Status and Trends of the Lake Huron Prey Fish Community, 1976-2024[1,2]

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Abstract

The U. S. Geological Survey-Great Lakes Science Center has monitored annual changes in the offshore (depth > 9m) prey fish community of Lake Huron since 1973. Monitoring of prey fish populations in Lake Huron is based on a bottom trawl survey that targets demersal species (i.e., those predominantly or intermittently associated with the lake bottom) and an acoustic-midwater trawl survey that targets pelagic species and life stages. Prey fish abundance and species composition in 2024 was generally consistent with trends observed over the past decade. Bloater (*Coregonus hoyi*) remains the most abundant and widespread prey species, although its abundance is starting to decline owing to changes in demographic factors that are interacting to suppress reproduction. Rainbow Smelt (*Osmerus mordax*) remain widely distributed across Lake Huron but their dynamics vary by basin. Rainbow Smelt populations currently are larger in Georgian Bay and the North Channel than in the main basin where they have produced eight weak year classes over the past decade including in 2024. Populations of Alewife (*Alosa pseudoharengus*) continue to be comprised of low numbers of age-0 individuals, and sculpin communities consist primarily of Deepwater Sculpin (*Myoxocephalus thompsonii*) due to the reduced abundance and distribution of Slimy Sculpin (*Cottus cognatus*). In contrast, biomass of the invasive Round Goby (*Neogobius melanostomus*) in 2024 was the highest observed in the bottom trawl time series and was over four times greater than in 2023. Overall status of main basin prey fish community was rated as 'fair.' Stable dynamics of main basin Bloater populations and evidence of continued recovery by Cisco (*Coregonus artedi*) in the North Channel were interpreted as positive community trends, whereas growth and expansion of Round Goby populations and low species diversity of pelagic prey fish communities are inconsistent with fish community objectives. Use of complementary surveys (bottom trawl, acoustics) remains useful for evaluating prey fish status in Lake Huron, where prey fish community dynamics vary by basin and prey fish responses to changing environmental conditions depend on species and/or habitat.

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[1]The data associated with this report are currently under review and will be publicly available in 2025. 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.

[2]Sampling and handling of fish during GLSC surveys are carried out in accordance with Guidelines for the Use of Fish in Research, a joint publication of the American Fisheries Society, the American Institute of Fishery Research Biologists, and the American Society of Ichthyologists and Herpetologists.

Introduction

The U. S. Geological Survey-Great Lakes Science Center (USGS-GLSC) began annual bottom trawl surveys of the Lake Huron prey fish community in 1973 to provide prey fish data for the Lake Huron fishery management community. The first full bottom trawl survey covering Michigan waters of Lake Huron was conducted in 1976. An integrated acoustics-midwater trawl survey (hereafter, "acoustics survey") was started by the USGS-GLSC in 2004 to better monitor pelagic species and life stages that were potentially underrepresented in the bottom trawl survey (Fabrizio et al. 1997). Data from these surveys are used to quantify relative abundance, species composition, and size/age structure of prey fish in "offshore" waters (depth > 9 m).

The purpose of this report is to describe the status and trends in the offshore prey fish community of Lake Huron from 1976 through 2024. Report objectives are to 1) characterize the status of the main basin prey fish community in 2024 based on trends in species composition and diversity; 2) describe differences in prey fish abundance, species composition, and spatial variability by lake basin (main basin vs. North Channel and Georgian Bay); and 3) describe population status of individual prey fish species based on trends in relative abundance, and when possible, year class strength, and demographics (e.g., size or age structure).

Methods

Bottom Trawl Survey—Since 1976, USGS has monitored demersal prey fish using 12-m headrope (1976-1991) or 21-m headrope (1992-2024) bottom trawls towed at fixed transects at up to eleven depths (9, 18, 27, 36, 46, 55, 64, 73, 82, 91, and 110 m) near five ports (De Tour Village, Hammond Bay, Alpena, Au Sable Point, and Harbor Beach) in Michigan waters of Lake Huron (Figure 1). A sixth port, Goderich (Ontario), was added to the survey in 1998. Bottom trawl surveys typically commence in early October and are completed by late October or early November, except for the 1992 and 1993 surveys, which occurred in September. Single 10-min. bottom trawl tows were conducted during daylight at each transect each year. Trawl catches were sorted by species, counted, and weighed. For Alewife (*Alosa pseudoharengus*), Rainbow Smelt (*Osmerus mordax*), and Bloater (*Coregonus hoyi*), length thresholds determined from length-frequency data were used to apportion bottom trawl catches into age-0 fish (young-of-the-year, or YOY) and those age-1 year or older (yearling and older, or YAO) (Hondorp et al. 2022, Riley et al. 2008). Length thresholds used in 2024 were 120 mm, 90 mm, and 110 mm for Alewife, Rainbow Smelt, and Bloater, respectively. Thresholds were adjusted annually due to interannual variation in fish size distributions. Mean catch weighted by the area of the main basin occurring within 10-m depth strata is used to generate a main-basin estimate of prey fish abundance expressed in density (number/ha) or biomass (kg/ha). The bottom trawl survey was not conducted in 2000, and data from the 2008 survey were excluded because all three southern ports (Au Sable Point, Harbor Beach, Goderich) were not sampled. Additional details on survey design and data analysis are summarized in Riley et al. (2008) and Hondorp et al. (2022).

Acoustic-midwater trawl survey—The GLSC has monitored pelagic prey fish abundance annually since 2004 using a scientific echosounder system deployed along randomly-selected transects within five geographic regions: main-basin east, main-basin west, main-basin south, Georgian Bay, and the North Channel (Figure 1). The first transect location within a region was selected based on random latitude and longitude, with subsequent transects spaced equidistant (north to south, east to west for North Channel only) within the constraints of region boundaries (O'Brien et al. 2022). Final transect locations were selected by alternating shallow (10-50 m) and deep (>50 m) depths to achieve a spatially balanced survey design within each region. Acoustic surveys are typically conducted in September through early October. In all years, sampling was initiated one hour after sunset and ended no later than one hour before sunrise.

Fish catches from midwater trawl tows conducted concurrently along each acoustic transect were used to identify the species composition of acoustic targets by depth strata. Information from acoustic surveys was combined with trawl data to produce region-specific fish abundance estimates expressed as density (number/ha) or biomass (kg/ha). Acoustic density was apportioned by age group (YOY vs. YAO) using length thresholds determined from age-length relationships for Alewife (100mm), Rainbow Smelt (90mm), and Bloater (100mm) (O'Brien et al. 2022). Length thresholds differ between surveys because the acoustics survey begins 4-6 weeks earlier than the bottom trawl survey. No sampling occurred in Georgian Bay or the North Channel in 2006 and 2020. Additional details on survey design and data analysis are provided in O'Brien et al. (2022).

Data analysis— Status of the main basin prey fish community in 2024 (objective 1) was assessed based on relative importance of native species (estimated as the percent of total prey fish biomass comprised of native prey species) and species diversity as estimated by the Shannon Diversity Index (Shannon and Weaver 1963), *H*:

$$H = -\sum_{i=1}^{s} p_i \ln(p_i)$$

where *p* is the proportion (by biomass) of species *i* in the community, and *s* is the total number of species sampled. Status was classified as 'Good,' 'Fair,' or 'Poor' based on indicator thresholds outlined in the 2022 State of the Great Lakes Report (Environment and Climate Change Canada and the U.S. Environmental Protection Agency 2022) and summarized in Table 1. If status categories for the two indicators did not agree, status was rated as 'Fair' if indicator categories were opposite (i.e., one 'Good,' and one 'Poor'), or the lower-rated status when indicators were in adjacent categories (e.g., Good' and 'Fair' = 'Fair'; 'Poor' and 'Fair' = 'Poor').

Table 1. Prey fish community status indicators and status category thresholds for each indicator.

		Status Category		
Indicator	**Measure**	Good	Fair	Poor
Native Species Importance	% Prey fish biomass comprised of native species	% Native ≥ 75	75 > % Native ≥ 25	% Native < 25
Species Diversity	Shannon Diversity (*H*)	$H \geq 0.75 \times H_{max}$	$0.75 \times H_{max} > H \geq 0.25 \times H_{max}$	$H < 0.25 \times H_{max}$

Trends in prey fish community status were assessed based on the slope of each indicator regressed against time (year) for two time periods: (1) the last 10 years of the survey (short-term trend), and (2) the entire time series (long-term trend). Indicator trends were classified as 'Improving' when slopes were positive and statistically significant ($P < 0.10$), and 'Deteriorating' for significant negative relationships. Otherwise, trends in the indicators were classified as 'Unchanging.' Condition of the main basin prey fish community was evaluated separately for each survey. Spatial variability in prey fish abundance and species composition (objective 2) was quantified solely on fish biomass estimates from the acoustics survey, which samples all three lake basins.

Status of individual prey fish species (objective 3) was determined from short- and long-term trends in biomass (all species), size/age structure (Bloater, Rainbow Smelt, and Alewife only), and year class strength (Bloater, Rainbow Smelt, and Alewife only). Relative year-class strength was calculated as the mean density (#'s/ha) of YOY-sized fish divided by the maximum observed density in the time series (index range: 0-1). When applicable, separate indices were calculated for both the bottom trawl and acoustics time series. Data from the acoustics survey also were used to describe current and long-term trends in the lake-wide distribution of dominant species (Bloater, Rainbow Smelt, Cisco (*Coregonus artedi*), and Alewife).

