Inland Seas Angler
GREAT LAKES BASIN REPORT©
Special Report – Lake Michigan Part 2
A Publication of the Great Lakes Sport Fishing Council April 2018
http://www.great-lakes.org Vol. 29, No. 4.4b

Highlights of the Annual Lake Committee Meetings

Great Lakes Fishery Commission proceedings, Sault Ste. Marie, Ontario

This third of a series of annual special reports is a two-part summary of Lake Michigan. This lake committee report is from the annual Lake Committee meetings hosted by the Great Lakes Fishery Commission in March/April 2018. We encourage reproduction with the appropriate credit to the GLSFC and the agencies involved. Our thanks to IL DNR; Brian Breidert, IN DNR; USFWS, and the many other DNR biologists who make this all happen, 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, Bob Lamb & Marc Gaden, for their efforts in again convening and hosting the Upper Lake Committee meetings in Sault Ste. Marie, Ontario.

Lake Michigan – Part 2

Index of Reports

Abbreviation	**Expansion**
CPH	Catch per hectare
CWT	Coded Wire Tag
KT	1,000 metric tons
MDNR	MI Dept. of Natural Resources
SLCP	Sea Lamprey Control Program
USFWS	U.S. Fish and Wildlife Service
WTG	Walleye Task Group
YAO	Age 1 and older
YOY	Young of the year (age 0)

Status and Trends of Prey Fish Populations in Lake Michigan, 2017 (USGS)

Abstract

The U.S. Geological Survey Great Lakes Science Center has conducted lake-wide surveys of the fish community in Lake Michigan each fall since 1973 using standard 12-m bottom trawls towed along contour at depths of 9 to 110 m at each of seven index transects. The resulting data 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 2017. 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 for burbot and yellow perch. Lake-wide biomass of alewives in 2017 was estimated at 0.09 kilotonnes (kt, 1 kt = 1000 metric tonnes), which was a record low, and 75% lower than in 2016. Age distribution of alewives remained truncated with no alewife age exceeding 5 years. Bloater biomass increased by more than 50% from 5.9 kt in 2016 to 9.1 kt in 2017. Round goby biomass declined by more than half from 1.1 kt in 2016 to 0.5 kt in 2017. Rainbow smelt biomass increased twofold up to 0.6 kt in 2017, but was still under 1 kt for the eighth straight year. Slimy sculpin biomass decreased from 0.8 kt in 2016 to 0.2 kt in 2017, whereas deepwater sculpin biomass in 2017 was 2.7 kt, which was within 10% of the 2016 level. Ninespine stickleback biomass in 2017 was at a near record low level (0.002 kt). Burbot lake-wide biomass (0.1 kt in 2017) has remained below 3 kt since 2001. No age-0 yellow perch were caught in 2017, indicating a weak year-class. 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 2017 was 13.3 kt, roughly a 20% increase over the 2016 total but still the fourth lowest estimate in the 45-year time series. In 2017, bloater and deepwater sculpin, two native fishes, constituted nearly 90% of this total.

Sampling

The U.S. Geological Survey Great Lakes Science Center (GLSC) has conducted daytime bottom trawl surveys in Lake Michigan during the fall annually since 1973. Estimates from the 1998 survey are not reported because the trawls were towed at non-standard speeds. From these surveys, the relative abundances of the prey fish populations are measured, and estimates of lake-wide biomass available to the bottom trawls (for the region of the main basin between the 5-m and 114-m depth contours) can be generated. Such estimates are critical to fisheries managers making decisions on stocking and harvest rates of salmonines and allowable harvests of fish by commercial fishing operations.

Ages were estimated for alewives (using otoliths) and bloaters (using scales) from our bottom trawl catches . Although our surveys have included as many as nine index transects in any given year, we have consistently conducted the surveys at seven transects, and data from those seven transects are reported herein. These transects are situated off Manistique, Frankfort, Ludington, and Saugatuck, Michigan; Waukegan, Illinois; and Port Washington and Sturgeon Bay, Wisconsin **(Fig 1).** All seven transects were completed in 2017.

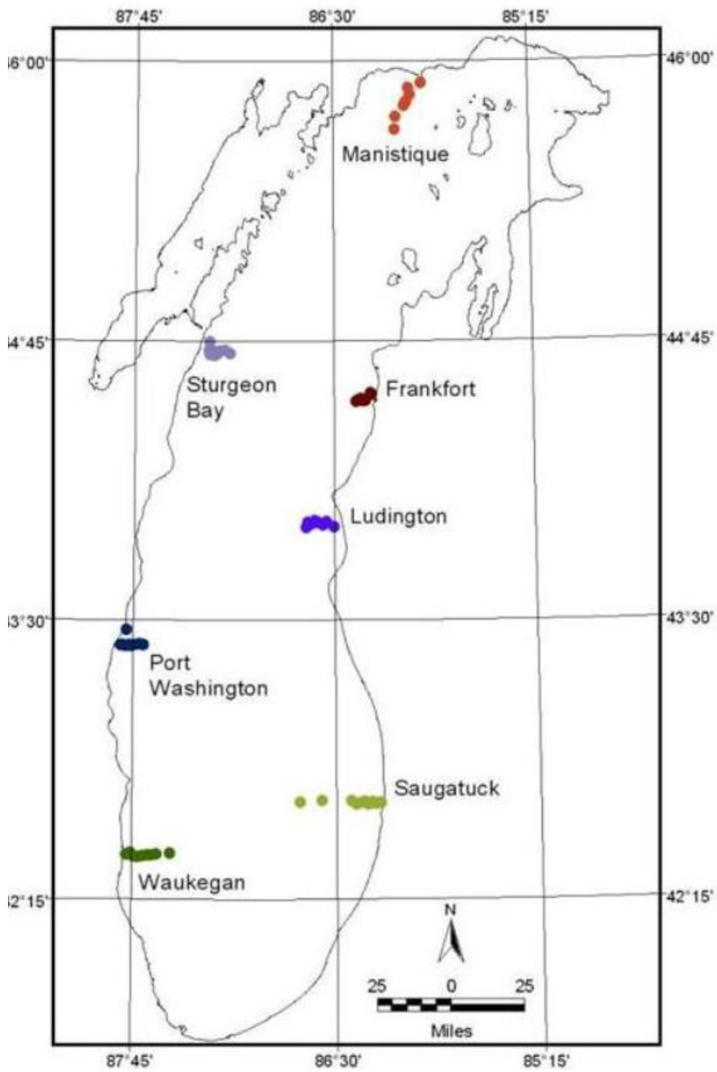


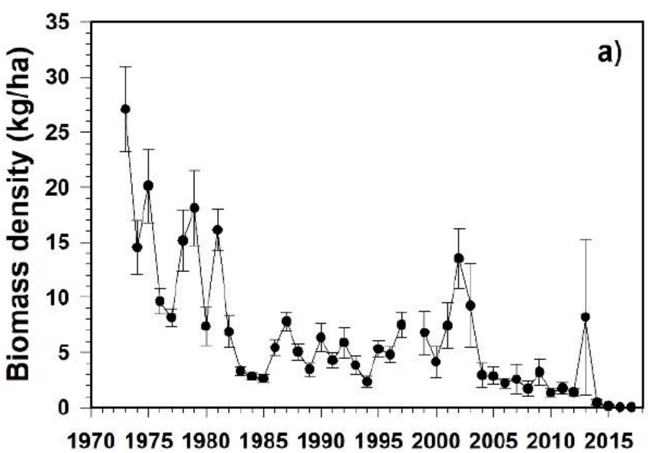
Fig 1-Established sampling locations for GLSC bottom trawls.

Alewife

Since its establishment in the 1950s, the alewife has become a key member of the fish community. As a predator on larval fish, 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.

According to the bottom trawl survey results, adult alewife biomass density equaled 0.02 kg per ha in 2017, a record low **(Fig 2a**). Likewise, adult alewife numeric density in 2017 equaled a record-low estimate of 0.9 fish per ha **(Fig 2b**). Alewives were caught at all ports other than Saugatuck during 2017, but estimates of biomass density did not exceed 0.5 kg per ha for any of the bottom trawls **(Fig 3).** Since 2013, alewives have been sampled in 13 of 23 deep tows. However, mean alewife biomass density at 128 m was between 2 and 3 times lower than those at 9 m and 18 m, and about 2 times lower than that at 110 m. Thus, apparently a relatively low proportion of the alewife population was situated in waters deeper than 110 m at the time of our survey during 2013-2017**.**

The long-term temporal trends in adult alewife biomass, as well as in alewife recruitment to age 3, in Lake Michigan are attributable to consumption of alewives by salmonines.



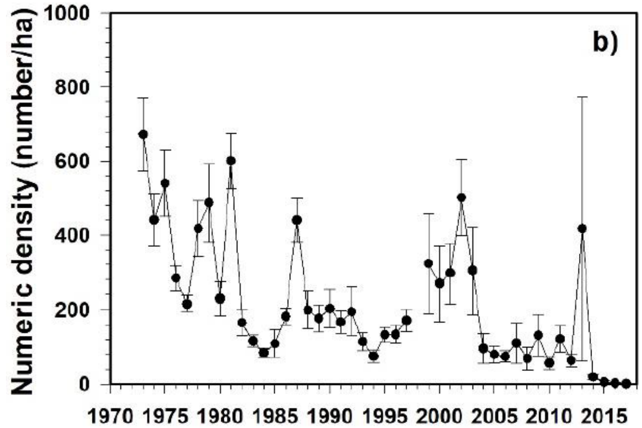


Fig 2- Density of adult alewives as biomass (a) and number (b) per ha (+/- standard error) in Lake Michigan, 1973-2017.

Several factors have likely maintained this high predation pressure in the 2000s including: a relatively high abundance of wild Chinook salmon in Lake Michigan, increased migration of Chinook salmon from Lake Huron in search of alewives, increased importance of alewives in the diet of Chinook salmon in Lake Michigan (Jacobs et al. 2013), a decrease in the energy density of adult alewives, and increases in lake trout abundance due to increased rates of stocking and natural reproduction.

In 2017, the bottom trawl survey captured only 41 “adult” (i.e., >100 TL) alewives for which we typically construct an age-length distribution. The age composition of these fish was dominated by age-1 (42%, 2016 year-class) and age-2 (46%, 2015 year-class) fish. Age-4 (2013 year-class), and age-5 (2012 year-class) fish represented 5% and 7%, respectively, of the remaining adults, and no age-3 fish were caught in the survey **(Fig 4**). In 2017, bloater and deepwater sculpin, two native fishes, constituted nearly 90% of this total.

; thus, the recent trend of age truncation in the alewife population continued through 2017. Likewise, no alewives older than age 5 were caught in the acoustics survey in 2017. Prior to 2009, age-8 alewives were routinely captured in the bottom trawl survey. In contrast to 2017, in most years the age composition of the alewife population is based on aging at least 200 alewives caught from the bottom trawl survey each year.

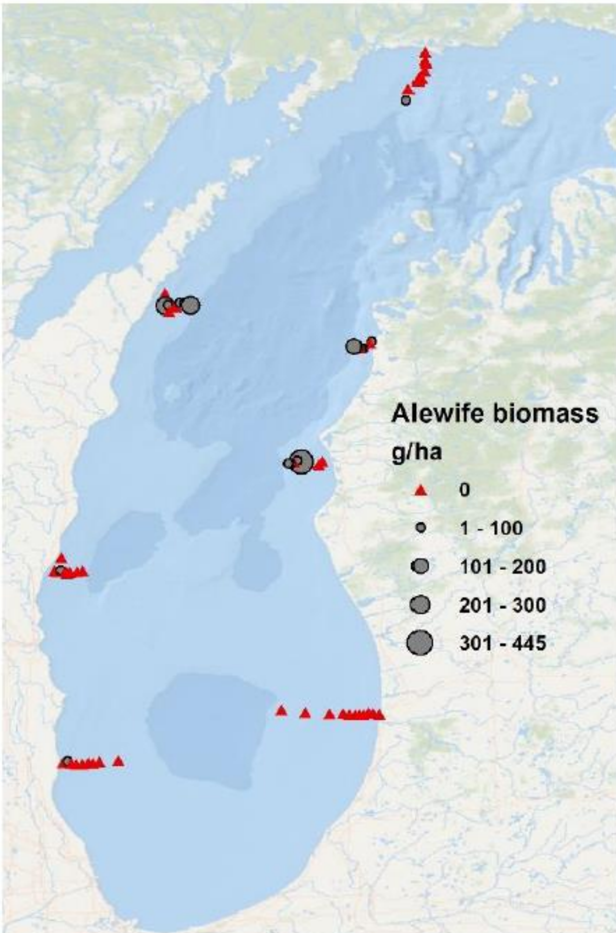


Fig 3- Scaled-symbol plot showing the biomass of alewife sampled at each of the 2017 bottom trawl sites.

Both the acoustic and bottom trawl survey time series for total alewife biomass are in general agreement, indicating that biomass during 2004-2017 was relatively low compared with biomass during 1994-1996. Across the 22 years, however, the acoustic estimate has been higher than the bottom trawl survey estimate 82% of the time. The discrepancy between the two estimates has increased between 2014 and 2017, with the acoustic estimate ranging from 10 to nearly 200 times higher during this 4-year period. The acoustic survey likely provides a less biased estimate of younger (age 3 and younger) alewives, owing to their pelagic orientation. Thus, this recent higher discrepancy between the two surveys may have been partly due to the alewife population in the lake becoming younger in recent years, but other factors were also likely involved. The acoustic survey assessed a 13% increase in total alewife biomass between 2016 and 2017, whereas the bottom trawl survey assessed a 75% decrease in total alewife biomass between these two years.

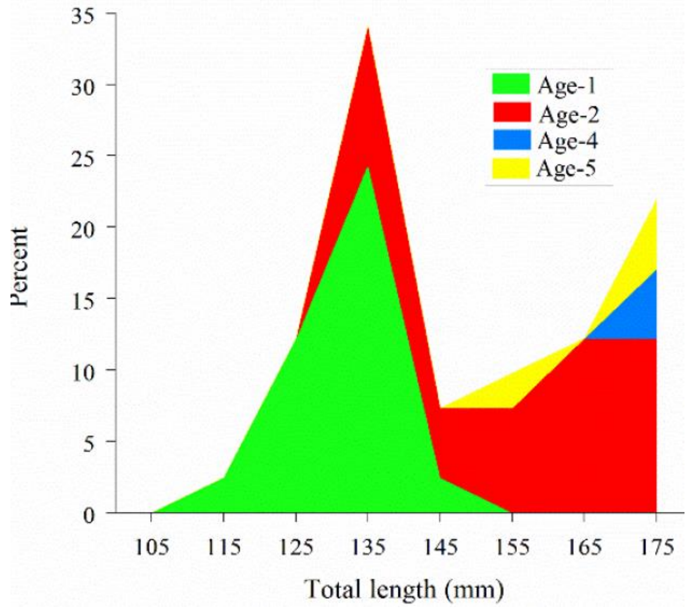


Fig 4. Age-length distribution of alewives ≥ 100 mm total length caught in bottom trawls in Lake Michigan, 2017.

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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 (< 500 mm) 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 declined sharply since the late 1990s. Adult bloater biomass density in our survey has been < 10 kg per ha since 1999 (**Fig 5a**). Nevertheless, adult bloater biomass nearly tripled between 2016 and 2017, when it reached a level of 2 kg per ha.

