Inland Seas Angler
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Highlights of the Annual Lake Committee Meetings

Great Lakes Fishery Commission proceedings, Saulte Saint Marie, Ontario

This second of a series of special reports is an extensive summary of Lake Michigan. These lake committee reports are from the annual Lake Committee meetings hosted by the Great Lakes Fishery Commission. We encourage reproduction with appropriate credit to the GLSFC and the agencies involved. Our thanks to the staffs of the GLFC, OMNR, USFWS, USGS, ILDNR, INDNR, MDNR, MNDNR, NYSDEC, PAFBC, ODNR, and WDNR for their contributions to these science documents.

Lake Erie

Index of Reports

Abbreviation	Expansion
AC	Acoustic Survey
BT	Bottom Trawl
CPH	Catch per hectare
CWT	Coded Wire Tag
DEC	NY Dept. of Environment Conservation
DFO	Dept. of Fisheries and Oceans
LEBS	Lake Erie Biological Station
LEC	Lake Erie Committee
ODNR	Ohio Dept. of Natural Resources
OMNRF	ON Ministry Natural Resources, Forestry
OSU	The Ohio State University
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)

The Great Lakes Valuation Report

Holding 20% of the world's surface freshwater, the Great Lakes are a finite resource with multiple uses and users. They are crucial to the cultural and ecological value of the region and 8 million people are dependent on their water resources, and recreational and commercial fisheries. Transboundary fisheries management in the Great Lakes is increasingly integrating the biological and social sciences, which is critical to long-term resource sustainability.

The lakes' benefits are susceptible to a multitude of human-caused factors and threats (e.g., aquatic invasive species, agricultural runoff, climate change), which will ultimately influence regional economies and quality of life. Policymakers at all levels must make allocation decisions regarding the Great Lakes including providing water for agricultural, industrial, and commercial and recreational fisheries uses. To support these allocation decisions, this study provides two different types of economic information: 1) economic benefits created by people directly using the lakes, and 2) the value held by the public related to the lakes' existence, indirect use and potential benefits. Both types of economic information are important to these globally important fisheries.

Economic Contributions

This study also looks at direct economic contributions, such as jobs and income, to illustrate the fisheries as an important economic engine. Measures of economic contributions convey the magnitude of economic losses that would result if fisheries were allowed to decline.

Recreational Sportfishing

The Great Lakes fisheries provided robust opportunities for an estimated 1.1 million licensed anglers in 2020 who spent at least one day fishing the Great Lakes and their tributaries. Accounting for anglers who fished more than one lake plus those not needing a license. We estimate 1.4 million people spent 34.1 million days fishing in 2020 which is how long it would take if you could walk to Pluto.

State	Total Anglers	Total fishing Days
Illinois	58,210	1,307.6
Indiana	24,700	784.5
Michigan	379,31	8,376.9
Minnesota	33,211	586.6
New York	341,187	7,799.9
Ohio	321,587	8,381.6
Penn	116,731	3,789.5
Wisconsin	154,200	3,073.4
Total	**1.4 Million**	**34.1 Million**

Residents of Great Lakes states place value on maintaining sustainable fisheries catch rates, even if they don't fish. These "non-use" values include altruistic, bequest, and ecological reasons. As such, the total value of the Great Lakes recreational fishery includes both recreational use and non-use values. This report uses both measures to quantify the amount the public is willing to pay to avoid 10%, 25% and 50% decreases in harvests for warm and cold water species.

We estimated that the aggregate economic value to Great Lakes states and Ontario residents of avoiding a 10% reduction in the sustainable recreational harvest is $1.1 billion and even greater for 25% and 50% reductions – or, about the value of the Detroit Red Wings U.S. National Hockey League franchise. The willing ness to pay indicates that respondents hold substantial economic value for maintaining recreational fishing harvests. Willingness to pay is greatest for recreational users, but still significant for those who do not fish. To review the full four page data and statistics, click here: The Great Lakes Valuation Report

Status/Trends of Pelagic/Benthic Prey Fish Populations in Lake Michigan, 2024

Executive Summary

Fall bottom trawl (fall BT) and lakewide acoustic (AC) surveys are conducted annually to generate indices of pelagic and benthic prey fish densities in Lake Michigan. The fall BT survey has been conducted each fall since 1973 using 12-m trawls at depths ranging from 9 to 110 m at fixed locations distributed across seven transects; this survey estimates densities of seven prey fish species [i.e., Alewife, Bloater, Rainbow Smelt, Deepwater Sculpin, Slimy Sculpin, Round Goby, Ninespine Stickleback, as well as age-0 Yellow Perch and large (> 350 mm) Burbot. In recent years, wild juvenile (<400 mm) Lake Trout have also become more common in the fall bottom trawl. The AC survey has been conducted each late summer/early fall since 2004 (except 2020). The 2024 AC survey consisted of 24 transects [468 km total (291 miles)] covering bottom depths ranging from 16 to 173 m and 38 midwater trawl tows at 4 to 72 m; this survey estimates densities of three prey fish species (i.e., Alewife, Bloater, and Rainbow Smelt, **Fig. 1).** The data generated from these surveys are used to estimate various population parameters that are, in turn, used by state and tribal agencies in managing Lake Michigan fish stocks. In spring of 2024, an additional spring bottom trawl survey (spring BT) was implemented across six of the transects sampled in the fall and sites ranged in depth from 9 to 237 m. The goal of the spring BT, conducted annually since 2021 with differing levels of effort, was to explore seasonal differences in biomass density and distributions of key prey species, mostly notably Alewife.

Total prey fish biomass density from the spring BT was 5.7 kg/ha. For the AC survey, total biomass density of prey fish equaled 10.8 kg/ha, more than double the long-term average (2004-2023) of 5.1 kg/ha but 4.0 kg/ha lower than the 2023 estimate. For the fall BT, total biomass density of prey fish equaled 2.1 kg/ha, the lowest value since 2020 and 69% lower than the average from 2004-2023 (6.8 kg/ha). The 2024 fall BT biomass density was only 6.3% of the average over the entirety of the time series (1973-2023; 33.1 kg/ha). Over the period both surveys have been conducted (2004-2024), total biomass density has trended downward in the fall BT (despite a high 2022 estimate) and remained stable in the AC survey.

Deepwater Sculpin and Bloater were the most common species (by biomass) among prey fishes in the spring BT while the AC survey and fall BT reported co-dominance of Bloater and Alewife. Mean biomass of yearling and older (YAO) Alewife was 1.30 kg/ha in the spring BT, 4.7 kg/ha in the AC survey, and 0.68 kg/ha in the fall BT. Since 2014, annual survey results suggest that the catchability of YAO Alewives for the fall BT is substantially lower than the AC survey. Like previous spring surveys, Alewives were aggregated in deeper habitats, with 93% of biomass collected between 110 and 201 m. Results of the 2024 spring BT align with past spring surveys and do not suggest that spring bottom trawling provides a better index of age-2 and older Alewives than fall bottom trawling, even with adjustments for differences in habitat use. However, the spring BT does appear to index age-1 Alewives more effectively than the fall BT.

The 2024 AC survey YAO Alewife biomass density estimate was 77% higher than the average from 2004-2023. The Alewife population of Lake Michigan appears to be composed mostly of young fish and the proportion of age-4 and older Alewives was <1.8% in each of the three surveys. Age-0 Alewife numeric density from the AC survey was 510 fish/ha in 2024, slightly higher than the long-term mean (486 fish/ha). Biomass density of large (È120 mm) Bloater was 5.2 kg/ha in the AC survey and 0.76 kg/ha in the fall BT, while total Bloater biomass in the spring BT was 1.8 kg/ha - all three estimates were much lower than what was estimated by the fall BT between 1981 and 1998. The density of small (<120 mm) Bloater was 456 fish/ha in the AC survey, the second highest value in the time series and potentially reflective of an above average 2024 year-class. Meanwhile, small Bloater density estimated in the fall BT was only 16 fish/ha. Biomass density of large Rainbow Smelt (È90 mm) was 0.21 kg/ha in the AC survey and 0.03 kg/ha in the fall BT survey, continuing the trend of low large Rainbow Smelt biomass observed since 2001. Numeric density of small (00 mm) Rainbow Smelt was 3 1 fish/ha in the AC survey and 143 fish/ha in the fall BT.

All four prey fish species indexed only by the fall BT indicated below-average biomass densities. Deepwater Sculpin biomass density was 0.26 kg/ha, which makes 14 of the past 15 years with biomass <1 kg/ha. Spring BT Deepwater Sculpin biomass density (2.0 kg/ha) was higher than any fall BT estimate since 2006, likely reflective of estimating biomass from bottom trawls at greater depths in the spring than the fall. Slimy Sculpin was estimated to be < 0.04 kg/ha in the spring and fall BT, an order of magnitude lower than the long-term average from the fall B T. Round Goby biomass density estimates were low and similar across seasons (0.43 kg/ha in the spring and 0.10 kg/ha in the fall). Ninespine Stickleback density was 3.9 fish/ha in the fall BT and no fish were collected in the spring BT.

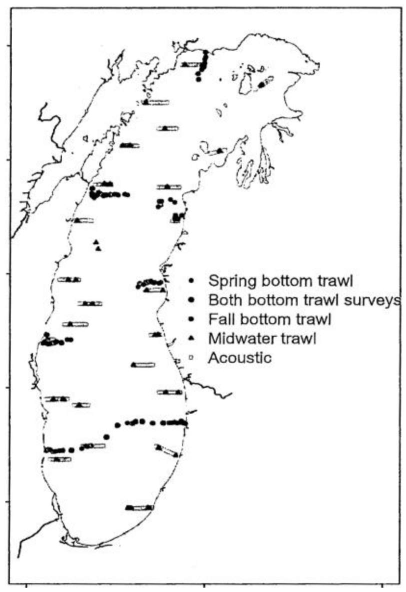


Fig 1. Map of sampling locations for the Lake Michigan bottom trawl and acoustic surveys in 2024. Gray squares represent acoustic transects magenta triangles represent midwater trawl locations. Bottom trawl sites are color-coded by season in which they were sampled: spring (black), fall (blue), and both seasons (red).

Results

__Alewife__

Yearling and older Alewife biomass density estimates in 2024 were 1.3 kg/ha in the spring BT, 4.7 kg/ha in the AC survey, and 0.68 kg/ha in the fall BT **(Fig. 2)**. The AC survey YAO Alewife biomass density estimate was the second highest in the time series and marks the second consecutive year of an above average biomass density estimate. Like past surveys in April and May (Tingley et al. 2023, Warner et al. 2024), spring BT Alewife densities were highest in deepwater habitats (>110 m) throughout the lake, with biomass >5 kg/ha in six tows between 110 and 201 m. By contrast, YAO Alewives were only collected sporadically in deepwater tows (128-164 m) during the fall BT, with almost 88% of total biomass coming in a single 18 m tow along the Sturgeon Bay transect in northwestern Lake Michigan. YAO Alewives were relatively well-distributed throughout the lake during the AC survey, with the highest catches occurring in northwestern Lake Michigan (79.5 kg/ha).

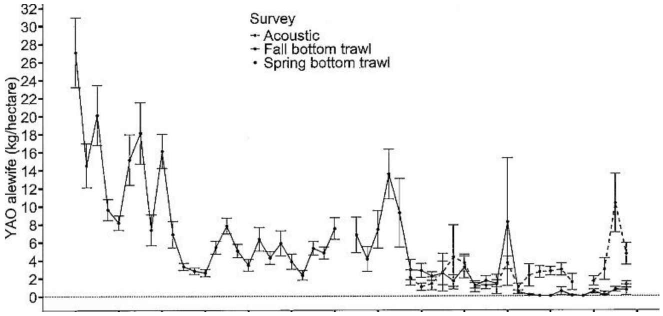


Fig 2. Yearling and older (YAO) Alewife (800 mm) biomass density for the spring bottom trawl, fall trawl, and acoustic surveys. Error bars are +1- standard error.

Fall BT and AC survey YAO Alewife biomass densities did not have overlapping standard error (SE) bars for the ninth consecutive year, a departure from general agreement through the first ten years of the AC survey (2004-2013). Results of the annual surveys over the past decade indicate that fall BT catchability has declined resulting in a notable reduction in annual index values that have remained below 0.75 kg/ha since 2014. However, assuming the AC survey more accurately indexes YAO Alewife biomass, estimates from the AC survey during the last five years sampled (averaging 4.7 kg/ha) are lower than acoustic estimates in 1987 [9.6 kg/ha, (Argyle 1992)], 1995 and 1996 [8.3 and 10.0 kg/ha respectively, (Argyle et al. 1998)], which were calculated by dividing the number of kg reported by 5,396,683 ha, the area covered by the acoustic survey. Similarly, except for 2023, recent AC estimates are below the mean biomass estimated by the fall BT in the 1970s (16.1 kg/ha), 1980s (6.1 kg/ha), and 1990s (6.0 kg/ha).