Results and Discussion

Survey overview—The Lake Huron acoustic and bottom trawl surveys were completed during 04-22 September 2024 and 10-21 October 2024, respectively. The bottom trawl survey was conducted aboard the R/V *Arcticus*, and all standard ports and transects were sampled (Table 2, Figure 1). The acoustic survey was conducted jointly by the GLSC (R/V *Sturgeon*) and U.S. Fish and Wildlife Service (M/V *Spencer F. Baird*). Twenty-two acoustic survey transects were sampled, and 38 midwater trawl tows were conducted in conjunction with acoustic data collection (Table 2, Figure 1). Over 30,000 fish representing 14 prey fish species were collected in bottom trawls in 2024, and over 8,000 fish representing 7 prey fish species were collected in midwater trawls (Table 2). Below we describe status and trends for the entire prey fish community and for the most common individual species. Appendix Tables A1 and A2 summarize biomass and density for all prey fish species sampled in 2024.

Table 2. Sampling effort and fish catch by survey, 2024.

	Survey	
Effort/catch metric	*Bottom Trawl*	*Acoustics-midwater trawl*
Number of ports or transects	6*	22**
Number of Trawls	47	38
Number of prey fish species (all species) sampled	14 (21)	7 (9)
Number of prey fish (all fish) sampled	29,941 (30,064)	8,635 (8,639)

*Number of ports
**Number of acoustic transects

Main Basin Status and Trends— Status of the main basin prey fish community in 2024 was considered ‘Fair’ (Table 3). Native species comprised less than 75% of the demersal prey fish community for only the second time since 2019, resulting in a native species index rank of ‘fair,’ but species diversity of the demersal prey fish community improved from ‘fair’ in 2023 to ‘good’ in 2024 (Table 3). Declines in the proportion of native species in the demersal fish community were due to declining biomass of Bloater, the most abundant and widespread native prey fish species, and historically large catches of Round Goby in bottom trawls in 2024. In fact, Round Goby comprised 22% of demersal prey fish biomass in the main basin in 2024 (Figure 2). The pelagic prey fish community as assessed by the acoustics survey is dominated by native species but has low diversity relative to the demersal prey fish community (Table 3). Low species diversity in the pelagic fish community reflects recent declines in non-native planktivores such as Alewife and Rainbow Smelt in addition to the extirpation of several deepwater ciscoes that occurred before lakewide prey fish monitoring began in the early 1970s (Berst and Spangler 1972, Rook et al. 2024). Temporal trends in the percent native and species diversity indicators since 2015 were not significant (Table 4), which indicates that species composition of the main basin has remained relatively table over the past decade. During this period, Bloater, followed by Rainbow Smelt, have been the most abundant prey fish species in the main basin (Figures 2, 3).

Prey fish abundance (biomass) was not considered as a factor in the evaluation of prey fish community status in the main basin because changes in lake trophic state have the potential to affect fish

Table 3. Status of the main basin prey fish community in 2024 by survey. "Max." is the maximum indicator value observed over the entire bottom trawl (1976-2024) or acoustics survey (2004-2024) time series.

	Native Species Index				Species Diversity Index				
Survey	2024	2019-2023 mean ± SE	Max.	Status	2024	2019-2023 mean ± SE	Max.	Status	**Overall Status**
Bottom trawl	69	76 ± 6	90	fair	1.37	1.05 ± 0.12	1.56	good	**fair**
Acoustics	92	90 ± 1	97	good	0.43	0.50 ± 0.05	0.84	fair	**fair**

Table 4. Trends in main basin prey fish community indicators by survey and time period.

		Whole Time Series		2015-2024
Survey	Indicator	Years	Trend	Trend
Bottom Trawl	Native Species	1976-2024	improving	unchanging
	Species Diversity	1976-2024	unchanging	unchanging
Acoustics	Native Species	2004-2024	improving	unchanging
	Species Diversity	2004-2024	unchanging	unchanging

production (Downing et al. 1990, Peters 1986). Mean prey fish biomass in the main basin estimated from the 2024 bottom trawl (7.2 kg/ha) and acoustics (5.6 kg/ha) surveys was well below levels observed prior to basin-wide declines in prey fish biomass that occurred during the early 2000s (Figure 2). Offshore areas of Lake Huron have become increasingly oligotrophic in recent years (Barbiero et al. 2012), so the prey fish biomass that can be supported by current levels of primary production is probably lower than in the past. Prey fish population sizes that are in balance with lake productivity are consistent with Lake Huron fish community objectives (DesJardine et al. 1995).

Community Trends by Basin—Prey fish abundance and species composition determined from the 2024 acoustics survey varied by lake basin (Figure 3). Prey fish biomass was higher in the North Channel (12.2 kg/ha) and Georgian Bay (10.8 kg/ha) than in the main basin (5.6 kg/ha). Bloater was the single-most dominant species in the main basin, representing 89% of prey fish biomass, whereas in Georgian Bay, Rainbow Smelt was the dominant species and accounted for 86% of pelagic prey fish biomass. The North Channel experienced a substantial increase in pelagic prey fish biomass from 2023 levels due to increased Cisco biomass (Figure 3).

Bloater—Bloater is the only remaining deepwater cisco species in Lake Huron and is not a favored prey of salmonid predators (Roseman et al. 2014), so its abundance tends to fluctuate as a result of demographic factors rather than predation (Bunnell et al. 2006, Schaeffer 2004). Currently, Bloater abundance in the main basin is exhibiting a downward trend, which seems to have begun around 2020 (Figure 4). From 2023 to 2024, Bloater biomass in the main basin declined by 20% based on acoustic estimates and by more than 60% based on bottom trawl estimates. Bloater year class strength in 2024 also was the lowest in the acoustics survey time series and second lowest since 2016 in the bottom trawl time series (Figure 4), which indicates that declining bloater biomass is likely to continue into 2025. Bloater recruitment in Lake Michigan declined during periods of female dominance (Bunnell et al. 2006), so the trend towards increasing female dominance observed between 2017 and 2023 may have contributed to poor reproductive success in 2024. Additionally, median age in the population in 2024 (3) exceeded 2 for the first time in the past decade, indicating that senescence of individuals from the large

2018 year class (now age 6) also contributed to the weak 2024 year class. However, Bloater biomass still is distributed among multiple age groups, which is a desirable characteristic of longer-lived fish stocks (Figure 5). Age 2-5 individuals representing the 2019-2022 year classes comprise the majority of the current population (Figure 5). Bloater biomass in 2024 was highest in the main basin between Thunder and Hammond bays, which was near historical strongholds in the northern main basin at the outflow of the St. Marys River (Figure 6).

Rainbow Smelt—Trends in the abundance of Rainbow Smelt in the main basin varied by survey. Biomass of YAO Rainbow Smelt estimated from the bottom trawl survey has been declining since 2020, and the 2024 YAO biomass estimate was the seventh lowest in the time series, whereas acoustic biomass fluctuated without trend during the period 2020-2024 (Figure 7). Only two relatively strong Rainbow Smelt year classes have occurred over the past decade as estimated by both surveys (2019, 2021), and 2024 was estimated as another weak year class in both the acoustics and bottom trawl surveys (Figure 7). The main basin Rainbow Smelt population in 2024 consisted primarily of individuals with total length (TL) > 100 mm (Figure 8), which also reflected the low abundance of age-0 individuals, presumed to have TL < 90 mm (Gorman 2007). Rainbow Smelt biomass historically is higher in the North Channel than elsewhere in Lake Huron, but in 2023, areas of high biomass also included northwestern Georgian Bay (Figure 9).

Alewife— Abundance of Alewife in Lake Huron has remained at historically low levels since the collapse of the adult population in 2003. Biomass of YAO Alewife has been below detectable limits in both surveys since 2015 (Figure 10); however, in 2024, 9 adult individuals (age-2+) were sampled in the bottom trawl survey (Figure 11), which was the second highest catch of adult individuals in the past decade. YOY Alewife have been sampled in both surveys since 2017, but recent year classes, including 2024, are consistently smaller than when adult populations were at their peak (Figures 10, 11). Alewife populations in the main basin of Lake Huron during 2021-2024 consisted almost exclusively of age-0 individuals with total length less than 125 mm (Figure 11). Consistent sampling of YOY individuals indicates that small adult populations still exist in Lake Huron, possibly in nearshore areas or shallow bays not sampled in either survey.

Sculpin— Slimy Sculpin (*Cottus cognatus)* and Deepwater Sculpin (*Myoxocephalus thompsonii*) are benthic species that are sampled only in the bottom trawl survey. Sculpin abundance in the main basin peaked in the late 1990s, decreased during the 2000s, and has remained relatively low since, although biomass of both species has increased slightly since 2021 (Figure 12). Sculpin communities in the main basin consist almost entirely of Deepwater Sculpin due to the low abundance of Slimy Sculpin (Figure 12). Slimy Sculpin have become rare since 2010, as no individuals were collected during the years 2007-2010, 2014, 2015, 2019, and 2020. De Tour is the only port where Slimy Sculpin have been sampled since 2014, indicating their range also has contracted.

