Status and Trends of the Lake Huron Offshore Demersal Fish Community, 1976-2010[1]

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Abstract

The USGS Great Lakes Science Center has conducted trawl surveys to assess annual changes in the offshore demersal fish community of Lake Huron since 1973. Sample sites include five ports in U.S. waters with less frequent sampling near Goderich, Ontario. The 2010 fall bottom trawl survey was carried out between 22 October – 12 November 2010. The 2010 main basin prey fish biomass estimate for Lake Huron was 29.09 kilotonnes, the second lowest estimate in the time series, and less than five percent of the maximum biomass estimated in 1987. The estimated biomass of adult alewife and rainbow smelt in 2010 were higher than 2009, but remained near the lowest observed in the time series, and populations were dominated by small fish. Estimated adult bloater biomass in Lake Huron has been increasing in recent years, and the 2010 biomass estimate was the highest observed since 1997. Biomass estimates for trout-perch and ninespine stickleback were the lowest observed in the time series. Deepwater sculpin biomass was higher than estimated in 2009, but remains near the lowest levels observed; slimy sculpins have not been captured since 2006. The 2010 biomass estimate for round goby was higher than in 2009 but remains relatively low. Wild juvenile lake trout were captured again in 2010, suggesting that low levels of natural reproduction by lake trout may be occurring. High variability in the abundance and biomass of several species may indicate that the offshore demersal fish community in Lake Huron is in an unstable state. Low prey fish abundance in Lake Huron may have continuing negative implications for populations of lake trout and Chinook salmon in the lake.

Introduction

Lake Huron supports valuable recreational and commercial fisheries that may be at risk due to recent widespread ecological changes in the lake (Bence and Mohr 2008). Recent major ecosystem changes in Lake Huron include the invasion of dreissenid mussels and drastic declines in the abundance of the native amphipod *Diporeia* sp. (McNickle et al. 2006; Nalepa et al. 2003, 2005, 2007), decreases in lake whitefish and Chinook salmon catches (Mohr and Ebener 2005; Bence and Mohr 2008), significant changes in the abundance and species composition of the zooplankton community (Barbiero et al. 2009), the invasion of the round goby, and the collapse of the offshore demersal fish community (Riley et al. 2008).

The 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 primary purpose of this report is to present estimates of the abundance and biomass of offshore demersal fish species that are important as prey to common predators in the lake (i.e., lake trout *Salvelinus namaycush* and Chinook salmon *Oncorhynchus tshawytscha*).

Methods

The U. S. Geological Survey (USGS) Great Lakes Science Center (GLSC) has monitored fish abundance annually from 1973-2010 using 12 m headrope (1973-1991) and 21 m headrope (1992-2010) 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 (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 and from the USGS R/V *Grayling* during 1978-2006; some transects were fished from the USGS R/V *Cisco* in 1990. The first year that all of the Michigan ports were sampled was 1976. Sampling has been conducted at Goderich (Ontario) from the R/V *Grayling* since 1998 using the same trawling protocols as U.S. ports, but this port was not sampled in 2010 due to weather conditions.

Single 10-min trawl tows were conducted during daylight at each transect each year. Tow duration was occasionally less than 10 min; catch for these tows was corrected to be equivalent to 10-min tows (see formula 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 kg/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 (USGS unpublished data). Catches were weighted by the area of the main basin of Lake Huron that occurred in each depth range. Lakewide biomass was estimated as the sum of the biomass of the common species sampled in the survey, and is not a true "lakewide" estimate, as sampling is conducted only to a depth of 110 m.

We partitioned the catches of alewife *Alosa pseudoharengus*, rainbow smelt *Osmerus mordax*, and bloater *Coregonus hoyi* into size-based age classes based on length-frequency data. Year-specific length cutoffs were determined from length-frequency data and used to apportion the catch into age-0 fish (young-of-the-year, or YOY) and those age-1 or older (yearling and older, or YAO). In earlier (pre-2009) reports, a constant length cutoff was used in all years.

To make density estimates from the two 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 slimy sculpin *Cottus cognatus* and 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 3 October and 15 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 highly 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.

Fish abundance estimates reported here are likely to be negatively biased, primarily due to variability in the catchability of fish by the trawl, which may reflect the vulnerability of fish to the gear or the distribution of fish off the bottom. Many individuals of some demersal species may be pelagic at some times and not available to our trawls, particularly young-of-the-year alewife, rainbow smelt and bloater. Results reported here should therefore not be interpreted as absolute abundance estimates for any species.

