Status and Trends of Pelagic Prey Fish in Lake Huron, 2018[†1,2]

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Abstract

Scientists from the U.S. Geological Survey's Great Lakes Science Center have conducted annual integrated acoustic and mid-water trawl surveys of Lake Huron from 2004-2018. The 2018 survey was conducted during September and included twenty-six acoustic transects and fifty-three mid-water trawls in Lake Huron's main basin, Georgian Bay, and North Channel. Mean lake-wide pelagic fish density was 1,145 fish/ha and mean pelagic fish biomass was 9.26 kg/ha in 2018, which represents 128% and 125% of the long-term mean, respectively. In 2018, mean lake-wide biomass was 23% lower and mean lake-wide fish density was 16% lower as compared to 2017. Lake-wide density and biomass of small alewife (< 100 mm) increased significantly in 2018, due primarily to increased abundance in the western main basin. Lake-wide density of small rainbow smelt (< 90 mm) decreased marginally in 2018, driven by decreased abundance in the main-basin south, main-basin west, and Georgian Bay. Biomass of large rainbow smelt (> 90 mm) increased in 2018 as a result of increased biomass in the main basin and Georgian Bay. Density of small bloater (< 120 mm) declined in the western main basin but increased in other regions. Biomass of large bloater (> 120 mm) decreased in 2018 primarily due to decreases in the main-basin south and North Channel. Emerald shiner density and biomass increased in 2018 due to increased abundance in the main-basin south and main-basin west regions. Density and biomass of large cisco (> 200 mm) increased in the North Channel but declined slightly in Georgian Bay between 2017 and 2018. Cisco biomass and density has shown an increasing trend in both the North Channel and Georgian Bay since 2011. Pelagic prey fish populations available to predators in the offshore waters of Lake Huron continue to be dominated by rainbow smelt and bloater.

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[1] See data at: U.S. Geological Survey, Great Lakes Science Center, 2019, Great Lakes Research Vessel Operations 1958-2018. (ver. 3.0, Pending 2019): U.S. Geological Survey data release, https://doi.org/10.5066/F75M63X0.

[2] This report replaces a draft version distributed in hard-copy form at the Lake Huron Committee Meeting on March 26, 2019. Results presented in the previous version of this report were found to contain errors generated from a programming bug.

Introduction

Estimates of fish biomass derived from scientific trawl surveys are critical to understanding ecosystem dynamics and managing fishery resources (Koslow 2009; Cotter et al. 2009). In Lake Huron, the U.S. Geological Survey Great Lakes Science Center (GLSC) began conducting annual bottom trawl surveys of the Lake Huron fish community in the 1970s. These surveys have tracked broad-scale changes in the benthic fish community and provided valuable information on prey fish population dynamics to fishery managers tasked with balancing predatory demand by native and introduced salmonines. Integrated acoustic and mid-water trawl surveys were implemented because it was recognized that a substantial proportion of the prey fish biomass was distributed in pelagic zones, which could not be measured using bottom trawl gear (Fabrizio et al. 1997, Stockwell et al. 2007, Yule et al. 2008). Acoustic surveys were first conducted during the 1970s, but the first lake-wide acoustic survey that included all of Lake Huron's distinct basins was conducted in 1997. Annual surveys have been conducted since 2004; however, only the main basin was sampled during 2006.

The primary objective of the acoustic program on Lake Huron is to provide fishery managers with basin-wide estimates of pelagic fish abundance as a means of monitoring prey resources available to predator fish populations. Additionally, the acoustic program serves to provide information on extant cisco *Coregonus artedi* stocks and the survival of stocked cisco or wild progeny as a tool to monitor current restoration efforts for this species in Lake Huron. The purpose of this report is to present abundance and biomass estimates for pelagic offshore prey fish species in Lake Huron during 2018 and compare these estimates to previous years (2004-2017). Furthermore, we emphasize spatial patterns in distribution and biomass of these species throughout Lake Huron.

Survey and analytical methods

The pelagic prey fish survey in Lake Huron is based on a stratified-random design with acoustic transects in five geographic strata: main-basin east (ME), main-basin west (MW), main-basin south (MS), Georgian Bay (GB), and the North Channel (NC) (Figure 1). Within each stratum, the first transect is selected randomly each year based on latitude and longitude; subsequent transects are spaced equidistant from the first within the constraints of the stratum boundary. Effort (transects per stratum) is reallocated each year based on stratum area and variability of total biomass in each stratum from previous surveys (sampling design described in Adams et al. 2006). For the purposes of this report, acoustic strata are hereafter referred to as "regions". For analyses, each transect was divided into 3,000 m horizontal units and 10 m depth layers. These divisions comprise the elementary sampling units (ESUs) within which fish density is summarized along transects.

During 2004-2005 and 2007-2008 acoustic data were collected during September through early October with a BioSonics split-beam 120 kHz echosounder deployed from the Research Vessel (R/V) *Sturgeon*. During 2006, acoustic data were collected during August with a 70 kHz echosounder and a transducer deployed via towfish from the R/V *Grayling*. During 2009, the survey was performed with a 38 kHz echosounder because the 120 kHz transducer failed field calibration tests. Because the 38 kHz echosounder results in higher fish density estimates than the 120 kHz, we chose to exclude 2009 data from this report until appropriate corrections can be applied to the 38 kHz data from that survey. In 2010-2018, we used both a 38 and 120 kHz echosounder to facilitate frequency comparisons, but only 120 kHz data are presented in this report. During 2011-2012 and 2014-2018, the survey was carried out jointly between GLSC and the United States Fish and Wildlife Service (USFWS) to increase spatial coverage. USFWS used 70 kHz and 120 kHz split-beam echosounders (Simrad EK60) to sample transects located in the MW region. In all years, sampling was initiated one hour after sunset and ended no later than one hour before sunrise. A threshold equivalent to uncompensated target strength (TS) of - 66 decibels (dB) was applied to S_v data.