The spring BT YAO Alewife biomass density index was double the value observed in the fall BT but SE bars were overlapping between the two surveys; by contrast, the Spring BT index was 73% lower than the AC survey index, and error bars did not overlap (Fig. 2). The relative differences in biomass density indices across the three surveys were similar to 2022, the last time a full spring BT was completed. However, we note that the YAO Alewife numeric density was far lower in the fall BT than the spring BT in 2024 (42 ± 39 vs. 236 ± 62/ha) and 2022 (4 ± 1 vs. 43 ± 15/ha). The difference between numeric density but not biomass density across seasons is due to higher yearling Alewife catchability during the spring than fall. YAO Alewife catch in the 2024 spring BT was 95% yearlings while the fall BT was 54% yearling fish, similar to differences observed in 2022 (85% in the spring, 29% in the fall) and reflective of observed underrepresentation of age-I fish in the fall BT on Lake Michigan (**Fig. 3a**; Eck and Brown 1985; Krause 1999). Greater catchability of yearlings during the spring than the fall aligns with differences observed in Lake Ontario, where yearling Alewife catch is consistently higher in the spring (B. Weidel, USGS, personal communication).

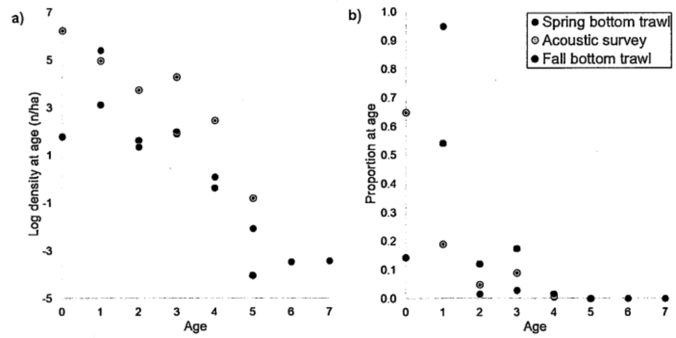


Fig 3: Natural density at age (n/ha; a) and proportion at age (b) for Alewives collected in the 2024 spring bottom trawl, acoustic survey, and fall bottom trawl.

The AC survey was predominately age-0 (65%) and age-I fish (19%; **Fig. 3b**). The 2021year class (age-3 fish) made up 9% of the total AC survey estimate while other ages made up the remaining 6%. Age-I fish were 54% of the fall BT catch, with age-3 Alewife being the next most abundant year-class (**fig 3b**). "No survey recorded age 4 and older fish accounting for more than 1.8% of catch. Evidence from the two annual surveys and the spring BT indicates age truncation in the Alewife population, likely due to high predation pressure (see Warner et al. 2022 and prior reports for a complete summary).

Similar to 2023, age-0 Alewives sampled in the AC survey were at the highest densities in the northwest and northcentral portion of the lake (Warner et al. 2024. Numeric density of age-0 Alewives estimated from the AC survey was 510 fish/ha in 2024 (**Fig. 4).** The 2024 estimate is just above the mean over the entire time series (486 fish/ha) and follows the 3rd strongest year class on record; however, it is less than one-third of the numeric densities reported during the high recruitment events observed in 2005 and 2010.

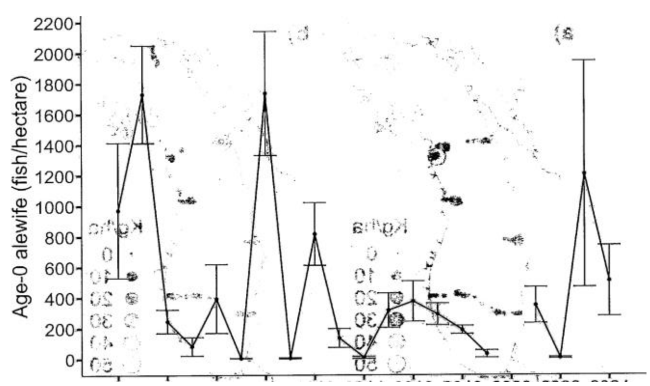


Fig 4 Age-0 Alewife numeric density as indexed by the acoustic survey from 20042024 in Lake Michigan. Error bars are +/- standard error.

Bloater

Biomass density of large Bloater in 2024 was 1.8 kg/ha in the spring BT, 5.2 kg/ha in the AC spring, and 0.76 kg/ha in the fall BT**.** Large Bloater densities in BT survey tows were highest northern Lake Michigan and were more dispersed in the AC survey. Large Bloater bio ss indices remain an order of magnitude lower than the maximum biomass density measured d 1981-1997. However, the AC survey has shown an increasing trend beginning in 2011 and the c t large Bloater biomass estimate is the highest recorded in the AC survey dataset (2004-2024).

The small Bloater (<120 mm) numeric density estimate from the AC survey was 456 fish/ha in 2024, the second highest value in the time series. However, only 16 fish/ha were recorded in the fall BT, well below the long-term mean but consistent with low recruitment years. Small bloater densities in the AC survey were highest in the central and southern basin.

Rainbow Smelt

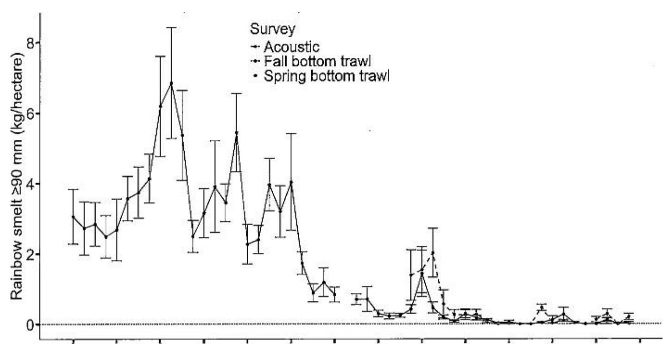


Fig 5. Biomass density of large Rainbow Smelt (> 90 mm) in Lake Michigan as indexed by the fall bottom trawl and acoustic surveys. Error bars in both panels are +1- standard error.

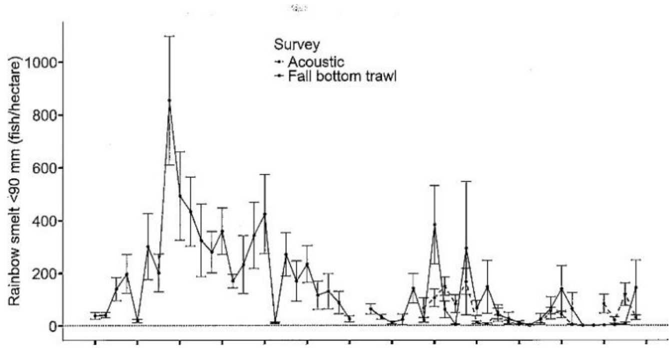


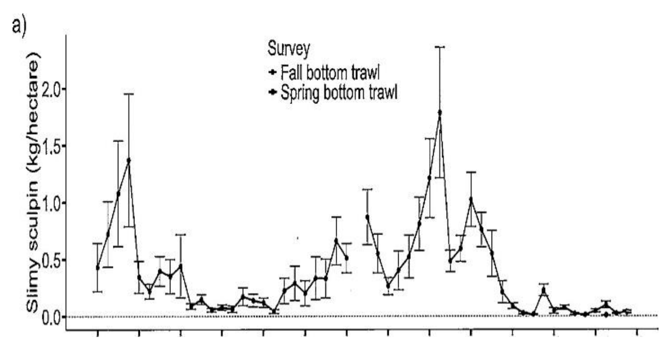
Fig 6. Numeric Density of small Rainbow Smelt; <90 mm) in Lake Michigan as indexed by the fall bottom trawl and acoustic surveys. Error bars in both panels are +/- standard error.

The 2024 index of large Rainbow Smelt biomass density was <0.20 kg/ha in all three surveys (**Fig. 5**). Biomass density of large Rainbow Smelt has been <2 kg/ha since 1994, following the 19731993 era when Rainbow Smelt density averaged 3.7 kg/ha. Numeric density of small Rainbow Smelt estimated by the 2024xAC survey was 31 fish/ha compared and 143 fish/ha by the fall BT, nearly opposite the values observed in 2023 **(Fig. 6)**. The value indexed by the fall BT was the highest in seven years, but most fish (84%) were collected in a single 18 m tow outside of Manistique. The causes for the lÞg-term 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 (Madenjian et al, 2002), yet abundance remained high. Current evidence suggests that predation by salmonines wa hot the primary driver of long-term temporal trends in Lake Michigan abundance (Tsehaye et al. 2014). Furthermore, a time series analysis through 2012 suggested that the production of age-0 fish relative to the number of spawners had increased since 2000, yet those age-0 fish do not appear to be surviving to adulthood (Feiner et al. 2015). In recent years, age-0 indices similar to what was observed in the 2024 fall BT have not translated into notably higher adult biomass in Lake Michigan.

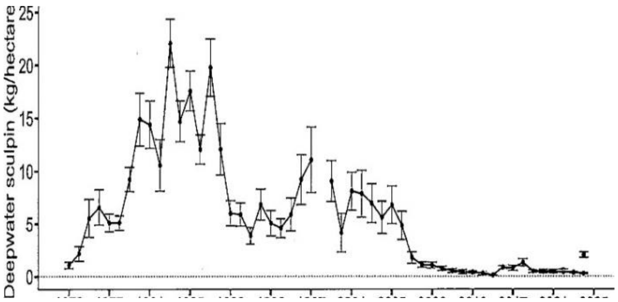
Slimy Sculpin

Slimy Sculpin biomass was < 0.04 kg/ha in the spring and fall BT surveys in 2024. Biomass density estimates from the fall BT have remained below 1 kg/ha for 15 consecutive years and Spring BT values in 2024 were similar to those observed in 2022 (**Fig. 7a).** While declines in total biomass have been observed in recent years across multiple prey species, Slimy Sculpin abundance is at least partially regulated by juvenile Lake Trout predation (Madenjian et al. 2005). In fact, Slimy Sculpin biomass began declining in 2010, which coincides with a substantial increase in juvenile Lake Trout stocking and natural recruitment (FWS/GLFC 2017; Lake Michigan LTWG 2019). The decline in Slimy Sculpin biomass does not appear to be an artifact of only sampling to 110 m during our standard survey. Comparisons of mean depth at capture and changes in biomass density with and without 128 m sites do not support the hypothesis that shifts of Slimy Sculpin distributions to depths outside our standard coverage have impacted density estimates (Madenjian et al. 2022).

Fig 7. Biomass density of a) Slimy Sculpin and b) Deepwater Sculpin in Lake Michigan as measured by the spring and fall bottom trawl surveys. Error bars in both panels are +/- standard error.



7b)



Deepwater Sculpin

The biomass density of Deepwater Sculpin in 2024 was 2.0 kg/ha in the spring and 0.26 kg/ha in the fall bottom trawl surveys (**Fig. 7b**). Previous analysis of the fall BT time series indicated Deepwater Sculpin density is negatively influenced by Alewife (predation on sculpin larvae) and Burbot (predation on juvenile and adult sculpin, Madenjian et al. 2005); because neither of these species has increased since 2007, these mechanisms likely do not underlie the long-term downward trend in the fall BT dataset. A likely explanation is that some portion of the Deepwater Sculpin population has shifted to waters deeper than 110 m (the deepest depth for the standard frawling sites). In support of this, Madenjian and Bunnell (2008) found that Deepwater Sculpins have been captured at increasingly greater depths since the 1980s. Mean depth at capture and biomass density estimates are substantially higher when 128 m sites are included (Madenjian et al. 2022). Further, 95% of Deepwater Sculpin biomass was collected at depths greater than 110 m in the spring of 2024, with the highest average tow density in the 237 m depth strata, highlighting the contemporary importance of habitats outside the historical range of the fall BT.

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 fall BT survey during 1984 (Stedman and Bowen 1985) but has been rare in recent sampling years. Ninespine Stickleback biomass density has also been low (i.e., <0.01 kg/ha) since 2010 and was only 0.008 kg/ha in the fall BT. No Ninespine Sticklbacks were collected in the spring BT, likely because the primary transect where they are collected, Manistique, was not sampled in the spring. Ninespine Stickleback biomass density remained 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 (Fig. 12a; Madenjian et al. 2010). Since 2009, Ninespine Sticklebacks have declined, potentially because piscivores began to incorporate them into their diets as Alewives declined. Jacobs et al. (2013) found Ninespine Sticklebacks in large Chinook Salmon diets (2% occurrence) during 2009-2010 after 0% occurrence in 1994-1996.

Round goby

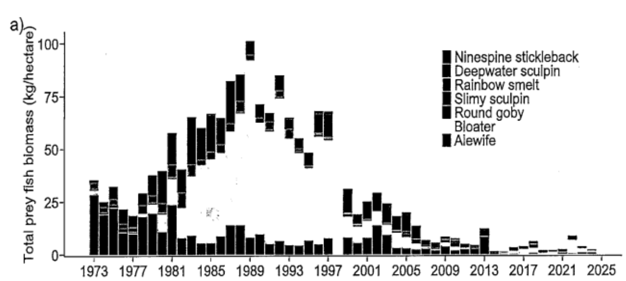
Invasive Round Gobies were first detected in bays and harbors of Lake Michigan in 1993 (Clapp et al. 2001) but were not widespread enough to be sampled by the fall BT until 2003. By 2008, Round Gobies were well established in the fall BT. However, as our survey samples only soft substrates > 9 m in depth, our index is biased low-because we are not sampling their preferred habitat in September (rocky substrate and shallow (<9m depths). -Round Goby biomass density was 0.43 in the spring BT and 0.11 kg/ha in 2024 BT survey, continuing the pattern of large yearly fluctuations in density estimates. Densities were highest in the spring BT between 90 and 150 m. By contrast, densities in the fall BT were highest in shallow habitats**,** reflective of seasonal migrations from rocky nearshore habitats to offshore waters during winter months (Janssen et al. 2005; Robinson et al. 2021).

