Status and Trends of the Lake Huron Offshore Demersal Fish Community, 1976-2018[1,2]

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Abstract

The U.S. Geological Survey Great Lakes Science Center has conducted bottom trawl surveys to assess annual changes in the offshore demersal fish community of Lake Huron since 1973. Sample sites include transects at five ports in U.S. waters and one near Goderich, Ontario. The 2018 fall bottom trawl survey was carried out between 13 and 29 October at all standard ports. The 2018 main basin prey fish biomass estimate for Lake Huron was 62.4 kilotonnes, nearly three times the estimate from 2017 and the highest estimate since 2012. Yearling-and-older (YAO) alewife abundance increased over 2017 but remained relatively low. Young-of-the-year (YOY) alewife biomass increased from 2017 and was the highest estimate observed since 2002. The estimated biomass of YAO rainbow smelt in 2018 was increased over 2017 and was the highest estimate since 2005. YOY rainbow smelt abundance and biomass decreased compared to 2017 and remained relatively low. Estimated YAO bloater biomass was higher than the 2017 estimate and the highest observed since 2014, while abundance and biomass estimates for YOY bloater were the highest observed in the time series. Biomass estimates for deepwater and slimy sculpins were higher than in 2017 but remained low relative to historical estimates. The estimated biomass of ninespine stickleback increased over 2017 and was the highest observed since 2006, while biomass of trout-perch was lower than in 2017 and remained very low compared to historical estimates. The 2018 biomass estimate for round goby was higher than in 2017 and was the fourth-highest observed in the survey. Overall, many native species, particularly bloater, showed increased abundance and biomass in 2018, but total estimated prey fish biomass remains low relative to historical estimates.

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

Introduction

Lake Huron supports valuable recreational and commercial fisheries that may be at risk due to continuing widespread ecological changes in the lake (Bence and Mohr 2008; Riley et al. 2013). These major ecosystem changes include the invasion of dreissenid mussels and drastic declines in the abundance of the native amphipod *Diporeia* spp. (McNickle et al. 2006; Nalepa et al. 2005, 2007); significant changes in the abundance and species composition of phytoplankton, zooplankton, and benthic communities (Barbiero et al. 2009; 2018; Burlakova et al. 2018); decreases in growth and recruitment of lake whitefish *Coregonus clupeaformis* (Mohr and Ebener 2005; Bence and Mohr 2008; Fera et al. 2015; 2017; Gobin et al. 2015; 2016); reduced Chinook salmon *Oncorhynchus tshawytscha* abundance (Dettmers et al. 2012; Bence and He 2015); the invasion of the round goby *Neogobius melanostomus*; natural reproduction of lake trout and walleye (Fielder et al. 2007; Riley et al. 2007); and changes in the distribution and abundance of fish species that make up the offshore demersal fish community (Riley et al. 2008; Riley and Adams 2010).

The U.S. Geological Survey (USGS) Great Lakes Science Center (GLSC) began annual bottom trawl surveys on Lake Huron in 1973, and the first full survey with ports covering the Michigan waters of the lake was conducted in 1976. These surveys are used to examine relative abundance, size and age structure, and species composition of the offshore demersal fish community. The purpose of this report is to present estimates of the relative abundance and biomass of offshore demersal fish species for the period 1976-2018. Results of an annual hydroacoustic survey of pelagic fish abundance in Lake Huron are reported separately (O'Brien et al. 2018).

Methods

The GLSC has monitored fish abundance annually from 1973-2018 using 12-m headrope (1973-1991) and 21-m headrope (1992-2018) bottom trawls at fixed transects at up to 11 depths (9, 18, 27, 36, 46, 55, 64, 73, 82, 92, and 110 m) at five ports (Detour, Hammond Bay, Alpena, Au Sable Point, and Harbor Beach) in the Michigan waters of Lake Huron (Fig. 1). Both trawls used a 4.76-mm square mesh cod end. The same fixed transects were sampled each year from the USGS R/V *Kaho* during 1973-1977, the USGS R/V *Grayling* during 1978-2014, and the USGS R/V *Arcticus* in 2015-2018; some transects were fished from the USGS R/V *Cisco* in 1990. Sampling has been conducted at Goderich (Ontario) since 1998 using the same trawling protocols that are used at U.S. ports (U.S. Geological Survey, Great Lakes Science Center 2019).

Single 10-min bottom trawl tows were conducted during daylight at each transect each year. Tow duration was occasionally less than 10 min due to large catches or obstacles in the tow path; catches for these tows were corrected to be equivalent to 10-min tows (see below). Trawl catches were sorted by species and each species was counted and weighed in aggregate. Large catches (> ca. 20 kg) were subsampled; a random sample was sorted, counted, and weighed, and the remainder of the catch was weighed for extrapolation of the sample.

We applied correction factors to standardize trawl data among depths, as the actual time on bottom for each trawl increased with depth (Fabrizio et al. 1997). Relative abundance was standardized to CPE (catch per 10 min on bottom) as

$$C_t = \frac{10N}{K_t T},$$

where C_t is the catch per 10 min (CPE) on bottom for trawl type t, N is the catch, T is tow time, and K_t is a correction factor that varies with fishing depth (D in m) and trawl type such that K_{12} = 0.00400D + 0.8861 for the 12-m trawl and K_{21} = 0.00385D + 0.9149 for the 21-m trawl. Catches were expressed in terms of density and biomass (number/ha and g/ha) by dividing the CPE by the area swept by the trawl. The area swept was estimated as the product of the distance towed (speed multiplied by tow time) and the trawl width. Trawl width estimates were depth-specific and were based on trawl mensuration data collected from the R/V *Grayling* in 1991, 1998, and 2005. Catches were weighted by the area of the main basin of Lake Huron that occurred in each depth range. Lake-wide relative biomass was estimated as the sum of the biomass of the common species sampled in the survey, and is not a true lake-wide estimate, as sampling is conducted only to 110 m and most Ontario waters are not sampled.

