differences in behavior, may influence the proportion of wild fish reported for each survey data source. Below we summarize the percentages of wild fish reported in 2021 by statistical district(s) among the three data sources (Figure 3), and then we describe overarching patterns in relative abundance of wild and hatchery fish as measured by CPUE (Figures 4-6). We point out that proportion wild data are useful to gauge broad-scale patterns of emerging natural recruitment, but the gillnet assessments' catch-per-unit-effort data for wild fish provides the better metric to evaluate whether *a self-sustaining lake trout population* has been achieved. An increasing trend in proportion 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.

In MM3 of northern Lake Michigan, the proportion of wild fish in 2021 remains low. Natural reproduction was low, as the observed proportion of unclipped fish was below the 3% detection threshold for the spring survey, but fall spawner and sport fishery surveys reported a slight increase to 6 to 7% in recent years (Figure 3). In nearby Grand Traverse Bay (MM4), wild recruits continue to trend upward with 13 to 24% of fish now of wild origin. Proportionally, wild fish in mid-latitude statistical districts are surging; both MM5/6 and WM3/4 now exceed 50% wild from FWS sport fishery surveys, while 68% of spawner survey catches were wild in WM3/4 in 2021. Similarly, wild lake trout comprised over half (55 to 62%) of the lake trout sport fishery catch in all southern Lake Michigan districts (ILL, IND, MM7/8, and WM5/6); however lower proportions of wild fish were reported for gillnet assessment surveys in IND and WM5/6. This discrepancy in IND may be an artifact of limited lake trout catch (n = 50 in fall, 18 in spring) from the gillnet assessments; however in WM5/6 sample sizes in each survey exceeded 300 fish, while both spring and fall gillnet surveys reported < 8% wild recoveries in 2021, far below the wild proportion for sport fishery data (55%). These discrepancies between survey results for WM5/6 are due at least in part to the nearshore bias of the sport fishery survey, as most lake trout from gillnet surveys in WM5/6 during 2021 were captured on Southern Refuge reefs. Until 2019, the proportion of wild fish in the fall spawner survey for the WM5/6 region, which includes the Southern Refuge, historically tracked that in the nearshore sport fishery survey, but this is no longer true. The wild proportion in the Southern Refuge has fallen precipitously now that Klondike lake trout, first stocked in 2012, are recruiting to offshore assessment surveys. Finally, aside from IND and WM5/6, we note that sport fishery and fall spawner surveys report similar estimates of wild proportions, but the spring assessment survey generally catches lower proportions of wild fish. In 2021, proportion wild estimates from spring gillnets averaged 46% and 60% of the corresponding sport fishery and fall spawner survey estimates, respectively (Figure 3). These data suggest that catchability of wild lake trout is higher during the fall spawning season compared to the spring pre-stratification period. Whether the estimate of the proportion of wild fish in the entire lake based on the spring gillnet survey is more accurate than that based the fall gillnet survey remains unknown. In sum, the proportion of wild fish in northern Lake Michigan is low but beginning to trend upwards, whereas wild fish comprise a higher percentage of lake trout in mid-latitude and southern management units. Broadly speaking, in these units the spring surveys suggest up to 30% of lake trout are wild but sport fishery and spawner survey data suggest higher percentages of at least 40 to 60% wild. Again, we emphasize that an increasing trend in proportion of wild fish over time may not only be due to an increase in wild lake trout abundance, but may also be due to a decrease in hatchery lake trout abundance.

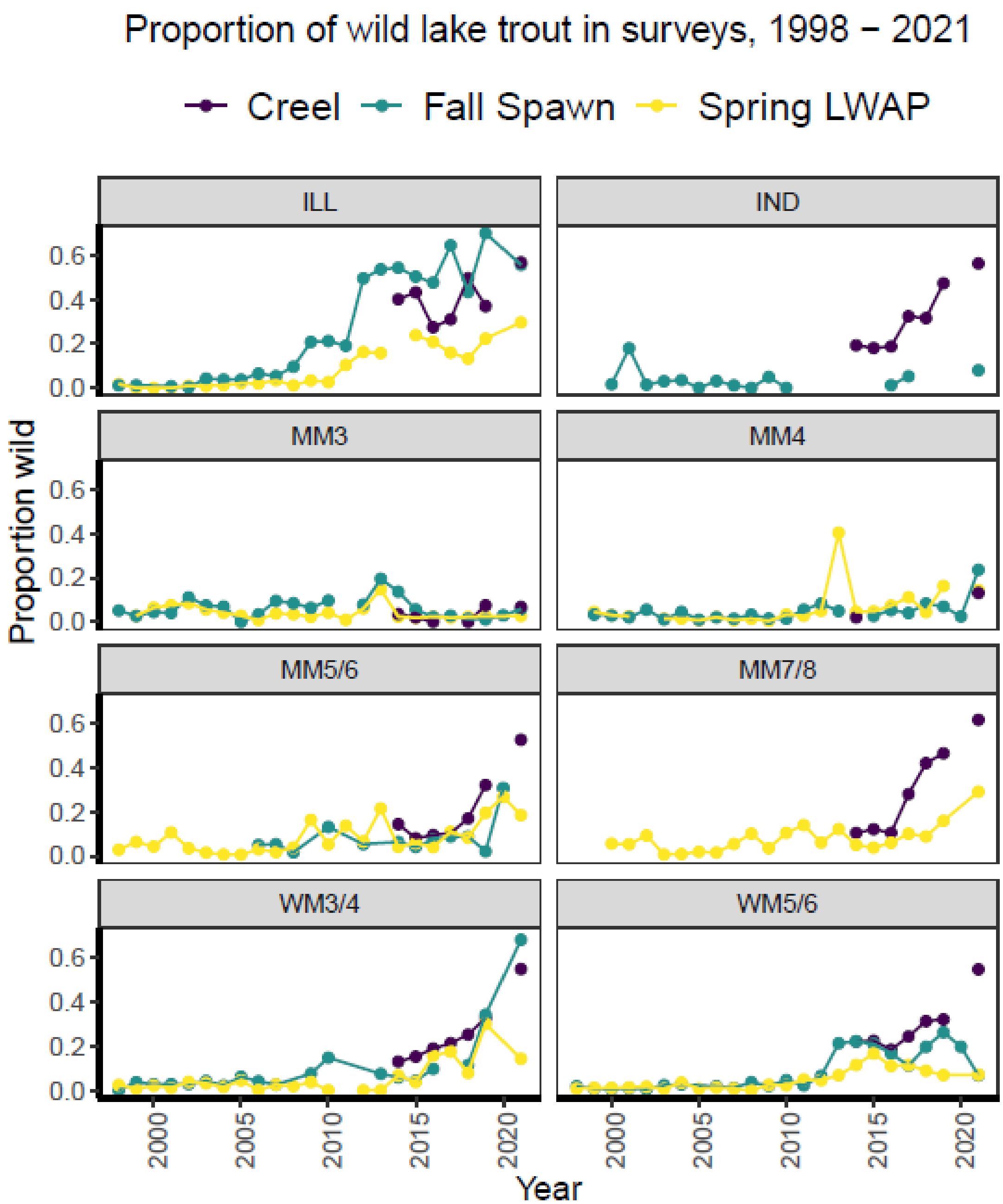


Figure 3: The proportion of wild (unclipped) lake trout captured in the sport fishery, fall spawner gillnet, and spring gillnet surveys within each statistical district(s). Sport fishery data were provided by the Great Lakes Fish Tagging and Recovery Lab and gillnet data originate from multi-agency surveys described in the LakeWide Assessment Plan (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.

