2016 Lake Michigan Lake Trout Working Group Report [1]

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* (Dexter et al. 2011); we also include data describing lake trout stocking and mortality to portray the present state of progress towards lake trout rehabilitation.

The Lake Michigan Lake Trout Working Group (LMLTWG)

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[1] The Great Lakes Science Center (GLSC) is committed to complying with the Office of Management and Budget data release requirements and providing the public with high quality data. We plan to make all USGS research vessel data collected between 1958 and 2016 publicly available from the GLSC website later in 2017. The anticipated citation will be http://doi.org/10.5066/F75M63X0. Please direct any immediate questions to our Information Technology Specialist, Scott Nelson, at snelson@usgs.gov. All GLSC sampling and handling of fish during research activities was 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 that we used 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 employ 2.5-6.0" graded multifilament mesh 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 modified LWAP design, 1.5-6.0" mesh, used by Michigan DNR and spring surveys following 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 surveys completed at selected reefs during October – November. Estimates of natural reproduction were determined from the proportion of unclipped lake trout from all lake trout sampled within a management unit. Roughly 3% of stocked lake trout were released without a fin clip (Hanson et al. 2013), and therefore we infer natural reproduction when unclipped fish exceed 3% of all lake trout recoveries. Data sources for lake trout recoveries included LWAP surveys, lake trout spawner surveys, Great Lakes Fish Tagging and Recovery Lab samples of recreationally caught lake trout, and assessment surveys targeting other species that also sampled lake trout. In general, these surveys sampled several hundred lake trout annually in most management units, but we only report data for management units with sample sizes $\geq$ 30 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 2016, salmon and trout (SAT) harvest was 2.53 million kg and for the second consecutive year has been below the minimum threshold (2.7 million kg) of the FCO harvest objective (Figure 1). Lake trout harvest in 2016 was 0.58 million kg. The lake trout harvest objective (0.54 – 1.7 million kg) was previously met from 1985 – 2001 and more recently from 2013 – 2016 (Figure 2).

Natural Reproduction: A total of 680 (10.1%) of the 6,730 lake trout examined for fin clips from 2016 spring and fall gillnet assessments were unclipped hence presumed to be wild. Wild fish accounted for 42% of lake trout in Illinois waters, and 10 – 15% in Wisconsin and southern Michigan (MM7 and MM8) waters of the lake. Fewer wild fish, between 2 and 7% of lake trout, were present in Indiana and northern Michigan (MM3, MM4, and MM5) waters of Lake Michigan. The Great Lakes Fish Tagging and Recovery Lab examined fin clips from 3,990 lake trout caught in the 2016 recreational fishery, and of these 17.1% were wild [2]. Patterns in the spatial recoveries of recreationally caught wild fish were generally similar to that from LWAP although the percentage of wild fish was lower in Illinois (28%) but higher in Indiana (19%) waters (Figure 3). We inferred temporal patterns in natural reproduction from the age structure of wild populations. Preliminary age estimates of wild fish in the 2016 recreational fishery ranged in age between 4 and 21 years with a modal age of 7 years (Figure 4) [3].

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

Fish Stocking: Stocking hatchery reared lake trout to achieve rehabilitation is the primary tool of the "Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan" (Strategy) approved by the Lake Michigan Committee in January 2011. The maximum stocking target is 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). The Lake Michigan Committee adopted an interim stocking target not to exceed 2.74 million yearling equivalents when the strategy was approved. Higher stocking rates could be adopted when Federal hatcheries are capable of more production and there is Lake Committee consensus after their review of decision support tools and information. Nearly 2/3 of the fish are stocked in first priority rehabilitation areas with rehabilitation as the primary objective. The remainder of the fish will be stocked in second priority rehabilitation areas to support local fishing opportunities in addition to rehabilitation.

Since 2008, lake trout have been stocked in accordance to the Strategy and this has substantially increased the numbers of fish stocked in high priority rehabilitation areas (Figure 5). In 2016, 3.02 million lake trout yearlings were stocked with 98.4% of these raised in Federal hatcheries. Lean strains, consisting of Lewis Lake, Seneca Lake, and Huron Parry Sound, represented 93% of all lake trout stocked. Klondike Reef strain, a humper morphotype from Lake Superior, were also stocked (n = 207,400) at Northeast Reef within the Southern Refuge following a Strategy recommendation to introduce a deep-water morphotype to occupy deep-water habitats. Priority rehabilitation areas (Charlevoix, East and West Beaver reef complexes in or near the Northern Refuge and the Southern Refuge reef complex including Julian's Reef) received 73.9% of the lake trout. Over 92% of the Federal lake trout were stocked in offshore waters using the M/V *Spencer F. Baird*.

Lake Trout Mortality: Tracking mortality experienced by Lake Michigan lake trout stocks is best accomplished by stock assessments conducted for the sport and commercial fisheries within the 1836 Treaty waters. Mortality estimated by application of stock assessment models 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 equal to 40% (Bronte et al. 2008; Dexter et. al. 2011).

[2] The lakewide contribution of wild fish to recreational lake trout harvest was derived from Great Lakes Fish Tagging and Recovery data for cases where all creeled fish were examined.

[3] Preliminary lake trout age estimates were derived from single readings of thin-sectioned otoliths for 484 fish. In total, 853 wild lake trout were sampled, and additional ages will be available in the spring of 2017. Preliminary ages may be subject to change following second readings.

In northern Lake Michigan, total mortality rates for lake trout ages 6-11 have exceeded the maximum targeted annual mortality rate of 40% since 1997 (Figure 6, upper panel; Technical Fisheries Committee: 2000 Consent Decree). Commercial fishing contributed to most of the mortality from the late 1990s though 2002 and more recently from 2011 to present day. By 2000 the Manistique River dam failed as a lamprey barrier and subsequently lamprey numbers increased substantially. As a result, the magnitude of lamprey induced mortality was similar to fishing mortality between 2003 and 2010. Since 2003, the Manistique River has been treated eight times which has effectively reduced sea lamprey abundance and mortality on lake trout in northern Lake Michigan (Figure 7). 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 6, bottom panel). Prior to 2003, recreational fishing was the main source of mortality in MM6/7, but with the reduction in overall recreational fishing effort since the 1990s, lamprey induced mortality is now substantially greater than fishing mortality in MM6/7.

<u>Evaluation Objective 1 :</u> Increase the average catch-per-unit-effort (CPUE) to $\geq$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 2016, 175 gillnet lifts were completed lakewide to assess spring lake trout abundance. This included at least 6 lifts at each nearshore LWAP site. Increased effort was directed at the offshore reef complexes with 12 lifts on Northeast Reef in the Southern Refuge reef complex and 34 lifts at 6 reefs (Boulder Reef, Dahlia Shoal, Fisherman's Island, Ile aux Galets, Irishman's Ground, and North Fox Is.) within the Northern Refuge reef complex. About 25% of the lifts stemmed from FIWS sampling that added additional effort to sites between Saugatuck and Manistique (Map 1).

Spring survey CPUEs in the Northern and Southern Refuge reef complexes were below the 25 fish per 1000' benchmark (Figure 8). However increased stocking since 2009 and reduced sea lamprey mortality has rapidly increased CPUE in the Northern Refuge reef complex, from 4.9 fish per 1000' in 2014 to 18.7 in 2016. An increasing trend in the nearshore waters of MM3 has also been observed with 2016 CPUEs of 13.3. CPUE has declined markedly in the Southern Refuge, from a high of 35.8 in 2013 to 9.8 in 2016 while there are no consistent trends in the nearby LWAP locations (Waukegan and Sheboygan).

<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.

