

## Status and Trends of Pelagic and Benthic Prey Fish Populations in Lake Michigan, 2025<sup>1,2</sup>

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<sup>1</sup> The data associated with this report are available in a U.S. Geological Survey data release, <https://doi.org/10.5066/P13MA3XE>. Previous versions of the data may be accessed at U.S. Geological Survey, Great Lakes Science Center, 2019, Great Lakes Research Vessel Operations 1958-2018. (ver. 3.0, April 2019): U.S. Geological Survey data release, <https://doi.org/10.5066/F75M63X0>. Please direct questions to our Data Management Librarian, Sofia Silvis, at [sasilvis@usgs.gov](mailto:sasilvis@usgs.gov).

<sup>2</sup> All GLSC sampling and handling of fish during research are carried out in accordance with guidelines for the care and use of fishes by the American Fisheries Society (<https://fisheries.org/policy-media/science-guidelines/guidelines-for-the-use-of-fishes-in-research/>).

## 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 (*Alosa pseudoharengus*), Bloater (*Coregonus hoyi*), Rainbow Smelt (*Osmerus mordax*), Deepwater Sculpin (*Myoxocephalus thompsonii*), Slimy Sculpin (*Cottus cognatus*), Round Goby (*Neogobius melanostomus*), Ninespine Stickleback (*Pungitius pungitius*)]. The AC survey has been conducted each late summer/early fall since 2004 (except 2020). The 2025 AC survey consisted of 26 transects [470 km total (292 miles)] covering bottom depths ranging from 5 to 259 m and 44 midwater trawl tows at 1.4 to 82.4 m fishing depth; this survey estimates densities of three prey fish species (i.e., Alewife, Bloater, and Rainbow Smelt). 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.

For the AC survey, total biomass density of prey fish equaled 9.3 kg/ha, continuing a recent trend of index values above the long-term average of 5.4 kg/ha. For the fall BT, total biomass density of prey fish equaled 3.4 kg/ha, close to values observed since 2014 and well below historic numbers and those observed earlier in the 2000s. Over the period both surveys have been conducted (2004-2025), the total biomass density index had trended downward in the fall BT through the mid-2010s and appears to have stabilized at low values, while the AC survey biomass density index has remained relatively stable over the time series.

Mean biomass of yearling and older (YAO) Alewife was 4.3 kg/ha in the AC survey and 0.45 kg/ha in the fall BT. Since 2014, annual survey results suggest that the catchability of YAO Alewife for the fall BT is substantially lower than the AC survey. The 2025 AC survey YAO Alewife biomass density estimate was 57% higher than the average from 2004-2024. The Alewife population of Lake Michigan appears to be composed mostly of young fish and the proportion of age-4 and older Alewife was ~5% in both surveys. Age-0 Alewife numeric density from the AC survey was 259 fish/ha in 2025, lower than the long-term mean (487 fish/ha). Biomass density of large ( $\geq 120$  mm) Bloater was 3.5 kg/ha in the AC survey and 1.9 kg/ha in the fall BT. The density of small ( $< 120$  mm) Bloater was 540 fish/ha in the AC survey, the second highest value in the time series. Meanwhile, small Bloater density estimated in the fall BT was only 6.1 fish/ha. Biomass density of large Rainbow Smelt ( $\geq 90$  mm) was 0.69 kg/ha in the AC survey and 0.04 kg/ha in the fall BT survey. Numeric density of small ( $< 90$  mm) Rainbow Smelt was 541 fish/ha in the AC survey, the highest value in the time series, and 41 fish/ha in the fall BT. All four prey fish species indexed only by the fall BT had below-average biomass densities. Deepwater Sculpin biomass density was 0.21 kg/ha, which makes 15 of the past 16 years with biomass  $< 1$  kg/ha. Slimy Sculpin was estimated to be 0.03 kg/ha, an order of magnitude lower than the long-term average from the fall BT. Round Goby biomass density was 0.44 kg/ha and Ninespine Stickleback density was 0.20 kg/ha, the highest value since 2007.

**Table 1. List of fish species common and scientific names.**

Common Name	Scientific Name
Alewife	<i>Alosa pseudoharengus</i>
Bloater	<i>Coregonus hoyi</i>
Brown Trout	<i>Salmo trutta</i>
Burbot	<i>Lota lota</i>
Cisco	<i>Coregonus artedi</i>
Chinook Salmon	<i>Oncorhynchus tshawytscha</i>
Coho Salmon	<i>Oncorhynchus kisutch</i>
Deepwater Sculpin	<i>Myoxocephalus thompsonii</i>
Emerald Shiner	<i>Notropis atherinoides</i>
Lake Trout	<i>Salvelinus namaycush</i>
Lake Whitefish	<i>Coregonus clupeaformis</i>
Ninespine Stickleback	<i>Pungitius pungitius</i>
Rainbow Smelt	<i>Osmerus mordax</i>
Round Goby	<i>Neogobius melanostomus</i>
Slimy Sculpin	<i>Cottus cognatus</i>
Smallmouth Bass	<i>Micropterus dolomieu</i>
Steelhead	<i>Oncorhynchus mykiss</i>
Threespine Stickleback	<i>Gasterosteus aculeatus</i>
Yellow Perch	<i>Perca flavescens</i>
Brook Stickleback	<i>Culaea inconstans</i>
Mysis	<i>Mysis diluviana</i>

## Introduction

Annual evaluation of prey fish dynamics is critical to understand changes to the Lake Michigan food web during the last 40 years (e.g., Madenjian et al. 2002, 2015) and continued ecosystem restructuring due to non-native species, changing nutrient inputs, changing climate, and management activities including harvest regulation and fish stocking. The non-native species Alewife (*Alosa pseudoharengus*) is a key prey fish in the Lake Michigan food web because it serves as the primary prey for salmonines (Elliott 1993; Rybicki and Clapp 1996; Warner et al. 2008; Jacobs et al. 2013). Alewife also influence food web structure because they are predators of native larval fish [e.g., Lake Trout (*Salvelinus namaycush*), Emerald Shiner (*Notropis atherinoides*); Madenjian et al. (2008)] and contribute to recruitment bottlenecks. Bloater (*Coregonus hoyi*, commonly known as “chub”) is a native coregonine prey fish that dominated the community biomass in the 1980s and early 1990s. Non-native Rainbow Smelt (*Osmerus mordax*) is another common planktivorous prey fish species since its introduction into Lake Michigan in the early 20th century. Alewife, Bloater, and Rainbow Smelt supported commercial fisheries in the 1980s that have either been closed (Alewife) or now have limited participation (Bloater, Rainbow Smelt) owing to low fish catches in recent decades. Key native benthic species include Deepwater and Slimy Sculpin (*Myoxocephalus thompsonii* and *Cottus cognatus*, respectively). Since 2004, non-native benthic Round Goby (*Neogobius melanostomus*) has become abundant in Lake Michigan and represent a key component of the food web given their importance as prey for Lake Trout (Happel et al. 2018, Leonhardt et al. 2020), Brown Trout (*Salmo trutta*, Leonhardt et al. 2020), Cisco (*Coregonus artedii*; Breaker et al. 2020) and Smallmouth Bass (*Micropterus dolomieu*; Steinhart et al. 2004a), but also for their ability to consume non-native dreissenid mussels (Bunnell et al. 2015). At the same time, Round Goby can potentially have a negative effect on native fishes by consuming their eggs (e.g., Chotkowski and Marsden 1999; Steinhart et al. 2004b).

Lakewide monitoring of prey fish began in 1973 with a fall bottom trawl (fall BT) survey that sampled the bottom ~1.5 m of water over soft or sandy substrates during the daytime. Although many adult prey fish occupy the bottom of the lake during the day, presumably to avoid predation, scientists recognized that the survey provided a relative (not absolute) density index because some proportion of adult Alewife, Bloater, and Rainbow Smelt remain pelagic during the daytime. In addition, age-0 Alewife are mostly above the thermocline, rather than below, during the day (Brandt 1980). To provide a complementary relative index of prey fish abundance, Lake Michigan scientists began conducting nighttime acoustic (AC) surveys in the early 1990s, and an interagency, lakewide, annual survey was formalized in 2004. Together, these two annual surveys have enabled the development of a stock assessment model for prey fish (Tsehaye et al. 2014) that is used to inform annual agency stocking decisions of Chinook Salmon (*Oncorhynchus tshawytscha*), Lake Trout, Steelhead (*Oncorhynchus mykiss*), Brown Trout, and Coho Salmon (*Oncorhynchus kisutch*) in Lake Michigan. The fall BT provides abundance indices for benthic species such as Deepwater Sculpin, Slimy Sculpin, Round Goby, Ninespine Stickleback (*Pungitius pungitius*), and even age-0 Yellow Perch (*Perca flavescens*). The fall BT has also traditionally indexed Burbot (*Lota lota*), a native piscivore, and has consistently collected wild juvenile Lake Trout since the early 2000s. In turn, the AC survey provides an abundance index for age-0 Alewife, which is an early indicator of Alewife year-class strength (Warner et al. 2008). Both surveys provide relative indices of Bloater, Rainbow Smelt and yearling and older (YAO) Alewife that can be used as two lines of evidence for tracking density changes over time.

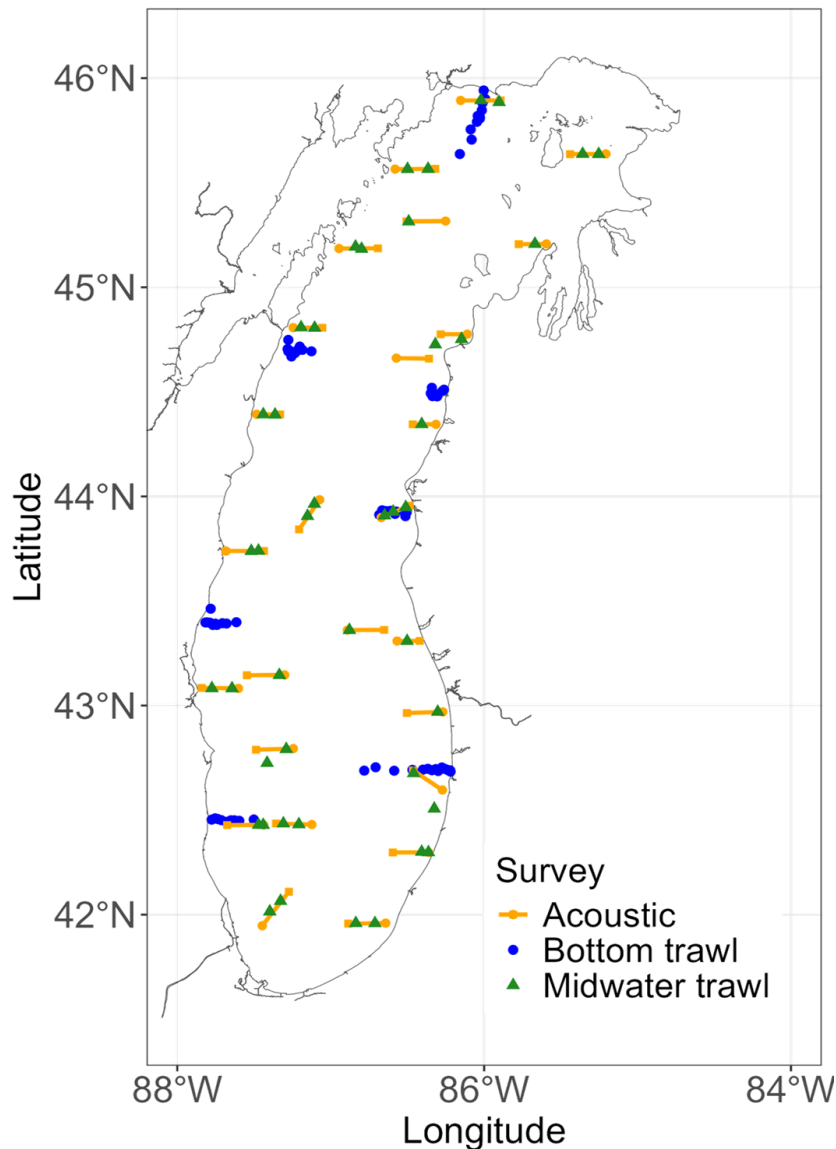
We have combined the results of the fall BT and AC survey in one report since 2019. Our goal is to provide a synthesized and concise report that emphasizes the complementarity of the two standard surveys. For methodological details, we invite readers to consult the previous separate survey reports (refer to Bunnell et al. 2019; Warner et al. 2019). Below, we provide a high-level overview of all methods.