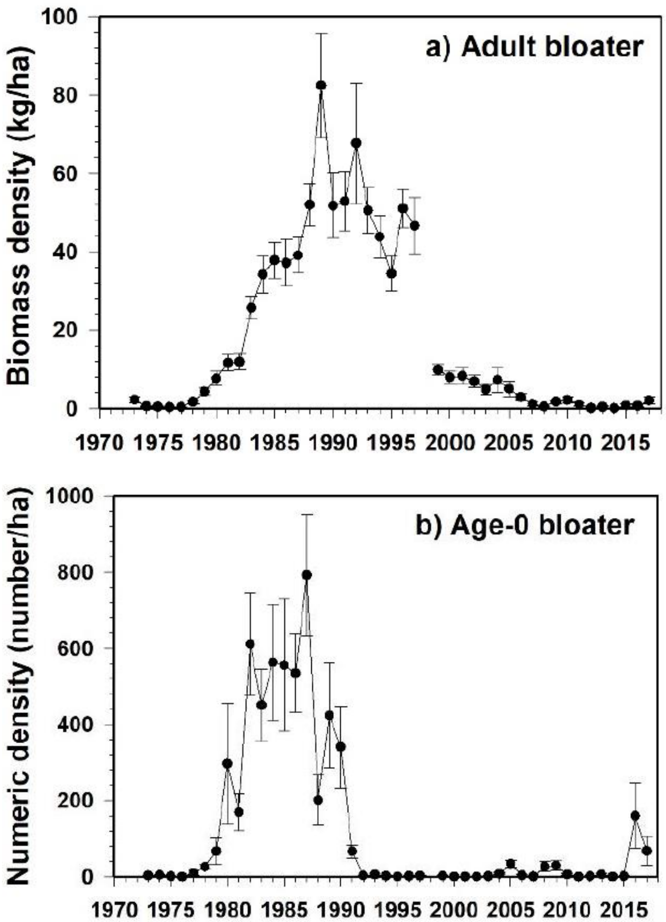

Fig 5-Panel (a) depicts biomass density (+/- standard error) of adult bloater in Lake Michigan, 1973-2017. Panel (b) depicts numeric density (+/- standard error) of age-0 bloater in Lake Michigan, 1973-2017.

This substantial increase in adult bloater biomass was attributable to the relatively strong 2016 year-class recruiting to the age-1 and older population in 2017 (**Fig 5**). Moreover, numeric density of age-0 bloaters (< 120 mm TL) in 2017 was 68 fish per ha, which the second highest estimate since 1990 **(Fig 5b**). Thus, bloater recruitment during the past two years has been much higher than bloater recruitment during other years since 1992, based on the bottom trawl survey results. Bloaters were sampled in all seven ports in 2017 **(Fig 6**), with the highest mean biomass densities at Ludington, Saugatuck, and Frankfort. Since 2013, bloaters have been sampled in 8 of 23 deep tows. Mean biomass density at 128 m was more than an order of magnitude lower than mean biomass densities at some of the shallower depths. Thus, according to the bottom trawl survey results, a relatively low proportion of the bloater population occurred in waters deeper than 110 m at the time of our survey during 2013-2017.

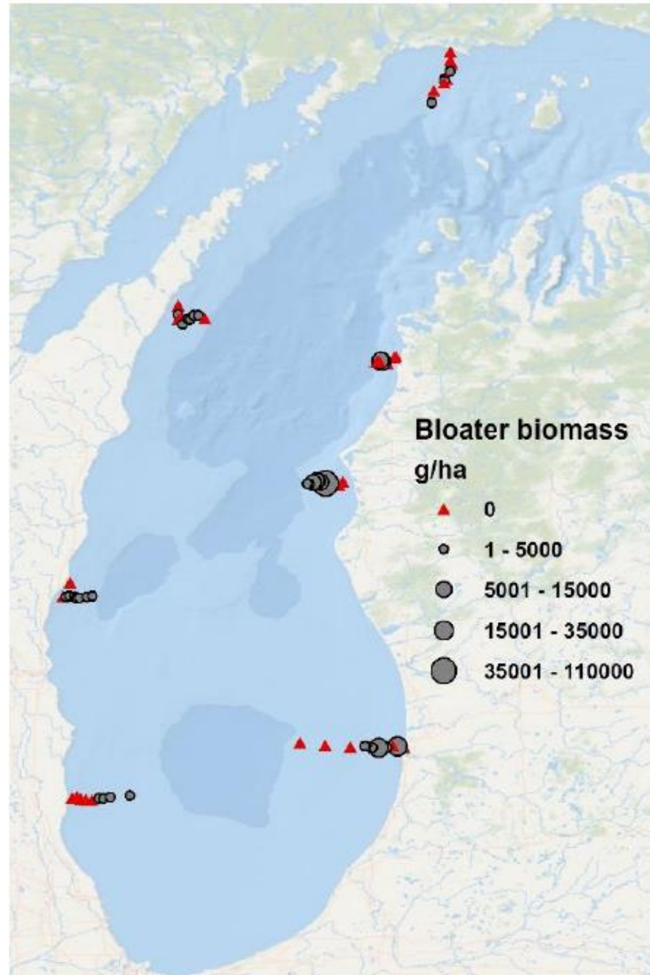

Fig 6-Scaled-symbol plot showing the biomass of bloater sampled at each of the 2017 bottom trawl sites.

The exact mechanisms underlying the apparently poor bloater recruitment for most of the 1992-2017 period **(Fig 5b),** and the low biomass of adult bloater since 2007 **(Fig 5a**), remain unknown. Madenjian proposed that the Lake Michigan bloater population may be cycling in abundance, with a period of about 30 years, although the exact mechanism by which recruitment is regulated remains unknown. Of the mechanisms that have been recently evaluated, reductions in fecundity associated with poorer condition and egg predation by slimy and deepwater sculpins may be contributing to the reduced bloater recruitment, but neither one is the primary regulating factor.

An important consideration when interpreting the bottom trawl survey results is that bloater catchability may have decreased in recent years, in response to the proliferation of quagga mussels and the associated increased water clarity and decreased *Diporeia* densities, which could be responsible for a shift to the more pelagic calanoid copepods in their diets. Hence, one hypothesis is that bloaters are less vulnerable to our daytime bottom trawls either owing to behavioral changes (more pelagic during the day) or increased ability to avoid the net while on the bottom (due to clearer water). Further, vulnerability of bloaters to our bottom trawl survey may have decreased more for large bloaters than for small bloaters. In recent years, nearly all of the bloaters captured by our bottom trawls were less than 240 mm in TL, whereas commercial fishers using gill nets continue to harvest bloaters well over 300 mm in TL. Perhaps, in recent years, bloaters have become more pelagic and/or better able to avoid the net as they grow.

Both the acoustic and bottom trawl survey have assessed that bloater biomass was more than an order of magnitude higher during 1992-1996 than during 2001-2017. A comparison of the two surveys during 1992-2006 revealed that the biomass estimate from the bottom trawl survey was always higher (about 3 times higher, on average) than the acoustic survey estimate. Since 2007, either survey was just as likely to yield the higher estimate as the other survey. In 2017, total biomass density estimated for bloater from the bottom trawl survey (2.59 kg per ha) was very similar to that from the acoustic survey (2.52 kg per ha). Age-0 bloater trends also have revealed relative differences between surveys varying through time. During 1992-1996, both surveys documented age-0 bloater numeric density to range between 0.3 and 6.2 fish per ha. Since 2001, however, the acoustic survey has documented a mean numeric density of age-0 bloater of 192 fish per ha, while mean numeric density of age-0 bloater from the bottom trawl survey was only 20 fish per/ ha since 2001. One potential explanation for these inconsistent relative differences in survey results over time is that catchability of age-0 bloater with the bottom trawl decreased sometime during the 2000s.

Rainbow smelt

Adult rainbow smelt have been an important part of the diet for intermediate-sized (400 to 600 mm) lake trout in the nearshore waters of Lake Michigan. 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. Rainbow smelt has been consistently rare in the diets of larger Chinook salmon since 1994. The rainbow smelt population has traditionally supported commercial fisheries in Wisconsin and Michigan waters, but its yields have also declined through time. Between 1971 and 1999, more than 1.3 million pounds were annually harvested on average. Between 2000 and 2011, the annual average dropped to about 375,000 pounds. Since 2013, less than 2,000 pounds have been harvested per year.

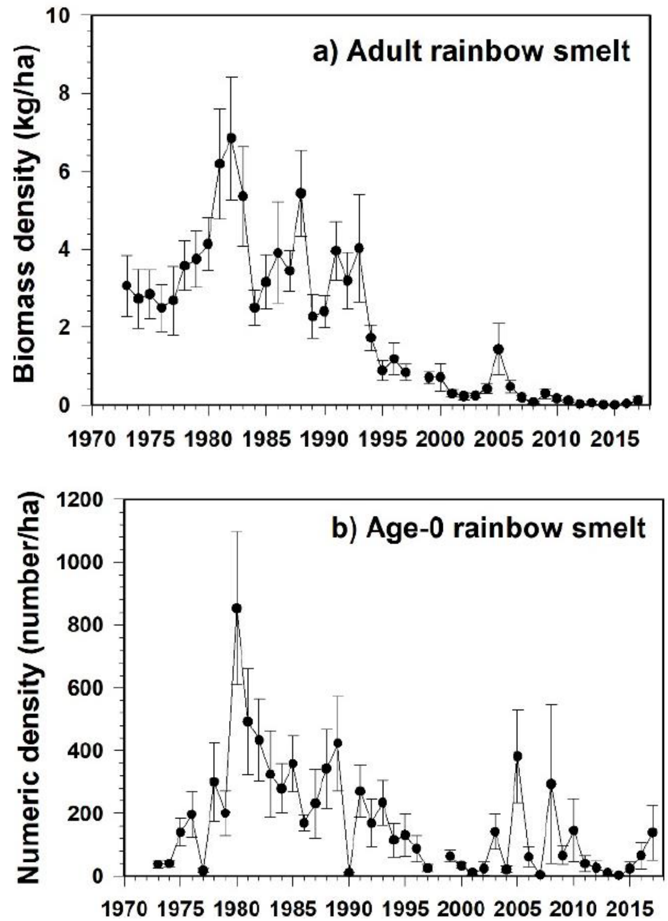

Fig 7-Panel (a) depicts biomass density (+/- standard error) of adult rainbow smelt in Lake Michigan, 1973-2017. Panel (b) depicts numeric density (+/- standard error) of age-0 rainbow smelt in Lake Michigan, 1973-2017.

Similar to the commercial yields, adult rainbow smelt biomass density in the bottom trawl has remained at low levels since 2001, aside from a relatively high estimate in 2005 **(Fig 7a**). Biomass density in 2017 was 0.12 kg per ha. Age-0 rainbow smelt numeric density has been highly variable since 1999 (**Fig 7b**), and equaled 138 fish per ha in 2017, marking the first time this density exceeded 100 fish per ha since 2010. Rainbow smelt were sampled at all seven ports in 2017 (**Fig 8),** with the highest mean biomass densities at Saugatuck, Ludington, and Manistique. Causes for the general decline in rainbow smelt biomass since 1993 remain unclear. Consumption of rainbow smelt by salmonines was higher in the mid-1980s than during the 1990s, yet adult and age-0 (< 90 mm TL) rainbow smelt abundance remained high during the 1980s **(Fig 7b).** Results from a recent population modeling exercise suggested that predation by salmonines was not the primary driver of long-term temporal trends in Lake Michigan rainbow smelt abundance. Furthermore, a recent analysis of our time series suggested that the productivity of the population has actually increased since 2000 (relative to 1982-1999), yet those recruits do not appear to be surviving to the adult population.

The bottom trawl and acoustic surveys detected similar temporal trends, with total (age-0 and adult pooled) rainbow smelt biomass densities more than 7 times higher, on average, during 1992-1996 than during 2001-2017. A comparison of the two survey estimates revealed that the acoustic survey estimate always exceeds that of the bottom trawl survey, on average by a factor of about 6. This difference is not surprising given that rainbow smelt tend to be more pelagic than other prey species during the day. In 2017, the total biomass estimate for all rainbow smelt was 1.03 kg per ha for the acoustic survey (Warner et al. 2018), which was about 6 times greater than the bottom trawl survey estimate (0.18 kg/ha).

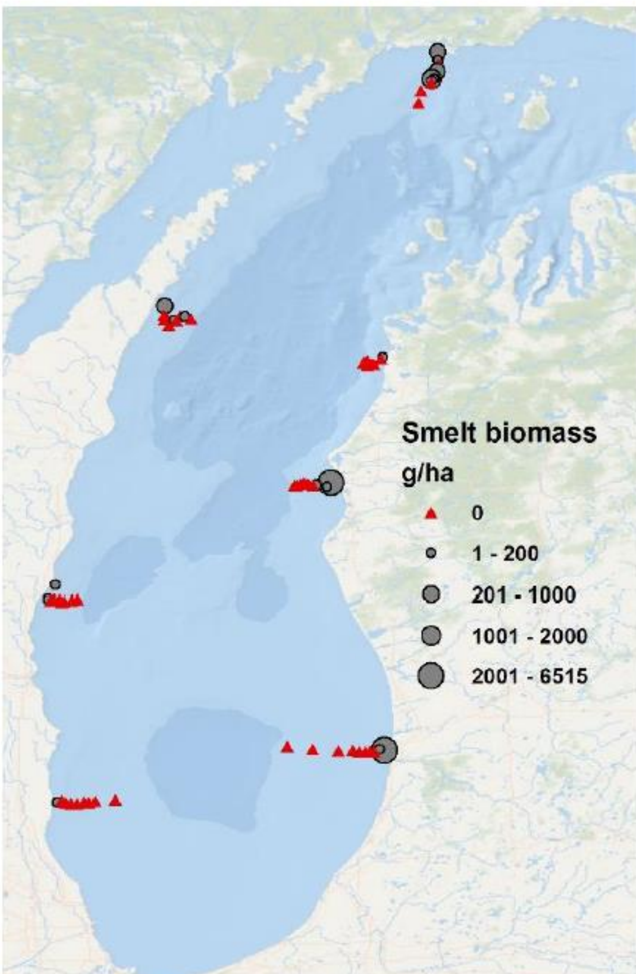

Fig 8-Scaled-symbol plot showing the biomass of rainbow smelt sampled at each of the 2017 bottom trawl sites.

Sculpins

From a biomass perspective, 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 Lake Michigan, but is only a minor part of adult lake trout diets. When abundant, deepwater sculpin can be an important diet constituent for burbot in Lake Michigan, especially in deeper waters. Deepwater sculpin biomass density in 2017 was 0.78 kg per ha, which was only 8% lower than the estimate of 0.85 kg per ha for 2016 (**Fig 9a).** Previous analysis of the time series indicated deepwater sculpin density is negatively influenced by alewife (predation on sculpin larvae) and burbot (predation on juvenile and adult sculpin. Based on bottom trawl survey results, neither alewife nor burbot significantly increased in abundance during 2007-2017 to account for this decline in deepwater sculpins. Following no clear trend between 1990 and 2005, the biomass of deepwater sculpin sampled in the bottom trawl has declined since 2005.It was demonstrated that deepwater sculpins have been captured at increasingly greater depths since the 1980s. Therefore, one potential explanation for the recent decline 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., 9-110 m), perhaps in response to the decline of *Diporeia* and proliferation of dreissenid mussels.