In 2016, 62 spawner survey lifts from 9 regions were performed during October-November. Adult CPUE was near or above the 50 fish benchmark in all surveyed regions except for Michigan City (CPUE = 25.5; Figure 9). Trends in spawner densities in the Northern Refuge reef complex mirrored spring survey trends; CPUE increased from 6.8 in 2014 to 47.8 in 2016. Generally spawner densities are increasing at all surveyed locations and remain highest in the Southern Refuge (CPUE = 135.3).

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

Percent Female: Since 1998, the percentage of females captured during the fall spawner surveys has generally exceeded the 25% benchmark (Figure 10).

Age Composition: Spawner survey fish were aged from a subset of surveyed management units including in MM3, MM4, MM6, WM3, and IN. Additionally, in IL waters ages were reported for coded wire tagged fish only. Only reefs surveyed in WM3 and IL contained 10 or more age groups older than age 7. Fish ranged between 2 and 25 years of age but in all units except WM3 the modal age was 5 or 6 years. Spawners in MM3 were young with few fish > age 8 but older fish were represented in all other units (Figure 11).

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

Egg Deposition: Egg deposition rates have remained low at the four sites where egg deposition has been measured in northern Lake Michigan during 2000-2016, although egg deposition in Little Traverse Bay increased during 2011-2016 to a level of about 60 eggs per m^2 in 2016 (Figure 12).

Egg Thiamine Concentration: Mean thiamine concentrations for lake trout eggs sampled in fall spawner surveys during 2001-2013 show that thiamine concentrations exceeded 4 nmol/g in most areas of the lake during 2005-2010 (Figure 13). In 2013, thiamine concentrations fell slightly to at or below the 4 nmol/g threshold in southern and eastern Lake Michigan waters, including reefs near Waukegan (ILL), Michigan City (IND), Milwaukee (WM5), and Portage Point and Ludington (MM6).

Conclusions: Since 2013, lake trout harvest from Lake Michigan has partly met the specified Fish-Community Objectives, as lake trout annual harvest has exceeded 0.54 million kg. The majority of the lake trout harvest has been from northern Lake Michigan, where lake trout annual mortality still exceeds the 40% target level. Since 2013, fishing mortality, largely attributable to commercial fishing, has been the predominant component of lake trout mortality in northern Lake Michigan. In the Southern Refuge and at Julian’s Reef, the Strategy evaluation objectives have largely been met, as lake trout populations in these areas are characterized by high spawner densities, a diverse age structure including older age-classes, and an increasing trend in the proportion of wild fish. However these populations are not considered self-sustaining yet as they are still stocked and comprised of ≥ 50% hatchery fish. Among northern populations, higher stocking rates in the northern priority area have resulted in increasing lake trout density. Recently, sea lamprey induced mortality rates in this northern priority area have declined as a result of intensive eradication efforts on the Manistique River since 2003. Progress toward lake trout rehabilitation in this northern priority area can be accelerated by a reduction in fishing mortality to achieve the target mortality level.

Fall spawner densities in the southern priority areas, western Lake Michigan sites at Sturgeon Bay, Sheboygan, and Milwaukee have generally met or exceeded the 50 fish per 1000 feet benchmark since 2007, and recent natural reproduction is evident in each of the corresponding management units to varying degrees. Spawner densities at Arcadia (MM5) have also consistently exceeded the spawner benchmark and evidence from the Great Lakes Fish Tagging and Recovery Lab suggests wild fish now comprise roughly 10 – 15% of the lake trout population in eastern Lake Michigan. Sites in northern Lake Michigan, including Grand Traverse Bay, the Northern Refuge, Little Traverse Bay, and nearshore MM3 reefs, have shown increasing spawner densities, but to date these populations are relatively young and substantial production of wild fish has yet to be observed.

The apparent onset of detectable and sustained natural reproduction by lake trout in Lake Michigan, as documented by Hanson et al. (2013) and Patterson et al. (2016), also coincided with reduced alewife abundance. A substantial increase in lake trout natural reproduction appeared to begin around 2004. Alewife abundance in Lake Michigan in 2004 was at a reduced level, and abundance has continued to decline to the present time (Madenjian et al. 2016). Reduced densities of alewives can facilitate natural reproduction by lake trout through decreased potential for alewife predation on lake trout larvae (Krueger et al. 1995). Continued declines in alewife densities since 2004 were also weakly correlated with an increase in mean thiamine content within lake trout eggs (Riley et al. 2011), although by 2013 egg thiamine concentrations have dropped below 4 nmol/g at selected sites in eastern and southern Lake Michigan. Recent evidence suggests that wild lake trout fry may be able to mitigate thiamine deficiency with early feeding on thiamine-rich zooplankton (Ladago et al. 2016).

In summary, widespread recruitment of wild fish is now occurring in southwest Lake Michigan where evaluation objectives for spawner abundance, spawner age composition, percent spawning females, target mortality, and thiamine egg concentrations (in most years) have been achieved. Recruitment of wild fish, at a lesser scale, is now evident in mid-latitude management units, especially on the western shore. We have shown that managing lake trout stocks to achieve the population objectives provided in the Implementation Strategy remains an appropriate strategy to achieve progress toward lake trout rehabilitation in Lake Michigan.

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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.