Round Gobies are consumed by a diverse array of fishes including Smallmouth Bass (Crane and Einhouse, 2016), Yellow Perch (Truemper et al. 2006), Burbot (Jacobs et al. 2010), Lake Trout (Luo et al. 2019), Lake Whitefish, Pothoven and Madenjian, 2013), and Cisco (Breaker et al, 2020), as well as Brown Trout, Steelhead, Coho Salmon, and Chinook Salmon (Turschak et al. 2022). We hypothesize that Round Goby abundance in Lake Michigan is controlled by predation, given that annual mortality rate estimates range from 79 to 84% (Huo et al. 2014), comparable to adult Alewives (Tsehaye et al. 2014).

Preyfish community trends

The prey fish community sampled by both BT surveys includes Alewife, Bloater, Rainbow Smelt, Deepwater Sculpin, Slimy Sculpin, Ninespine Stickleback, and Round Goby. Total prey fish biomass density was 5.7 kg/ha in the spring and 2.1 kg/ha in the fall. Differences between the two BT surveys were partially due to sample design (i.e. Deepwater Sculpin habitat is sampled to a greater extent in the spring) and higher catchability of yearling Alewwife in the spring than in the fall. Total fall BT biomass is still well below the long-term average of33.l kg/ha (**Fig. 8**). Total biomass density first dropped below 10 kg/ha in 2007 and has since remained below that level except in 2013, when the biomass estimates for Alewife and Round Goby were uncertain due to high catches in single tow locations.

Fig 8. Estimated biomass density of prey fishes sampled in the fall bottom trawl survey, 1973-2024 and the estimated biomass density of prey fishes sampled by the current acoustic survey, 2004-2024,



The prey fish community sampled by the AC survey includes Alewife, Bloater, Rainbow Smelt, and Cisco. In 2024, this survey estimated a total biomass density of 10.8 kg/ha **(Fig. 8**), the second highest since the modern AC survey began in 2004 but only 15% of the mean of the 1987, 1995, and 1996 surveys [72.4 kg/ha, Argyle 1992; Argyle et al. 1998)].

Other species of interest

Burbot and Lake Trout - Lake Trout and Burbot represent the native top predators in Lake Michigan. Burbot biomass density in the fall BT survey was 0.04 kg/ha, in line with recent low estimates observed since 2012 (Warner et al. 2024). While it is unclear why Burbot catches in the fall BT survey have remained low in the face of relatively low densities of Sea Lamprey and Alewife over the past decade, Madenjian et al. (2022) hypothesized that a proportion of the Burbot population may have followed the Deepwater Sculpin population into deeper waters of Lake Michigan. Conversely, wild juvenile Lake Trout have been collected by the bottom trawl each year since 2008 (Leonhardt et al. 2024, wild juvenile Lake Trout abundance was 0.10 fish/ha, higher than any value to 2015 but lower than the past three years (average = 0.29 kg/ha; **Fig. 9**). While catches [a]ane sporadic, the fall BT\does appear to track the increase in Lake Trout natural recruitment in Lake Michigan.

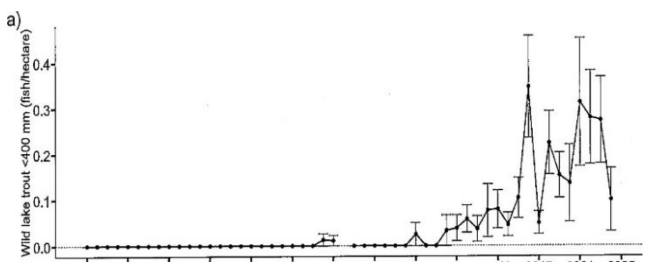


Fig 9. Biomass density of a) wild juvenile Lake Trout; <400 mm). Error bar are +/- standard error.

Small Yellow Perch - The Yellow Perch population in Lake Michigan has supported valuable recreational and commercial fisheries (Wells 1977). The fall BT provides an index of small (<100 mm) Yellow Perch numeric density, which serves as an indication of recruitment success. The 2005 year-class of Yellow Perch was the largest recorded **(Fig. 10)** and the 2009 and 2010 year-classes were also higher than average. In the 2024 fall BT survey, no age-0 Yellow Perch were collected, continuing a 14-year trend of poor recruitment index values.

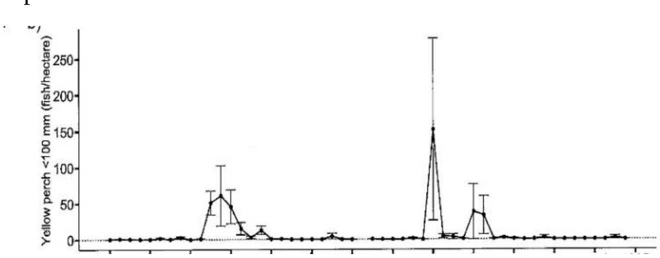


Fig 10. Numeric density of small Yellow Perch; <100 mm) in Lake Michigan as indexed by the fall bottom trawl survey. Error bars are +/- standard error.

Conclusions

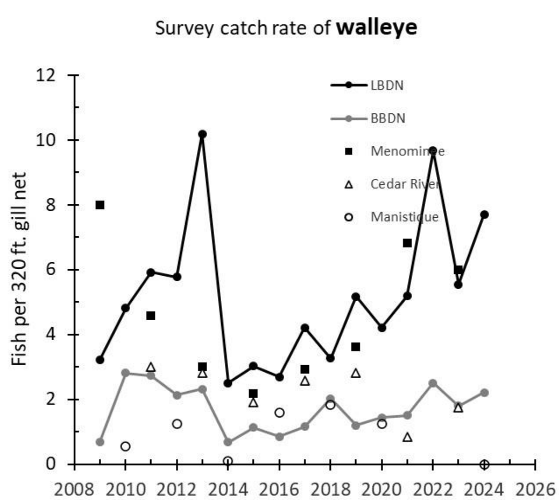
Alewife year-class strength in 2024 appears to be at least average, and densities of age-0 Alewife were highest in the northwestern portion of Lake Michigan for the second consecutive year. Our results indicate that three of the last four years produced relatively strong Alewife year-classes, but older fish (age-4 and older) are still uncommon across our surveys. Results of all three surveys still suggest high predation on Alewives and an age-truncated population. Rainbow Smelt and small Yellow Perch remain in low abundance. While there is some support for a moderate recruitment event for Rainbow Smelt in 2024, we do not anticipate the adult population to increase substantially in the coming years. Estimates of small Bloater from the AC survey indicate a strong recruitment event for Bloater in 2024, but further otolith aging will provide additional insight. The AC estimate of YAO Alewife biomass remains well above the 2004-2022 mean, providing evidence of an increase in biomass since 2022. This year's fall BT survey did not indicate an increase in Alewife biomass density from 2023, but we note the high uncertainty associated with the estimate. Overall, prey fish biomass remains low relative to previous decades.

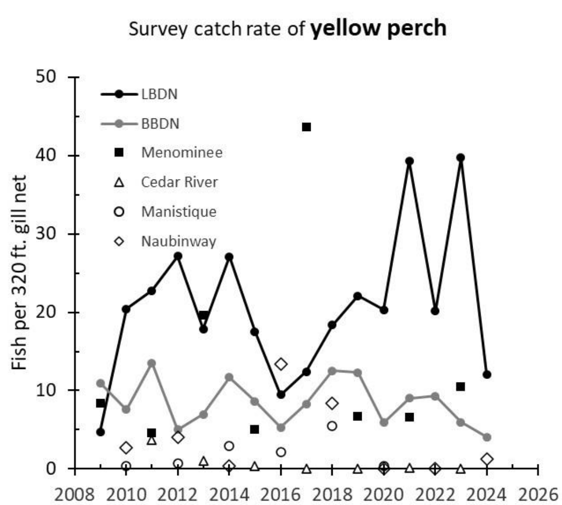
Differences in Alewife habitat use, biomass density, and life-stage specific catchability between the 2024 spring and fall BT align with results from past years (2021-2023; Tingley et al. 2023, Warner et al. 2024). For the fourth consecutive spring season, were largely absent from shallow habitats and mean densities were highest in the 146 m strata, outside the historical range of the fall BT. The 2024 survey results support the hypothesis that Alewives in the Great Lakes overwinter in deepwater habitats, perhaps to take advantage of slightly warmer conditions (Wells 1968; O'Gorman et al. 2000; Weidel et al. 2023). Alewives were still aggregated in deepwater habitats in late April 2024, providing more evidence of a later migration to the nearshore environment than historically observed in lakes Michigan and Ontario (Wells 1968, O' Gorman et al. 2000). Bottom trawling in the spring provides a better index of age-I Alewife than the fall on Lake Michigan, as values in 2022 and 2024 are comparable to AC survey estimates while the fall BT likely underestimated yearling fish in both years (Tingley et al. 2023). However, as we observed in 2022, the YAO Alewife spring BT biomass density index is only slightly higher than the index generated from the 2024 fall BT. Further, few age-3 and older Alewives were captured in the 2024 spring BT, and age-specific density estimates of ages 2-5 from both the spring and fall BT surveys were an order of magnitude lower than those from the AC survey. Together, our results suggest that a spring survey does not more effectively sample older Alewives than the fall BT, but an annual spring BT would provide an additional early indicator of year-class strength. The mechanism for the apparently reduced catchability of YAO Alewives, especially age-2 and older fish, in the Lake Michigan bottom trawl surveys since 2014 remains unclear.

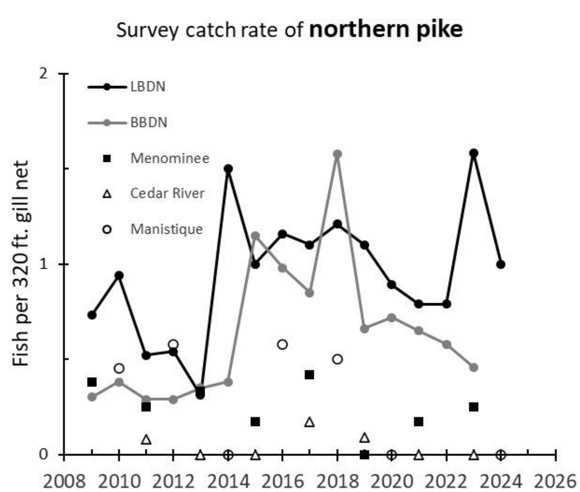
Fish Community Status in the Bays de Noc and Waters of Northern Lake Michigan

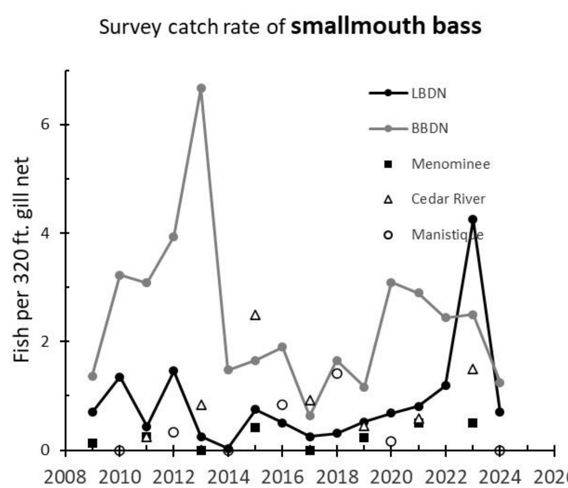
Background:
Since 2009, MDNR Fisheries Division has been conducting a standardized fish community assessment in the nearshore waters of northern Lake Michigan and Michigan's portion of Green Bay. The objectives of the project are to describe the status and trends in fish populations, provide data on abundance, growth, and reproductive success for species of management importance including walleye, yellow perch, northern pike, smallmouth bass, lake sturgeon, and others. Data are collected in August and September using experimental mesh gill nets and trawling. Sampling occurs annually in Little Bay de Noc (LBDN) and Big Bay de Noc (BBDN), and during alternate years in Lake Michigan near eastern ports (Manistique and Naubinway) and western ports (Cedar River and Menominee). Information from this survey also supports various projects with agency and university collaborators. Data to track the sport fishery are collected at some locations through an on-site creel survey.

Recent trends:
The charts below show the survey catch rate (number of fish per 320 ft of gill net) for important fishes in northern Green Bay. These data suggest a gradual increase in walleye abundance at most locations since 2014. Yellow perch survey catch rates have been variable but relatively stable during the survey period at all locations. Northern pike abundance in LBDN and BBDN increased in association with higher water levels in Lake Michigan but has declined in recent years. Smallmouth bass survey catch rates may be trending slightly upward during the last several years, a pattern consistent with increasing angler catch rates during the last couple decades.



