Status and Trends of the Lake Huron Prey Fish Community, 1976-2020[1,2,3]

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Abstract

The United States Geological Survey-Great Lakes Science Center (USGS-GLSC) has assessed annual changes in the offshore prey fish community of Lake Huron since 1973. Assessments are based on a bottom trawl survey conducted in October and an acoustics-midwater trawl survey conducted in September-October. In 2020, USGS-GLSC vessels were not permitted to cross into Canada due to the COVID-19 pandemic, so prey fish surveys sampled only sites in U.S. (Michigan) waters of Lake Huron. This prevented USGS from providing information about the current status and trends of prey fish communities in Georgian Bay and the North Channel. Prey fish biomass in U.S. waters of Lake Huron in 2020 remained below levels observed prior to community-wide declines that began in the early to mid-1990s. Fish community biomass was dominated by two species, Bloater (*Coregonus hoyi*) and Rainbow Smelt (*Osmerus mordax*). While both surveys found Bloater biomass in the main basin had declined from levels observed in 2019, Bloater still comprised over three-quarters of prey fish biomass in Lake Huron in 2020. Biomass and abundance for other prey fish species were within the range observed over the past five years. Current low biomass of invasive species like Alewife (*Alosa pseudoharengus*) and Rainbow Smelt is consistent with fish community objectives focused on restoration of native fish communities. Reduced lake productivity, predation by a recovering piscivore community, and shifts in food web dynamics that favor fish production in nearshore environments may prevent

prey fish biomass in offshore areas from returning to levels observed prior to the early 1990's. However, the dominance of Bloater in bottom trawl catches and acoustic surveys suggests that current lake conditions are conducive to the recovery of some native species.

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[1] The data associated with this report have not received final approval by the U.S. Geological Survey (USGS) and are currently under review. The Great Lakes Science Center is committed to complying with the Office of Management and Budget data release requirements and providing the public with high quality scientific data. We plan to release all USGS research vessel data collected between 1958 and 2020 and make those publicly available. Please direct questions to our Information Technology Specialist, Scott Nelson, at snelson@usgs.gov.

[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.

[3] *COVID Impacts Statement*—As was the case for all Great Lakes fisheries management and research agencies, the impacts of the COVID-19 pandemic on the Center's deepwater science work in 2020 were significant. The most severe impacts were related to deepwater science cruises scheduled in the spring/early summer, and those requiring extended overnight stays on vessels. In addition, USGS vessels could not get clearance to cross into Canadian waters as a result of the pandemic. Because of these limitations, reporting for 2020 deepwater science surveys are limited in scope, and in some cases, limited in the ability to make meaningful comparisons to data from previous years.

Introduction

Lake Huron historically supported a diverse and abundant prey fish community that provided food for native piscivores and commercial and recreational fishing opportunities (Berst and Spangler 1972). The endemic prey fish community in offshore waters (depth ≥ 9-m) included several species of deepwater Cisco (*Coregonus hoyi*, *C. johannae*, *C. kiyi*, *C. nigrippinis, C. zenithicus*, *C. reighardi*, *C. alpenae*) and at least two species of Sculpin (Cottidae). Deepwater ciscoes and Sculpin were the primary prey of Lake Trout (*Salvelinus namaycush*), which sustained a large commercial fishery. Cisco (*C. artedi*) likely roamed the entire lake but mainly inhabited depths above the thermocline. Native prey fish in nearshore areas (depth < 9 m) included Yellow Perch (*Perca flavescens*) and Emerald Shiner (*Notropis atherinoides*).

Overfishing, introduction of exotic species, and habitat degradation precipitated major shifts in the Lake Huron prey fish community beginning in the late nineteenth century. Unsustainable harvest resulted in the extirpation of deepwater ciscoes except for Bloater (*C. hoyi*) and main basin populations of Cisco (*C. artedi*) by the early 1900s. Pollution and eutrophication of spawning habitats in Saginaw Bay also may have contributed to Cisco declines (Berst and Spangler 1972). Losses of native prey species and commensurate declines in native piscivores such as Lake Trout and Burbot (*Lota lota*) created vacant niche space that was exploited by exotic Rainbow Smelt (*Osmerus mordax*) and Alewife (*Alosa pseudoharengus*), which were first detected in Lake Huron in 1925 and 1951, respectively. By the late 1950s or early 1960s, the Lake Huron prey fish community consisted mainly of Rainbow Smelt, Alewife, and Bloater (Berst and Spangler 1972). Starting in 1968, Pacific Salmon (*Oncorhynchus* spp.) were stocked into Lake Huron to create a sport fishery and to control populations of Alewife and

Rainbow Smelt (Johnson et al. 2010). Stocking of Lake Trout commenced in 1970 in an effort to rehabilitate native predator populations (Eshenroder et al. 1995).

Quantitative assessment of the Lake Huron prey fish community was soon a critical need of fishery managers who were concerned that stocking rates of Pacific salmon and Lake Trout might exceed levels that could be supported by the available prey base. Assessment of the Lake Huron prey fish community also was considered necessary to address potential negative impacts of exotic prey fish (e.g., Alewife) on native fish populations and food web dynamics (Crowder 1980, Evans and Loftus 1987, Madenjian et al. 2008, Smith 1970). To address the need for prey fish assessment, the United States Geological Survey-Great Lakes Science Center (USGS-GLSC) began annual bottom trawl surveys on Lake Huron in 1973 and added an integrated acoustic-midwater trawl survey starting in 2004. Addition of the acoustic survey was a response to concerns that bottom trawls were under-sampling pelagic fish (Fabrizio et al. 1997, Stockwell et al. 2006, Yule et al. 2008). Both surveys were designed to assess prey fish communities in "offshore" waters (depth ≥ 9 m).

Numerous ecosystem changes have occurred during the time periods covered by the trawl and acoustic surveys that have the potential to influence the Lake Huron prey fish community. These include widespread Sea Lamprey (*Petromyzon marinus*) control which began in 1960s; rapid declines in offshore nutrient concentrations and primary productivity over the past two decades (Barbiero et al. 2018, Stadig et al. 2020); introduction of Dreissenid mussels and declines in the abundance of the benthic amphipod *Diporeia* spp. during the 2000s (McNickle et al. 2006, Nalepa et al. 2005, Nalepa et al. 2007); significant changes in the abundance and species composition of phytoplankton and zooplankton (Barbiero et al. 2009, Barbiero et al. 2018, Burlakova et al. 2018); reduced Chinook Salmon (*O. tshawytscha*) abundance (Bence and

He 2015, Dettmers et al. 2012); the introduction (in 1990) and rapid proliferation of the Round Goby (*Neogobius melanostomus*); and recovery of predators such as Lake Trout and Walleye (*Sander vitreus*) (Fielder et al. 2007, Riley et al. 2007).