Based on results from the spring gillnet and sport fishery surveys, the increase in proportion of wild fish in some regions of the lake during 2014-2021 may be primarily attributable to a decline in hatchery fish abundance. At several locations of the lake, notably WM3/4, WM5/6, MM2/3, and MM7/8, catch per unit of effort (CPUE) of hatchery lake trout in the sport fishery has shown an overall decreasing trend during 2014-2021 (Figure 4). Likewise, hatchery lake trout CPUE has also decreased during 2014-2021 in several areas of the lake indexed by the spring gillnet survey, including Saugatuck, Sheboygan, Sturgeon Bay, and Leland (Figure 5). Thus, increases in the proportion of wild fish in these surveys during this time period were mainly driven by a decrease in hatchery fish CPUE rather than an increase in wild fish CPUE, although wild fish CPUE has generally increased in the lake. In contrast to these results from the spring gillnet and sport fishery surveys, increases in proportion of wild fish in the fall gillnet survey during 2005-2021 have been primarily driven by increases in wild fish CPUE rather than decreases in hatchery fish CPUE. For example, percentage of wild fish in the fall gillnet survey in Illinois waters of the lake exhibited a sharp increase in 2012 to a value greater than 50% (Figure 3). This sudden increase coincided with a sharp increase in wild fish CPUE in 2012 (Figure 6). In Illinois waters, hatchery fish CPUE trended neither significantly upward nor significantly downward ($P > 0.10$) during 2005-2021 while wild fish CPUE showed a dramatic increase during this time period. Likewise, in the Southern Refuge, the increases in proportion of wild fish beginning in 2013 in the fall gillnet survey were primarily attributable to increases in wild fish CPUE rather than decreases in hatchery fish CPUE (Figures 3 (WM5/6 panel) and 6). Similarly, the recent increases in proportion of wild fish in the fall gillnet survey at Sturgeon Bay and Grand Traverse Bay were primarily driven by increases in wild fish CPUE (Figures 3 and 6). One possible explanation for rising wild fish CPUE in the fall gillnet survey at some sites would be that earlier year-classes of wild fish are now becoming mature and exhibiting spawning site affinity to their natal reefs. The estimated percentage of wild lake trout in the Lake Michigan lakewide population in 2021 based on the fall gillnet survey (24%) is similar to the estimated percentage of wild lake trout in the Lake Michigan adult population in 2019 based on results of statistical catch at age models that cover the entire lake (20%). Note that this estimated percentage of 20% is likely an underestimate, because the catch at age model applications assumed that wild fish resided in only the southern waters of the lake. The discrepancy between the spring gillnet survey results and fall gillnet survey results in some regions of the lake may potentially be due, in part, to a difference in lake trout age selectivity between the two surveys. The spring survey, based on gill nets with mesh sizes ranging from 2.5 to 6.0 inches stretched measure, is suitable for capturing lake trout over a wide range of ages, from younger juveniles to older adults; whereas the fall spawner survey, based on gill nets with sizes ranging from 4.5 to 6.0 inches stretched measure, targets adult lake trout. Perhaps the recent decline in hatchery fish CPUE in the spring gillnet survey in some regions of the lake, while the fall gillnet survey results indicate either a flat temporal trend or even a recent increase in hatchery fish CPUE, reflects an actual recent decline in hatchery fish CPUE that is detectable by the spring survey capable of accurately assessing CPUE of younger fish, but not yet detectable by the fall gillnet survey.

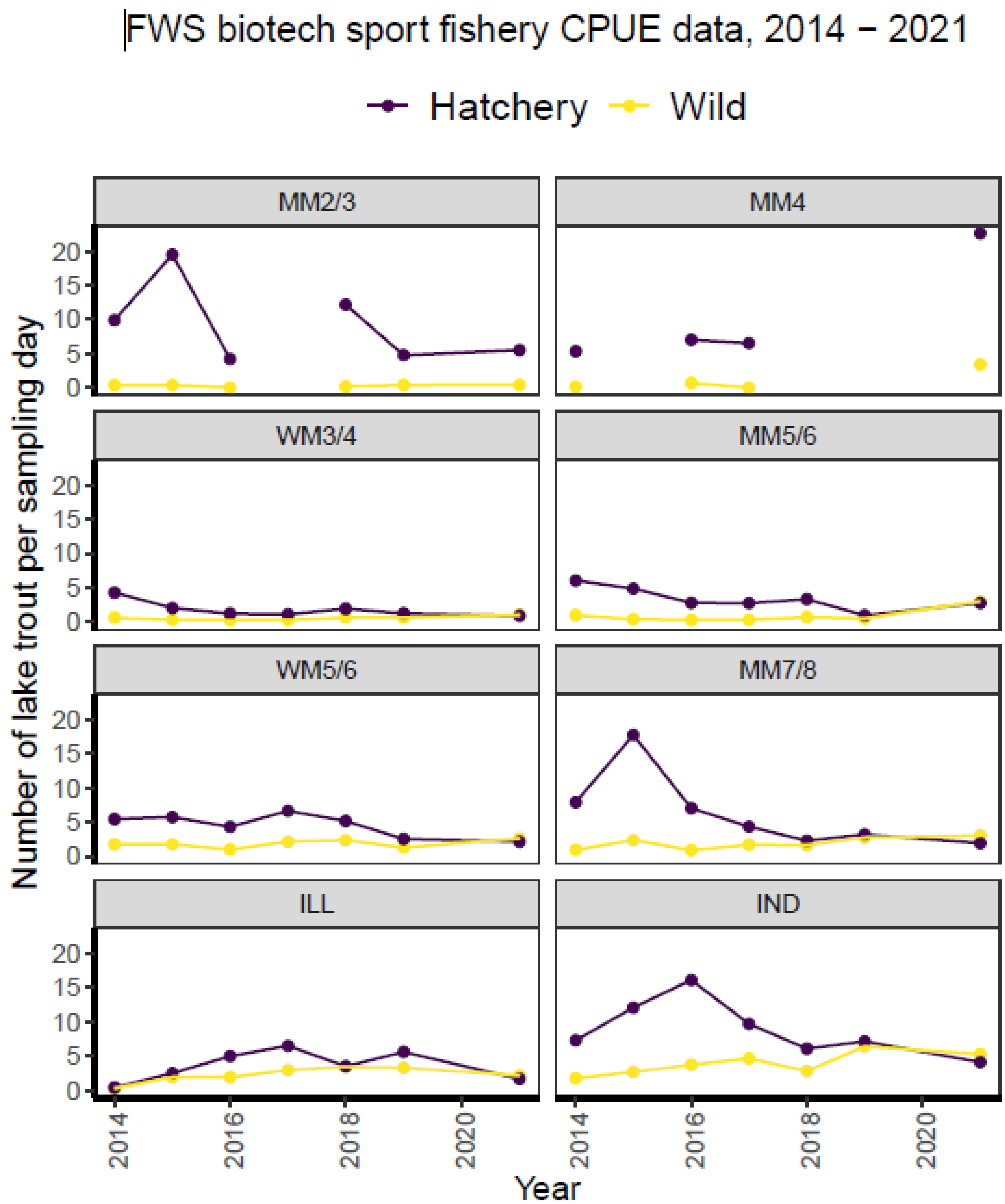


Figure 4: Angler catch rates of lake trout based on the Great Lakes Fish Tagging and Recovery Lab sport fishery survey of the recreational sport fishery, 2014-2021.

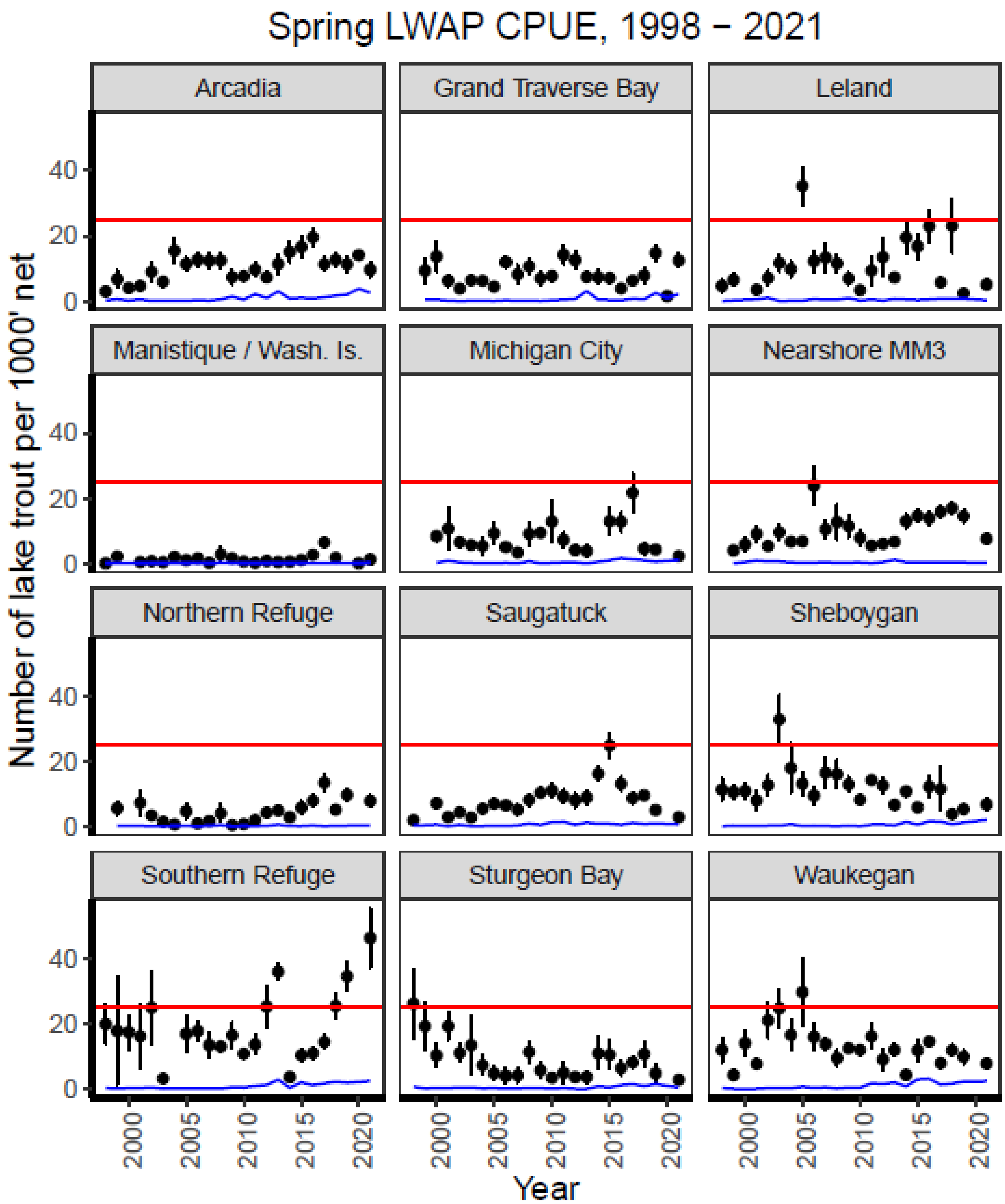


Figure 5: Time series of spring survey lake trout catch per effort (mean number of fish/1000 ft of graded mesh gill net) for the 11 LWAP sites plus 2 supplemental sites with comparable data (Grand Traverse Bay, and non-Refuge MM3 waters). Vertical bars represent $\pm$ 1 SE and the horizontal red line shows the spring CPUE benchmark of 25 fish per 1000'. The black circles portray CPUE of all lake trout (hatchery and wild fish pooled) whereas blue lines show the CPUE of wild lake trout.