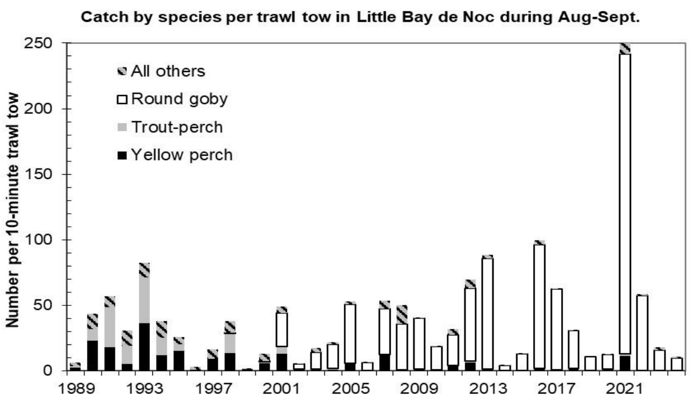


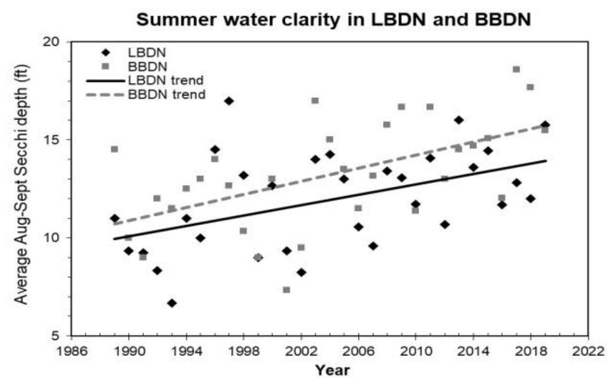




Longer-term perspective:

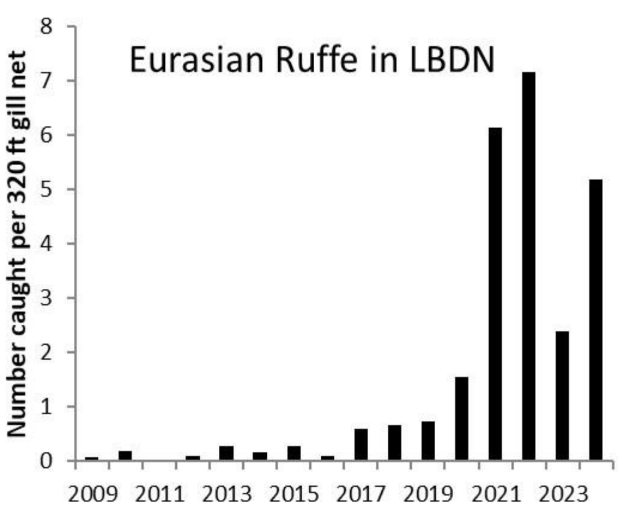
While recent trends show a relatively stable fish community, sampling over the past 30 years demonstrates considerable change. MDNR has been sampling smaller bottom fishes in LBDN and BBDN by daytime trawling in late summer since 1989, and these data show a substantial change in catch rates of smaller bottom fishes indicative of a changing fish community. Round goby have dominated trawl catches in LBDN since 2001, with trout-perch and yellow perch now being caught at much lower levels (see graph below). Angler harvest of yellow perch fishery has been relatively stable since about 2008 but with lower harvest levels than during 1998-2007. In BBDN, average open-water yellow perch harvest since 2008 has been higher than during 1998-2007. Information from walleye tagging studies, creel census estimates, and data on water clarity from Secchi disk measurements (see graph below) collectively indicate that habitat, fish communities and the sport fishery have changed since zebra and quagga mussels invaded the Bays de Noc, along a similar timeline to mussel-induced changes in the main basin of Lake Michigan. Nevertheless, northern Green Bay continues to host self-sustaining populations of many prized species of sport fish.

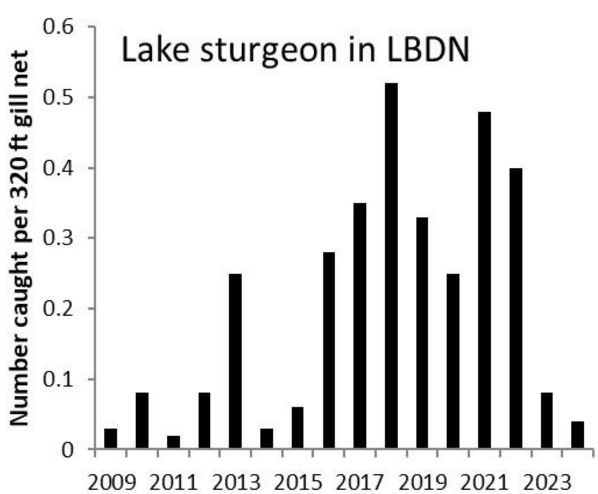




Other fishes:

Anglers might encounter two relatively "new" species that have shown notable increases MDNR assessment catch rates in recent years. Eurasian ruffe, an invasive fish from eastern Europe and northern Asia, have been at low abundance in LBDN since the early 2000's but much more abundant in recent years. Eurasian ruffe were the 3rd most abundant fish in our 2022 LBDN fish community assessment survey. Lake sturgeon, a Lake Michigan native, are increasing in abundance in LBDN due to reintroduction stocking efforts started in 2006.





Lake Trout Monitoring in Lake Michigan

2024 Spring and Fall Assessments

Lake Trout was the top native predator in Lake Michigan before its decline due to a combination of overfishing and mortality caused by the invasive Sea Lamprey Petromyzon marinus, resulting in the extirpation of Lake Trout in Lake Michigan by the 1950s (Wells and McLain 1972; Holey et al. 1995). A Sea Lamprey control program was initiated shortly thereafter and a Lake Trout stocking program, with the goal of rehabilitation, began in 1965 (Wells and McLain 1972).

Lake-wide stocking of Lake Trout continues annually at a combination of nearshore and offshore locations. Stocking locations and harvest restrictions were first formalized in A Lakewide Management Plan for Lake Trout Rehabilitation in Lake Michigan (LMLTTC 1985). Primary stocking sites (areas with the best spawning habitat and where high commercial harvests of Lake Trout occurred) were established as well as refuges in the northern and mid-lake regions that were closed to all forms of harvest. In addition, secondary stocking sites were adopted which were deemed to have sub-par habitat but provided for more localized fisheries. In Illinois waters, Julian's Reef was established as a primary stocking site and regulated as a commercial refuge, where sport fishing was allowed but commercial fishing was prohibited **(Fig 1).** Julian's Reef was first stocked in 1981 and has received annual stocking each year with the exception of five years **(Fig 2**). Despite these efforts, successful natural reproduction was negligible until recently and thus the Management Plan's goal of establishing a self-sustaining Lake Trout population has been unmet for decades.

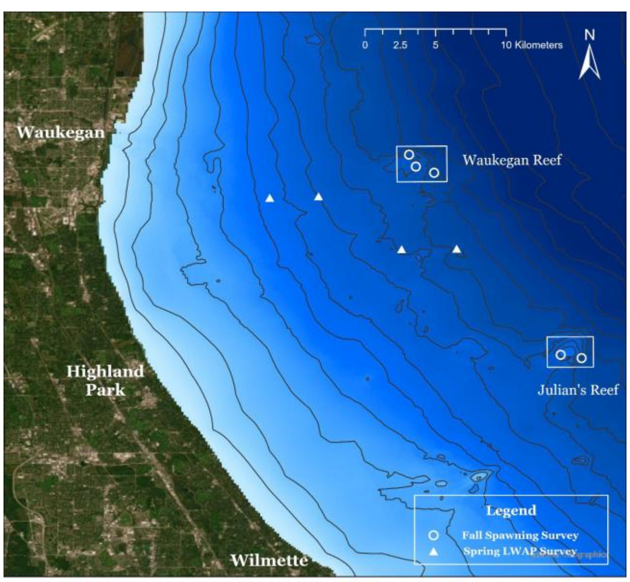


Fig 1. Location of the spring Lake Trout survey sites (white triangles) and fall spawning Lake Trout surveys (Open Circles) in the Illinois waters of Lake Michigan in 2024. Bottom insets show bathymetric placement of fall survey nets on Waukegan and Julian's Reefs

Stocking locations and numbers were revised under A Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan (Dexter et al. 2011; referred to hereafter as the Implementation Strategy). Julian's Reef was retained as a First Priority stocking site and 60,000 yearling Lake Trout of Lewis Lake (LLW) strain and 60,000 yearling Lake Trout of Seneca Lake (SLW) strain have been stocked each year since 2011 (with the exception of the COVID-19 pandemic-related interruption of 2020-2021). The Implementation Strategy contained four Evaluation Objectives to monitor progress toward targeted rehabilitation, which were updated and supplemented in 2024 under A Stocking Strategy and Evaluation Objectives for the Rehabilitation of Lake Trout in Lake Michigan (Wesley et al., 2024; referred to hereafter as the Stocking Strategy). The Stocking Strategy also contained objectives that only apply to regions outside Illinois waters (Objectives 4 and 5). The relevant objectives under the Stocking Strategy were: 1) catch-per-unit-effort (CPUE) of >25 Lake Trout/1000 ft graded-mesh gill nets in spring stock assessments; 2) CPUE of >50 Lake Trout/1000 ft graded mesh gill nets in spawning 1 surveys; 3) spawning populations of at least 25% female and which have ten or more age groups older than age-7; 6) detect eggs with thiamine concentrations of >4 nmol/g; and 7) CPUE > 19 wild Lake Trout/1000 ft graded-mesh gill nets in spring stock assessments. Objectives 2, 3, and 6 are used to assess first priority stocking sites.

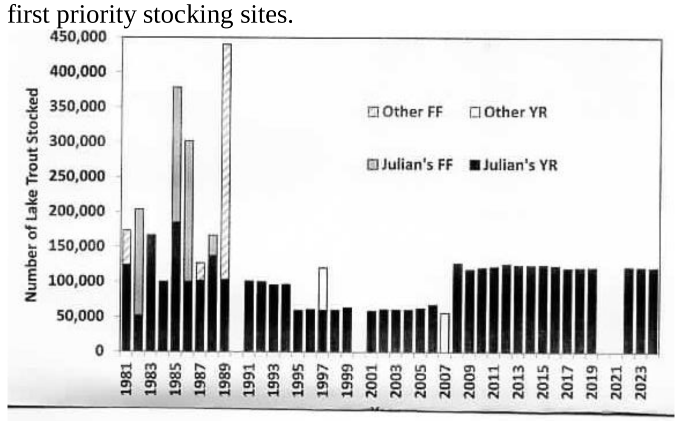


Fig 2. Lake Trout stocking in Illinois waters of Lake Michigan, 1981 to 2024 (FF = fall fingerling, YR = yearling). Due to COVID-19 restrictions, federally reared Lake Trout allocated to Illinois were stocked from shore in Wisconsin during 2020 and 2021. The number of fish stocked in 2024 had not been officially reported at the time of writing of this report, thus the number displayed (120,000) represents the target total

To assess progress toward these Evaluation Objectives in the Illinois waters of Lake Michigan, annual gill net surveys are conducted in the spring at offshore locations near Waukegan, IL and at spawning reefs in the fall. Gill nets have been used annually to sample spawning Lake Trout at both Waukegan and Julian's reefs since the early 1980s. Patterson et al. (2017)

found no significant differences in catch statistics between Julian's Reef and Waukegan Reef during 1999-2014. Thus, Evaluation Objectives 2, 3, and 6 were assessed annually at Julian's Reef, with data from Waukegan Reef being used in years when no sampling occurred at Julian's Reef.

Considering the similarities between Julian's and Waukegan reefs and an increase in Lake Trout of wild origin, a change in fall Lake Trout sampling site selection was instituted. Beginning in 2017, these priority sites were sampled in alternate years to allow investigation of population parameters at other Illinois reefs where Lake Trout may be spawning. Fall Lake Trout sampling included the "non-priority sites" consisting of North Reef (2017), Wilmette Reef (2018), and Lake Bluff 10-Mile Reef (2019), which were sampled in addition to either Julian's or Waukegan reefs. However, this rotation of priority sites was interrupted in 2020, when COVID-19 restrictions prevented both spring and fall Lake Trout sampling. Both surveys resumed in 2021 and Julian's and Waukegan reefs were sampled during the fall given that neither priority reef had been visited the previous year. Due to vessel operation and lake condition issues causing an incomplete sampling of the two sites in 2021, 2022, and 2023, both reefs were sampled again in 2024.

This report covers progress towards Evaluation Objectives 1-3, 6 and 7 in Illinois waters.

METHODS

Lake Trout were sampled with gill nets during two offshore surveys. Presented data are from surveys conducted in 2005-2024.

Spring and Fall Lake Trout Surveys

Two graded mesh gill nets, each with two 100 ft panels of 2.5" to 6" (½ inch increments) mesh sizes (1600 ft total) were fished overnight (Schneeberger et al. 1998) on 15-17 May 2024. One net was set at an established site within two out of three targeted depth bins (50-100, 100-150, and 150-200 ft) at 2 each of two identified transects offshore of Waukegan, IL. Typically, all three depth bins are sampled along both transects, however adverse lake conditions limited sampling capabilities resulting in one depth bin from each transect being omitted. A total of four nets were fished during the 2024 spring survey and all depth bins were sampled at least once.

In fall, two graded mesh gill nets, each with two 100 ft panels of 4.5" to 6" (½ inch increments) mesh sizes (800 ft total) were fished overnight on two occasions and one net was fished overnight on one occasion during 23 October-08 November 2024. A total of five nets were fished during the 2024 fall survey, three at Waukegan Reef and two at Julian's Reef.

In both surveys, fish were measured to the nearest 5 mm (maximum total length) and weighed to the nearest 50 grams. In addition, clipped fins, lamprey wounds, sex, and maturity were recorded. Lake Trout with an adipose fin clip, indicating the presence of a coded-wire tag (CWT), had the head removed for tag extraction in the laboratory.