Round Goby—Round Goby (*Neogobius melanostomus*) is a non-native, bottom-dwelling fish species that was first captured in Lake Huron bottom trawls in 1997. Round Goby biomass in 2024 (1.57 kg/ha) was the highest observed in the time series and was over four times greater than in 2023 (Figure 12). Increased catches of Round Goby were particularly apparent at ports south of Hammond Bay (i.e., Alpena, Au Sable Point, Harbor Beach, and Goderich). Round Goby is more common in nearshore (depth < 9-m) areas but may seasonally migrate offshore (Pennuto et al. 2021, Walsh et al. 2007), which might explain why they are sometimes caught in high numbers in the bottom trawl survey. It was not immediately apparent why Round Goby in offshore areas were so much more abundant in 2024 than in previous years. It has been hypothesized that bottom trawls do not provide a robust estimate of Round Goby abundance (He et al. 2014), probably because of the species' preference for rocky, untrawlable habitats.

Cisco—Cisco is a pelagic species that is sampled only during the acoustics survey. Cisco have been most consistently sampled in Georgian Bay, the North Channel, and areas of the northern main basin adjacent to the North Channel. Cisco were infrequently observed in Georgian Bay and the North Channel until about 2015 when their biomass started increasing (Figure 13). Cisco Biomass in both systems leveled off in 2018, but thereafter after declined again in Georgian Bay, whereas Cisco biomass in the North Channel remained relatively stable until 2022 when their biomass increased again (Figure 13).

Summary and Conclusions

1. Status of the main basin prey fish community in 2024 was considered 'Fair.' Positive trends included the stable dynamics of main basin Bloater populations and evidence of continued recovery by Cisco in the North Channel. In contrast, growth and expansion of invasive Round Goby populations and low pelagic prey fish diversity are inconsistent with fish community objectives focused on species diversity and recovery of native species. Consistent trends in the abundance of major species indicates that prey fish populations in Lake Huron are matched to primary production and predator demands as specified by current fish community objectives.

2. Status of major prey fish stocks varied by species. Main basin stocks of Bloater were stable and healthy, although biomass has decreased likely due to changes in demographic factors that have interacted to suppress reproduction. Rainbow Smelt remained the second-most abundant prey species across much of Lake Huron, but main basin populations have produced multiple relatively weak year classes over the past decade including in 2024. Populations of Alewife, whose population collapsed in 2004, consist primarily of low numbers of age-0 individuals.

3. Status of benthic prey fish in the main basin in 2024 also varied by species. As in prior years, the native sculpin community in 2024 consisted primarily of Deepwater Sculpin because Slimy Sculpin abundance is historically low. In contrast, biomass of Round Goby, a non-native species that is ecologically similar to sculpin, reached an all-time high in 2024.

4. Cisco, which are the target of a large reintroduction effort in Saginaw Bay, continued to show signs of recovery across the northern part of the main basin and in the North Channel. North Channel Cisco populations also have sustained population increases first observed in 2016.

5. Use of complementary surveys (bottom trawl, acoustics) remains a useful tool for evaluating prey fish status in Lake Huron, where prey fish community dynamics vary by basin and species responses to changing environmental conditions are non-uniform.

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Figures

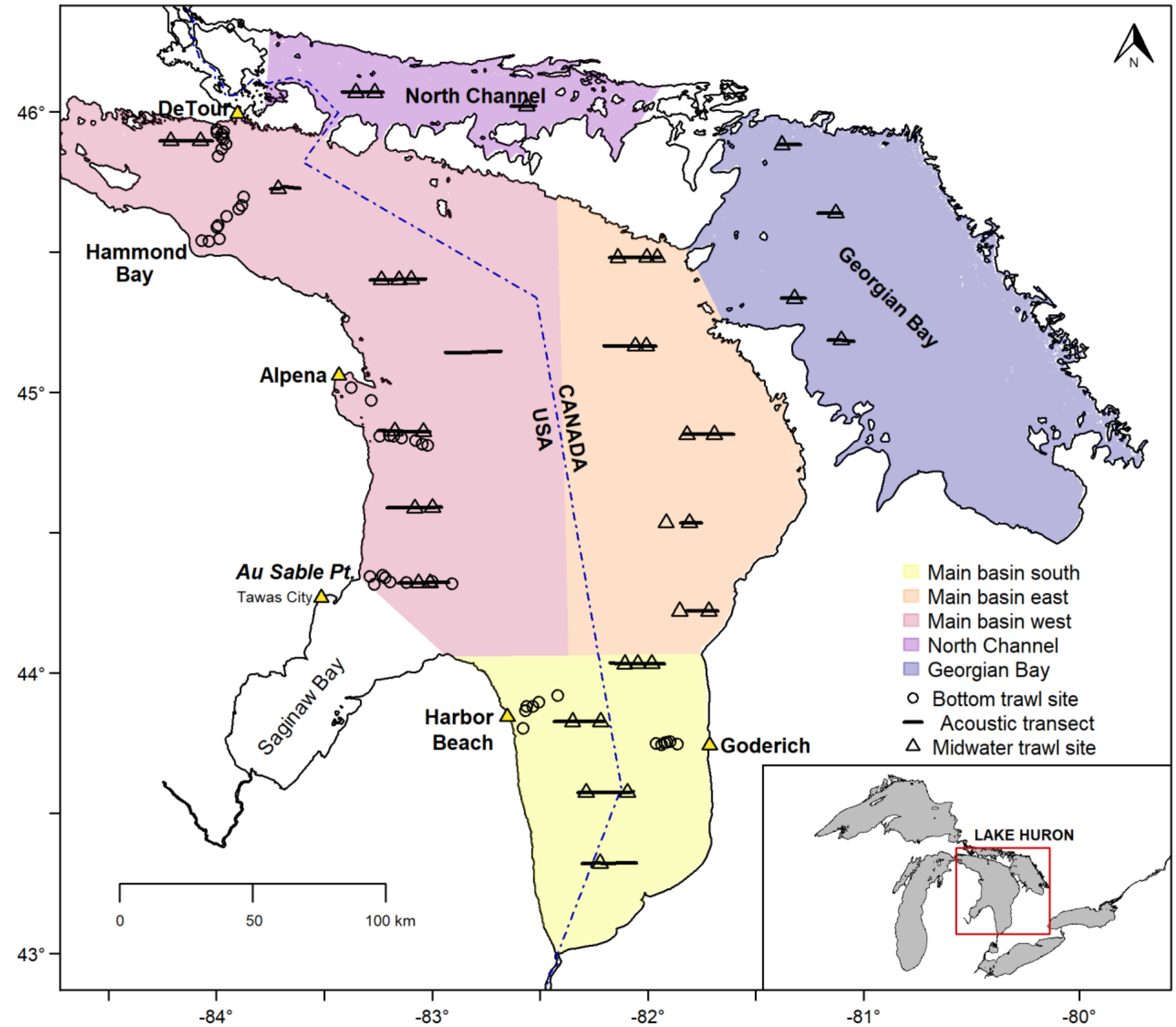

Figure 1. Location of bottom trawls, acoustic transects, and midwater trawls sampled in Lake Huron during 2024. Acoustic sampling strata (shaded areas) correspond to geographic regions: main-basin east, main-basin west, main-basin south, Georgian Bay, and North Channel. Saginaw Bay (unshaded) is not part of the standard bottom trawl or acoustics survey areas. The base map layer (gl_lakes_ESRI_100k.shp) was downloaded from the Great Lakes Aquatic Habitat Framework (https://hub.glahf.org/).

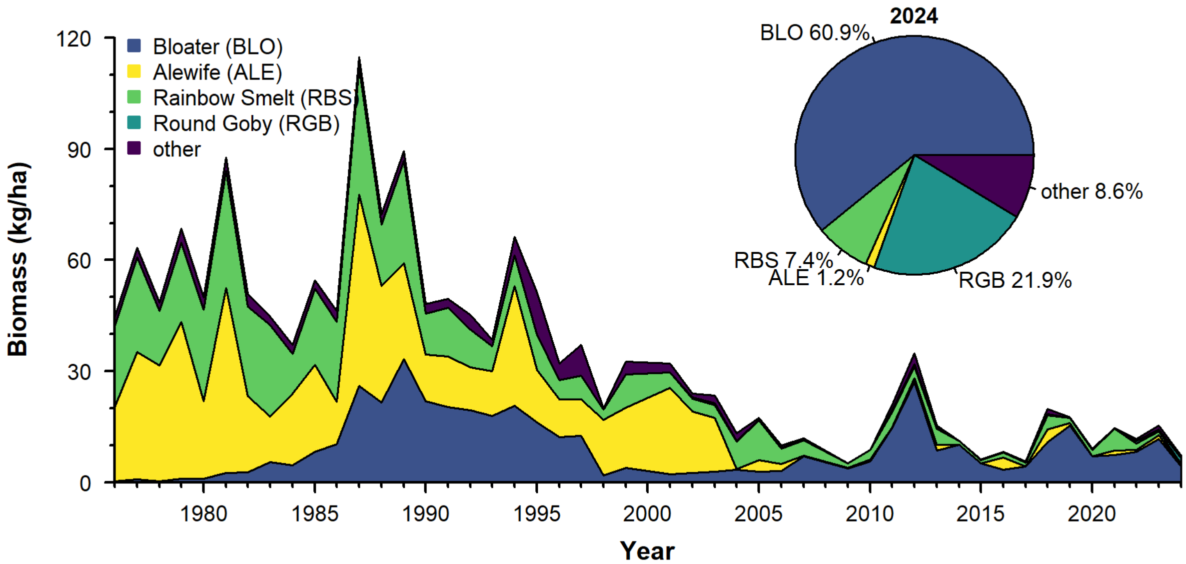

Figure 2. Biomass (kg/ha) and species composition of prey fish sampled in bottom trawls in the main basin of Lake Huron, 1976-2024 (pie chart: species composition by biomass in 2024).