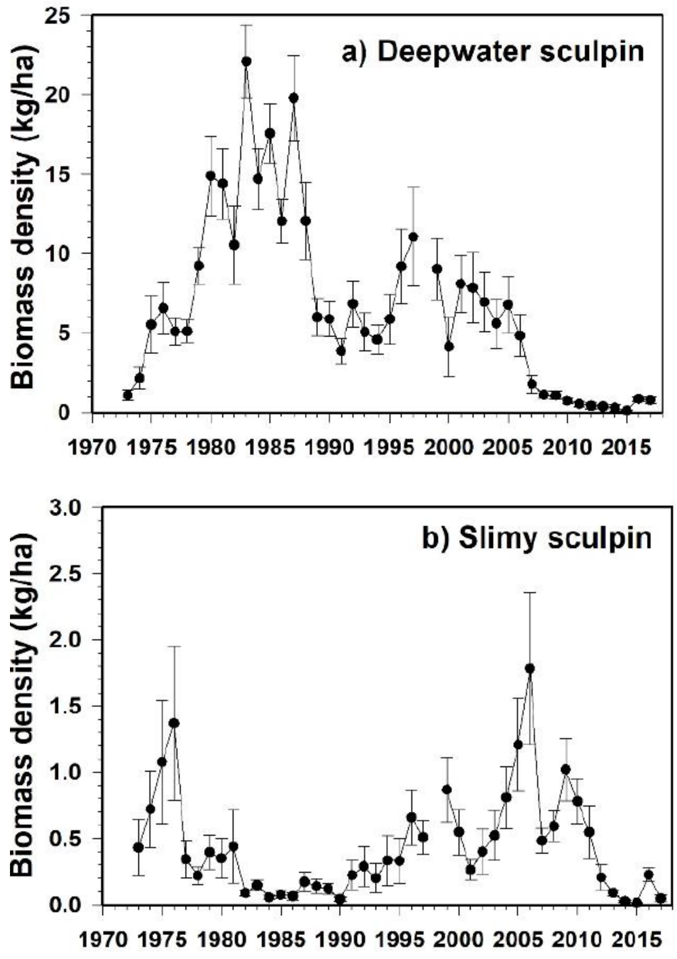

Fig 9-Biomass density for deepwater sculpin (a) and slimy sculpin (b) in Lake Michigan, 1973-2017.

Furthermore, because the deepwater sculpin has historically occupied 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. Our sampling at deeper depths has been supportive of this hypothesis. Since 2013, deepwater sculpins have been sampled in all 23 deep tows. Moreover, mean biomass densities at 73, 82, 91, 110, and 128 m were 0.16, 0.26, 0.61, 2.52, and 4.45 kg per ha, respectively, suggesting that the bulk of the deepwater sculpin population in Lake Michigan now occupies waters deeper than 110 m.

Slimy sculpin biomass density in 2017 was 0.05 kg per ha, which was nearly 5 times lower than the 2016 density. Overall, slimy sculpin biomass density has substantially declined since 2009 (**Fig 9b).** Slimy sculpin abundance in Lake Michigan is regulated, at least in part, by predation from juvenile lake trout. We attribute the slimy sculpin recovery that occurred during the 1990s to, in part, the 1986 decision to emphasize stocking lake trout on offshore reefs (as opposed to the areas closer to shore where our survey samples. Likewise, the slimy sculpin decline that began in 2009 coincided with a substantial increase in the rate of stocking juvenile lake trout into Lake Michigan and an increase in natural reproduction by lake trout. Since 2013, slimy sculpins have been sampled in 12 out of 23 deep tows. However, mean biomass density of slimy sculpins at 128 m was about 7 times lower than the peak mean biomass density at 82 m, and mean biomass densities at 73, 91, and 110 m were at least 5 times higher than that at 128 m. These results suggested that a relatively small proportion of the population resided in waters deeper than 110 m.

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; our survey likely markedly underestimates round goby abundance given their preferred habitat includes rocky and inshore (i.e., < 9 m bottom depth) areas that we do not sample. By 2002, round gobies had become an integral component of yellow perch diets at nearshore sites (i.e., < 15 m depth) in southern Lake Michigan. Recent studies have revealed round gobies are an important constituent of the diets of Lake Michigan burbot, yellow perch, smallmouth bass, lake trout, and even lake whitefish.

Round goby biomass density equaled 0.15 kg per ha in 2017 (**Fig 10a**). Since 2011, round goby biomass density has ranged between 0.15 and 1.0 kg per ha in every year except for 2013 (due to a few extraordinarily large catches inflating the mean and causing high uncertainty) and 2015 (due to consistently low catches). Round goby were sampled at all seven ports in 2017 (**Fig 11),** with the highest mean biomass densities at the 9-m and 18-m bottom depths at Waukegan. We hypothesize that round goby abundance in Lake Michigan is now being controlled by predation. This hypothesis was supported by recent estimates of annual mortality rates of between 79 and 84%, which are comparable to the mortality rates currently experienced by Lake Michigan adult alewives.

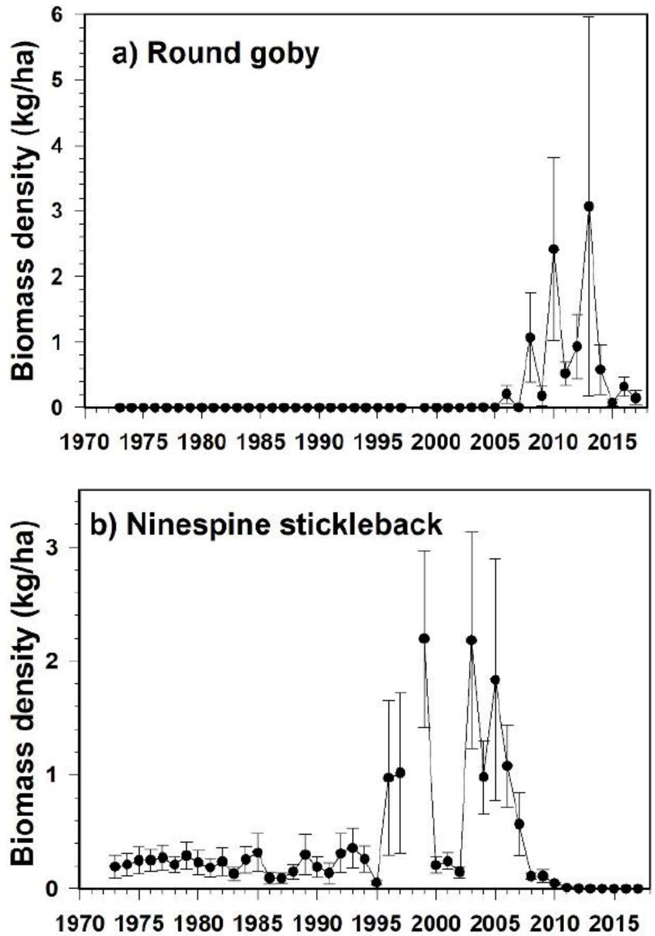

Fig 10-Biomass density of round goby (a) and ninespine stickleback (b) in Lake Michigan, 1973-2017.

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, but has been extremely rare in recent sampling years. Biomass density of ninespine stickleback in 2017 was only 0.7 g per ha, the second lowest estimate ever recorded **(Fig 10b**). Biomass of ninespine stickleback remained fairly low from 1973-1995 and then increased dramatically through 2007, perhaps attributable to dreissenid mussels enhancing ninespine stickleback spawning and nursery habitat through proliferation of *Cladophora*, however, biomass has been maintained at or near record-low levels. One plausible explanation for the low ninespine stickleback abundance during 2008-2017 is that piscivores began to incorporate ninespine sticklebacks into their diets as the abundance of alewives has remained at a low level. For example, in 2013 it was found ninespine sticklebacks in large

Chinook salmon diets during 2009-2010 after 0% occurrence in 1994-1996.

Lake-Wide Biomass

We estimated a total lake-wide biomass of prey fish available to the bottom trawl in 2017 of 13.3 kilotonnes (kt) (1 kt = 1000 metric tons) (**Fig 11a,**). Total prey fish 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, primarily due to a dramatic decrease in bloater biomass (**Fig 11a**). Total biomass first dropped below 30 kt in 2007, and has since remained below that level with the exception of 2013 (when the biomass estimates for alewife and round goby were highly uncertain).

As **Fig 11b** depicts, the 2017 prey fish biomass was apportioned as: bloater 68.8% (9.13 kt), deepwater sculpin 20.7% (2.75 kt), rainbow smelt 4.7% (0.62 kt), round goby 3.9% (0.52 kt), slimy sculpin 1.3% (0.17 kt), alewife 0.6% (0.09 kt), and ninespine stickleback 0.02% (0.002 kt).

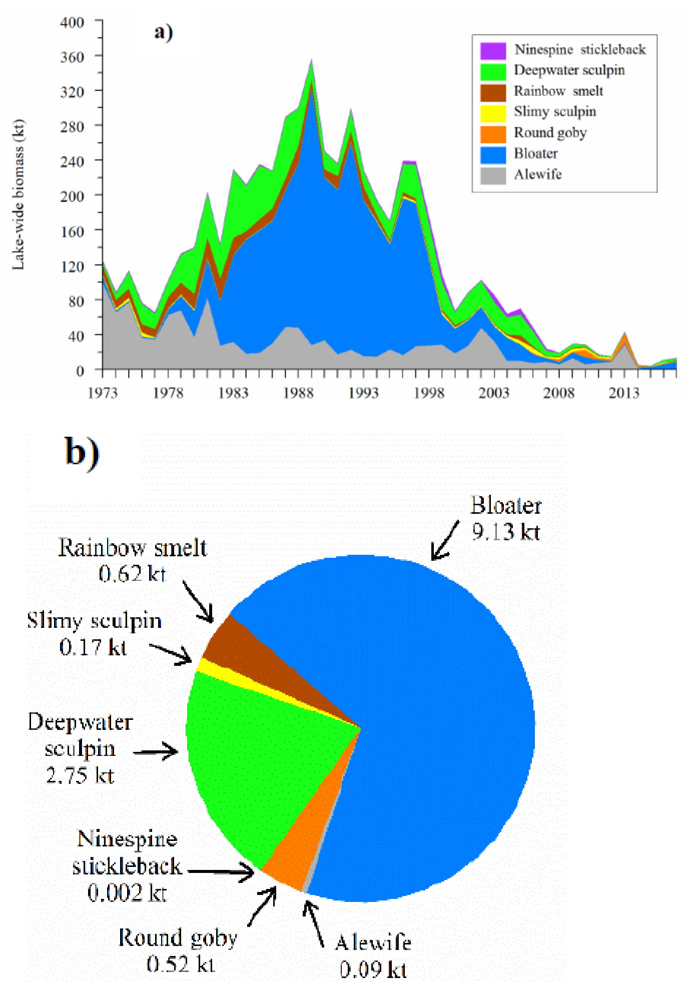

Fig 11-Estimated lake-wide (i.e., 5-114 m depth region) biomass of prey fishes inLake Michigan, 1973-2017 (a) and species composition in 2017 (b).

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 it was proposed in1999 that 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 usually covered by the bottom trawl survey. Burbot biomass density was 0.03 kg per ha in 2017, the lowest estimate since 1983 when none were captured. After a period of low biomass density in the 1970s, burbot showed a strong recovery in the 1980s **(Fig. 12**). Densities increased through 1997, but declined thereafter. It is unclear why burbot catches in the bottom trawl survey have declined in the face of relatively low alewife densities. The continued burbot decline in the past 10 years may have been due to movement of a portion of the population to waters deeper than 110 m, as the mean biomass density at 128 m was comparable to the mean biomass density at shallower depths.

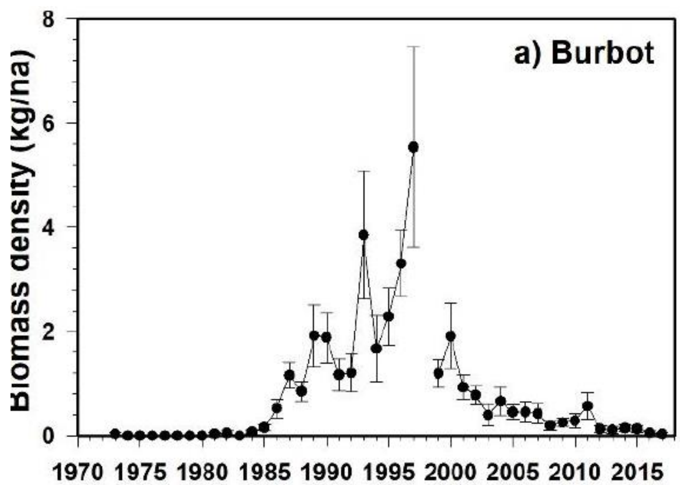

Fig 12-Biomass density of burbot in Lake Michigan, 1973-2017.

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 13**) and the 2009 and 2010 year-classes also were higher than average. In 2017, no age-0 yellow perch were caught, indicating a weak year-class.

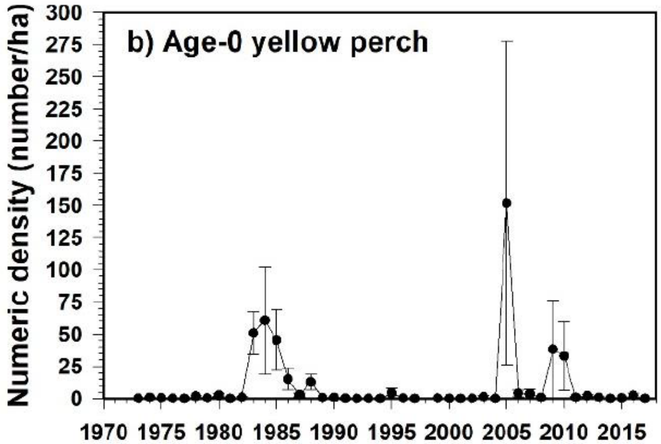

Fig 13-Numeric density of age-0 yellow perch in Lake Michigan, 1973-2017.

Conclusions

In 2017, total prey fish biomass was estimated to be 13.3 kt, a 17% increase over 2016. The bulk of this increase was driven by the increasing biomass of the bloater population. The increase in rainbow smelt biomass also contributed to this increase in total prey fish biomass. Relative to previous years in the time series, however, total prey fish biomass for 2017 was still relatively low- the fourth lowest estimate ever.

This low level of prey fish biomass can be attributable to a suite of factors, two of which can be clearly identified: (1) a prolonged period of poor bloater recruitment for most of the years during 1992-2017 and (2) intensified predation on alewives by salmonines during the 2000s and 2010s. Adult alewife density has been maintained at a relatively low level over the last 14 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 2013, 2014, and 2017 was age 5.

We also note that the striking decrease in deepwater sculpin biomass after 2006 appears to have been due, at least in part, to a substantial portion of the population moving to waters deeper than 110 m. Results from the deep tows that we have conducted since 2013 corroborate the contention that the bulk of the deepwater sculpin population in Lake Michigan now inhabits waters deeper than 110 m.

In addition to the importance of top-down forces, prey fishes also may be negatively influenced by reduced prey resources (i.e., “bottom-up” effects). For example, several data sets are indicating a reduction in the base of the food web, particularly for offshore total phosphorus and phytoplankton, as a consequence of long-term declines in phosphorus inputs and the proliferation of dreissenid mussels. Grazing of phytoplankton by dreissenid mussels and reduced availability of phosphorus in offshore waters appeared to be the primary drivers of the 35% decline in primary production in offshore waters between the 1983-1987 and 2007-2011 periods. The quagga mussel expansion into deeper waters may have been partly responsible for this reduced availability of phosphorus in offshore waters. The evidence for declines in “fish food” (e.g., zooplankton, benthic invertebrates) in offshore waters of Lake Michigan is somewhat less clear. *Diporeia* has undoubtedly declined in abundance, but whether or not crustacean zooplankton and mysids have declined depends on which data set is examined. Crustacean zooplankton biomass density in nearshore waters appeared to decrease during 1998-2010, likely due to a reduction in primary production mainly stemming from grazing of phytoplankton by dreissenid mussels. The above-mentioned decline in *Diporeia* abundance appeared to have led to reductions in growth, condition, and/or energy density of lake whitefish, alewives, bloaters, and deepwater sculpins during the 1990s and 2000s. Of course, decreases in growth, condition, and energy density do not necessarily cause declines in fish abundance. The challenge remains to quantify bottom-up effects on prey fish abundances and biomasses in Lake Michigan. Given the complexities of the food web, disentangling the effects of the dreissenid mussel invasions and the reduction in nutrient loadings from other factors influencing the Lake Michigan food web will require a substantial amount of ecological detective work.