We partitioned catches of alewife *Alosa pseudoharengus*, rainbow smelt *Osmerus mordax*, and bloater *Coregonus hoyi* into size-based age classes for analysis. Year-specific length cutoffs were determined from length-frequency data and then used to apportion the catches into age-0 fish (young-of-the-year, or YOY) and those age-1 or older (yearling and older, or YAO).

To make density estimates from the 12-m headrope (1973-1991) and 21-m headrope (1992-2018) trawls comparable, we multiplied density estimates from the 12-m trawl (1976-1991) by species-specific fishing power corrections (FPCs) developed from a comparative trawl experiment (Adams et al. 2009). We applied FPCs greater than 1.0 to the density and biomass of alewife, rainbow smelt (YAO only), bloater, and FPCs less than 1.0 to the density and biomass of deepwater sculpin *Myoxocephalus thompsonii*. Catches of trout-perch *Percopsis omiscomaycus* were not significantly different between the two trawls. Insufficient data were available to estimate FPCs for ninespine stickleback *Pungitius pungitius* and YOY rainbow smelt; density estimates were not corrected for these species.

Trawl surveys on Lake Huron are typically conducted between early October and mid-November. In 1992 and 1993, however, trawl surveys occurred in early- to mid-September, and these data were not used in this report because the distribution of many offshore species in the Great Lakes is seasonally variable (Dryer 1966; Wells 1968) and data collected in September may not be comparable to the rest of the time series. In 1998, sampling was conducted in a non-standard manner, and these data were also excluded. The fall survey was not conducted in 2000 and was not completed in 2008. We did not use data prior to 1976 because all ports and depths in Lake Huron were not consistently sampled until 1976.

Results

The 2018 Lake Huron fall bottom trawl survey was carried out during 13–29 October. Fifty trawl tows were completed and all standard ports were sampled. Twenty-three fish species were captured in the 2018 survey: rainbow smelt, alewife, bloater, slimy sculpin *Cottus cognatus*, deepwater sculpin, trout-perch, lake whitefish, threespine stickleback *Gasterosteus aculeatus*, ninespine stickleback, lake trout, round goby, yellow perch *Perca flavescens*, round whitefish *Prosopium cylindraceum*, cisco *Coregonus artedi*, burbot *Lota lota*, white sucker *Catostomus commersonii*, walleye *Sander vitreus*, freshwater drum *Aplodinotus grunniens*, channel catfish *Ictalurus punctatus*, white perch *Morone americana*, white bass *Morone chrysops*, gizzard shad *Dorosoma cepedianum*, and spottail shiner *Notropis hudsonius*.

Adult (YAO) alewife abundance in Lake Huron remained relatively low in 2018; abundance and biomass estimates remained among the lowest observed in the survey (Fig. 2). Age-0 alewife density and biomass estimates in 2018, however, were much higher than in 2017 and were the highest observed since 2005 (Fig. 2). As in 2017, YOY alewife catches varied spatially, with most fish captured at Alpena, while most YAO alewife were captured at Harbor Beach (Fig. 3).

YAO rainbow smelt abundance and biomass estimates in 2018 increased over 2017 and were the highest estimates observed since 2005, although these are still low compared to historical estimates (Fig. 4). YOY rainbow smelt abundance and biomass estimates decreased over 2017 and remained relatively low. YOY rainbow smelt were most abundant at Alpena and Detour, while YAO rainbow smelt were most abundant at Goderich and Detour (Fig. 5).

YOY bloater abundance and biomass estimates have been highly variable since 2005, and the 2018 estimates were the highest observed in the time series (Fig. 6). YAO bloater abundance and biomass reached peaks in 2012 and had been declining steadily since, but the 2018 estimates were higher than 2017 and the abundance estimate was the highest observed since 2012 (Fig. 6). Both age-classes of bloater were most abundant at Goderich (Fig. 7).

Slimy sculpin abundance and biomass estimates in 2018 increased from the 2017 estimates and remained relatively low compared to historical estimates (Fig. 8). The abundance estimate for deepwater sculpin in 2018 was the highest observed since 2004, while the biomass estimate was the highest since 2012 (Fig. 8). Deepwater sculpins were most abundant at deep transects at Hammond Bay and Detour, while slimy sculpins were captured only at Detour (Fig. 9). The 2018 abundance and biomass estimates for ninespine stickleback increased substantially from 2017 and were the highest observed since 2006 (Fig. 10). Abundance and biomass estimates for trout-perch decreased since 2017 and were the third-lowest observed in the survey. Ninespine stickleback and trout-perch were most abundant at Goderich (Fig. 11). Round goby abundance and biomass estimates for 2018 increased over 2017 levels and were among the highest estimates in the time series (Fig. 12). Round goby were most abundant at Harbor Beach and Hammond Bay (Fig. 13).

The total main basin prey biomass estimate (5 - 114 m) in 2018 was 62.4 kilotonnes, nearly three times the 2017 estimate (Fig. 14). This estimate is the highest observed since 2012 but represents only about 17 percent of the maximum lake-wide biomass estimate observed in 1987. Approximately 34 percent of the 2018 total prey biomass estimate was composed of YAO bloater.

Discussion

The abundance of prey fish in Lake Huron has remained at low levels since the collapse of the offshore demersal fish community in 2004 (Riley et al. 2008), although survey catches in 2012 suggested that several species were beginning to increase in abundance. The estimated lake-wide biomass of prey fish in 2018 was the highest observed since 2012 but represents only about 17 percent of the maximum biomass observed in the survey. Biomass estimates for YAO rainbow smelt and alewife in 2018 were higher than in 2017 but remained low compared to historical estimates. The collapse of alewife in the lake may have been precipitated by an extremely cold winter (Dunlop and Riley 2013) but was likely ultimately caused by bottom-up controls due to reduced production at all trophic levels (Barbiero et al. 2018), which may have been related to the invasion of dreissenid mussels, and also by predators such as lake trout and Chinook salmon (Kao et al. 2016). The persistence of low abundance and biomass estimates for exotic alewife and rainbow smelt is consistent with fish community objectives for Lake Huron (DesJardine et al. 1995) but may be related to declines in the abundance of Chinook salmon in the lake (Roseman and Riley 2009), which rely heavily on these species as prey (Roseman et al. 2014).