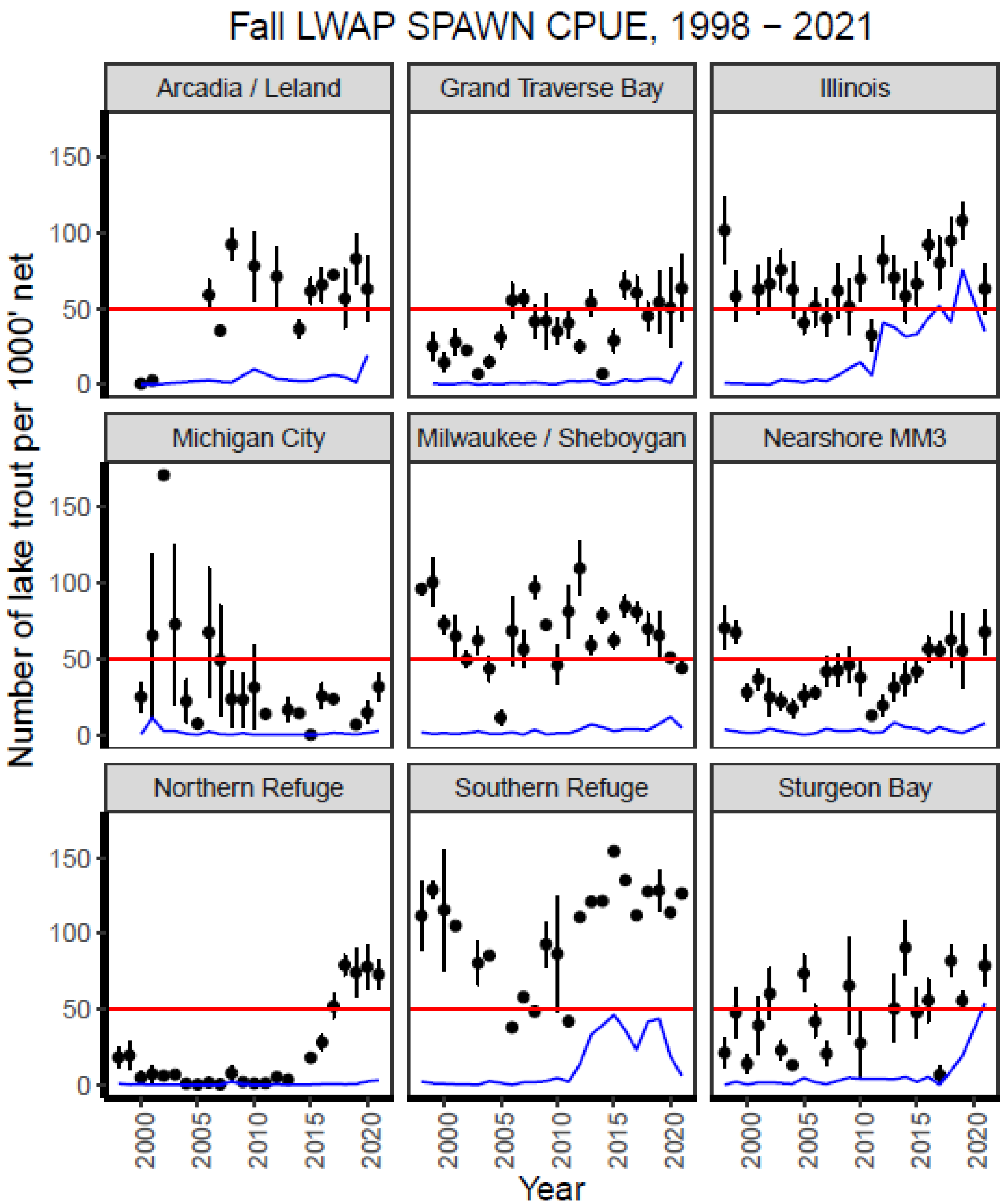


Figure 6: Time series of fall lake trout spawner survey catch per effort (mean number of fish/1000 ft of graded mesh gill net) for reefs within or near the spring LWAP stations. Vertical bars represent ± 1 SE and the horizontal red line shows the fall CPE benchmark of 50 fish per 1000'. The black circles portray CPUE of all lake trout (hatchery and wild fish pooled) whereas blue lines show the CPUE of wild lake trout.

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

Fish Stocking: 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, the Lake Michigan Committee adopted an interim stocking target not to exceed 2.74 million yearling equivalents when the strategy was approved. Beginning in 2009, at least 2/3 of all lake trout were stocked on the Northern and Southern refuges with the remaining fish planted 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 or "humper" strain, an offshore reef spawning morphotype from Lake Superior, at one reef on the Southern Refuge to replace the lean Seneca Lake strain. This Klondike stocking initiative began in 2012 at Northeast Reef. In 2017, the Lake Committee reduced the interim stocking target to 2.54 million fish and achieved this through eliminating stocking of nearshore non-priority areas in southern Lake Michigan. In 2019, bacterial infection (*Vagococcus salmoninarun*) resulted in the destruction of the Klondike strain broodstock at Iron River NFH. Subsequently, the Lake Committee cancelled future requests for this strain and annual stocking requests for the Southern Refuge were decreased by 255,000 yearlings. Therefore, considerable changes to regional stocking patterns have occurred over the last decade. Annual stocking is now ~1.5 million fish on the Northern Refuge complex and ~0.5 million on the Southern Refuge complex, and overall stocking numbers have declined at nearshore sites in southern Lake Michigan (Figure 7). Due to personnel safety protocols enacting 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.