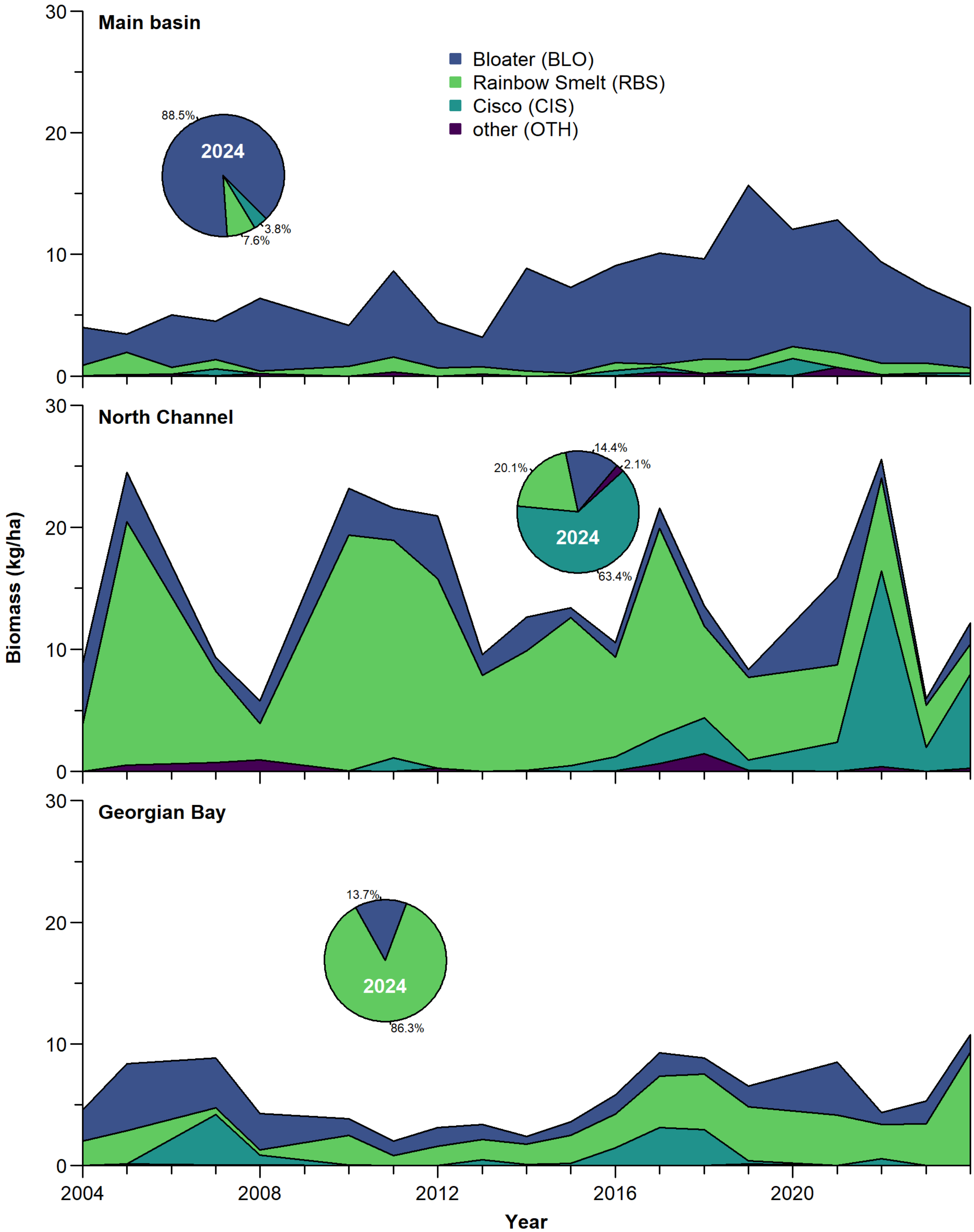

Figure 3. Acoustic prey fish biomass and species composition in Lake Huron by year and lake basin. Pie charts denote species composition by biomass in 2024.

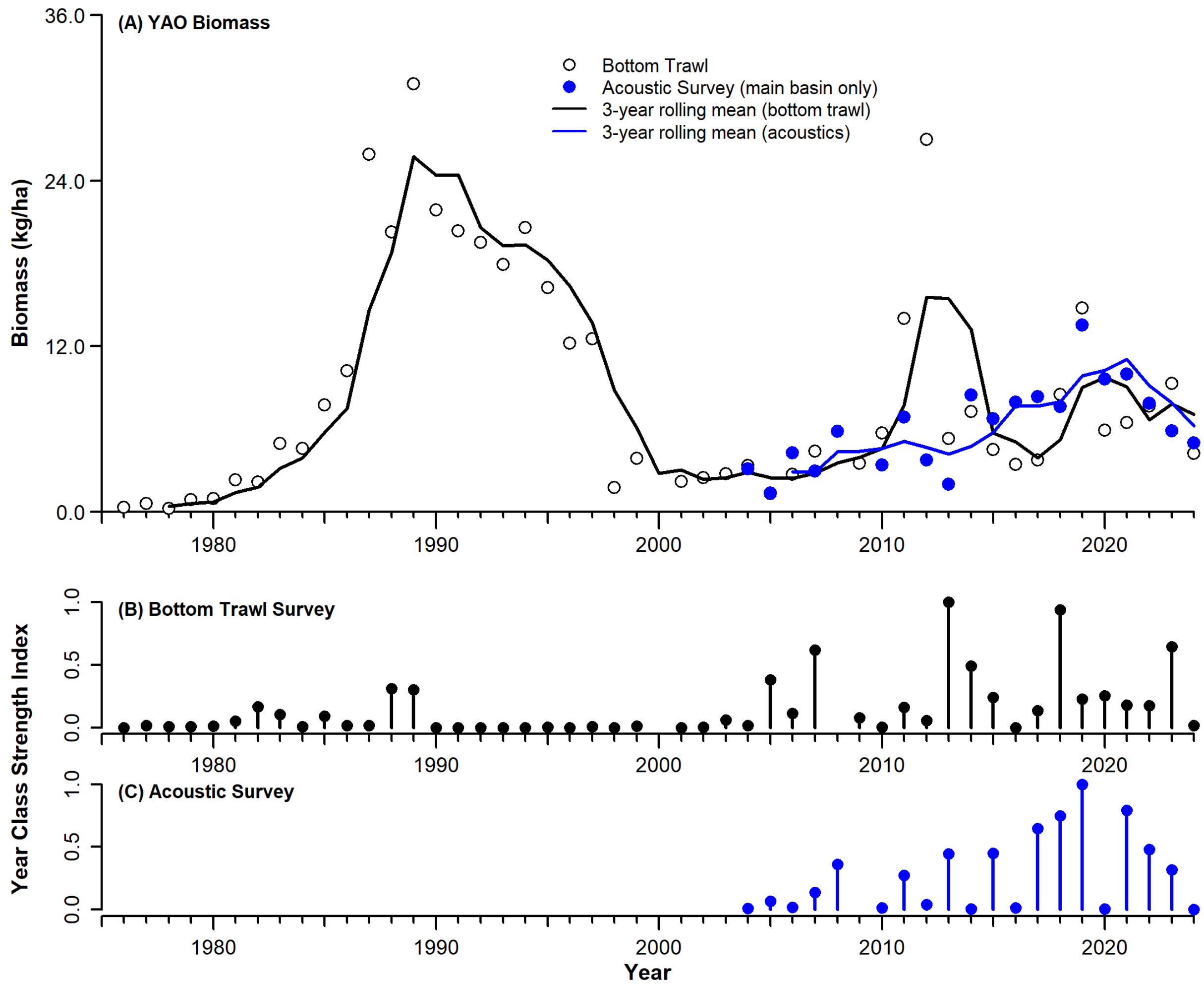

Figure 4. Biomass of yearling-and-older (YAO) Bloater *Coregonus hoyi* (A) and Bloater year-class strength (B, C) as estimated from annual USGS bottom trawl (1975-2024) and acoustics (2004-2024) surveys in the main basin of Lake Huron. Relative year-class strength was calculated as the mean annual density (#'s/ha) of YOY-sized fish divided by the maximum annual mean (index range: 0-1).