## Methods

The standard unit of sampling for bottom trawl surveys is a 10-min tow using a “Yankee” trawl (12-m headrope, 25- to 45-mm bar mesh in net body, 6.4-mm bar mesh in cod end). In the fall BT, the trawl is dragged along depth contours at 9 m (5 fathom) depth increments. At most survey transects, towing depths range from 9 or 18 m to 110 m. Depths shallower than 9 m cannot be sampled at most sites because the draft of the research vessel (i.e., vertical distance between the waterline and the bottom of the hull) prevents safe navigation while trawling. In 2013, we began adding tows at deeper depths to assess the extent to which some species (e.g., Deepwater Sculpin, Bloater) have migrated outside of our traditional survey range. In 2025, we sampled 5 deepwater sites at 128 m depth and three supplemental shallow water sites (5,13,22 m) for a total of 76 tows. During each fall BT survey, seven transects are sampled offshore of Manistique, Frankfort, Ludington, and Saugatuck, Michigan (MI); Waukegan, Illinois (IL); and Port Washington and Sturgeon Bay, Wisconsin (WI; Fig. 1). Since 2016, we have directly estimated time on lake bottom for each tow with a head-rope depth sensor that provides a more accurate estimate of area (ha) swept.

We estimate both numeric (fish per hectare [fish/ha]) and biomass (kg/ha) density with lakewide means and variances calculated using a stratified design (fall BT) and a stratified cluster design (AC). For the BT survey, the mean densities presented in this report are based on the standard trawl tows only (supplemental tows not included in the averaging). For the AC survey, split beam transducers with a nominal frequency of 120 kHz (range 120-129) were used to estimate numeric fish density along each of the 26 transects sampled in 2025 (Fig. 1). While sampling those transects, midwater trawls are deployed to sample fish, enabling estimation of species and size composition of fish for the numeric fish density data. Trawl deployment is generally driven by the presence or absence of fish. Acoustic fish density estimates were generated with consideration of the six geographic strata (north nearshore east, north nearshore west, north offshore, south nearshore, south offshore, west nearshore; refer to Warner et al. 2019) and vertical depth layer. Numeric fish density estimates for the upper part of the water column (<40 m) were derived using the NearD method whereby catch from the nearest midwater trawl (Euclidean distance) in the same depth layer was used to apportion acoustic data to fish categories (age or size groups within species; Yule et al. 2013). Fish density in the >40 m layer was apportioned to fish categories (age or size groups within species) using acoustic target strength (TS) and prior information about the composition of midwater trawl catch in this layer (Warner et al. 2012). Lakewide average numeric and biomass density are estimated by calculating the population mean for a stratified cluster with known areas.

Given the importance of Alewife age distribution for the stock assessment model, sagittal otoliths were removed from a subset of Alewife in all surveys. Otoliths were mounted and the number of annual rings was read independently up to three times by two readers. If consensus on



**Figure 1. Map of sampling locations for the Lake Michigan bottom trawl and acoustic surveys in 2025. Yellow squares represent acoustic transects and green triangles represent midwater trawl locations. Fall bottom trawl sites are represented by blue circles.**

results in a proportion of age-1 and age-2 fish being <120 mm. Further, recent age data are not available for Rainbow Smelt and Yellow Perch. Therefore, we restrict the term age-0 to Alewife and instead refer to “small” Bloater, Rainbow Smelt, and Yellow Perch as indices of relative recruitment strength. Estimated age-0 Alewife biomass density from the AC survey was derived from aged fish, and the lakewide age-0 Alewife index is reported only from the AC survey. Proportion-at-age and catch distributions are reported for <100 mm Alewife from the fall BT for completeness only.

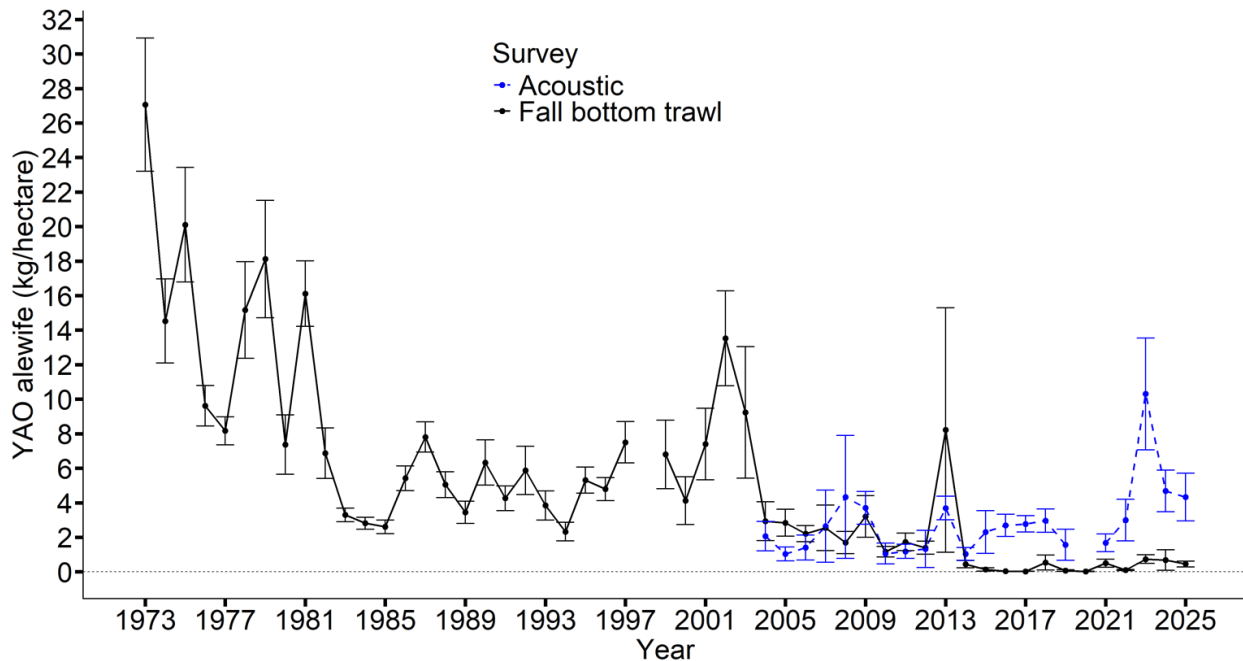
the number of annual rings could not be reached, the otolith age was deemed unknown. In 2025, ages from 385 and 374 otoliths were successfully obtained from Alewife sampled in the fall BT survey and the AC survey, respectively. Aging was unsuccessful for 26 Alewife across the surveys. Independent age-length keys were developed for the AC survey and fall BT.

By convention, we classified Alewife, Bloater, Rainbow Smelt, and Yellow Perch caught in the fall BT and AC based on total length (TL) cutoffs: Alewife = 100 mm, Bloater = 120 mm, Smelt = 90 mm, Yellow Perch = 100 mm. For Alewife, this cutoff can reliably be used to estimate YAO densities for the fall BT in a given sample year. However, recent examination of Bloater age-length frequencies from 2016-2018 from both surveys indicates that annual variability in growth

## Results

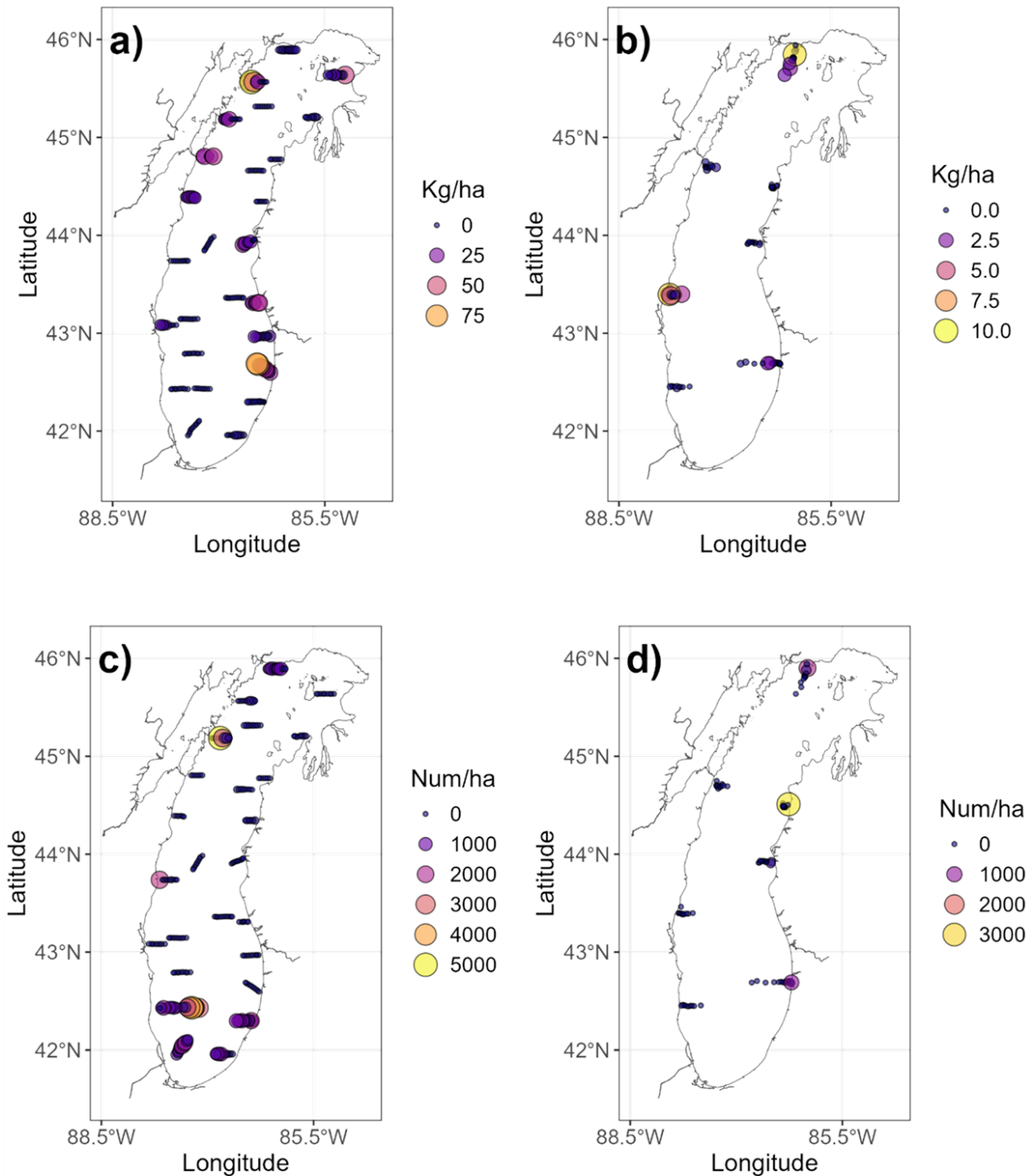
### Alewife

Yearling and older Alewife biomass density estimates in 2025 were 4.3 kg/ha in the AC survey, and 0.45 kg/ha in the fall BT (Fig. 2). The AC survey YAO Alewife biomass density estimate was the third highest in the time series and marks the third consecutive year this estimate has been above average. YAO Alewife catch was relatively well distributed across the lake in each survey but was approximately an order of magnitude lower in the fall bottom trawl (Fig. 3). In the acoustic survey, catches were highest in the northwest and southeast, with the highest catch at 94 kg/ha at a 65 m depth site near the mouth of Green Bay (Fig 3a). In the bottom trawl, catches were highest along the Manistique transect in the north and Port Washington in the west, with a high catch of 9.4 kg/ha at 37 m depth outside Manistique (Fig. 3b).



