Inland Seas Angler

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Highlights of the Annual Lake Committee Meetings

Great Lakes Fishery Commission proceedings, Duluth, MN

This second of a series of annual special reports is a summary of Lake Michigan. This lake committee report is from the annual Lake Committee meetings hosted by the Great Lakes Fishery Commission in March 2013. We encourage reproduction with the appropriate credit to the GLSFC and the agencies involved. Our thanks to Steve Robillard, IL DNR; Brian Breidert, IN DNR; Dale Clapp, MI DNR; Dale Hanson, Charles Bronte and Mark Holey, USFWS; and also thanks to the staffs of the GLFC and USGS for their contributions to these science documents. Thanks also to the Great Lakes Fishery Commission, its staff, Chris Goddard & Marc Gaden, for their efforts in again convening and hosting the Upper Lake Committee meetings in Duluth.

Lake Michigan

Index of Reports

Abbreviation	Expansion
CPH	Catch per hectare
CWT	Coded Wire Tag
KT	1,000 metric tons
MDNR	MI Dept of Natural Resources
USFWS	US Fish and Wildlife Service
WTG	Walleye Task Group
YAO	age 1 and older
YOY	Young of the year (age 0)

Status of Pelagic Prey Fish Populations in Lake Michigan, 2012(USGS)

Abstract

The 2012 survey consisted of 26 acoustic transects (576 km total) and 31 midwater tows. Mean total prey fish biomass was 6.4 kg/ha or 31 kilotonnes (kt = 1,000 metric tons), which was 1.5 times the estimate for 2011 and 22% of the long-term mean. The increase from 2011 resulted from increased biomass of age-0 alewife, age-1 or older alewife, and large bloater. The abundance of the 2012 alewife year class was similar to the average, and this year-class contributed 35% of total alewife biomass (4.9 kg/ha), while the 2010 alewife year-class contributed 58%. The 2010 year class made up 89% of age-1 or older alewife biomass. In 2012, alewife comprised 77% of total prey fish biomass, while rainbow smelt and bloater were 4 and 19% of total biomass, respectively. Rainbow smelt biomass in 2012 (0.25 kg/ha) was 40% of the rainbow smelt biomass in 2011and 5% of the long term mean. Bloater biomass was much lower (1.2 kg/ha) than in the 1990s, and mean density of small bloater in 2012 (191 fish/ha) was lower than peak values observed in 2007-2009. In 2012, pelagic prey fish biomass in Lake Michigan was similar to Lake Superior and Lake Huron. Prey fish biomass remained well below the Fish Community Objectives target of 500-800 kt, and key native species remain absent or rare.

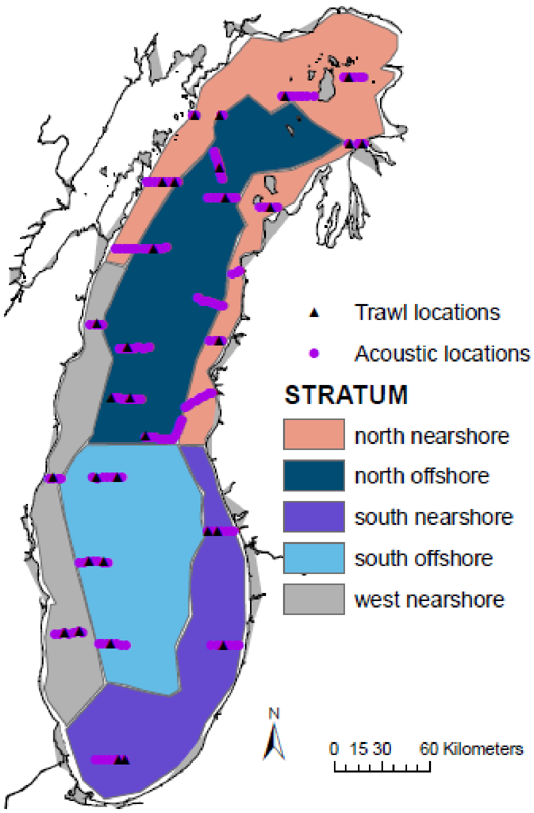


Fig 1-Map of Lake Michigan showing strata used in design and analysis of the lakewide acoustic. Symbols represent acoustic and midwater trawl locations for 2012.

Introduction

In light of changes in the Lake Michigan food web during the last 40 years and the continued restructuring due to exotic species, pollution, fishing, and fish stocking, regular evaluation of long-term data on prey fish dynamics is critical. The traditional Great Lakes Science Center (GLSC) prey fish monitoring method (bottom trawl) is inadequate for fish located off bottom. In particular, bottom trawls provide particularly biased estimates for age-0 alewives. Alewives are the primary prey in Lake Michigan and of especial importance to introduced salmonines in the Great Lakes, and, as such, constitute an important food web component. Alewife dynamics can reflect occurrences of strong year-classes because total alewife density is highly correlated with the density of alewife ≤ age-2. Much of the alewife biomass will not be recruited to bottom trawls until age-3, but significant predation by salmonines may occur on alewives ≤ age-2. Because of the ability of acoustic equipment to count organisms far above bottom, this type of sampling is ideal for highly pelagic fish like age-0 alewives, rainbow smelt, and bloater and is a valuable complement to bottom trawl sampling.

Alewife

Alewife density in 2012 (1,410 fish/ha) was five times that observed in 2011 and was similar to the long-term (1992-2011) mean of 1,770 fish/ha. This increase was primarily the result of higher density of age-0 alewife. Alewife biomass (4.9 kg/ha) in 2012 was 35% of the long-term mean of 14.2 kg/ha but was the fourth lowest in the time series. Age-0 alewife density (1,242 fish/ha, **Fig 2**), was similar to the long-term mean of 1,282 fish/ha. Age-1 or older (YAO) alewife biomass was highly variable in the 1990s but the highest values of the time series were in 1995 and 1996. The high biomass in 1996 was in large part the result of a very strong year class in 1995. Biomass of this age group was relatively constant from 2001-2007 (**Fig 3**), increased in 2008-2010, and then declined by 69% from 2010 to 2011.

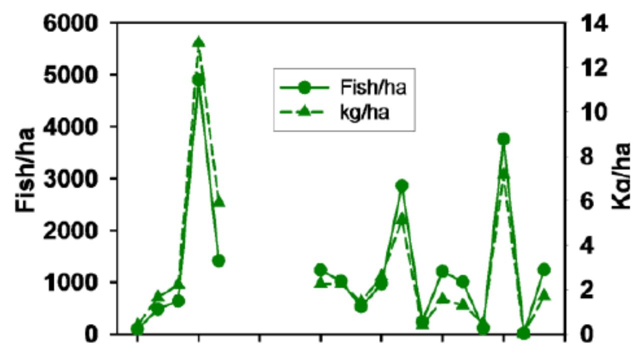


Fig 2-Acoustic estimates of age-0 alewife density and biomass in Lake Michigan, 1992-2012

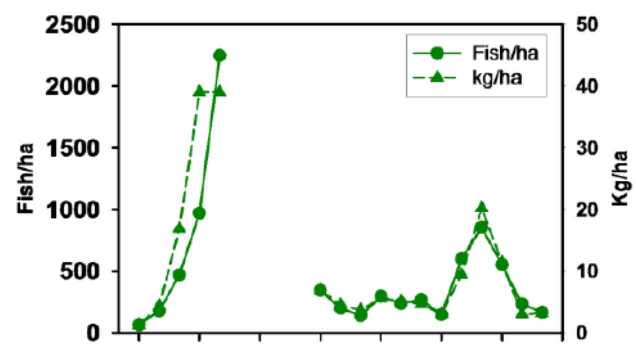


Fig 3-Acoustic estimates of age-1 or older alewife density in Lake Michigan, 1992-2012

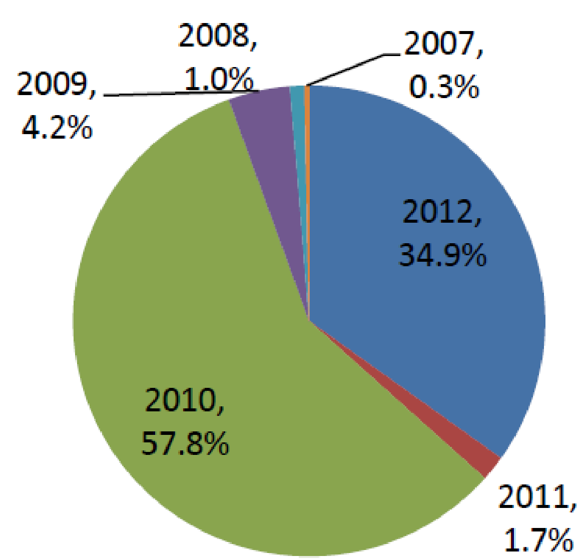


Fig 4-Percent contribution of alewife year- classes to alewife biomass during 2012. Labels show year class and percent of alewife biomass

In 2012 biomass of the YAO group was 3.2 kg/ha, which consisted of fish from the 2007-2010 year-classes (**Fig 4).** Mean age of YAO increased from 1.3 years in 2011 to 2.1 years in 2012 **(Fig 5**). Estimated density of spawners (age-3 and older surveyed in 2012) was the second lowest in the time series. Acoustic and bottom trawl results both indicated that biomass of YAO alewife in 2012 was similar to that in 2011 and both surveys indicated that age-2 alewife (2010 year class) made up most of the population in both numbers and biomass. However, the acoustic estimate of YAO alewife biomass was more than twice the bottom trawl estimate.

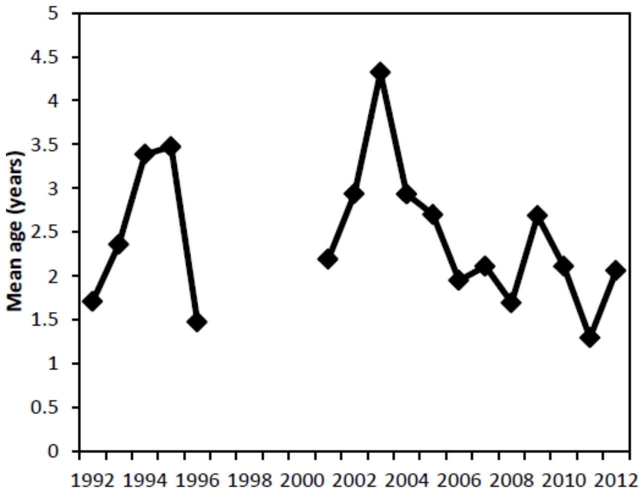


Fig 5-Mean age of YAO alewife in Lake Michigan in 1992-2012.

Rainbow smelt

Density of rainbow smelt increased from 2002-2008 **(Fig 6),** before declining to much lower levels in 2009-2012. However, biomass has been consistently low since 2007. Rainbow smelt density in 2012 (196 fish/ha) was the second lowest in the time series. Biomass of rainbow smelt (0.25 kg/ha) was 20% of the 2011 biomass and was only 4% of the long term mean. Rainbow smelt > 90 mm in length constituted roughly 60% of the population and 65% of biomass. Both acoustic and bottom trawl survey results showed biomass in 2012 was similar to 2011, but the acoustic biomass estimate was nearly five times the bottom trawl estimate.

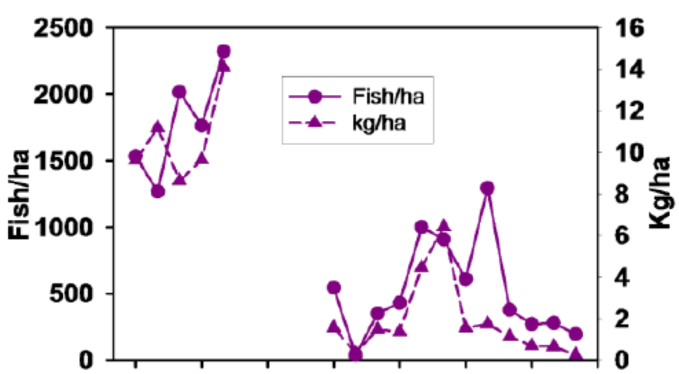


Fig 6-Acoustic estimates of rainbow smelt density and biomass in Lake Michigan in fall 1992-2012

Bloater

Bloaters continue to be present at low densities relative to the 1990s. Mean density of all bloater in 2012 (232 fish/ha) was higher than in 2011, as was total bloater biomass (1.2 kg/ha). Small bloater showed an increasing trend from 2001-2009 (**Fig 7**), while large bloater showed no trend during this period **(Fig 8**). Acoustic results for small bloater were consistent with bottom trawl results, as density and biomass increased for this size group in both surveys. However, results were not consistent for larger bloater; the acoustic estimate of biomass nearly doubled from 2011-2012, while the bottom trawl biomass estimate in 2012 was only 10% of the 2011 estimate. Neither acoustic or bottom trawl estimates for large bloater show any evidence of increased abundance resulting from recruitment of fish hatched in the previous 10 years.