The goal of this report is to describe and explain changes in the Lake Huron prey fish community from 1976 (the first year of a complete bottom trawl survey) through 2020, the most recent year of data collection. Due to the COVID-19 pandemic, USGS vessels were not permitted to cross into Canada in 2020, so bottom trawl and acoustic surveys sampled only sites in U.S. (Michigan) waters of Lake Huron. The reduced spatial scope of sampling prevented the USGS from providing the latest information on the status and trends of prey fish communities in Georgian Bay and the North Channel. However, the bottom trawl survey samples only one Canadian port, which was not added to the survey until 1998, so bottom trawl estimates of prey fish biomass in the main basin in 2020 are comparable to the remainder of the time series. Report objectives are to 1) describe temporal trends in biomass and species composition of the Lake Huron prey fish community, 2) assess temporal change in the abundance of dominant species (Alewife, Bloater, and Rainbow Smelt), and 3) describe abundance trends and population characteristics of other prey fish species of interest to fishery managers.

Methods

Bottom Trawl Survey—The GLSC has monitored prey fish abundance annually from 1973-2020 using 12-m headrope (1973-1991) and 21-m headrope (1992-2019) bottom trawls at fixed transects at up to eleven depths (9, 18, 27, 36, 46, 55, 64, 73, 82, 92, and 110 m) at five ports (De Tour, Hammond Bay, Alpena, Au Sable Point, and Harbor Beach) in Michigan waters of Lake Huron (Figure 1). Sampling has been conducted at Goderich (Ontario) since 1998 using the same trawling protocols that are used at U.S. ports. The bottom trawl survey was conducted between mid-October and early November most years. Single 10-min bottom trawl tows were conducted during daylight at each transect each year. Trawl catches were sorted by species and each species was counted and weighed in aggregate. For Alewife, Rainbow Smelt, and Bloater, length cut-offs (Table 1) were determined from length-frequency data and used to apportion bottom trawl catches into age-0 fish (young-of-the-year, or YOY) and those age-1 or older (yearling and older, or YAO). Mean catch weighted by the area of the main basin occurring within 10-m depth strata was used to generate a main-basin estimate of abundance expressed in density (number/ha) or biomass (kg/ha) for individual species or species-age groups. Data from surveys prior to 1976, and in 1992, 1993, 1998, 2000, and 2008 were excluded from analyses because surveys were conducted in a non-standard manner (1973-1975, 1992, 1993, 1998) or were not completed (2000, 2008). Additional details concerning survey design and data analysis are provided in the 2019 report (Hondorp et al. 2020).

Acoustic 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). Sampling effort (number of transects per region) is proportional to region size (See Figure 1). For data analyses, each transect was divided into 3,000 m horizontal units, or "intervals," which comprise the elementary sampling units (ESUs) within which fish density is summarized (Adams et al. 2006). 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 along each acoustic transect were used to identify species composition of acoustic targets. Acoustic density of Alewife, Rainbow Smelt, and Bloater was apportioned by age group (YOY vs. YAO) using fixed length cut-offs determined from age-length relationships (see Table 1). Lake-wide fish abundance expressed in density (number/ha) or biomass (kg/ha) was estimated as the weighted average of acoustic fish density, with region area as the weighting variable. Additional details concerning survey design and data analysis are provided in the 2019 report (Hondorp et al. 2020).

Data analysis— Bottom trawl and acoustic data were not integrated into a single time series due to differences between surveys in sampling gear, survey design, and observation period. Data from both surveys were used to quantify prey fish community biomass and species composition (Objective 1) and to describe abundance of individual species (Objectives 2, 3). Abundance was expressed in density (numbers/ha) for YOY Alewife, Rainbow Smelt, and Bloater. Biomass (kg/ha) was used to describe abundance of YAO Alewife, Rainbow Smelt, and Bloater and all species that were not subdivided by age group.

Results and Discussion

Survey overview—The Lake Huron acoustics and bottom trawl surveys were completed during 17 September - 10 October 2020 and 11-22 October 2020, respectfully. Due to the COVID-19 pandemic, USGS vessels were not permitted to cross into Canada, so prey fish surveys sampled only sites in U.S. (Michigan) waters of Lake Huron. Consequently, the acoustic survey was not able to assess status of prey fish communities in the eastern main basin, the North Channel, and Georgian Bay, which are predominantly located in Canadian waters (Figure 1). Sixteen acoustic transects were sampled, and 27 midwater trawl tows were conducted in conjunction with acoustic data collection (Figure 1). The bottom trawl survey sampled all standard transects and ports (41 trawl tows) except for sites off Goderich, ON, which are in Canadian waters (Figure 1). A total of 18 species were captured in the prey fish surveys in 2020: Bloater, Rainbow Smelt, Alewife, Ninespine Stickleback *Pungitius pungitius*, Threespine Stickleback *Gasterosteus aculeatus*, Cisco (acoustics only), Emerald Shiner Notropis *atherinoides* (acoustics only), Deepwater Sculpin *Myoxocephalus thompsoni* (bottom trawl only), Trout-perch *Percopsis omiscomaycus* (bottom trawl only), Round Goby (bottom trawl only), White Bass *Morone chrysops* (bottom trawl only), White Perch *Morone americanus* (bottom trawl only), Yellow Perch *Perca flavescens* (bottom trawl only), Lake Trout (bottom trawl only), Lake Whitefish *C. clupeaformis*, Round Whitefish *Prosopium cylindraceum* (bottom trawl only), Walleye (bottom trawl only), and Common Carp *Cyprinus carpio* (bottom trawl only).

Community biomass and species composition— Prey fish biomass in the region sampled by the bottom trawl and acoustic surveys in 2020 averaged 9.1 kg/ha and 12.1 kg/ha respectively (Figures 2, 3). Bloater was the dominant species in both surveys and accounted for 78% (bottom trawl) to 80% (acoustics) of prey fish biomass (Figures 2, 3). The only other abundant species in 2020 prey fish surveys were Rainbow smelt, which accounted for 20% and 8% of prey fish sampled in the bottom trawl and acoustic surveys (Figure 2), respectively, and Cisco, which comprised 12% of prey fish sampled in the acoustics survey (Figure 3). Cisco were sampled only in the acoustics survey and were collected only at transects near Detour (see Figure 1). All other prey fish species combined accounted for less than 3% (by weight) of prey species sampled in both surveys.

Bloater— Biomass of YAO bloater estimated from 2020 bottom trawls (5.6 kg/ha) was lower than in 2019 (8.5 kg/ha) but remained in the range of values observed since 2013 (Figure 4A). Biomass of YAO bloater estimated from the acoustic survey also decreased from 2019 (13.5 kg/ha) to 2020 (9.6 kg/ha) (Figure 4B). Bloater have been the most abundant prey fish in the main basin of Lake Huron over the past decade but are not a major component of piscivore diets (Happel et al. 2017, Roseman et al. 2014).