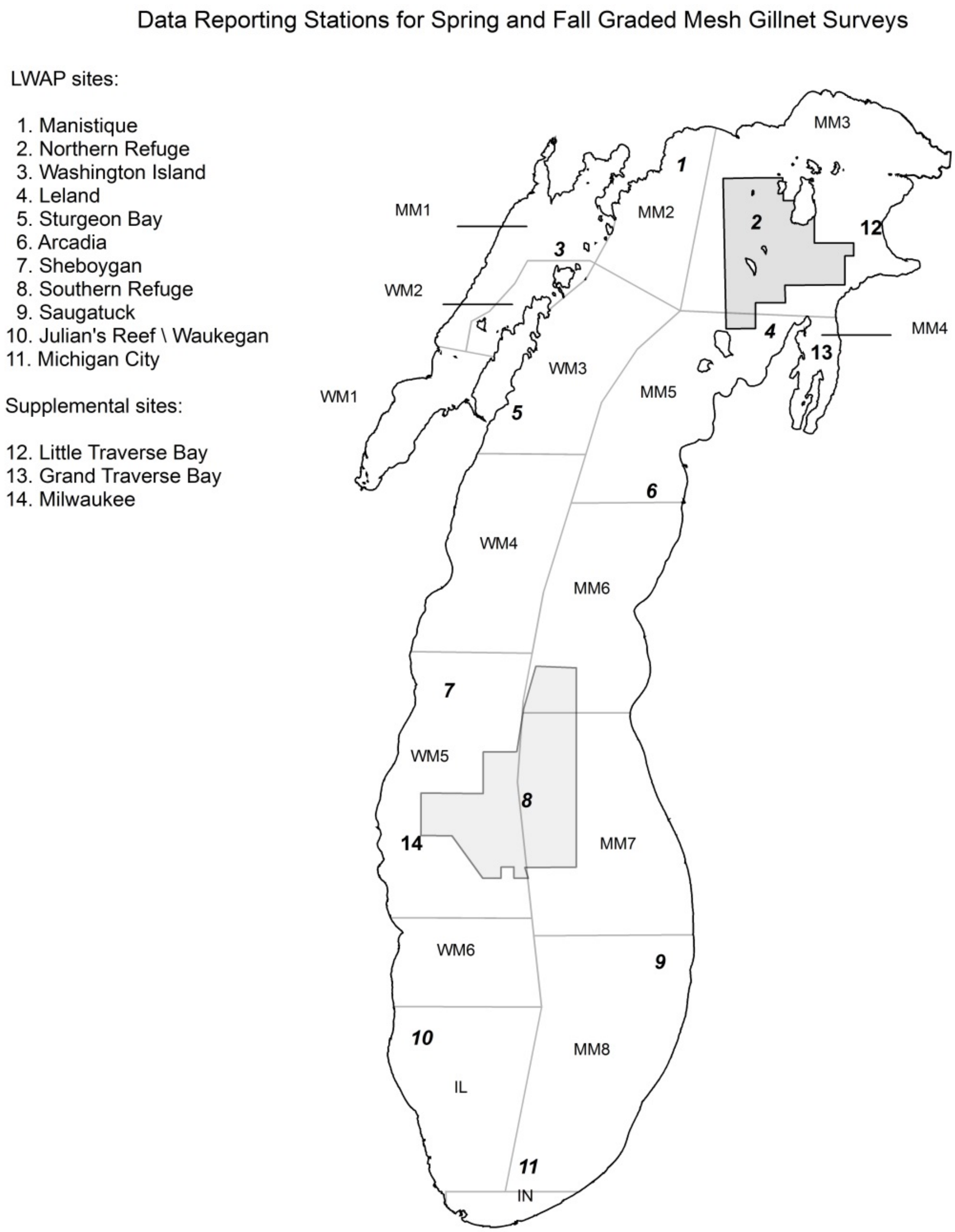


Figure 1. Lake Michigan total harvest (1985 – 2016) of for lake trout and all species of salmon and trout (SAT); green-shading depicts the range of SAT harvest in the FCO while blue-shading depicts the 20-25% range of SAT harvest reserved for lake trout.

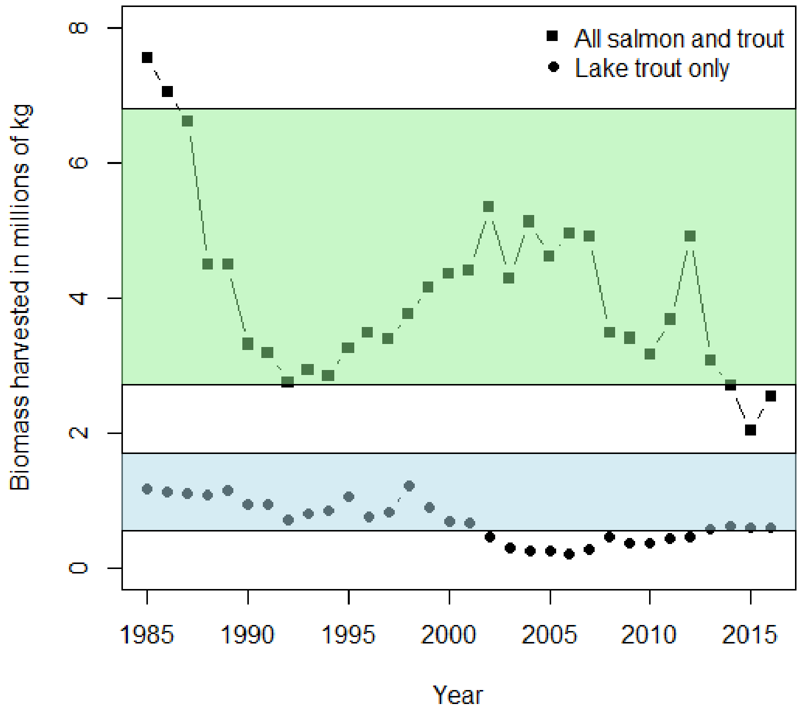


Figure 2. The percentage of SAT harvest comprised of lake trout; blue shading represents the 20 - 25% specified in the FCO.

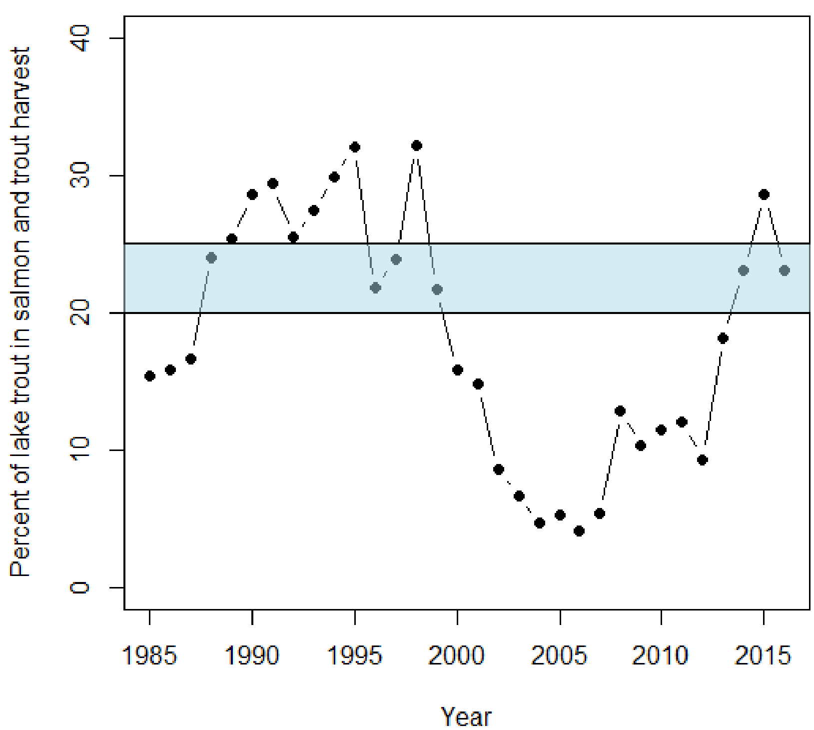


Figure 3. The proportion of wild (unclipped) lake trout captured in spring and fall assessment surveys from each statistical district (black lines). Data points are only included when at least 30 lake trout per year were examined. Red boxes show the proportions of unclipped lake trout examined from the Great Lakes Fish Tagging and Recovery Lab sampling between 2014 and 2016. The gray line represents 3% marking error, e.g. hatchery origin fish that were stocked with no fin clip.