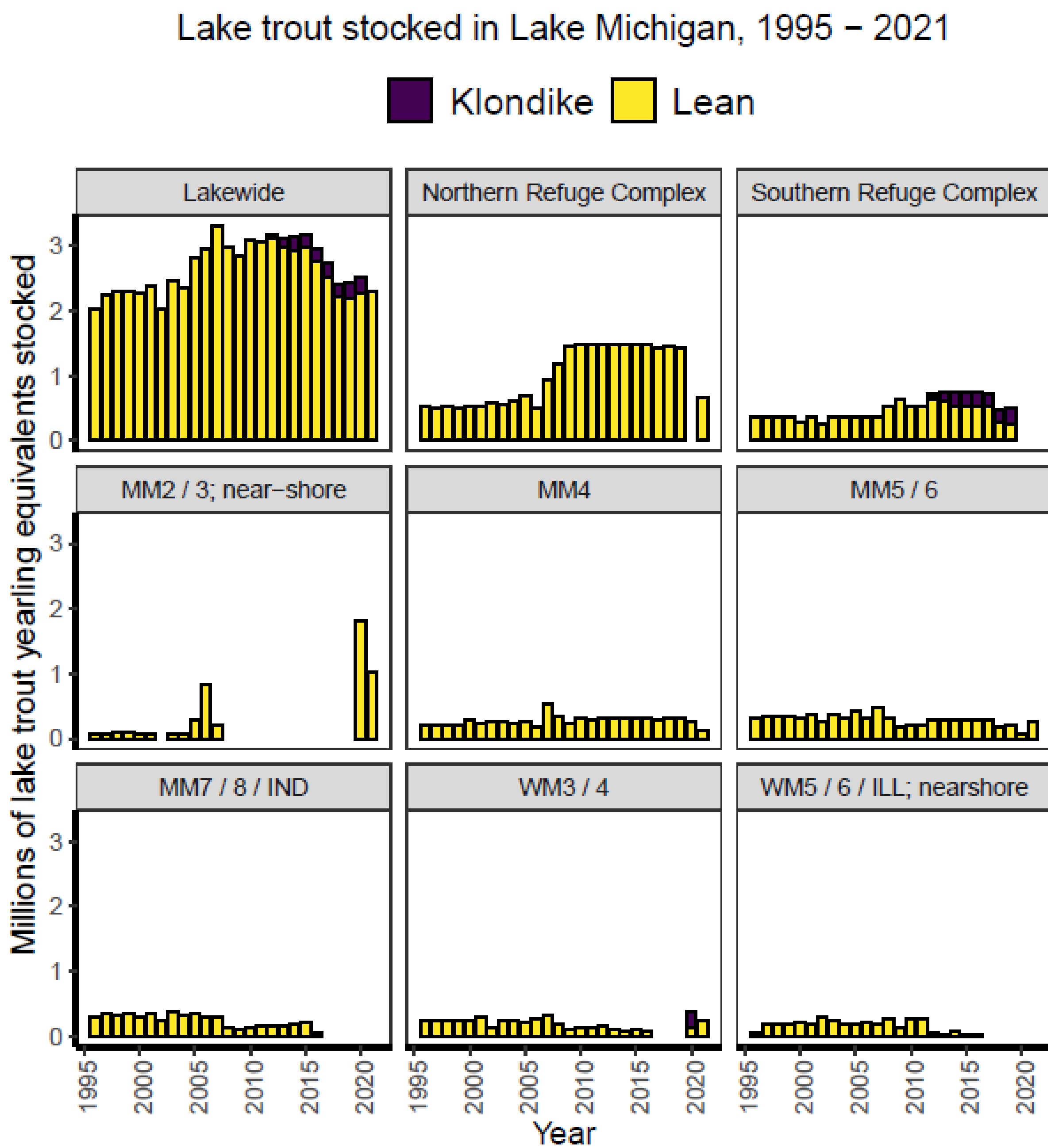


Figure 7: Number of lake trout (yearling equivalents) stocked in Lake Michigan by region, 1995-2021. Several lean strains of lake trout have been stocked in Lake Michigan since 1995; the Klondike strain, a humper morphotype selected for deep-water reefs, is shown separately and was first stocked in 2012.

Lake Trout Mortality: Tracking mortality on lake trout stocks is best estimated by stock assessments conducted within the 1836 Treaty waters using survey, sport, and commercial fishery data. Total mortality is partitioned into natural mortality, sea lamprey induced mortality, and fishing (both sport 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).

Currently, the most recent mortality rate estimates from Treaty Water SCAA models are not yet available. In the coming weeks, updated mortality rates, including those estimated from the recently developed southern Lake Michigan SCAA model, will be appended to this report. In northern Lake Michigan, the most recent available total annual mortality estimate for 2019 was virtually the same as for 2018 (43%), a slight decrease from 45% in 2017 for lake trout ages 6-11 (Figure 8, upper panel; Technical Fisheries Committee: 2000 Consent Decree). In the north, commercial fishing is the primary source of mortality (Figure 8, upper panel). Previously in the 2000s there was an extended period of elevated sea lamprey mortality thought to be caused by additional recruitment of parasitic adults produced after spawners breached the dam on Manistique River. In recent years lamprey mortality has dropped precipitously after several years of intensive lampricide treatments on the Manistique River and other Lake Michigan tributaries (Figure 9, upper panel; Technical Fisheries Committee: 2000 Consent Decree).

Annual mortality rates in the Southern Refuge priority area have not been estimated, but those estimated from the proximal waters of MM6/7 have been at or below 40% since 1999 (Figure 8, bottom panel). Prior to 2003, recreational fishing was the main source of lake trout mortality in MM6/7. Fishing mortality decreased following a reduction of recreational fishing effort beginning in the 1990s, and sea lamprey induced mortality exceeded fishing mortality in MM6/7 until 2014, though combined these sources were still less than assumed natural mortality. As in northern Lake Michigan, sea lamprey induced mortality in MM6/7 has also declined in recent years, and the 2018 total annual mortality is below target at 33%.

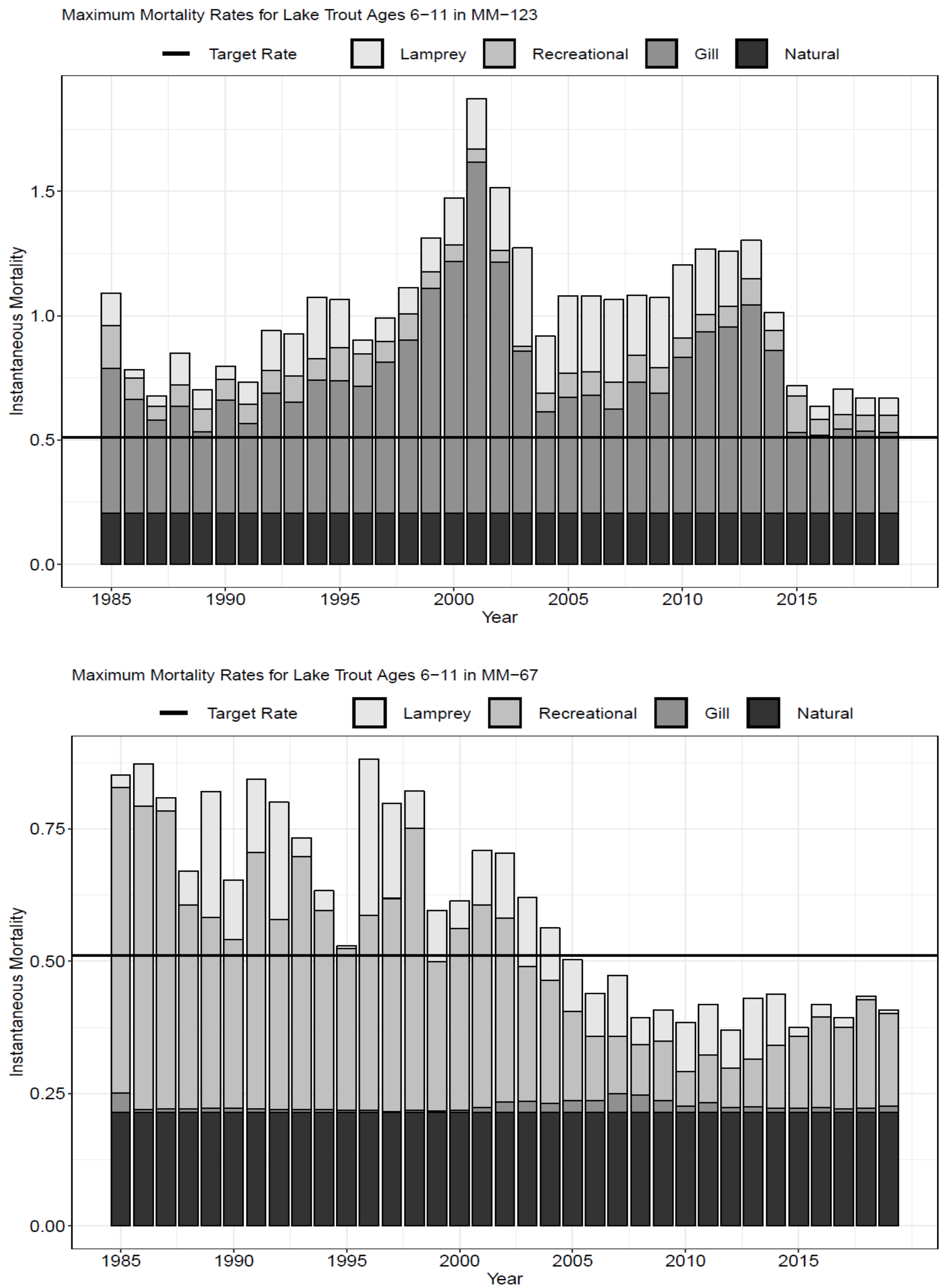


Figure 8: Model estimates of instantaneous mortality rates (Z) for lake trout ages 6-11 in non-refuge waters of northern Lake Michigan (MM1/2/3; top plot) and in MM6/7 waters proximal to the Southern Refuge (bottom plot). Horizontal black line represents an instantaneous mortality rate of 0.51 that is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