Large Bloater year classes have occurred more frequently since the basin-wide collapse of Alewife in 2004 (Figure 4C), which is consistent with the hypothesized negative effect of Alewife on Bloater recruitment (Collingsworth et al. 2014). Density of YOY Bloater in Lake Huron in 2020 declined dramatically from levels observed in 2018 and 2019 (Figures 4C, 4D). Acoustic density of YOY Bloater in 2020 (4 fish/ha) was the second lowest in the time series, and the bottom trawl estimate (226 fish/ha) was the third lowest density in the past decade.

In 2020, Bloater within Michigan waters of the main basin were most abundant north of Thunder Bay (Figure 5). Main-basin Bloater populations in 2020 consisted mainly of individuals with total length (TL) between 100 mm and 160 mm. Frequency of large bloater (TL > 150 mm) was greater in midwater trawls than in bottom trawls (Figure 5).

Rainbow Smelt—Biomass of YAO Rainbow Smelt in Lake Huron was greatest before 1990 (Figure 6A), exhibited a decreasing trend between 1991 and 2003, and has remained low ever since (Figure 6A). Biomass of YAO Rainbow Smelt in the main basin in 2020 was 1.7 kg/ha and 1.0 kg/ha for the bottom trawl and acoustic surveys, respectively, and has fluctuated without trend since 2004 (Figure 6B). Rainbow Smelt were introduced into Lake Huron in the 1920's and were a dominant member of the Lake Huron prey fish community by the time the GLSC prey fish surveys commenced in 1973 (Berst and Spangler 1972). Despite declines in their numbers, YAO Rainbow Smelt remain important prey for Chinook salmon, Lake Trout, and Walleye in Lake Huron (Diana 1990, Roseman et al. 2014).

Abundance of YOY Rainbow Smelt in Lake Huron has fluctuated with few distinct trends (Figures 6C, 6D). In 2020, density of YOY Rainbow Smelt estimated from the bottom trawl and acoustic surveys was 42 fish/ha and 16 fish/ha, respectively. Large spikes in YOY density since 1999 may have been the result of declines in YAO Rainbow Smelt, which are known to cannibalize smaller individuals (Henderson and Nepszy 1989). However, smelt recruitment may be limited by other factors as these strong reproductive events have so far failed to kindle recovery of the YAO population.

Rainbow Smelt were widely distributed in Michigan waters of Lake Huron in 2020 but were most abundant south of Thunder Bay (Figure 7). Large concentrations of Rainbow Smelt were found in outer Saginaw Bay and at the extreme southern end of the main basin near Port Huron, MI (Figure 7). Size distributions of Rainbow Smelt 2020 were bimodal with the peak at 30-80 mm TL representing the 2020 year-class, and the peak at 90-150 mm TL representing YAO individuals (Figure 7).

Alewife—Alewife are the preferred prey of piscivorous fish in Lake Huron (Diana 1990, Happel et al. 2017, Roseman et al. 2014) and were the first- or second-most abundant prey species in Lake Huron until 2004 when YAO individuals disappeared from trawl catches (Figure 8A). Catches of Alewife since 2004 have consisted almost exclusively of age-0 individuals (Figures 8B, 8C, and 8D), and, in 2020, all individuals sampled in the bottom trawl and acoustic surveys were age-0. Relative abundance of age-0 Alewife estimated from the bottom trawl and acoustic surveys in 2020 was 3 and 7 fish/ha, respectively. The median total length of Alewife sampled in bottom and midwater trawls in 2020 was 81 mm (n = 55).

Causes of the Alewife decline in Lake Huron have been debated and include unsustainable levels of predation by salmon and Lake Trout (He et al. 2015), a severe winter mortality event in 2003 (Dunlop and Riley 2013), bottom-up forces related to nutrient reduction (Kao et al. 2016), Dreissenid mussel-induced disruption of inshore-offshore energy exchange (Barbiero et al. 2018), and declines in the abundance of the benthic amphipod *Diporeia* spp., an important Alewife prey (Nalepa et al. 2007). We hypothesize that the severe winter of 2002-03 reduced the adult Alewife population to historically low levels, but that recovery of the adult population presently is restricted both by bottom-up and top-down forces. Alewife abundance and population dynamics are more influenced by nutrients and primary production in Lake Huron than in Lake Michigan (Bunnell et al. 2014, Collingsworth et al. 2014), so we concur with Kao et al. (2016) that reductions in phosphorous inputs to Lake Huron and the sequestration of nutrients in Dreissenid mussel biomass has likely reduced Alewife carrying capacity below historical levels. Predation by a recovering lake trout population may keep alewife biomass below current carrying capacity if they and other predators are sustained by alternate prey (e.g., Round Goby) when alewife are unavailable (He et al. 2015, Madenjian et al. 2013).

Sculpin——Historically, Slimy Sculpin *Cottus cognatus* and Deepwater Sculpin were important prey of the native piscivore community in deep, offshore waters of Lake Huron (Van Oosten and Deason 1938). Juvenile and adult sculpins are confined to the lake bottom, so they are sampled only during the bottom trawl survey. Sculpin populations in Lake Huron declined gradually between 1976 and 1992, experienced a brief resurgence in the middle to late 1990s, and then declined rapidly in the early to mid 2000's (Figure 9A). Slimy Sculpin have become rare over the past decade (2010-2020), with surveys failing to collect a single individual in 2010, 2014, 2015, 2019, and 2020. The current low abundance of sculpin in Lake Huron coincides with the expansion and proliferation of a potential competitor, the Round Goby, as well as the decline of an important prey, *Diporeia* spp.

Round Goby—Round Goby have become a significant part of Lake Trout diets in some areas of the Great Lakes (Dietrich et al. 2006), including Lake Huron (Roseman et al. 2014). Round Goby were first captured in the Lake Huron bottom trawl survey in 1997, reached a peak in abundance in 2003, and declined in abundance until increasing again in 2011-2012 and 2018 (Figure 9B). Our results suggest that they were at relatively low abundance in the offshore waters of Lake Huron in 2020 (Figure 9B). However, the bottom trawl may not provide a robust estimate of lake-wide Round Goby biomass because gobies are thought to prefer rocky (i.e., untrawlable) habitat(s) not sampled in GLSC surveys. Round Goby also may seasonally migrate offshore (Walsh et al. 2007), which could explain why they are sometimes caught in high numbers in the bottom trawl survey.