**Figure 2. Yearling and older (YAO) Alewife (*Alosa pseudoharengus*;  $\geq 100$  mm) biomass density for the fall bottom trawl and acoustic survey in Lake Michigan, United States. Error bars are  $\pm$  standard error.**

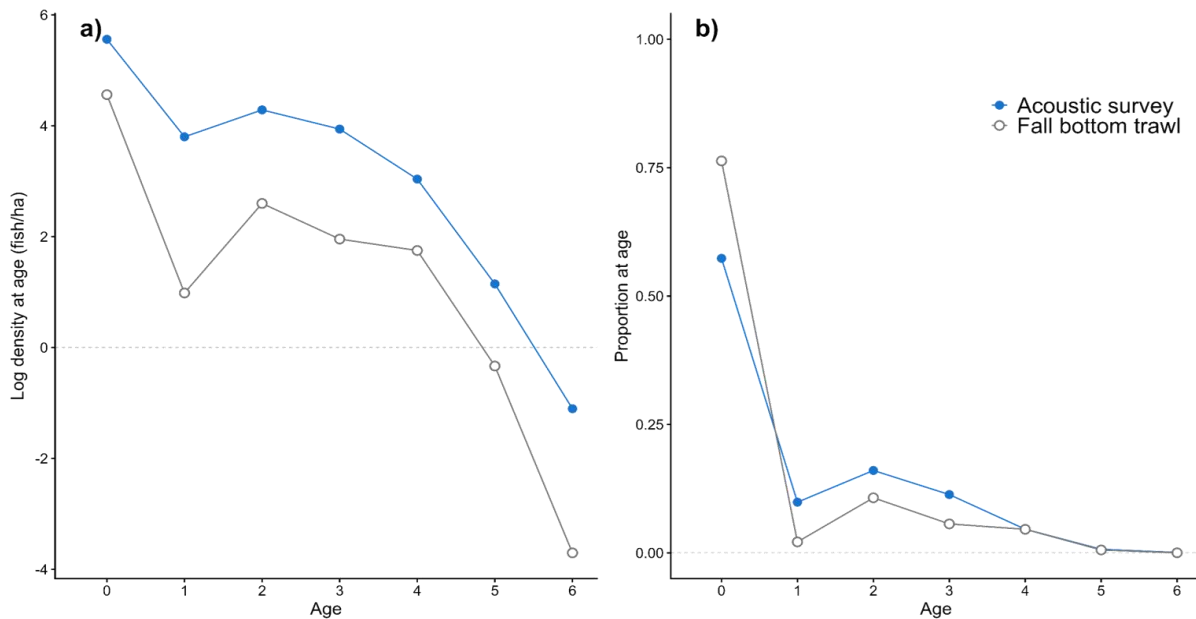
Fall BT and AC survey YAO Alewife biomass densities did not have overlapping standard error (SE) bars for the tenth consecutive year in which both surveys were completed, a departure from general agreement through the first ten years of the AC survey (2004-2013). Results of the annual surveys over the 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 4.8 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 still 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).



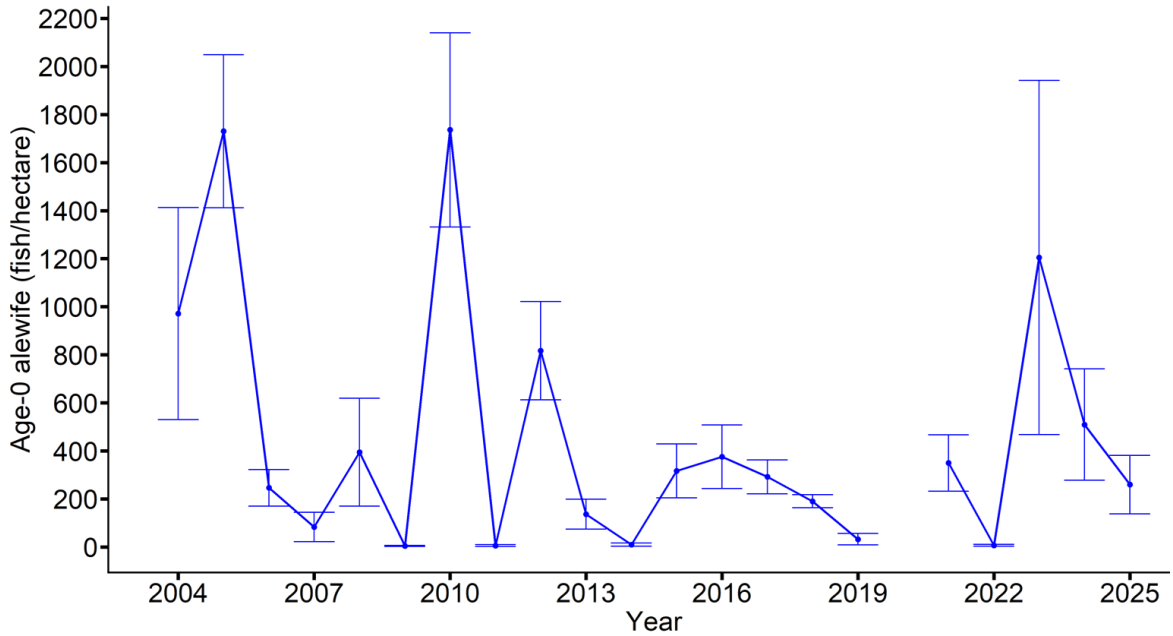
**Figure 3. Yearling and older (YAO) Alewife (*Alosa pseudoharengus*;  $\geq 100$  mm) biomass density as indexed by the acoustic survey (a) and the fall bottom trawl survey (b) as well as the numeric density of age-0 Alewife from the acoustic survey (c) and the fall bottom trawl survey (d) of Lake Michigan, United States in 2025. Note the scale difference between maps.**

Similar to recent surveys, young Alewife dominated catches in both annual surveys, with age-4+ fish representing only ~5% of the total catch in each survey (Figure 4). Age-0 and age-2 Alewife accounted for the highest proportions of the catch in both surveys, comprising 57% and 16% of the AC survey catch and 76% and 11% of the fall BT catch, respectively (Figure 4b). The strong representation of Age-2 fish is consistent with results from the 2023 AC survey, which indicated that 2023 was a higher-than-average recruitment year for Alewife. Age-1 fish were underrepresented in both surveys. Low age-1 catch is common in the bottom trawl survey because catchability for this age group is relatively low, but similarly low proportions in the AC survey may indicate a relatively weak 2024 year-class. The low proportion of age-4+ fish observed in both surveys suggests that the Alewife population remains dominated by younger age-classes, consistent with a truncated age structure potentially associated with elevated mortality on older fish (see Warner et al. 2022 and prior reports for a full summary).

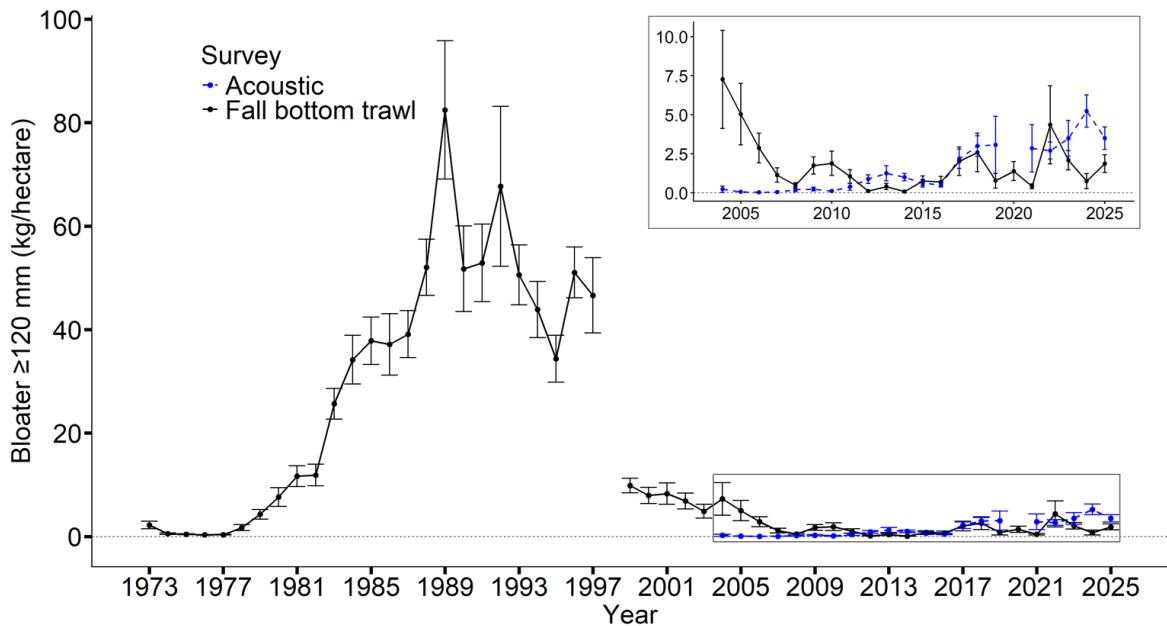
Age-0 Alewife sampled in the AC survey were at the highest densities in northwest and southcentral Lake Michigan (Fig. 3c). Catches were low along the eastern shoreline. Numeric density of age-0 Alewife estimated from the AC survey was 259 fish/ha in 2025, below the mean over the entire time series (487 fish/ha; Fig. 5). Catches of age-0 Alewife in the BT survey were greatest at the Frankfort and Manistiquet transects in 2025 (Fig. 3d).