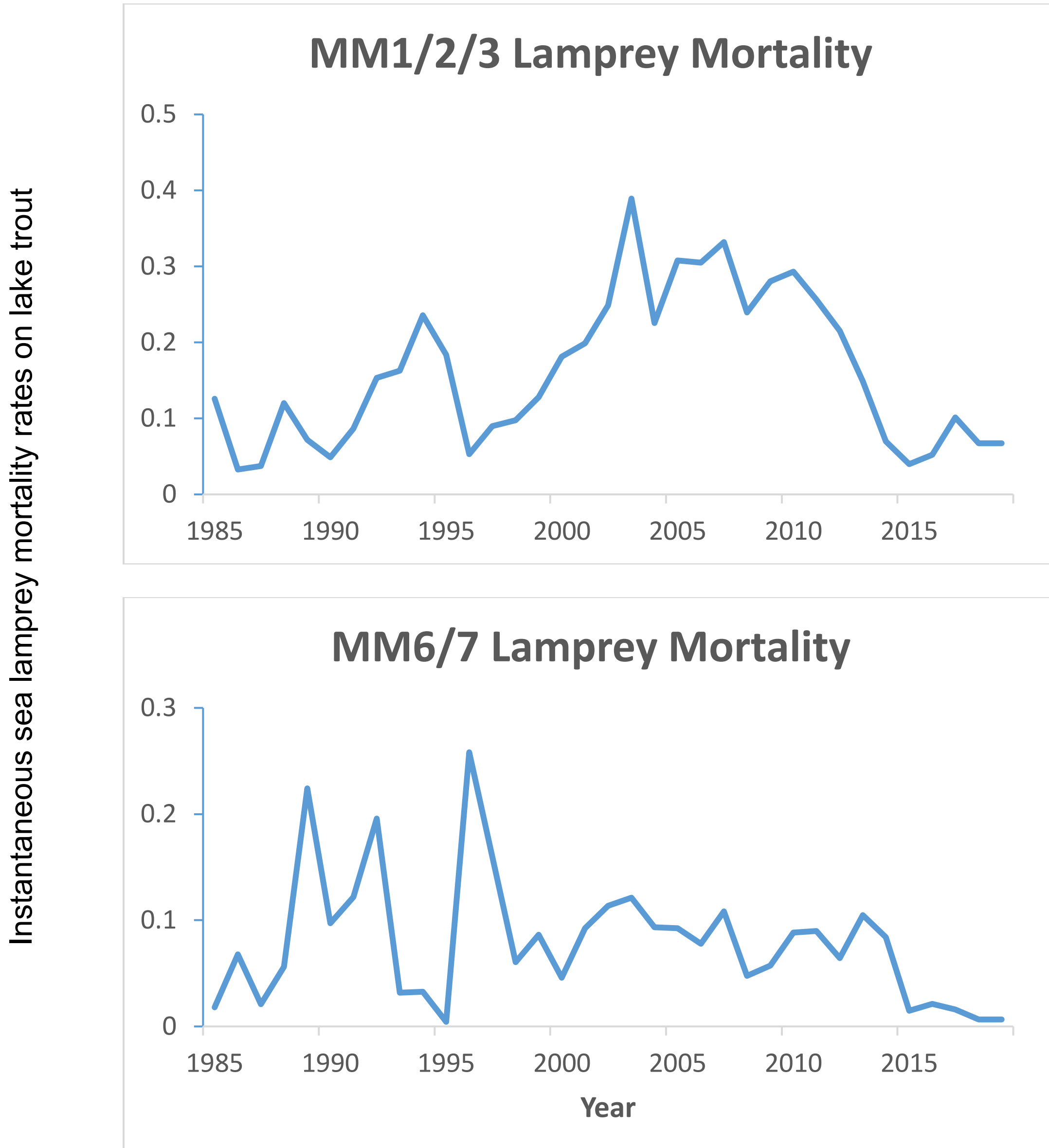


Figure 9: Estimated sea lamprey-induced instantaneous mortality on lake trout ages 6-11 for Lake Michigan management units MM1/2/3 and MM6/7. Estimates are based on observed marking rates. The 2019 value in each time series has been assumed to be equal to the 2018 value because data are not yet available to inform the most recent year.

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

In 2021, 178 gillnet lifts were completed lakewide to assess spring lake trout abundance. This included at least six lifts at each nearshore LWAP site, 12 lifts on the Southern Refuge, and 12 lifts on the Northern Refuge. In addition, we report data from other LWAP and FIWS survey lifts along the eastern shore (MM3 – MM8); 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 5).

On a lakewide basis, this evaluation objective is not being attained (Figure 5). In general, trends in total (hatchery and wild combined) spring lake trout CPUE are declining at LWAP sites impacted by the 2017 elimination of near-shore stocking and earlier stocking reduction in southern Lake Michigan. Along the eastern shore, this declining trend is particularly evident at Leland, Saugatuck, and Michigan City where the 2021 CPUEs range from 2.2 to 5.0 lake trout per 1000' net, compared to CPUEs that averaged 13.0 to 17.6 lake trout per 1000' net from 2014 – 2018. On the western shore, this trend exists at Sturgeon Bay (2021 CPUE of 2.7, compared to an average of 9.2 from 2014-2018), and to a lesser extent at Sheboygan and Waukegan (2021 CPUEs of 6.7 and 7.7, compared to 2014-2018 averages of 8.8 and 10.0, respectively), where stocking at the Southern Refuge complex (2021 CPUE of 46.2 compared to the 2014-2018 average of 12.9) may buffer these latter sites. In northern Lake Michigan, intensive stocking had been modestly elevating densities at Northern Refuge and nearshore MM3 with CPUEs reaching 13.4 and 15.8 fish per 1.000', respectively, in 2017. However, this upward trend has stopped and current CPUEs are now halved (CPUEs = 7.8 and 7.5 in Northern Refuge and nearshore MM3 respectively) from recent highs. In contrast, CPUE on the Southern Refuge shows a steep increasing trend that began in 2015 and is now at its highest point with 46.2 fish per 1,000'. This steep increase stems from the Klondike strain stockings that began in 2012; in 2021, 92% of the 403 CWT tagged lake trout processed in the Southern Refuge LWAP survey were Klondike strain. The Southern Refuge has met the evaluation objective of attaining a total lake trout CPUE ≥ 25 since 2018.

We earlier reported an increasing trend in the proportion of wild fish (see Natural Reproduction section). For spring LWAP surveys in 2021, about 30% of captured lake trout were wild in mid and southern management units. However, increases in the proportion of wild fish are not translating to steep increases in numbers of wild fish caught in the spring LWAP survey (Figure 5). In 2021, the highest CPUE reported was 2.3 wild lake trout per 1,000'at the Southern Refuge; this is up from 0.4 in 2010. Other sites also show an increasing trend, but the slope of this increase, although positive, is near zero. For comparison, we also report the CPUE, in terms of number of lake trout per sample day, from Great Lakes Fish Tagging and Recovery Lab sport fishery surveys (Figure 4). In general, the within-site trends in the sport fishery data largely match the trends reported by the spring LWAP survey. Specifically, sport fishery data indicate hatchery lake trout abundance has been stable or declining in recent years, while sport fishery CPUE of wild fish exhibits a gradual increase, especially in southeastern regions of the lake. Spring LWAP assessments have also shown declining hatchery CPE in most southern Lake Michigan locations except the Southern Refuge, combined with gradual increases in wild lake trout CPE. In summary, both the spring LWAP and sport fishery time series indicate that recent increases in wild proportions of lake trout have not been accompanied by appreciably higher densities of total lake trout abundance in Lake Michigan, due to being offset by equivalent or larger decreases in relative abundance of hatchery fish in several non-refuge areas.

<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) gill net fished on spawning reefs in MM3, WM5, and at Julian's Reef by 2019.

On a lakewide basis, this evaluation objective is being attained (Figure 6). In 2021, we determined total spawner (wild and hatchery fish combined) CPUE from 31 fall spawner survey lifts from a subset of nine LWAP regions. CPUEs at priority reefs in the Northern Refuge, nearshore MM3, Julian's Reef, and the Southern Refuge met the evaluation objective of $\geq$ 50 fish per 1,000' net. At nearshore sites, total CPUEs are generally high (above or near CPUEs of 50). Therefore, the fall spawner survey results clearly show that total lake trout abundance has increased over time, in contrast to spring LWAP and sport fishery survey data that report relatively low abundances with flat-to-declining trends. Thus, results from the fall gillnet survey are in good agreement with output from statistical catch at age models that show that adult lake trout population size in Lake Michigan has roughly doubled during 2005-2019. Moreover, fall gillnet survey results indicate that on a lakewide basis, hatchery fish CPUE has substantially increased during 2005-2019 (Figure 6). This increasing trend is in accord with results from statistical catch at age models, which indicate that population size of hatchery adult lake trout in Lake Michigan increased by about 75% during 2005-2019. High fall spawner survey CPUEs of total lake trout spawner abundance, along with the increasing trends in proportions of wild fish (Figure 3), are accompanying steep increases in numbers of wild fish at some regions in fall. Wild fish densities in the 2021 spawner surveys were highest in WM3/4 (Sturgeon Bay; 53.8 wild fish per 1,000' net), Illinois reefs (CPUE = 35.2), and Grand Traverse Bay (CPUE = 15.0). In the Southern Refuge, 2021 wild CPUE was 6.3 fish, representing a drastic decline since 2019. However, this data point represents a single spawner survey lift from Northeast Reef, the reef selected for exclusive stocking of Klondike strain fish during 2012-2019. Of the 303 lake trout captured, 280 had an adipose clip and 129 CWTs were processed; 91.4% of the CWTs were Klondike strain from the 2011 to 2015 year-classes. Therefore, this apparent decline in 2021 is likely not representative of the Southern Refuge complex. On the Northern Refuge, wild CPUE increased to 3.1 fish in 2021, up from 0.6 in 2019.

<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.

<u>Percent Female and Age Composition:</u> On a lakewide basis, more than 25% of the lake trout caught in the fall gillnet survey are 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 2021, the proportions of females caught in the Northern Refuge (18.6%) and Southern Refuge (20.3%) are below the 25% benchmark.