YAO bloater showed consistent positive trends in abundance and biomass during 2009-2012, but then declined. Abundance and biomass estimates in 2018, however, showed a substantial increase over 2017. The biomass of this native species is currently at a moderate level, higher than the extreme low estimates observed in 2001-2006, but still lower than the peak historical estimates. Estimated YOY bloater biomass in 2018, however, was the highest observed in the time series. USGS bottom trawl data suggest that the abundance and biomass of YOY bloater and rainbow smelt have been highly variable but generally much higher since about 2005 than in previous years, suggesting that conditions in Lake Huron may currently be suitable for successful reproduction of these species, but not necessarily for their recruitment to older age classes.

Deepwater and slimy sculpins, ninespine sticklebacks, and trout-perch are typically minor components of lake trout diets in the Great Lakes (Diana 1990; Roseman et al. 2014) but were probably more important before the invasion of the lakes by alewife, rainbow smelt, and round goby (Van Oosten and Deason 1938). In 2018, despite increases in estimated biomass over 2017 for some species, biomass estimates for all of these species remained low compared to historical estimates.

Round goby have become a substantial 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. Our results suggest that they were at relatively high abundance in the offshore waters of Lake Huron in 2018, although sharp fluctuations in the time series indicate that abundance estimates for this species may be particularly sensitive to various environmental factors such as water temperature. Moreover, round gobies primarily inhabit nearshore areas but may seasonally migrate offshore (Walsh et al. 2007), and they tend to be most common on rocky substrates not sampled by bottom trawls. The Lake Huron bottom trawl survey may not provide a robust estimate of their relative abundance or biomass in the lake.

The estimated lake-wide biomass of offshore prey fish in Lake Huron increased from 2009–2012, but then generally decreased through 2017. The lake-wide biomass estimate for 2018 increased substantially over 2017 and was the highest observed since 2012. The peak estimated biomass of prey fish in Lake Huron occurred in the late 1980s and has generally declined since; similar declines have occurred in Lake Michigan and Lake Ontario (Bunnell et al. 2015; Gorman and Weidel 2016). It is possible that these declines are associated with the invasion of the lakes by several exotic species, including the spiny water flea (*Bythotrephes*), zebra mussels, quagga mussels, and round gobies, all of which have been introduced since the mid-1980s (Bunnell et al. 2014; Kao et al. 2016). However, similar declines in some species (particularly coregonines) have occurred in Lake Superior (Vinson et al. 2016), which has been less impacted by invasive species than the other Great Lakes.

Fish abundance estimates reported here are likely to be negatively biased, primarily due to variability in the catchability of fish by the bottom trawl, which may reflect the vulnerability of fish to the gear and/or the distribution of fish off the bottom. Many individuals of some demersal species may be pelagic at times and not available to our bottom trawls, particularly YOY alewife, rainbow smelt, and bloater. Fluctuations in the estimated abundance of individual species may also be a result of changes in catchability caused by altered fish distributions related to annual variability in temperature or food distribution. The invasion of Lake Huron by dreissenid mussels may also have affected the efficiency of the bottom trawl, as has been observed in Lake Ontario (O'Gorman et al. 2005). Data reported here were collected at a restricted range of depths in areas that were free of obstructions with sandy or gravel substrates, and it is therefore possible that USGS bottom trawl data do not fully characterize the offshore demersal fish community of Lake Huron. Results reported here should not be interpreted as absolute abundance estimates for any species (see Riley and Dunlop 2016).