Cisco—Cisco is a native planktivore that was once common in offshore areas throughout Lake Huron. They were overfished to historically low abundance, and most spawning populations in the main basin were extirpated by the early 1900s (Berst and Spangler 1972). Cisco exhibit diel, vertical feeding migrations and during the fall-early winter move into shallow water to spawn (Hrabik et al. 2006, Stockwell et al. 2009), so their movements were important to the transfer of energy and nutrients between benthic and pelagic habitats and between nearshore and offshore areas. Cisco in Lake Huron are most abundant in the North Channel, Georgian Bay, and adjacent waters of the northern main basin and are typically sampled only in the acoustics survey. During the 2020 acoustics survey, which did not sample the North Channel or Georgian Bay, Cisco were detected only on a single transect located 18 km WSW of Detour, MI (Figure 10). In 2020, catches of Cisco in midwater trawls consisted of large, adult-sized fish with TL > 350 mm (median TL = 404 mm; n = 3).

Minor species—Threespine Stickleback, Ninespine Stickleback, Trout-perch, White Bass, White Perch, and Yellow Perch were the only other prey fish species sampled in bottom trawl and acoustic surveys in Lake Huron in 2020 (Table 2). Collectively, these species comprised < 1.3 % of prey fish community biomass in 2020. Trout-perch and Yellow Perch were the most abundant minor species in bottom trawls, whereas Ninespine Stickleback was numerically the most abundant minor species sampled in the acoustic survey (Table 3).

Summary and Conclusions

1. Prey fish biomass in the main basin of Lake Huron remains low relative to levels observed prior to 1995. Return to historical levels of prey fish biomass in offshore waters is unlikely due to reduced nutrient inputs, high predation levels by recovering piscivore populations (e.g., Lake Trout, Walleye), and changes in food web dynamics that potentially favor nearshore benthic species such as Round Goby.

2. Persistent low abundance of Alewife and Rainbow Smelt in the main basin of Lake Huron means an uncertain future for recreational fisheries focused on Pacific Salmon, but is consistent with fish community objectives focused on restoration of native fish communities (Dettmers et al. 2012). Current efforts to reestablish Cisco into the main basin also may benefit from low abundance of YAO Alewife and Rainbow Smelt.

3. Offshore prey fish communities in Lake Huron, particularly in the main basin, are characterized by extremely low species diversity. At present, a single species, Bloater, accounts for over three-quarters of prey fish biomass in the main basin. Theory suggests that community resiliency is positively related to species diversity (Mellin et al. 2014), so offshore prey fish abundance and species composition in Lake Huron could change quickly in response to climate change and other ecosystem-scale disturbances.

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Table 1. Length thresholds (total length, in mm) used to assign Bloater, Alewife, and Rainbow Smelt to age groups representing young-of-the-year (YOY) and yearling-and-older (YAO) individuals. Fish with total length < threshold length were classified as YOY.

	Survey	
Species	**Bottom Trawl**	**Acoustic**
Alewife	110	100
Rainbow Smelt	80	90
Bloater	110	100

Table 2. Mean (±1SE) prey fish biomass (g/ha) in Lake Huron during 2020 by species and survey.

	Survey	
Common Name	**Bottom Trawl**	**Acoustic**
YOY[1] Alewife	12 ± 8	4 ± 1
YAO[2] Alewife	1 ± 1	—[3]
YOY Rainbow Smelt	35 ± 12	14 ± 2
YAO Rainbow Smelt	1747 ± 921	983 ± 168
Threespine Stickleback	< 1	3 ± 1
Ninespine Stickleback	5 ± 2	2 ± 0
Trout-perch	25 ± 24	—
White Perch	< 1	—
White Bass	4 ± 4	—
YOY Bloater	1465 ± 1116	11 ± 3
YAO Bloater	5568 ± 2918	9639 ± 1128
Emerald Shiner	—	< 1
Yellow Perch	83 ± 46	—
Deepwater Sculpin	113 ± 22	—
Round Goby	4 ± 3	—

[1]young-of-year

[2]yearling and older

[3]not collected during survey

Table 3. Mean (±1SE) prey fish density (number/ha) in Lake Huron during 2020 by species and survey.

	Survey	
Common Name	**Bottom Trawl**	**Acoustic**
YOY[1] Alewife	3 ± 1	7 ± 2
YAO[2] Alewife	< 1	—[3]
YOY Rainbow Smelt	42 ± 15	16 ± 2
YAO Rainbow Smelt	193 ± 98	112 ± 19
Threespine Stickleback	< 1	3 ± 1
Ninespine Stickleback	3 ± 1	2 ± 0
Trout-perch	5 ± 5	—
White Perch	< 1	—
White Bass	< 1	—
YOY Bloater	226 ± 172	4 ± 1
YAO Bloater	437 ± 257	223 ± 30
Emerald Shiner	—	< 1
Yellow Perch	14 ± 8	—
Deepwater Sculpin	23 ± 4	—
Round Goby	1 ± 0	—