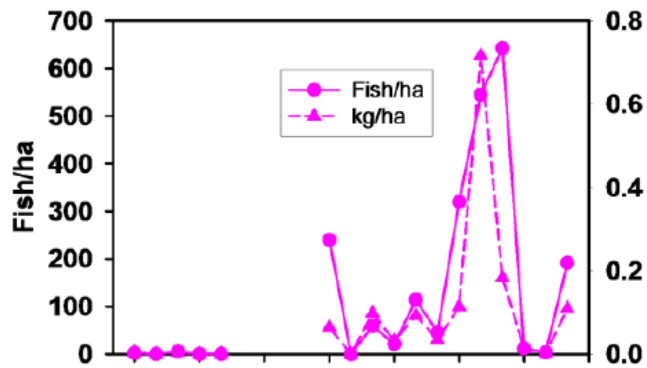


Fig 7-Acoustic estimates of small bloater density and biomass in Lake Michigan in fall 1992-2012

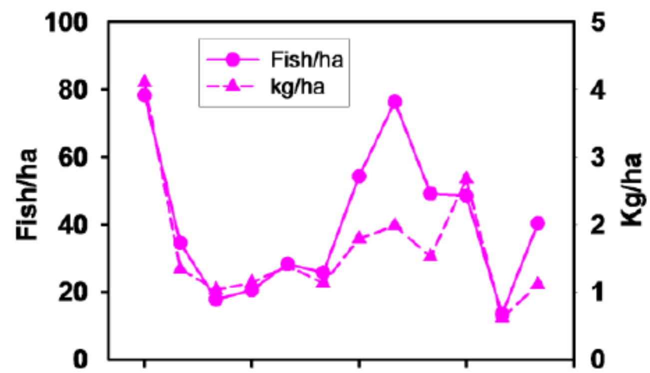


Fig 8-Acoustic estimates of large bloater density and biomass in Lake Michigan in fall 2001-2012

Summary

The results of the 2012 Lake Michigan acoustic survey indicate continued variability in alewife biomass as well as persistently low biomass of smelt and bloater. Peak alewife biomass occurred in 1995 and 1996, and the two highest values during 2001-2012 (2009-2010) were only half as high as in 1995-1996. Total prey fish biomass in 2012 was the second lowest ever observed **(Fig 9**).

As with any survey, it is important to note that trawl or acoustic estimates of fish density are potentially biased and, when possible, we should describe the effects of any bias when interpreting results. With acoustic sampling, areas near the bottom and the surface (0-3 m) are not sampled well or at all. The density of fish in these areas therefore is unknown. Air-water interface problems, technology limitations, as well as time limitations preclude the use of upward or side-looking transducers. If one assumes that fish available to a bottom trawl with ≈ 1 m fishing height at night are not available to acoustic sampling, it is doubtful that the bottom dead zone contributes much bias for alewife and rainbow smelt because of their pelagic distribution at night. In Lake Michigan, day-night bottom trawling was conducted at numerous locations and depths in 1987, with day and night tows occurring on the same day. After examining these data we found that night bottom trawl estimates of alewife density in August/September 1987 were only 6% of day estimates.

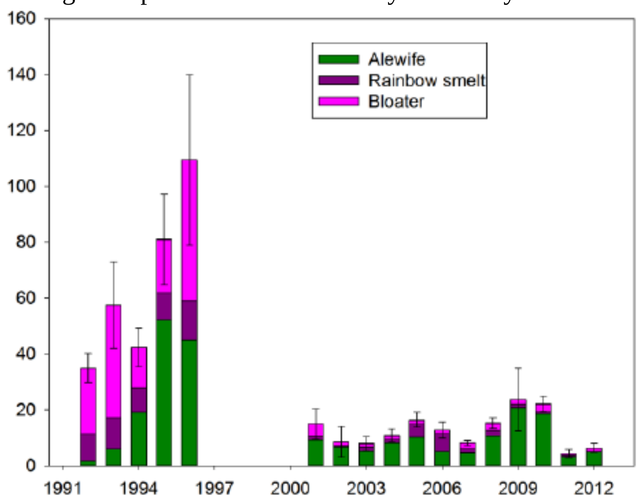


Fig 9-Acoustic estimates of total prey fish biomass in Lake Michigan, 1992-2012

Similarly, night bottom trawl estimates of rainbow smelt density were ≈ 6% of day estimates. Evidence suggests bloater tend to be more demersal; in Lake Superior, night acoustic/midwater trawl sampling may detect only 60% of bloater present. Day-night bottom trawl data from Lake Michigan in 1987 suggested that the availability of bloater to acoustic sampling at night was somewhat higher. Slimy sculpins and deepwater sculpins are poorly sampled acoustically and we must rely on bottom trawl estimates for these species. Alewife and rainbow smelt (primarily age-0) may occupy the upper 3 m of the water column and any density calculation in this area results in underestimation of water column and mean lakewide density. Depending on season, in inland New York lakes and Lake Ontario, 37-64% of total alewife catch in gill nets can occur in the upper-most 3 m. However, highest alewife and rainbow smelt catches and catch-per-unit-effort with midwater tows generally occur near the thermocline in Lake Michigan. We also assumed that our midwater trawling provided accurate estimates of species and size composition. Based on the relationship between trawling effort and uncertainty in species proportions observed by Warner et al. (2012), this assumption was likely reasonable.

Prey fish biomass in Lake Michigan remains at levels much lower than in the 1990s, and the estimate of total lakewide biomass (31 kt) from acoustic sampling was the 2nd lowest in the time series. This is in contrast to 2008-2010, when biomass was relatively high (but still lower than in the 1990s). This recent decline, resulting primarily from decreased alewife biomass, demonstrates the dynamic nature of the pelagic fish community in Lake Michigan. The large difference in prey fish biomass in the 1990s and 2000s resulted primarily from the decrease in large bloater abundance, but alewife and rainbow smelt declined as well. Bloater densities showed an increasing trend 2001-2009, with most of the increase driven by increases in small bloater. A similar pattern has been observed in Lake Huron, but only in Lake Huron has there been any evidence of increased abundance resulting from recruitment to larger sizes, as bottom trawl estimates of large bloater density have increased in recent years in Lake Huron but not in Lake Michigan. Pelagic fish biomass was not evenly split among the species present in 2012, and limited recruitment of small bloater, along with the continued absence of other native species, suggests that little progress is being made toward meeting the Fish Community Objectives of maintaining a diverse planktivore community, particularly relative to historical diversity. Bloater and emerald shiner were historically important species, but bloater currently exist at low biomass levels and emerald shiner have not been captured in Lake Michigan by GLSC surveys since 1962.

Similarly, kiyi are absent from offshore regions of Lake Michigan, which is in stark contrast to Lake Superior, where kiyi were found to be the most numerous species in 2011. As a result, large areas of Lake Michigan which were formerly occupied by fish are devoid of fish, and movement of energy and nutrients through vertical migration has essentially disappeared. In Lake Huron, collapse of the alewife population in 2003-2004 was followed by resurgence in emerald shiner abundance in 2005-2006 (Schaeffer et al. 2008) and by increased abundance of cisco. Given evidence from acoustic surveys from lakes Michigan and Huron, it appears that emerald shiners are suppressed by all but the lowest levels of alewife abundance. In 2012 total pelagic fish biomass in Lake Michigan (6.4 kg/ha) was similar to that in Lake Huron in 2012 (6.3 kg/ha as well as Lake Superior in 2011 (6.8 kg/ha. ✧

Status and Trends of Prey Fish Populations in Lake Michigan, 2012(USGS)

Abstract

The surveys on relative abundance, size and age structure, and condition of individual fishes are used to estimate various population parameters that are in turn used by state and tribal agencies in managing Lake Michigan fish stocks. All seven established index transects of the survey were completed in 2012. The survey provides relative abundance and biomass estimates between the 5-m and 114-m depth contours of the lake (herein, lake-wide) for prey fish populations, as well as burbot, yellow perch, and the introduced dreissenid mussels. Lake-wide biomass of alewives in 2012 was estimated at 9 kilotonnes (kt, 1 kt = 1000 metric tonnes), which continues the trend of unusually low alewife biomass since 2004 but represented a 20% increase from the 2011 estimate. The age distribution of alewives larger than 100 mm was dominated (i.e., 84%) by age-2. Record low biomass was observed for several species, including bloater (0.4 kt), rainbow smelt (0.1 kt), deepwater sculpin (1.5 kt), and ninespine stickleback (0.01 kt). Slimy sculpin lake-wide biomass was 0.73 kt in 2012, which was the third consecutive year revealing a decline.

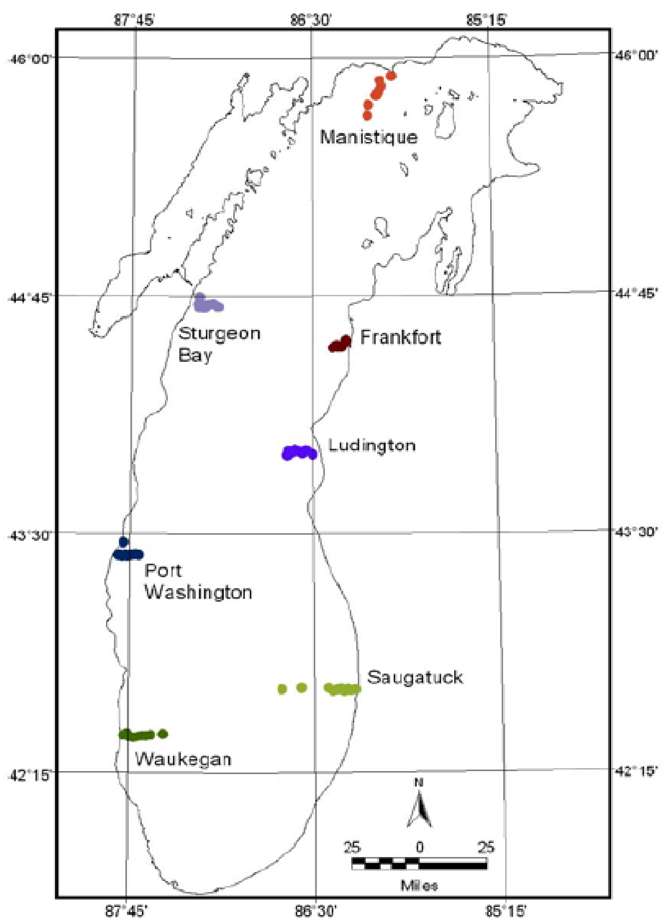


Fig 1-Established sampling locations for GLSC bottom trawls in Lake Michigan

Estimated biomass of round goby increased by 79% to 3 kt. Burbot lake-wide biomass (0.5 kt in 2012) has remained below 3 kt since 2001. Numeric density of age-0 yellow perch (i.e., < 100 mm) was only 2 fish per ha, which is indicative of a relatively poor year-class. Lake-wide biomass estimates of dreissenid mussels have continued to increase from 2010, from 12 to 95 kt in 2012. Overall, the total lake-wide prey fish biomass estimate (sum of alewife, bloater, rainbow smelt, deepwater sculpin, slimy sculpin, round goby, and ninespine stickleback) in 2012 was 15 kt, which represented the lowest total biomass of the time series.

Alewife

Since its establishment in the 1950s, the alewife has become a key member of the fish community. As a larval predator, adult alewife can depress recruitment of native fishes, including burbot, deepwater sculpin, emerald shiner, lake trout, and yellow perch. Additionally, alewife has remained the most important constituent of salmonine diet in Lake Michigan for the last 45 years. Most of the alewives consumed by salmonines in Lake Michigan are eaten by Chinook salmon. A commercial harvest was established in Wisconsin waters of Lake Michigan in the 1960s to make use of the then extremely abundant alewife that had become a nuisance and health hazard along the lakeshore. In 1986, a quota was implemented, and as a result of these restrictions, the estimated annual alewife harvest declined from about 7,600 metric tons in 1985 to an incidental harvest of only 12 metric tons after 1990. Lake Michigan currently has no commercial fishery for alewives.