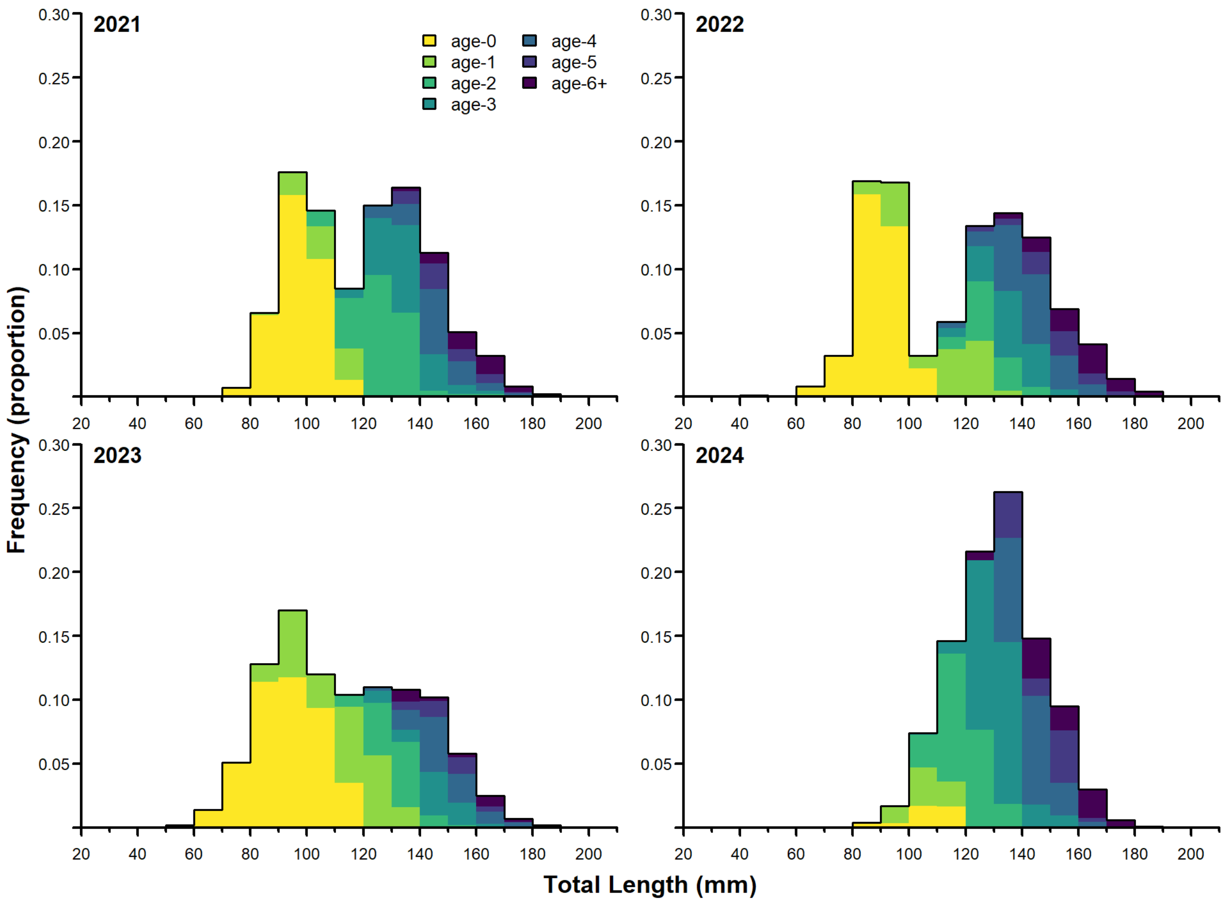

Figure 5. Length frequency and age composition of Bloater *Coregonus hoyi* sampled in bottom trawls conducted in the main basin of Lake Huron, 2021-2024. Ages were estimated from a subsample of up to 10 fish per 10-mm length bin for each port where Bloater were sampled and expanded to the total length frequency. Note that the 2024 Bloater age data has not yet completed quality assurance checks, so the 2024 length-age distribution should be considered provisionary.

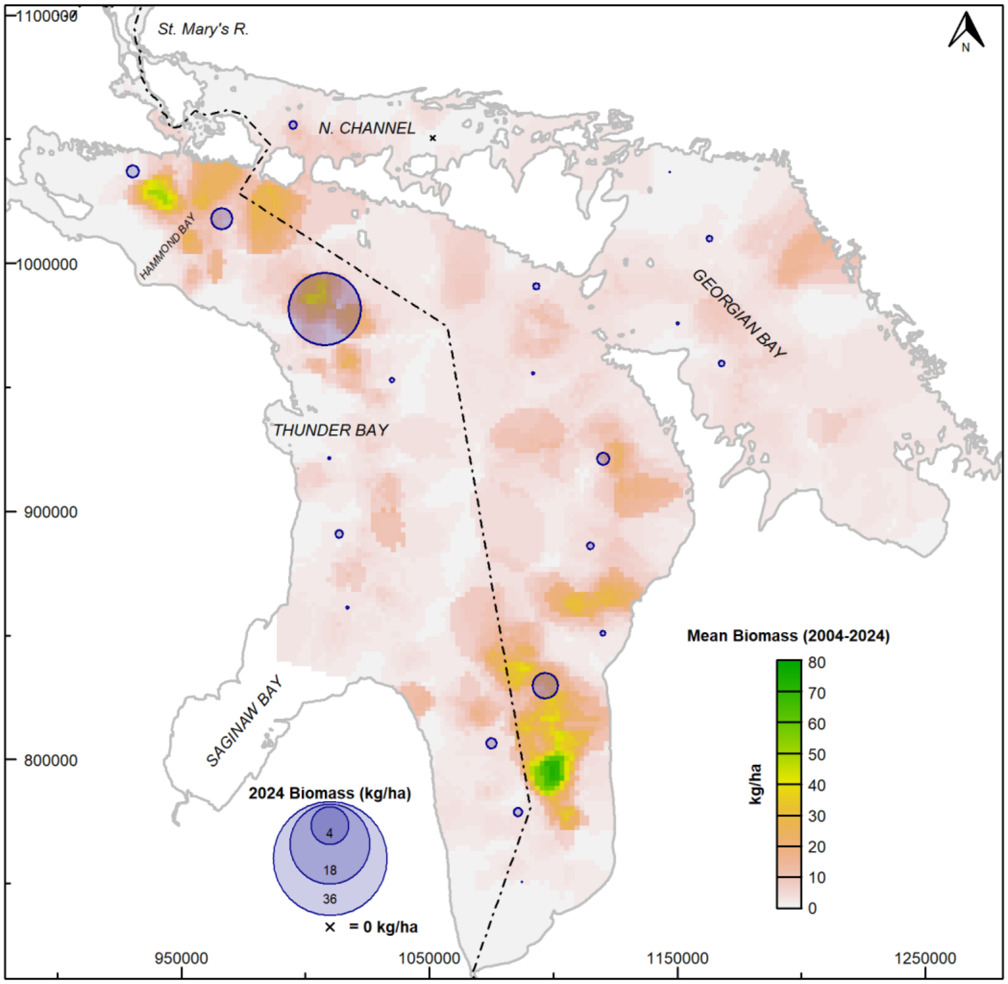

Figure 6. Distribution of Bloater *Coregonus hoyi* in Lake Huron for the most recent survey year, 2024 (bubbles), and mean distribution based on sampling during the period 2004-2024 (heat map). Bloater biomass was estimated solely from the acoustics-midwater trawl survey. Nearest-neighbor interpolation was used to extrapolate fish biomass from acoustic transects to the lake-wide scale. X's denote 2024 sampling transects where Bloater density = 0.0 kg/ha. The base map layer (gl_lakes_ESRI_100k.shp) was downloaded from the Great Lakes Aquatic Habitat Framework (https://hub.glahf.org/).