[1]young-of-year

[2]yearling and older

[3]not collected during survey

Figures

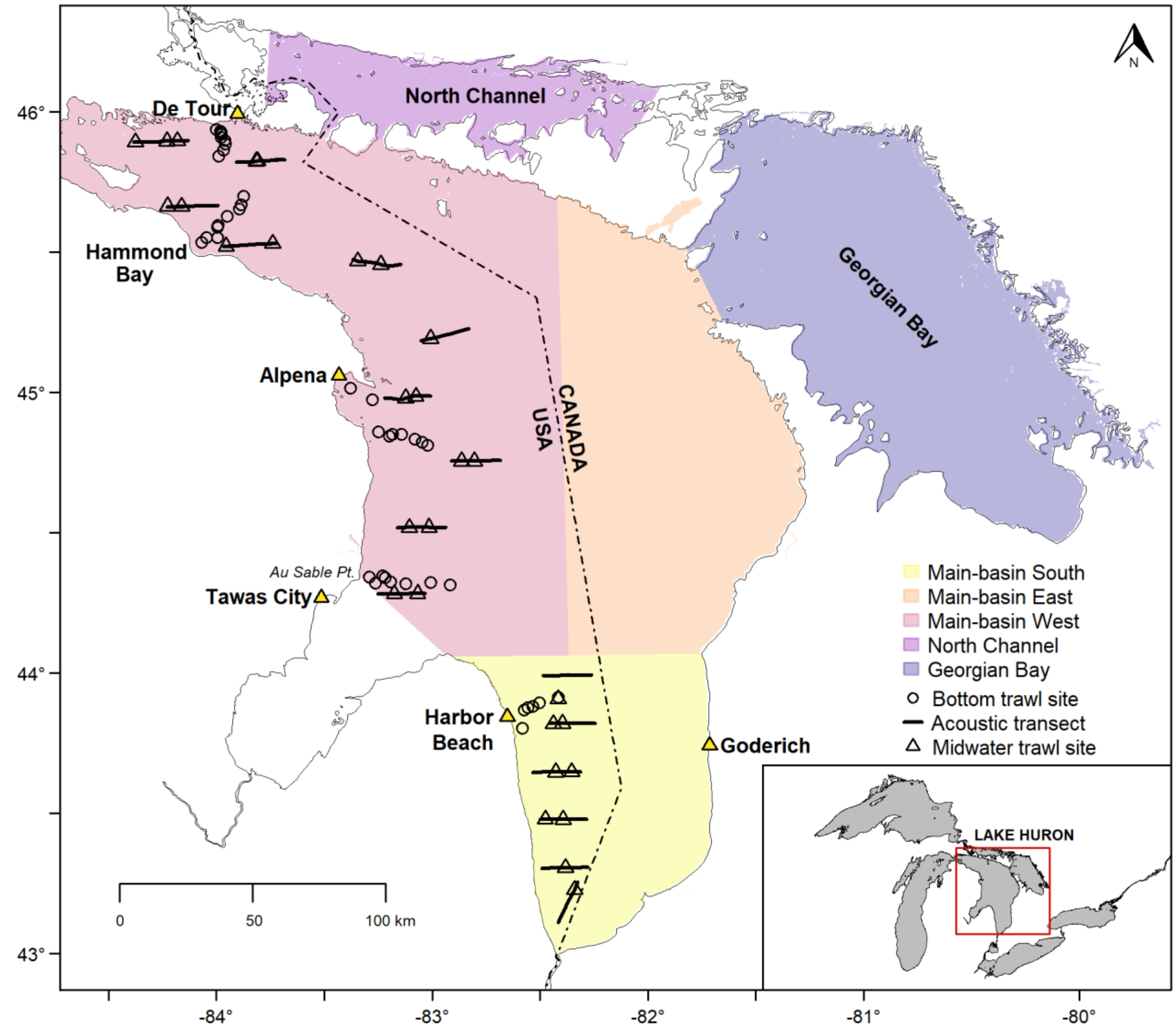

Figure 1. Location of bottom trawls, acoustic transects, and mid-water trawls sampled in Lake Huron during 2020. Acoustic sampling strata (shaded areas) correspond to geographic regions: main-basin east, main-basin west, main-basin south, Georgian Bay, and North Channel.

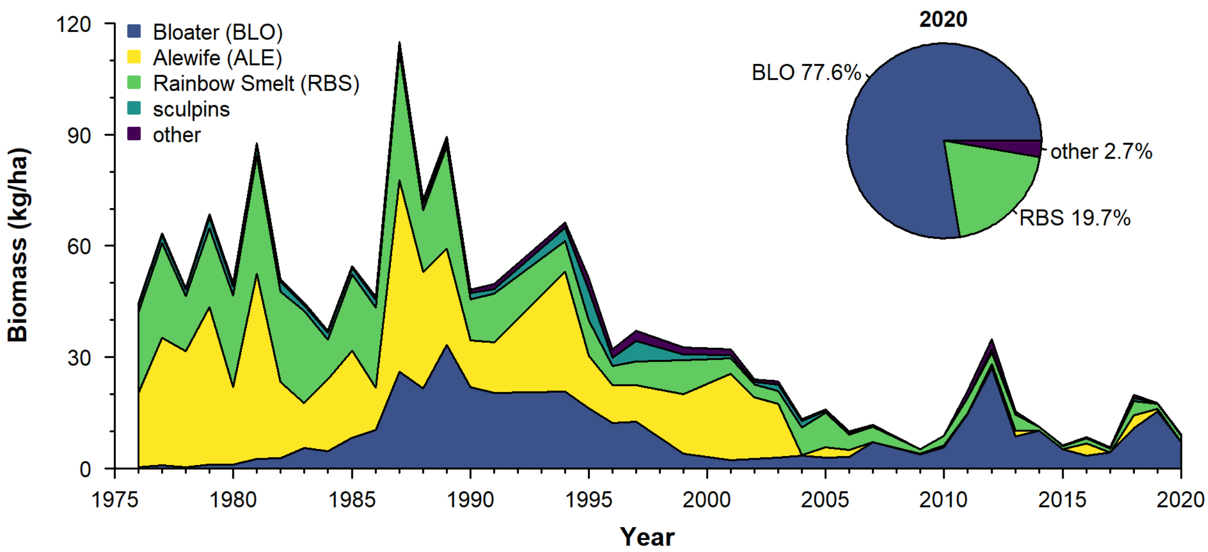

Figure 2. Prey fish biomass and species composition in the region sampled by the bottom trawl (i.e., 9-110 m depth) in Lake Huron, 1976-2020, and in 2020 (pie chart).

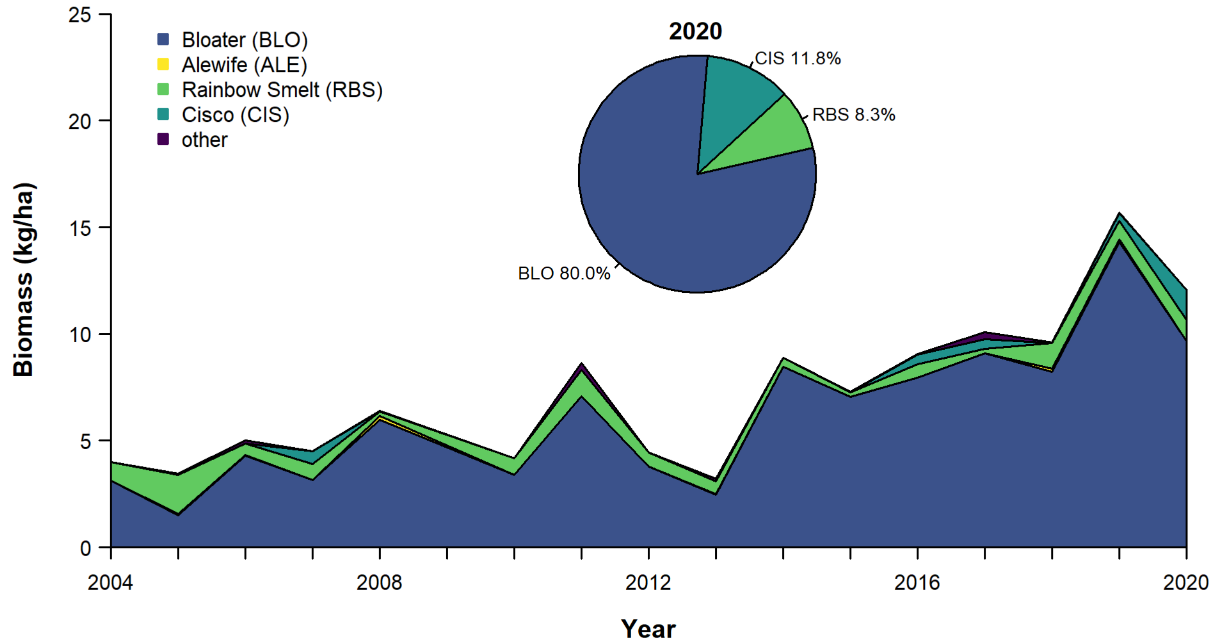

Figure 3. Prey fish biomass and species composition in areas of Lake Huron sampled by the integrated acoustics-midwater trawl survey in Lake Huron, 2004-2020, and in 2020 (pie chart).