Data Analyses

Lake Trout CPUE was calculated as number of fish per 1000 feet of gill net in both the spring and fall surveys. Because CPUE values are highly dependent on standardized effort, nets that were fished for more than 1 day in duration (since a 2-day set ≠ twice the number of fish of a 1-day set) or with incorrect mesh sizes were removed from CPUE analyses. For this report, all nets from the spring Lake Trout survey in 2003, two nets from the spring Lake Trout survey in 2007, and two nets from the fall spawner survey in 2011 were removed from analysis. Across the time series (1999-2024), CPUE data from 138 gillnet sets is included in the spring lake trout survey analysis, while the fall spawner survey analysis includes data from 154 gillnet sets. Catch data from all net sets and information from CWTs was used in the reporting of proportion female, number of age classes, proportion of unmarked fish, strain, and stocking origin since effort and mesh size has less influence on these indices.

Results

Spring Lake Trout Survey

Spring Lake Trout CPUE was 5.0 fish/1000 ft of net in 2024. This was only 20% of the target (25 fish/1000 ft), which has only been achieved once in 23 years of spring sampling **(Fig 3).** Spring CPUE during 2024 was noticeably lower than in recent years, being roughly ½ the average CPUE of the previous 5 sampling years (9.7 fish/1000 ft of net) and the lowest CPUE recorded since 2014. The shallowest net (90ft) was covered with dense algae and caught zero lake trout. It is possible that unusually early algae 3 production led to this net being abnormally visible to lake trout and thus avoidable, resulting in the low catch and contributing to the low overall CPUE for the survey. Evaluation Objective 1 of the Stocking Strategy has not been achieved in Illinois waters.

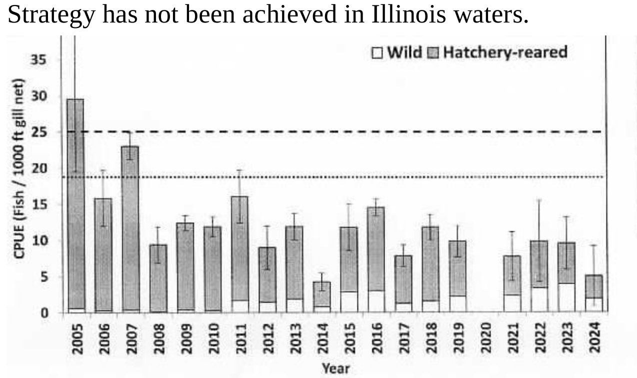


Fig 3. Catch per unit effort (CPUE) of Lake Trout sampled in spring 2005-2024 broken into the portion of the catch consisting of wild (white) and hatchery-reared (grey) fish. The dashed line represents the CPUE goal (>25 fish/1000 ft of gill net) of Evaluation Objective 1 in A Stocking Strategy and Evaluation Objectives for the

Rehabilitation of Lake Trout in Lake Michigan, while the dotted line represents the wild CPUE goal (>19 fish/1000ft of gill net) of Evaluation Objective 7. Error bars represent the standard error for the total CPUE (not accounting for hatchery or wild origin). Due to COVID-19 restrictions no sampling .

Twelve Lake Trout (38%) were not fin clipped and presumed to be of wild origin **(Fig 4).** This represents the second highest proportion of wild fish observed in the spring survey to date (the highest proportion of wild fish [41%] occurred in 2023). The percentage of unmarked fish in spring catches increased after 2010 and has averaged 23% (2011-2024 average) since that time. The CPUE of wild fish was 1.9 wild fish/1000ft of net, only 10% of the 19 wild fish/1000ft target. The maximum CPUE of wild fish in the spring survey (3.9 wild fish/1000ft of net in 2023) was considerably below the target level **(Fig 3**). Thus, Evaluation Objective 7 has not been achieved in Illinois waters and the target level seems unlikely to be met.

Thirteen Lake Trout had an adipose fin clip and a coded-wire tag, and all tags were successfully decoded. A majority (11) were stocked on Julian's Reef (6 to 21 years old at capture) and two were stocked on the Mid-lake Reef Complex (12 and 13 years old at capture).

Four strains of lake trout were represented in the catch of stocked fish (containing CWTs) during the spring 2024 survey **(Fig 9):** nine were Lewis Lake (69%), two were Seneca Lake (15%), and one each were Green Lake (8%) and Klondike (8%). Strain composition of the spring catch has been generally consistent since 2016 after a steep decline in the abundance of Green Lake strain, which ceased to be stocked at Julian's Reef after 2006. Prior to 2016, Green Lake fish averaged 70% of the annual spring catch, but has since only averaged 5%. Lewis Lake strain comprised an average of 59% of spring catch on an annual basis since 2016, compared to 32% for Seneca Lake strain. This is despite having been stocked in roughly equal numbers at nearby Julian's Reef since 2011. Because Seneca Lake strain fish are typically more common than Lewis Lake strain in the fall survey (see below), the discrepancy in spring catches between the strains does not necessarily reflect differential survival. It could also be due to differences in depth distribution or another aspect of habitat use between the strains. In Lake Huron, Great Lakes-origin strains (including Lewis Lake) were found to occupy consistently warmer temperatures and shallower depths during stratification than Seneca Lake strain (Bergstedt et al., 2012). It is possible this difference in temperature preference plays a part in the seasonal difference in catch composition between the two primary strains.

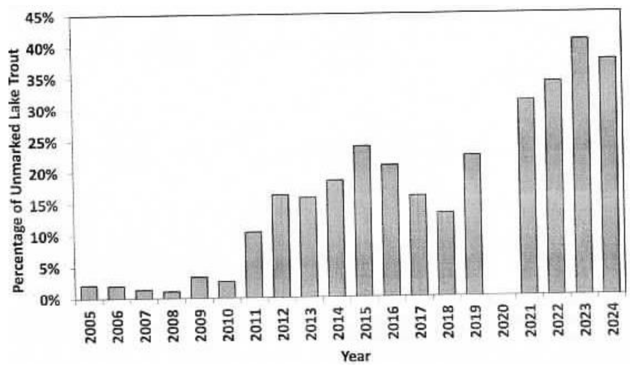


Figure 4. Percentage of unmarked Lake Trout sampled in spring 2005-2024 near Waukegan, IL. Due to COVID-19 restrictions no sampling occurred in 2020.

Fall Spawner Survey

Fall Lake Trout CPUE was 100.0 fish/1000 ft of net in 2024 across both reefs. Fall CPUE has exceeded the 50 fish/1000 ft target in all but three years of the fall survey **(Fig 5).** Consistent CPUEs above the target indicate that Evaluation Objective 2 of the Stocking Strategy has been achieved in Illinois waters. Unseasonably warm bottom temperatures (53-58 F) may explain the uncharacteristically low catches observed for some gill net sets in 2021-2023, as fall spawning aggregations avoided the sampled reefs during our typical fall survey period (mid-October to mid-November). Persistent west winds observed during the 2024 sampling window likely caused upwellings, helping to bring colder water up from greater depths and providing ideal temperatures to attract Lake Trout to offshore spawning reefs. Bottom temperatures measured during the 2024 survey ranged from 41.3-43.5 F.

Evaluation Objective 3 of the Stocking Strategy has two components. The first is a goal of at least 25% female Lake Trout at spawning sites. This target has been met in 8 out of 21 years at Julian's Reef (**Fig 6),** the priority site for the

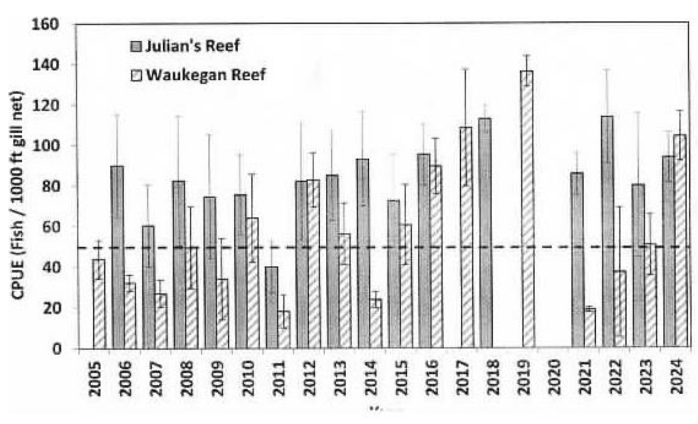


Fig 5. Catch per unit effort (CPUE) of Lake Trout sampled in fall 2005-2024 at Julian's Reef (sold gray bars) and Waukegan Reef (crosshatched). The dotted line represents the CPUE target (>50 fish/1000 ft of gill net) of Evaluation Objective 2 in A Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan. No sampling occurred in 2020.

assessment of progress towards evaluation objectives. In 2024, percent female was 43% at Julian's Reef and 39% across both reef sites. Over the duration of the fall Lake Trout survey, the percentage of sampled fish that were female has been consistently higher at Waukegan Reef (mean = 35%) than at Julian's Reef (mean = 25%). In years where both reefs were sampled, percent female has been higher at Waukegan Reef 80% of the time (16 out of 20 years). Spatial and temporal variation in sex ratio has been observed across the time series and the mechanisms are currently under investigation. While this target has been met inconsistently at Julian's Reef (the priority site) over the time series, it has been met consistently at Waukegan Reef indicating that significant progress has been made towards meeting this objective.

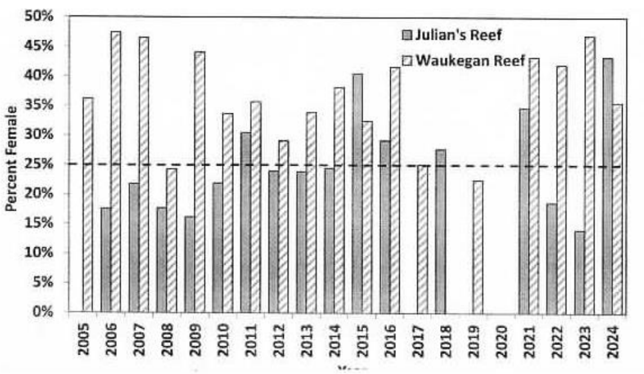


Fig 6. Percent female Lake Trout sampled in fall 2005-2024 at Julian's Reef (sold gray bars) and Waukegan Reef (crosshatched). The dotted line represents the female proportion target (>25% female for spawning populations) of Evaluation Objective 3 in A Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan.

The second component of Evaluation Objective 3 is a spawning population consisting of 10 or more age classes present greater than age-7. The Lake Trout catch at Julian's Reef consisted of 11 age groups older than age-7 in 2024 **(Fig 7**) and there were 12 age groups older than age-7 across both reefs. Since the start of the fall survey, Lake Trout catches have consisted of 10-14 age classes older than age-7 in 12 of 24 years, indicating inconsistency in meeting the age-class target of Evaluation Objective 3. Currently, CWTs represent the only source of ages for Lake Trout collected from spawning sites in the fall survey; ages from wild Lake Trout or Lake Trout with rotational fin clips are not yet represented within the data being used to evaluate Objective 3 in Illinois waters. Furthermore, no CWTs were given to Lake Trout between 2005-2009, meaning that in the 2024 data 15–19-year-old age classes were not readily identifiable. Aging structures have been collected from Lake Trout during previous and current 5 annual assessments and processing of these structures is anticipated in the coming years. Future inclusion of this data, particularly from unclipped, wild Lake Trout, should provide a more complete age structure of the existing mixed stock of hatchery-reared and wild Lake Trout.

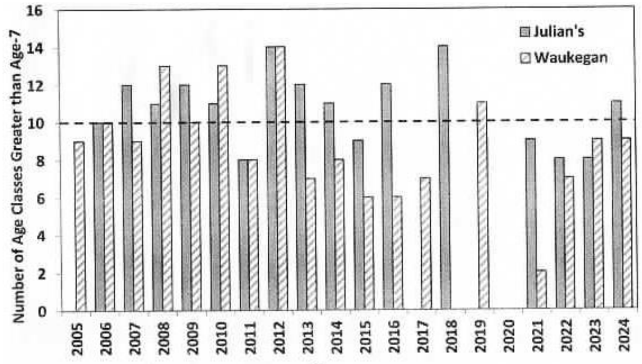
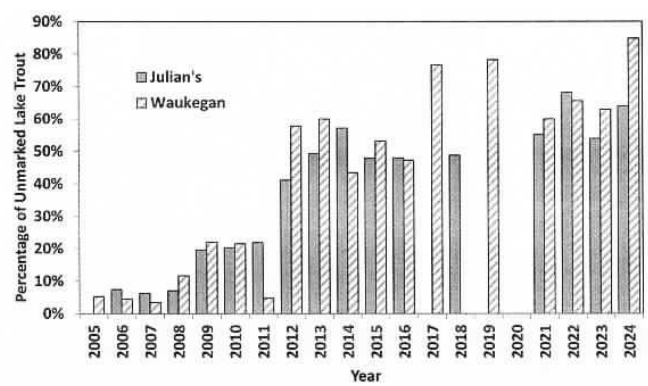


Fig 7. Number of Lake Trout age classes greater than age-7 sampled in fall 2005-2024 at Julian's Reef (sold gray bars) and Waukegan Reef (crosshatched). The dotted line represents the age class target (≥10 age groups older than age-7 for spawning populations) of Evaluation Objective 3 in A Fisheries Management Implementation Strategy for the Rehabilitation of Lake Trout in Lake Michigan. No sampling occurred in 2020

About 85% of Lake Trout sampled at Waukegan Reef (212 of 250) did not have a fin clip in 2024, while the percentage of non-clipped fish at Julian's Reef was 64% (96 of 150). The presence of unmarked, potentially wild fish has increased substantially in recent years (**Fig 8).**

In 2024, 38 Lake Trout sampled at Julian's Reef had an adipose fin clip and a coded wire tag. The stocking locations of those fish were closely split between Julian's Reef (19 fish, 6 to 14 years old at capture) and the Mid-Lake Reef Complex (17 fish, 10 to 30 years old at capture). Of the remaining fish, one was stocked from shore in southern Michigan (15 years old at capture), and one was stocked in the Northern Refuge (11 years old at capture). At Waukegan Reef, 24 Lake Trout were sampled with an adipose fin clip and coded wire tag. Most (19) were stocked at Julian's Reef (6 to 14 years old at capture), and five were stocked at the Mid-lake Reef Complex



(8 to 30 years old at capture).