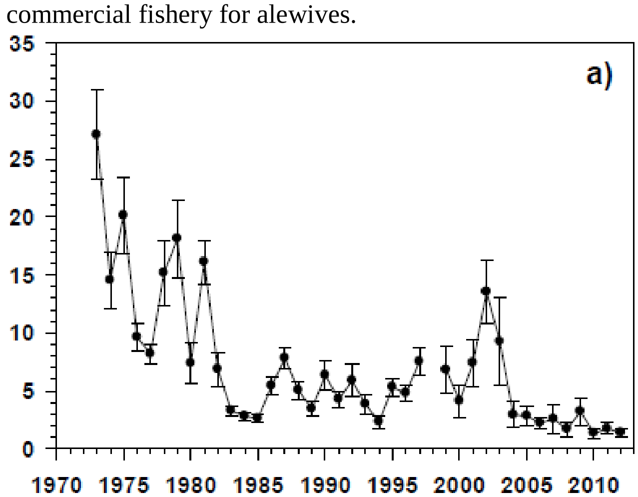


Fig 2-Density of adult alewives as biomass in Lake Michigan, 1973-2012

Adult alewife biomass density was 1.4 kg per ha in 2012 (**Fig 2**), which was only 20% of the long-term average biomass. Only 2010 yielded a lower adult alewife biomass estimate. Similarly, adult alewife numeric density in 2012 (62.8 fish/ha) was only 27% of the long-term average. The overall temporal trends in alewife recruitment to age 3 and subsequent adult biomass are likely driven by consumption by salmonines.

Adult alewife density has remained at low levels during 2004-2012 **(Fig 2**). This continued depression of adult alewife abundance may reflect a recently intensified amount of predation exerted on the alewife population by Chinook salmon due to four factors: (1) a relatively high percentage of wild Chinook salmon in Lake Michigan, (2) increased migration of Chinook salmon from Lake Huron in search of alewife, (3) increased importance of alewives in the diet of Chinook salmon in Lake Michigan between the 1990s and the 2000s, and (4) a decrease in the energy density of adult alewives during the late 1990s.

Using an age-length key and a length distribution that corrected for densities, we estimated that 84% of adult alewives captured in the bottom trawl during 2012 were age 2 and classified as the 2010 year-class **(Fig 3**). This unevenness in age composition was also observed in 2011, as the 2010 year-class comprised 83% of the adults captured. These two years are in stark contrast to the previous four years (2007-2010) when more evenness was estimated among the age-classes, as indicated by at least three age-classes each contributing at least 10% to the catch. One additional change in recent years is a truncation in the age distribution. The maximum age sampled has decreased from age 9 in 2007 to age 7 in 2008-2009 to age 6 in 2010-2011 to age 4 in 2012.

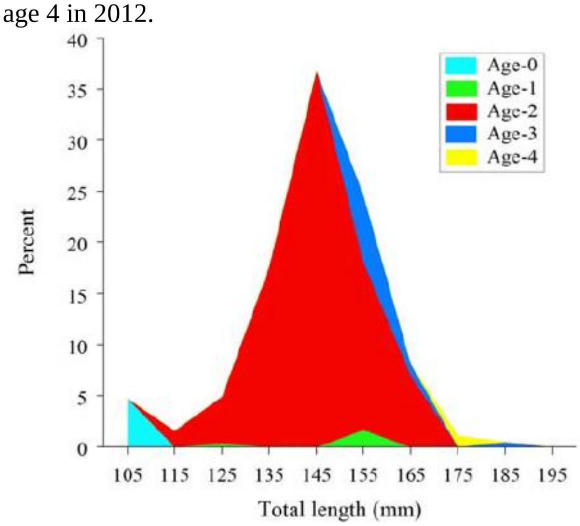


Fig 3-Age-length distribution of alewives >100 mm total length caught in bottom trawls in Lake Michigan, 2012. Smaller alewives were captured but were not included herein

Our results for temporal trends in adult alewife density were in partial agreement with results from the lake-wide acoustic survey, which reported biomass of adult alewife during 2004-2012 to be relatively low in comparison to the biomass during 1994-1996. Comparisons between the age distributions measured in the two surveys also exhibited commonality in the dominance of the 2010 year class among the adults (84% in the bottom trawl and 89% in the acoustic survey). The biomass estimate for adult alewife in the acoustic survey, however, is over three times higher than what was estimated in the bottom trawl survey.

Bloater

Bloaters are eaten by salmonines in Lake Michigan, but are far less prevalent in salmonine diets than alewives. For large (≥ 600 mm) lake trout, over 30% of the diets offshore of Saugatuck and on Sheboygan Reef were composed of adult bloaters during 1994- 1995, although adult bloaters were a minor component of lake trout diet at Sturgeon Bay. For Chinook salmon, the importance of bloater (by wet weight) in the diets has declined between 1994-1995 and 2009-2010. For small Chinook salmon the proportion declined from 9% to 6% and for large Chinook salmon the proportion declined from 14% to <1%. The bloater population in Lake Michigan also supports a valuable commercial fishery, although its yield has generally been declining since the late 1990s.

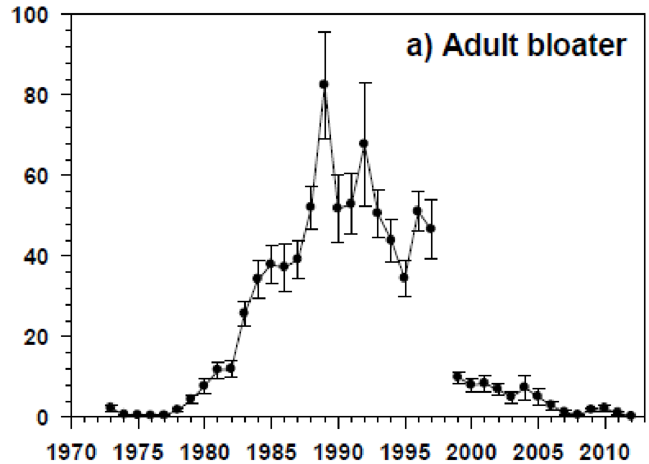


Fig 4-biomass density of adult bloater in Lake Michigan, 1973-2012

Adult bloater biomass density was 0.11 kg per ha in 2012 **(Fig 4**), which was only 0.5% of the long term average biomass and the lowest estimate of the time series. The estimate for 2012 was also 90% lower than that measured in 2011. Similarly, adult bloater numeric density in 2012 (2.5 fish/ha) was only 0.5% of the long-term average. Adult bloater numeric and biomass densities have shown an overall declining trend since 1989 (**Fig 4).** Numeric density of age-0 bloaters (< 120 mm TL) was only 2 fish per ha in 2012. 2012 was the third consecutive year of very low densities of age-0 bloater following relatively high values in 2005, 2008, 2009.

Results from the acoustic survey can provide some insight into catchability concerns raised above. With regard to bloater moving deeper than 110 m, the acoustic survey estimated bloater densities ranging 8-25 fish/ha in depths 125-220m between 2003 & 2012. However, the survey also documented that the bulk of the bloater population was sampled in depths 30-100 m. In terms of comparing trends between the two surveys, for the adults an order of magnitude decrease between 1992-1996 and 2001-2012 was revealed by both surveys. Similarly, low densities of age-0 bloaters in the 1990s and strong inter-annual variability in the 2000s were detected in both surveys. However, the years (2005, 2008, 2009) in which relatively high age-0 densities were estimated by the bottom trawl survey were a subset of the high density years (2001, 2005, 2007-2009, 2012) estimated by the acoustic survey.

Rainbow smelt

Adult rainbow smelt are an important part of the diet for intermediate-sized (400 to 600 mm) lake trout in the nearshore waters of Lake Michigan (Stewart et al. 1983; Madenjian et al. 1998; Jacobs et al. 2010). For Chinook salmon, rainbow smelt comprised as much as 18% in the diets of small individuals in 1994-1996, but that dropped precipitously to 2% in 2009-2010 and rainbow smelt has been consistently rare in the diets of larger Chinook salmon in all time periods. The rainbow smelt population supports commercial fisheries in Wisconsin and Michigan waters.

Adult rainbow smelt biomass density was 0.02 kg per ha in 2012 (**Fig 5**), which was only 1% of the long-term average biomass and the lowest estimate of the time series. The estimate for 2012 was also 81% lower than that measured in 2011. Adult rainbow smelt numeric density in 2012 (3 fish/ha) was only 2% of the long-term average. Adult rainbow smelt numeric density was highest from 1981 to 1993, but then declined between 1993 and 2001, and has remained at a relatively low density, except in 2005, since 2001. Age-0 rainbow smelt has been highly variable since 2002. Age-0 numeric density in 2012 was 26 fish per ha, which was only 14% of the long-term average.

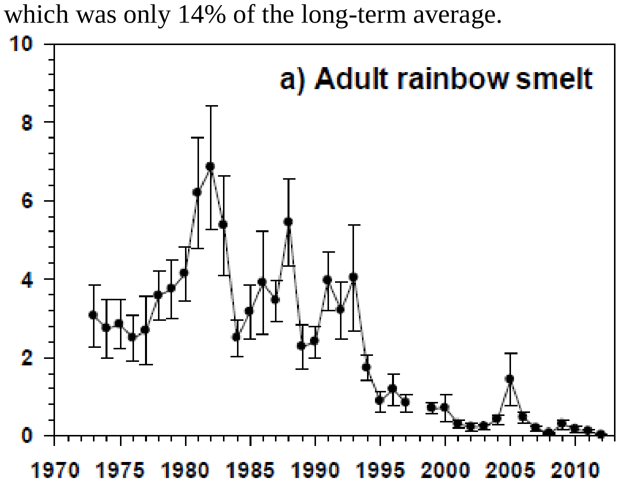


Fig 5-Biomass density of adult (a) and age-0 (b) rainbow smelt in Lake Michigan, 1973-2012

Temporal trends in rainbow smelt biomass from the acoustic and bottom trawl surveys in Lake Michigan have been similar since 2001. The bottom trawl survey has documented relatively low rainbow smelt biomass during 2001-2012, with a minor peak in 2005 **(Fig 5).** Similarly, biomass of rainbow smelt in the acoustic survey was relatively low during 2001-2012, with minor peaks occurring during 2005-2006 and 2008-2009. Results from both the acoustic and bottom trawl surveys indicated that rainbow smelt biomass in Lake Michigan during 1992-1996 was roughly four times higher than rainbow smelt biomass during 2001-2012.

Sculpins

The cottid populations in Lake Michigan have been dominated by deepwater sculpins, and to a lesser degree, slimy sculpins. Spoonhead sculpins, once fairly common, suffered declines to become rare to absent by the mid 1970s. Spoonhead sculpins were encountered in small numbers in our survey between 1990 and 1999, but have not been sampled since 1999. Slimy sculpin is a favored prey of juvenile lake trout in nearshore regions of the lake, but is only a minor part of adult lake trout diets. Deepwater sculpin is an important diet constituent for burbot in Lake Michigan, especially in deeper waters. A recent study of burbot from northern Lake Michigan sites revealed sculpins to comprise 11% of their diets.

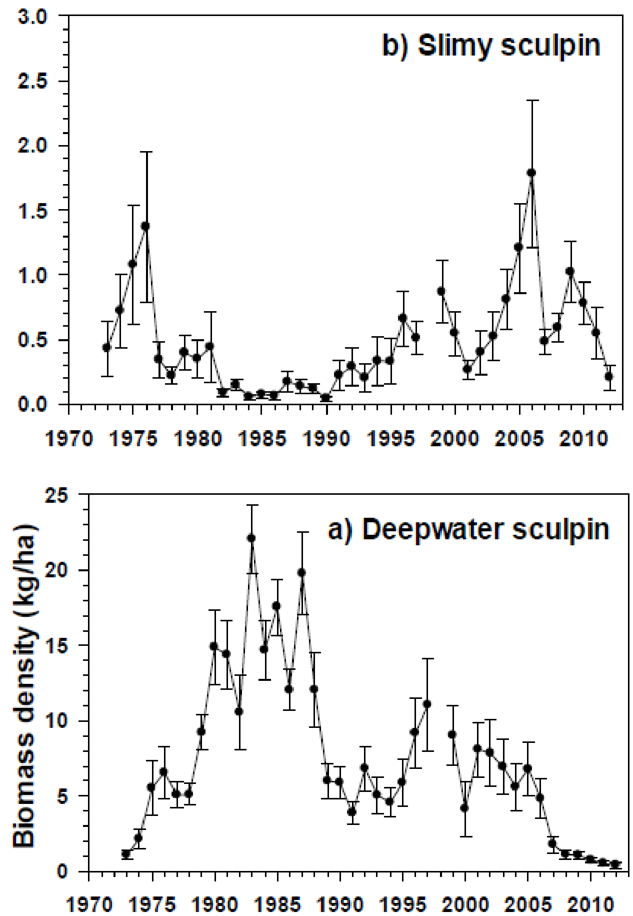


Fig 6-Biomass density for deepwater (a) and slimy sculpin (b) in Lake Michigan, 1973-2012

Deepwater sculpin biomass density was 0.4 kg per ha in 2012 **(Fig 6a)**, which was only 5% of the long-term average biomass and the lowest estimate of the time series. For every year since 2009, this biomass estimate has reached a record low. Similarly, deepwater sculpin numeric density in 2012 (44 fish/ha) was only 11% of the long-term average. During 1990-2005, both deepwater sculpin biomass density and numeric density trended neither downward nor upward.