An emerging issue for Lake Michigan’s prey fish base is whether the apparent recent increase in bloater recruitment will eventually translate into a long-term sustained increase in adult bloater biomass. Failure of these apparently large year-classes to recruit to the adult population could suggest that survival of age- 1, age-2, and age-3 bloaters is sufficiently low to prevent buildup of the adult population, and this poor survival could be due to top-down or bottom-up forces, as well as other factors. Alternatively, failure to recruit to the adult population could reflect reduced catchabilities of large bloaters for both surveys.

✧

Status of Pelagic Prey Fishes in Lake Michigan, 2017 (USGS)

Abstract

Acoustic surveys were conducted in late summer/early fall during the years 1992-1996 and 2001-2017 to estimate pelagic prey fish biomass in Lake Michigan. Midwater trawling during the surveys as well as target strength provided a measure of species and size composition of the fish community for use in scaling acoustic data and providing species-specific abundance estimates. The 2017 survey consisted of 29 acoustic transects [711 kin total (442 miles)] and 40 midwater trawl tows. Mean prey fish biomass was 7.99 kg/ha [38.9 kilotonnes (kt = 1,000 metric tons)], which was 46% higher than in 2016 and 35% of the long term (22 years) mean. The numeric density of the 2017 alewife year-class was 27% of the time series average and 60% times the 2016 density. This year-class contributed 15% of total alewife biomass (4.4 kg/ha). In 2017, alewife comprised 55% of total prey fish biomass, while rainbow smelt and bloater were 32% and 14 % of total biomass, respectively. Rainbow smelt biomass in 2017 (1.0 kg/ha) was 29% of the long-term mean and increased for the second time since 2008. Bloater biomass in 2017 was 2.5 kg/ha and 32% of the long-term mean. Mean density of small bloater in 2017 (120 fish/ha) was 80% of the long-term mean. Biomass density of large bloater increased to 2.2 kg/ha in 2017. This remains much lower than in the 1990s but likely shows evidence of recruitment of small fish observed in the past 5 years. Although prey fish biomass remains low relative to the 1990s, it did increase in 2017.

The main basin sampling consisted of 40 midwater trawl tows and 29 transects for a total transect distance of 711 kin, which was similar to the distance sampled in 2016. The bottom range over which acoustic data were collected was 12-231 in (39-758 ft). Survey locations are shown in **Fig 1.**

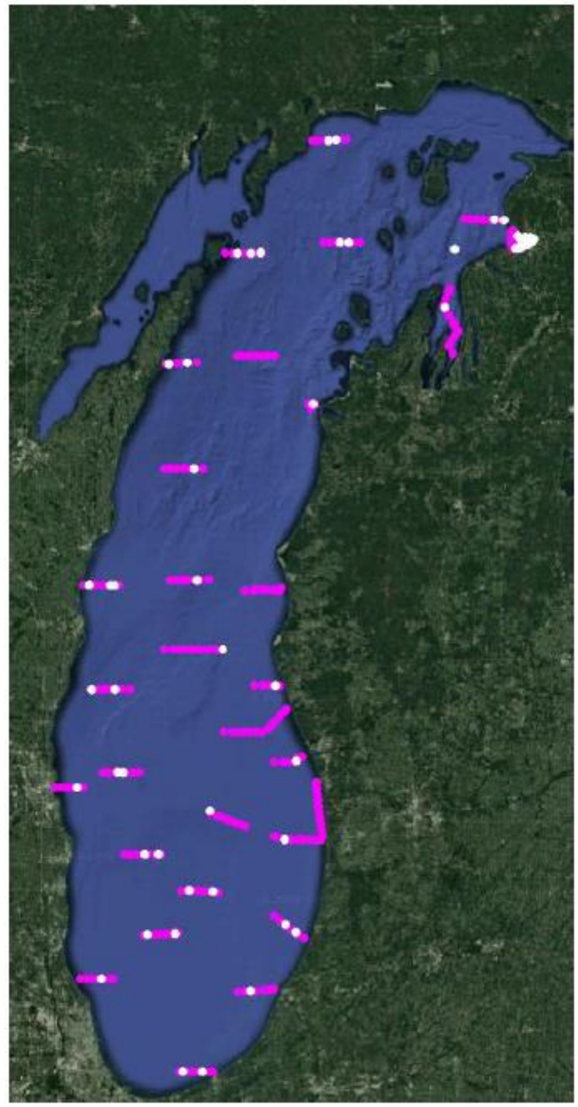

Fig 1- Location of acoustic (magenta symbols) and midwater trawl (white symbols) samples in the 2017 acoustic survey of Lake Michigan.

Alewife

Ages were estimated for 367 alewife - ranging from 60-202 mm total length. These fish were captured during both the acoustic survey and bottom trawl survey. Ages in this sample ranged from 0-6 years old. The age-6 fish made up only 0.3% of all aged fish and came from non-standard deep bottom tows not included in the bottom trawl reporting and were very large (around 200 mm) relative to any of the alewife caught in the midwater trawling during the acoustic survey. The length composition of alewife in the acoustic survey were such that none were older than age-5. No alewife <85 mm was older than age-0. Fish older than age-2 made up <3% of the population numerically, which means very few of the alewife in the population are of reproductive age.

The numeric density of the 2017 alewife year-class in 2017 was 60% the density of age-0 alewife in 2016 and was identical to the density observed in 2015. At 277 fish/ha, the 2017 estimate was 27% of the long-term mean. The biomass density of age-1 or older alewife was 3.8 kg/ha **(Fig 2),** which was 41% of the long-term mean and 18% higher than in 2016. The biomass of alewife age-1 was predominantly the 2016 (63%) and 2015 (32%) year classes. The acoustic biomass density estimate for all alewife was approximately 182 times the bottom trawl estimate in 2017 and over the time series (years in which both surveys took place), the acoustic estimates have been greater than the bottom trawl estimates 82q7o of the time

(18 of 22 years). The bottom trawl alewife biomass has been 66% of the acoustic estimate on average but the difference has become much larger in 2014-2017. Although we observed lower than average density of alewife in Lake Michigan, the density is still much higher than the density of alewife in Lake Huron as no alewife were caught during the Lake Huron acoustic survey.

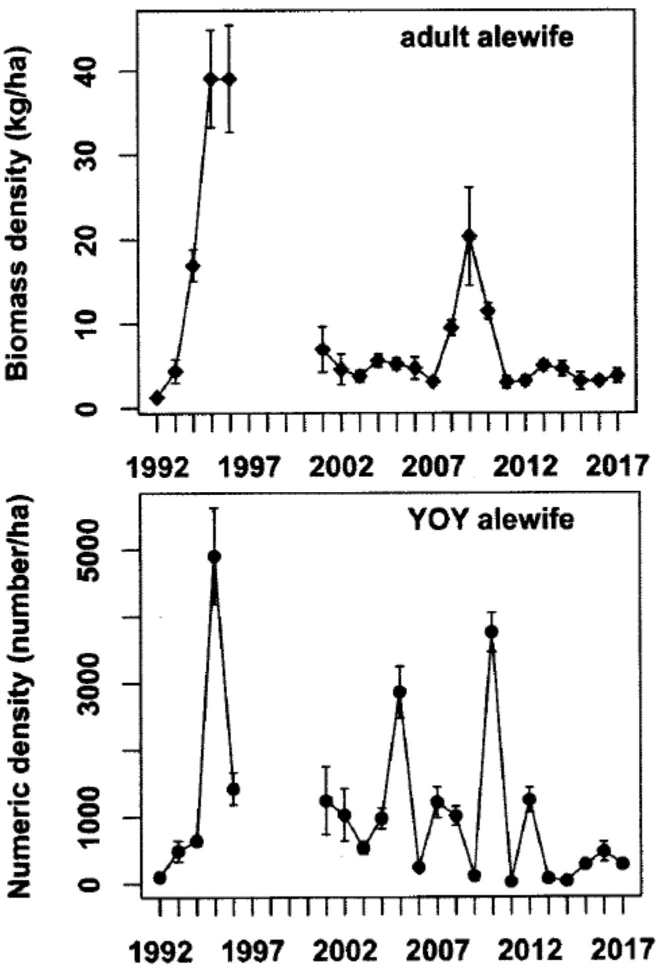

Fig 2. Biomass density of age-1 or older alewife (top) and Numeric density of age-0 alewife (bottom) in Lake Michigan during 1992-1996 and 2001-2017.

Spatial patterns in YOY alewife indicate that these fish have a patchy distribution**.** Highest numeric densities of YOY alewife were observed in the southern third of the lake with the maximum observed near Michigan City, Indiana. Densities were much lower in the northern 2/3 of the lake with the exception of the areas near Ludington, Point Betsie, and Little Traverse Bay in Michigan. Densities of YAO alewife were highest in the southeastern portion of the lake in areas closer to shore, followed by the northern I/4 of the lake and Grand Traverse Bay, MI.

Rainbow smelt

At 209 fish/ha, numeric density of small rainbow smelt (<90 mm) in 2017 (**Fig 3**) was slightly higher than that observed 2016. This density was almost identical to the time series mean of 204 fish/ha. Similarly, at 0.95 kg/ha, biomass density of large rainbow smelt (>90 mm) increased from that observed in 2016. This was the third consecutive year of increase for small rainbow smelt and the second for large rainbow sinelt. Even though acoustic biomass density estimates of large smelt have always exceeded bottom trawl estimates, both surveys show there was an order of magnitude decrease from 1992-1996 to 2001-2014. Recent low biomass is in stark contrast to observations from the late 1980s but are consistent with the findings of, who reported a shift in the pelagic fish community away from rainbow smelt numeric dominance in the mid-1990s following this period of dominance in the late 1980s.

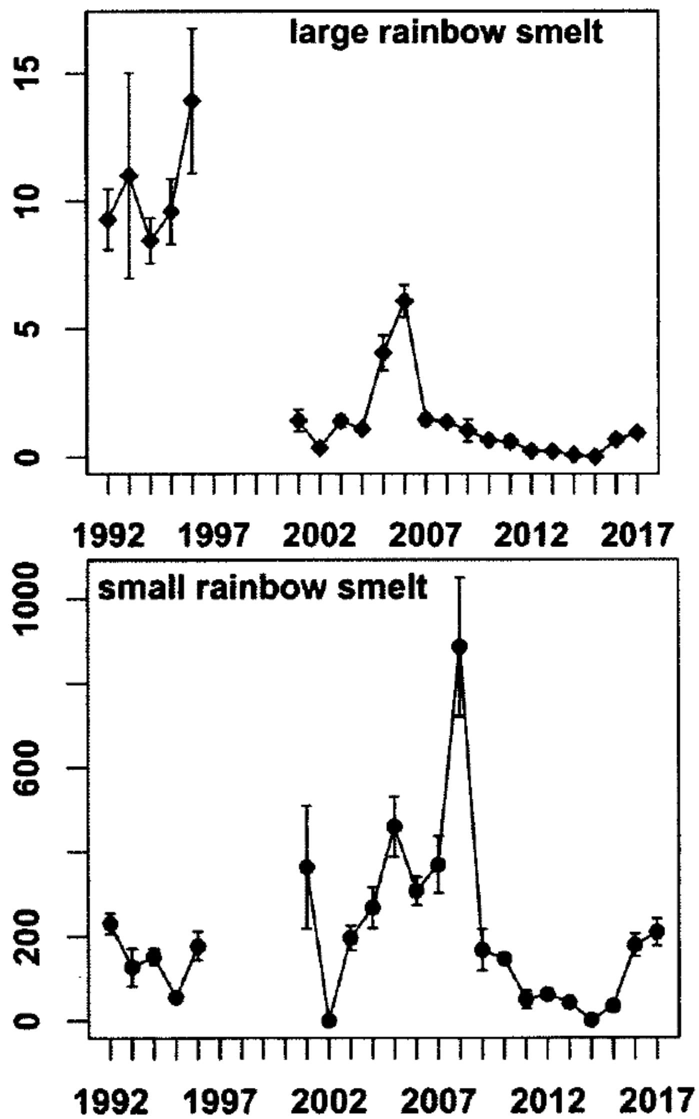

Fig 3- Biomass density of large rainbow smelt (>_90 mm), and numeric density of small rainbow smelt(<90 mm) during 1992-1996 and 2001-2017

Spatial patterns in rainbow smelt density differed from alewife. Small rainbow smelt were distributed throughout much of the lake at low density but were absent from several parts of the lake. Large rainbow smelt were much more limited in their distribution, with none observed in approximately the southern half of the lake.

Bloater

Densities of both small and large bloater have been variable in 2001-2017. Mean numeric density of small bloater in 2017 (120 fish/ha) was 81% the time series mean (**Fig 4).** Biomass density of large bloater in 2017 was 2.2 kg/ha, which was 27% of the time series mean, and 7% of the mean in 1992-1996. Bloater biomass has been only 16% of total prey fish biomass density in 2001-2017, on average. This is in contrast to the 1992-1996 period, when bloater made up 48% of total prey fish biomass density. For 13 of 22 years acoustic estimates of biomass density of large bloater were lower than bottom trawl estimates. In the 1992-2006 period the acoustic estimates averaged 43% of the bottom trawl estimates but in the 2007-2017 period acoustic estimates have been on average 3.7 times bottom trawl estimates. However, in 2017, the estimates were similar at 2.5 kg/ha for the acoustic survey and 2.6 kg/ha for the bottom trawl survey.

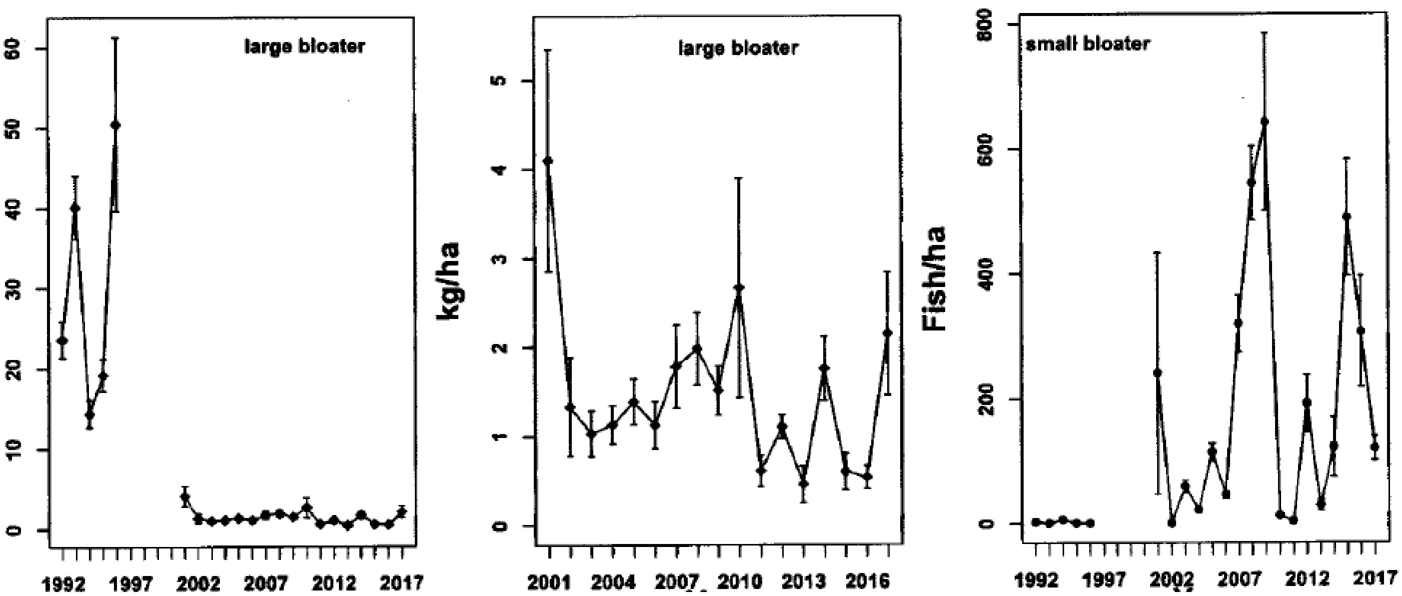

Fig 4-Biomass density of large bloater (>_120 mm, left panel) from 1992-2017, biomass density of large bloater for 2001-2017 (middle panel), and numeric density of small bloater (<120 mm, right panel) from 1992-2017 in Lake Michigan.