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Figures

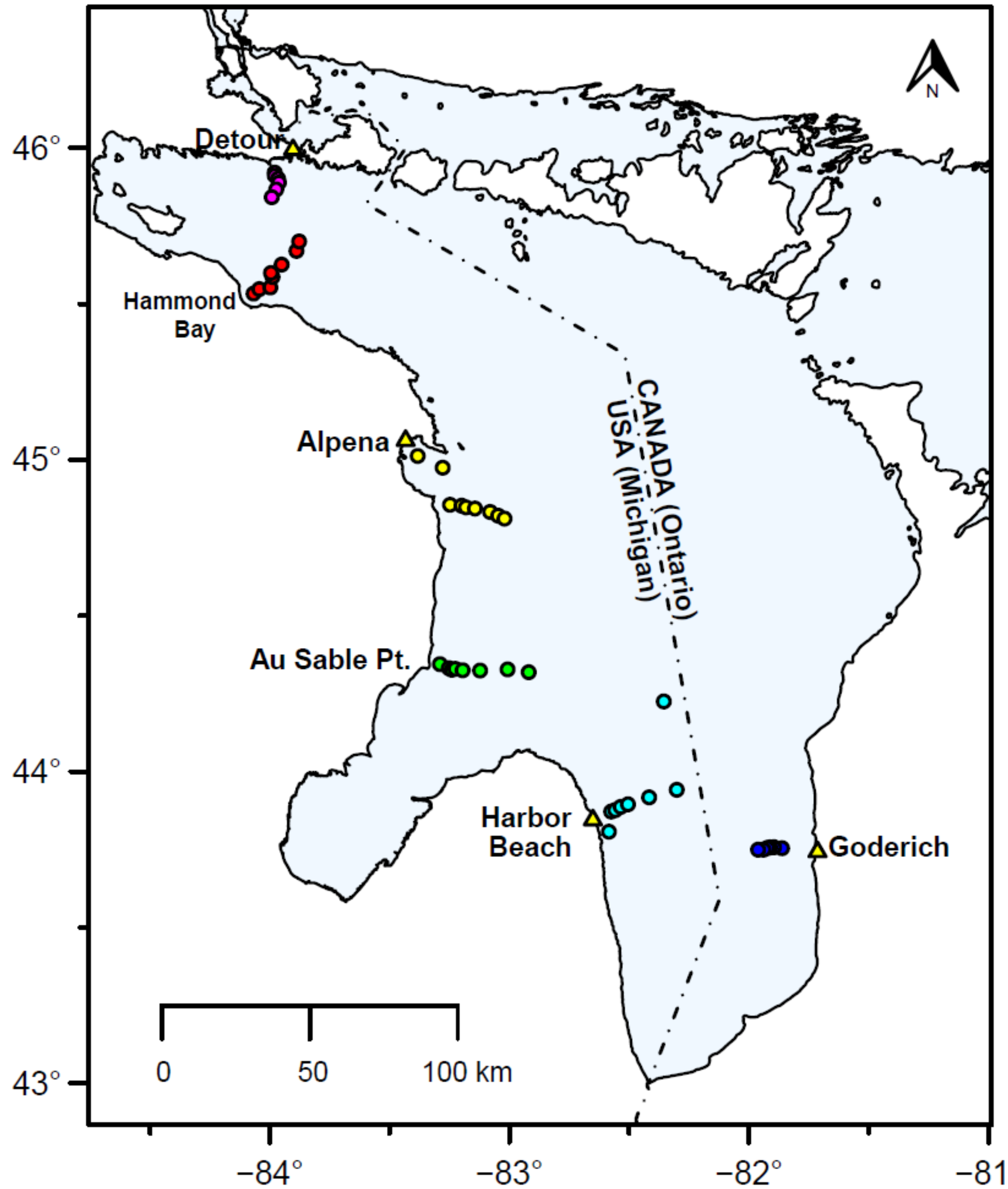

Figure 1. USGS bottom trawl survey sampling locations in Lake Huron.

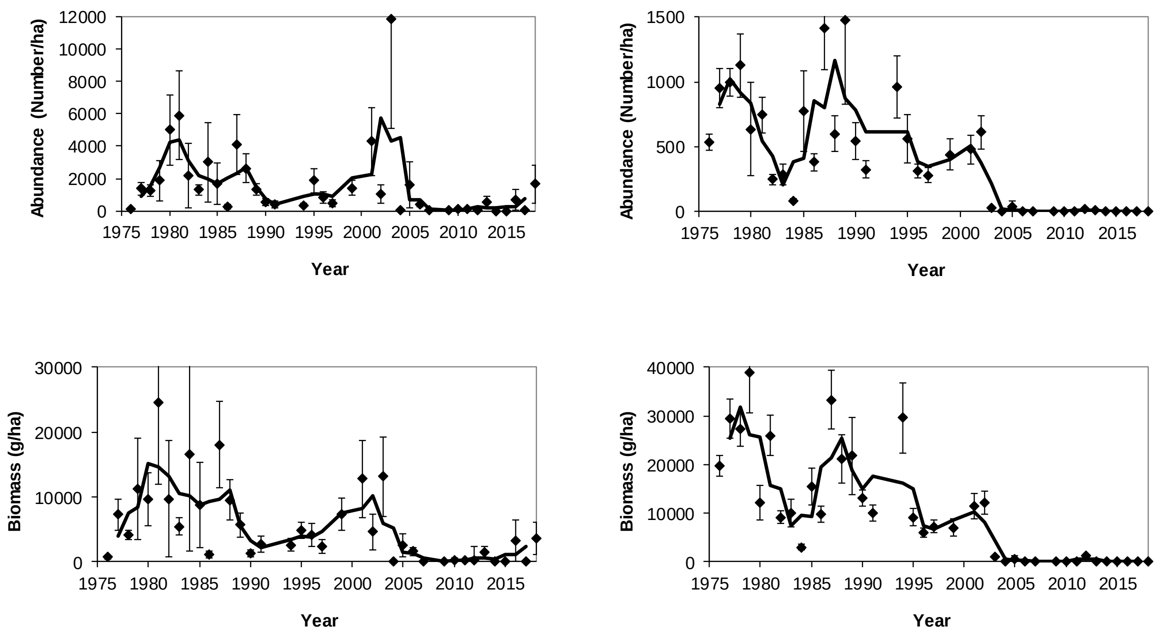

Figure 2. Density of young-of-the-year (YOY: left panels) and adult (YAO: right panels) alewives as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2018. The 1976-1991 estimates were corrected using fishing power corrections developed by Adams et al. (2009). Solid lines are 3-year running averages; error bars are 95% confidence intervals.

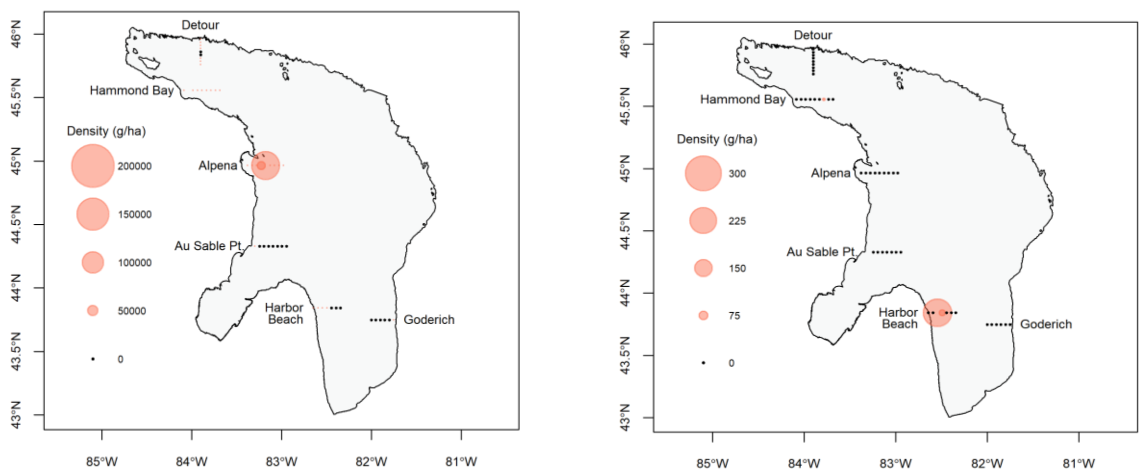

Figure 3. Distribution of catches of young-of-the-year (YOY: left) and adult (YAO: right) alewife in Lake Huron in 2018.