However, biomass of deepwater sculpin sampled in the bottom trawl has declined precipitously since 2005. Deepwater sculpins have been captured at increasingly greater depths since the 1980s. Therefore, one potential explanation for the recent declines in deepwater sculpin densities is that an increasing proportion of the population is now occupying depths deeper than those sampled by our survey (i.e., 110 m).

Furthermore, because the deepwater sculpin occupies deeper depths than any of the other prey fishes of Lake Michigan, a shift to waters deeper than 110 m would seem to be a reasonable explanation for the recent declines in deepwater sculpin densities. Previous analysis of the time series indicated deepwater sculpin density is negatively influenced by alewife (predation on sculpin larvae) and burbot. Based on bottom trawl survey results, neither alewife nor burbot increased in abundance during 2007-2012 to account for this decline in deepwater sculpins. Which factor or factors could have driven the bulk of the deepwater sculpin population to move to waters deeper than 110 m during 2007-2011? This shift to deeper water by deepwater sculpins coincided with the population explosion of the profundal form of the quagga mussel in depths between 60 and 90 m. Perhaps some consequences of the colonization of deeper waters by quagga mussels prompted a move of deepwater sculpins to deeper water. If this hypothesis were correct, then a substantial decline in quagga mussel abundance in the 60-m to 90- m deep waters could lead to a shift of deepwater sculpins back to shallower waters.

Slimy sculpin biomass density was 0.21 kg per ha in 2012 (**Fig 6b**). Among all of the prey fishes that have been sampled since 1973, the biomass of slimy sculpin was closest to its long-term average of 0.48 kg/ha (i.e., 43% of the long-term average biomass). Numeric density of slimy sculpin was 36 fish per ha in 2012, which was only 33% of the long-term average. Biomass densities of slimy sculpins from 2005-2006 were considerably higher than those estimated in the 1980s and even late 1990s, when slimy sculpins were recovering. Biomass of slimy sculpin has declined annually since 2009, however, with a marked 62% decline between 2011 and 2012. The slimy sculpin decline since 2009 coincided with an increase in lake trout stocking rate.

Round goby

The round goby is an invader from the Black and Caspian Seas. Round gobies have been observed in bays and harbors of Lake Michigan since 1993, and were captured in the southern main basin of the lake as early as 1997. Round gobies were not captured in the GLSC bottom trawl survey until 2003, however. By 2002, round gobies had become an integral component of yellow perch diet at nearshore sites (i.e., < 15 m depth) in southern Lake Michigan. Round gobies also had become an important constituent of the diet of burbot in northern Lake Michigan by 2005.

Round goby biomass density was 0.9 kg per ha in 2012 (**Fig 7a**). Numeric density was 121 fish per ha. The variability associated with the annual mean is extremely high in some years, such as 2010. Hence, biomass in 2012 did not appear to be substantively different from that measured in 2010 and 2011.

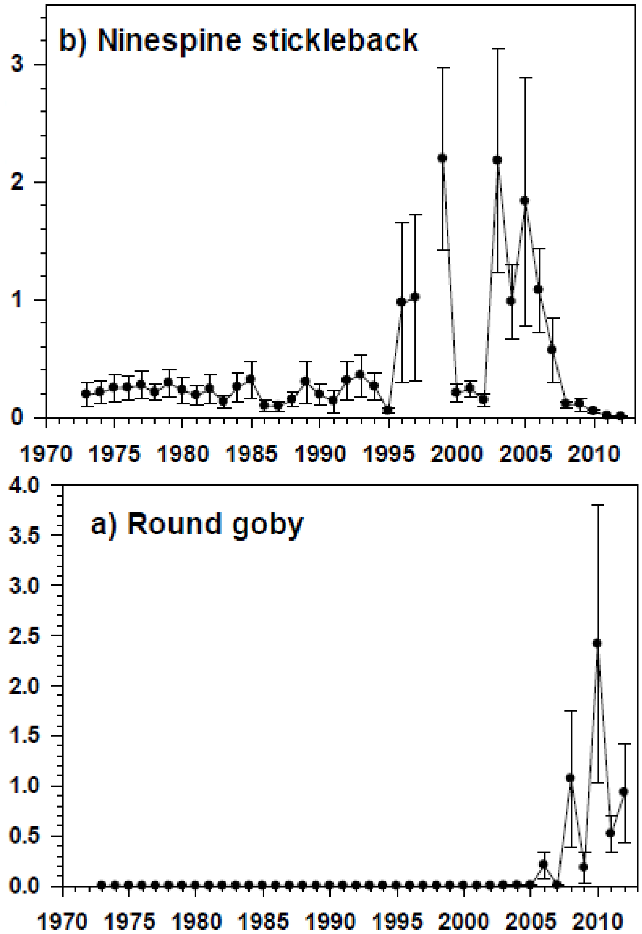


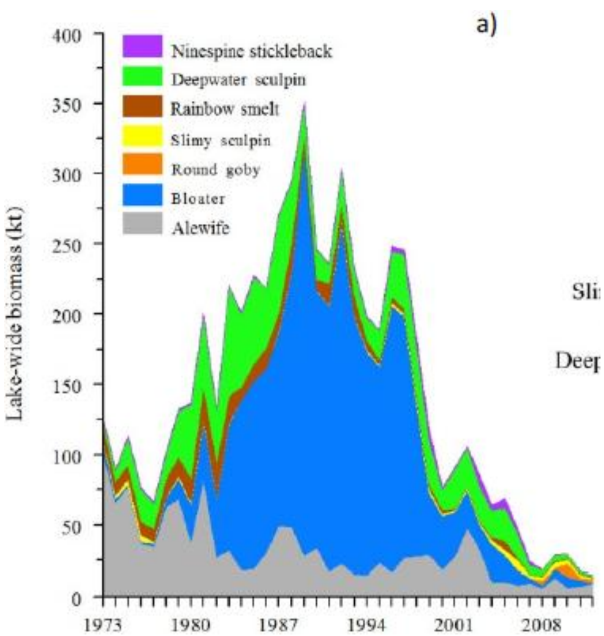
Fig 7-Biomass density of round goby (a) and ninespine stickleback (b) in Lake Michigan, 1973-2012

Ninespine stickleback

Two stickleback species occur in Lake Michigan. Ninespine stickleback is native, whereas threespine stickleback is non-native and was first collected in the GLSC bottom trawl survey during 1984. Ninespine stickleback is generally captured in far greater densities than the threespine, especially in recent years. Relative to other prey fishes, ninespine sticklebacks are of minor importance to lake trout and other salmonines. In northern Lake Michigan, for example, sticklebacks occur infrequently in the diet of lake trout (Elliott et al. 1996; Jacobs et al. 2010). Biomass density was 3 g per ha in 2012 **(Fig 7b)**, the lowest value of the time series and only 0.9% of the long-term average. Mean numeric density was only 3 fish per ha. Biomass of ninespine stickleback remained fairly low from 1973-1995, increased dramatically in 1996-1997, and exhibited larger interannual variability between 1999 and 2007. Since 2008, however, biomass has been maintained at near record-low levels. An analysis of ninespine stickleback densities in lakes Michigan and Superior revealed that the increase in Lake Michigan in the mid-2000s coincided with the expansion of dreissenid mussels in the lake.

We estimated a total lake-wide biomass of prey fish available to the bottom trawl in 2012 of 15 kilotonnes (kt) (1 kt = 1000 metric tonnes) *(***Fig 8a***)*, which was the lowest value in the time series and only 10% of the long-term average total prey fish biomass. Total prey biomass was the sum of the population biomass estimates for alewife, bloater, rainbow smelt, deepwater sculpin, slimy sculpin, ninespine stickleback, and round goby. Total prey fish biomass in Lake Michigan has trended downward since 1989 (**Fig 8a**). This decline was largely driven by the dramatic decrease in bloater biomass. During 2002-2012, decreases in alewife and deepwater sculpin biomasses also contributed to the continued decrease in total prey fish biomass. Total biomass first dropped below 30 kt in 2007, and has remained below 30 kt since that time.

As **Fig 8b** depicts, the 2012 prey fish biomass was apportioned as: alewife 60.3% (9.2 kt), round goby 21.6% (3 kt), deepwater sculpin 9.7% (1.5 kt), slimy sculpin 4.8% (0.7 kt), bloater 2.7% (0.4 kt), rainbow smelt 0.9% (0.1 kt), and ninespine stickleback < 0.1% (0.01 kt)



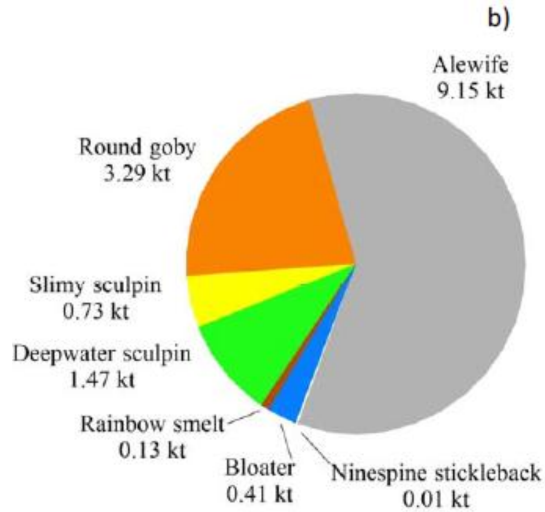


Fig 8-Estimated lake-wide biomass of prey fishes in Lake Michigan, 1973-2012(a) and species composition in 2012 (b)

Other Species Of Interest

Burbot

Burbot and lake trout represent the native top predators in Lake Michigan. The decline in burbot abundance in Lake Michigan during the 1950s has been attributed to sea lamprey predation. Sea lamprey control was a necessary condition for recovery of the burbot population in Lake Michigan however a reduction in alewife abundance was an additional prerequisite for burbot recovery.

Burbot collected in the bottom trawls are typically large individuals (>350 mm TL); juvenile burbot apparently inhabit areas not covered by the bottom trawl survey. Burbot biomass density was 0.1 kg per ha in 2012, which was 15% of the long-term average. After a period of low numeric density in the 1970s, burbot showed a strong recovery in the 1980s (**Fig 9a**).