**Figure 4: Natural log-transformed density at age (n/ha; a) and proportion at age (b) for Alewife (*Alosa pseudoharengus*) collected in the 2025 acoustic survey and fall bottom trawl survey in Lake Michigan, United States.**



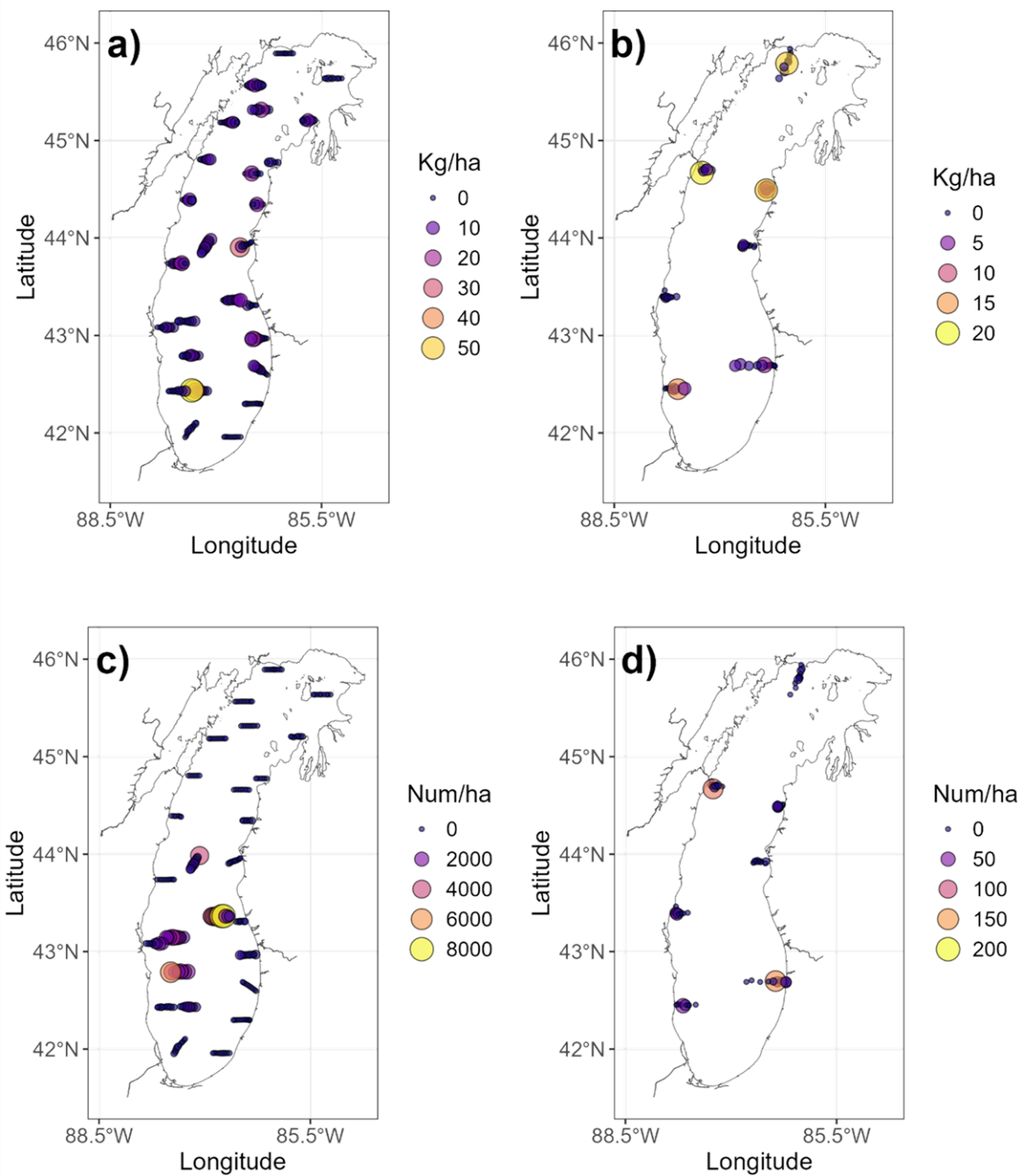
**Figure 5. Age-0 Alewife (*Alosa pseudoharengus*) numeric density as indexed by the acoustic survey from 2004-2025 in Lake Michigan, United States. Error bars are +/- standard error.**



**Figure 6. Biomass density of large Bloater (*Coregonus hoyi*;  $\geq 120$  mm) in Lake Michigan, United States as indexed by the fall bottom trawl and acoustic survey. Error bars are +/- standard error. Inset is a call-out for the period in which data were collected for both surveys (2005-2025).**

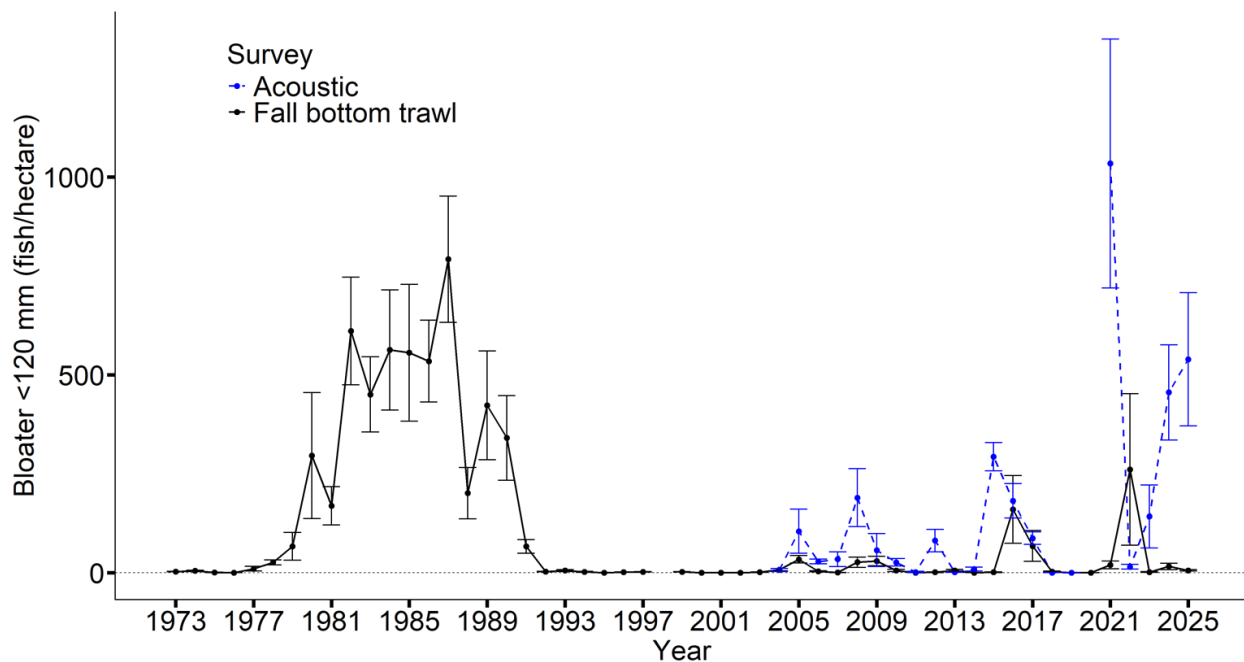
### *Bloater*

Large Bloater ( $\geq 120$  mm) biomass density in 2025 was 3.5 kg/ha in the AC survey and 1.9 kg/ha in the fall BT survey (Fig. 6). Large Bloater were well-distributed across fall BT tows (Fig. 7a, b), but biomass indices remain an order of magnitude below the maximum measured during 1981–1997. Although the AC survey has shown a generally increasing trend since 2011, the 2025 biomass density index was lower than in 2024 (5.2 kg/ha).



**Figure 7. Large Bloater (*Coregonus hoyi*;  $\geq 120$  mm) biomass density as indexed by the acoustic survey (a) and the fall bottom trawl survey (b) as well as the numeric density of small Bloater ( $< 120$  mm) from the acoustic survey (c) and the fall bottom trawl survey (d) of Lake Michigan, United States in 2025. Note the scale difference between maps.**

The 2025 AC survey estimated small Bloater (<120 mm) numeric density at 540 fish/ha, the second highest value in the time series and similar to the 2024 estimate (Fig. 8). However, only 6.1 fish/ha were recorded in the fall bottom trawl (BT) in 2025, well below the long-term mean. In the AC survey, small Bloater densities were highest at depths of approximately 75–125 m in central Lake Michigan and the southern basin (Fig. 7c). In contrast, small Bloater densities in the fall BT were highest at intermediate depths (46–64 m; Fig. 7d).



**Figure 8. Numeric density of small Bloater (*Coregonus hoyi*; < 120 mm) in Lake Michigan, United States as indexed by the fall bottom trawl and acoustic surveys. Error bars are +/- standard error.**

### Rainbow Smelt

The 2025 index of large Rainbow Smelt was 0.04 kg/ha in the fall BT survey and 0.69 kg/ha in the AC survey, the highest since 2006 (Fig. 9). Numeric density of small Rainbow Smelt estimated by the 2025 AC survey was 541 fish/ha, compared with 41 fish/ha in the fall BT survey (Fig. 10). The AC index of small Rainbow Smelt is the highest value on record, exceeding the previous peak of 167 fish/ha in 2008. Large Rainbow Smelt catches in the AC survey were highest in the northern basin as well as along a transect offshore from Saugatuck, MI on the eastern shoreline (Fig. 11a). Large Rainbow Smelt were much less common in the bottom trawl survey, with catches all below 2 kg/ha and largely collected in the central portion of the lake (Fig. 11b). Small Rainbow Smelt were collected in their highest densities in the central portion of Lake Michigan in both surveys (Fig. 11c,d).

In recent years, elevated age-0 indices of Rainbow Smelt have not translated into increases in adult biomass in Lake Michigan, so the significance of the high AC survey estimate in 2025 remains uncertain. A time-series analysis through 2012 indicated that production of age-0 fish relative to spawning stock increased after 2000, yet those cohorts did not appear to survive to adulthood (Feiner et al. 2015). The causes of the long-term decline in Rainbow Smelt biomass since 1993 remain unclear. Although consumption by salmonines was higher during the mid-1980s than in

the 1990s (Madenjian et al. 2002), Rainbow Smelt abundance remained high during that period, and subsequent analyses suggest that salmonine predation has not been the primary driver of long-term trends in Lake Michigan Rainbow Smelt abundance (Tsehaye et al. 2014).