The 2018 pelagic prey fish survey was completed from 5 September – 2 October. Sampling was conducted by both the GLSC (R/V *Sturgeon*) and U.S. Fish and Wildlife Service (USFWS; M/V *Spencer F. Baird*). Twenty-six acoustic transects were sampled, resulting in approximately 480 km of acoustic data. Fifty-three mid-water trawl tows were conducted in conjunction with acoustic data collection (Figure 1).

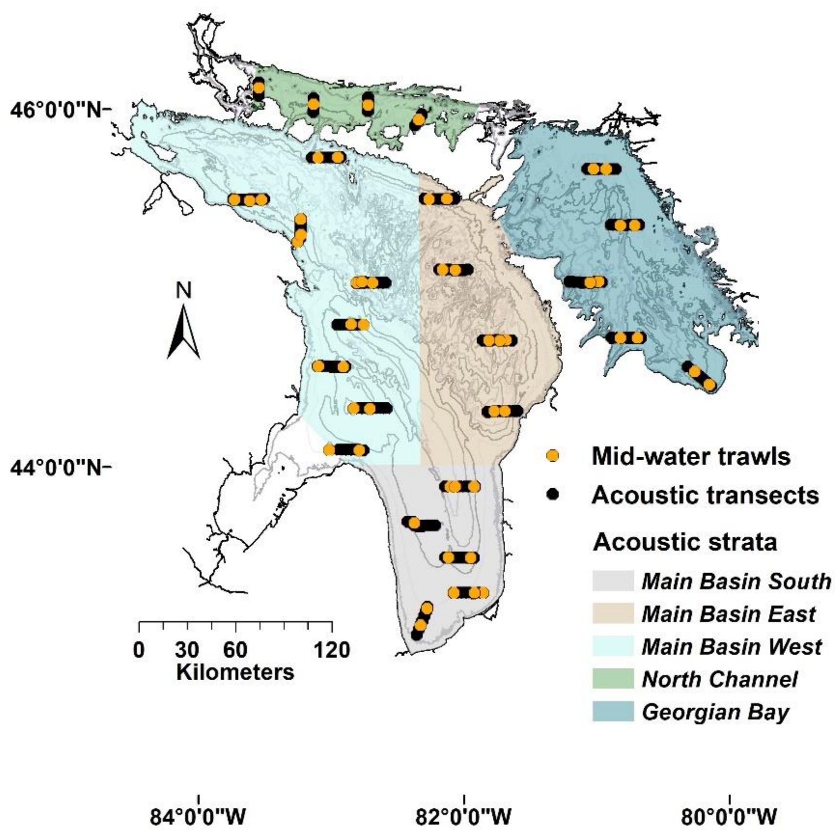

Figure 1. Location of acoustic transects (n=26) and mid-water trawls (n=53) sampled in Lake Huron during 2018. Acoustic sampling strata correspond to geographic regions: main basin east, main basin west, main basin south, Georgian Bay, and North Channel.

Fish were collected using a 16.5-m headrope mid-water trawl with 76, 38, 25, and 6.35 mm stretch meshes (USGS) and a 19.8-m headrope mid-water trawl with 200, 150, 100, 75, 50, and 38 mm stretch mesh with a cod-end liner having 3.175 mm stretch mesh (USFWS). Mid-water trawl locations and depths were chosen to target fish aggregations. Multiple tows per transect were conducted when fish were present at multiple depths so that trawl data within a region were available from each scattering layer formed by fish. At a minimum, a single mid-water trawl was conducted on each transect except in rare instances when very few fish targets were detected. Trawl fishing depth was monitored using Netmind™ (2004-2015) and Marport M3 (2016-2018) systems (USGS) and a Simrad PI44 catch monitoring system (USFWS). In 2018, trawling depths ranged from 6 to 80 m (mean = 25 m, mode = 7 m). Most mid-water trawl tows were of 20-minute duration, with tow times extended up to 25 or 30 minutes when few fish were present. All fishes captured in the mid-water trawl tows were identified, counted, and weighed in aggregate (g) by species. Total length in millimeters was measured on a random subsample (100-200 fish) per species per tow. Individual fishes were assigned to two size categories based on the following length cutoffs: alewife *Alosa pseudoharengus* =100 mm; rainbow smelt *Osmerus mordax* = 90 mm; bloater *Coregonus hoyi* = 120 mm, and cisco *Coregonus artedi* = 200 mm.

Density (fish/ha) of individual species was estimated for each transect as the product of acoustic fish density and the proportion of each species (by number) in the mid-water trawl catches at that location. Total density per species was subdivided into length classes (for applicable species) by multiplying total density by the numeric proportions of each size group. Biomass (kg/ha) of each species was estimated for each transect as the product of density and size-specific mean mass estimated from fish lengths in trawls, and length-weight relationships. The arithmetic mean and standard error are presented for total and species-specific density and biomass estimates for the survey area.

Acoustic estimates of fish density presented in this report from 2004-2018 were derived using the NearD method (Yule et al. 2013). Previous analyses of the acoustic and mid-water trawl data from USGS surveys of Lake Huron have relied on the Hierarchical Averaging Method (HAM, Yule et al. 2013) as described by Warner et al. (2008, 2009). Both methods rely on the composition of midwater trawl catch (for acoustic data < 40 m below the surface) or target strength (for acoustic data ≥ 40 m below the surface) to apportion density to species. However, one notable difference between the HAM method and the NearD method is that only trawls from the same geographic stratum can be used for a given acoustic sample with the NearD method. This approach more accurately reflects spatial patterns in fish density and biomass for evaluation of long-term trends in the fish community. Numeric fish density estimates and biomass density were generated using the function estimateLake() in The EchoNet2Fish package for R (Adams 2018). This function calculates numeric fish density estimates and apportions them to user-defined fish groups using catch data.