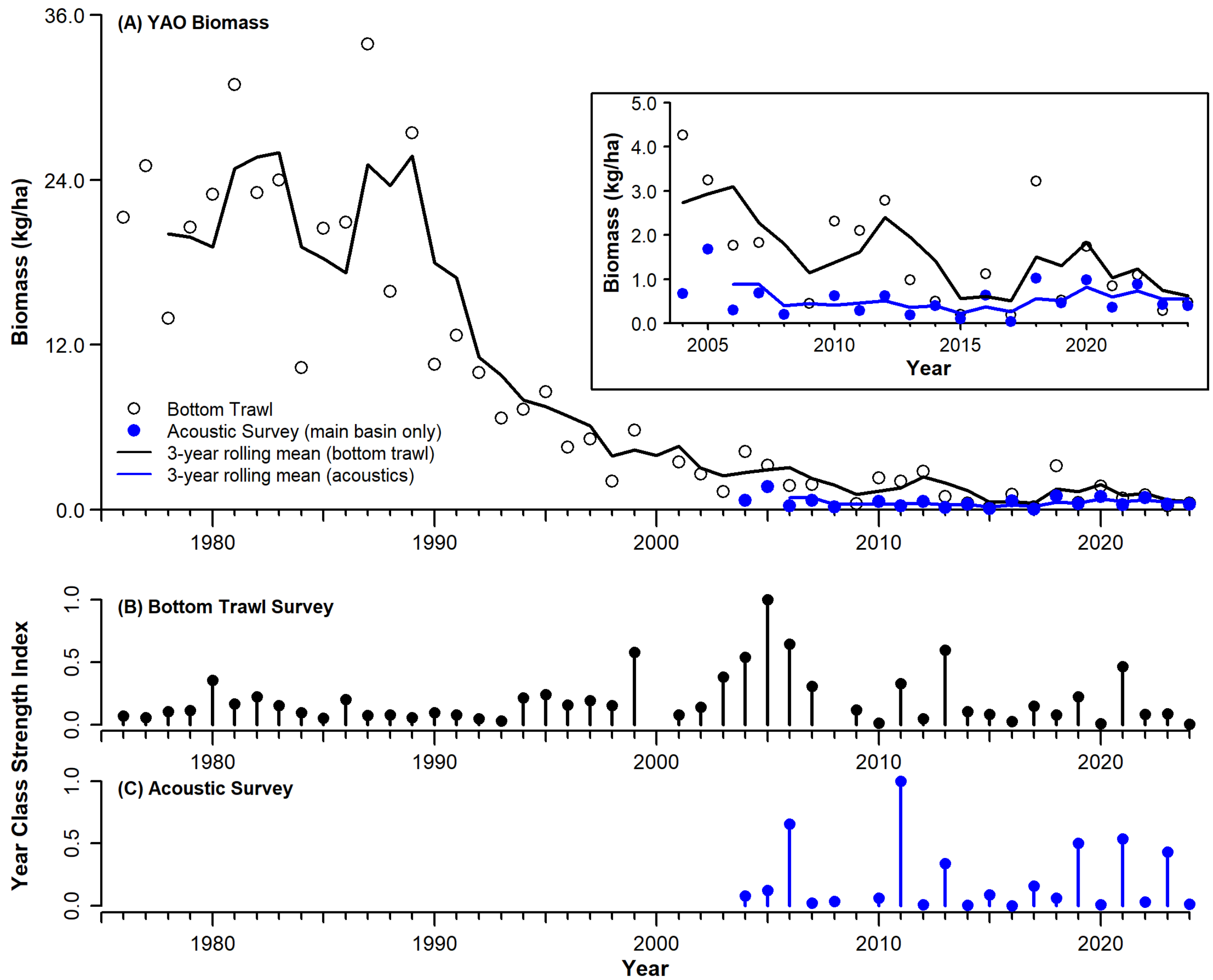

Figure 7. Biomass of yearling-and-older (YAO) Rainbow Smelt *Osmerus mordax* (A) and Rainbow Smelt year-class strength (B, C) as estimated from annual USGS bottom trawl (1975-2024) and acoustic (2004-2024) surveys in the main basin of Lake Huron. Inset: Biomass of yearling-and-older (YAO) Rainbow Smelt for the years 2004-2024. Relative year-class strength was calculated as the mean annual density (#'s/ha) of YOY-sized fish divided by the maximum annual mean (index range: 0-1).

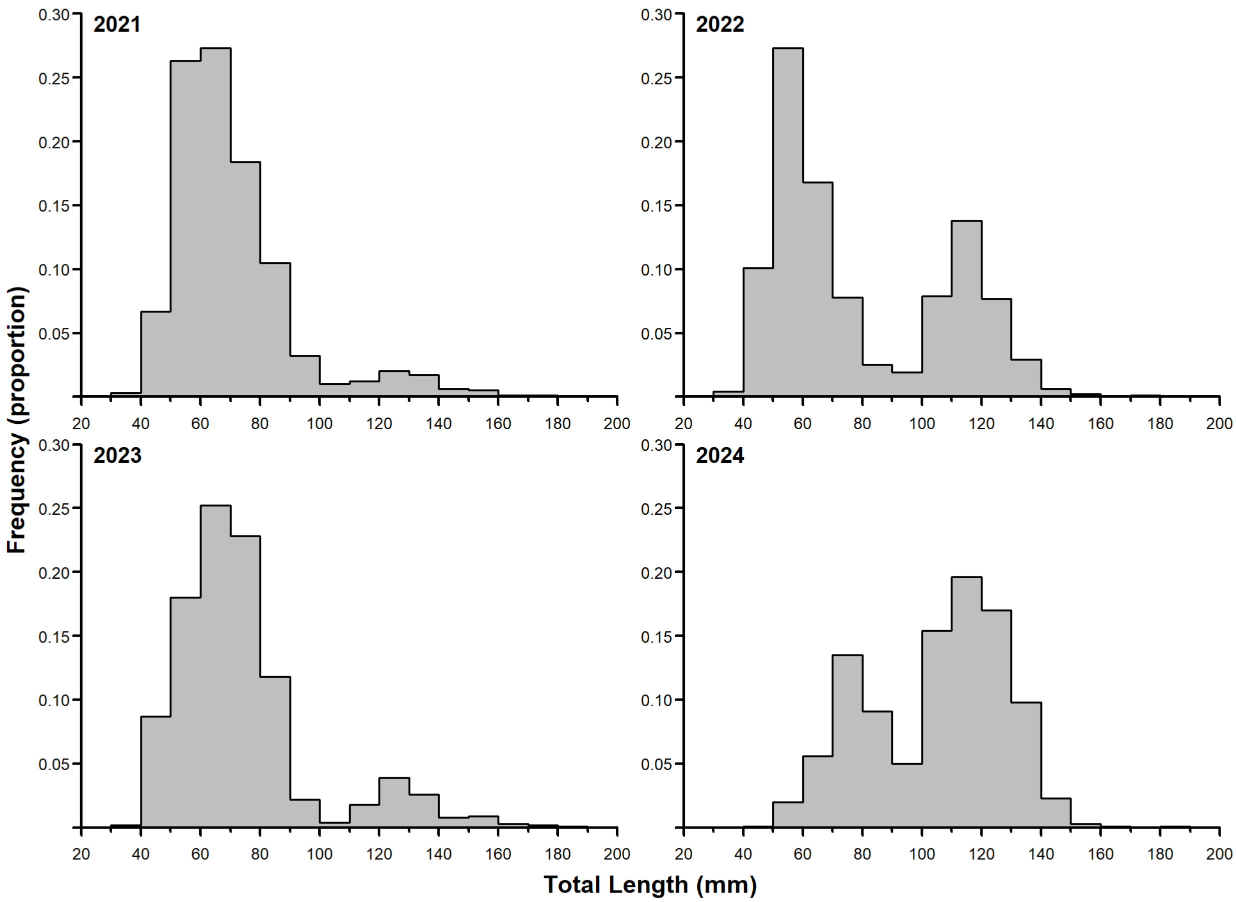

Figure 8. Length-frequency distribution for Rainbow Smelt *Osmerus mordax* sampled in the main basin of Lake Huron during 2021-2024.

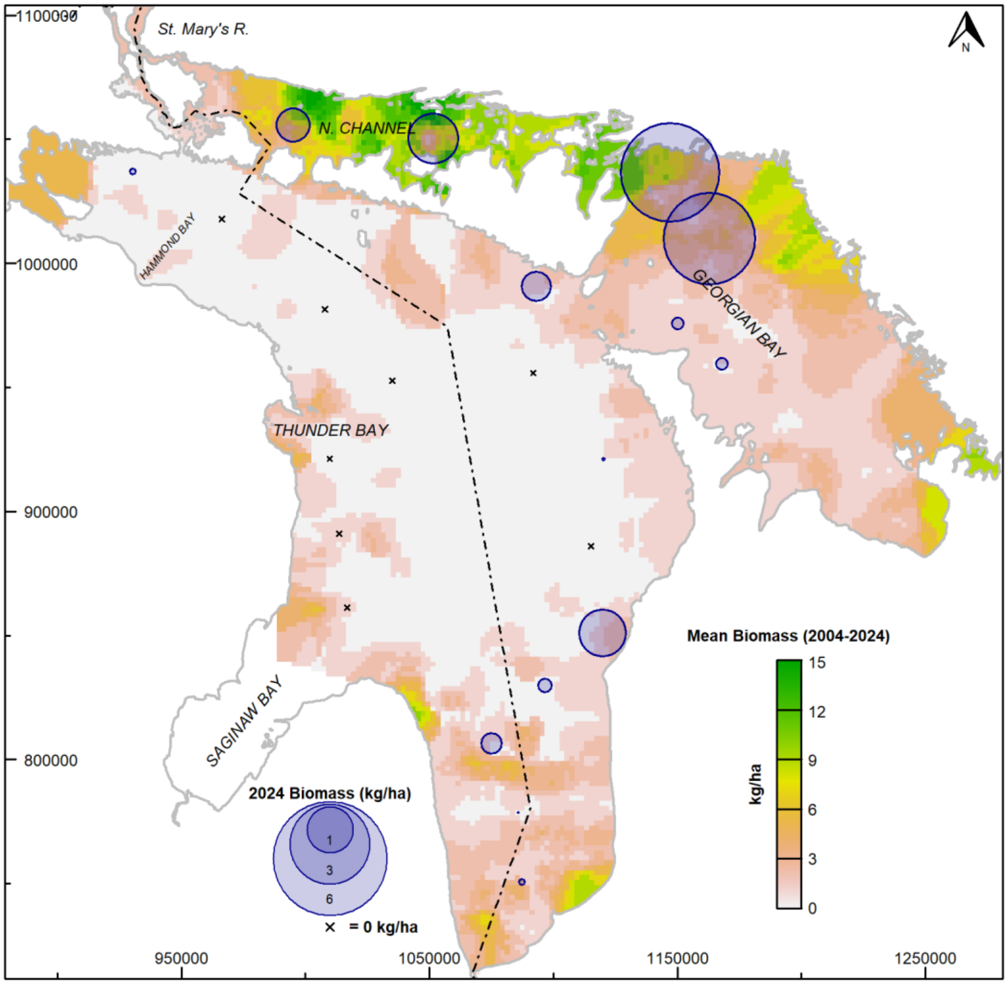

Figure 9. Distribution of Rainbow Smelt *Osmerus mordax* in Lake Huron for the most recent survey year, 2024 (bubbles), and mean distribution based on sampling during the period 2004-2024 (heat map). Rainbow Smelt biomass was estimated solely from the acoustics-midwater trawl survey. Nearest-neighbor interpolation was used to extrapolate fish biomass from acoustic transects to the lake-wide scale. X's denote 2024 sampling transects where Rainbow Smelt density = 0.0 kg/ha. The base map layer (gl_lakes_ESRI_100k.shp) was downloaded from the Great Lakes Aquatic Habitat Framework (https://hub.glahf.org/).