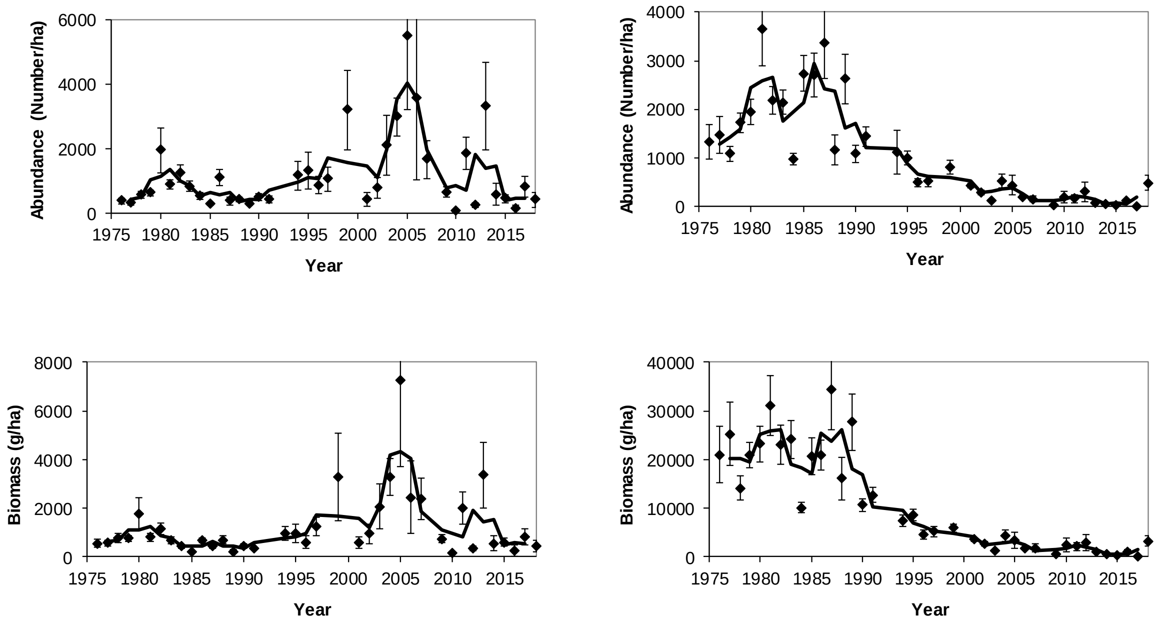

Figure 4. Density of young-of-the-year (YOY: left panels) and adult (YAO: right panels) rainbow smelt as number (top panels) and biomass (bottom panels; fish/ha in Lake Huron, 1976-2018. The 1976-1991 estimates for YAO were corrected using fishing power corrections (Adams et al. 2009); YOY data are uncorrected. Solid lines are 3-year running averages; error bars are 95% confidence intervals.

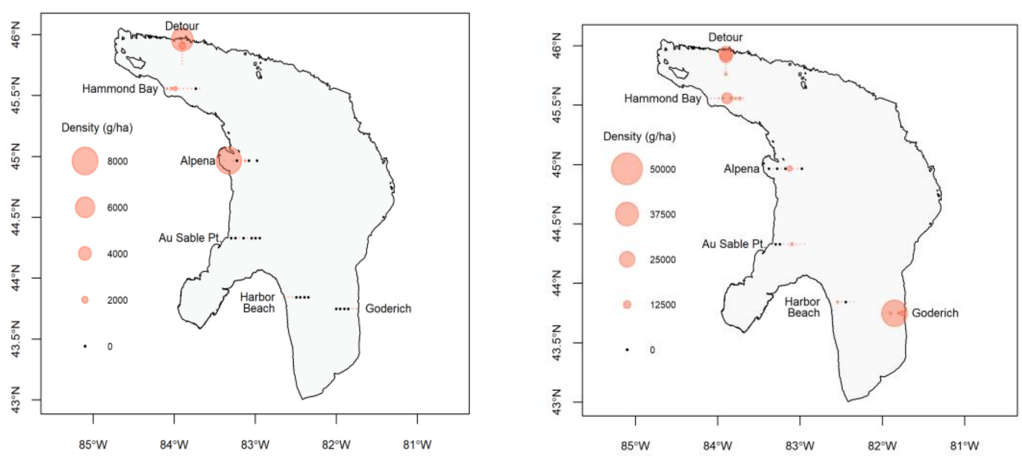

Figure 5. Distribution of catches of young-of-the-year (YOY: left) and adult (YAO: right) rainbow smelt in Lake Huron in 2018.