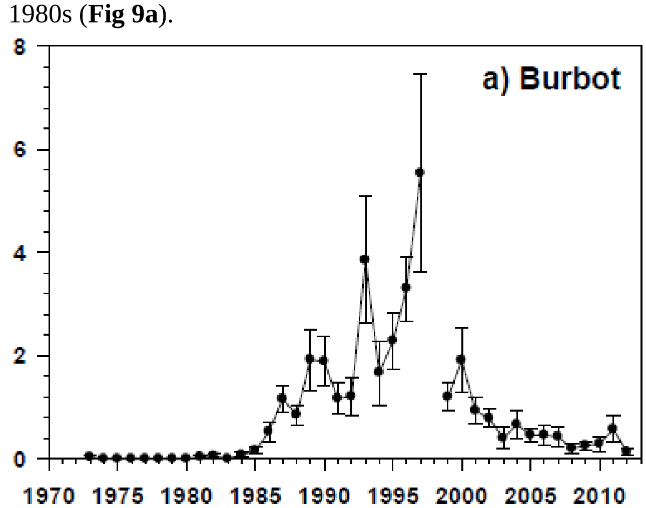


Fig 9-Biomass density of burbot in Lake Michigan, 1973-2012

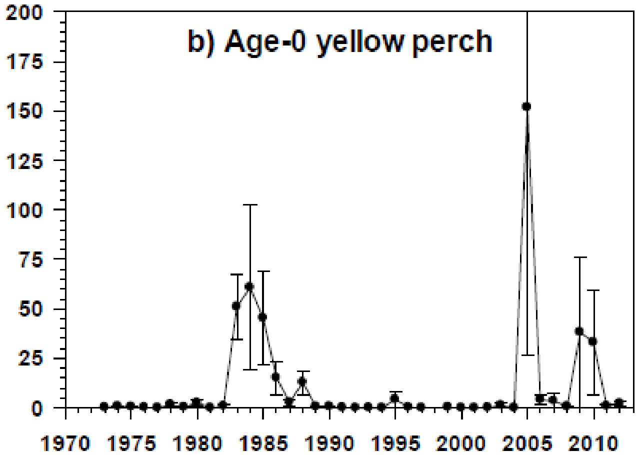


Fig 10-Biomass density of age-0 yellow perch (b) in Lake Michigan, 1973-2012

Age-0 yellow perch

The yellow perch population in Lake Michigan has supported valuable recreational and commercial fisheries. GLSC bottom trawl surveys provide an index of age-0 yellow perch numeric density, which serves as an indication of yellow perch recruitment success. The 2005 year-class of yellow perch was the largest ever recorded **(Fig 9b**) and the 2009 and 2010 year-classes also were higher than average. Strong yellow perch recruitment in these recent years was likely attributable to a sufficient abundance of female spawners and favorable weather. Numeric density of the 2012 year-class was only 2 fish per ha, indicative of a relatively weak year-class despite a warmer than average year.

Dreissenid mussels

The first zebra mussel noted in Lake Michigan was found in May 1988 in Indiana Harbor at Gary, Indiana. By 1990, adult mussels had been found at multiple sites in the Chicago area, and by 1992 were reported to range along the eastern and western shoreline in the southern two-thirds of the lake, as well as in Green Bay and Grand Traverse Bay. In 1999, catches of dreissenid mussels in our bottom trawls became significant and we began recording biomass for each tow.

Lake Michigan dreissenid mussels include two species: the zebra mussel and the quagga mussel. The quagga mussel is a more recent invader to Lake Michigan than the zebra mussel. According to the GLSC bottom trawl survey, biomass density of dreissenid mussels was highest in 2007 (**Fig 10a),** which followed an exponential like increase between 2004 and 2006. The biomass density of dreissenid mussels in 2012 was 27 kg per ha, the highest value estimated since the peak in 2007 **(Fig 10a).** According to the results of the benthic macroinvertebrate survey, quagga mussel biomass density in Lake Michigan appears to have peaked sometime between 2008 and 2010. This peaking may be in response to the exceeding of the carrying capacity, and a decline in quagga mussel biomass density may be expected in upcoming years.

Over this same period of dreissenid mussel increases, prey fish biomass was declining, which led to a dramatic increase in the percentage of dreissenids in the total bottom trawl catch (**Fig 11**). The bulk of the decline in total prey fish biomass may be better explained by factors other than food-web-induced effects by

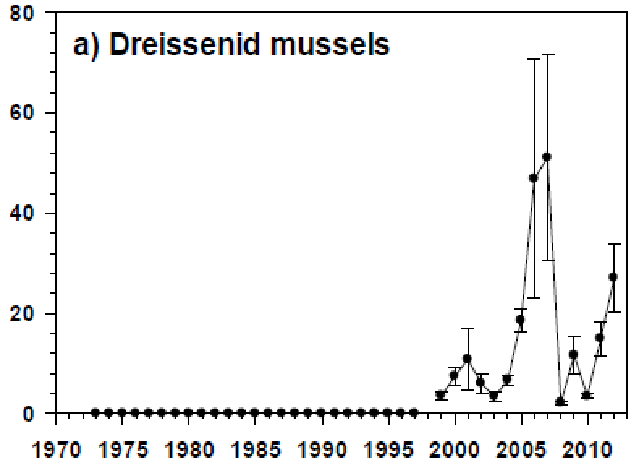


Fig 11-Bbiomass density of dreissenid mussels in the bottom trawl in Lake Michigan, between1999 and 2012.

A comparison of the biomass density of dreissenid mussels (27 kg per ha) with biomass density of all species of fish (5 kg per ha) caught in the bottom trawl in 2012 indicated that 85% of the daytime benthic biomass available to the bottom trawl was dreissenid mussels (**Fig 11).**

Summary

Total prey fish biomass in 2012 was the lowest since our bottom trawl survey began in 1973, and follows five years of sustained, record low biomass estimates. These low prey fish biomass estimates for 2007- 2012 were probably due to a suite of factors. We can clearly identify two of these factors as: (1) a prolonged period of poor bloater recruitment since 1992 and (2) intensified predation on alewives by Chinook salmon during the 2000s. Adult alewife density has been maintained at a relatively low level over the last nine years and the age distribution of the adult alewife population has become especially truncated in recent years. As recent as 2007, alewives as old as age 9 were sampled in this survey whereas the oldest alewife sampled in 2012 was age 4. Whether or not the alewife population in Lake Michigan will undergo a collapse in coming years (*similar to what occurred in Lake Huron*) will depend on several factors. Primarily, the extent to which predation by salmonines influences the survival of the large 2010 year-class is critical. In addition, alewife sustainability will depend on the success of 2010 year-class in producing another strong year-class in the next few years, which will at least partially depend on appropriate environmental factors being met.

Scientists and managers continue to ask critical questions regarding the importance of "bottom-up" effects on prey fish biomass in Lake Michigan. For example, to what extent do 1) ongoing declines in total phosphorus, 2) the proliferation in dreissenid mussels, and 3) the resultant diminishment of the spring phytoplankton bloom reduce the capacity of Lake Michigan to produce the biomass of prey fish that was observed only two decades ago? We point out that Lake Michigan has already demonstrated its capacity to produce a strong year-class of alewives in 2010 despite the changes described above. Nonetheless, having a complete understanding of the answers to these questions will require additional years of surveillance, across-lake comparisons, and food-web analyses.

The GLFC Fish Community Objective for planktivores is not being achieved according to the bottom trawl survey results. The Objective calls for a lake-wide biomass of 500-800 kt, and the total prey fish biomass estimated by the bottom trawl survey was only 15 kt. The Objective also calls for a diversity of prey species. The diversity in 2012 was far less than that measured in recent years, and we note that native prey fishes comprised only 18% of total prey fish biomass. In fact, native bloater, deepwater sculpin, and ninespine stickleback were at record-low levels in 2012 and native slimy sculpin has been trending downward since 2009. In 2013, we plan to add deeper depths (out to 128 m at as many as three ports) to our survey to evaluate the extent to which some of these native species inhabit depths beyond 110 m. ✧

Evidence of Wild Juvenile Lake Trout Recruitment in Western Lake Michigan

Abstract

Lake Trout were extirpated from Lake Michigan by the early 1950s, and as part of an effort to restore naturally reproducing populations, hatchery-reared fish have been stocked since the early 1960s. Stocked fish are marked with a fin clip to differentiate them from wild, lake-produced Lake Trout; marking error for the 2007–2010 year-classes of Lake Trout stocked by federal hatcheries averaged 3.0%. Egg deposition, emergent fry, and wild juvenile Lake Trout have previously been observed, but no sustained wild recruitment has been measured in assessment surveys or in sport and commercial fishery catches. In 2011 and 2012, we caught juvenile Lake Trout in gill-net and bottom trawl catches that were targeting Bloater in water depths greater than 80 m. Unclipped, wild Lake Trout represented 20% of all Lake Trout caught in a southern offshore region of Lake Michigan. In northwestern Lake Michigan wild recruits represented from 10% to 27% of the 2007–2009 year-classes and we recovered a small number of wild Lake Trout from the 2010 year-class. This is the first evidence for consecutive year-classes of naturally produced Lake Trout surviving beyond the fry stage in Lake Michigan.

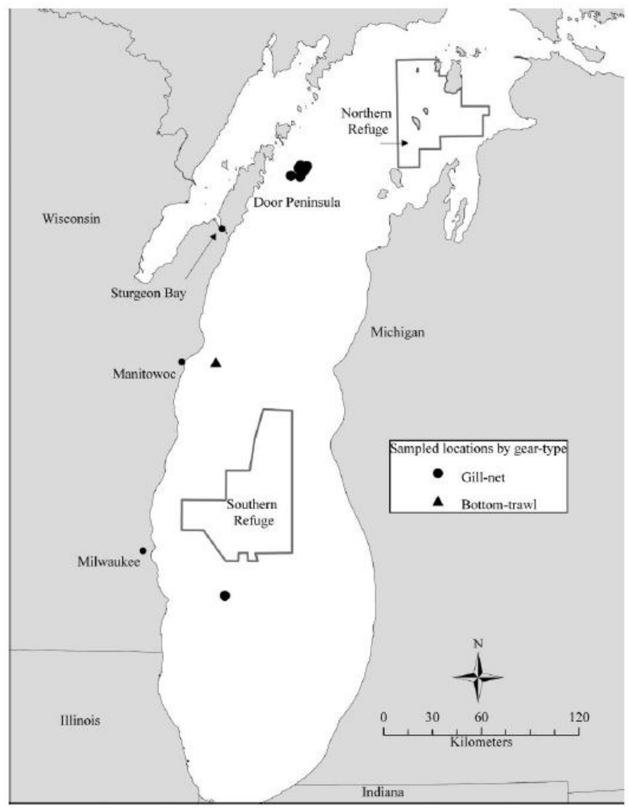


Fig 1-Gill-net and trawl survey locations in 2011 and 2012 where Lake Trout were captured in Bloater spawner surveys

Lake Michigan once supported the world's largest commercial fishery for Lake Trout, but in the 1950s all populations in Lake Michigan and in most other Great Lakes were extirpated due to predation by Sea Lamprey and overfishing. In 1960, the USFWS began stocking Lake Trout fingerlings and yearlings to restore self-sustaining populations in Lake Michigan; Illinois, Michigan, and Wisconsin state agencies also stocked Lake Trout in later years. Between 2000 and 2010, an average of 2.8 million fall-fingerling and yearling Lake Trout were stocked annually in Lake Michigan. Stocked fish have been marked by the removal of one or more fins; fin clips were rotated every 6 years to help differentiate year-classes at recapture.

Also, a proportion of the 1984, 1985, 1988–2004, and 2009 year-classes, and all fish in the 2010–2011 year-classes were tagged with coded wire tags (CWT) and marked with an adipose fin clip. These marks and tags allowed stocked fish to be differentiated from wild fish. Fin clip marking error, measured as the percentage of fish that were unintentionally released without fin clips, averaged about 6% in federal hatcheries between 1990 and 2001 (Bronte et al. 2007). Despite nearly five decades of stocking, there has been no consistent wild juvenile Lake Trout recruitment in Lake Michigan as evidenced by the recovery of unclipped fish.

Stocked Lake Trout survive to spawn in Lake Michigan, and egg deposition fry emergence, and recruitment of wild age-1 and older Lake Trout have been reported. However, recruitment of wild age-1 and older Lake Trout has been not been consistent. Population assessments performed between 1983 and 1989 in Grand Traverse Bay and nearby Platte Bay in northeastern Lake Michigan documented that 15% of the 1976 year-class, 8.9% of the 1981 year-class, and 5.7% of the 1983 year-class comprised unclipped, presumably wild Lake Trout, but none thereafter.

Since 2010, the USFWS has collected Bloater gametes during winter at multiple deepwater (>80 m) locations in western Lake Michigan to support reintroduction efforts into Lake Ontario. As part of these collections, many juvenile Lake Trout were captured, and here we summarize the demographics of this bycatch that provide evidence of consecutive and consistent natural reproduction by Lake Trout in Lake Michigan.