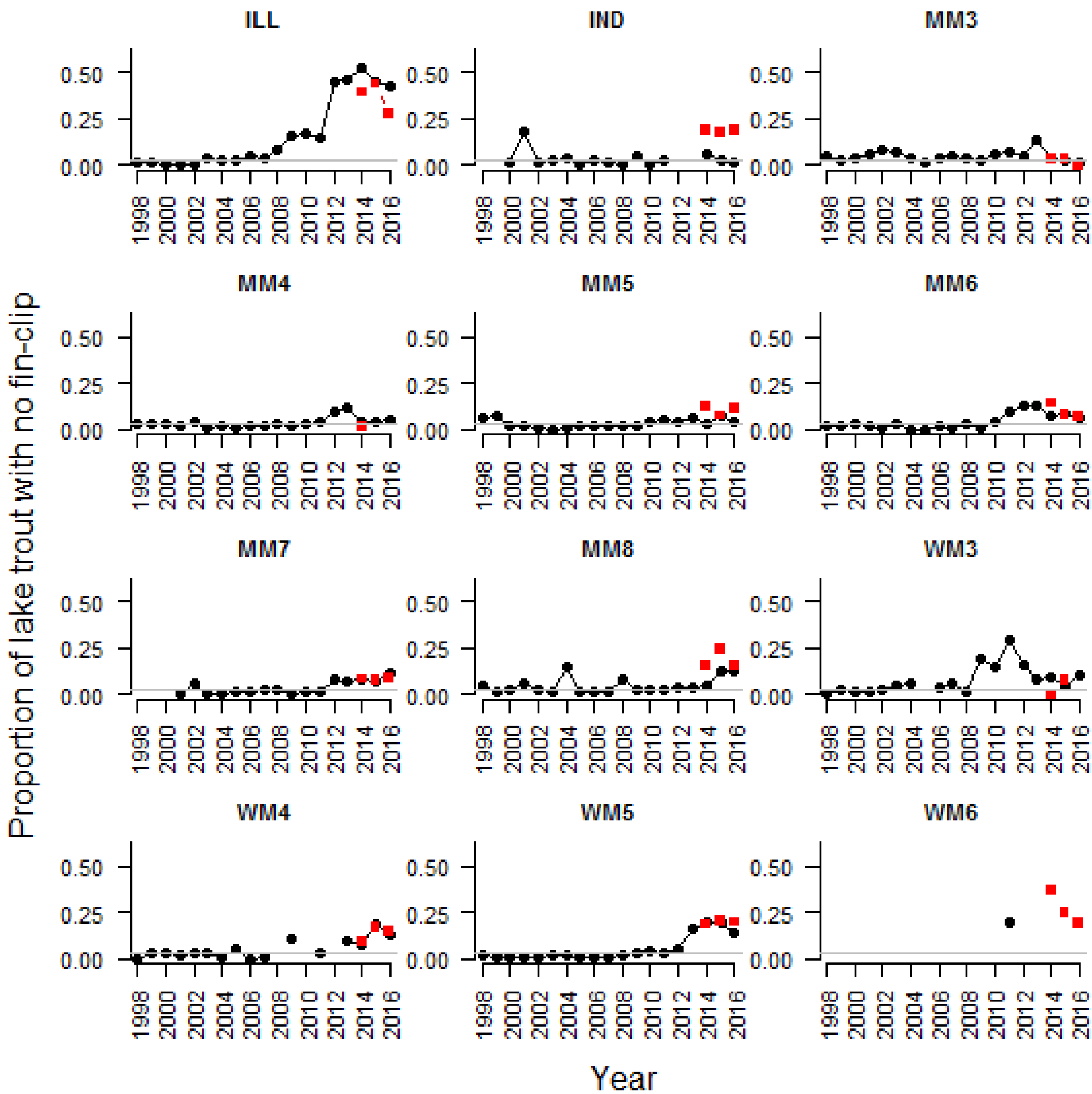


Figure 4. Wild lake trout age structure determined from thin-sectioned otolith reads for recreationally caught fish sampled by the Great Lakes Fish Tagging and Recovery Lab in 2016. These preliminary data represent age estimates (from a single reader) for 484 fish. In total 853 wild lake trout were sampled and additional ages will be available in the spring of 2017. Preliminary ages may be subject to change following second readings.

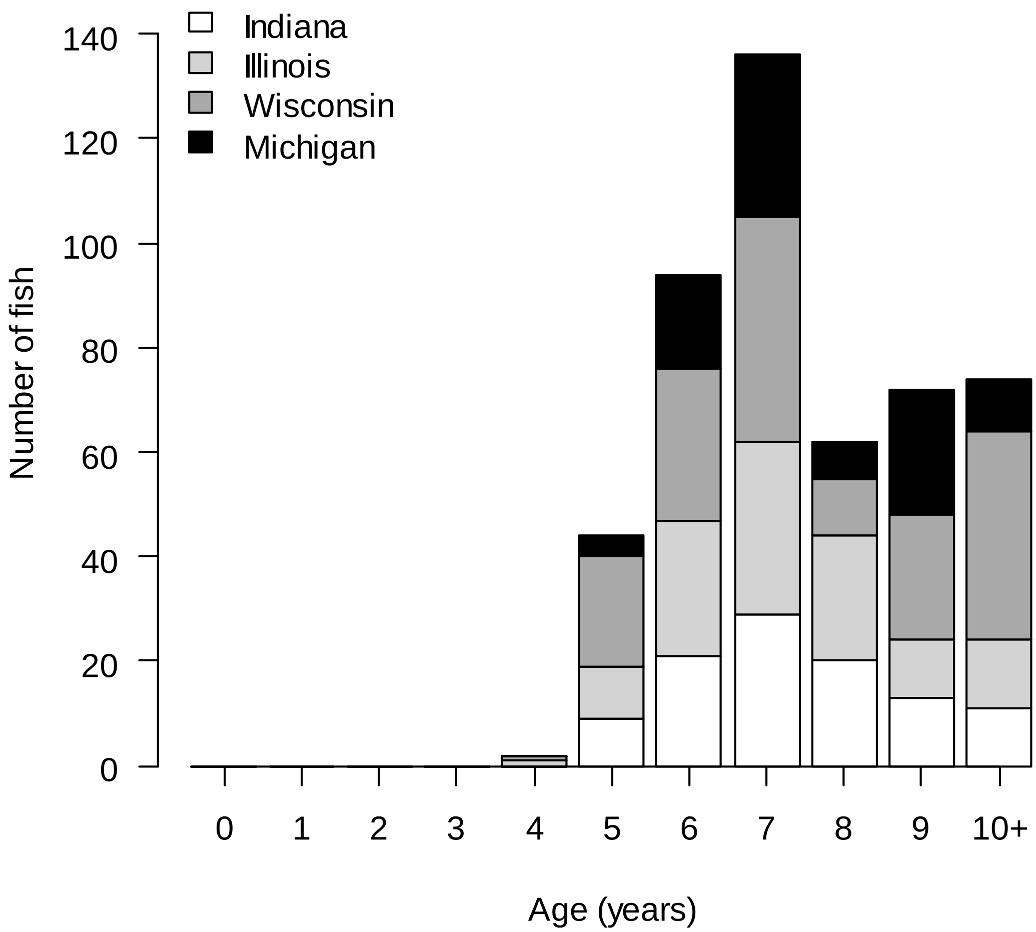


Figure 5. Number of lake trout (yearling equivalents) stocked in Lake Michigan by region, 1995 – 2016. In the "lakewide" panel, the black line represents the 3.53 million maximum stocking target prescribed in the Strategy while the red line represents the 2.74 million interim target currently approved by the Lake Committee.