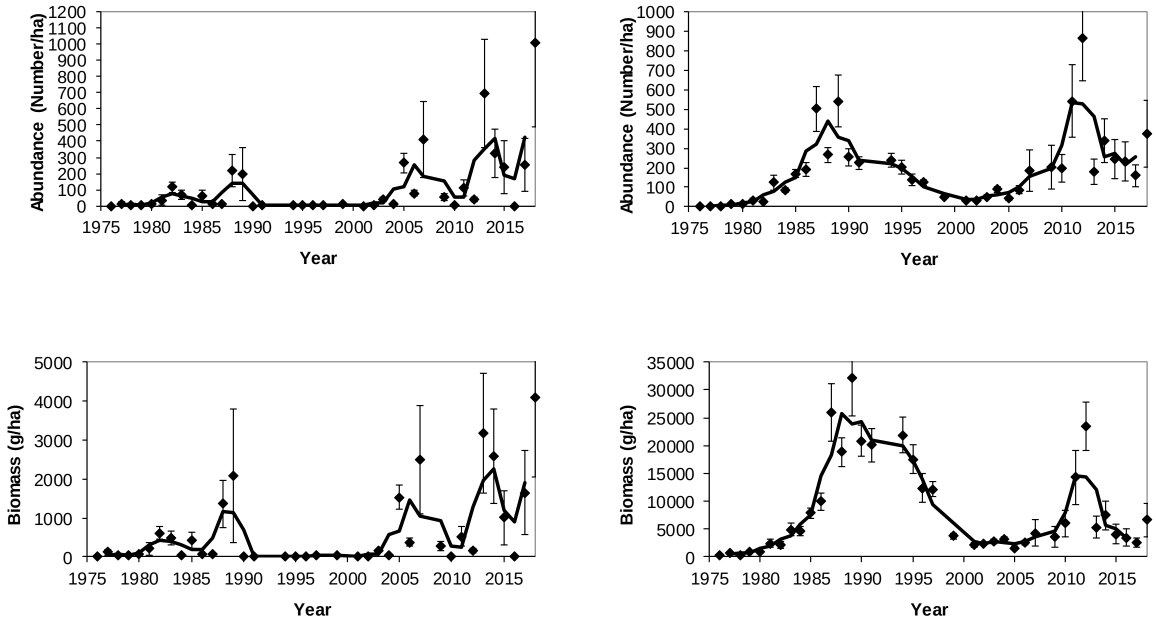

Figure 6. Density of young-of-the-year (YOY: left panels) and adult (YAO: right panels) bloater as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2018. The 1976-1991 estimates were corrected using fishing power corrections developed by Adams et al. (2009). Solid lines are 3-year running averages; error bars are 95% confidence intervals.

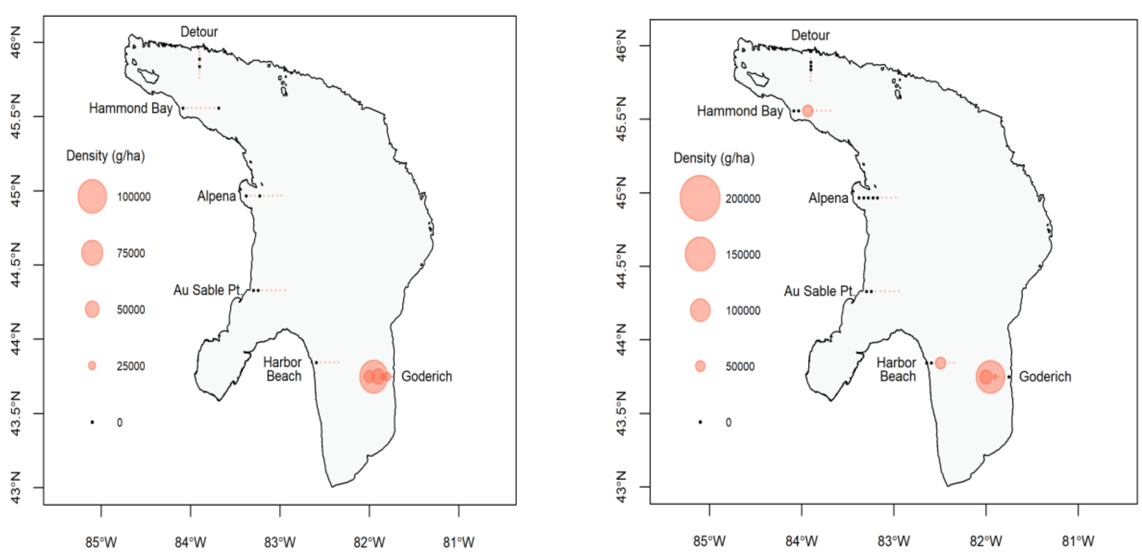

Figure 7. Distribution of catches of young-of-the-year (YOY: left) and adult (YAO: right) bloater in Lake Huron in 2018.

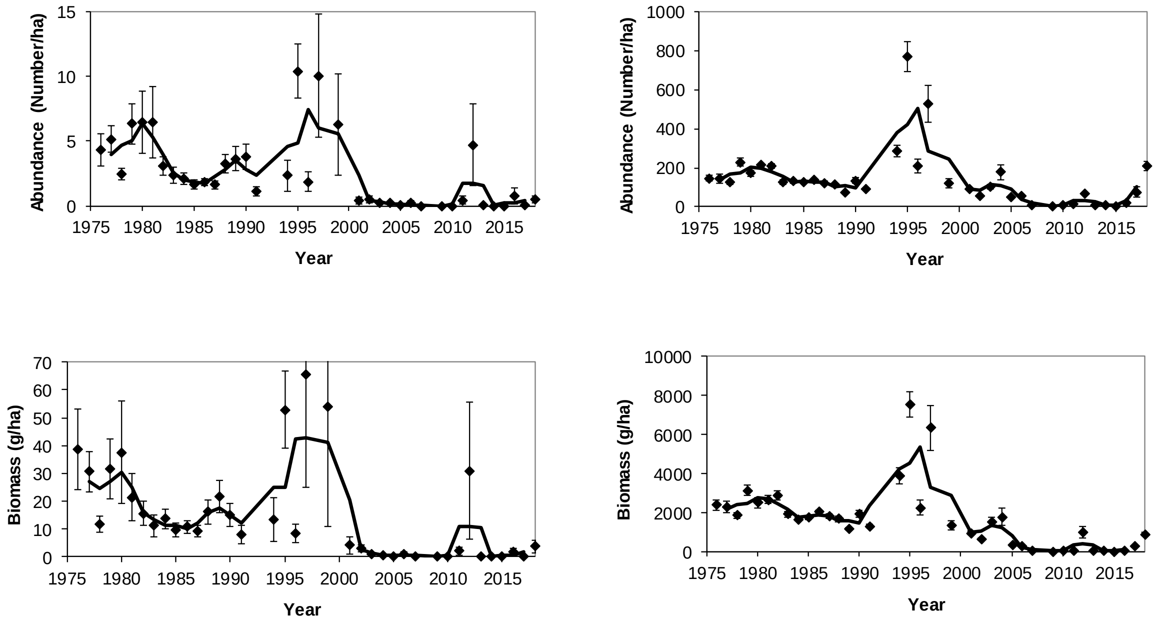

Figure 8. Density of slimy (left panels) and deepwater (right panels) sculpins as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2018. The 1976-1991 estimates were corrected using fishing power corrections developed by Adams et al. (2009). Solid lines are 3-year running averages; error bars are 95% confidence intervals.