Spatial patterns in bloater indicated different distributions for small and large bloater**.** High densities of small bloater were generally in the southern half of the lake, with highest values in the southeastern part of the lake. Large bloater were less restricted in distribution but had highest densities in the eastern portion of the central lake.

Assumptions

As with any survey, it is important to note that bottom 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 surface (upper blind zone 0-4 in) or near the bottom (bottom dead zone, bottom 0.3-I in) are not sampled well or at all. The density of fish in these areas therefore is unknown. Recent technological advances allow for acoustic sampling of the upper blind zone over large spatial areas but the cost of this technology has been prohibitive. While our highest alewife and rainbow smelt catches and catch-per-unit-effort with midwater tows generally occur near the thermocline in Lake Michigan, it is possible that some are located in the top 4 in and can't be captured with trawls because the ship displaces this water and the fish.

We are less concerned with bias in alewife and rainbow smelt densities attributable to ineffective acoustic sampling of the bottom because of their pelagic distribution at night, when our sampling occurs. 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. These data indicate that night bottom trawl estimates of alewife density in August/September 1987 were only 6% of day estimates. Similarly, night bottom trawl estimates of rainbow smelt density were I 6% of day estimates. Disparities between day and night bottom trawl data demonstrate that alewife and rainbow smelt make an upward diel vertical migration at night in Lake Michigan which facilitates accurate sampling using acoustics and midwater trawling. However, bloaters tend to be more demersal; in Lake Superior, night acoustic/midwater trawl sampling may detect only 60% of bloater present. The 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. 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, this assumption was likely reasonable.

We made additional assumptions about acoustic data not described above. For example, we assumed that all targets below 40 in with mean target strength (TS) > -45 dB were bloater. It is possible that this resulted in a slight underestimation of rainbow smelt density. We also assumed that conditions were suitable for use to estimate fish density, which could also lead to biased results if conditions are not suitable for measuring TS and biased TS estimates are used. However, we used the Nv index of Sawada to identify areas where bias was likely. We assumed that noise levels did not contribute significantly to echo integration data and did not preclude detection of key organisms. Detection limits were such that the smallest fish were detectable well below the depths they typically occupy. Finally, we have assumed that the estimates of abundance and biomass are relative and do not represent absolute measures. This assumption is supported by recent estimates of catchability derived from a multispecies age structured stock assessment model. Even though subject to various biases, our stratified random sampling design and use of standardized data processing techniques allow for comparisons of prey fish abundance estimates between years and throughout the time series.

Summary

The long-term pattern in total prey fish biomass has been a decrease **(Fig 5),** with the current estimate, 7.99 kg/ha, being much lower than values in the 1990s and only 35% of the survey mean. There has been and continues to be debate about the causes of this decline, with some arguing the cause is bottom-up limitation and others arguing the cause is predation (top-down). The states surrounding Lake Michigan have made several cuts to predator stocking as a result of this pattern in an effort to promote a better balance between the demand for prey and the availability of prey in the system. How this balance plays out in the future remains to be seen. While alewife biomass has stopped declining and even increased slightly from 2015, and both bloater and rainbow smelt biomass have increased, the vast majority of the alewife population in 2017 was not sexually mature, which likely had a negative impact in year class size. This limitation to year potential year class strength is likely to persist as long as the alewife population remains young and small in size.

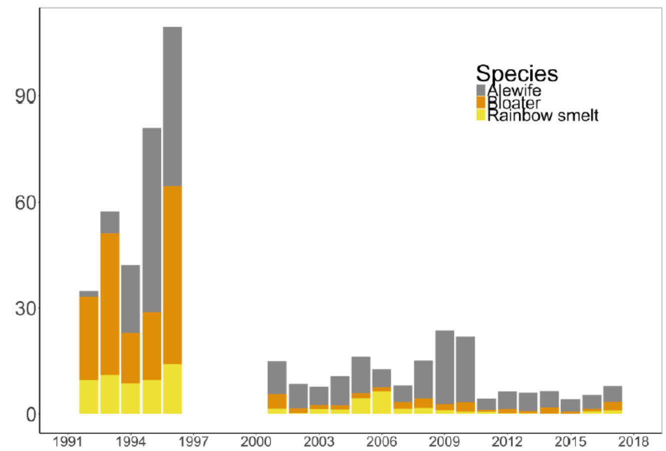

Fig 5. Total preyfish biomass density estimated for the acoustic survey of Lake Michigan, 1992-20]7.

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Green Bay Aquatic Invasive Species Detection & Monitoring Program, (USFWS)

Fish Sampling

Fish community sampling was performed at five hotspot locations **(Fig 1).** Effort using nighttime boat electrofishing, experimental gill nets, and paired modified fyke was approximately 40%, 35%, and 25%. Sampling was performed during late summer to early fall, 2017.

Larval Sampling

Sampling for fish eggs and larvae occurred from May through August, 2017 using bongo nets and quatrefoil light traps at four of the hotspot locations: Green Bay, Milwaukee Harbor, Chicago Harbor, and Calumet Harbor.

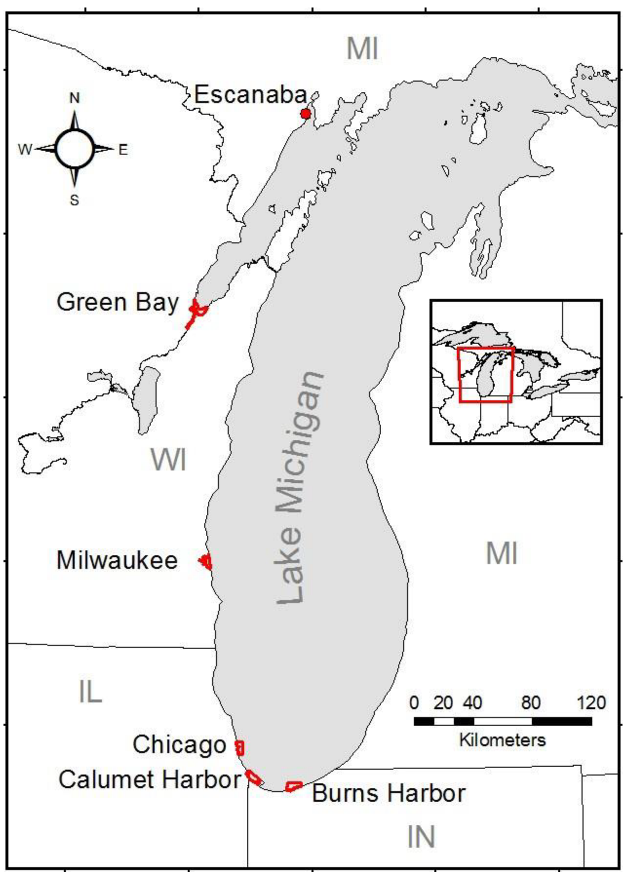


Fig 1. Lake Michigan study area for the aquatic invasive species early detection and monitoring project. The specific sites are highlighted in red and are considered hotspots.

Sampling

Seventeen facilities with warm-water discharges on Lake Michigan or adjacent waters that were operational (at least intermittently) were selected. Sampling occurred during April and early May, 2017 when water temperatures in the main lake were still cool (<15°C).

Two passive gears (i.e., colonization "rock" bags, modified minnow traps) and one active gear (i.e., D-frame dip net) were used to target amphipods, decapods, bivalves, and gastropods during August and September 2017. Modified minnow traps (baited and fished overnight) and D-frame dip net sampling was also used. Effort per hotspot was approximately six modified minnow trap and D-frame dip net samples and nine rock bag samples.

1. No new aquatic invasive fish species were detected in Lake Michigan in 2017.

2. 25,453 individual juvenile and adult fish representing 70 species were collected with 422 units of effort.
   - Known invasive species (Round Goby, White Perch, Alewife, Common Carp, Rainbow Smelt, and Eurasian Ruffe represented 16% (4,185 individuals) of the total catch. Species order represents high to low relative abundance based on our total catch.
   - Our catch was dominated by rare species. 54 of 70 species comprised <1% of our total catch.

Fig 2. Alewife

3. Our multi-gear sampling approach of nighttime boat electrofishing, experimental gill nets, and paired modified fyke nets provided a representative sample of the fish community at the five hotspot locations**.**

4. One invasive Eurasian Ruffe was captured in Escanaba, MI (new to our sampling regime) suggesting our sampling methods can capture this species and that they likely are not present at other hotspot locations.

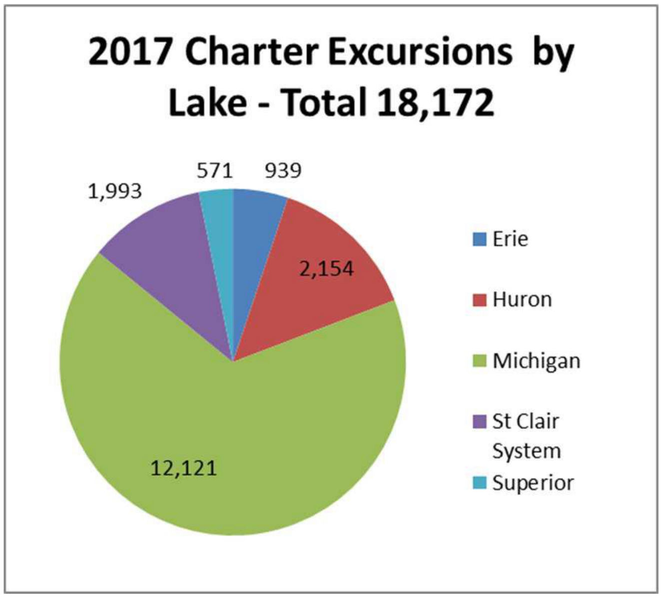
5. 333,555 fish eggs and 14,211 fish larvae were collected in 26 bongo net tows and 187 light traps.

6. Benthic macroinvertebrate sampling efforts recovered 32 of 45 rock bags and collected 25 modified minnow traps and 21 D-frame dip net samples.

7. Evidence of Asian clams were found at 4 of 17 sites in the nearshore zone of Lake Michigan and adjacent waters.
   - They occurred at low abundance and were most abundant at the source of thermal discharges.
   - Live specimens were collected at the discharge from a steel making facility in the Indiana Harbor Ship Canal in East Chicago, IN. All other specimens were relic shells from dead individuals.
   - We found limited evidence of expansion into warm-water refuges in Lake Michigan and adjacent water bodies, despite being present in the basin for at least four decades. ✧

Charlevoix Fisheries Research Station (MIDNR)

Charter Boat Survey



The objective of the state-wide Charter Boat Program is to obtain a continuous annual record of charter boat fishing effort, catch, and catch rates of the major sport fish in the Michigan waters of the Great Lakes. Charter businesses operated an average of 625 fishing boats in 2017; 60 charter businesses chartered with more than one boat.

The charter captains reported 18,172 charter fishing trips in 2017, 800 more trips than in 2016. The number of charters trips per lake was similar to that in 2016. 67% of the charters were in Lake Michigan, 14% in Lake Huron, 11% in the St. Clair System, 5% in Lake Erie, and 3% in Lake Superior. The number of hours fished by charter anglers (400,390) was an increase of 7,800 when compared to angler hours fished in 2016.

The total of all fish species reported caught during charter trips in State of Michigan Great Lakes and select tributary waters was 292,000, which is up by 48,000 compared to 2016 (and up by 86,000 compared to 2015!). The vast majority of that increase came from increased Walleye, Yellow Perch, and Coho Salmon catch. Lake Trout was the most prevalent fish harvested (55,400) making up 25% of the total charter fishing harvest. Walleye and Yellow Perch harvest continued to increase in 2017, making up 24% (51,500 fish) and 23% (50,700 fish) of the total harvest, respectively. Coho salmon harvest (23,000 fish) was 11% of the total, and 2-1/2 times the harvest in 2016 (9,000 fish). Chinook salmon harvest was 12% (25,300) fish, an increase of 3,000 fish in comparison to 2016. Rainbow trout (steelhead) harvest was 3% (6,900 fish) and brown trout harvest was less than 1% (370 fish).

Northern Lake Michigan Smallmouth Bass Study

Since 2006, CFRS staff have assisted the Central Lake Michigan Management unit and CMU in conducting a Smallmouth Bass population and movement study in the waters around the Beaver Island Archipelago, Waugoshance Point, and Grand Traverse Bay. At Waugoshance Point, overall our catch seemed to be down a bit in 2017. We had 16 net lifts and 2 net lifts that netted zero fish!

Our total catch was only 132 bass, of which we tagged 92 new bass and collected 30 bass for a USGS contaminant study. Only 2 previously tagged bass were caught and both were previously tagged in the Waugoshance area. Large percentages of the bass captured were females and most were still green (pre spawn) which was expected as the water temperatures were only in the low 50’s. The largest bass weighed in at 5.8 pounds, and the longest was measured at 19.5 inches. The next most frequently captured species was Common White Sucker (60) and we also captured (2) Walleye, (4) Northern Pike and (1) Atlantic Salmon (adipose-clipped).

Two trips were made to sample bass around the Beaver Island Archipelago. During the first trip (June), we were able to set 6 nets around Garden Island and 1 net in Paradise Bay (St. James Harbor). With near perfect weather that week, we were able to fish every net each day for a total of 24 lifts. We captured a total of 356 Smallmouth Bass. Out of the 356, we tagged 209 new bass and had 52 recaptured fish, 35 of which no longer had a tag (lost or angler removed). Three of the recaptured tagged bass were tagged at Waugoshance Point and one was tagged in Grand Traverse Bay.

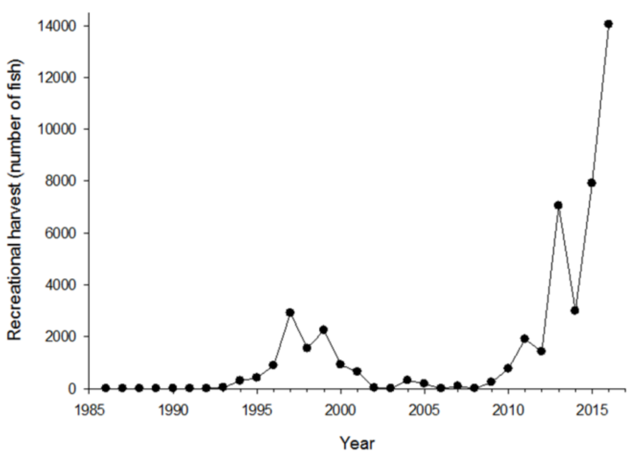
During a second trip, in July, we set 7 trap nets in various bays in the archipelago. Weather prevented the crew from lifting all the nets except on the first day after being set. All the nets were pulled by Friday and the survey ended with a total of 21 lifts for 25 net nights. A total of 500 bass were captured, from which we tagged 247 new bass and recorded 63 recaptures. The largest bass captured was 20.2 inches long and was the only bass seen longer than 20” this trip. Over 35% (187) of the bass caught were less than 12” in length. Other species seen were Bullheads (745), Rock Bass (42), Northern Pike (18), Bowfin (4), Carp (3), Largemouth Bass (2), Common White Sucker (2), and Yellow Perch (1). Notably the Northern Pike population has increased significantly around Garden Island over the past few years. These fish look very healthy with the largest fish measuring over 37 inches long!