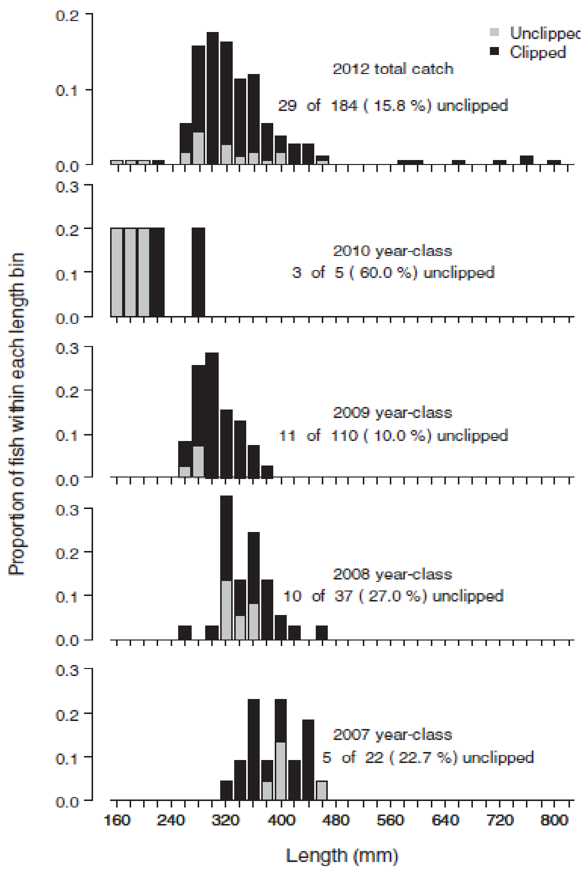


Fig 2-Stacked barplot showing length frequencies for fin-clipped and unclipped Lake Trout caught in gill-net and trawl sampling, 2012. The top panel shows the total catch while the lower four panels show the proportion within each length bin by year-class.

For the 2007–2010 year-classes of Lake Trout stocked in Lake Michigan, mean weighted lake-wide marking error averaged 3.0%, and was 2.5% for fish stocked near Milwaukee and <1% near Manitowoc and the northern Door Peninsula. Stocked Lake Trout from the 2010 year-class were marked with an adipose fin clip and tagged with a CWT. Loss of CWTs averaged 2.5% in the hatchery for the 2010 year-class; hence, the probability that this year-class was stocked with no CWT and no fin clip was <0.09%. We inferred wild recruitment when the proportion of unclipped Lake Trout exceeded 3.0% of all Lake Trout caught, which we noted was a conservative estimate given that marking error in Wisconsin waters was lower than the lake-wide mean.

In 2011, three gill-net lifts were made in southern Lake Michigan, but Lake Trout bycatch was only retained from the last lift on February 10. A total of 295 Lake Trout were caught resulting in a CPUE of 24.2 fish/km of net per night fished. Lake Trout mean TL was 385 mm (SD = 101 mm) and 93% of the fish were less than 500 mm. The percentage of unclipped fish was 20.0% (59 of 295) and no CWTs or fin regeneration were detected in these unclipped fish. The majority of the unclipped fish were probably from the 2006 and 2007 year-classes based on the age–length frequencies of stocked fish. For fin-clipped fish less than 500 mm (n = 216), 3.7% were from the 2005 year-class, 42.6% from the 2006 yearclass, 45.8% from the 2007 year-class, and 6.0% were from the 2008 year-class. No Lake Trout less than 500 mm possessed an adipose fin clip or a CWT.

In 2012, eight gill-net lifts off the northern Door Peninsula were made between January 21 and February 23. A total of 180 Lake Trout were caught and the mean CPUE was 0.8 (SD = 0.3). Lake Trout mean TL was 353 mm (SD =86 mm); 14.4% (26 of 180) of all Lake Trout were unclipped and none of these fish contained CWTs. Six fin-clipped fish contained CWTs: two fish of the 2009 year-class and one fish of the 2010 year-class all stocked in the Northern Refuge, and one each from the 1999, 2000, and 2003 year-classes stocked in the Southern Refuge. The single bottom trawl tow near Manitowoc caught four Lake Trout. Three fish were unclipped (75%) and had a mean length of 190 mm (SD = 13 mm), while a 224-mm fin-clipped Lake Trout with a CWT code of the 2010 year-class stocked at multiple locations as fall fingerlings was also captured. The percentages of unclipped fish caught in 2012 were 22.7, 27.0, 10.0, and 60.0% for the 2007, 2008, 2009, and 2010 year-classes, respectively **(Fig 2).** Size comparisons within year-classes indicate unclipped Lake Trout were smaller than fin-clipped fish at ages 2 and 3, but modal size was similar for fish captured at ages 4 and 5 (**Fig 2**).

Summary

We have provided the first evidence of consistent recruitment of wild age-1 and older Lake Trout in Lake Michigan based on the percent of unclipped Lake Trout that exceeded the 3.0% lakewide marking error for Lake Trout stocked between 2007 and 2010. In northwestern Lake Michigan we observed contribution of wild recruits for the 2007 (22.7%), 2008 (27.0%), 2009 (10.0%), and 2010 (60.0%) year-classes (though the sample size for the 2010 year-class was small). The length frequencies of these fish at ages 4 and 5 were similar between wild and stocked fish, which suggests we can be reasonably confident in our year-class assignments where no otolith was available. Twenty percent of the Lake Trout we sampled in the southern offshore location in Lake Michigan were wild recruits, and length frequency comparisons suggested these were most probably age-5 fish from the 2006 year-class and age-4 fish from the 2007 year class.

The occurrence of these wild fish is much higher than can be attributed to marking error and provides evidence of some successful Lake Trout natural reproduction during 2007–2010 in northwestern Lake Michigan, in addition to the 2006 and 2007 year-classes in the southern portion of the lake.

Our findings are corroborated by a small yet notable increase in the mean percentage of unclipped Lake Trout caught in the standardized, multiagency, spring, graded-mesh gill net survey. The spring survey targets Lake Trout at depths between 15 and 61 m in nine nearshore areas and offshore in the Northern and Southern Refuges. Generally Lake Trout recruit to this survey's graded mesh, beginning at age 3 with a modal age of 5. Between 1999 and 2010, <3% of the Lake Trout catch from all sites combined were unclipped. In 2011, 4.3% of all Lake Trout caught in the spring survey were unclipped and these fish were smaller (mean = 563 mm) than fin-clipped fish (638 mm). Our Bloater surveys employed 65-mm stretch mesh in deepwater (>80 m) habitats preferred by juvenile Lake Trout and we caught mostly small Lake Trout < 500 mm. The 2006 year-class of wild Lake Trout captured in our survey probably contributed to the 2011 spring survey catch (as 5-year-old fish); however, later year-classes were not yet fully recruited. We predict the percentage of wild fish will continue to increase as natural recruits from 2007 and later year-classes become vulnerable to the spring survey, but the percentage of unclipped recoveries lakewide reflects both the proportion of wild recruits relative to stocked fish and the spatial scale over which natural recruits are produced.

In 2011, 16 of 154 (10.4%) Lake Trout sampled in the spring survey near Waukegan, Illinois, were unclipped, which provides evidence that wild recruits are also being produced in Illinois waters in addition to the southern offshore and nearshore waters near Manitowoc and the northern Door Peninsula where we detected wild fish.

Impediments to natural reproduction of Lake Trout in Lake Michigan have been evaluated and are summarized as having poor survival of early life stages, a lakewide population too low to overcome bottlenecks, and inappropriate stocking practices. Currently Lake Trout total and adult abundance remains below target levels. Thiamine deficiency complex has been implicated as the primary cause for poor survival of early life stages. This complex is linked to a maternal diet of Alewives that causes a thiamine deficiency in eggs that result in poor hatching success and high post hatch mortality among fry. In Lake Michigan, mean egg thiamine levels in Lake Trout have increased in recent years and are correlated with a concomitant decrease in Alewife abundance. Lake Trout eggs now exceed the 4-nmol/g thiamine concentration threshold level and meet the definition of viable eggs for restoration efforts at most sites; this may partially explain the recent detection of wild recruits. Based on our results, it appears that some reproduction of Lake Trout is now occurring in western Lake Michigan, albeit at a low level. As progress toward the abundance and egg quality targets for rehabilitation continues, we would expect increasing levels of wild recruitment to occur. ✧

Salmonid Stocking Totals for Lake Michigan 1976-2012

The Great Lakes Fishery Commission's fish stocking database is designed to summarize federal, provincial, state, and tribal fish stocking events. This database contains agency provided records dating back to the 1950's (http://www.glfc.org/fishstocking/). The purpose of this report is to briefly summarize the information in the GLFC database for Lake Michigan federal lake trout stocking and stocking rates of all salmonids within state waters of Lake Michigan (**Table 1**).

A summary of lake trout stocking locations, described by priority area in *A Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan*, is also included (**Figure 1**). Salmonid stocking totals for each state are described in **Tables 2-5** (Wisconsin, Illinois, Indiana, and Michigan, respectively).

	Atlantic Salmon	Brook Trout	Brown Trout	Chinook Salmon	Coho Salmon	Lake Trout	Rainbow Trout	Splake	Total
1976	0.020	0.075	1.129	3.317	3.196	2.548	1.863	0.000	12.148
1977	0.019	0.643	1.160	2.977	3.087	2.418	1.312	0.000	11.616
1978	0.046	0.248	1.503	5.365	2.685	2.539	1.933	0.000	14.319
1979	0.000	0.196	1.228	4.984	4.044	2.497	2.589	0.000	15.538
1980	0.000	0.204	1.292	6.106	2.943	2.791	2.630	0.000	15.967
1981	0.020	0.208	1.169	4.747	2.451	2.642	1.971	0.000	13.208
1982	0.045	0.259	2.139	6.312	2.181	2.746	2.525	0.000	16.207
1983	0.000	0.300	2.180	6.539	2.364	2.241	2.595	0.000	16.219
1984	0.000	0.233	1.803	7.710	2.954	1.565	3.111	0.034	17.410
1985	0.000	0.307	1.798	5.956	3.181	3.782	1.825	0.054	16.903
1986	0.000	0.197	1.434	5.693	2.291	3.297	2.222	0.115	15.249
1987	0.000	0.117	1.341	5.801	2.305	1.998	1.831	0.018	13.411
1988	0.017	0.466	1.516	5.417	3.210	2.546	1.429	0.104	14.706
1989	0.060	0.150	1.504	7.859	2.334	5.377	1.845	0.088	19.217
1990	0.000	0.400	1.772	7.129	2.380	1.317	1.600	0.050	14.648
1991	0.000	0.326	1.383	6.238	2.471	2.779	1.975	0.396	15.568
1992	0.000	0.272	1.615	5.795	2.712	3.435	1.689	0.099	15.618
1993	0.000	0.294	1.759	5.530	1.709	2.697	1.680	0.141	13.809
1994	0.000	0.269	2.172	5.837	1.497	3.854	2.220	0.166	16.015
1995	0.000	0.328	1.876	6.549	2.401	2.265	1.878	0.151	15.448
1996	0.000	0.180	1.787	6.193	3.112	2.141	1.849	0.201	15.463
1997	0.000	0.115	1.804	5.745	2.620	2.235	1.864	0.155	14.538
1998	0.000	0.408	1.742	5.721	2.059	2.302	1.618	0.097	13.948
1999	0.000	0.191	1.649	4.324	2.765	2.348	1.680	0.077	13.034
2000	0.000	0.045	1.666	4.049	2.499	2.260	1.244	0.079	11.842
2001	0.000	0.102	1.749	4.518	2.765	2.382	1.849	0.131	13.495
2002	0.000	0.050	1.754	4.015	2.690	2.224	1.861	0.126	12.721
2003	0.000	0.024	1.649	4.422	3.124	2.609	2.078	0.104	14.010
2004	0.000	0.001	1.601	4.303	1.687	2.354	1.583	0.122	11.651
2005	0.000	0.000	1.523	4.306	2.561	2.887	2.170	0.099	13.546
2006	0.000	0.001	1.611	3.253	2.430	3.255	1.788	0.166	12.504
2007	0.000	0.000	1.471	3.173	2.269	3.624	2.000	0.125	12.662
2008	0.000	0.005	1.469	2.725	2.029	3.122	1.618	0.087	11.056
2009	0.000	0.000	1.632	3.020	1.746	3.177	2.068	0.000	11.643
2010	0.000	0.041	1.426	3.295	2.516	3.385	1.677	0.000	12.339
2011	0.000	0.000	1.376	3.219	2.567	3.454	1.833	0.000	12.936
2012	0.000	0.000	1.523	3.243	2.743	3.598	1.929	0.000	12.788
10 year mean	0.000	0.007	1.528	3.496	2.367	3.147	1.874	0.070	12.514

Table 1-Millions of salmonids, fingerling and yearling stages combined, stocked between 1976 and 2012