Results and Discussion

Density and biomass by species

<u>Alewife</u> – Alewife abundance in Lake Huron was consistently low during 2004-2017 and was characterized by sporadic catches of young-of-year fish, primarily in the MW region. During this period, most catches of alewife were extremely localized and consisted of few individuals. In

2018, lake-wide biomass of alewife < 90 mm (small alewife) increased significantly from 2017 estimates (Figure 2); however, small alewife densities are still likely much lower than historic densities observed prior to the 2004 collapse. In 2018, alewife catches were composed almost entirely of age-0 fish < 100 mm in length (Figure 3) and were primarily caught in the MW region, with catches also occurring in the NC region (Figure 3). In the MW region during 2018, density of small alewife increased over 100-fold from 2017 estimates and biomass exceeded 100 % of the long-term mean. Biomass estimates of alewife > 100 mm (large alewife) have remained low for the last decade despite the occasional production of age-0 fish. Although sporadic catches of alewife have continued, recruitment to older age classes has been limited based on evidence from both mid-water and bottom trawl surveys conducted by the GLSC.

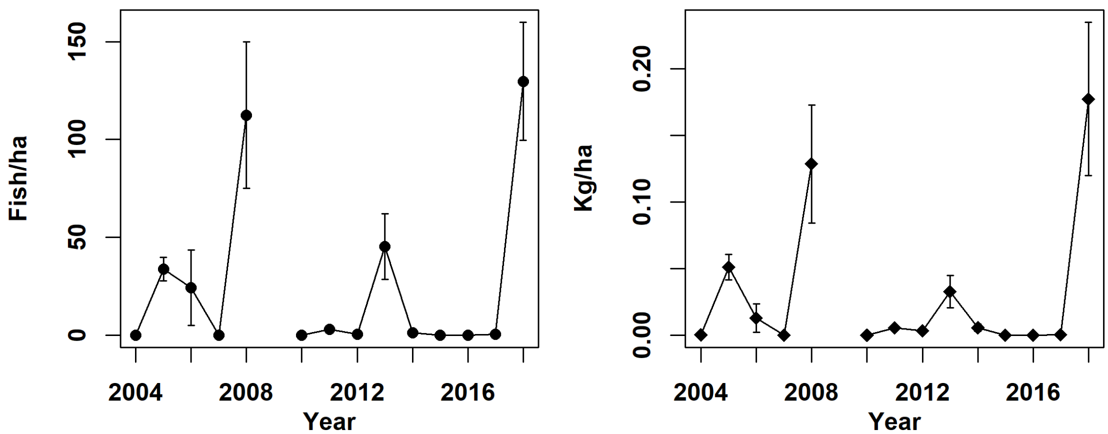

Figure 2. Lake-wide acoustic and mid-water trawl estimates of small alewife density (left panel; fish/ha, fish <100 mm) and small alewife biomass (right panel; kg/ha, fish <100 mm) in Lake Huron during 2004-2018. Error bars represent ±1 standard error.

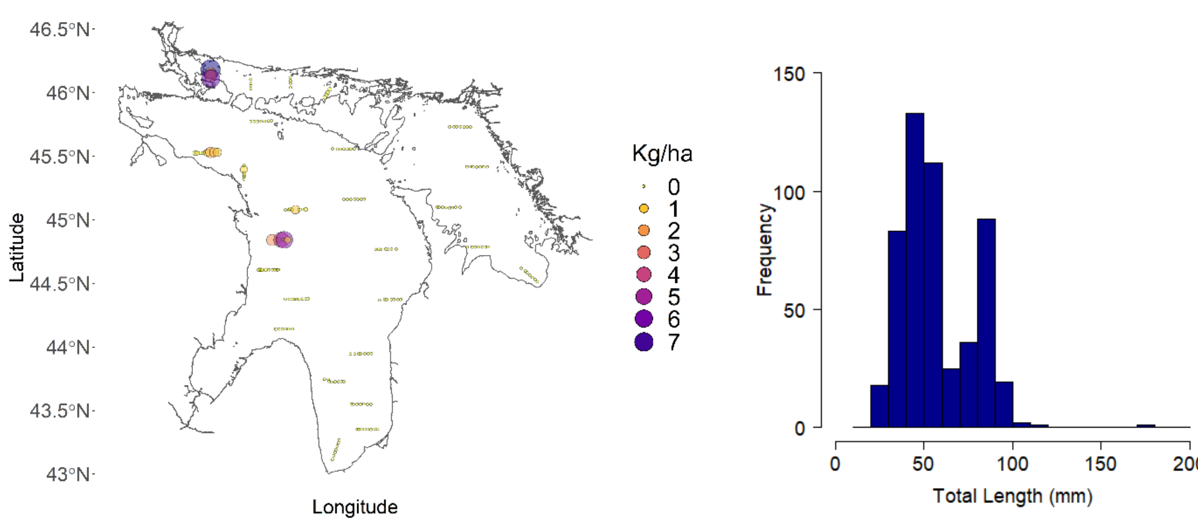

Figure 3. Distribution of small alewife biomass density (kg/ha of fish < 100 mm) summarized along 3 km acoustic cells (dots) in Lake Huron during September-October 2018 (left panel). Length-frequency distribution of all alewife sampled with mid-water trawls during September-October 2018 (right panel).

Rainbow smelt – Lake-wide density of rainbow smelt < 90 mm (small rainbow smelt) in Lake Huron decreased marginally from 2017 to 2018 and was roughly 72% of the long-term mean of 376 fish/ha (Figure 4). This decline in small rainbow smelt was due to declines in most regions of Lake Huron, with the exception of NC where small rainbow smelt increased during 2018. Lake-wide biomass of rainbow smelt > 90 mm (large rainbow smelt) increased during 2018 and was roughly 140 % of the long-term mean of 1.07 kg/ha (Figure 4). Increased abundance of large rainbow smelt was due to increases in all main-basin regions and in GB during 2018. In the MS region, large rainbow smelt biomass was nearly 26 times that estimated during 2017. In the NC region, where long-term mean biomass of large rainbow smelt exceeds 8 kg/h, biomass in 2018 decreased by over 60% from 2017 estimates. Biomass of large rainbow smelt was primarily distributed in the MS, NC, and GB regions during 2018 and trawl catches were largely composed of fish between 80-140 mm (Figure 5).