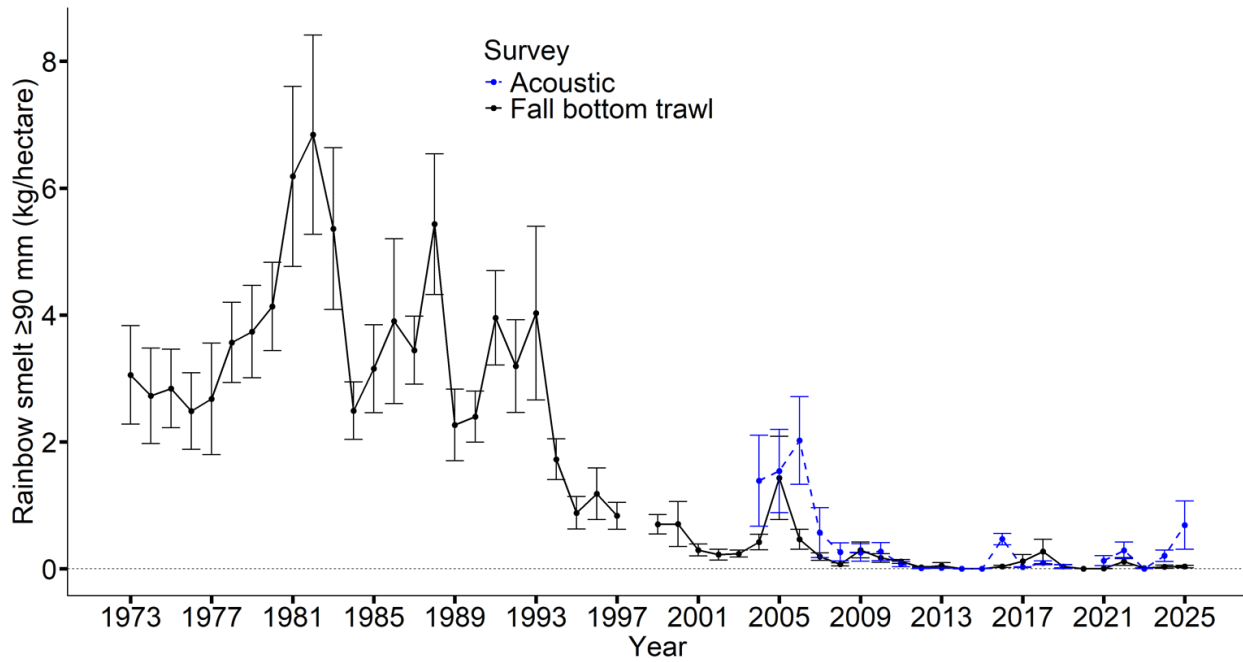


Figure 9. Biomass density of large Rainbow Smelt (*Osmerus mordax*;  $\geq 90$  mm) in Lake Michigan, United States as indexed by the fall bottom trawl and acoustic surveys. Error bars are +/- standard error.

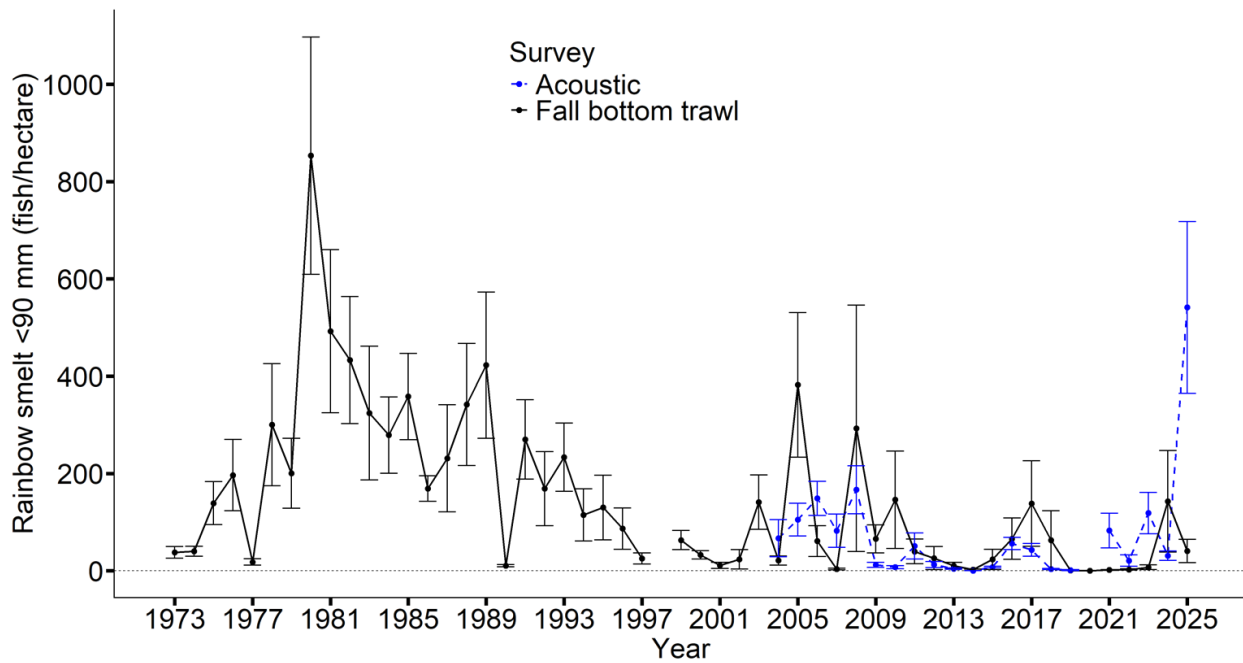
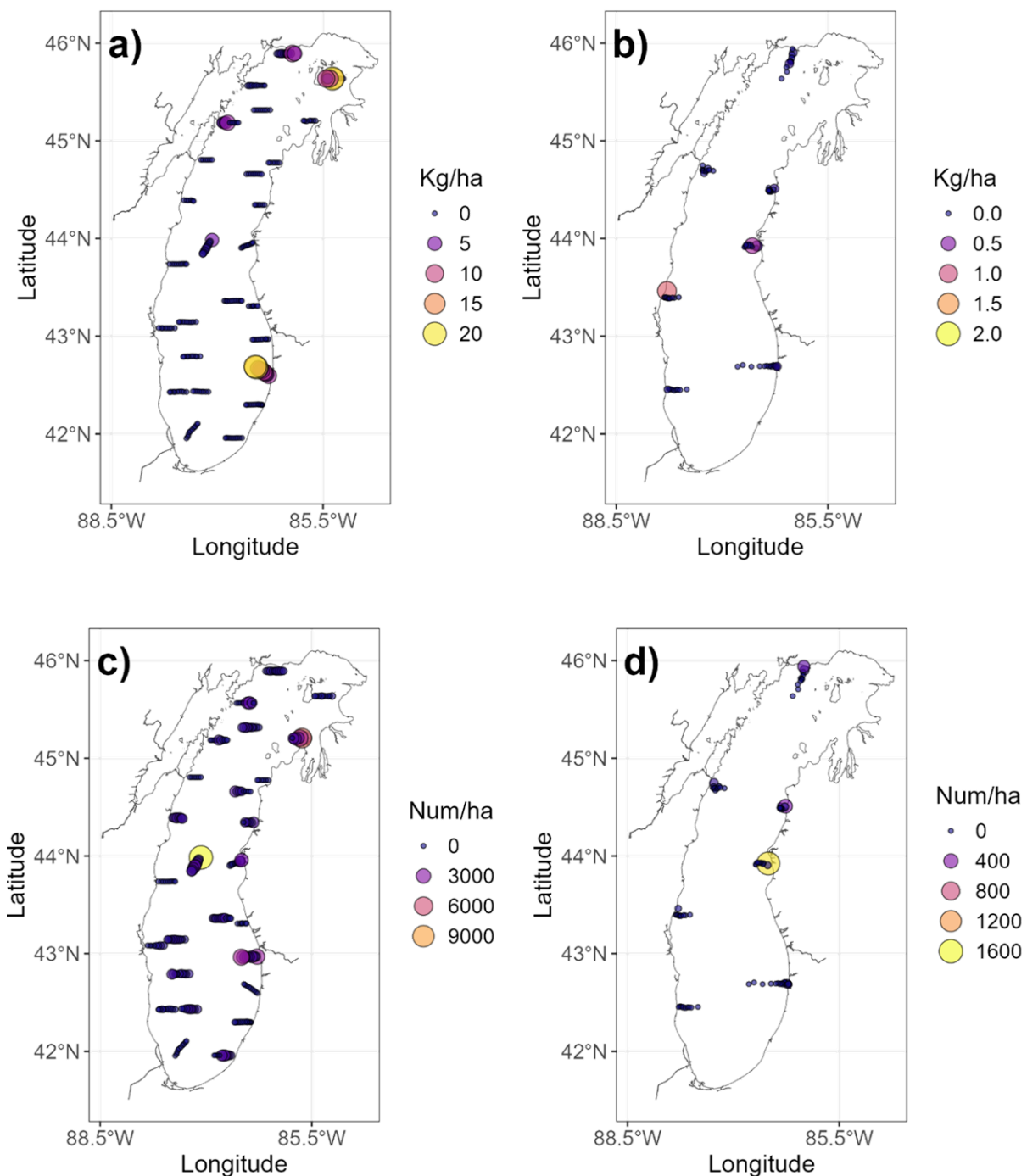


Figure 10. Numeric Density of small Rainbow Smelt (*Osmerus mordax*;  $<90$  mm) in Lake Michigan, United States as indexed by the fall bottom trawl and acoustic surveys. Error bars are +/- standard error.



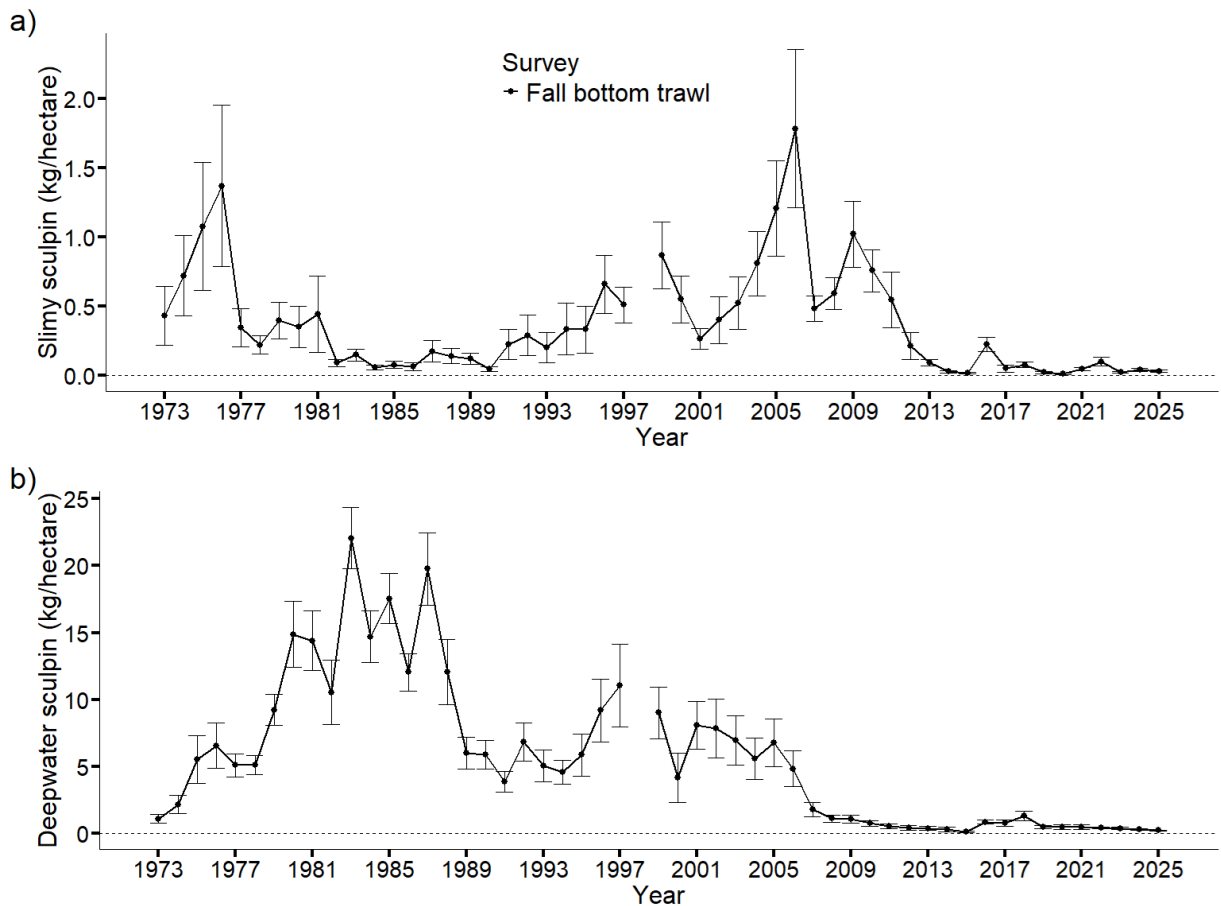
**Figure 11. Large Rainbow Smelt (*Osmerus mordax*;  $\geq 90$  mm) biomass density as indexed by the acoustic survey (a) and the fall bottom trawl survey (b) as well as the numeric density of small Rainbow Smelt ( $< 90$  mm) from the acoustic survey (c) and the fall bottom trawl survey (d) of Lake Michigan, United States in 2025. Note the scale difference between maps.**

### *Slimy Sculpin*

Slimy Sculpin biomass was 0.03 kg/ha in the fall BT survey in 2025. Biomass density estimates from the fall BT have remained below 1 kg/ha for 16 consecutive years (Fig. 12a). While declines in total biomass have been observed in recent years across multiple prey fish 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).