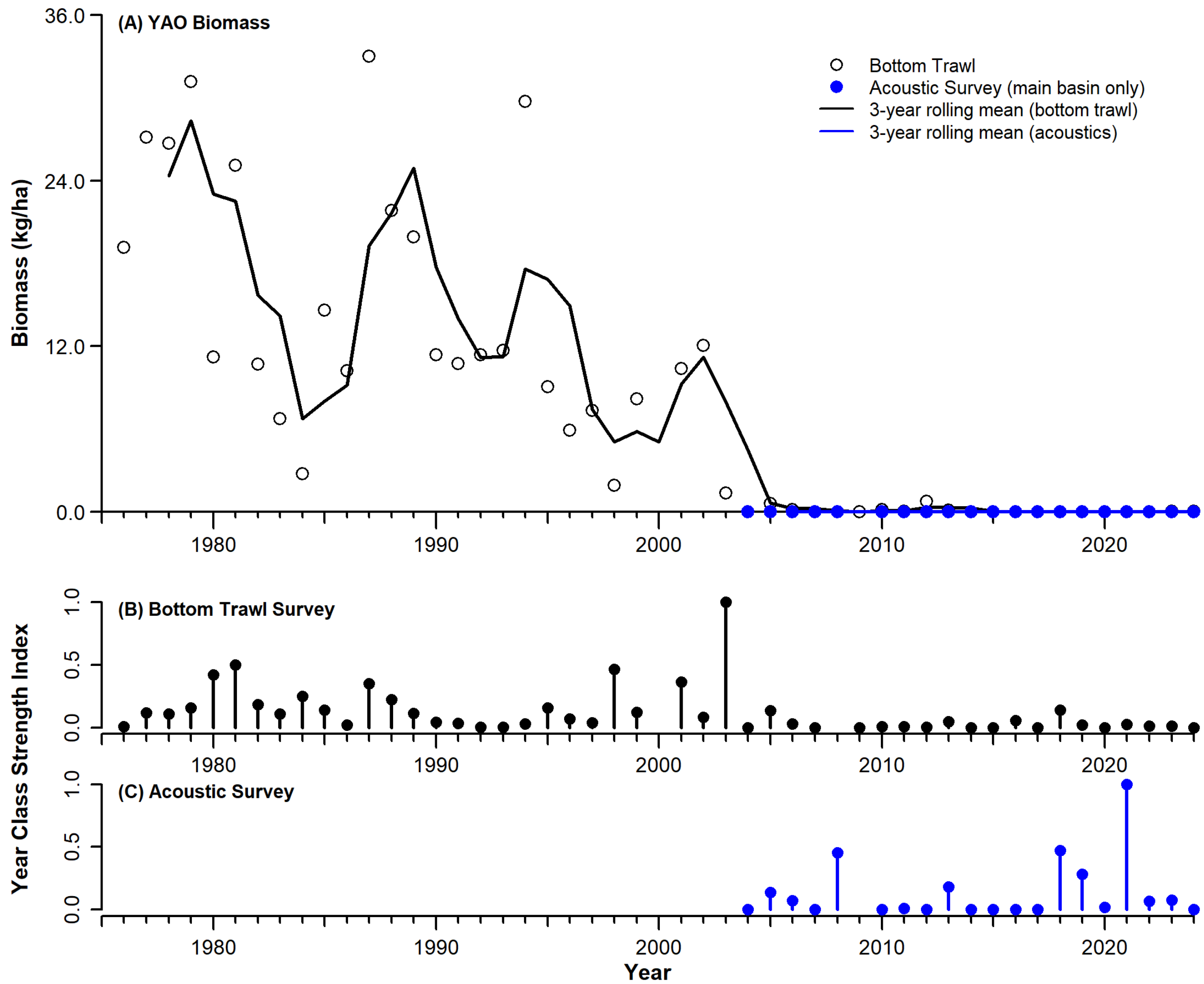

Figure 10. Biomass of yearling-and-older (YAO) Alewife *Alosa pseudoharengus* (A) and Alewife year-class strength (B, C) as estimated from annual USGS bottom trawl (1975-2024) and acoustic (2004-2024) surveys in the main basin of Lake Huron. Relative year-class strength was calculated as the mean annual density (#'s/ha) of YOY-sized fish divided by the maximum annual mean (index range: 0-1).

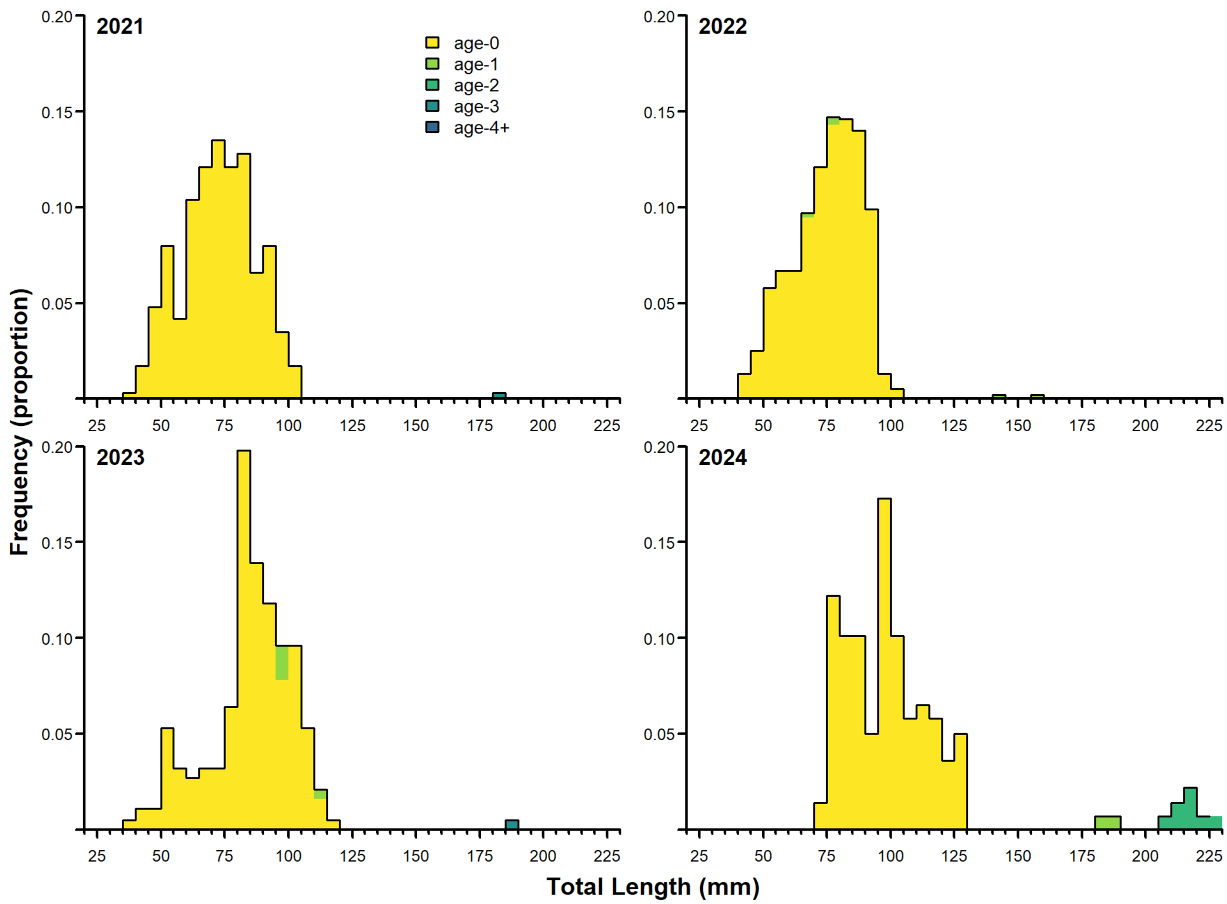

Figure 11. Length frequency and age composition of Alewife *Alosa pseudoharengus* sampled in bottom trawls conducted in the main basin of Lake Huron, 2021-2024. Ages were estimated from a subsample of up to 7 fish per 5-mm length bin for each port where Alewife were sampled and expanded to the total length frequency.