Fig 8. Percent of unmarked Lake Trout sampled in fall 2005-2024 at Julian's Reef (sold gray bars) and Waukegan Reef (crosshatched). No sampling occurred at Julian's Reef in 2005, 2017, and 2019 or Waukegan Reef in 2018 and neither site was sampled in 2020. ..

Three strains of lake trout were represented in the catch of stocked fish (containing CWTs) during the 2024 Fall Spawner survey **(Fig 9):** 43 were Seneca Lake (69%), 16 were Lewis Lake (26%), and three were Klondike (5%). Similar to the spring survey, the strain composition in the fall has gone from predominately Green Lake to a combination of Lewis Lake and Seneca Lake, though Seneca Lake tend to be more dominant in the fall compared to the spring. In the fall, a larger proportion of the lake trout catch with CWTs had been stocked at the Mid-Lake Refuge. Only Seneca Lake and

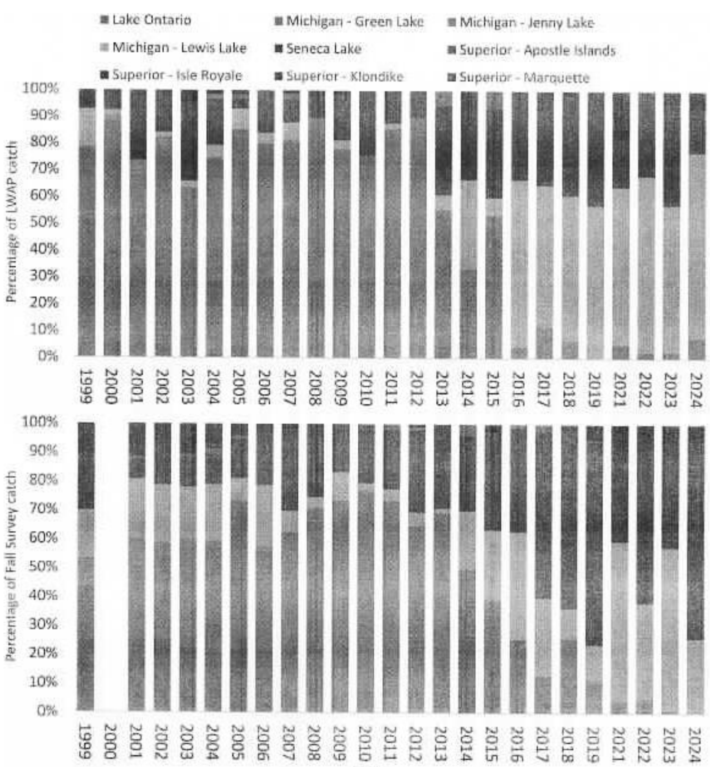


Fig 9. Lake trout strain composition of the catch of hatchery-reared fish with CWTs in the spring (top) and fall spawner (bottom) surveys. No fall sampling occurred in 2000 (empty space) and no spring or fall sampling occurred in 2020 (data point omitted

Klondike strains are stocked at the Mid-Lake Refuge, providing one possible explanation for this discrepancy in strain composition between fall and spring.

Management Recommendations

Spring Lake Trout survey CPUE was anticipated to be lower than fall CPUE when targets were set because Lake Trout aren't necessarily aggregated in the spring as they are during the fall spawning season. Spring CPUE in the Illinois waters of Lake Michigan however has remained below target in most years sampled, not reaching 25 fish/1000 ft since the mid-2000s. Similarly, the target has been met only briefly at 4 of the 12 spring sampling sites lake-wide and has not been achieved with any regularity or consistency at any site (LMLTWG 2021). Spring CPUE of wild fish is also well below the target level (19 fish/1000 ft) specified in Objective 7 of the newly updated Stocking Strategy.

Continue participation in the spring Lake Trout survey and evaluate results toward achieving Evaluation Objective 1 of the Stocking Strategy; share results with Lake Trout Working Group of the Lake Michigan Technical Committee.

Lake Trout population parameters for the fall spawner survey have been showing positive signs toward rehabilitation over the last decade. Catch per unit effort, proportion of females present in the spawning population, and number of older age classes have been at or above the targeted levels recently, suggesting movement toward rehabilitation success at some sites (LMLTWG 2021). The increased presence of unmarked fish in recent years indicates successful recruitment to adult life stages, especially in Illinois waters.

Continue participation in the fall spawner survey at Julian's and Waukegan Reef with a special focus on presence of unmarked fish in the population as well as Objectives 2 and 3 of the Strategy, and disseminate results of progress toward rehabilitation goals with constituents and the Lake Trout Working Group of the Lake Michigan Technical Committee. ✧

2024 Great Lakes Fisheries Surveys Wrap-up

Highlights from annual assessments on Michigan Great Lakes

Every year from April to November, the Michigan DNR is on the Great Lakes, surveying the important and diverse Great Lakes fisheries. Crews from research stations in Marquette, Charlevoix, Alpena and Harrison Township gather data on fish populations, fish health and the presence and effects of invasive species. It's vital information that directly informs fisheries management decisions — such as stocking levels or regulated catch limits — and provides data to help gauge the success of past actions.

With surveying for 2024 wrapped up, DNR fisheries biologists are now synthesizing the findings and preparing for next year's surveys. Interested in what the surveys found? Check out highlights from each research station's survey efforts.

Lake Superior and northern Lake Michigan

The crew of the research vessel (RV) Lake Char began work on Lake Superior as soon as the ice melted and continued through early November. The Marquette Fisheries Research Station's work focuses on lake trout, though species studied this year also included lake whitefish and burbot.

Data from the spring 2024 Lake Superior surveys showed a slight increase in adult lake trout populations in nearly all areas. The summer juvenile lake trout survey indicated slight increases in recruitment (reproduction and survival) on the west side of the Keweenaw and Munising areas and a slight decline in all other locations, with stable populations overall. During the field season, 257,100 feet (48.7 miles) of assessment gill net was deployed for these surveys at 123 sampling stations across the lake.

Research tech Lydia Doerr with a large lake trout caught during survey at Isle Royale, June 2024.

The RV Lake Char surveyed waters around Isle Royale in spring to assess the status of lake trout populations around the island. The crew also conducted surveys in the deepest waters of Lake Superior (and all the Great Lakes) — about 1,320 feet — to survey siscowet lake trout populations. The RV Lake Char crew finished the survey season with lake trout survey work at Klondike Reef, a remote location 40 miles from shore, in October and then surveyed nearshore lake trout spawning reefs near Munising in early November.

Nearshore Great Lakes fisheries assessment work from Upper Peninsula ports involved 10 miles of trawling in Lake Michigan's Little Bay de Noc and Big Bay de Noc. In addition, over 25,000 feet of survey gill net was used in four locations in northern Lake Michigan (Big Bay de Noc, Little Bay de Noc, Naubinway and Manistique) and two locations in southern Lake Superior (Keweenaw Bay and Huron Bay). Catch data from these fall surveys provide useful metrics for assessing fish community change and populations of species including walleye, yellow perch, smallmouth bass, northern pike, lake sturgeon and invasive Eurasian ruffe.

This winter, the Marquette Fisheries Research Station staff will perform maintenance in preparation for the 2025 field season and process the samples and data collected during 2024. These surveys provided data for collaborations with researchers from Purdue University, University of Wisconsin-Milwaukee, State University of New York-Brockport, Michigan Technological University and Michigan State University.

Lake Michigan

Three surveys accounted for the majority of the Great Lakes survey work for the Charlevoix Fisheries Research Station staff and the survey vessel (SV) Steelhead in 2024.

Spring gill net survey

Since 1997, the DNR has participated in a spring gill net survey, in collaboration with other Lake Michigan agencies. The objective is to assess recreationally, commercially and ecologically important fish populations, with a focus on lake trout, burbot, lake whitefish and yellow perch in Michigan waters. The information collected is used to inform ongoing research and management efforts for multiple species in Lake Michigan. Due to the broad area covered and multispecies focus, this survey provides the most comprehensive information on the status of adult Lake Michigan fish populations.

The spring gill net survey was conducted at eight ports this year: St. Joseph, South Haven, Saugatuck, Grand Haven, Arcadia, Leland, Elk Rapids and Charlevoix. Across all ports, more than 100,000 feet of experimental bottom gill net was deployed and provided data on more than 5,000 fish.

Lakewide acoustic (forage fish) survey

From late August to early September, the SV Steelhead and crew conducted the prey fish survey, a multiagency effort measuring the abundance of alewife, rainbow smelt, bloaters and other prey fish throughout Lake Michigan. This survey uses hydroacoustic (high-precision, recordable fish finder) gear. Results inform research and interjurisdictional trout and salmon management around predator/prey balance and lower food web changes in Lake Michigan, including the lakewide "predator-prey ratio" analysis to ensure prey fish can support the lake's salmon and trout populations.

The hydroacoustic survey comprised 25 sections spanning nearshore and offshore regions around the basin. Areas surveyed this season by the SV Steelhead stretched from waters offshore of Beaver Island in the north around the Michigan shore to St. Joseph in the south.

Strong offshore winds Aug. 2–21 resulted in persistent coldwater upwelling along the eastern shoreline. These environmental conditions likely changed normal fish distributions and abundance estimates relative to previous survey years. Despite this challenge, preliminary results suggest relatively similar densities of age-1 (1+ years old) alewife and higher abundances of bloaters compared to previous years. However, young-of-year alewife abundance was estimated to be very low in 2024.

Experimental bottom gill netting aboard the SV Steelhead in 2024.

Bottom trawl survey

The SV Steelhead crew completed the annual bottom trawl survey in September and October at three of the ports sampled during the spring gill net survey (Saugatuck, South Haven and Grand Haven), as well as at the port of Pentwater. Ten trawl samples were collected at each port, covering a range of water depths from 25 feet to 120 feet. This survey provides information on the overall status of the nearshore fish community, including the presence, range expansion and effects of invasive species, and the status of yellow perch recruitment.

Other assessments

Charlevoix Fisheries Research Station staff also used small vessels for targeted surveys in 2024. Staff assisted Central Michigan University researchers with scuba surveys of mussel populations in large rivers and continued a multiyear assessment of spawning reefs in northern Lake Michigan. Reef assessments included characterization of habitat quality, deployment and collection of egg-sampling gear, and tagging of lake whitefish with acoustic tags to assess movement and spawning site use.

Lake Huron

The 2024 field season for the Alpena Fisheries Research Station and research vessel (RV) Tanner began in April with the annual spring lake trout assessment. The crew surveyed 14 locations in U.S. waters of Lake Huron from Drummond Island to Port Sanilac to determine the abundance and distribution of both young and adult lake trout. The catch rate of adult lake trout was similar to that of recent years, and most young lake trout (both hatchery-reared and wild-born) continue to be collected in northern Lake Huron.

Following the conclusion of the lake trout survey in late May, commercial fishery sampling in June, and tending Great Lakes Acoustic Telemetry Observation System, or GLATOS, receivers for fish movement studies in July, the RV Tanner completed a sonar and trawl survey of outer Saginaw Bay that targeted cisco. Cisco are important Great Lakes species that help maintain healthy predator species and provide fishing opportunities, as well as serve as an indicator of ecosystem health. Because of this, cisco are a focus of ongoing restoration efforts by multiple natural resource agencies around Lake Huron.

In the fall, the RV Tanner crew completed the annual Saginaw Bay fish community survey. This survey is done each September in partnership with the Lake St. Clair Fisheries Research Station and RV Channel Cat, and the 2024 Saginaw Bay assessment covered 16 net stations and 24 trawl sites. Survey catches showed a high abundance of young-of-year walleye in the bay (the second highest on record!), and adult walleye gill net catch rates that were similar to recent years' numbers. However, both gill net and trawl catch rates of adult yellow perch in Saginaw Bay remained very low. A highlight of the survey was an encounter with two juvenile lake sturgeon, confirming their survival from ongoing stocking efforts in the Saginaw River system.

Soon after departing Saginaw Bay, the RV Tanner once again made its way to the eastern Upper Peninsula for an annual fish community survey in the Les Cheneaux Islands, where the gill net catch rate of yellow perch increased, and other indicators of perch population health were within sustainable ranges.