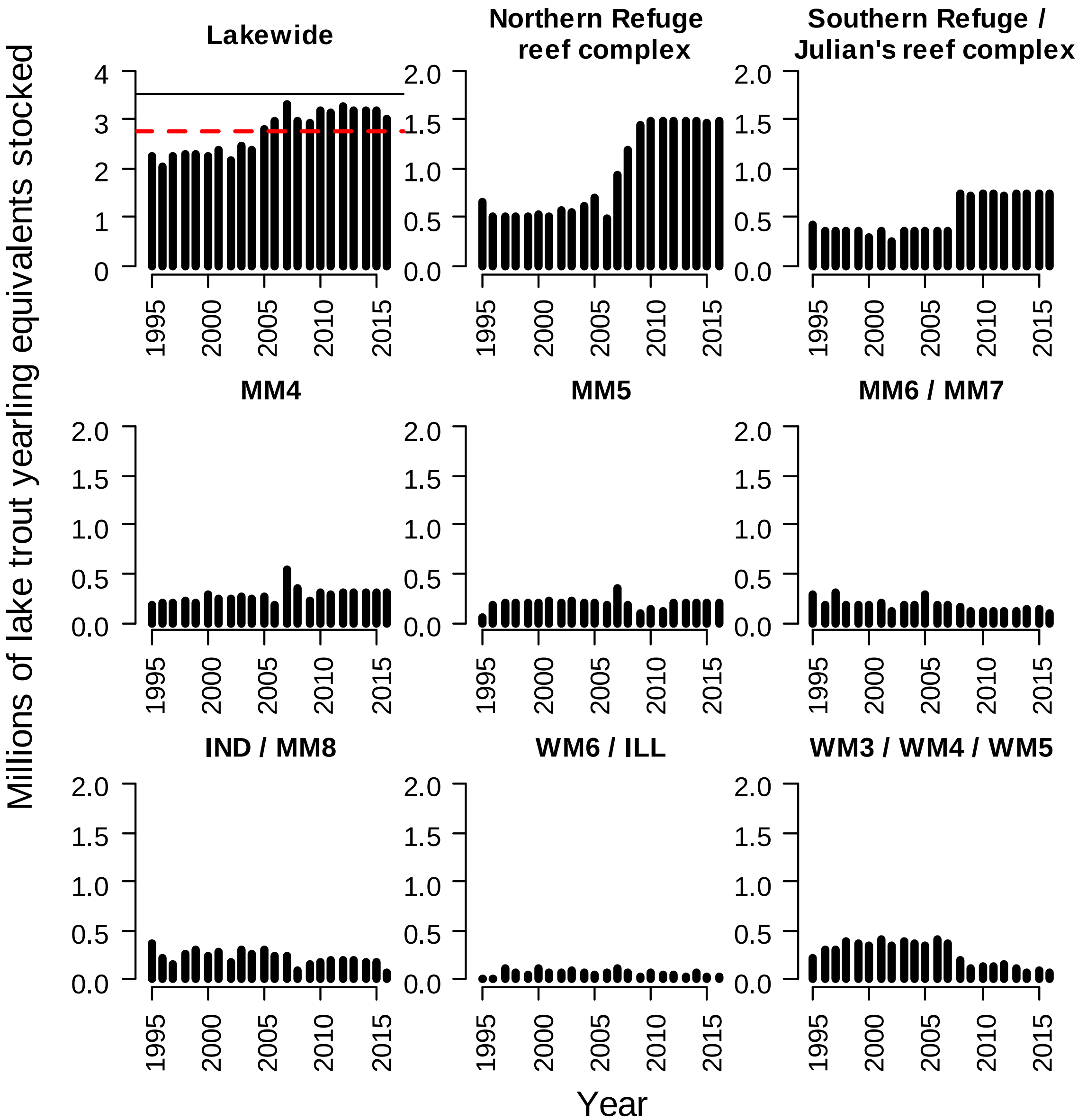
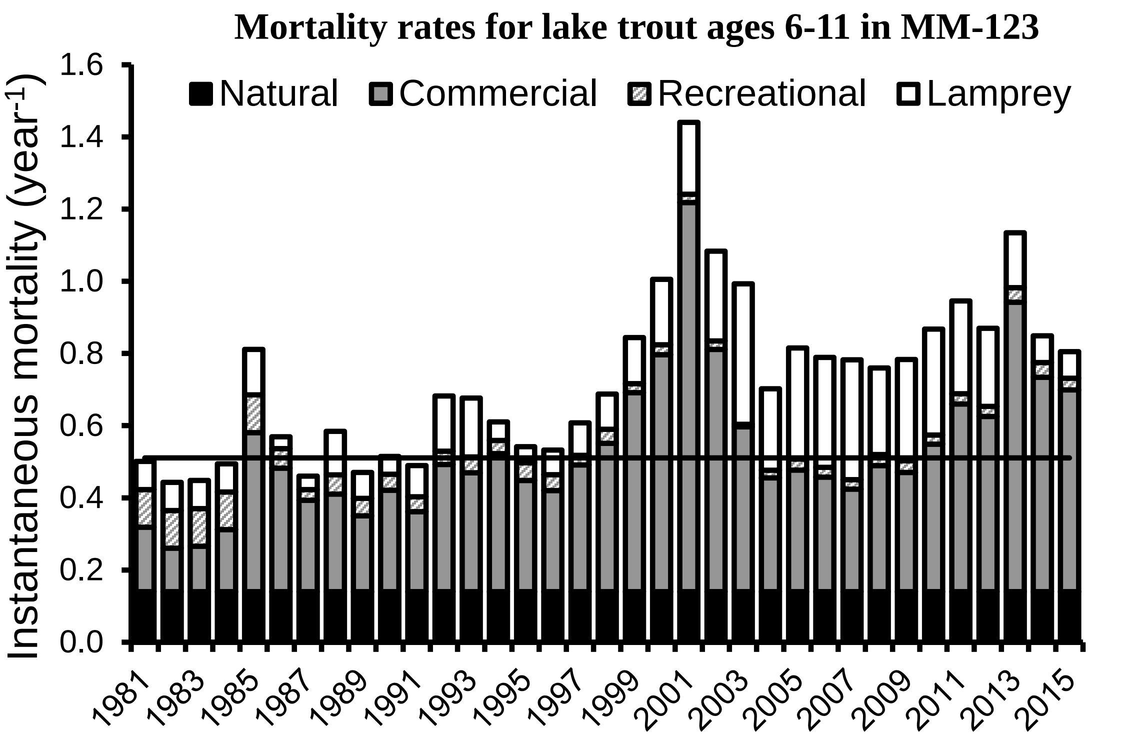


Figure 6. Instantaneous mortality rates for lake trout ages 6-11 in northern Lake Michigan and in MM6/7 waters proximal to the Southern Refuge. The black dashed line represents an instantaneous mortality rate of 0.51 that is equivalent to a 40% annual mortality rate.



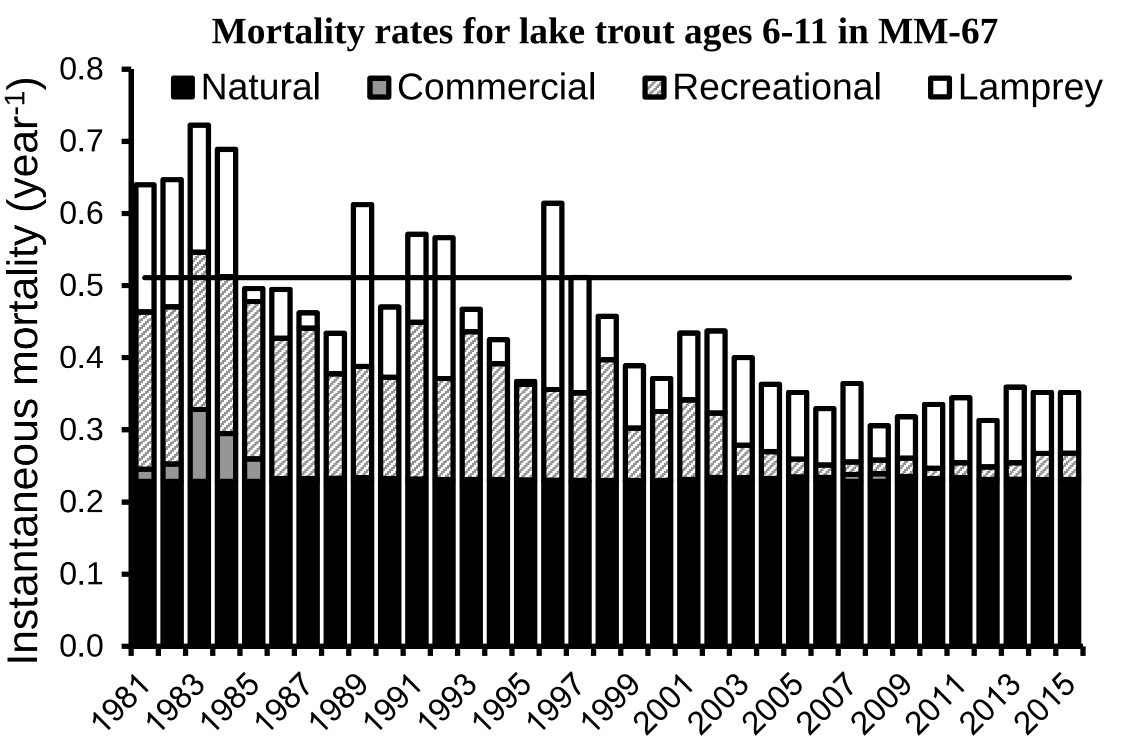


Figure 7. Sea lamprey induced mortality on lake trout ages 6-11 for Lake Michigan management units MM3 and MM6/7.