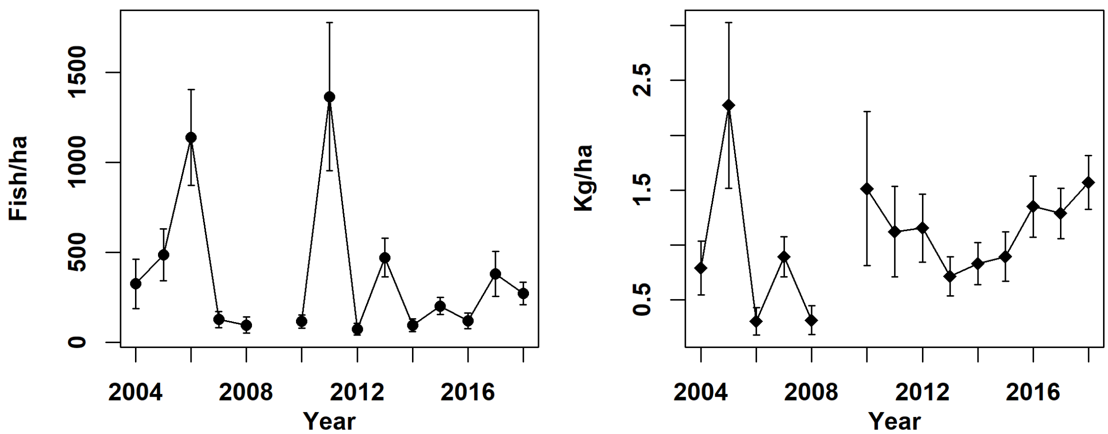

Figure 4. Lake-wide acoustic and mid-water trawl estimates of small rainbow smelt density (left panel; fish/ha, fish <90 mm) and large rainbow smelt biomass (right panel; kg/ha, fish >90 mm) in Lake Huron during 2004-2018. Error bars represent ±1 standard error.

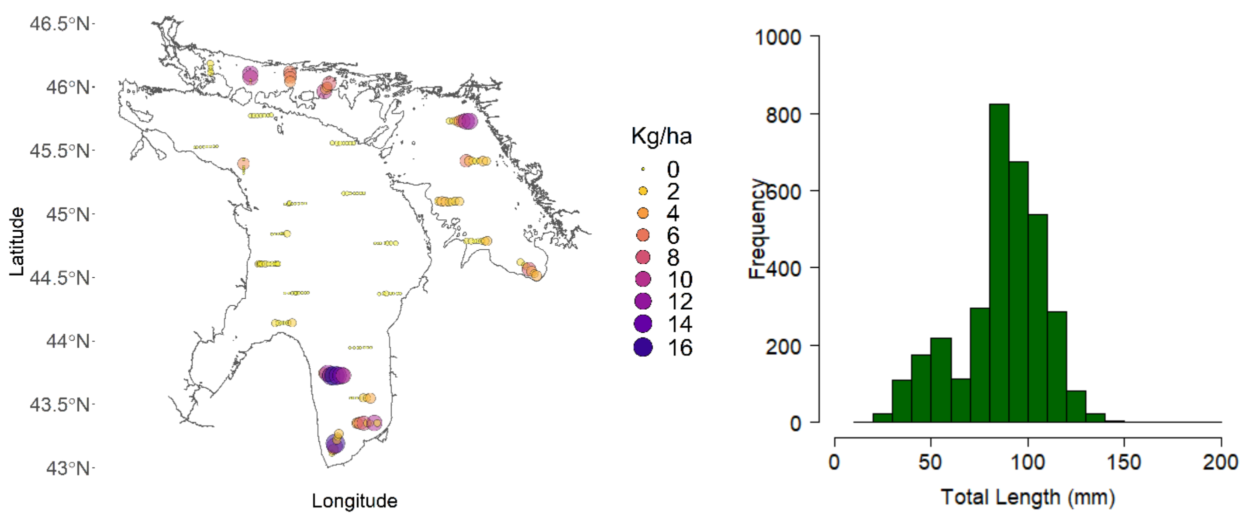

Figure 5. Distribution of large rainbow smelt biomass density (kg/ha of fish > 90 mm) summarized along 3 km acoustic cells (dots) in Lake Huron during September-October 2018 (left panel). Length-frequency

distribution of all rainbow smelt sampled with mid-water trawls during September-October 2018 (right panel).

Bloater – Lake-wide density of bloater < 120 mm (small bloater) increased by 17 % in 2018, but was over 300 % of the long-term mean of 123 fish/ha (Figure 6). Density of small bloater has been variable but increasing over the 15-year time series. Estimates of small bloater density increased in 2018 for all regions but MW. Lake-wide biomass of bloater > 120 mm (large bloater) declined by approximately 28 % in 2018 but was estimated at roughly 100 % of the long-term mean. Spatial distribution of large bloater biomass in Lake Huron during 2018 was similar to previous years and highly variable across the main-basin regions (Figure 7). Most bloater sampled with midwater trawls in 2018 were less than 100 mm (Figure 7).

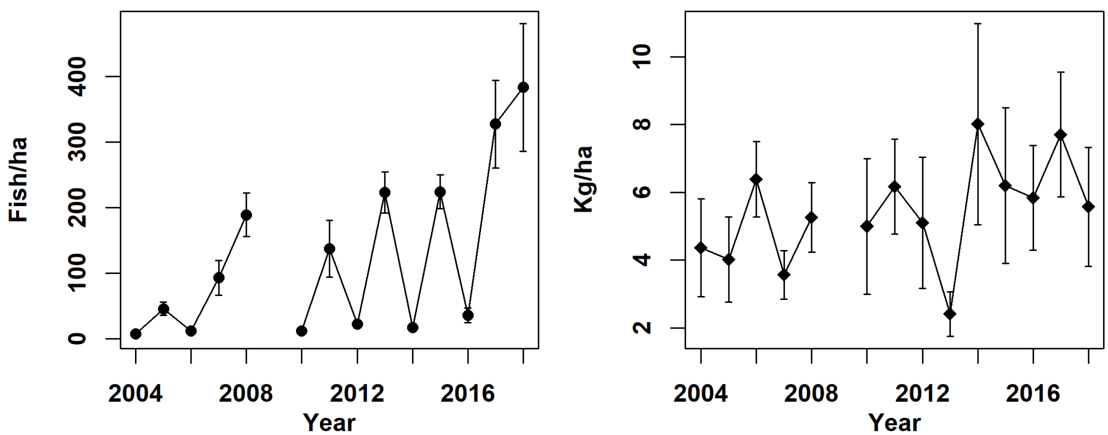

Figure 6. Lake-wide acoustic and mid-water trawl estimates of small bloater density (left panel; fish/ha, fish <120 mm) and large bloater biomass (right panel; kg/ha, fish >120 mm) in Lake Huron during 2004-2018. Error bars represent ±1 standard error.