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 specifically 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 use fish length from spawner surveys on a lakewide basis to enable a general inference of lake trout age structure at a regional level (Figure 11). Modal length distributions of spawners at southern Lake Michigan sites (excluding the Southern Refuge in 2021) are larger, and presumably older, than spawners in the Northern Refuge and nearshore MM3 waters where both proportions and CPUEs of wild fish remain low. However, spawner lengths at northern sites are similar to Sturgeon Bay and Grand Traverse Bay sites, as both sites report higher densities of wild fish. Wild spawners in Sturgeon Bay (WM3/4) and Grand Traverse Bay had modal lengths in the 600-700 mm bin; mean age (otolith annuli counts) averaged 7 years (range 5 to 13) in Sturgeon Bay compared to 5.7 years (range 3 to 10) in Grand Traverse Bay. Therefore, the spawner size structure at these northern sites appears adequate to support at least limited levels of natural production, which is consistent with the low, but detectable, CPUEs of wild fish reported in fall spawner surveys at these sites. Figure 12 illustrates how this inferred age structure has changed at the Northern and Southern Refuge over the last decade. In 2011, most Northern Refuge spawners were small (500-600 mm total length) but the distribution has gradually shifted to larger and presumably older adults. For the Southern Refuge, the length distributions have shifted towards smaller fish in 2021, but the 2021 data is specific to Northeast Reef where Klondike fish, which are known to grow slower than lean lake trout, dominated the 2021 gillnet assessments.

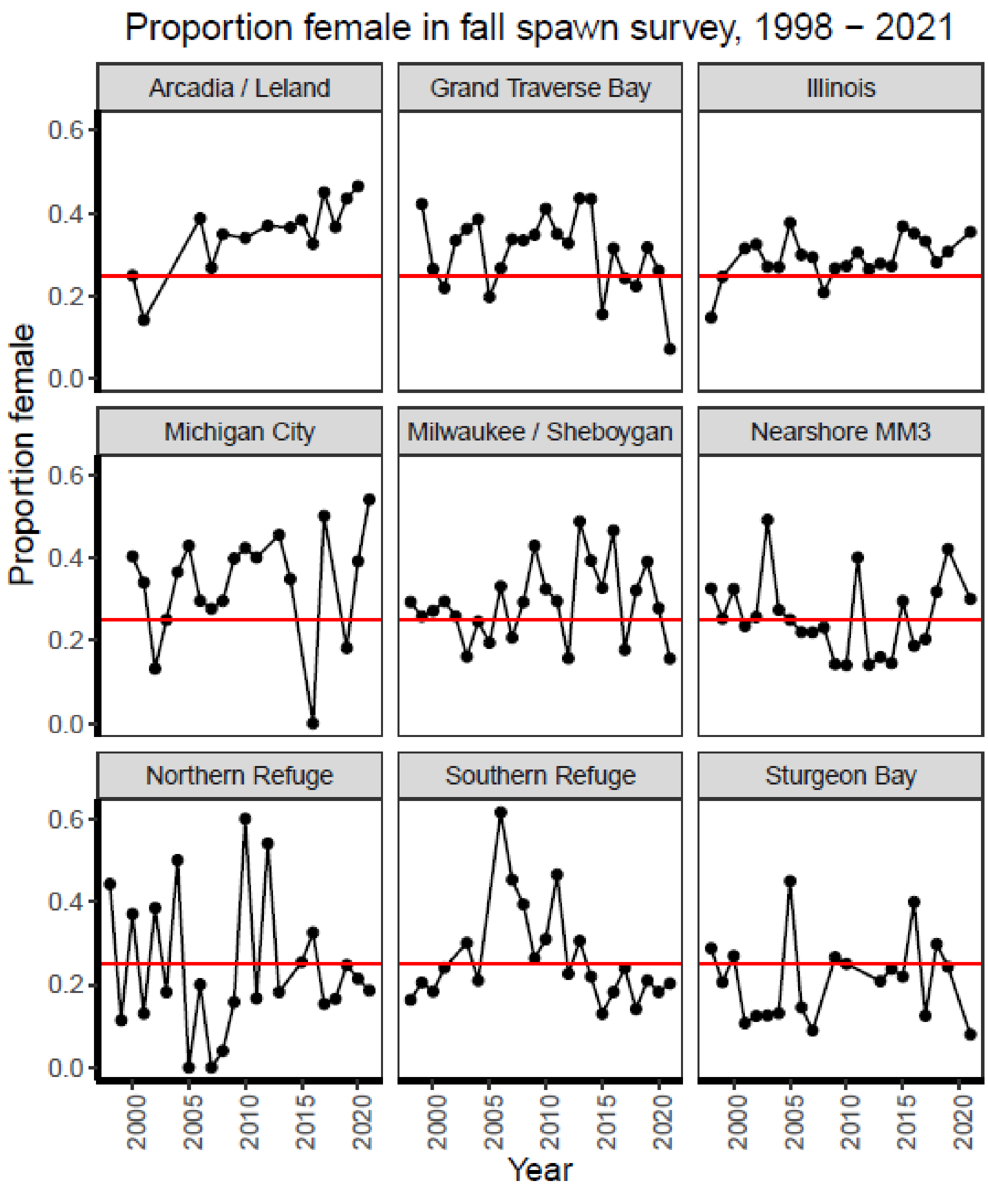


Figure 10: Proportion of females in fall spawner survey catches; the horizontal red line portrays the Strategy evaluation objective of 25% females.

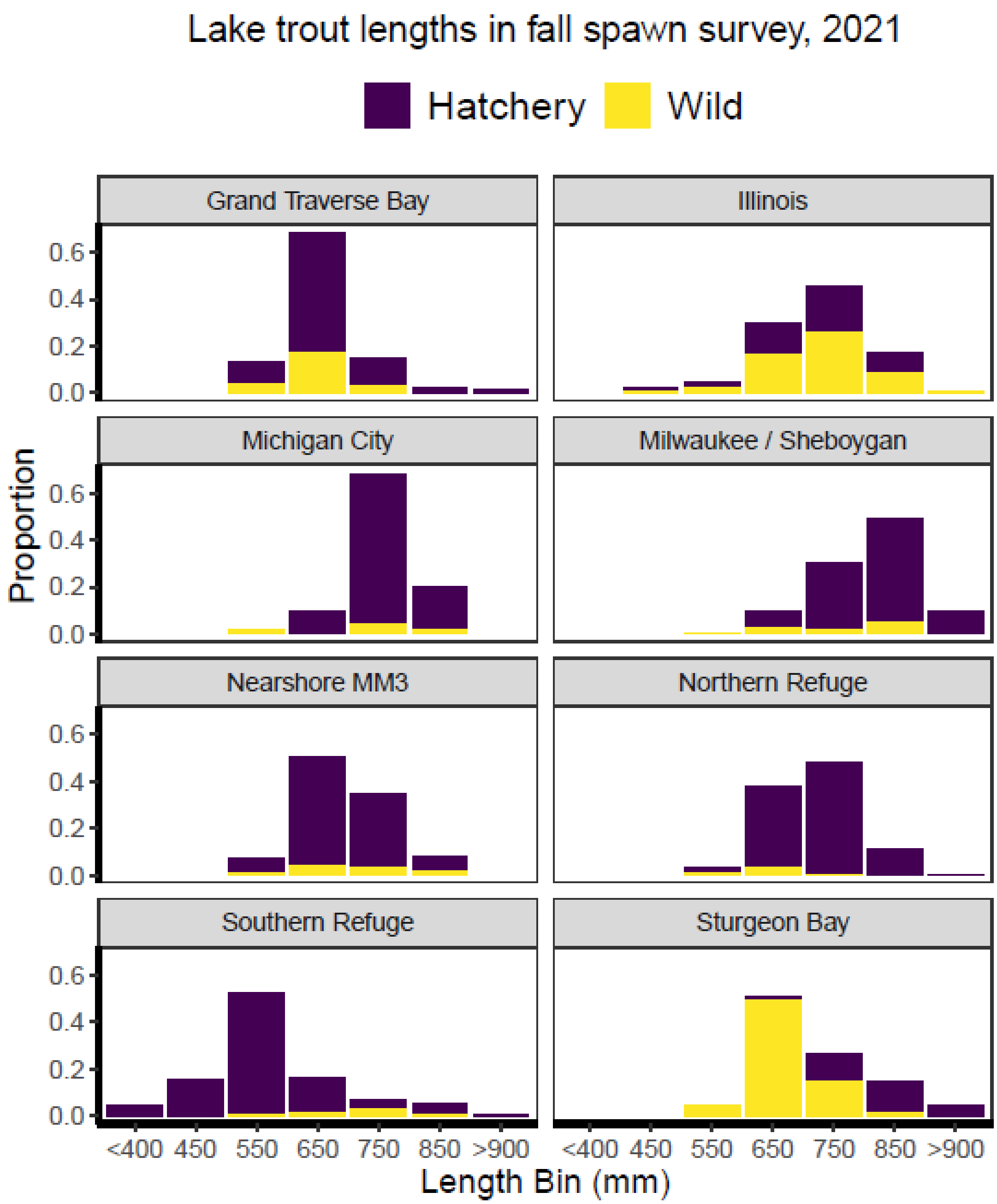


Figure 11: Proportion of lake trout captured in 2021 fall spawner survey within each 100 mm length bin.