In East Grand Traverse Bay (Elk Rapids to Acme), we had a total of 19 lifts. We captured a total of 468 Smallmouth Bass, tagging 370 new bass and only getting 7 recaptured fish. One of the recaptured bass was originally tagged near Beaver Island (Garden Island, Manitou Bay). The Largest bass caught weighed 6.1 pounds and measured 21.7 inches in length. Female bass seemed to make up a large portion of the catch with several losing eggs while being handled.

We also caught Rock bass (67), Common White Suckers (64), Alewife (20), Bullhead (14), Walleye (9), Northern Pike (9), Carp (8), Greater Redhorse Sucker (4), Channel Catfish (1), Long Nose Gar (1) and Rainbow Trout (1).

Cisco Research

In 2017, we continued to investigate the rapidly expanding Lake Michigan Cisco population. It's been exciting to watch as Cisco become an important component of the sport harvest in northern Lake Michigan and Grand Traverse Bay. Over 19,000 Cisco were harvested by anglers in 2017.



We continue to collaborate with researchers in a variety of fields to document the expansion and better understand the ecology and behaviors of these fish. Diet studies have indicated that in Lake Michigan, Cisco (which are typically considered prey fish) are actually behaving as top predators consuming alewife and round goby. Future work will further explore the foraging patterns and growth of Lake Michigan Cisco to better understand how they are able to capitalize on fish as prey and not simply invertebrates or zooplankton as most Cisco populations do.

Genetic and morphometric evaluations are being conducting to better understand the genome of Cisco and identify functional traits. This research will help us to better understand interactions with the environment, informing improved management of Cisco stocks. Partnering with Little Traverse Bay Band of Odawa Indians, Grand Traverse Bay Band and USGS we are attempting to learn more about spawning behaviors of Cisco in Grand Traverse Bay. We have used a combination of methods which include hydroacoustics, gill netting, egg sampling with mats, vacuum pumps and egg collection bags.

We have learned that some Cisco in Grand Traverse Bay spawn on reef habitat and this has been well documented. Reef spawning is not typical for Cisco so yet again they are proving to behave differently. We hadn't really explored the potential for open water or pelagic spawning which is more typical for Cisco. In 2017, we were able to document the presence of ripe and running individuals over deep water in Grand Traverse Bay with gill nets set at the surface and information determined in acoustic surveys.

Eggs of Cisco were collected in deep water with a suction sampler near this location. Investigators from Cornell U. collaborated in providing expertise and equipment to complete this work. Indications are that Cisco show diverse spawning preferences in Lake Michigan, perhaps contributing to their recent success.✧

Summary of Predator/Prey Ratio Analysis for Chinook Salmon and Alewife in Lake Michigan

Maintaining balance between predator and prey populations is critical for successful fisheries management. In Lake Michigan, several top predators contribute to important fisheries including native lake trout along with non-native Chinook salmon, Coho salmon, rainbow trout and brown trout. These predators are sustained through stocking and wild production, and stocking level adjustments to balance overall predator populations with available forage is a major component of ongoing fisheries management efforts. The Predator/Prey Ratio Analysis for Chinook salmon and alewife in Lake Michigan is a recently developed approach to help guide fisheries management decisions for stocking.

Lake Michigan historically has experienced wide fluctuations in populations of fish predators and prey, due largely to fishing exploitation, changes in habitat quality, and invasive species. Notably, native lake trout populations collapsed during the 1950s partly from overfishing and predation by invasive sea lamprey, and subsequently (without a top predator) invasive alewife populations greatly expanded. Sea lamprey control efforts were implemented in the late 1960s and, combined with abundant alewife forage, created opportunity to successfully stock top predators. Fisheries managers began stocking native lake trout along with non-native Chinook salmon, Coho salmon, rainbow trout and brown trout to utilize available forage and create diverse fishing opportunities. These stocking efforts continue today, and several past stocking level adjustments have been implemented to help sustain a balanced and diverse fishery.

Non-native Chinook salmon and alewife are important components of Lake Michigan's recent ecosystem and fishery, but not without challenges. In Lake Michigan, Chinook salmon are a dominant and generally mid-water predator whose diet consists mostly of alewives, a generally mid-water prey fish. Chinook salmon and alewives together support an important recreational fishery, and Chinooks are a preferred and targeted species for many recreational and charter anglers. During the late 1980s to early 1990s, this Chinook salmon population and fishery declined (despite high stocking levels) due to mortality from bacterial kidney disease and associated nutritional stress from relatively low alewife abundance. More recently, predator/prey and energy dynamics in Lake Michigan have changed due to bottom-up ecosystem effects (by invasive mussels) and top-down predation effects (by stocked and wild predators). Invasive filter feeding mussels are effective consumers of microscopic plants and animals, which is the same food that alewife and other forage fish eat. Naturally produced Chinook salmon are common, and in combination with stocked Chinooks (plus other trout and salmon species) these predators exert high predation pressure on alewife and other prey.

A "Red Flags Analysis" and the recently developed and implemented "Predator/Prey Ratio Analysis" were both designed to evaluate predator/prey balance and to provide guidance for stocking decisions. The Red Flags Analysis used from 2004-2011 looked at 15-20 individually plotted datasets and evaluated deviations from historic trends to trigger discussions about stocking level adjustments. A critical review of the Red Flags Analysis was completed during 2012 and subsequently a new approach called the Predator/Prey Ratio (PPR) Analysis was developed. These previously mentioned references provided detailed accounts of the Red Flags Analysis and development of the PPR Analysis (e.g., methods, pros, cons, etc.) but the intent of this document herein is to only summarize the PPR Analysis and provide results through 2016.

Predator/Prey Ratio

The Predator/Prey Ratio Analysis consists of a Predator/Prey Ratio (PPR) for Chinook salmon/alewife and five auxiliary indicators. The PPR is a ratio of total lake-wide biomass (i.e., weight) of Chinook salmon (≥ age 1) divided by the total lake-wide biomass of alewives (≥ age 1; **Fig 1a**).

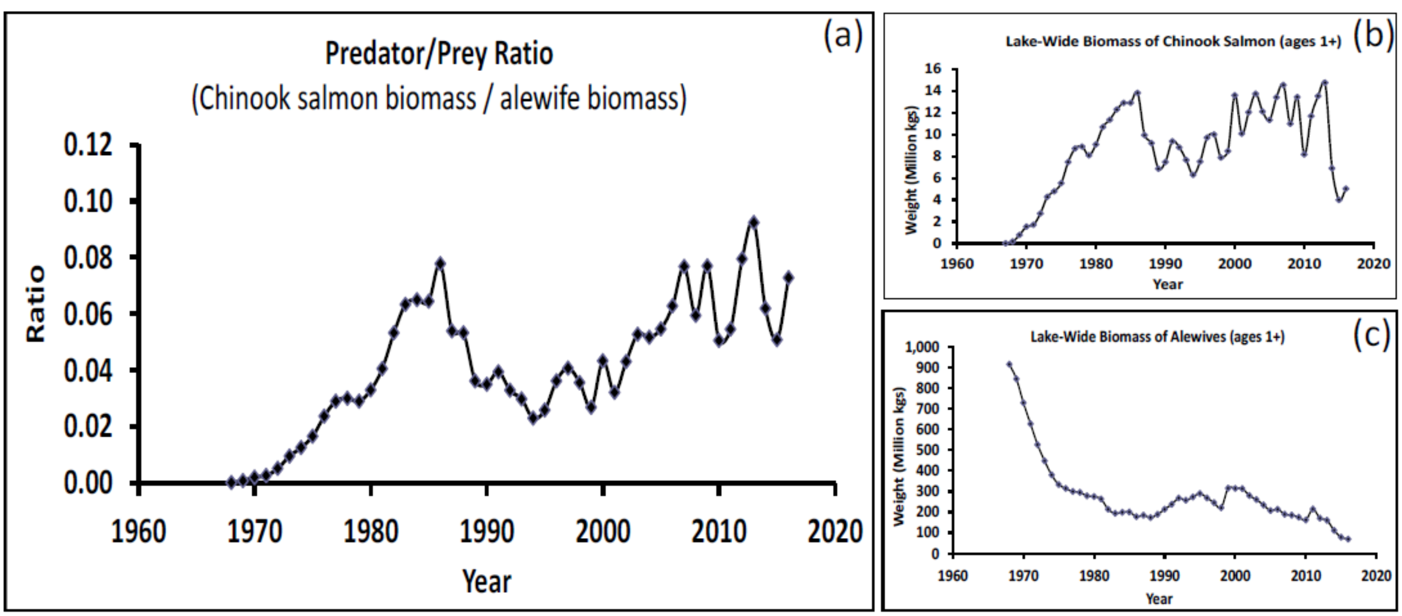


Fig 1-Predator/Prey Ratio calculated for Chinook salmon and alewife in Lake Michigan (a) and separate components of this ratio plotted individually as Chinook salmon biomass (b) and alewife biomass (c). (Note: figures b and c have different scales for the y-axis.)

A high PPR value indicates too many predators with insufficient prey and a low value suggests too few predators with surplus prey. The PPR is a fairly simple descriptor of balance between Chinook salmon and alewives, however the underlying methods are comprehensive and use statistical catch-at-age analysis that incorporate lake-wide datasets from several surveys and agencies**.** Generally, SCAA models estimate fish abundance based on numbers of fish harvested, age of fish harvested, recruitment information (i.e., numbers of fish produced naturally and numbers stocked), and other factors. This modelling process can be explained simply as a mathematical approach to provide the most likely answer to the question of how many fish must have been present to produce the observed data. For the PPR, numbers of Chinook salmon lake-wide are estimated for each age class using a SCAA model, and these abundance estimates are then multiplied by age-specific average weights and summed to calculate total lake-wide biomass (**Fig 1b**).

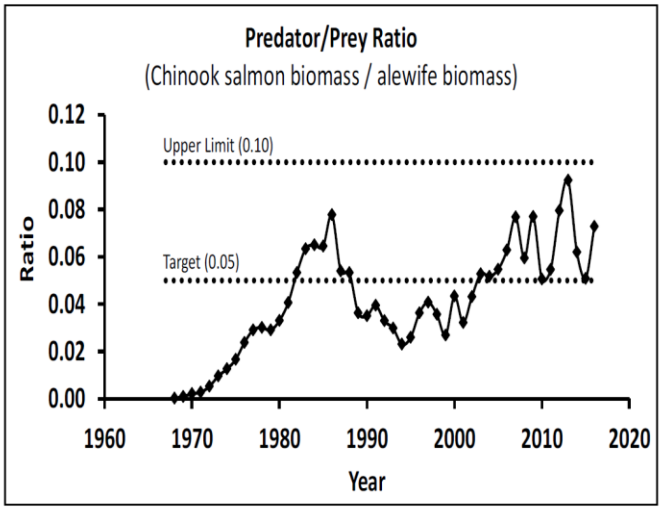


Fig 2. Predator/Prey Ratio calculated for Chinook salmon and alewife in Lake Michigan (through 2016).

Specific values or reference points have been established to help interpret the PPR. An established target of 0.05 represents a balanced Chinook salmon/alewife ratio, while an established upper limit of 0.10 is a high and unbalanced ratio (**Fig 2).** Several criteria were used to develop these reference points, including examples from other lakes, literature reviews, and risk assessments. For example, theChinook salmon population in Lake Ontario was relatively stable from 1989-2005 and during this period the average ratio (for Chinook salmon and alewife) was estimated to be 0.065. In Lake Huron, the alewife population collapsed in 2003 following a five year period during which Lake Huron's estimated PPR averaged 0.11 (estimated at 0.12, 0.13, 0.11, 0.11, and 0.10 per year respectively for 1998-2002) and subsequently the Chinook salmon population collapsed in 2006. From published scientific literature, it is generally accepted there is a 10% efficiency in converting food to body tissue, so it would take 10 pounds of alewife to produce 1 pound of Chinook salmon (i.e., 1 pound Chinook ÷ 10 pounds alewife = 10% or 0.10). Risk levels (i.e., potential to collapse the alewife population) acceptable to fishery managers and stakeholders were also considered from previous public meetings. Although the alewife SCAA incorporates consumption of alewives by several salmonid species, the current predator model includes only Chinook salmon, so another important consideration especially as the PPR increases is that less alewife are available as forage for other predator species.

Auxiliary Indicators:

Five additional datasets or "auxiliary indicators" were established to compliment the PPR and provide additional feedback on predator/prey balance (Figure 3). These auxiliary indicators are plotted as individual datasets through time (without targets or upper limits) to evaluate trends and recent conditions. Auxiliary indicators are calculated with lake-wide datasets from several agencies and include:

1) standard weight of 35" Chinook salmon from angler caught fish during July 1 to Aug 15 **(Fig 3a),**

2) average weight of age 3 female Chinook salmon from fall weir and harbor surveys **(Fig 3b),**

3) catch-per-hour for Chinook salmon from charter boats **(Fig 3c),**

4) percent composition of angler harvested weight by species (**Fig 3d**), and

5) age structure of the alewife population **(Fig 3e).**

Conclusions

Overall, the PPR Analysis is a new and focused approach to evaluate balance between a top predator (Chinook salmon) and its primary prey (alewife) that will provide guidance for future stocking decisions and should help achieve overall management goals of a balanced and diverse fishery within Lake Michigan's complex and dynamic ecosystem.