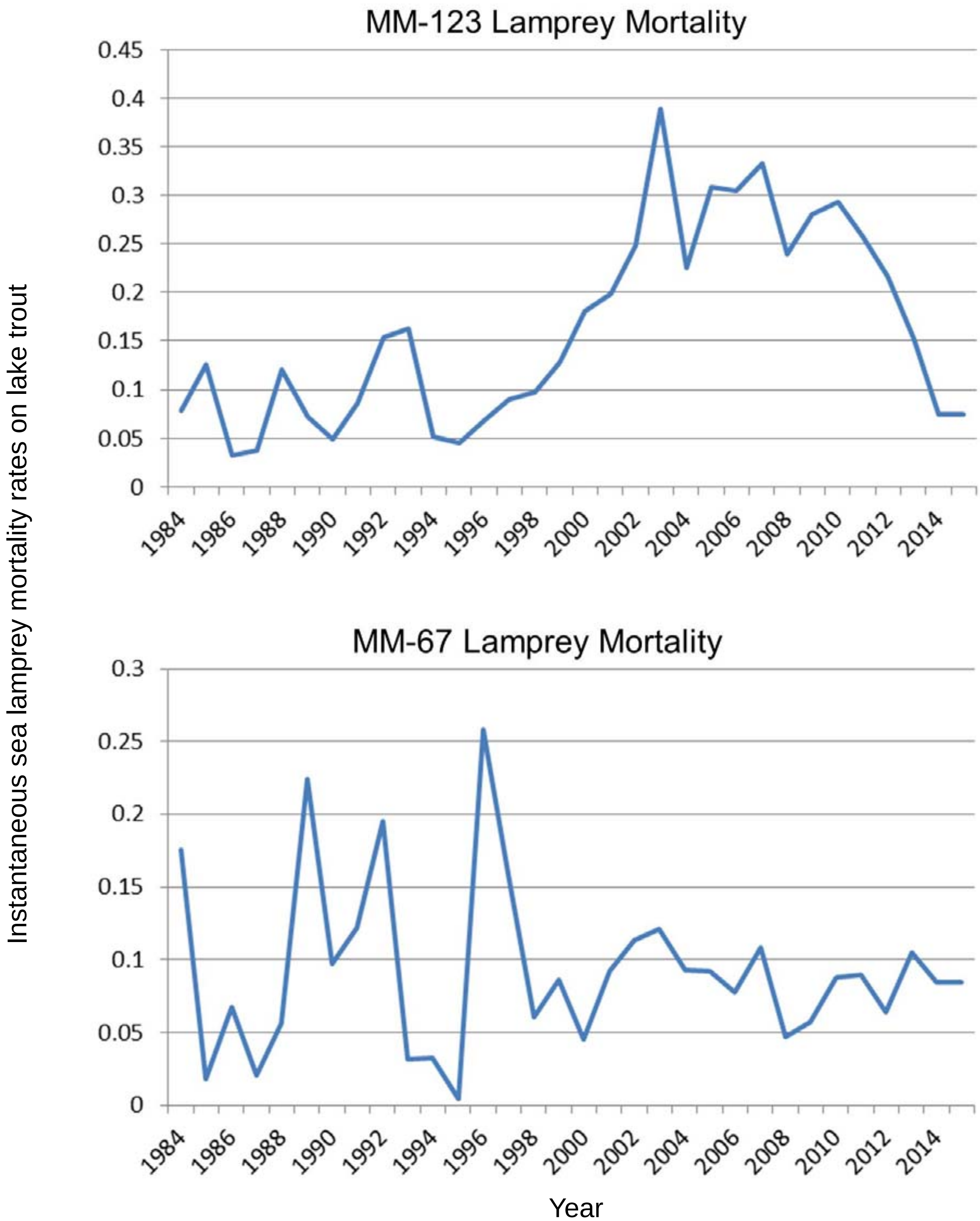


Figure 8. Time series of spring survey lake trout catch per effort (mean number of fish/1000 ft of graded mesh gill net) for the 11 LWAP sites plus 2 supplemental sites with comparable data (Grand Traverse Bay, Little Traverse Bay including near shore MM3 waters). Vertical bars represent ± 2 SE and the horizontal gray line shows the spring CPE benchmark of 25 fish per 1000'.

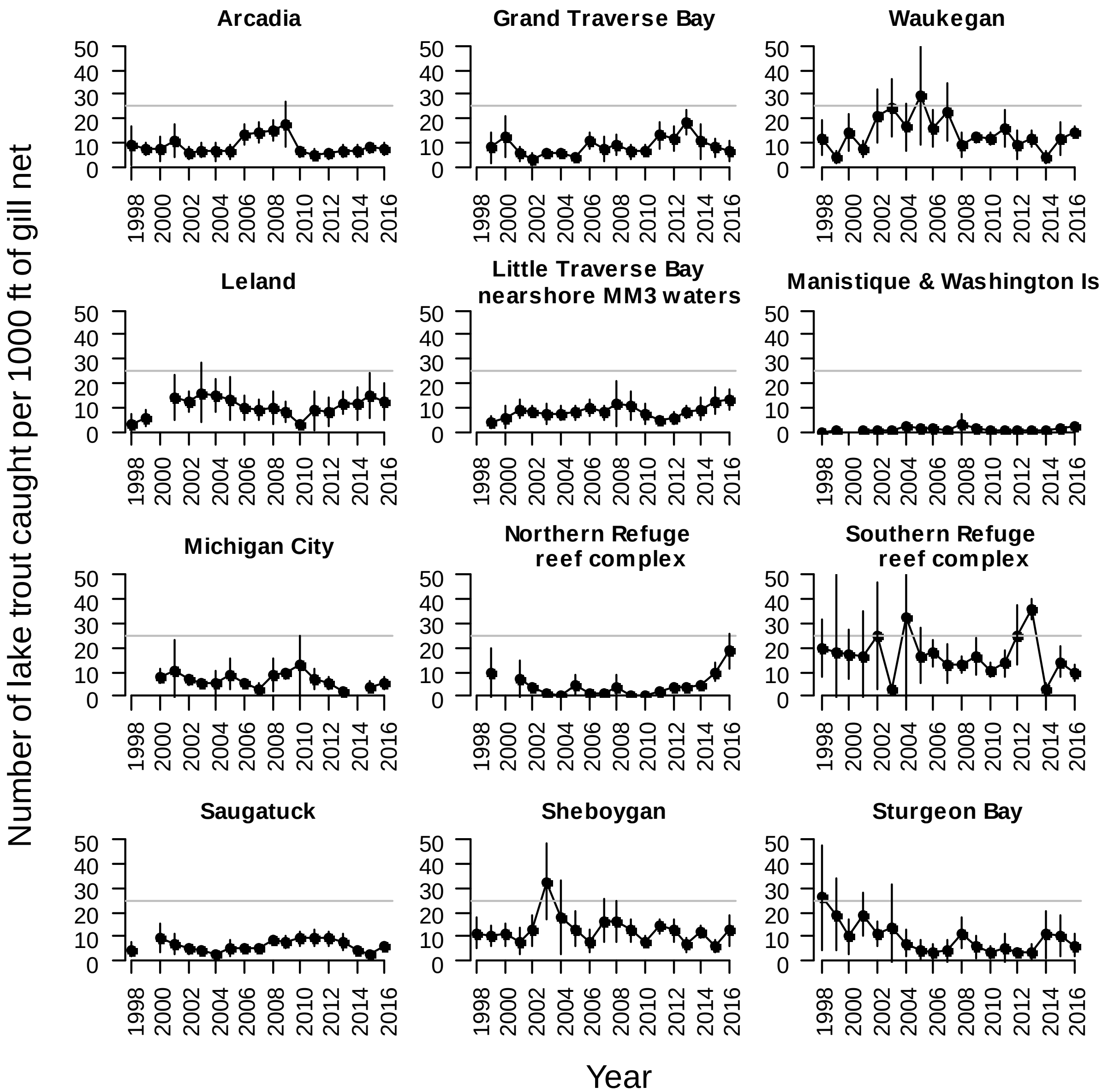


Figure 9. Time series of fall lake trout spawner survey catch per effort (mean number of fish/1000 ft of graded mesh gill net) for reefs within or near the spring LWAP stations. Vertical bars represent ± 2 SE and the horizontal gray line shows the fall CPE benchmark of 50 fish per 1000'.