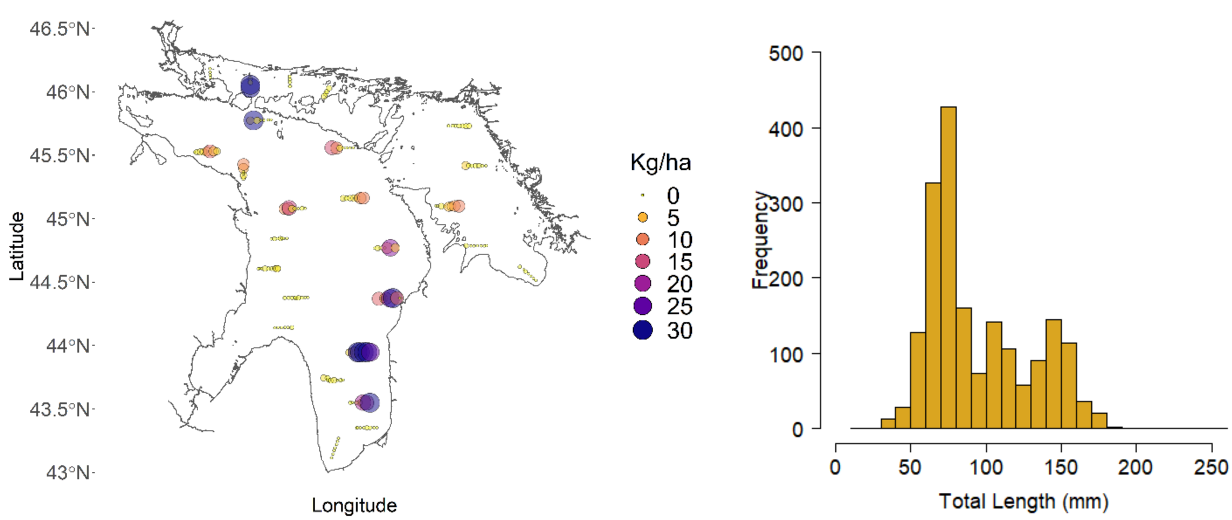

Figure 7. Distribution of large bloater biomass density (kg/ha of fish > 120 mm) summarized along 3 km acoustic cells (dots) in Lake Huron during September-October 2018 (left panel). Length-frequency distribution of all bloater sampled with mid-water trawls during September-October 2018 (right panel).

Cisco – Cisco catches in mid-water trawls were sporadic during acoustic surveys in 2007-2014 with few (<10) specimens caught in most years. Cisco are still uncommon in trawl catches throughout most of the lake but catches of cisco in trawls have increased since 2014. In the MW and ME regions, cisco > 200 mm (large cisco) were caught in 2007, 2016 and 2017 and low numbers of fish captured in those regions led to low precision in regional estimates of abundance and biomass. Between 2007 and 2018, catches were variable in NC and GB but biomass and density of large cisco appears to be trending upwards (Figures 8, 9). Most captures of large cisco in mid-water trawls occur in Georgian Bay and the North Channel (Figure 10). Increased biomass of cisco during 2015-2018 in NC and GB was due in part to increased numbers of larger fish (> 300 mm) caught in mid-water trawls.

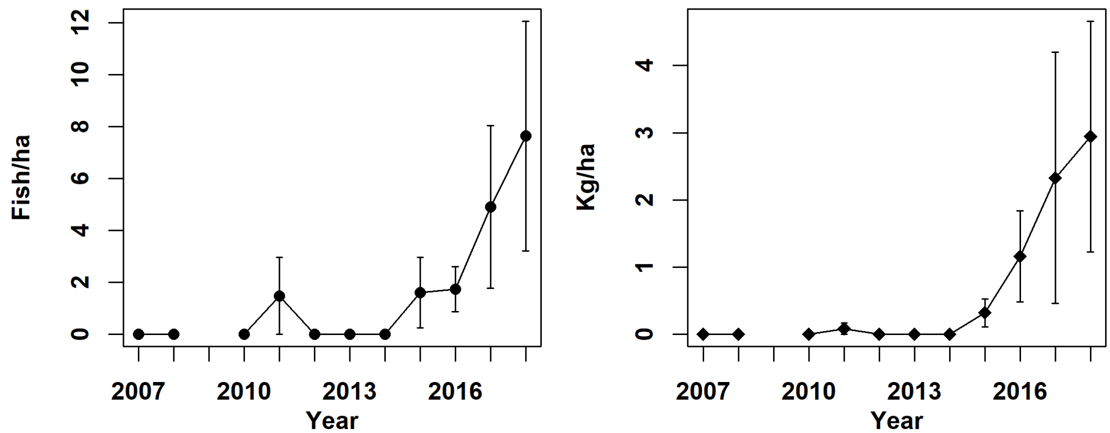

Figure 8. Acoustic and mid-water trawl estimates of large cisco density (left panel; n/ha, fish > 200 mm) and large cisco biomass (right panel; kg/ha, fish > 200 mm) in North Channel, Lake Huron during 2007-2018. Error bars represent ±1 standard error.