Some of the fluctuations in abundance of individual species that we observed may be a result of changes in catchability caused by altered fish distributions. For example, catchability of a given species might differ from year to year due to changes in temperature or food distribution, and observed changes in abundance might result from fish becoming less catchable by bottom trawls in recent years. The invasion of Lake Huron by dreissenid mussels may also have affected the efficiency of the 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 and were characterized by sandy or gravel substrates, and it is therefore possible that USGS trawl data do not fully characterize the offshore demersal fish community. There are no other published long-term data on offshore demersal fish abundance in Lake Huron that would allow us to investigate the representativeness of the trawl data. Despite the foregoing constraints, however, these data are currently the best available to assess the Lake Huron offshore demersal fish community.

Results

The 2010 Lake Huron fall bottom trawl survey was carried out during 22 October – 12 November. A total of 36 trawl tows were completed and all Michigan ports were sampled; the port of Goderich, Ontario, was not sampled due to persistent bad weather conditions at the end of the survey. The lake remained stratified during the survey. Seventeen species were captured in the 2010 survey: rainbow smelt, alewife, bloater, deepwater sculpin *Myoxocephalus thompsonii*, trout-perch, lake whitefish *Coregonus clupeaformis*, ninespine stickleback, threespine stickleback *Gasterosteus aculeatus*, lake trout, walleye *Sander vitreus*, emerald shiner *Notropis atherinoides*, spottail shiner *Notropis hudsonius*, round goby *Neogobius melanostomus*, yellow perch *Perca flavescens*, gizzard shad *Dorosoma cepedianum*, white sucker *Catostomus commersonii*, and common carp *Cyprinus cyprinus*.

Alewife abundance in Lake Huron remained low in 2010. Adult alewife density and biomass estimates increased over 2009, but were the fourth-lowest observed in the time series (Fig. 2). Age-0 alewife density and biomass also showed an increase in 2010, but remain near the all-time low for the time series (Fig. 2).

Adult (YAO) rainbow smelt density in Lake Huron increased over 2009, but remained low (5.6% of the maximum; Fig. 4). YOY rainbow smelt abundance and biomass were reduced compared to recent years, with 2010 estimates being the lowest observed in time series. The rainbow smelt population in Lake Huron was dominated by age-0 fish in 2010, but a greater proportion of the population was greater then 100 mm in length in 2010 (15%) than in 2009 (<1%).

Adult (YAO) bloater densities in Lake Huron have been increasing in recent years, but the 2010 abundance estimate was slightly lower than 2009. Bloater biomass, however, increased over 2009 due to the presence of more larger fish, and was the highest biomass observed since 1997 (Fig. 6). YOY bloater abundance was lower than 2009 and the lowest observed since 2002 (Fig. 6). Nearly 20% (19.55%) of bloaters captured in the 2010 survey were greater than 100 mm (Fig. 7).

Abundance and biomass estimates for deepwater sculpins in Lake Huron in 2010 were higher than 2009 but were the second-lowest observed in the time series (Fig. 8), and represented 5 percent of the maximum estimate (1995). Slimy sculpins have not been captured in the Lake Huron bottom trawl survey since 2006. The 2010 abundance and biomass estimates for ninespine stickleback were the lowest in the time series (Fig. 9). Trout-perch abundance was also the lowest estimate in the time series; biomass was the second-lowest (after 2009; Fig. 9). The 2010 biomass estimates for ninespine stickleback and trout-perch were 1.3% and 1.1% of the maxima, respectively. Round goby abundance and biomass estimates for 2010 were slightly higher than 2009 and were the second-lowest since 1998, the year after the species was first captured in the survey (Fig. 10).

The total main basin prey biomass estimate (5 - 114 m) was 29.1 kilotonnes, the second-lowest estimate in the time series (Fig. 11), which represents 7.9 percent of the maximum lakewide biomass estimated in 1987. Approximately 65 percent of the 2010 biomass estimate was made up of YAO bloater.

Three wild juvenile lake trout were captured in the 2010 fall survey (Fig. 12). Aside from the 2009 survey, when no wild juvenile lake trout were captured, this represents the lowest density of juvenile lake trout since they started appearing in the catches in 2004.