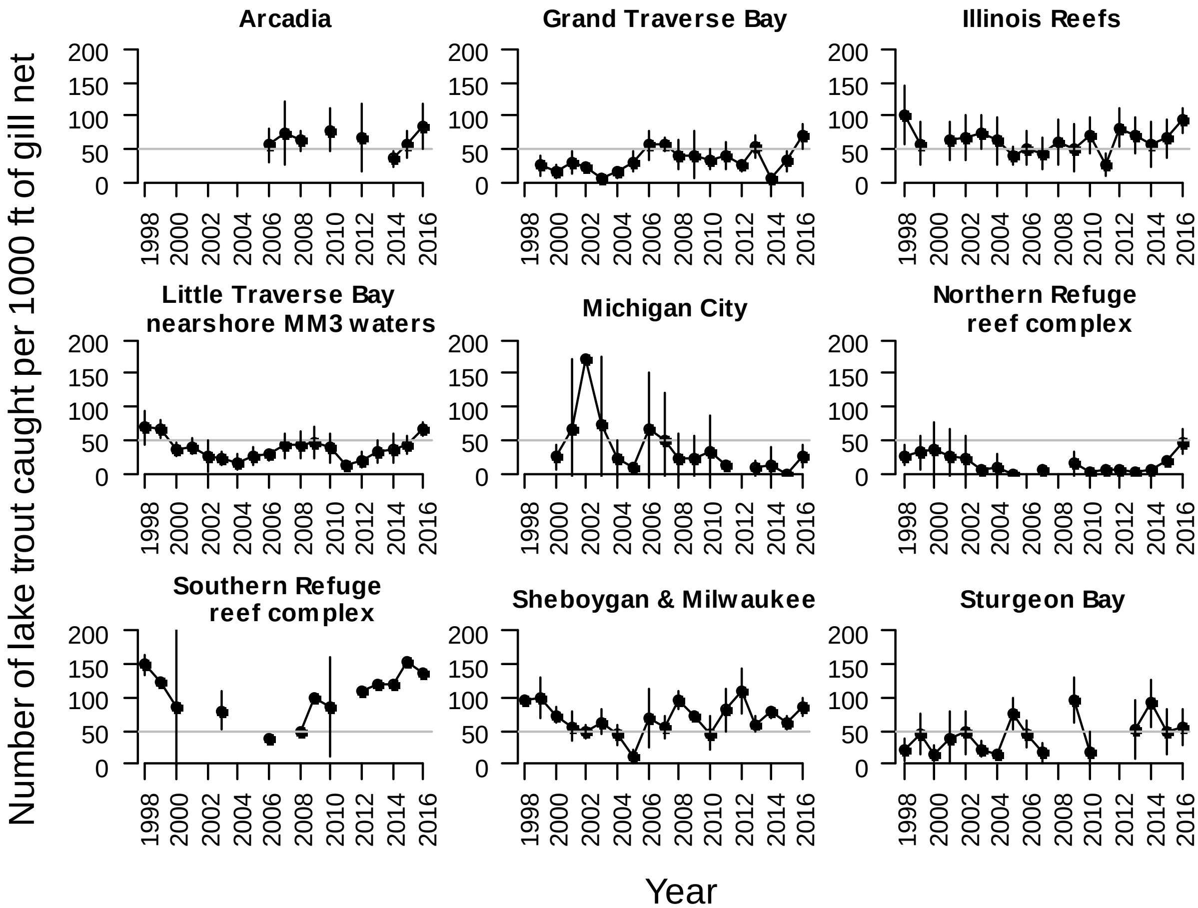


Figure 10. Proportion of females in fall spawner survey catches; the horizontal gray line portrays the Strategy evaluation objective of 25% females.

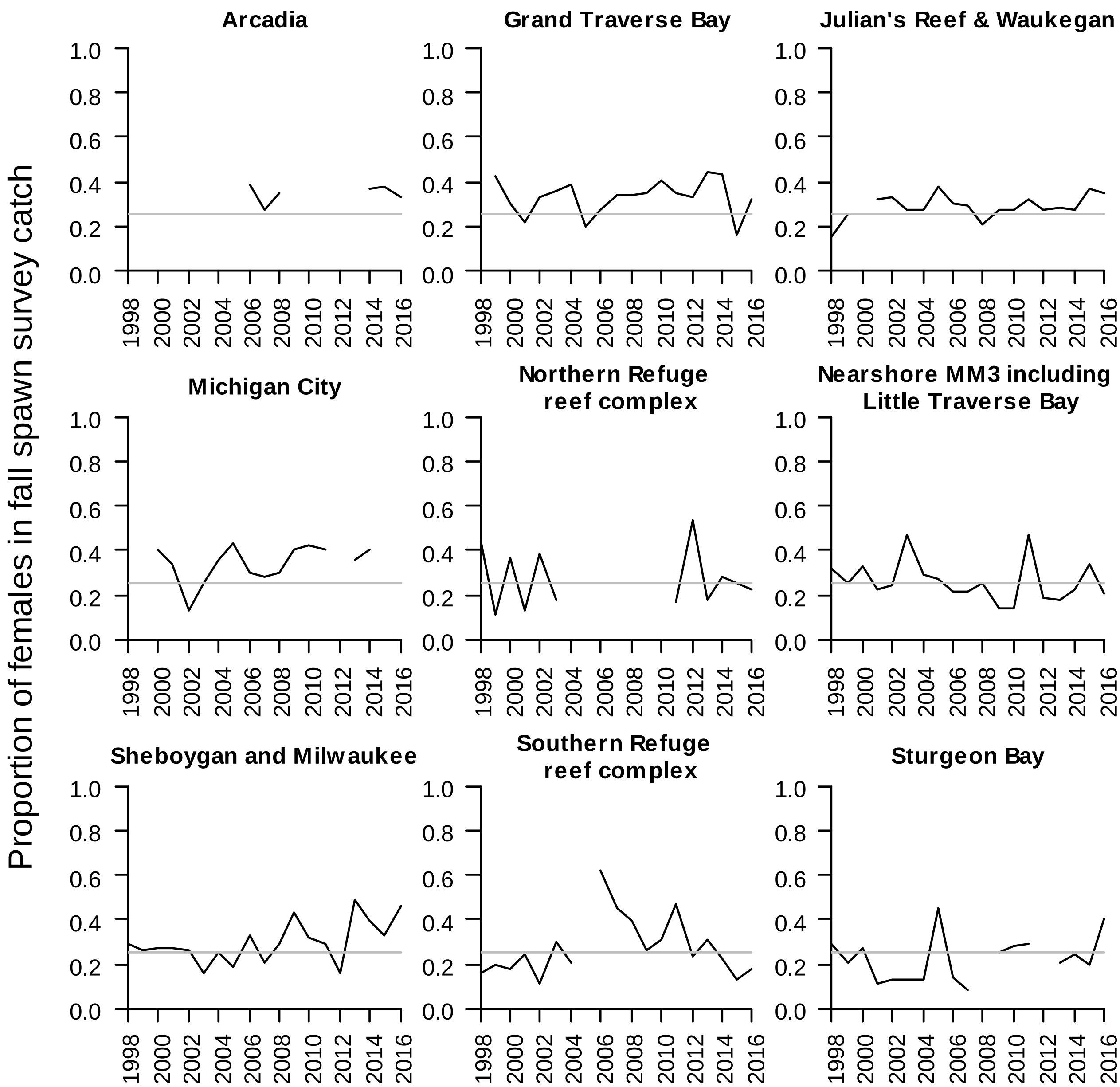


Figure 11. Number of lake trout captured during 2016 spawner surveys, by age-class and management unit.