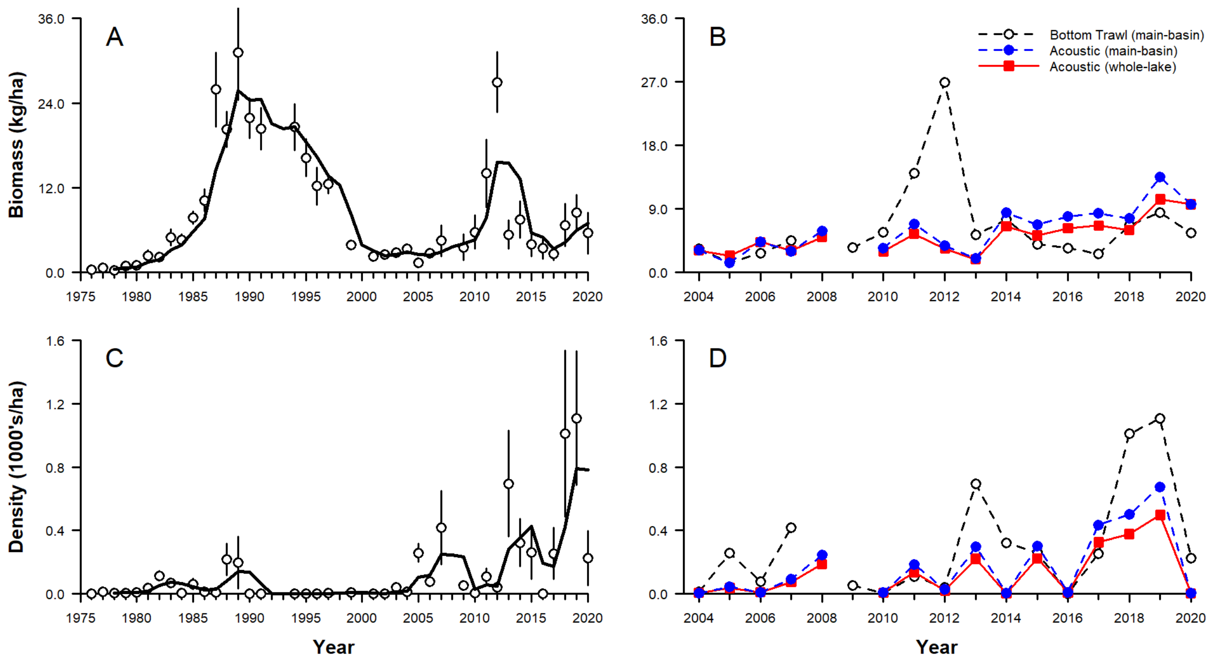

Figure 4. Bloater abundance in Lake Huron by age group (yearling-and-older, young-of-year), period (1976-2020, 2004-2020), and survey (bottom trawl, acoustic). A-B: Estimated biomass of yearling-and-older bloater from bottom trawls and acoustics during 1976-2020 (A) and 2004-2020 (B). C-D: Estimated density of young-of-year bloater from bottom trawls and acoustics during 1976-2020 (C) and 2004-2020 (D). Lines in panels A and C represent the 3-year running mean. Error bars in panels A and C represent ±1 standard error. Colored lines in panels B and D represent mean acoustic biomass (B) or density (D) for all three basins combined (red) and for the main basin only (blue).

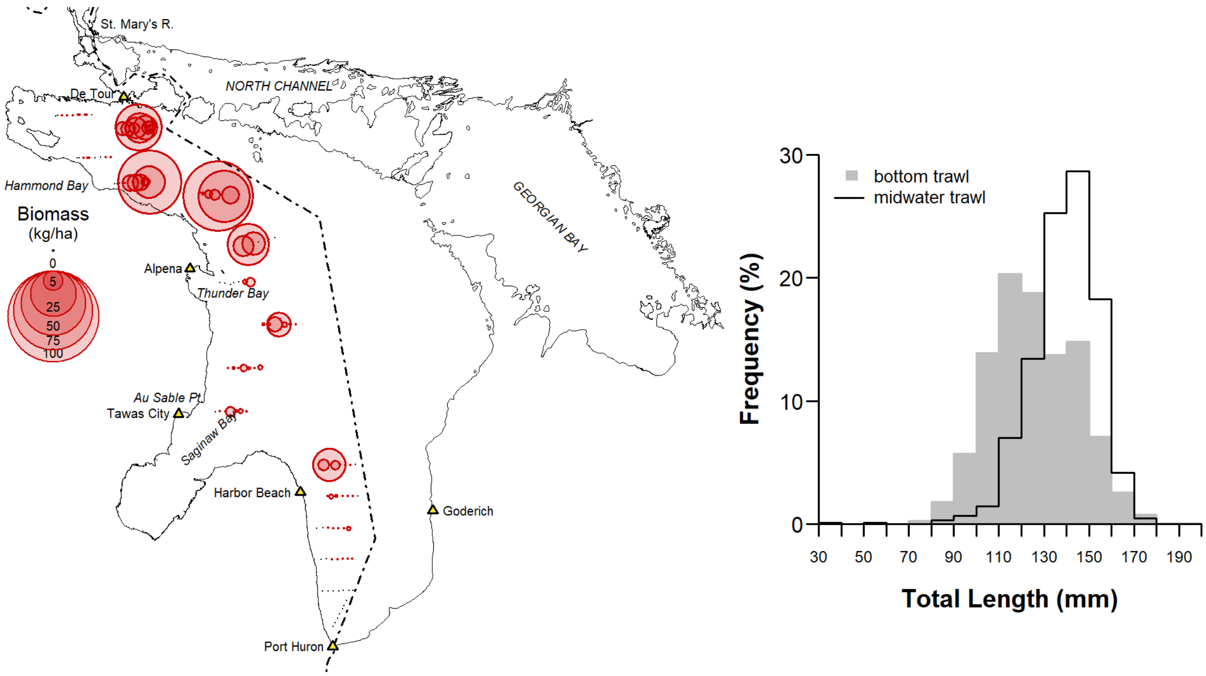

Figure 1. Bloater biomass distribution (left) and size structure (right) in Lake Huron in 2020. Biomass distribution was estimated from the acoustic survey and includes all age groups. Bubble size is proportional to acoustic fish biomass within transect intervals.