### *Deepwater Sculpin*

The biomass density of Deepwater Sculpin in 2025 was 0.21 kg/ha in the fall bottom trawl survey (Fig. 12b). 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 increased at the start of



**Figure 12. Biomass density of Slimy Sculpin (*Cottus cognatus*; a) and Deepwater Sculpin (*Myoxocephalus thompsonii*; b) in Lake Michigan, United States as measured by the fall bottom trawl survey. Error bars in both panels are +/- standard error.**

the decline in 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 trawling sites). In support of this, Madenjian and Bunnell (2008) found that Deepwater Sculpin 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 a spring bottom trawl survey of Lake Michigan in 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 (Tingley et al. 2025).

#### *Ninespine and Threespine Stickleback*

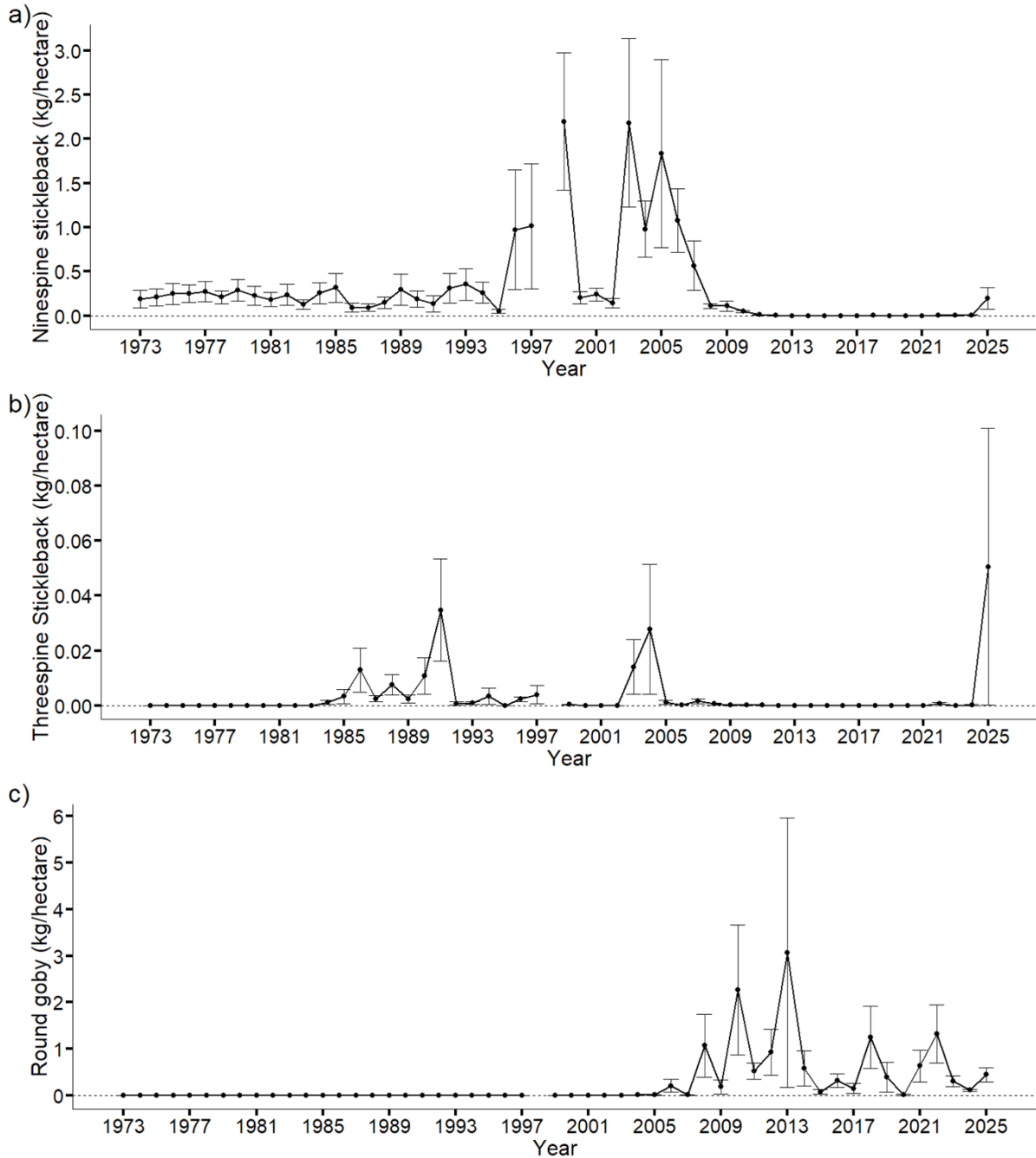
Two stickleback species are caught in the Lake Michigan fall BT. Ninespine Stickleback is native, whereas Threespine Stickleback (*Gasterosteus aculeatus*) is non-native and was first collected in the fall BT survey during 1984 (Stedman and Bowen 1985) but has been rare in recent years. While Ninespine Stickleback biomass density has been low (i.e., <0.01 kg/ha) since 2010, the 2025 biomass density index was 0.20 kg/ha, the highest since 2007 (Fig. 13a). Similarly, Threespine Stickleback were recorded at the highest numeric density of the time series in 2025 (0.05 kg/ha; Fig. 13b), largely due to a single high tow at the 27 m depth site along the Manistique transect.

The mechanism driving higher catches of both stickleback species in 2025 is unclear. Above-average catches were also reported in Lake Superior (personal communication, Nicole Watson, USGS GLSC, Ashland, WI), and Brook Stickleback (*Culaea inconstans*) reached record highs in a long-term trawl dataset from Grand Traverse Bay, Lake Michigan (personal communication, Lauren Sheffer, Inland Seas Education Association, Suttons Bay, MI). One possible explanation is a predation buffer associated with increases in preferred prey, such as Alewife in Lake Michigan and strong 2022 coregonine year-classes in Lake Superior. It has been speculated that Ninespine Stickleback declines since 2009 may have resulted from piscivores incorporating them into their diets as Alewife became scarce, an idea supported in part by diet comparisons between periods of high and low Alewife densities (Jacobs et al. 2013). Alternatively, these patterns may reflect responses to broader climate forcing, or elevated catches observed in 2025 may simply reflect natural variation in abundance.

#### *Round Goby*

Invasive Round Goby 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 Goby were well established in the fall BT. However, as our survey samples only soft substrates  $\geq 9$  m in depth, our index is biased low because we are not sampling their preferred habitat in September (rocky substrate and shallow [ $< 9$  m] depths). Round Goby biomass density was 0.44 kg/ha in the 2025 survey (Fig. 13c). Densities in the fall BT were highest in shallow habitats, especially in the southern main basin. Round Goby 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 (*Coregonus clupeaformis*, 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

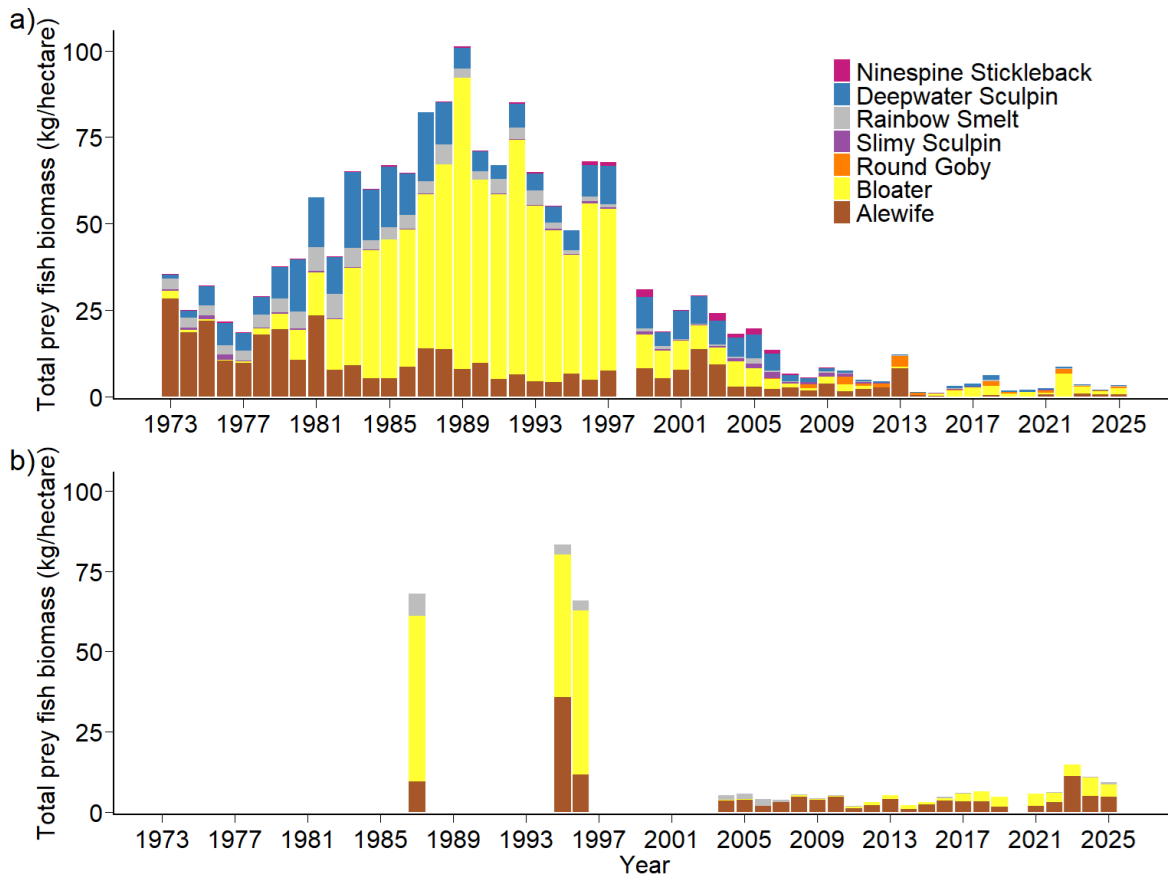


**Figure 13. Biomass density of Ninespine Stickleback (*Pungitius pungitius*; a), Threespine Stickleback (*Gasterosteus aculeatus*; b), and Round Goby (*Neogobius melanostomus*; c) in Lake Michigan, United States as measured by the fall bottom trawl survey. Error bars in both panels are +/- standard error.**

rate estimates range from 79 to 84% (Huo et al. 2014), comparable to adult Alewife (Tsehaye et al. 2014).