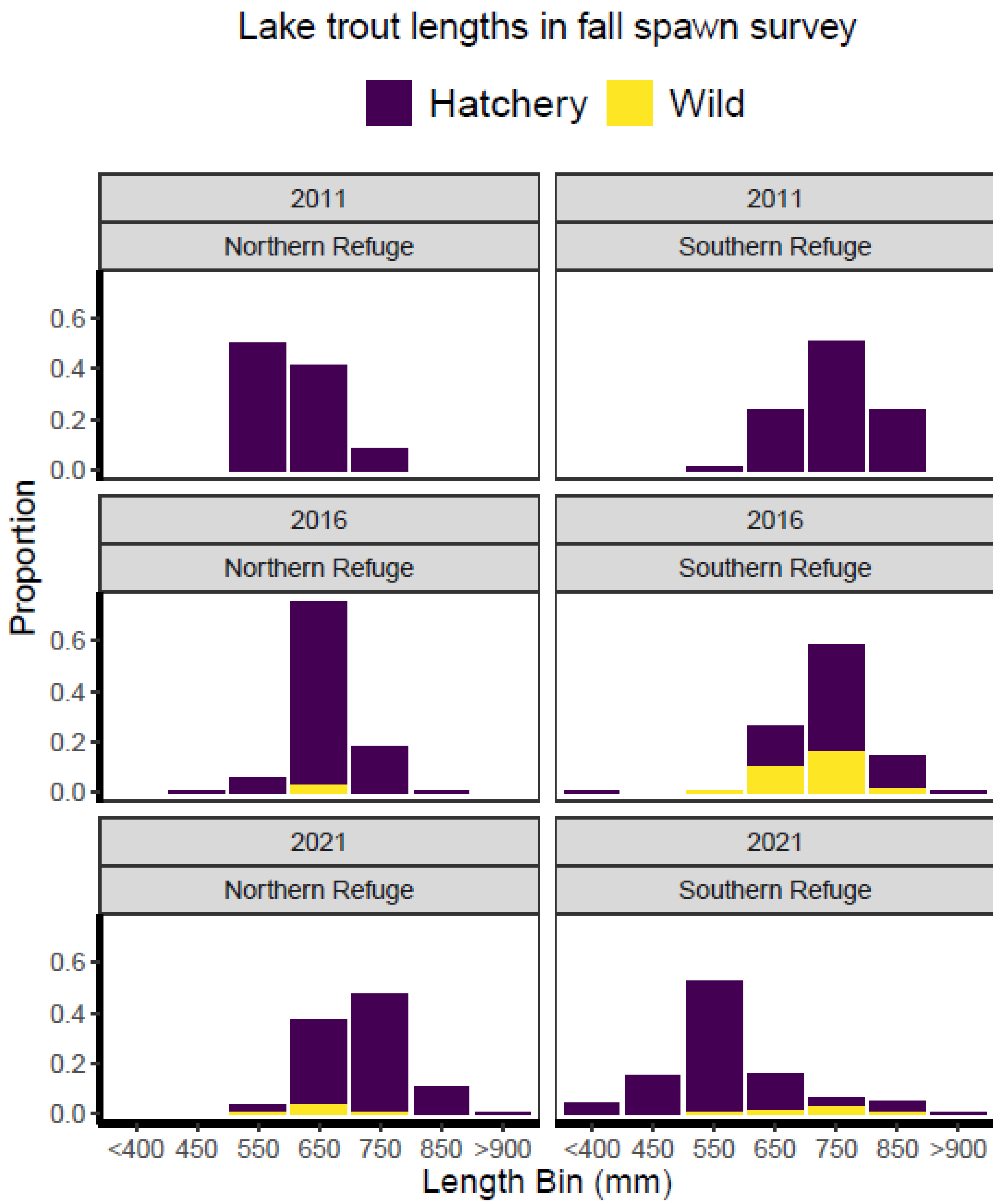


Figure 12: Proportion of lake trout captured in fall spawner survey within each 100 mm length bin for the Northern Refuge and Southern Refuge in 2011, 2016, and 2021.

<u>Evaluation Objective 4:</u> 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.

<u>Egg Deposition:</u> Egg deposition rates have remained below target densities at four sites in northern Lake Michigan during 2000-2021. In 2021, three sites were evaluated, and egg deposition ranged from ~1 to 40 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> During the late 1990s and early 2000s, egg thiamine concentrations were generally near or below the 4 nmol/g evaluation objective threshold. Since the mid-2000s, egg thiamine has increased above the threshold but there has been substantial variation across years and locations (Figure 14).

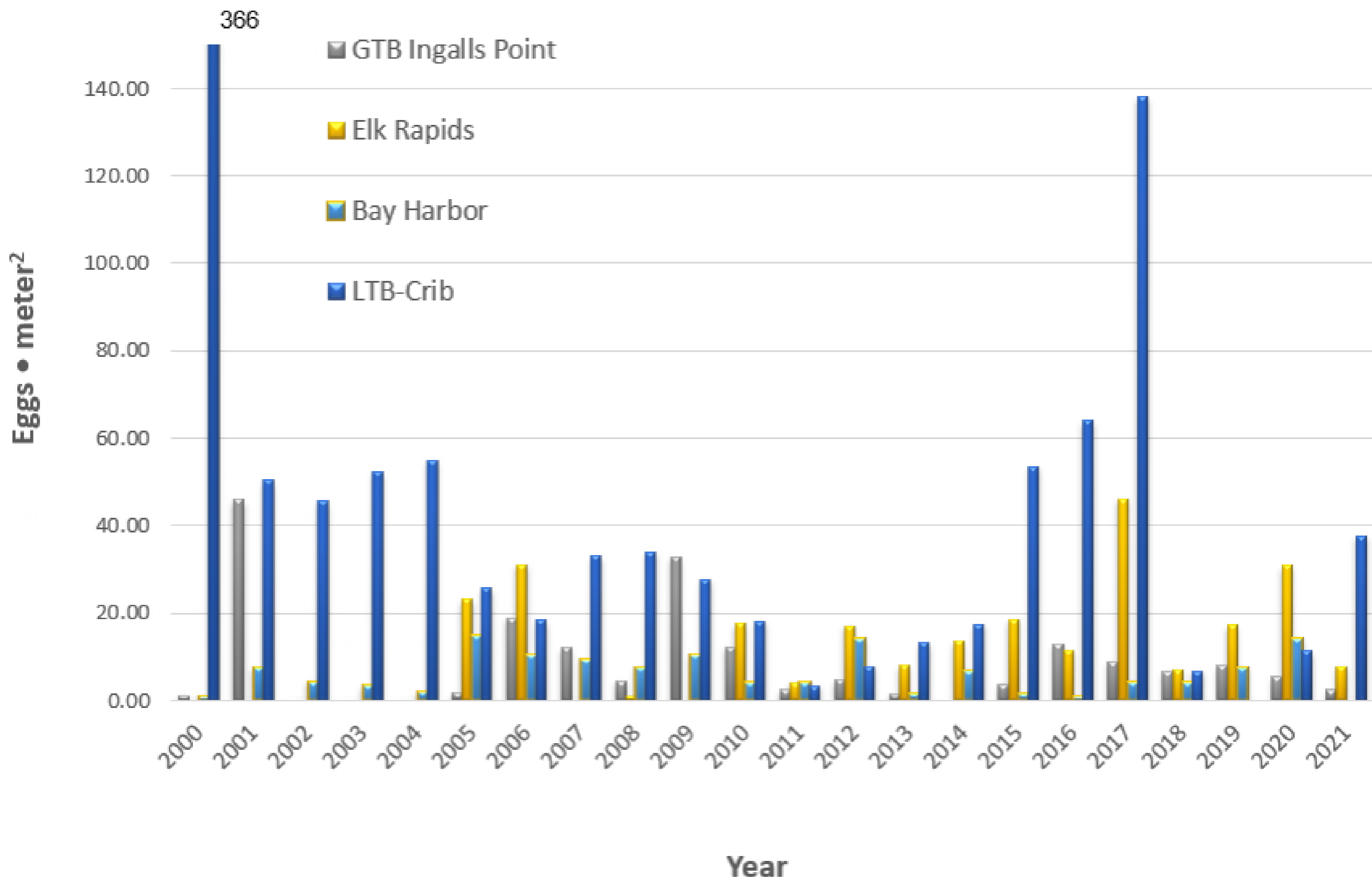


Figure 13: Numbers of lake trout eggs observed per square meter in northern Lake Michigan fall egg deposition surveys, 2000-2021. Egg deposition was measured using standard egg bag methodologies (Jonas et al. 2005).