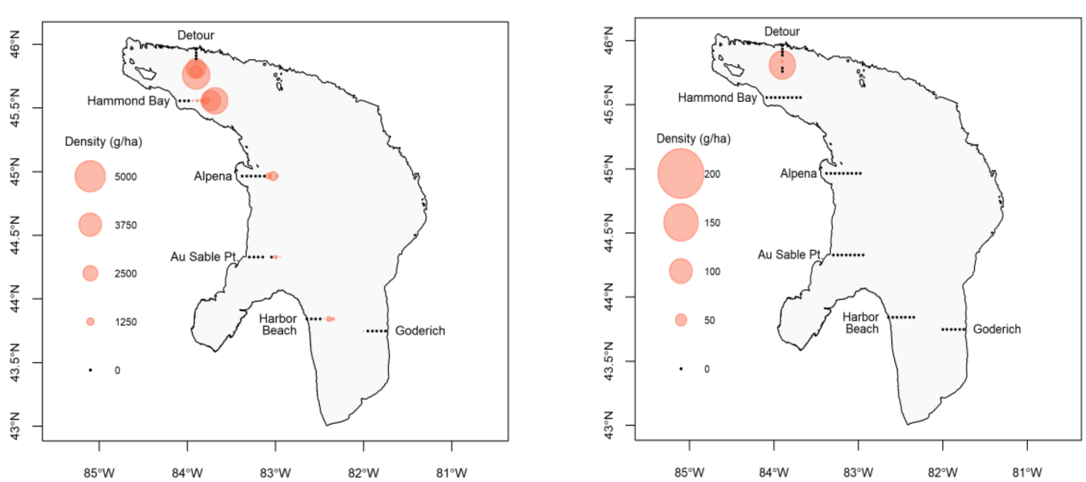

Figure 9. Distribution of catches of deepwater sculpin (left) and slimy sculpin (right) in Lake Huron in 2018.

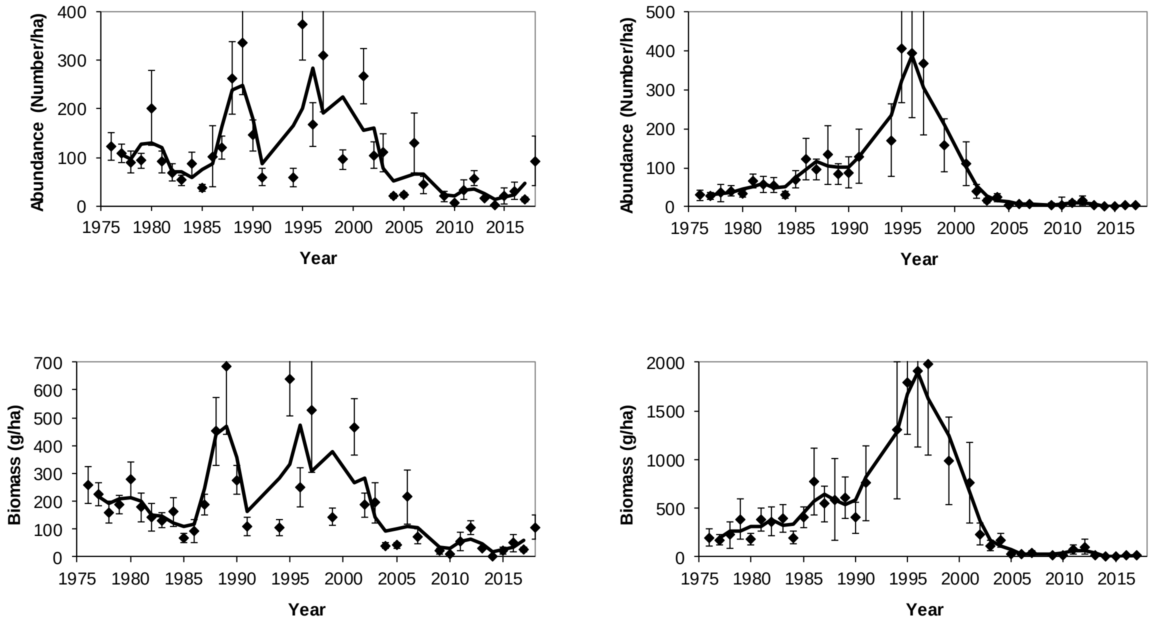

Figure 10. Density of ninespine stickleback (left panels) and trout-perch (right panels) as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2017. Error bars are 95% confidence intervals.

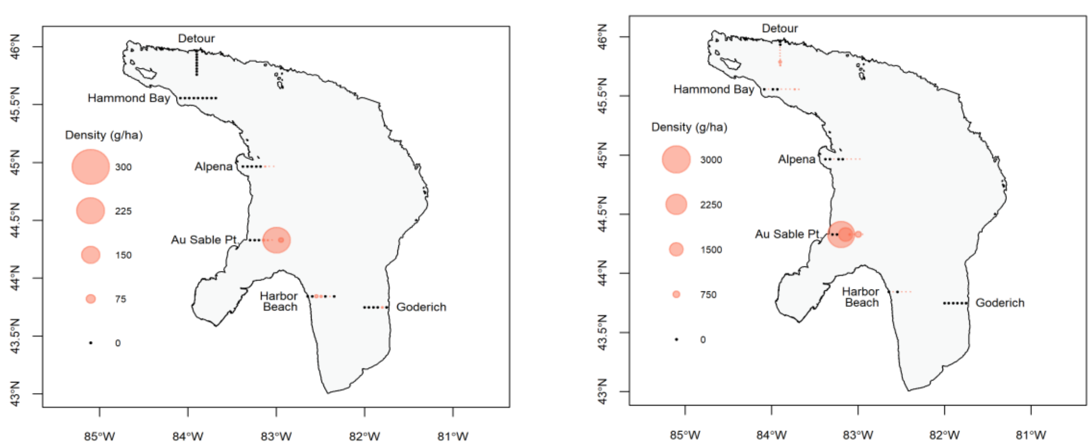

Figure 11. Distribution of catches of ninespine stickleback (left panel) and trout-perch (right panel) in Lake Huron in 2018.