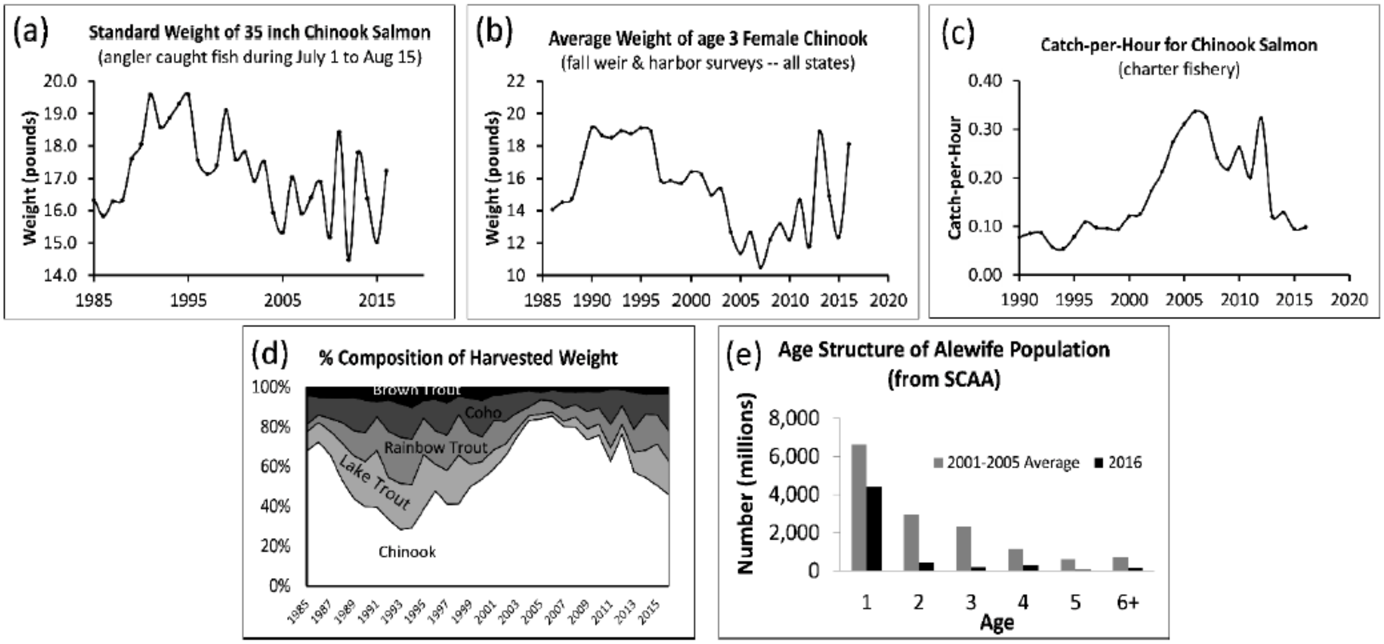


Fig 3. Auxiliary indicators calculated with lake-wide datasets to compliment the Predator/Prey Ratio and provide additional information to guide fisheries management decisions. ✧

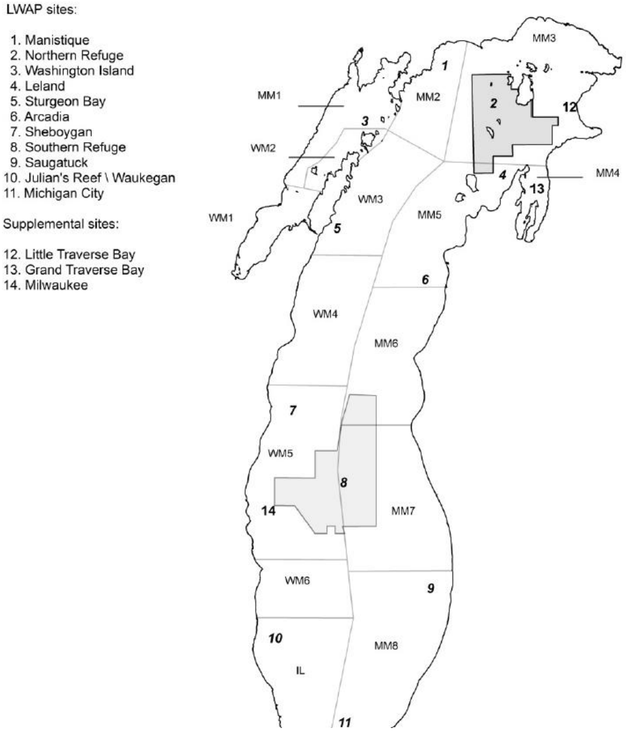
2017 Lake Michigan Lake Trout Working Group Report

This report provides a review on the progression of lake trout rehabilitation towards meeting the Salmonine Fish Community Objectives (FCOs) for Lake Michigan and the interim goal and evaluation objectives articulated in A Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan; we also include lake trout stocking and mortality data to portray progress towards lake trout rehabilitation.

Harvest information was supplied by the Lake Michigan Extraction database. Trends in spring catch-per-unit-effort (CPUE) were based on the spring (April – June) lakewide assessment plan (LWAP) gillnet survey that employs 2.5-6.0” graded multifilament mesh at nine nearshore and two offshore locations distributed throughout the lake. 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 recently stocked lake trout were released without a fin clip (Hanson et al. 2013), and therefore we infer natural reproduction when percentage of unclipped fish exceeds 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 from the recreational fishery, and assessment surveys targeting other species that also captured 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 > 30 lake trout recoveries.

Harvest

In 2017, salmon and trout (SAT) harvest was 2.52 million kg and for the third consecutive year has been below the 2.7 million kg minimum threshold of the FCO harvest objective **(Fig 1**). Lake trout harvest in 2017 was 0.62 million kg. The lake trout harvest objective (0.54 – 1.7 million kg) was previously met from 1985 – 2001 and more recently from 2013 – 2017 (**Fig 1).** In 2017 lake trout comprised 24% of the total salmonid catch and met the FCO harvest objective of 20 – 25%.



Map 1. Data reporting stations for spring and fall surveys

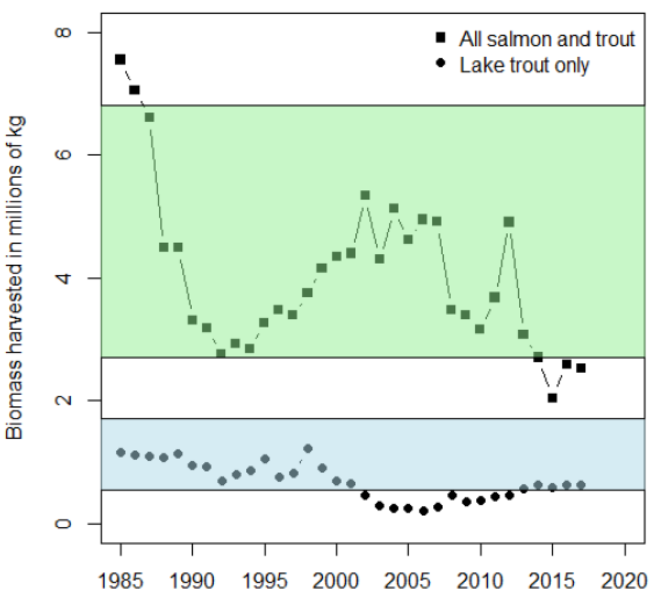


Fig 1-Lake Michigan total harvest (1985 – 2017) of lake trout and all other species of salmon and trout (SAT); green-shading depicts the range of SAT harvest in the FCO while blue-shading depicts the 20-25% range of SAT harvest reserved for lake trout.

Natural Reproduction

A total of 809 (11.7%) of the 6,938 lake trout examined for fin clips from 2017 gillnet assessments were unclipped and presumed to be wild. Wild fish accounted for 58% of lake trout in Illinois waters, and 10 – 24% in Wisconsin (WM3, WM4, and WM5) and southern Michigan (MM6, MM7 and MM8) waters of the lake**.** Fewer wild fish, between 2 and 7% of lake trout, were present in Indiana and northern Michigan (MM2, MM3, MM4, and MM5) waters of Lake Michigan. An additional data source, recreationally caught fish that were examined by the Great Lakes Fish Tagging and Recovery Lab, reported 26.4% of 2,120 lake trout examined were wild. In the southern half of Lake Michigan the proportion of wild fish from recreational catches was generally higher than that reported from assessment surveys. This was especially true in Indiana, 32% versus 5%, but this trend also occurred in WM4—WM6 and MM7—MM8; only Illinois waters had a substantially higher proportion of wild lake trout reported from assessment surveys.

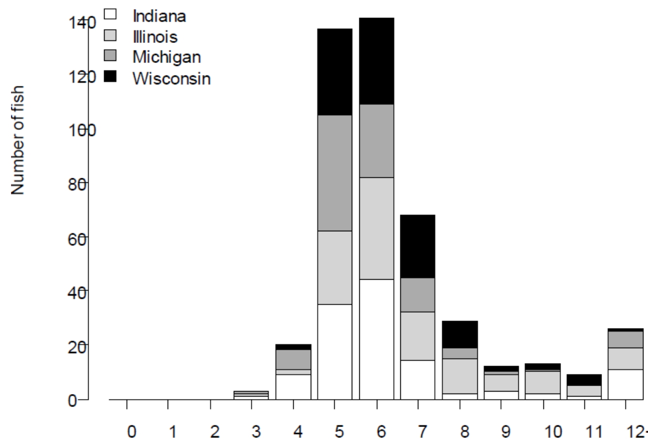


Fig 2 – Ages of wild lake trout from the recreational fishery

Age estimates from sectioned otoliths were derived from 458 wild lake trout recovered from the recreational fishery and 354 fish from assessment surveys (all assessment net catches are reported, including surveys using 38-mm mesh). Assessment surveys caught wild fish as young as age 1 while age 3 was the minimum age from the recreational fishery. For both data sources, the modal age occurred at age 5 or 6 years and had a right-skewed distribution with relatively few fish older than age 12 (**Fig 2).**

Fish Stocking

Stocking hatchery-reared fish to achieve rehabilitation is the primary tool of the Strategy. 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, however the Lake Michigan Committee adopted an interim stocking target not to exceed 2.74 million yearling equivalents when the strategy was approved. In 2017 the Lake Committee reduced this interim target to 2.54 million though actual stocking within +10% of the interim target is allowed. About 65% of the fish are stocked in first priority areas (Northern and Southern Refuges) with rehabilitation as the primary objective. The remaining fish are stocked in second priority areas to support local fishing opportunities in addition to rehabilitation. The stocking reduction in 2017 was achieved through reduced stocking of nearshore secondary priority areas in southern Lake Michigan. Higher stocking rates could be adopted when Federal hatcheries are capable of more production but only with Lake Committee consensus.

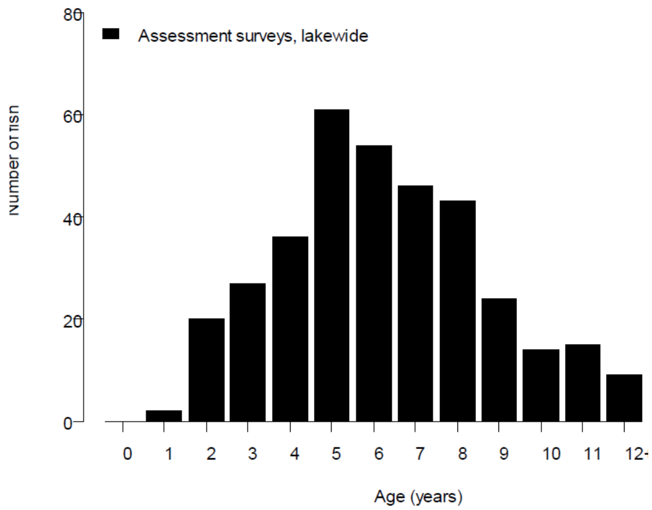


Fig 3-Ages of wild lake trout from assessment surveys

Since 2008, lake trout have been stocked according to the Strategy and this has substantially increased the numbers of fish stocked in high priority rehabilitation areas **(Fig 3**). In 2017, 2.77 million lake trout yearlings were stocked with 99% of these raised in FWS 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 = 199,319) at Sheboygan 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 78% of the lake trout. Over 97% of Service lake trout were stocked in offshore waters using the M/V Spencer F. Baird.

Lake Trout Mortality

In northern Lake Michigan, total annual mortality has now declined to 40.4% for lake trout ages 6-11 and is near the 40% target for the first time since 1990 **(Fig 4)**. Commercial fishing is the primary source of mortality. Previously in the 2000s there was an extended period of elevated sea lamprey mortality owing to additional recruitment of parasitic adults produced after spawners breached the dam on Manistique River. In recent years lamprey mortality has dropped precipitously after several years of intensive lampricide treatments on the Manistique River and other Lake Michigan tributaries.

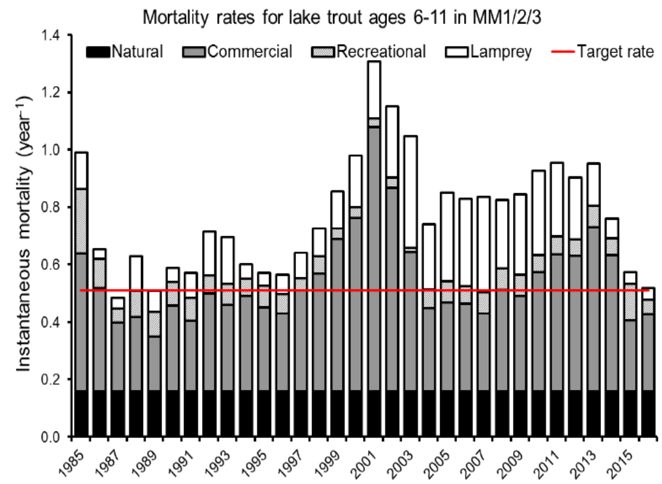


Fig 4-Mortality rates for lake trout ages 6-11 in northern Lake Michigan, MM1/2/3.

Annual mortality rates in the Southern Refuge priority area have not been estimated, but those estimated from the proximal waters of MM6/7 have been at or below 40% since 1999 (**Fig 5**). Prior to 2003, recreational fishing was the main source of lake trout mortality in MM6/7. Fishing mortality decreased following a reduction of recreational fishing effort beginning in the 1990s and sea lamprey-induced mortality exceeded fishing mortality in MM6/7 until 2014, though combined these sources were still less than assumed natural mortality. As in northern Lake Michigan, sea lamprey lamprey-induced mortality in MM6/7 has also declined in recent years, and the 2017 total annual mortality is below target at 31%.

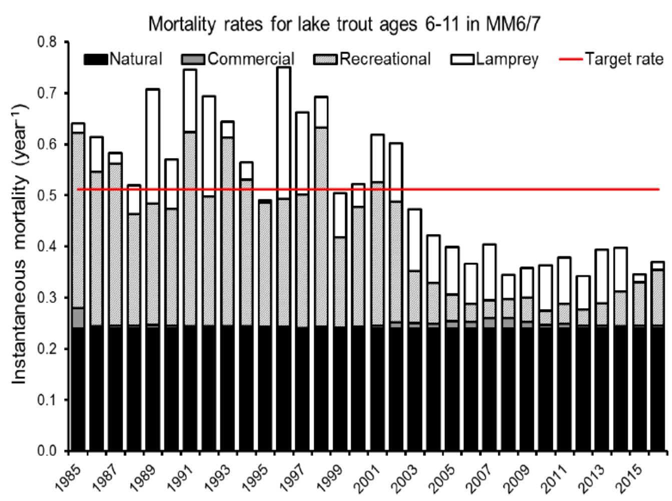


Fig 5-Mortality rates for lake trout ages 6-11 in southern refuge, and in MM6/7

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 lake trout harvest has been from northern Lake Michigan. Within the last two years lake trout annual mortality in MM1/2/3 has approached the 40% target level due to recent reductions in sea lamprey-induced mortality and regulation of fishing mortality through Consent Decree oversight. As a result of increased lake trout survival and elevated stocking, northern populations are currently building. However northern populations remain below spring abundance targets though some have now met fall abundance metrics. These spawning populations are young and do not meet the evaluation objective regarding the presence of older age-classes. Further, the proportion of wild fish in MM3 recovered from either assessment surveys or sport-caught fish is indistinguishable from the 3% fin-clipping error rate. Therefore, initial progress toward lake trout rehabilitation in this northern priority area is recently evident but must demonstrate continued progress towards population objectives to achieve recovery.

In the Southern Refuge and at Julian's Reef, the population objectives have been achieved more consistently compared with northern populations. Lake trout in these areas are characterized by high spawner densities, a more diverse age structure including older age-classes, an increasing trend in the proportion of wild fish, and mortality rates in proximate areas below 40%. However, these populations are not considered self-sustaining yet as they are still stocked and generally comprised of > 50% hatchery fish. Further, spring surveys in the Southern Refuge and Waukegan, the LWAP site most proximate to Julian's Reef, have shown that the spring abundance metric has not been met since 2013, despite recruitment of wild fish.

Detectable and sustained natural reproduction since 2004 by lake trout in Lake Michigan, continues to increase particularly among sport-caught fish caught in southern Lake Michigan. Large increases in the proportion of wild fish, based on ages of recovered wild fish, began with 2005-2013 year classes, especially in areas with denser and older parental stocks. Large increases in natural reproduction in northern Lake Huron also coincided with substantial increases in the densities and age composition of the adult lake trout that occurred after total mortality was reduced (Modeling Subcommittee & Technical Fisheries Committee, 2017).