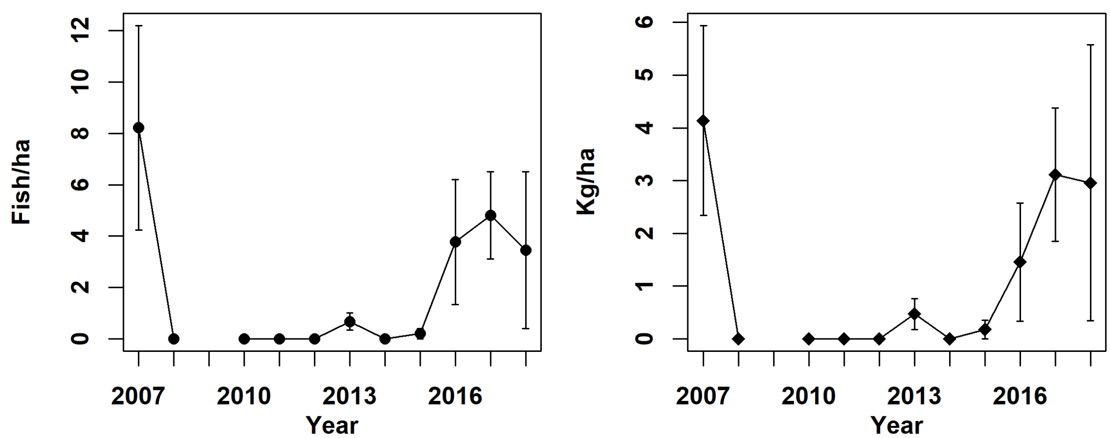

Figure 9. Acoustic and mid-water trawl estimates of large cisco density (left panel; n/ha, fish > 200 mm) and large cisco biomass (right panel; kg/ha, fish > 200 mm) in Georgian Bay, Lake Huron during 2007-2018. Error bars represent ±1 standard error.

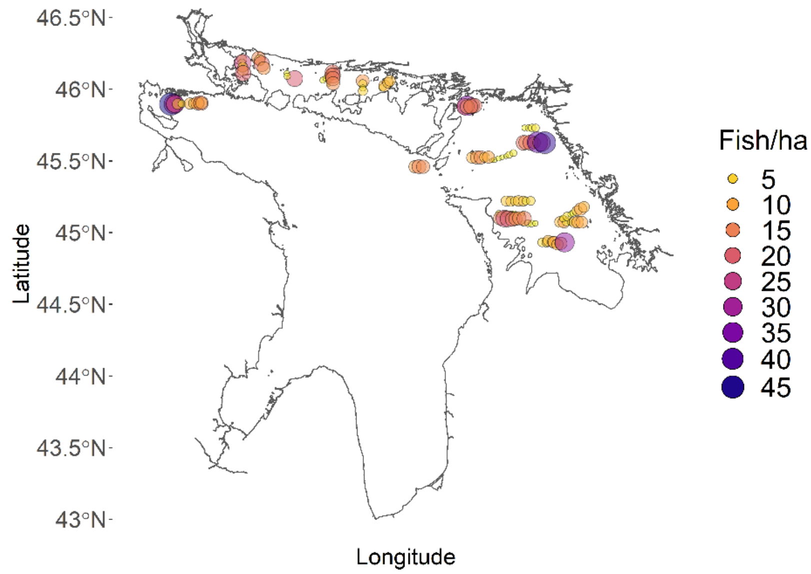

Figure 10. Geographic distribution of large cisco (> 200 mm) numeric density (fish/ha) summarized along 3 km acoustic cells (dots) in Lake Huron during 2007-2018. Only cisco catches >0 are shown.

<u>Emerald shiner</u> – Mean lake-wide density of emerald shiner experienced a two-fold increase in 2018 but was only 35 % of the long-term mean of 53 fish/ha. In 2018, lake-wide mean biomass of emerald shiner increased to roughly 3.5 times the 2017 estimate and was 73 % of the long-term mean biomass of 0.04 kg/ha (Figure 11). Emerald shiner was caught exclusively in the MW and MS regions of Lake Huron during 2018 and fish size was variable (Figure 12).

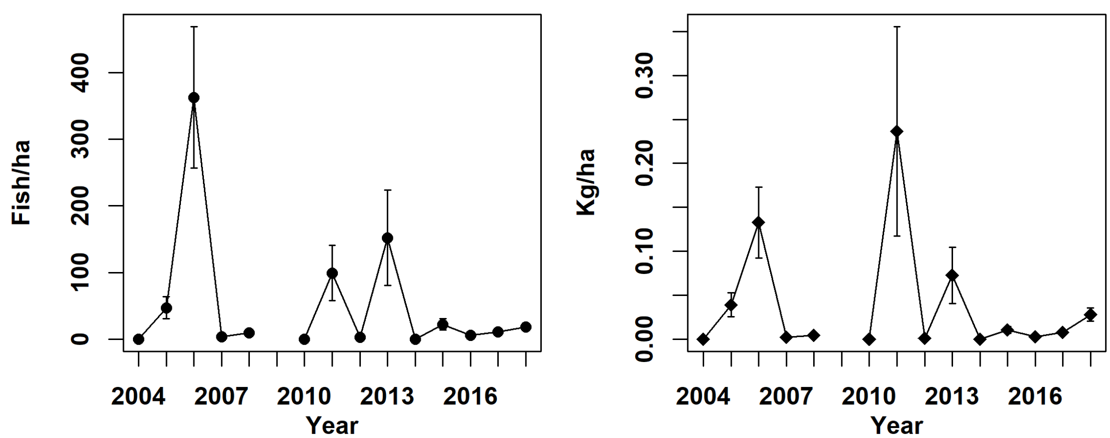

Figure 11. Lake-wide acoustic and mid-water trawl estimates of emerald shiner density (left panel; fish/ha) and biomass (right panel; kg/ha) in Lake Huron during 2004-2018. Error bars represent ±1 standard error.

<u>Other species</u> - Other species captured during acoustic and mid-water trawl surveys included threespine stickleback *Gasterosteus aculeatus*, ninespine stickleback *Pungitius pungitius*, chinook salmon *Oncorhynchus tshawytscha*, lake whitefish *Coregonus clupeaformis*, and lake

trout *Salvelinus namaycush*. These species typically compose a small proportion of the mid-water trawl catch and total biomass.