*Prey fish community trends*

The prey fish community biomass density index as reported by the annual fall BT survey was 3.44 kg/ha and includes Alewife, Bloater, Rainbow Smelt, Deepwater Sculpin, Slimy Sculpin, Ninespine Stickleback, and Round Goby. Total fall BT biomass remains well below the long-term average of 32.5 kg/ha (Fig. 14a). Biomass first dropped below 10 kg/ha in 2007 and has remained low since, with the exception of 2013, when biomass estimates for Alewife and Round Goby were uncertain due to unusually high catches in single tows. The prey fish community sampled by the AC survey includes Alewife, Bloater, Rainbow Smelt, and Cisco (which are rare and have not been collected since 2021). In 2025, this survey estimated a total biomass density of 9.3 kg/ha (Fig. 14b), the third highest since the modern AC survey began in 2004, trailing only 2024 and 2023, but only 13% of the mean of the 1987, 1995, and 1996 surveys [72.4 kg/ha, Argyle 1992; Argyle et al. 1998].



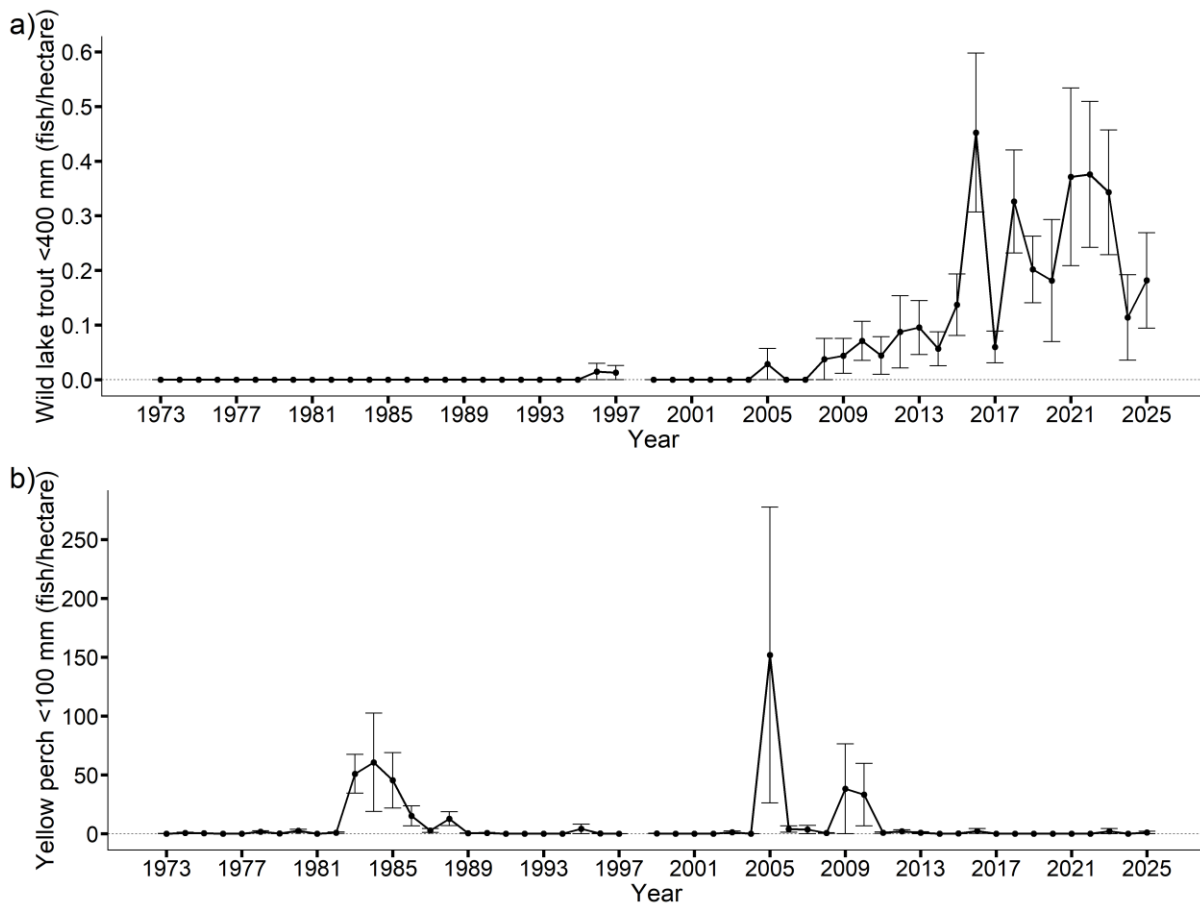
**Figure 14. Estimated biomass density of prey fish sampled in Lake Michigan, United States in the fall bottom trawl survey, 1973-2025 (a) and the estimated biomass density of prey fishes sampled by the current acoustic survey, 2004-2025, with historic estimates included (b). Refer to Table 1 for scientific names of fish species.**

*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 0.08 kg/ha, consistent with the

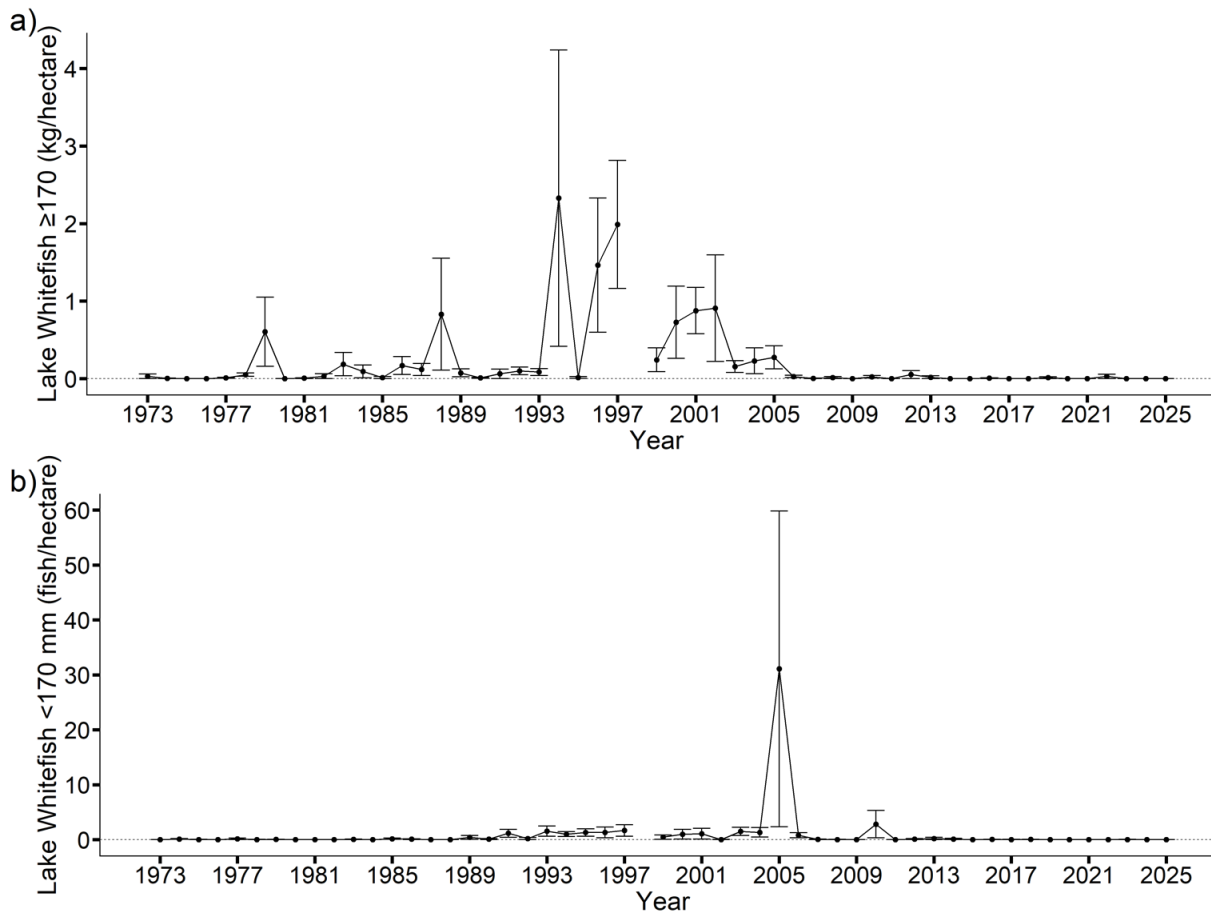
relatively low estimates observed since 2012 (Tingley et al. 2025). The cause of continued low Burbot catches remains unclear. Madenjian et al. (2022) hypothesized that part of the Burbot population may have shifted into deeper waters of Lake Michigan, potentially following Deepwater Sculpin. In contrast, wild juvenile Lake Trout (<400 mm) have been collected in the bottom trawl survey each year since 2008 (Leonhardt et al. 2024). In 2025, wild juvenile Lake Trout abundance was 0.18 fish/ha, higher than any value observed prior to 2015 (Fig. 15a). Although catches remain sporadic, the fall BT survey appears to have tracked the substantial increase in natural recruitment of Lake Trout in Lake Michigan during the past 20 years.

**Yellow Perch** – Yellow Perch in Lake Michigan have historically supported valuable recreational and commercial fisheries (Wells 1977). The fall BT survey provides an index of small (<100 mm) Yellow Perch numeric density and recruitment success. The 2005 age-class was the largest recorded (Fig. 15b), and the 2009 and 2010 age-classes were also above average. In 2025, small Yellow Perch density at the standard tow locations was 1.17 fish/ha. However, three additional shallow-water tows conducted annually off Saugatuck provide supplemental recruitment indices. Including these tows, small Yellow Perch were captured in the highest number of tows (n = 4) since 2012 and produced the highest density (135 fish/ha) for a single tow since 2011.



**Figure 15.** Biomass density of wild juvenile Lake Trout (*Salvelinus namaycush*; <400 mm; a) and numeric density of small Yellow Perch (*Perca flavescens*; <100 mm; b) in Lake Michigan, United States as indexed by the fall bottom trawl survey. Error bars in both panels are +/- standard error.

Lake Whitefish – Lake Whitefish (*Coregonus clupeaformis*) are occasionally collected during the fall bottom trawl (BT) survey. This species is of considerable importance to tribal and state commercial fisheries, managers, and recreational anglers; however, yields have declined sharply throughout the 21<sup>st</sup> century following a peak in the mid- to late-1990s (Ebener et al. 2021). Although the fall BT survey was not designed to index Lake Whitefish abundance, observed trends are consistent with broader population declines in Lake Michigan. No Lake Whitefish were collected during the 2025 fall BT survey, and only nine individuals  $\geq 170$  mm (the threshold used to approximate YAO fish) have been collected since 2006 (Fig. 16a). Small Lake Whitefish ( $< 170$  mm; likely age-0 fish) have historically been encountered only sporadically in the bottom trawl, with a single anomalously high value of 31 fish/ha observed in 2005 (Fig. 16b). No small Lake Whitefish were collected in 2025, and only one individual has been collected in the past seven years.