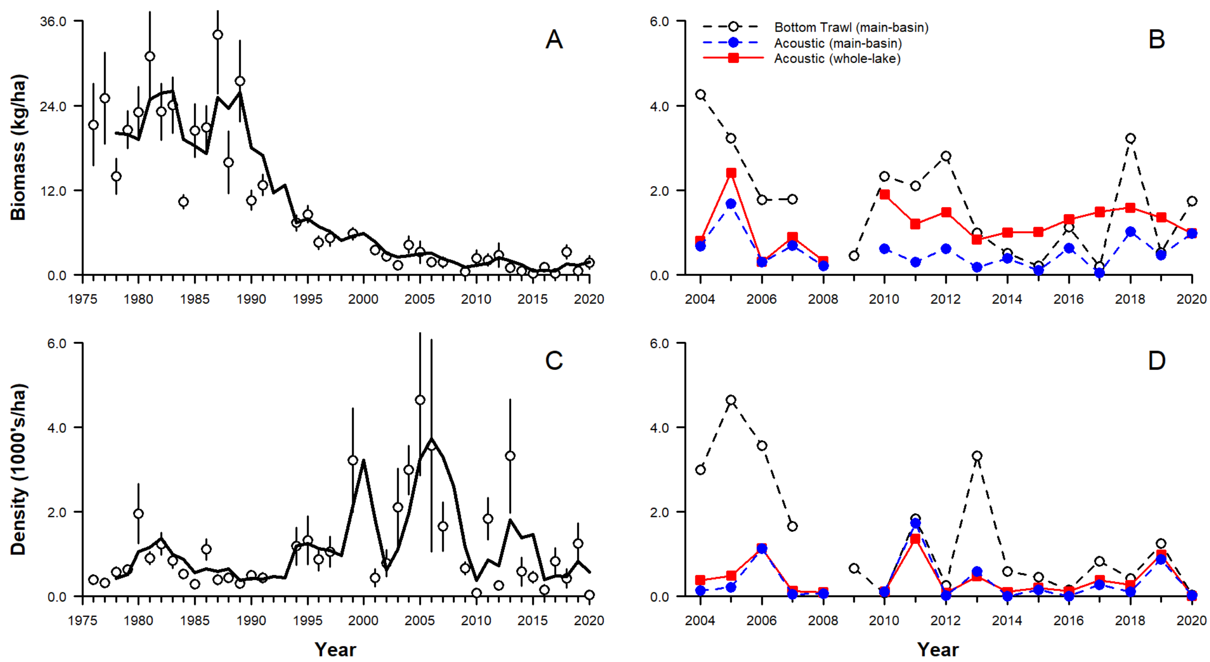

Figure 6. Rainbow Smelt abundance in Lake Huron by age group (yearling-and-older, young-of-year), period (1976-2020, 2004-2020), and survey (bottom trawl, acoustic). A-B: Estimated biomass of yearling-and-older Rainbow Smelt from bottom trawls and acoustics during 1976-2020 (A) and 2004-2020 (B). C-D: Estimated density of young-of-year Rainbow Smelt from bottom trawls and acoustics during 1976-2019 (C) and 2004-2020 (D). Lines in panels A and C represent the 3-year running mean. Error bars in panels A and C represent ±1 standard error. Colored lines in panels B and D represent mean acoustic biomass (B) or density (D) for all three basins combined (red) and for the main basin only (blue).

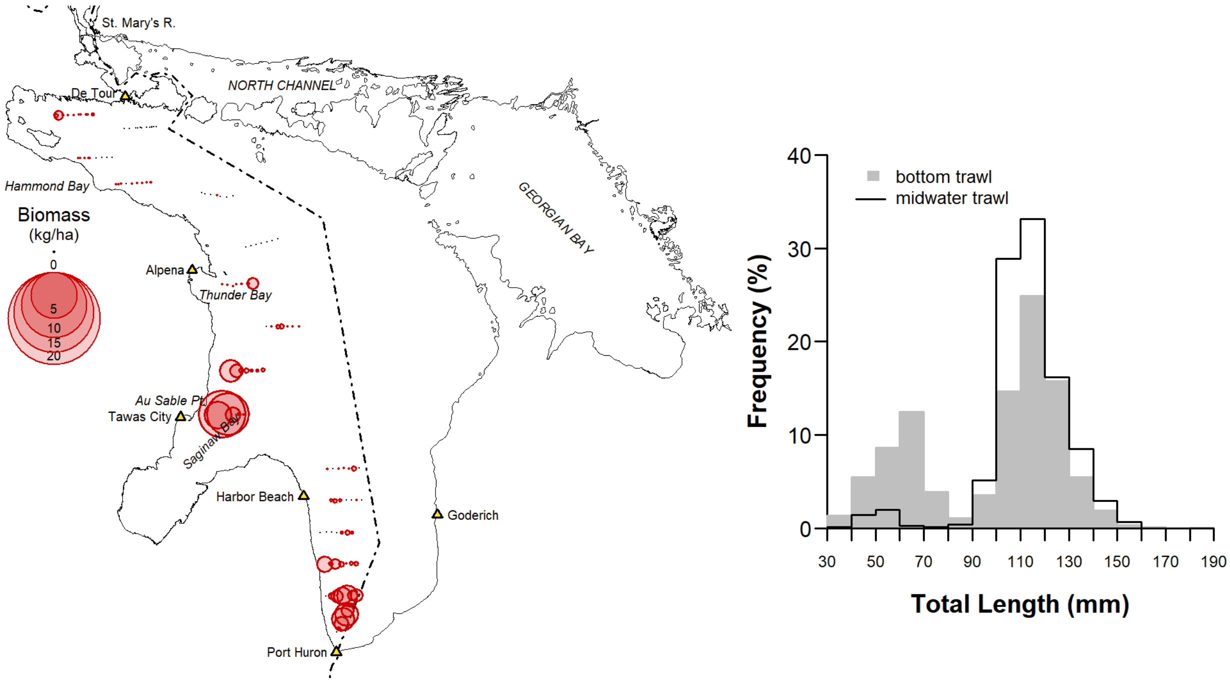

Figure 7. Rainbow Smelt biomass distribution (left) and size structure (right) in Lake Huron in 2020. Biomass distribution was estimated from the acoustic survey and includes all age groups. Bubble size is proportional to acoustic fish biomass within transect intervals.