Year	Brook trout	Brown trout	Chinook salmon	Coho salmon	Lake trout	Rainbow trout	Splake
1976	6,900	298,212	1,291,840	716,773	-	999,629	-
1977	643,352	802,193	912,608	491,346	-	712,031	-
1978	242,625	1,233,101	2,017,149	499,300	-	622,642	-
1979	187,330	959,542	1,963,811	319,865	-	1,211,340	-
1980	184,900	1,046,493	2,429,500	491,876	-	1,146,838	-
1981	199,867	1,014,198	1,848,260	318,500	-	996,752	-
1982	259,000	1,820,693	2,520,700	216,040	49,417	1,041,628	-
1983	300,158	1,554,818	2,791,700	356,500	31,480	1,492,804	-
1984	225,042	1,184,934	2,891,850	551,494	20,440	1,380,834	34,160
1985	307,065	1,170,070	2,740,800	1,044,222	-	431,891	54,488
1986	188,296	882,934	2,377,567	267,171	76,000	801,044	115,000
1987	94,777	836,762	2,263,484	624,432	-	562,192	-
1988	466,486	1,020,904	1,409,293	1,019,866	-	307,678	28,880
1989	150,100	972,699	2,713,891	511,286	-	495,281	-
1990	315,148	1,229,055	2,379,331	498,355	-	460,591	-
1991	326,100	981,523	1,734,618	402,804	-	586,922	147,000
1992	272,420	1,228,615	1,523,139	568,519	-	569,380	43,830
1993	294,094	1,333,311	1,600,120	-	-	679,181	40,000
1994	268,586	1,261,136	1,548,557	457,249	-	798,327	71,700
1995	327,957	1,325,118	1,901,420	722,081	-	553,441	-
1996	167,794	1,301,118	1,726,957	563,588	-	565,880	69,912
1997	114,530	1,279,830	1,917,116	514,712	-	569,950	40,000
1998	307,765	1,242,769	1,591,539	504,894	-	533,092	22,000
1999	190,669	1,181,306	1,308,766	520,224	-	521,351	26,667
2000	44,580	1,056,347	1,010,830	253,712	-	197,940	-
2001	101,500	1,257,559	1,502,607	512,774	-	641,747	54,502
2002	50,388	1,211,758	1,419,303	595,491	-	545,539	28,509
2003	23,877	1,080,538	1,511,206	540,145	-	758,275	22,086
2004	-	1,021,711	1,502,885	484,840	-	430,601	43,859
2005	-	952,104	1,475,456	515,978	-	553,861	16,259
2006	-	1,009,330	1,166,185	387,639	-	578,444	80,056
2007	-	994,566	1,112,683	610,282	-	705,133	44,352
2008	-	885,728	725,605	282,930	-	393,297	-
2009	-	934,420	995,804	344,471	-	636,329	-
2010	40,546	735,493	1,234,994	345,464	-	446,247	-
2011	-	704,755	1,127,575	433,348	-	436,427	-
2012	-	722,800	1,175,925	542,554	-	398,547	-
10 year mean	6,442	904,145	1,202,832	448,765	-	533,716	20,661

Table 2-Number of fingerling and yearling salmonids, excluding USFWS stocked lake trout, stocked in Wisconsin waters, 1976 – 2011

Year	Brook trout	Brown trout	Chinook salmon	Coho salmon	Lake trout	Rainbow trout
1976	6,420	94,265	141,999	80,261		45,254
1977		42,200	346,696	102,742		276,164
1978	5,000	13,380	611,351	278,780		39,848
1979	8,260	1,000	183,090	289,440		215,448
1980	19,500	23,762	152,181	39,000		112,880
1981		65,080	430,600	323,814		186,368
1982		18,300	793,270	158,675		169,950
1983		50,925	533,600			
1984		88,452	537,750	276,800		164,678
1985		114,695	195,000	304,600	135,506	146,265
1986		59,324	215,000	312,191	111,000	151,908
1987		88,466	539,111	187,071	24,984	88,950
1988		94,695	456,805	297,272	66,548	116,097
1989		105,484	650,425	99,690	27,223	110,490
1990			479,400	302,600		
1991		113,912	496,338	312,731		133,718
1992		100,107	352,669	308,581		105,271
1993		105,117	364,197	117,789		182,101
1994		100,528	285,583	328,004		74,625
1995		98,211	362,718	308,204		99,068
1996		85,160	124,950	305,581		50,071
1997		90,085	360,117	302,288		91,678
1998		100,000	366,172	305,835		102,983
1999		102,665	304,645	301,589		84,660
2000		100,000	305,706	302,300		100,000
2001		72,316	304,000	300,900		87,608
2002		100,000	305,341	300,992		106,464
2003		100,000	299,462	244,066		126,852
2004		70,000	302,673	300,076		112,723
2005		100,170	295,242	301,006		111,396
2006		57,568	251,612	304,242		105,203
2007		100,638	252,265	301,377		117,317
2008		100,145	254,009	282,208		107,043
2009		100,174	236,983	300,559		102,146
2010		104,954	251,143	308,805		112,249
2011		104,577	235,972	281,429		91,738
2012		99,496	253,234	300,745		101,422
10 year mean		93,772	263,260	292,451		108,809

Table 3-Number of fingerling and yearling salmonids, excluding USFWS stocked lake trout, stocked in Illinois waters, 1976 – 2012

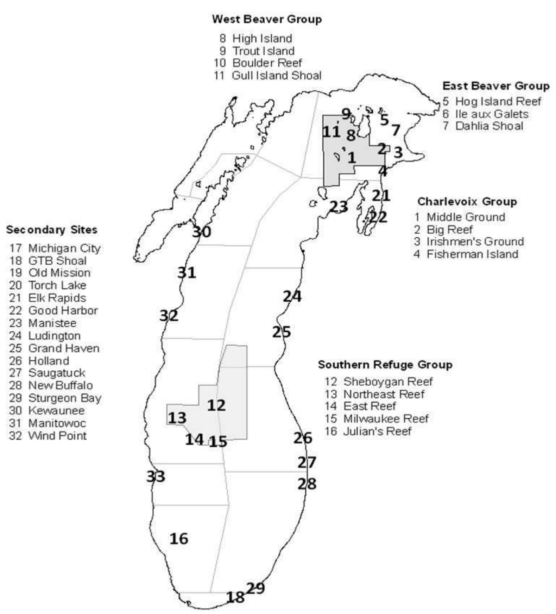


Fig 1-First and 2nd priority areas for Lake Trout in Lake Michigan

Year	Brown trout	Chinook salmon	Coho salmon	Rainbow trout
1976	199,000	38,000	179,473	217,069
1977	109,000	141,373	179,000	47,731
1978	131,010	213,209	105,000	129,739
1979	68,526	530,670	117,506	181,905
1980	116,125	621,351	169,486	69,803
1981	58,110	263,392	101,953	230,357
1982		313,071	160,381	247,709
1983		238,383	127,555	378,344
1984		405,912	156,304	258,822
1985	7,350	761,753	139,018	509,367
1986		697,658	132,854	635,700
1987		569,210	161,781	511,156
1988		879,839	160,365	461,345
1989		717,419	40,720	503,497
1990		630,236	114,153	538,788
1991		694,351	99,980	493,206
1992		504,231	100,765	411,787
1993		458,606	12,316	315,640
1994		536,964	84,397	568,057
1995		555,001	169,109	542,003
1996		571,569	357,027	577,620
1997		422,559	80,817	610,039
1998		593,512	148,320	464,034
1999		415,419	146,882	551,537
2000		417,776	157,748	374,548
2001		450,715	157,048	571,446
2002	35,000	253,000	224,797	605,181
2003	40,400	232,395	233,248	591,991
2004	46,238	237,052	236,026	465,220
2005	36,371	251,281	237,009	933,047
2006	42,900	225,131	79,018	491,417
2007	41,110	217,389	231,342	643,546
2008	22,556	215,770	248,667	572,000
2009	23,039	206,714	239,846	602,445
2010	35,053	232,789	252,186	566,170
2011	36,300	279,431	223,457	572,878
2012	71,125	222,457	148,797	742,779
10 year mean	39,509	232,041	212,960	618,149

Table 4-Number of fingerling and yearling salmonids, excluding USFWS stocked lake trout, stocked in Indiana waters, 1976 – 2012

Year	Brook trout	Brown trout	Chinook salmon	Coho Salmon	Lake trout	Rainbow trout	Splake
1976	61,290	537,333	1,845,218	2,219,892	-	600,627	-
1977	-	206,470	1,576,202	2,314,130	-	276,102	-
1978	-	125,038	2,523,554	1,801,961	-	1,140,591	-
1979	-	198,781	2,306,700	3,317,032	75,000	980,763	-
1980	-	105,458	2,902,892	2,243,008	62,000	1,300,584	-
1981	8,000	32,000	2,204,741	1,707,164	453,230	557,693	-
1982	-	300,000	2,685,086	1,645,435	90,000	1,066,127	-
1983	-	574,006	2,975,730	1,879,957	-	723,464	-
1984	8,000	529,560	3,874,237	1,969,449	-	1,307,049	-
1985	-	505,532	2,258,470	1,692,954	-	737,300	-
1986	8,600	491,795	2,402,453	1,579,181	-	632,877	-
1987	22,500	415,941	2,428,952	1,331,287	-	668,411	17,747
1988	-	400,136	2,670,933	1,732,590	-	544,315	75,000
1989	-	425,792	3,777,744	1,682,229	-	735,897	88,000
1990	85,000	542,646	3,639,756	1,464,945	-	600,680	50,000
1991	-	287,844	3,312,255	1,655,396	-	761,077	249,200
1992	-	285,885	3,415,426	1,734,592	-	602,577	55,496
1993	-	320,294	3,107,027	1,578,646	-	502,736	101,030
1994	-	810,716	3,465,751	626,914	-	779,086	94,548
1995	-	452,731	3,729,454	1,201,734	105,628	683,967	150,819
1996	-	400,468	3,529,424	1,885,735	-	603,058	131,499
1997	-	434,014	3,045,101	1,722,219	-	592,339	114,974
1998	-	399,584	3,170,173	1,100,039	-	517,785	75,000
1999	-	364,808	2,295,649	1,796,218	-	522,438	50,664
2000	-	509,815	2,314,490	1,785,240	-	571,862	79,139
2001	-	419,081	2,260,965	1,794,647	-	548,172	76,090
2002	-	406,917	2,037,558	1,568,973	149,927	604,173	97,434
2003	-	428,240	2,379,317	2,106,472	-	600,896	81,500
2004	1,000	463,150	2,260,211	666,474	-	574,119	77,732
2005	-	434,300	2,283,737	1,507,100	-	571,596	82,606
2006	-	500,831	1,609,841	1,658,880	-	612,736	86,200
2007	-	334,376	1,590,909	1,125,860	-	534,092	80,350
2008	4,960	460,897	1,529,994	1,215,149	-	545,926	86,993
2009	-	574,669	1,580,535	861,145	80,000	727,554	-
2010	-	550,563	1,575,713	1,609,802	47,000	552,294	-
2011	-	490,793	1,575,545	1,628,923	80,000	732,358	-
2012	-	629,683	1,591,019	1,750,685	80,993	686,083	-
10 year mean	596	486,750	1,797,682	1,413,049	28,799	613,765	49,538

Table 5- Number of fingerling and yearling salmonids, excluding USFWS stocked lake trout, stocked in Michigan waters, 1976 – 2012

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2012 Lake Michigan Lake Trout Working Group Report

This report provides an overview of the status of lake trout populations and restoration efforts in Lake Michigan. It provides a quick, graphical representation of pertinent data, and is structured to review the population objectives articulated in *A Lake Trout Restoration Guide for Lake Michigan.* Graphical presentations provide current measures within a time series (when available) and compare current values with target values to gauge progress towards restoration.

Overall Goal of Restoration efforts

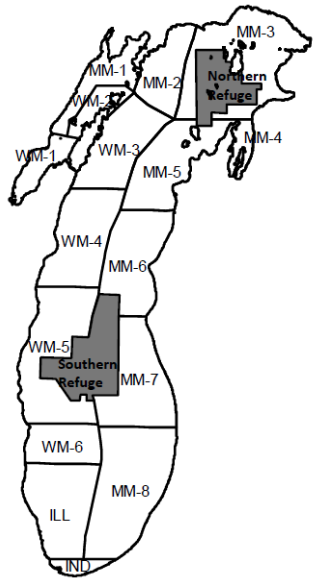
In targeted rehabilitation areas, reestablish genetically diverse populations of lake trout composed predominately of wild fish able to sustain fisheries.

Objective 1: (Increase genetic diversity): Increase the genetic diversity of lake trout by introducing morphotypes adapted to survive and reproduce in deep-water, offshore habitats, while continuing to stock shallow-water morphotypes.