St. Clair-Detroit River System

The field season in Great Lakes waters of southeast Michigan kicked off with northern pike, mooneye and smallmouth bass tagging in Lake St. Clair and tributaries during March, April and May. The tags, which are surgically implanted into fish and send a signal to receivers in GLATOS, allow scientists to track movement of fish throughout the region and the Great Lakes as a whole. While data from northern pike and mooneye tagging is still coming in, the results from smallmouth bass tagging suggest that Lake St. Clair smallmouth bass exist in multiple, smaller subpopulations rather than one large lakewide population. These subpopulations occupy well-known areas of the lake such as Anchor Bay and the Mile Roads and appear to mix very little with smallmouth bass from other locations.

The annual lake sturgeon assessment in the North Channel of the St. Clair River showed continued recruitment of young lake sturgeon into the adult population—which means that young lake sturgeon are surviving into adulthood. The North Channel sampling location is considered a "hot spot" for young lake sturgeon, and this is supported by DNR survey data. During the past 27 years, survey crews have encountered individual fish from each year class born between 1997 (the year the survey began) and 2019 (the most recent year class that, because of their age and size, can effectively be caught by the sampling gear). In 2024, the DNR tagged 24 juvenile lake sturgeon in the North Channel with tags that are detected by GLATOS (like the northern pike, mooneye and smallmouth bass mentioned above) and more will be learned about the specific movements and habitat use by these fish in the coming years. New molecular analysis of fin clips from captured lake sturgeon shows that most fish larger than 63 inches are females, while those less than 63 inches long are evenly split between males and females.

During the annual Lake St. Clair lake sturgeon survey in 2024, the crew caught a 75.2-inch, 125-pound sturgeon, the largest caught in the history of that survey.

Since 2021, DNR staff have completed lakewide surveys on Lake St. Clair in partnership with the Ontario Ministry of Natural Resources and the U.S. Fish and Wildlife Service. The partnership completed a netting survey that targeted larger-bodied fish in offshore areas of the lake in 2024, complementing other netting and electrofishing surveys completed in 2021 through 2023. These surveys will be conducted on a rotational basis to monitor any changes that occur in Lake St. Clair and inform future fisheries management decisions.

The 56-year-old RV Channel Cat made a weeklong trip to Lake Erie in early August to conduct a bottom trawl survey that documented walleye and yellow perch reproduction and an abundance of 8-inch and larger yellow perch. The RV Channel Cat and crew then returned to Lake St. Clair to collect lake sturgeon using 35 individual trawl tows. The individual sturgeon captured in this survey, which sometimes exceed 100 pounds, are rarely encountered in the North Channel survey efforts described earlier. August concluded for the crew with a micro-mesh gill net survey to describe the Lake St. Clair forage fish community. Micro-mesh gill nets were deployed at six locations and commonly captured logperch, yellow perch and round goby.

The RV Channel Cat closed out the year with a trip to Lake Erie in early October for the annual walleye assessment. Catch rates in the survey gill nets were the third highest observed since 1992, and the catch included many year classes (ages) of fish, which represents strong walleye reproduction in Lake Erie since 2015.✧

Status of Sea Lamprey Control in Lake Michigan

Sea lampreys (*Petromyzon marinus*) are parasitic fish native to the Atlantic Ocean. Sea lampreys, which parasitize other fish by sucking their blood and other body fluids, have remained largely unchanged for more than 340 million years and have survived through at least four major extinction events.

Sea lampreys are unique from many other fishes in that they do not have jaws or other bony structures, and instead possess a skeleton made of cartilage. While sea lampreys resemble eels, they are not related and are set apart by their unique mouth: a large oral sucking disk filled with sharp, horn-shaped teeth surrounding a razor sharp rasping tongue.

Sea lampreys attach to fish with their suction cup mouth then dig their teeth into flesh for grip. Once securely attached, sea lampreys rasp through the fish's scales and skin with their sharp tongue. Sea lampreys feed on the fish's body fluids by secreting an enzyme that prevents blood from clotting, similar to how a leech feeds off its host.

In their native Atlantic Ocean, thanks to co-evolution with fish there, sea lampreys are parasites that typically do not kill their host. In the Great Lakes, where no such co-evolutionary link exists, sea lampreys act as predators, with each individual capable of killing up to 40 pounds (more than 20 kilograms) of fish over their 12-18 month feeding period.

Host fish in the Great Lakes are often unable to survive sea lamprey parasitism, either dying directly from an attack or from infections in the wound after an attack. Host fish that survive an attack often suffer from weight loss and a decline in health and condition.

Sea lampreys prey on most species of large Great Lakes fish such as lake trout, brown trout, lake sturgeon, lake whitefish, ciscoes, burbot, walleye, catfish, and Pacific salmonids including Chinook and coho salmon and rainbow trout/steelhead.

Where are sea lampreys found?

The first recorded observation of a sea lamprey in the Great Lakes was in 1835 in Lake Ontario. Niagara Falls served as a natural barrier, confining sea lampreys to Lake Ontario and preventing them from entering the remaining four Great Lakes. However, in the late 1800s and early 1900s, improvements to the Welland Canal, which bypasses Niagara Falls and provides a shipping connection between Lakes Ontario and Erie, allowed sea lampreys access to the rest of the Great Lakes.

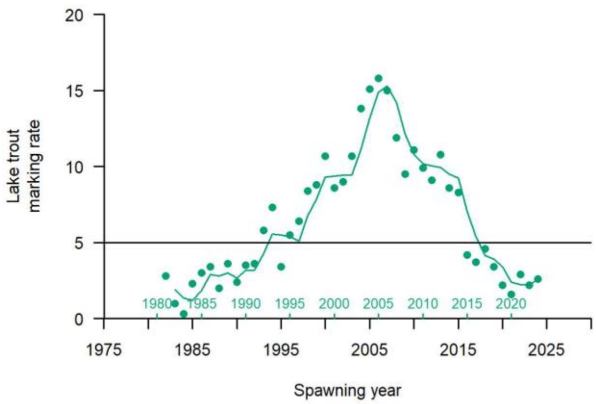


Fig. 1 Number of A1-A3 marks per 100 lake trout > 532 mm in Lake Michigan, from standardized assessments during August-November plotted against the sea lamprey spawning year, including the three-year moving average (line). The three year (spawning years 2022-2024) average marking rate of 2.6 met the target of 5 A1-A3 marks per 100 lake trout > 532 mm (horizontal line). A second x-axis shows the year the lake trout were surveyed.

Within just a short time, sea lampreys spread throughout the system: into Lake Erie by 1921, Lakes Michigan and Huron by 1936 and 1937, and Lake Superior by 1938. Sea lampreys were able to thrive once they invaded the Great Lakes because of the availability of excellent spawning and larval habitat, an abundance of host fish, a lack of predators, and their high reproductive potential—a single female can produce as many as 100,000 eggs!

What is the impact of the sea lamprey invasion?

Sea lampreys have had an enormous, negative impact on the Great Lakes fishery, inflicting considerable damage. Before the sea lamprey invasion, Canada and the United States harvested about 15 million pounds of lake trout in the upper Great Lakes each year. By the late 1940s, sea lamprey populations had exploded. They fed on large numbers of lake trout, lake whitefish, and ciscoes—fish that were the mainstays of a thriving Great Lakes fishery. By the early 1960s, the catch had dropped dramatically, to approximately 300,000 pounds, about 2% of the previous average. During the time of highest sea lamprey abundance, up to 85% of fish that were not killed by sea lampreys were marked with sea lamprey attack wounds. The once thriving fisheries were devastated, and along with them, the hundreds of thousands of jobs related to the region's economy.

What can be done about sea lampreys?

The sea lamprey control program, administered by the Great Lakes Fishery Commission, relies on exploiting sea lamprey vulnerability when they are congregated in Great Lakes tributaries, at either the larval or adult stages of their life cycle. Lampricides—pesticides selective to lampreys and the primary sea lamprey control tactic—are deployed to kill larval sea lampreys in the tributaries, while a combination of barriers and traps are used to prevent the upstream migration and reproduction of adult sea lampreys. See Sea Lamprey Control in the Great Lakes for more information on the various sea lamprey control techniques.

Status of Sea Lamprey Control in Lake Michigan

Part of a successful sea lamprey control program is monitoring adult sea lamprey abundance in each lake and sea lamprey impacts on fish; the sea lamprey marking rate on lake trout, their preferred host, is used to assess impacts on fish. To better understand the relationship between sea lamprey abundance and marking rates on lake trout, the number of lake trout also needs to be assessed (i.e., the number of lake trout can influence the marking rate).

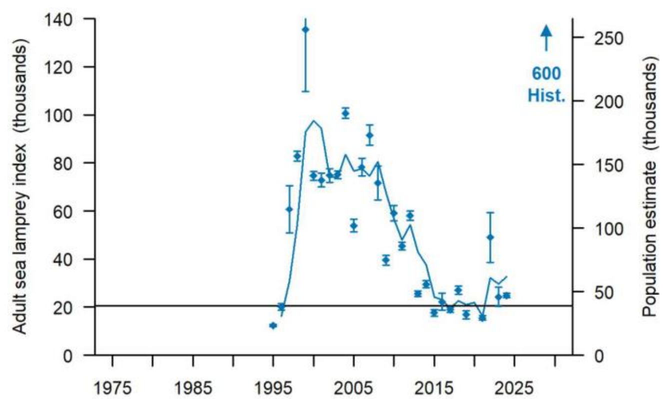


Fig 2. Index estimates with 95% confidence intervals (vertical bars) of adult sea lampreys in Lake Michigan, including historic pre-control abundance (as a population estimate) and the three-year moving average (line). The population estimate scale (right vertical axis) is based on the index-to-PE conversion factor of 1.89. The adult index in 2024 was 25,000 with 95% confidence interval (24,000-26,000). The three-year (2022-2024) average of 33,000 was above the target of 21,000. The new index target (2024) was estimated as the mean of indices during a period with acceptable marking rates (2015-2019)

The Sea Lamprey Control Program has adjusted the Lake Michigan adult index target from 34,982 to 20,526. This change was made based on the average sea lamprey abundance estimate from 2015-2019, when wounding was near the target of 5 wounds/100 lake trout. The stream specific estimates for the Manistique and Big Manistee Rivers contributed most to the lakewide index estimate in 2024 (45% and 22% respectively). Sea lampreys were documented upstream of the sea lamprey barrier on the Kewaunee River.

Sea lamprey populations are monitored by generating an adult sea lamprey abundance index for each lake. The index is calculated by assessment crews who capture migrating adult sea lamprey in index streams with traps during the spring and early summer. A mark-recapture study is conducted on each index stream to generate a population estimate. Individual index stream population estimates are then summed to create the lake-wide adult sea lamprey abundance index. Whole-lake adult sea lamprey abundance estimates can be calculated by multiplying the lake-wide index by a lake-specific conversion factor. Lake trout marking and abundance data are collected annually from management agencies around the Great Lakes to generate lake-wide marking rates and population estimates.

Successin meeting targets for both the adult sea lamprey abundance index and sea lamprey marking rates on lake trout is determined by assessing the 3-year average index or marking rate compared to the targets. There are no targets for lake trout abundance in the context of reporting sea lamprey status. The trend of the adult sea lamprey abundance index, sea lamprey marking rate on lake trout, and lake trout abundance is determined by the direction of the slope over the past five years. Single year point estimates fluctuate and can have wide error bars, thus the focus on 3-year averages and 5-year trends.✧

Whitefish in Lake Michigan

Whitefish are on brink in Michigan. Can they learn to love rivers to survive? Northern Michigan's beloved whitefish are in peril. For decades, the fish have struggled to breed on the rocky reefs of lakes Michigan and Huron, where their eggs are under attack by invasive species and other threats. Some scientists fear a collapse in just a few years, which could sink Michigan's commercial fishing industry and a way of life.

"We don't have a lot of time," said Kris Dey, hatchery manager for the Little Traverse Bay Band of Odawa Indians.

Like others, the tribe's diet, culture and economy have been sustained for centuries by the silvery, mild-tasting fish that remains a staple in Up North restaurants. "Whitefish is synonymous with northern Michigan," said Mark Smolak, whose family has run the historic Legs Inn in the tip-of-the-Mitt beach town of Cross Village since the 1930s.

The fish has almost always been on the menu, Smolak said, and losing it would be like "losing a part of your local culture, a part of your identity." So now, a race is on to save the fish before a collapse ripples onto dinner plates and throughout the ecosystem. The best hope for survival? Collecting whitefish eggs, then using turkey basters, casserole trays and containers resembling giant Lego pieces to plant them in rivers. The hope is to rewire the fish's brains, so they spawn away from lakes — and danger. It all starts with 120,000 eggs tethered to the bottom of the Jordan River, where whitefish haven't traveled for more than a century.

A severed bloodline

Once abundant throughout the region, lake whitefish love cold water. Historically, they'd spend most of their lives deep in the Great Lakes before returning to spawn near shore, with some laying eggs on shallow reefs and others going inland to rocky river bottoms.

Early Native Americans powdered smoked fish for soup, and European settlers loved them too. In 1695, French explorer Antoine de la Mothe Cadillac, who is credited with founding Detroit, declared that "better fish can not be eaten."

Those days have been replaced by "a century-and a half of battling the landscape for those fish to even keep going," said Amanda Holmes, executive director of the Fishtown Preservation Society, a Leland-based nonprofit that owns historic shanties, docks and boats.