Discussion

The abundance of prey fish in Lake Huron has remained at very low levels since the collapse of the offshore demersal fish community (Riley et al. 2008). The estimated lakewide biomass of prey fish in 2010 was higher than reported in 2009, but is nevertheless the second-lowest recorded since the survey began, and is less than eight percent of the maximum biomass estimated in 1987. The estimated biomass of YAO alewife and rainbow smelt in 2010 were higher than 2009 estimates, but remained low compared to earlier data. Existing populations of alewife and rainbow smelt were dominated by small fish. The reduction in the abundance of these exotic species is consistent with fish community objectives for Lake Huron (DesJardine et al. 1995), but does not bode well for lake trout and Chinook salmon populations in the lake (Roseman and Riley 2009), which rely on these species as prey.

YAO bloater are the only offshore demersal fish species in Lake Huron to show a positive trend in abundance in recent years. YAO bloater biomass has been increasing since approximately 2001, and the 2010 biomass estimate was the highest observed since 1997. The abundance of this native species appears to be approaching the levels observed in the 1980s and 1990s, but biomass remains lower due to a relative lack of larger fish.

Abundance and biomass of all three of the primary prey species (alewife, rainbow smelt, and bloater) in Lake Huron were very low in 2010. All of these species have shown the highest estimated abundance of YOY fish in the time series since 2003. Estimated YOY alewife abundance reached an all-time high in 2003, the year that the adult population crashed, and YOY bloater abundance estimates were very high in 2005 and 2007. Estimated YOY rainbow smelt abundance peaked in 2005, but was high during 2004-2006. These high YOY abundance estimates do not appear to have resulted in recruitment of larger fish, however, with the potential exception of bloater, which have shown slight recent increases in adult abundance. These observations suggest that recent conditions in the lake have been intermittently conducive to the production of large year-classes of these species, but not to their long-term survival. The fact that all three species showed very low YOY abundance in 2010 indicates that conditions in Lake Huron were not suitable for YOY benthopelagic planktivore production in 2010.

Deepwater and slimy sculpins, ninespine sticklebacks, and trout-perch are currently minor components of lake trout diets in the Great Lakes, but were probably more important before the invasion of the lakes by alewife and rainbow smelt (e.g., Van Oosten and Deason 1938). Biomass estimates for sculpins, sticklebacks, and trout-perch in 2010 were the near the lowest observed in the time series. These species all reached peak abundance simultaneously in 1995 and 1997. The fact that all of these species were uncharacteristically highly abundant in the same years suggests that these peaks may not reflect actual abundance but may be the result of some factor, such as fish movement due to temperature or currents. As these species are all benthic feeders, this observation may be related to changes in the benthic environment associated with the invasion of dreissenid mussels, which occurred previous to these anomalously high observations. The fact that all of these native species are currently at or near record low abundance suggests that benthic offshore conditions in Lake Huron may have changed in a way that does not favor their survival.

Round gobies have recently become a significant part of the diet of lake trout in some areas of the Great Lakes (Dietrich et al. 2006), including Lake Huron (Ji He, MDNR Alpena, pers. comm.). Round gobies were first captured in the Lake Huron trawl survey in 1997, reached peak abundance in 2003, and have declined in abundance since. Our results suggest that round goby are currently at low abundance in the offshore waters of Lake Huron.

The estimated lakewide biomass of common offshore prey species in Lake Huron has increased since 2009, but remains near the lowest level observed since the survey began. The peak estimated biomass of prey fish in Lake Huron occurred in the late 1980s, and has declined steadily since then; a similar decline has occurred in Lake Michigan (Bunnell et al. 2009). It is possible that these declines are associated with the invasion of the lakes by several exotic species including zebra mussels, quagga mussels, and round gobies, all of which have been introduced since approximately 1990. Similar declines in some species (particularly coregonids) have occurred in Lake Superior (Gorman and Bunnell, 2009; Gorman et al. 2009), however, where these exotic species have not invaded.

Naturally-produced juvenile lake trout were first captured in relatively large numbers by the Lake Huron fall survey in 2004, the year after the alewife population collapsed (Riley et al. 2007). Catches have generally declined since then, and were relatively low in 2010. This suggests that the conditions that were conducive to natural reproduction of lake trout in Lake Huron may have been temporary, and that natural reproduction of lake trout may be less widespread in Lake Huron in recent years. We note, however, that this survey was not designed to catch juvenile lake trout, and the lack of catches in our survey does not necessarily mean that naturally-produced juvenile lake trout are not present in some areas of the lake.