Results show the Klondike Reef strain from Lake Superior has been recommended for introduction to deep-water habitats; the LMC has decided that a limited number should be stocked experimentally in the near future. In 2012, about 80,000 Klondike Reef strain yearlings were stocked on Northeast Reef in the Mid-lake Refuge (MLR), also known as the Southern Refuge. Lean lake trout from Seneca Lake (Finger Lakes, NY), Apostle Islands (Lake Superior), and Lewis Lake (Lake Michigan remnant) have been selected as the primary lean lake trout strains. Additionally, a remnant, nearshore form of lean lake trout from Parry Sound (Lake Huron) has been raised in USFWS hatcheries and is scheduled to be stocked into Lake Michigan during 2013.

Objective 2: (Increase overall abundance): By 2014, increase densities of lake trout populations in targeted rehabilitation areas to levels observed in other Great Lakes locations where recruitment of wild fish to the adult population has occurred. To achieve this objective, CPUE in spring assessments should consistently exceed 25 lake trout/1000 feet of graded-mesh (2.0 – 6.0 inch) gill net fished.

Results: Spring gill net assessments in 2012 indicated that overall abundance remains substantially below the target level of 25 lake trout/1000 ft of net (horizontal line) lakewide. In most areas, abundance was well below the target level. However, abundance has, at times, approached or exceeded the target level in a few statistical districts (Illinois waters, MM-5, MM-6, and WM-5) and in the MLR. According to the spring assessments, lakewide lake trout abundance decreased from about 9 fish/1000 ft in 2011 to about 7 fish/1000 fit in 2012.



Lake Michigan lakewide management zones

Objective 3: (Increase adult abundance): By 2020, achieve densities of spawning adult lake trout in targeted rehabilitation areas comparable to those observed in other Great Lakes locations where recruitment of wild fish to the adult population has occurred. To achieve this objective, CPUE in fall assessments should consistently exceed 50 fish/1000 ft of graded-mesh (4.5-6.0 inch) gill net fished.

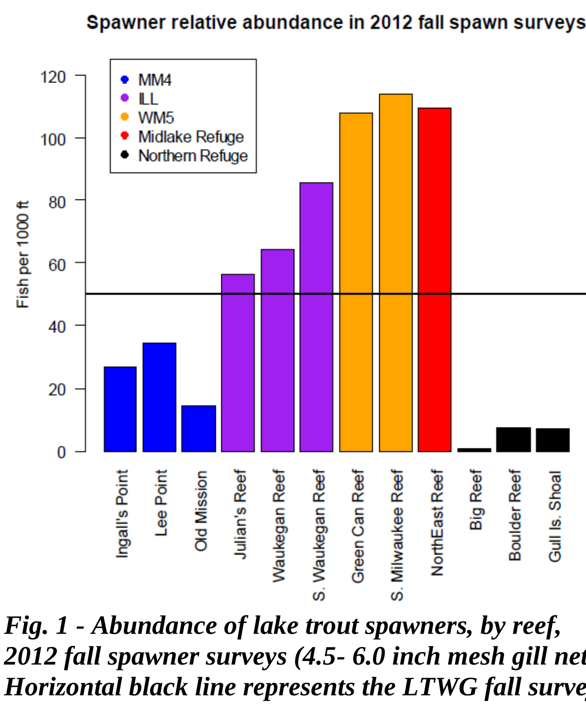


Fig. 1 - Abundance of lake trout spawners, by reef, 2012 fall spawner surveys (4.5- 6.0 inch mesh gill nets). Horizontal black line represents the LTWG fall survey benchmark of 50 fish per 1000 ft of gill net

Results: Of the 12 spawning areas sampled during fall 2012, 6 areas met or exceeded the target **(Fig. 1).** In some areas, abundance of adult fish is low and may not be adequate to result in egg deposition rates sufficiently high to overcome impediments to rehabilitation. The lowest spawner abundances were measured at Big Reef, Boulder Reef, and Gull Island Reef within the Northern Refuge. These low abundances could be attributed, at least in part, to reduced stocking rates within the Northern Refuge during 1995-2008.

Objective 4: (Build spawning populations): By 2024, spawning populations in targeted rehabilitation areas stocked prior to 2008 should be at least 25% females and contain 10 or more age groups older than age 7. These milestones should be achieved by 2032 in areas stocked after 2008.

Results: On average, the percentage of females in the fall spawner surveys conducted during 2012 exceeded the benchmark value of 25% **(Fig. 2).** Moreover, the percentage of females in the fall spawner catch during 2012 exceeded 25% at 7 of the 12 locations included in the plot.

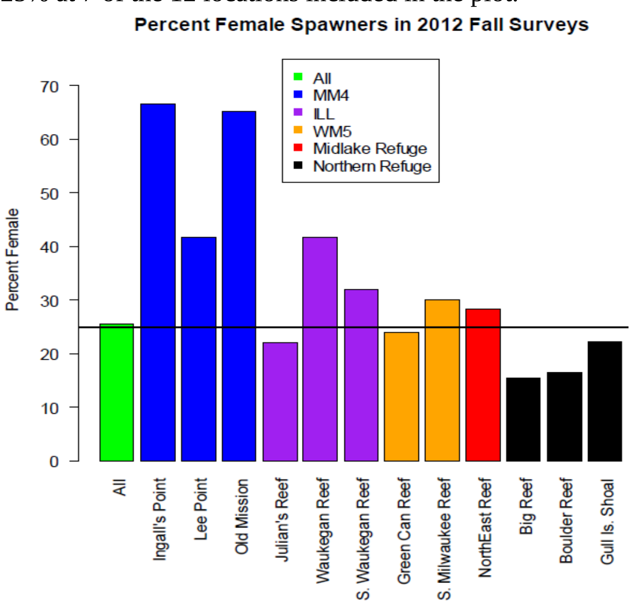


Fig. 2 - Percentage of fall spawners that were female by location, fall 2012. Horizontal black line represents LTWG fall survey benchmark value of 25%.

Objective 5: (Detect egg deposition): By 2021, detect a minimum density of 500 viable eggs/m2 (eggs with thiamine concentrations > 4 nmol/g) in previously stocked areas. This milestone should be achieved by 2025 in newly stocked areas.

Results: Egg deposition rates have remained low at the sites where egg deposition has been measured in northern Lake Michigan during 2000-2009. Nearly all of the measured densities of lake trout eggs have been less than 60 eggs/m2 **(Fig 3).**

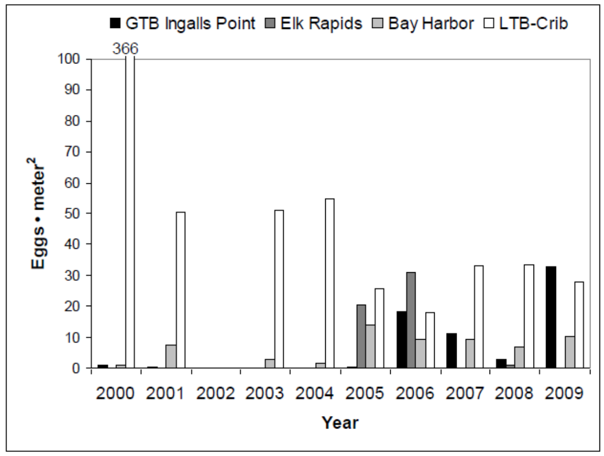


Fig.3 - Numbers of lake trout eggs observed per square meter in northern Lake Michigan fall egg deposition surveys .Egg deposition was measured using standard bag methodologies

Objective 6: (Detect recruitment of wild fish): Consistent recruitment of wild lake trout in targeted rehabilitation areas should occur as follows: by 2022 detect age-1 fish in bottom trawls, by 2025 detect age-3 fish in spring graded-mesh-gill-net assessments, and by 2028 consistently detect sub-adults.

Results: In 2012, 5.0% of lake trout caught during the spring LWAP survey were fish that had no fin clip which is above the recently estimated 3.0% rate of marking error (fish released from the hatchery without a fin-clip). This suggests that natural reproduction is slowly increasing in at least some areas of Lake Michigan **(Fig. 4).**

In 2011 and 2012, about 20% of the juvenile lake trout incidentally caught in gill nets set for bloaters off the Door Peninsula and Mid-lake reef in Wisconsin during February surveys were unclipped fish and most were <500 mm in length.

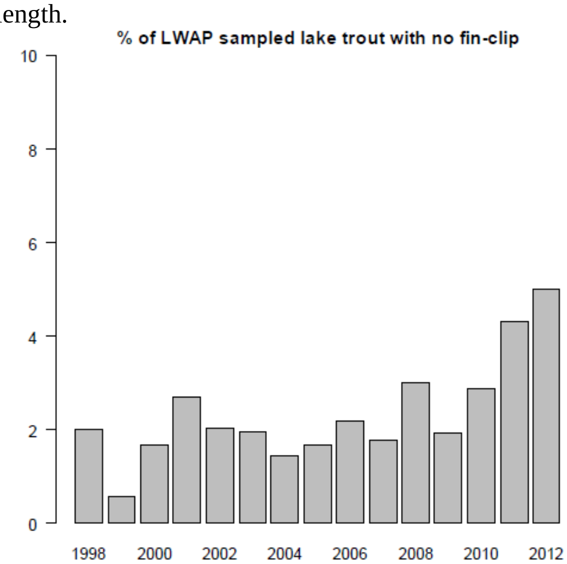


Fig. 4 - Percentage of lake trout captured in spring surveys without fin clips. Lack of a fin clip suggests the fish were produced in the lake

In 2013, gillnet collections off Door Peninsula returned 22% (29 of 129) unclipped while bottom trawls near Manitowoc had an unclipped recovery rate of 21% (7 of 33). The most substantive evidence of natural reproduction was in 2012 fall spawn surveys in Illinois waters were 50% (262 of 528) of lake trout were unclipped. Lastly the USGS Great Lakes Science Center (GLSC) fall bottom trawl survey in September and October of 2012 caught 4 age-0 lake trout and 2 were wild. Since 2005, 18 of the 113 lake trout, or 16% of the lake trout, caught in the GLSC bottom trawl survey were unclipped. Prior to 2005, less than 2% of the lake trout caught in the GLSC bottom trawl survey were unclipped.

Lake trout stocking

The U. S. Fish and Wildlife Service stocked 2.96 million yearling (14-16 months old) lake trout into Lake Michigan in 2012. Stocking totals for each state jurisdiction were 122,692 in Illinois, 42,420 in Indiana, 2,093,339 in Michigan, and 703,349 in Wisconsin (**Fig. 5).** All yearling fish received an AD fin clip paired with a coded wire tag. The stocked yearling lake trout consisted of four strains: Apostle Islands, Lewis Lake, Seneca Lake, and Klondike Reef. All Klondike Reef strain lake trout were stocked at Northeast Reef. Additionally, 552,847 fall fingerlings (Parry Sound, Lewis Lake, Apostle Islands, and Seneca Lake) were stocked into nearshore waters of Lake Michigan.

End ✧✧

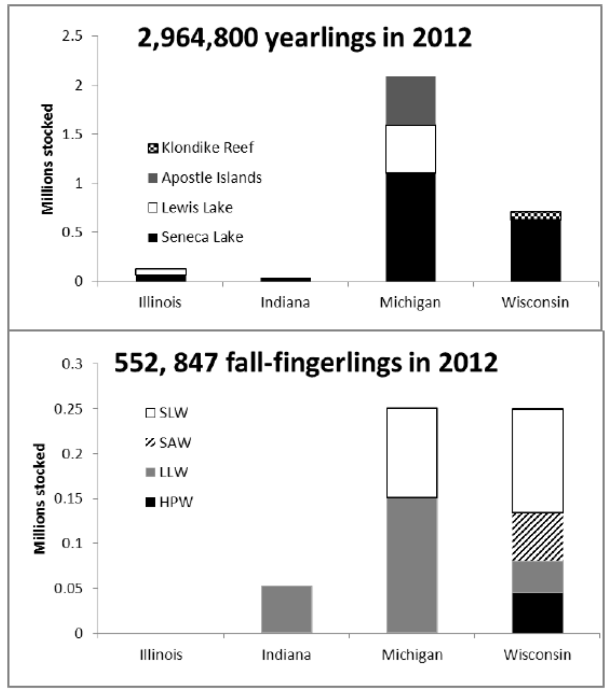


Fig. 5 - Spring yearling and fall fingerling lake trout stocking in Lake Michigan, 2012