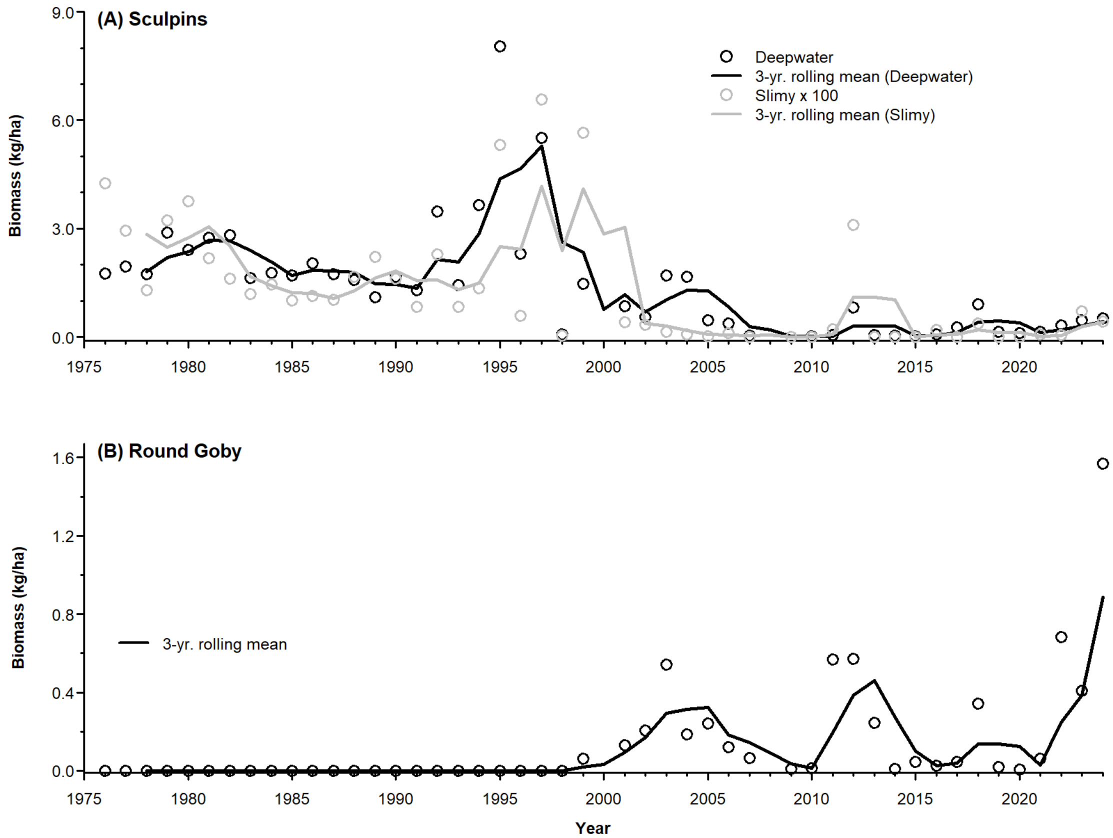

Figure 12. Biomass of sculpins—Slimy Sculpin *Cottus cognatus* and Deepwater Sculpin *Myoxocephalus thompsonii* (A)—and Round Goby *Neogobius melanostomus* (B) as estimated from annual bottom trawl surveys in the main basin of Lake Huron, 1976-2024. Slimy Sculpin biomass was multiplied by 100 to facilitate comparison of abundance trends between sculpin species.

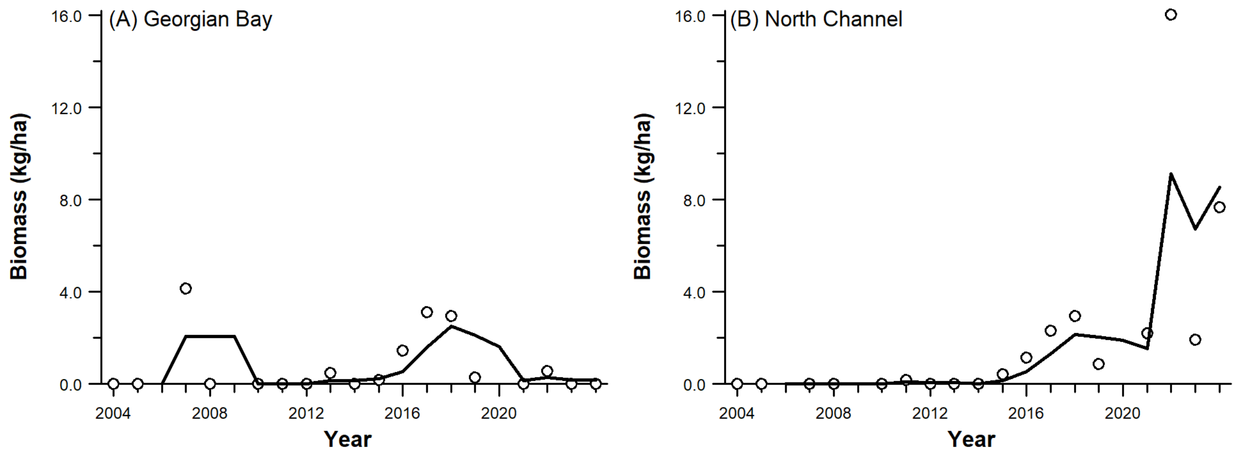

Figure 13. Biomass of Cisco *Coregonus artedi* in Georgian Bay (A) and the North Channel (B) as estimated from annual acoustics surveys in Lake Huron, 2004-2024. Lines represent 3-year rolling means.

Appendix

Table A1. Mean (±SE) prey fish biomass (g/ha) from the Bottom Trawl Survey (main basin) and Acoustics Survey (lake-wide) in Lake Huron by species in 2024. Biomass estimates for Alewife, Rainbow Smelt, Bloater, and Cisco are stratified by age class (YOY = young-of-year; YAO = yearling and older).

			Survey	
Common Name	**Scientific Name**	**Age Class**	*Bottom Trawl (g/ha)*	*Acoustics (g/ha)*
Alewife	*Alosa Pseudoharengus*	YOY	43.8 ± 22.7	0.2 ± 0.2
		YAO	41.4 ± 39.5	—
Bloater	*Coregonus hoyi*	YOY	95.5 ± 31.6	4.8 ± 1.5
		YAO	4259.5 ± 1219.5	4076.4 ± 1464.9
Cisco	*Coregonus artedi*	YOY	—	1.8 ± 1.4
		YAO	—	554.3 ± 255.5
Deepwater Sculpin	*Myoxocephalus thompsonii*		510.4 ± 54.7	—
Gizzard Shad	*Dorosoma cepedianum*		4.1 ± 2.4	—
Logperch	*Percina caprodes*		< 0.1	—
Ninespine Stickleback	*Pungitius pungitius*		31.1 ± 12.4	0.2 ± 0.1
Rainbow Smelt	*Osmerus mordax*	YOY	54.0 ± 22.7	1005.9 ± 828.0
		YAO	475.6 ± 125.3	1411.7 ± 684.5
Round Goby	*Neogobius melanostomus*		1568.3 ± 497.0	—
Slimy Sculpin	*Cottus cognatus*		4.3 ± 2.9	—
Spottail Shiner	*Notropis hudsonius*		0.2 ± 0.2	—
Threespine Stickleback	*Gasterosteus aculeatus*		—	16.4 ± 11.1
Trout-perch	*Percopsis omiscomaycus*		4.9 ± 3.3	—
Unidentified minnows	*Notropis spp.*		< 0.1	—
White Perch	*Morone americana*		2.0 ± 1.6	—
Yellow Perch	*Perca flavescens*		58.1 ± 27.4	—

Table A2. Mean (±SE) prey fish density (number/ha) from the Bottom Trawl Survey (main basin) and Acoustics Survey (lake-wide) in Lake Huron by species in 2024. Density estimates for Alewife, Rainbow Smelt, Bloater, and Cisco are stratified by age class (YOY = young-of-year; YAO = yearling and older).

			Survey	
Common Name	**Scientific Name**	**Age Class**	*Bottom Trawl (number/ha)*	*Acoustics (number/ha)*
Alewife	*Alosa Pseudoharengus*	YOY	6 ± 4	< 1
		YAO	1 ± 1	—
Bloater	*Coregonus hoyi*	YOY	13 ± 4	2 ± 0
		YAO	280 ± 86	174 ± 36
Cisco	*Coregonus artedi*	YOY	—	< 1
		YAO	—	1 ± 1
Deepwater Sculpin	*Myoxocephalus thompsonii*		98 ± 10	—
Gizzard Shad	*Dorosoma cepedianum*		< 1	—
Logperch	*Percina caprodes*		< 1	—
Ninespine Stickleback	*Pungitius pungitius*		16 ± 7	< 1
Rainbow Smelt	*Osmerus mordax*	YOY	24 ± 10	405 ± 336
		YAO	56 ± 14	247 ± 130
Round Goby	*Neogobius melanostomus*		336 ± 95	—
Slimy Sculpin	*Cottus cognatus*		1 ± 0	—
Spottail Shiner	*Notropis hudsonius*		< 1	—
Threespine Stickleback	*Gasterosteus aculeatus*		—	20 ± 14
Trout-perch	*Percopsis omiscomaycus*		1 ± 0	—
Unidentified minnows	*Notropis spp.*		< 1	—
White Perch	*Morone americana*		< 1	—
Yellow Perch	*Perca flavescens*		3 ± 1	—