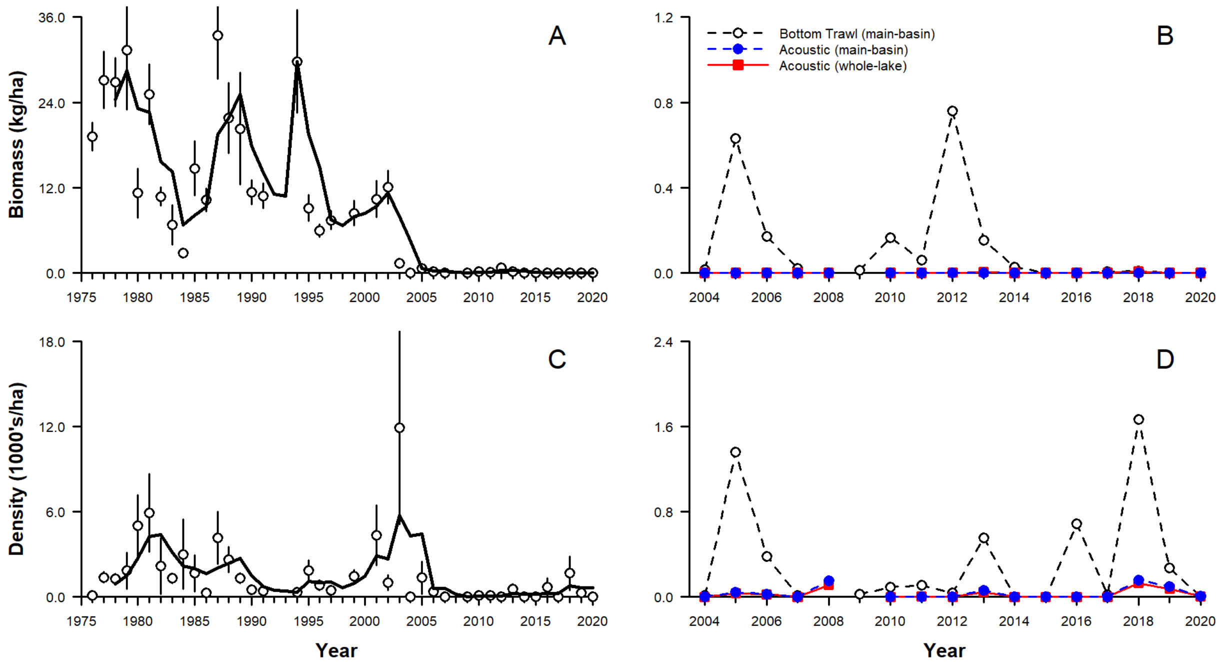

Figure 8. Alewife abundance in Lake Huron by age group (yearling-and-older, young-of-year), period (1976-2020, 2004-2020), and survey (bottom trawl, acoustic). A-B: Estimated biomass of yearling-and-older Alewife from bottom trawls and acoustics during 1976-2020 (A) and 2004-2020 (B). C-D: Estimated density of young-of-year Alewife from bottom trawls and acoustics during 1976-2020 (C) and 2004-2020 (D). Lines in panels A and C represent the 3-year running mean. Error bars in panels A and C represent ±1 standard error. Colored lines in panels B and D represent mean acoustic biomass (B) or density (D) for all three basins combined (red) and for the main basin only (blue).

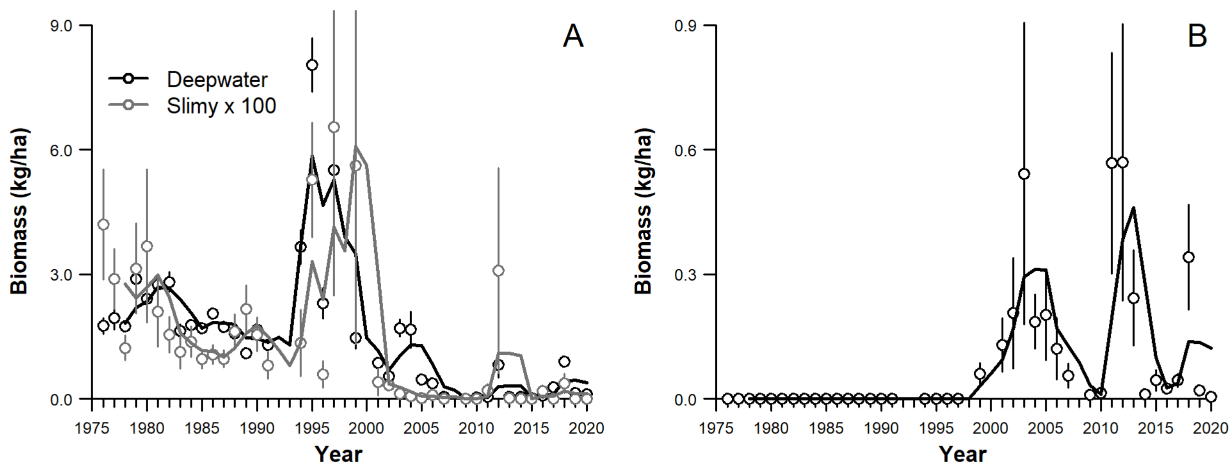

Figure 9. Estimated biomass of sculpins (A) and Round Goby (B) from bottom trawls during 1976-2020. Lines represent the 3-year running mean. Error bars represent ±1 standard error. Slimy Sculpin abundance was multiplied by 100 to facilitate comparison of abundance trends between sculpin species.

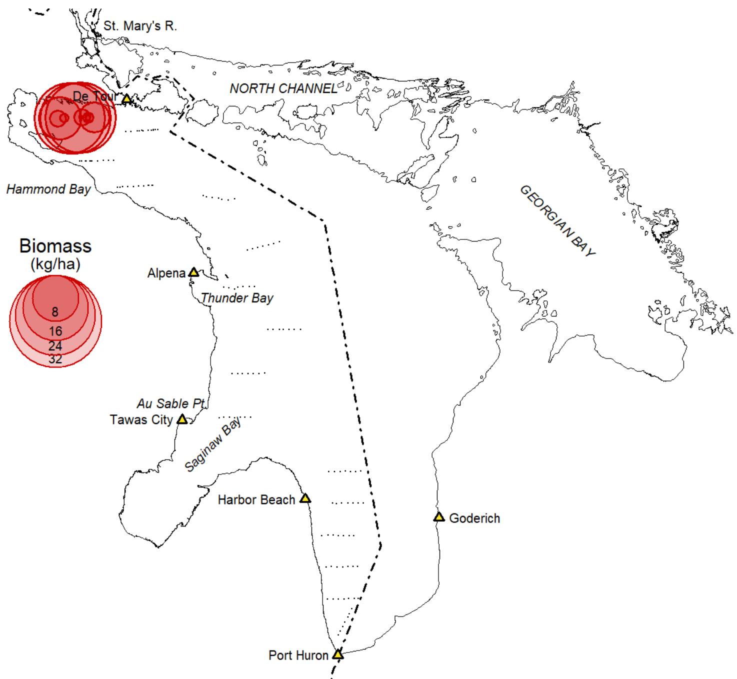

Figure 10. Cisco biomass distribution in Lake Huron in 2020. Biomass distribution was estimated from the acoustic survey and includes all age groups. Bubble size is proportional to acoustic fish biomass within transect intervals.