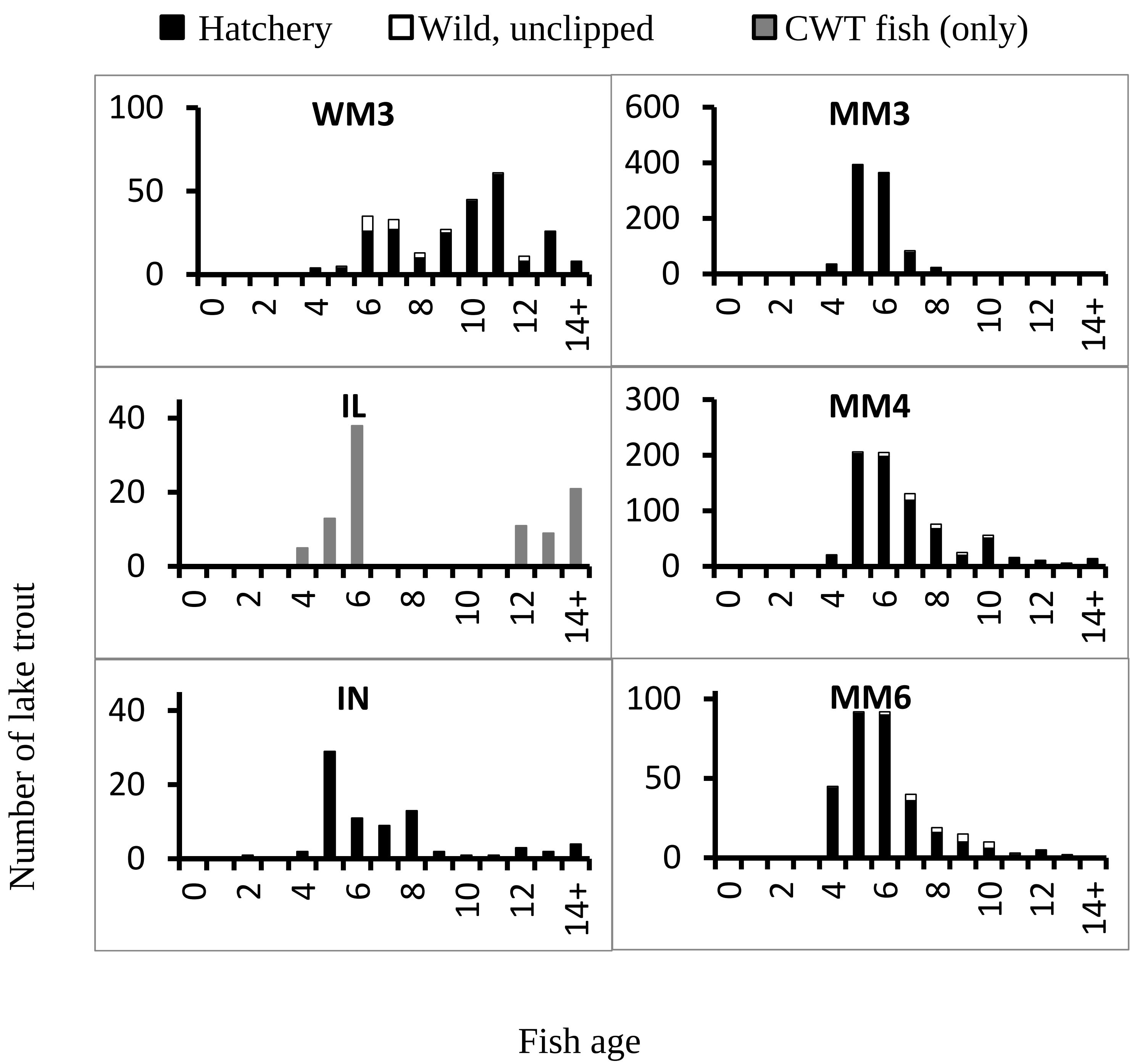


Figure 12. Numbers of lake trout eggs observed per square meter in northern Lake Michigan fall egg deposition surveys, 2000-2016. Egg deposition was measured using standard egg bag methodologies (Jonas et al.2005).

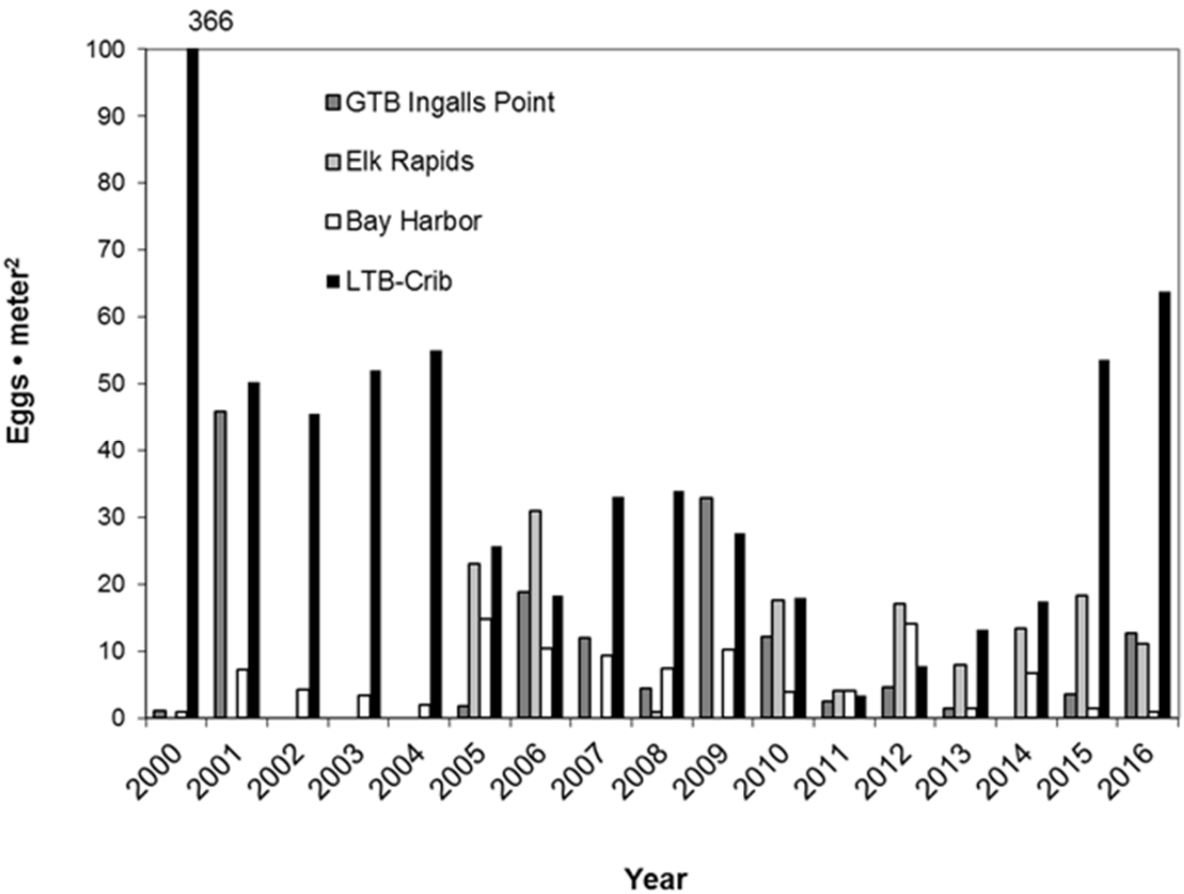


Figure 13. Mean egg thiamine concentrations (nmol/g) for ovulated lake trout females sampled in Lake Michigan fall spawner surveys, 2001 – 2013. Larvae produced from eggs with thiamine concentrations ≤ 4 nmol/g are often correlated with observations of early mortality syndrome (EMS).