The trouble began with European settlers damming rivers and logging forests, which blocked access to fish and choked spawning grounds with sawdust. That killed off the river-spawning bloodline more than a century ago. But whitefish that spawn in the lakes persevered through periods of overfishing, habitat degradation and sea lamprey invasions.

They remain the backbone of Michigan's commercial fishing industry, making up about 85% of the catch. But state-licensed operations have declined to just 16 from hundreds in the 1970s, and their whitefish harvests have fallen to 1.6 million pounds last year from 6.3 million in 2011. Tribal operations have seen similar declines.

In recent years, invasive quagga and zebra mussels have transformed the Great Lakes ecosystem, creating an existential crisis for whitefish. Oceangoing ships brought the b ivalves from Europe in the 1980s, and they now carpet the bottom of every Great Lake except Superior. Voracious filter feeders, they have stripped the lakes of nutrients and phytoplankton at the bottom of the food chain.

Because Lake Superior is not infested with mussels, its whitefish population has remained stable. But in lakes Michigan and Huron, the water's stunning clarity is the marker of a barren ecosystem — and it exposes whitefish's delicate eggs to deadly UV rays. "Imagine laying on the beach and getting so sunburned, your skin falls off," Dey said. "That's what happens to these guys."

The eggs that survive hatch into "a vast wasteland of nothingness," with little food and predators like invasive round gobies that have a taste for baby whitefish. Scientists aren't sure what happens to the few juvenile whitefish that survive that gauntlet, Dey said. A few months after hatching, they venture into deeper waters "and we don't ever see them again."

Whitefish typically live 30 years, and researchers say parts of the lakes haven't seen a good spawning season for 20. "We don't know where things are going to be in 10 years," said Holmes of the Fishtown group. "But there is a sense that they're not going to be good if we don't try to do something, and it needs to happen sooner versus later."

Michigan's rivers present a glimmer of hope.
Just as the lakes have become inhospitable, scientists believe decades of restoration work have made rivers capable of supporting whitefish. The Little Traverse Bay Band, Sault Ste. Marie Tribe of Chippewa Indians, Bay Mills Indian Community, The Nature Conservancy and the Michigan Department of Natural Resources are now working to revive Michigan's river runs. The tribes draw inspiration from Wisconsin, where whitefish resumed spawning in the tributaries of Green Bay in the 1990s. Scientists believe that's a key reason why Green Bay's whitefish populations are stable, even while the fish struggle elsewhere.

Researchers believe a recovery is possible in Michigan, too. But because whitefish spawn only in the spot where they were born, they need help rediscovering rivers. "There's a lot of really good habitat that's available," said Matt Herbert, a senior conservation scientist with The Nature Conservancy in Michigan. "We just need to help them find it."

Last fall, the team collected eggs from adult fish swimming in Lake Michigan. On a sunny morning last week, they used basters to transfer eggs into yellow plastic containers destined for the Jordan River. Another batch went to the Carp River, a Lake Huron tributary in the Upper Peninsula. If all goes well, the fish will hatch within weeks, escaping through holes in the boxes. Instead of immediately migrating into Lake Michigan, scientists hope the hatchlings will hang out for a few months in the Jordan River and Lake Charlevoix, where there is ample food and shade — and fewer round gobies.

The hope is the fish will pick up the Jordan River's scent, prompting them to return there and spawn when they reach adulthood in about five years. If that happens, Herbert said, scientists will declare success, "and we can move on to the next tributary." ✧

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

Introduction:
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. 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 was developed 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, changes in predator stocking rates, disease outbreaks, and invasive species. Notably, lake trout populations collapsed during the 1950s due to a combination of predation by invasive sea lamprey and overfishing. 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 lake trout along with 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.

Chinook salmon and alewife are important components of Lake Michigan's current ecosystem and fishery but maintaining a predator-prey balance is challenging. In Lake Michigan, Chinook salmon are a dominant predator whose diet consists mostly of alewives, an important 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. 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, which serve as the base of the food web. Naturally produced Chinook salmon are common and, in combination with stocked Chinook salmon and other trout and salmon species, these predators exert high predation pressure on alewife and other prey.

The currently used "Predator/Prey Ratio Analysis" and its precursor, a "Red Flags 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 (Clark et al. 2012), and subsequently led to the development and implementation of the Predator/Prey Ratio (PPR) Analysis approach (Clark et al. 2014; Jones et al. 2014; Lake MI SWG et al. 2014). 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 2023.

Predator/Prey Ratio:

The Predator/Prey Ratio Analysis consists of a Predator/Prey Ratio (PPR) for Chinook salmon/alewife and six secondary 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; Figure 1). 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 (SCAA; Tsehaye et al. 2014a; Tsehaye et al. 2014b) that incorporate lake-wide datasets from several surveys and agencies (Table 1). 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 1).

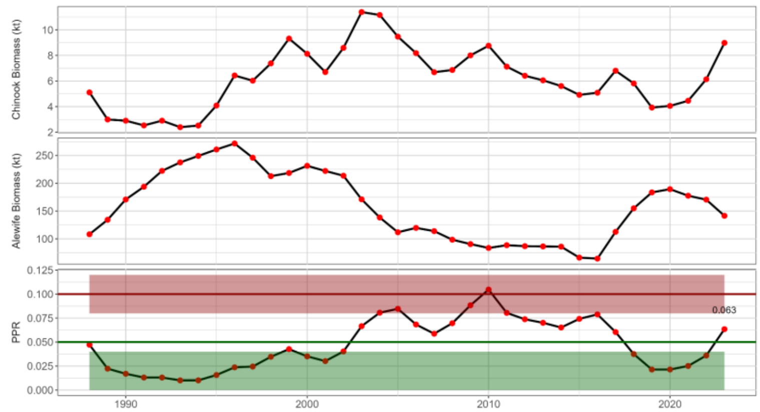


Fig. 1 - (abundance of age 1 Chinook × avg. weight of age 1 Chinook) + (abundance of age 2 Chinook × avg. weight of age 2 Chinook) + (etc. for each age class) = total lake-wide Chinook biomass.

A similar process is used to estimate alewife biomass (Figure 1). The alewife SCAA also incorporates consumption of alewives by several predator species including lake trout, rainbow trout, brown trout and coho salmon, in addition to Chinook salmon.

Predator/Prey Ratio (PPR) calculated for Chinook salmon and alewife in Lake Michigan (bottom) and separate components of this ratio plotted individually as Chinook salmon biomass (top) and alewife biomass (middle). Shaded areas and horizonal lines correspond to upper 0.1 (red) and lower 0.05 (green) management reference points. Note that panels have different vertical axis scales.

Reference Points:

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 (Figure 1). Additional guidance and management action zones are provided by the Lake Michigan Committee (LMC 2018). Several criteria were used to develop these reference points, including examples from other lakes, literature reviews, and risk assessments. For example, the Chinook 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 approximately 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—used to derive the "prey" component of the PPR—incorporates consumption of alewives by several salmonid species, the current "predator" component of the PPR includes only Chinook salmon. Therefore, another important consideration under increasing PPR scenarios is that fewer alewives will be available as forage for non-Chinook predator species.

Recent Model Updates:

Numerous SCAA model updates were incorporated beginning in 2022 (data through 2021) with resultant changes on PPR results. Several of these updates were simply necessary to handle 2020 COVID-19 marking/sampling restrictions. However, more substantive changes in data input and/or model structure in the Chinook SCAA and alewife SCAA were aimed at improving accuracy of PPR estimates by better resolving data series which have lacked sufficient data or been held constant through time. For instance, reliance on both age-1 and age-2 Chinook salmon (formerly just age-1) for calculations of proportion wild and movement from Lake Huron improved historically low sample sizes owing to the higher selectivity of age-2 fish in the sport fishery. Likewise, decreased biomass of Chinook salmon since the early 2000s has resulted in proportionally greater consumption by lake trout and steelhead. Incorporating time-varied consumption and population dynamics of lake trout and steelhead (formerly fixed values since 2008) has improved recent estimates of alewife consumption and subsequent scaling of abundance and biomass. Updates to model inputs using data through 2023 indicated increased Chinook salmon biomass and declining alewife biomass relative to 2022. Corresponding to these changes, the PPR increased from 0.036 (2022) to 0.063 (2023; **Fig 1).**

Secondary Indicators:

Six additional datasets were established to compliment the PPR and provide supplemental feedback on predator/prey balance (Figure 2). These indicators are plotted as individual datasets through time (without targets or upper limits) to evaluate trends and recent conditions. These indicators are calculated with lake-wide datasets from several agencies and include:

1. standard weight of 35-inch Chinook salmon from angler caught fish during July 1 to Aug 15 **(Fig 2a),**
2. average weight of age-3 female Chinook salmon from fall weir and harbor surveys (**Fig 2b**),
3. catch-per-hour for Chinook salmon from charter boats (**Fig 2c),**
4. percent composition of angler harvested weight by species **(Fig 2d**),
5. lake-wide biomass of alewife (**Fig 3e**), and
6. age structure of the alewife population **(Fig 2f).**

Fig 2A

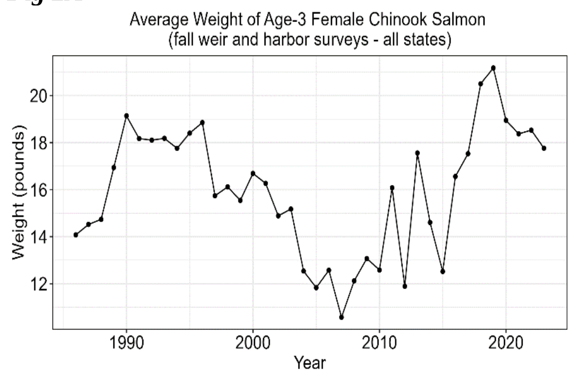


Fig 2B

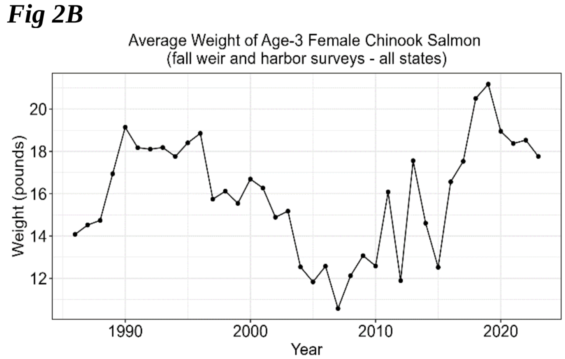


Fig 2C

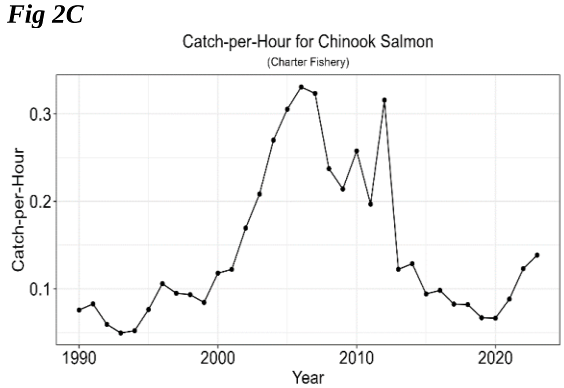


Fig 2D

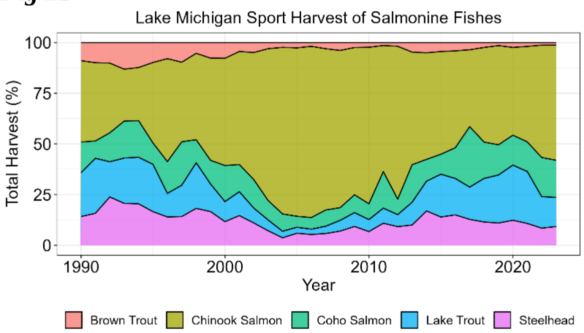


Fig 2E

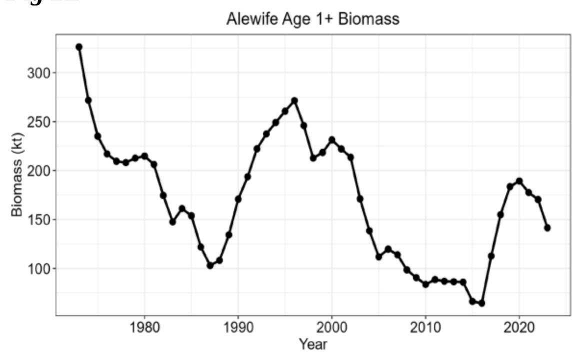


Fig 2F

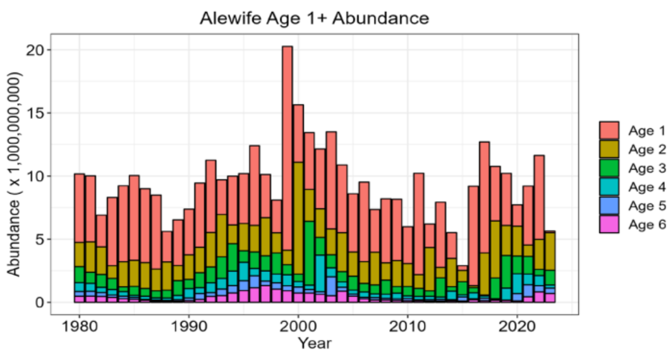


Fig 2. Additional indicators calculated with lake-wide datasets through 2023 to compliment the Predator/Prey Ratio and provide supplemental information to guide fisheries management decisions.

End