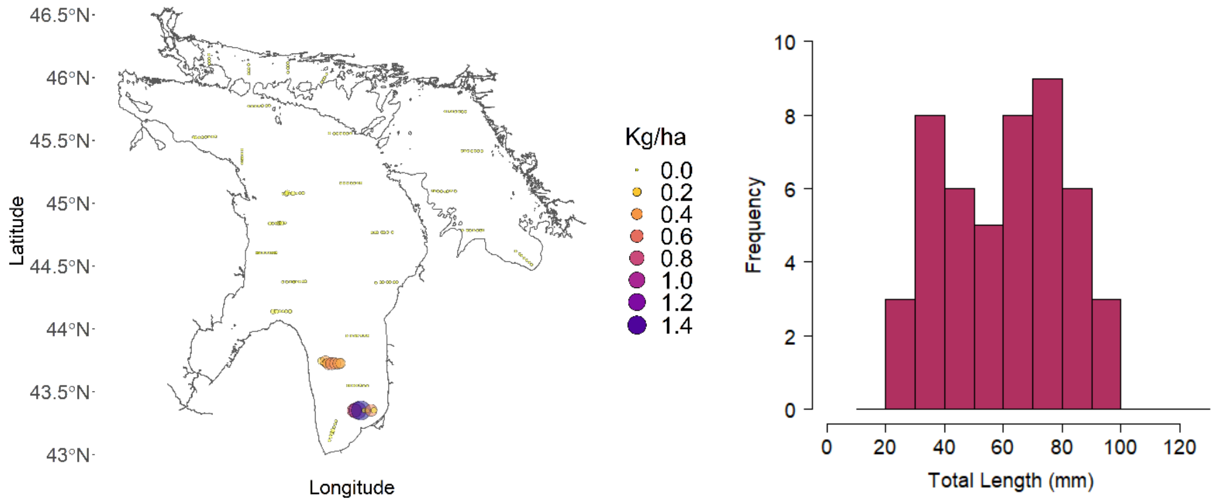

Figure 12. Distribution of emerald shiner biomass (kg/ha) summarized along 3 km acoustic cells (dots) in Lake Huron during September-October 2018 (left panel). Length-frequency distribution of all emerald shiner sampled with mid-water trawls during September-October 2018 (right panel).

Among-region comparisons of areal fish biomass

In 2018, pelagic prey fish biomass in Lake Huron was dominated by large rainbow smelt and large bloater, which comprised approximately 70 % of fish biomass. However, differences in species-specific biomass proportions were evident across the regions of Lake Huron (Figure 13).

During 2018, the MS region had the highest biomass of any of the five regions of Lake Huron (Figure 13). In the MS region, large bloater comprised 71.5 % of the biomass, while large rainbow smelt (21.6 %), small bloater (5.5 %), emerald shiner (0.96 %), and small rainbow smelt (0.37 %) made up the remainder of fish biomass. Biomass in the NC region was roughly 33 % large bloater, 25 % large rainbow smelt, 17 % large cisco, 15.6 % small rainbow smelt, 6.7 % small alewife, 0.82 % threespine stickleback, 0.67 % large alewife, 0.41 % small bloater, and 0.02 % ninespine stickleback. In the ME region, large bloater comprised roughly 87 % of the biomass, and small bloater (8.5 %), small rainbow smelt (3.3 %), large rainbow smelt (0.90 %), and ninespine stickleback (0.006 %) made up the remaining biomass (Table 1).

The MW and GB regions had the lowest biomass for any of the five regions in 2018. In GB, large cisco accounted for 34 % of the biomass and large rainbow smelt (32.3 %), small rainbow smelt (20.5 %), large bloater (11.7%), small bloater (1.5 %), and ninespine stickleback (0.006 %) made up the remaining biomass. Large bloater was approximately 70 % of the biomass in the MW region, while large rainbow smelt (10.6 %), small alewife (10.3 %), small bloater (6.2 %), small rainbow smelt (2.6%), ninespine stickleback (0.18 %), emerald shiner (0.1 %), and threespine stickleback (0.004 %), made up the remainder of biomass.