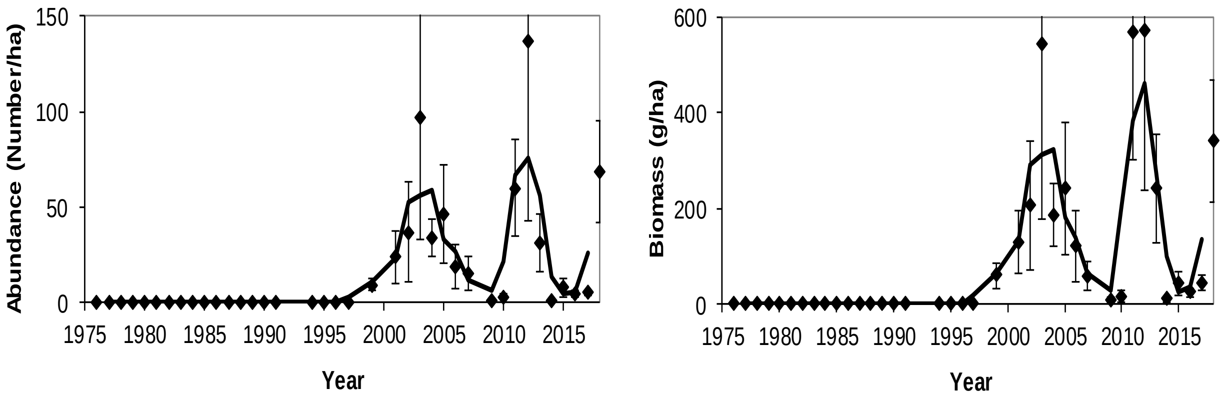

Figure 12. Density of round goby as number (left panel) and biomass (right panel) of fish per hectare in Lake Huron, 1976-2018.

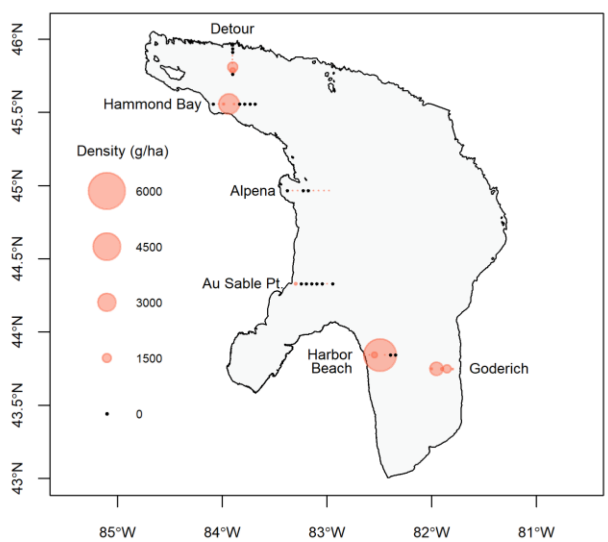

Figure 13. Distribution of catches of round goby in Lake Huron in 2018.

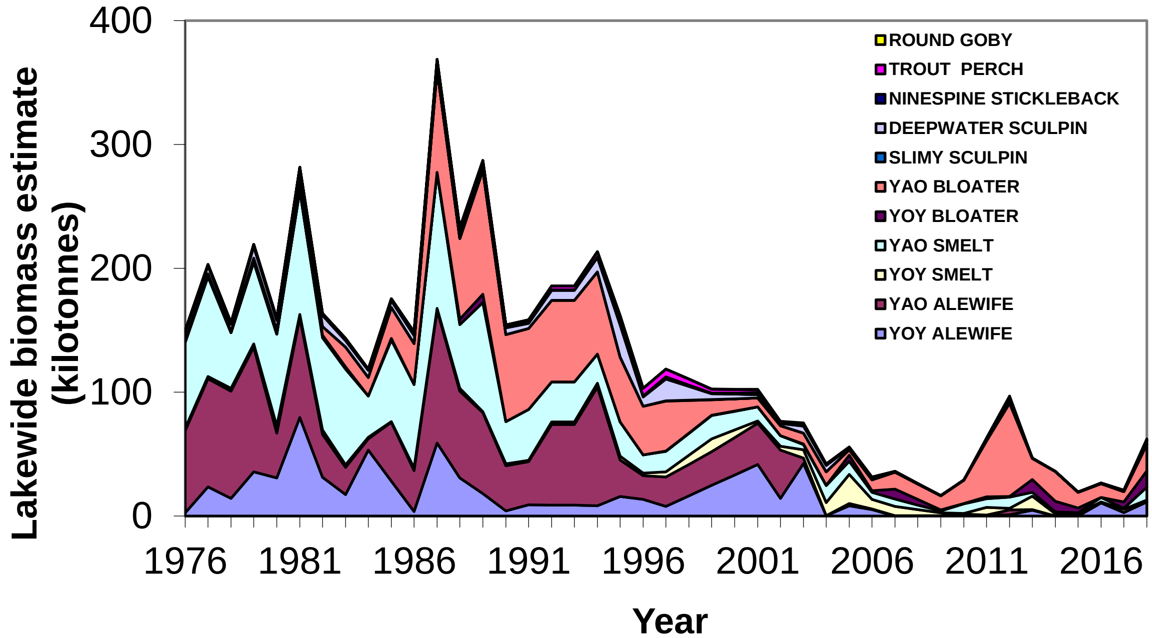

Figure 14. Estimated total offshore demersal prey fish biomass in the main basin of Lake Huron, 1976-2018. Valid data were not collected in 1992, 1993, 1998, 2000, and 2008; biomass estimates for those years represent interpolated values.