**Figure 16. Biomass density of large ( $\geq 170$  mm) and numeric density of small ( $\geq 170$  mm) Lake Whitefish (*Coregonus clupeaformis*) in Lake Michigan, United States collected during the fall bottom trawl survey. Error bars in both panels are  $\pm$  standard error.**

Mysis – Mysids are an important component of the Lake Michigan food web and serve as a key prey resource for many pelagic fishes, including Alewife and Bloater (Hondorp et al. 2005). Although *Mysis diluviana* (*Mysis*) are not a primary focus of prey fish assessments, *Mysis* samples have been collected regularly during AC surveys. In 2025, 19 *Mysis* samples were collected with a 1-m diameter, 1000 or 500- $\mu\text{m}$  mesh net and 250- $\mu\text{m}$  cod end towed vertically from 1-m off bottom to the surface. Samples were preserved in ethanol and later processed by enumerating all individuals, measuring total length from the apex of the rostrum to the cleft of the telson, and assigning sex based on diagnostic morphological characteristics. Males were identified by the modified fourth pleopod, females by the presence of a marsupium or embryos, and individuals lacking clear sex-specific characteristics were classified as unknown.

**Table A1. *Mysis diluviana* mean densities ( $\pm 1$  standard deviation; SD), lengths ( $\pm 1$  SD), and percent unknown sex from tows conducted in August during the 2025 Lake Michigan acoustic survey.**

Strata	Tows	Depth range (m)	Mean density (#/m <sup>2</sup> $\pm$ SD)	Count measured	Mean length (mm $\pm$ SD)	Unknown sex (%)
North offshore	2	107-159	61.8 $\pm$ 51.3	95	9.1 $\pm$ 3.9	72.6
West nearshore	4	84-118	9.2 $\pm$ 8.8	27	10.4 $\pm$ 4.2	55.6
South offshore	3	79-135	11.5 $\pm$ 7.7	27	10.9 $\pm$ 5.2	48.1
South nearshore	5	55-114	6.9 $\pm$ 9.8	27	8.9 $\pm$ 4.1	74.1
North nearshore east	2	106-133	29.9 $\pm$ 29.7	47	11.6 $\pm$ 4.5	46.8
North nearshore west	3	55-168	46.3 $\pm$ 55.8	106	11 $\pm$ 5.2	54.7

Mean *Mysis* density and standard deviation across all tows was  $22.5 \pm 31.3$  ind/m<sup>2</sup>, with the highest mean densities observed in the north offshore ( $61.8 \pm 51.3$  ind/m<sup>2</sup>) while the western nearshore had the lowest observed mean density ( $9.2 \pm 8.8$  ind/m<sup>2</sup>, Table 1). Overall mean body length was  $10.3 \pm 4.7$  mm. Length-frequency distributions were broadly similar among AC survey sample strata and exhibited a bimodal pattern (Fig. A1). Sex of most measured individuals was classified as unknown (59.9%), while 27.7% were female and 12.5% were male. *Mysis* density increased with water column depth ( $R^2 = 0.63$ ,  $p < 0.001$ ; Fig. A2). In contrast, mean body size was not related to depth ( $R^2 = 0.05$ ,  $p = 0.40$ ; Fig. A3).

## Conclusions

Our results suggest that Alewife year-class strength in 2025 is below average and provide additional evidence of a relatively weak year class in 2024. Older Alewife (age-4+) are uncommon across the surveys which suggests high predation on Alewife and an age-truncated population. While Rainbow Smelt indices continue to be low from the fall BT survey, evidence from the AC survey suggests increased recruitment for Rainbow Smelt in 2025. Estimates of small Bloater from the AC survey indicate a strong recruitment event for Bloater in 2025, similar to what was observed in 2024 and broadly reflective of generally increasing Bloater biomass in the lake, which is supported by estimates from both surveys in the last 10 years. The AC estimate of YAO Alewife biomass remains above the 2004-2022 mean, but Alewife and prey fish biomass overall remains low relative to previous decades.

## Acknowledgments

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## Appendix 1. Summary of 2025 *Mysis diluviana* (*Mysis*) data

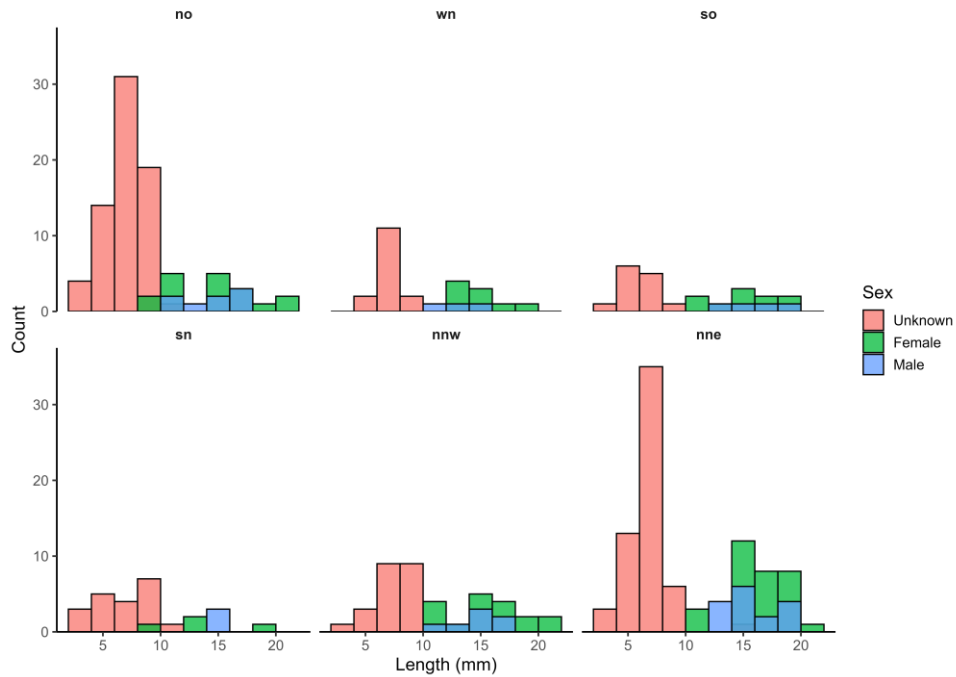


Figure A1. Length frequency by sex (male, female, or unknown) of *Mysis diluviana* collected in August during the 2025 Lake Michigan acoustic survey. Individual lengths from tows (n=19) are pooled by strata used for site selection in the acoustic survey (see main text for more details). no = north offshore, wn = west nearshore, so = south offshore, sn = south nearshore, nnw = north nearshore west, nne = north nearshore east

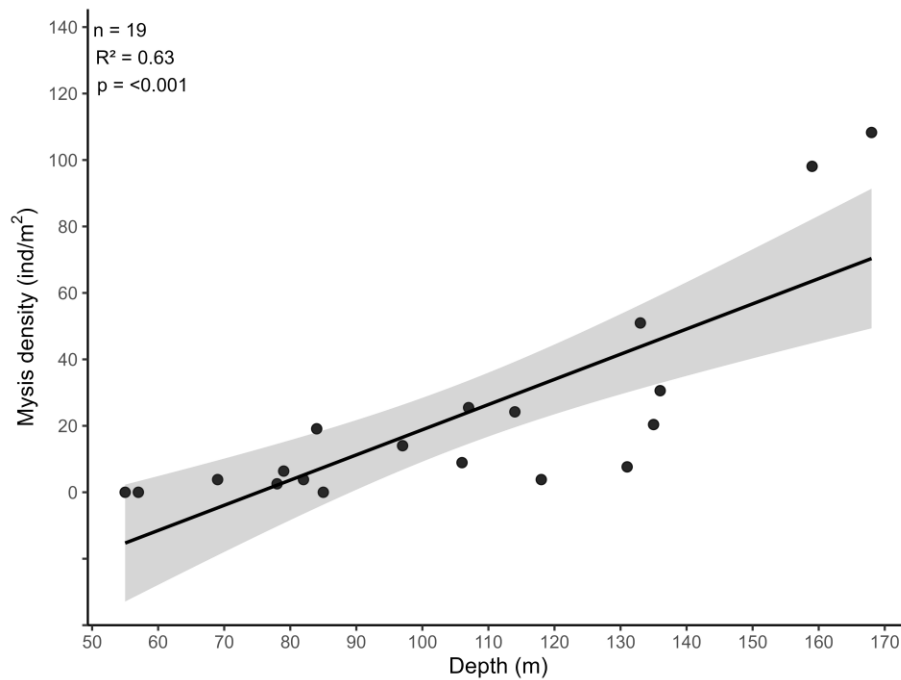
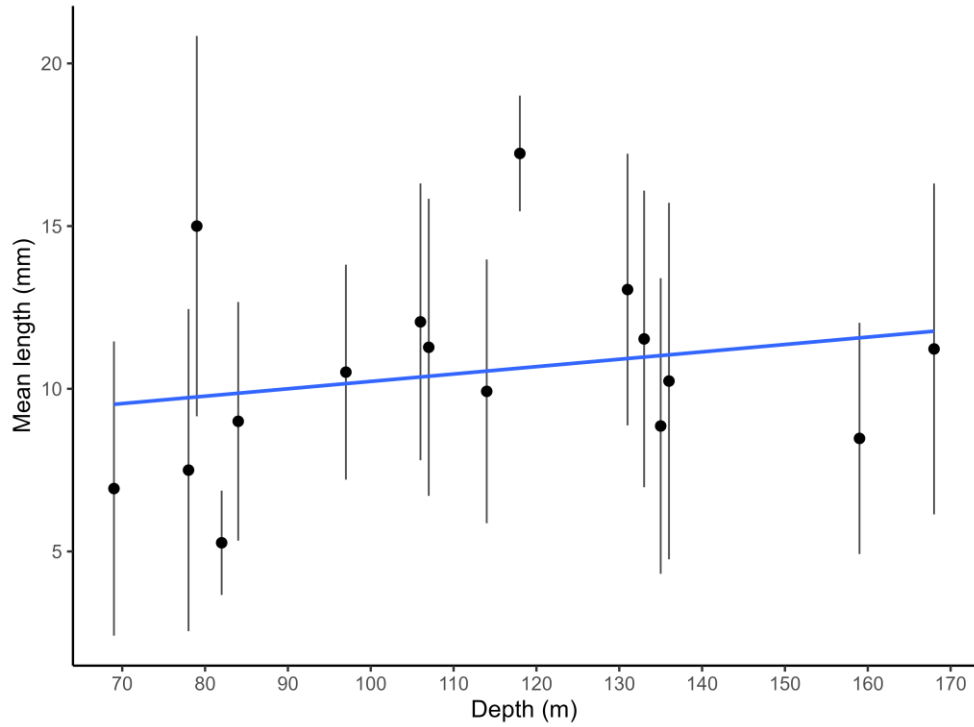


Figure A2. Mean density of *Mysis diluviana* collected in August during the 2025 Lake Michigan acoustic survey plotted against lake bathymetric depth (m) with 95% confidence band shown in gray.



**Figure A3. Mean length of *Mysis diluviana* (mm) by tow (n=19) collected in August during the 2025 Lake Michigan acoustic survey plotted against lake bathymetric depth (m) with  $\pm 1$  standard deviation error bars shown.**