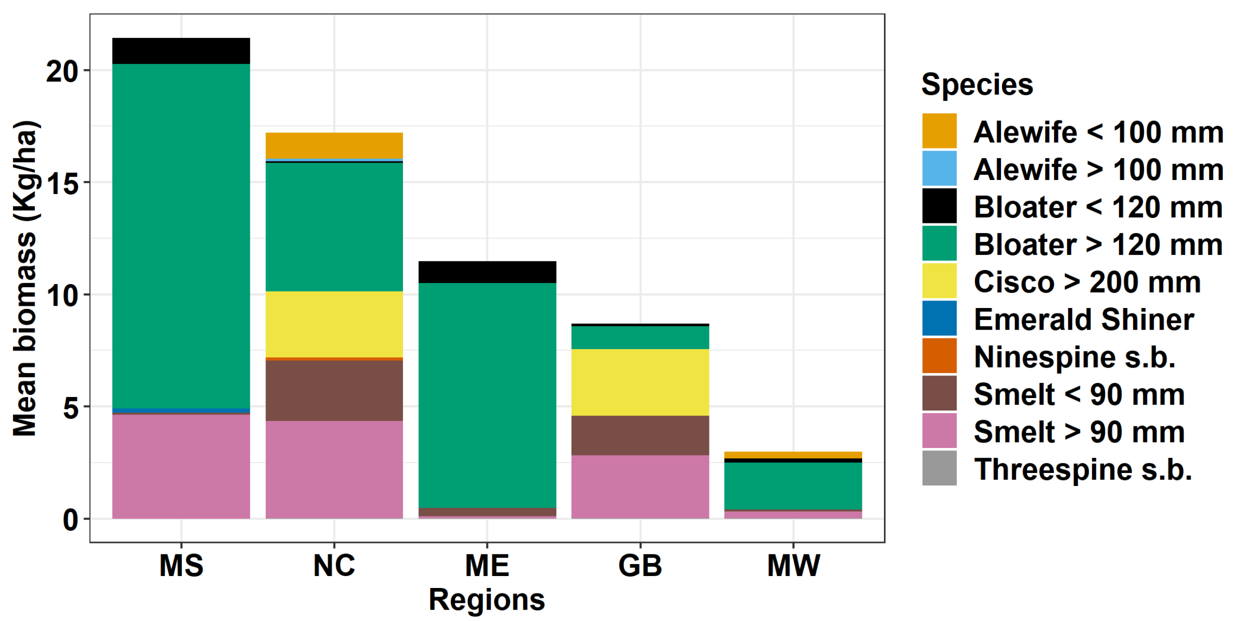

Figure 13. Regional acoustic and mid-water trawl estimates of mean biomass (kg/ha) of pelagic prey fish species in Lake Huron during 2018 (bar labels left to right; main-basin south (MS), North Channel (NC), main-basin east (ME), Georgian Bay (GB), and main-basin west (MW)).

Table 1. Regional acoustic and mid-water trawl estimates of mean biomass (kg/ha) and mean density (n/ha) of pelagic prey fish species in Lake Huron during 2018.

Species	North Channel		Main South		Georgian Bay		Main East		Main West	
	kg/ha	n/ha	kg/ha	n/ha	kg/ha	n/ha	kg/ha	n/ha	kg/ha	n/ha
Alewife < 100 mm	1.17	243.23	0.00	0.00	0.00	0.00	0.00	0.00	0.31	308.04
Alewife > 100 mm	0.11	6.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smelt < 90 mm	2.69	1258.30	0.08	34.76	1.78	599.61	0.38	165.02	0.08	101.48
Smelt > 90 mm	4.35	756.09	4.63	624.61	2.81	445.32	0.10	20.04	0.32	46.67
Threespine s.b.	<0.01	3.89	0.00	0.00	<0.01	0.68	<0.01	0.442	0.01	16.80
Ninespine s.b.	0.14	71.89	0.00	0.00	0.00	0.00	0.00	0.00	<0.01	0.10
Cisco > 200 mm	2.94	7.64	0.00	0.00	2.96	3.453	0.00	0.00	0.00	0.00
Bloater < 120 mm	0.07	17.32	1.18	1223.97	0.13	38.85	0.98	756.54	0.19	114.42
Bloater > 120 mm	5.73	170.31	15.35	218.71	1.02	19.37	10.03	115.63	2.09	65.26
Emerald Shiner	0.00	0.00	0.21	130.52	0.00	0.00	0.00	0.00	<0.01	4.04

Fish population estimates derived from the lake-wide acoustic survey, as with any other type of fishery survey, include assumptions about the sampling and data analysis techniques. For example, we assumed that the areas sampled were representative of the respective basins. This survey sampled areas of Lake Huron from 10 to 250 m in depth. These depths encompass 85% of the range of depths in Lake Huron, although sampling is limited in shallower (<20 m) areas of the lake. For example, nearshore zones and large shallow embayments, especially Thunder Bay, Saginaw Bay, and Parry Sound, are not sampled. These areas could be responsible for high rates of pelagic fish production (Fielder and Thomas 2014, Höök et al. 2001, Klumb et al. 2003), but could not be sampled safely due to the draft of our research vessel (3 m). Given the small surface areas of these shallow-water embayments relative to the total surface area, densities would need to be considerable to influence the lake-wide mean. However, species such as emerald shiner, which represent an important native forage fish, may be underestimated from acoustic surveys because of their vertical and horizontal distribution in the environment. This could result if emerald shiners are abundant in nearshore areas not sampled by acoustic surveys (i.e., < 20m) or in the upper 3-4 m of the water column which is under-sampled due to the depth of the transducer.

Conclusions

Lake-wide biomass of common pelagic species in Lake Huron continues to consist of primarily rainbow smelt and bloater in offshore areas. In 2018, mean lake-wide biomass decreased by roughly 18.5 % relative to 2017, but still remains above the long-term mean of 7.39 kg/ha. Mean lake-wide fish density decreased by approximately14 % in 2018 relative to 2017, but also remains above the long-term mean of 894.7 fish/ha. Lake-wide density and biomass have been relatively stable throughout the 15-year time series, however, biomass has shown an increasing trend over the last decade. Variation in lake-wide prey fish biomass and density in Lake Huron is due to high spatiotemporal variation in the NC and MS regions. Although alewife abundance increased in 2018, the probability of survival to larger sizes remains uncertain given the long-term trends for this species in Lake Huron. Distribution of prey fish biomass continues to be patchy across the five regions of Lake Huron, with areas of high biomass such as NC (rainbow smelt) and MS (bloater and rainbow smelt) and other regions with relatively low fish biomass (e.g., southern portion of the MW region).

Improving our understanding of cisco stock delineation, abundance, and ecology continues to be a focus of the acoustic program on Lake Huron. Based on catches in mid-water trawls during 2007-2018, cisco in offshore areas appear to be mostly confined to the northern main basin, Georgian Bay, and the North Channel. Extant cisco stocks in Lake Huron are not well understood but acoustic surveys have served to help better define offshore habitat use by this species. Most information on cisco spatial distribution and abundance in Lake Huron is based on collections made during the late fall when fish are aggregated for spawning purposes. We anticipate acoustic surveys to continue to provide important information on ecology and habitat use of cisco during other seasons.

To provide accurate estimates of available prey fish resources in Lake Huron, the continuation of acoustic surveys will be instrumental in assessing the pelagic component of the prey fish community, while complementing bottom trawl surveys that better estimate benthic prey resources. The information gathered from acoustic surveys that sample areas where bottom trawling is not feasible will increase our understanding of variation in prey fish biomass across large temporal and spatial scales (i.e., all of Lake Huron's regions). As no single gear is best for assessing all species, life stages, or habitats, estimates of fish biomass from multiple gear types will lead to a better understanding of fish population dynamics.

Acknowledgements

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