The initial onset of natural reproduction in Lake Michigan coincided with reduced alewife abundance that has remained low since the mid-2000s. Reduced densities of alewives may facilitate natural reproduction by lake trout through decreased potential for alewife predation on lake trout larvae. Continued declines in alewife densities since 2004 were also weakly correlated with an increase in mean thiamine content within lake trout eggs, although by 2013 egg thiamine concentrations had dropped below 4 nmol/g at selected sites in eastern and southern Lake Michigan. Whether alewives reduce lake trout recruitment through diet-mediated thiamine deficiencies is equivocal, as recent evidence suggests that wild lake trout fry may be able to mitigate thiamine deficiency with early feeding on thiamine-rich zooplankton.

In summary, widespread recruitment of wild fish is now occurring in the southern Lake Michigan where evaluation objectives for spawner abundance, spawner age 7 composition, percent spawning females, target mortality, and thiamine egg concentrations (in most years) have generally been achieved. Recruitment of wild fish, albeit lower, is now evident in mid-latitude management units on both the eastern and western shores, but, remains inconsequential in most areas of northern Lake Michigan. Overall, based on recent gillnet assessments, the percentage of wild lake trout within the lake trout population remains below 20% in all areas of Lake Michigan except Illinois waters and MM8. Therefore, we conclude that lake trout populations are in the early stages of recovery, and we recommend adhering to the implementation strategy objectives, which are appropriate management tools to measure continued progress toward lake trout rehabilitation in Lake Michigan.✧

Sea Lamprey Control in Lake Michigan 2017, (USFWS)

Introduction

This report summarizes Sea Lamprey control activities conducted by Fisheries and Oceans Canada (Department) and the United States Fish and Wildlife Service (Service) as agents of the Great Lakes Fishery Commission (Commission) in Lake Michigan during 2017. The Sea Lamprey is a destructive invasive species in the Great Lakes that contributed to the collapse of Lake Trout and other native species in the mid-20th century and continues to affect efforts to restore and rehabilitate the fish-community. Sea Lampreys subsist on the blood and body fluids of large-bodied fish. It is estimated that about half of Sea Lamprey attacks result in the death of their prey and up to 18 kg (40 lbs) of fish are killed by every Sea Lamprey that reaches adulthood. The Sea Lamprey Control Program (SLCP) is a critical component of fisheries management in the Great Lakes because it facilitates the rehabilitation of important fish stocks by significantly reducing Sea Lamprey-induced mortality.

Lake Michigan has 511 tributaries. One hundred twenty-eight tributaries have historical records of larval Sea Lamprey production, and of these, 92 tributaries have been treated with lampricides at least once during 2008- 2017.

Twenty-nine tributaries are treated every 3-5 years. Details on lampricide applications to Lake Michigan tributaries and lentic areas during 2017 are found in **Figure 1**.

• Lampricide applications were conducted in 42 streams and 3 lentic areas**.** Of these, 30 streams and three lentic areas were included as a targeted treatment effort to reduce sea lamprey recruitment from large producers to Lake Michigan.

• Seiners Creek was added to the treatment schedule after large Sea Lamprey larvae were detected in the system during 2017 evaluation surveys. This was the first time the stream was treated since 1984.

• The upper Days River was added to the treatment schedule after large Sea Lamprey larvae were detected upstream from the barrier.

• The following streams were treated under unusually high stream discharge: Hog Island Creek, Black, Millecoquins, Days, Ford, Cedar, Bark, Oconto, and East Twin rivers.

• To conserve lampricide under high discharge conditions, treatments of the East Twin and upper Cedar rivers were supplemented with Bayluscide for the first time.

• The South Branch Black River (Van Buren County) was treated for the first time.

• Hock Creek was treated for the first time since 1984.

• Treatment of the Muskegon River was scheduled for mid-September in coordination with the Michigan Department of Natural Resources (MIDNR) and Little River Band of Ottawa Indians (LRBOI).

• A significant rain event caused the Oconto River treatment, originally scheduled for late April, to be rescheduled to late October. Likewise, the Ford River treatment was postponed until early June from its originally scheduled time in mid-May.

Barriers

The Sea Lamprey Barrier Program priorities are to:
1) Operate and maintain existing Sea Lamprey barriers that were built or modified by the SLCP.
2) Ensure Sea Lamprey migration is blocked at important non-SLCP barrier sites.
3) Construct new structures in streams where they:
   a. provide a cost-effective alternative to lampricide control;
   b. provide control where other options are impossible, excessively expensive, or ineffective;
   c. improve cost-effective control in conjunction with attractant and repellent based control, trapping, and lampricide treatments; and
   d. are compatible with a system's watershed plan.

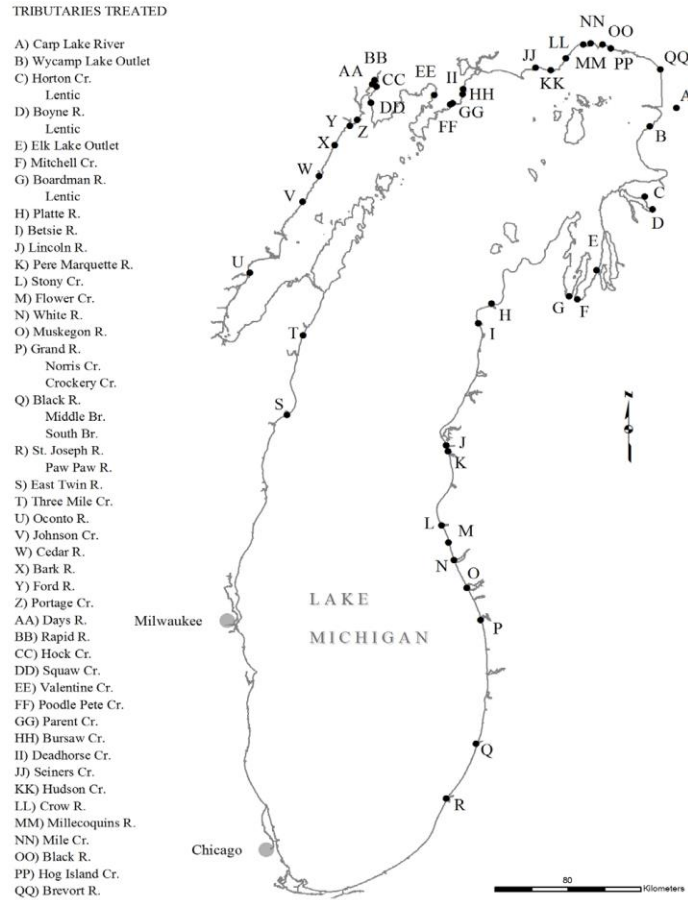


Fig 1- Location of Lake Michigan tributaries treated with lampricides (corresponding letters in Table 1) during 2017

The Commission has invested in 15 barriers on Lake Michigan**.** Of these, seven were purpose-built as Sea Lamprey control barriers and eight were constructed for other purposes, but have been modified to block Sea Lamprey migrations. Data gathered during field visits to assess the status of other dams and structures were recorded in the SLCP's Barrier Inventory and Project Selection System (BIPSS). These data may be used to: 1) select barrier projects; 2) monitor inspection frequency; 3) schedule upstream larval assessments; 4) assess the effects of barrier removal or modifications on Sea Lamprey populations, or; 5) identify structures that are important in controlling Sea Lampreys.

• Field crews visited 99 structures on tributaries to Lake Michigan to assess Sea Lamprey blocking potential and to improve the information in the BIPSS database.

• Routine maintenance, spring start-up, and safety inspections were performed on 25 barriers.

• Boardman River – Removal of the Boardman Dam and construction of the Cass Road Bridge took place during 2017. Removal of Sabin Dam will occur during 2018 contingent upon Union Street Dam continuing to perform as a blocking structure to Sea Lampreys. Larval and habitat surveys were conducted above the Union Street Dam during July 2017 to determine the production potential for Sea Lampreys in areas upstream of the dam.

• Grand River – The City of Grand Rapids along with several citizens groups are considering removing the 6th Street Dam on the Grand River to provide for more varied use of the downtown rapids area. The current plan calls for removal of the existing structure and the creation of an artificial rapids complex that can be used by kayakers and fishermen. A new inflatable crest structure that will theoretically act as a velocity barrier under high flows is proposed approximately one mile upstream of the 6th Street Dam. Project partners met at the United States Army Corps of Engineers Engineer Research and Development Center in April to discuss design and operational criteria for the new structure. The Service and DFO are engaged in the review of the proposed structure and will maintain a presence at various levels of project coordination.

• Kalamazoo River – Larval and habitat surveys were conducted above the Calkins Bridge Dam during July 2017 to determine the production potential for Sea Lampreys in areas upstream of the dam.

• Barrier removals/modification – Consultations to ensure blockage at barriers were conducted with partner agencies at 20 sites in 6 streams**.**

New Construction

• Manistique River – The USACE is the lead agency administering a project to construct a Sea Lamprey barrier to replace a deteriorated structure in the Manistique River. The existing Manistique Paper Inc. Dam was identified as the most feasible site for a new barrier. The USACE is completing additional design work in order to reduce upstream inundation as part of the Michigan Department of Environmental Quality permit requirements. Once the new design elements have been identified, the Environmental Assessment and Takings Analysis can be updated and the Detailed Project Report can be reviewed internally prior to the public review period opening. During October 2107, the Service contracted the removal of several hundred yards of wooden debris from the dam crest.

• Little Manistee River – The USACE is the lead agency on a project to replace the current dam at the MIDNR egg taking facility on the Little Manistee River. The current barrier height is insufficient to prevent Sea Lampreys from migrating upstream. The Preliminary Restoration Plan is complete for the barrier and trap project at or near the current weir location. The project would include improvements to the weir structure and construction of permanent traps. The MIDNR is working with the Service to develop new operational procedures to reduce the length of time stop logs must be removed in the fall/winter to clean sand deposited above the barrier. The State has also acquired funding to upgrade the structure, combining these two projects would save considerable dollars in mobilization and dewatering costs.

Larval Assessment

Tributaries considered for lampricide treatment during 2017 were assessed during 2017 to define the distribution and estimate the abundance and size structure of larval Sea Lamprey populations. Assessments were conducted with backpack electrofishers in waters <0.8 m deep, while waters ≥0.8 m in depth were surveyed with gB or by deep-water electrofishing (DWEF). Additional surveys are used to define the distribution of Sea Lampreys within a stream, detect new populations, evaluate lampricide treatments, evaluate barrier effectiveness, and to establish the sites for lampricide application.

• Larval assessments were conducted on 90 tributaries and 14 lentic areas.

• Surveys to estimate larval Sea Lamprey abundance were conducted in five tributaries.

• Surveys to detect the presence of new larval Sea Lamprey populations were conducted in 13 tributaries. No new Sea Lamprey infestations were discovered.

• Post-treatment assessments were conducted in 29 tributaries and 1 lentic area to determine the effectiveness of lampricide treatments during 2016 and 2017. Deadhorse Creek is scheduled for treatment in 2018 based on the presence of residual Sea Lampreys.

Tributary	Bayluscide (kg)1	Area Surveyed
Manistique River (Lentic)	5.81	1.04
Manistique River (Lotic)	3.48	0.62
Fishdam River (Lentic)	1.74	0.31
Ogontz River (Lentic)	2.32	0.41
Tacoosh River (Lenic)	2.32	0.41
Days River (Lentic)	2.32	0.41
Ford River (Lentic)	2.32	0.41
Portage River (Lentic)	0.58	0.10
Menominee River (Lentic)	2.32	0.41
Peshtigo River (Lotic)	2.32	0.41
Whitefish Bay Crk (Lentic)	0.58	0.10
Loeb Creek (Lentic)	0.28	0.05
Elk Lake Outlet (Lentic)	1.40	0.25
Leland River (Lentic)	0.84	0.15
Crystal River (Lentic)	0.84	0.15
Platte River (Lotic)	1.40	0.25
Total for Lake	**30.87**	**5.48**

Table 1-Applications of granular Bayluscide to tributaries nd lentic areas of Lake Michigan for larval assessment purposes during 2017.

• Surveys were conducted in eight tributaries to Lake Michigan to evaluate sea lamprey barrier effectiveness. Significant numbers of large Sea Lamprey larvae were collected in barrier surveys in the Days River. This additional infested area above the barrier was added to the 2017 treatment schedule.

• Larval assessment surveys were conducted in 15 non-wadable lentic and lotic areas using 30.87 kg active ingredient of gB **(Table 1).**

Juvenile Assessment

• Lake Trout marking data for Lake Michigan are provided by the Service, Michigan, Wisconsin, Illinois, and Indiana DNRs, the Chippewa-Ottawa Resource Authority, and USGS, and analyzed by the Service's GBFWCO.

• The number of A1-A3 marks on Lake Trout from fall assessments in 2017 were submitted in February 2018 and have yet to be analyzed.

• Based on standardized fall assessment data, the marking rate during 2016 (plotted as the 2017 Sea Lamprey spawning year) was 3.7 A1-A3 marks per 100 Lake Trout >532mm. This was the lowest marking rate observed since the 1995 spawning year (**Fig 2).**

Adult Assessment

• A total of 7,506 Sea Lampreys were captured at eight locations in eight tributaries, six of which are index locations. Adult population estimates based on mark-recapture were obtained for each index location **(Table 2**).

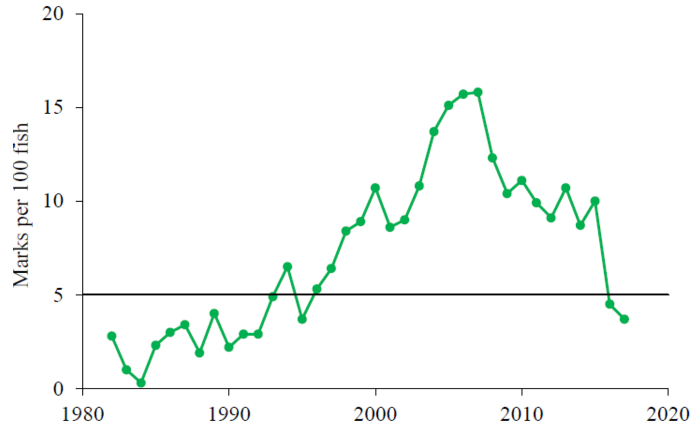


Fig 2-Average number of A1-A3 marks per 100 Lake Trout >532 mm from standardized fall assessments in Lake Michigan. The horizontal line represents the target of 5 A1-A3 marks per 100 Lake Trout. The spawning year is used rather than the survey year (shifted by one year) to provide a comparison with the adult index.

• The index of adult Sea Lamprey abundance was 15,881 (95% CI; 13,168 – 18,593), which was less than the target of 24,874**.** The index target was estimated as the mean of indices during a period with acceptable marking rates (1995-1999)

• Adult Sea Lamprey migrations were monitored in the Boardman and Betsie rivers through a cooperative agreement with the Grand Traverse Band of Ottawa and Chippewa Indians.

Tributary	Number Caught	Adult Estimate	Trap Efficiency (%)	Number Sampled[1]	Percent Males[2]	Mean Length (mm) Males	Mean Length (mm) Females	Mean Weight (g) Males	Mean Weight (g) Females
Carp Lake Outlet (A)	1,119	1,293	87	109	56	487	480	252	254
Boardman R. [3] (B)	144	415	35	42	40	497	485	265	263
Betsie R. (C)	576	984	59	80	65	505	505	271	286
Big Manistee R. (D)	332	2,972	11	25	60	490	519	276	305
St. Joseph R. (E)	575	1,921	30	49	45	484	506	246	280
Trail Cr. [3] (F)	64	---	---	---	---	---	---	---	---
Peshtigo R. (G)	1,606	2,159	74	99	42	505	510	266	267
Manistique R. (H)	3,090	6,549	47	120	53	507	511	283	306
Total or Mean	**7,506**	---	---	**524**	**52**	**499**	**501**	**267**	**278**

Table 2- Information regarding adult Sea Lampreys captured in assessment traps or nets in tributaries of Lake Michigan during 2017. ✧

End Lake Michigan Part 2