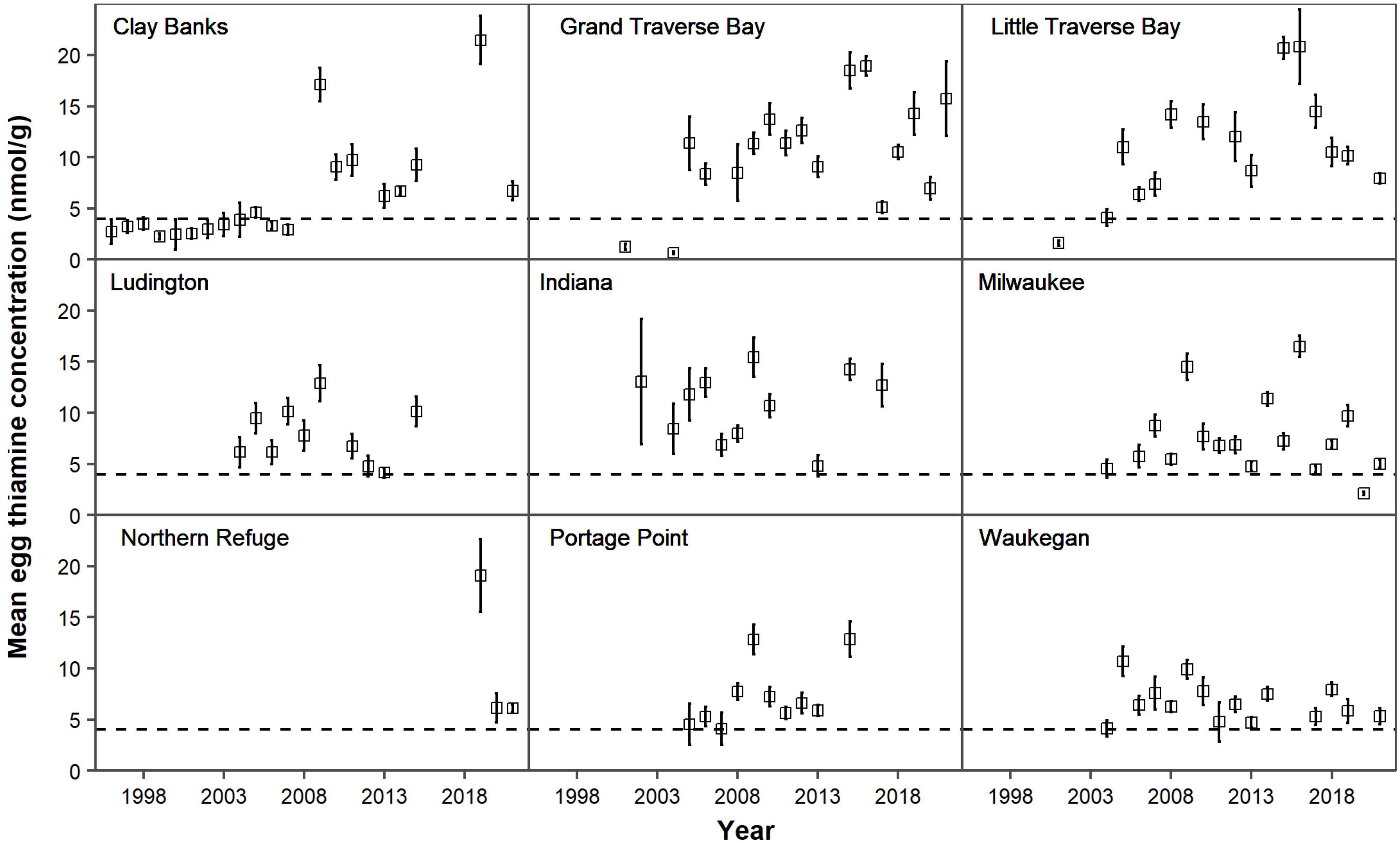


Figure 14: Mean egg thiamine concentrations (nmol/g) for ovulated lake trout females sampled in Lake Michigan fall spawner surveys, 2001-2021. Eggs with thiamine concentrations $\leq$ 4 nmol/g are correlated to a higher probability of exhibiting early mortality syndrome (EMS). Data are provided by Jacques Rinchard, State University of New York at Brockport.

<u>Conclusions</u>: Spring and fall gillnet assessments over the last few years suggest very different trajectories for lake trout restoration in Lake Michigan. Spring survey CPUEs have been recently declining at most locations except for the increase at the Southern Refuge, which appears to be entirely driven by the stocked Klondike strain. Annual increases in proportions of wild fish in the spring gillnet survey, documented for at least a decade in most southern management units, are not attributable to rapid increases in wild lake trout CPUE. Instead, increasing trends in the proportion of wild fish are due to modest increases in wild lake trout CPUE combined with equivalent or larger decreases in hatchery lake trout CPUE in several units. In short, spring data suggest that current levels of natural reproduction may be insufficient to offset the declines associated with the 2017 stocking reduction of lean lake trout in certain nearshore sections of the lake. Therefore, without substantial increases in natural reproduction, total lake trout abundance, as indexed by the spring gillnet survey, may continue to decline in the next few years until wild recruitment offsets the decrease in abundance presumably induced by the stocking rate cuts. Sport fishery survey data suggest a similar outlook but the higher rate of increase of wild fish CPUE in this survey may indicate wild recruitment rates may be already sufficient to compensate for declining CPUEs of hatchery fish. Assuming that annual stocking rates are maintained into the future, lake trout abundance in Lake Michigan should eventually slowly increase as natural recruitment slowly increases, based on the spring gillnet survey results. In contrast, fall survey data suggest lake trout recovery may be on a much faster timeline. Priority refuge complexes and most nearshore reefs throughout the lake have seen increased fall spawner CPUEs over the last two decades and meet the *Strategy* fall benchmark for total lake trout density (CPUE $\geq$ 50). Most impressively, wild fish are now near this benchmark value in Illinois and Sturgeon Bay, WI, and both sites went from wild CPUEs $\leq$ 5 to benchmark values within a decade. Therefore, fall survey wild CPUE can build quickly after detection of natural reproduction at a low threshold level, and presently several locations, including Arcadia, Leland, and Grand Traverse Bay, in northern Lake Michigan may be nearing this threshold level.

Differences in both proportions of wild fish and temporal trends of CPUEs among sport fishery, spring gillnet assessment, and fall gillnet assessment data are difficult to explain. Whether there are ecological differences between wild and hatchery lake trout is an underexplored research theme. Marsden et al. (2022) report 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). The wild proportional differences in our survey data suggest altered habitat use may extend beyond the juvenile life-stage. For the spring survey, we advocate for ancillary studies relating diet to pelagic or benthic habitat use in wild versus hatchery fish.

In addition to the proportion of wild fish differences, temporal trends in lake trout abundance indices are different among our surveys. High CPUE of spawners from targeted gillnet sets on reef tops generate abundance indices at geographically restricted scales; without supplementary data, such as paired hydroacoustic sampling (Warner et al. 2009), spawner CPUE may not accurately characterize densities at scales broad enough to reflect population trends. On the other hand, the flat-to-declining CPUEs reported by spring survey are hard to reconcile with high fall spawner CPUEs that have generally increased during the past two decades. Although fall CPUE is measured at restricted spatial scales, the fall trends are consistent throughout Lake Michigan spawning reefs, which supports the view that adult lake trout population size has increased over time at a lakewide scale. Such an increase is in accord with estimates of adult lake trout population size from statistical catch at age models that indicate that the adult lake trout population size in Lake Michigan has roughly doubled during 2005-2019. One explanation is that the effects of recent stocking cuts in certain nearshore areas are being reflected in the spring assessments, which include mesh sizes suitable to capture small fish from recent year-classes, while not being reflected in the fall gillnet survey, which targets larger fish. However, lake trout stocking reductions were primarily in southern nearshore waters of Lake Michigan, and thus this would not explain discrepancies between spring and fall surveys observed in some northern areas. Another explanation is that lake trout abundance is only one of many factors that affect catch of lake trout in spring survey gill nets, and as a consequence the spring survey may not be accurately tracking lake trout abundance over time. In addition, as previously mentioned, wild lake trout appear to be more catchable in the fall gillnet survey than in the spring gillnet survey. One possible explanation for lower catchability in the spring stems from bathythermal habitat differences between strains of lake trout. In Lake Huron, Seneca Lake lake trout occupied colder water temperatures during May-September and deeper water depths throughout the year than Marquette strain or Lewis Lake strain lake trout (Bergstedt et al. 2012). Perhaps Seneca Lake lake trout are more pelagic than other lake trout strains. Most of the wild lake trout in Lake Michigan are of the Seneca Lake strain (Larson et al. 2020). If Seneca Lake fish tend to exhibit their pelagic behavior much more so during spring than during the fall spawning season, then this could explain, at least in part, the greater catchability of wild lake trout in the fall gillnet survey than in the spring gillnet survey.

The trajectories for lake trout restoration in Lake Michigan differ between that based on spring gillnet survey data and that based on fall gillnet survey data. Based on spring survey results, restoration will proceed at a relatively slow rate, whereas restoration appears to be occurring at a faster rate according to fall survey results. Renewed focus on survey-specific biases will help resolve this discrepancy. In the meantime, sea lamprey suppression efforts continue to be successful, and egg thiamine concentrations are sufficient for lake trout larvae to survive under current forage-base management actions (i.e., maintaining low alewife abundance).

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