The results of this survey show that there has been great variability in the abundance or biomass of a number of fish species (YOY benthopelagic planktivores, round goby, wild juvenile lake trout) over the last decade, while the overall abundance and biomass of prey species in the main basin of Lake Huron remain near the lowest levels observed since the inception of the survey. These very low levels of prey fish abundance have persisted since approximately 2006. These results, along with other analyses of these data (Riley and Adams 2010), may indicate that the offshore demersal fish community in Lake Huron is currently in an unstable state. Continuing low levels of prey fish abundance may have serious implications for the growth, condition, and survival of lake trout and Chinook salmon populations in the lake.

Acknowledgements

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Figures

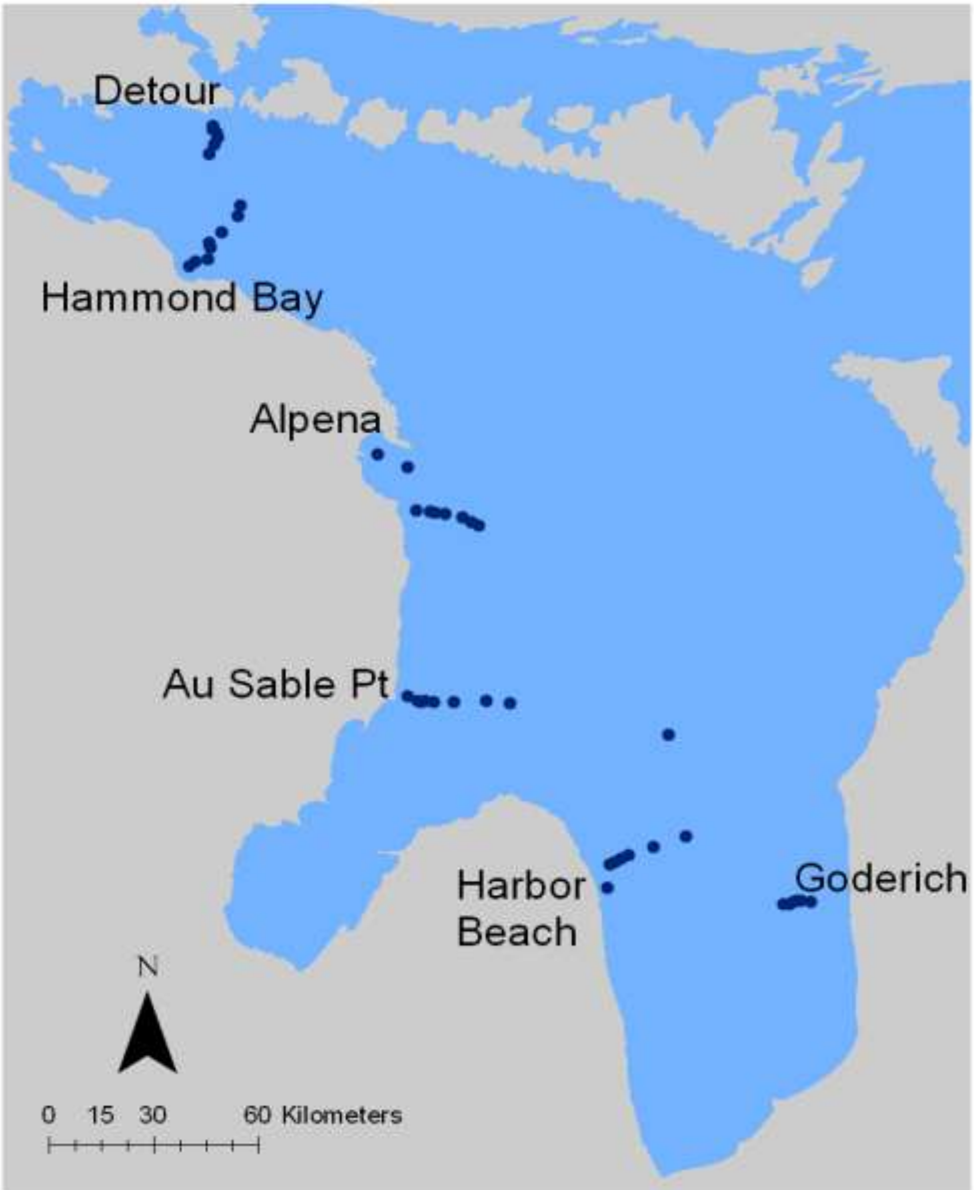

Figure 1. Sampling locations in Lake Huron, 2010.

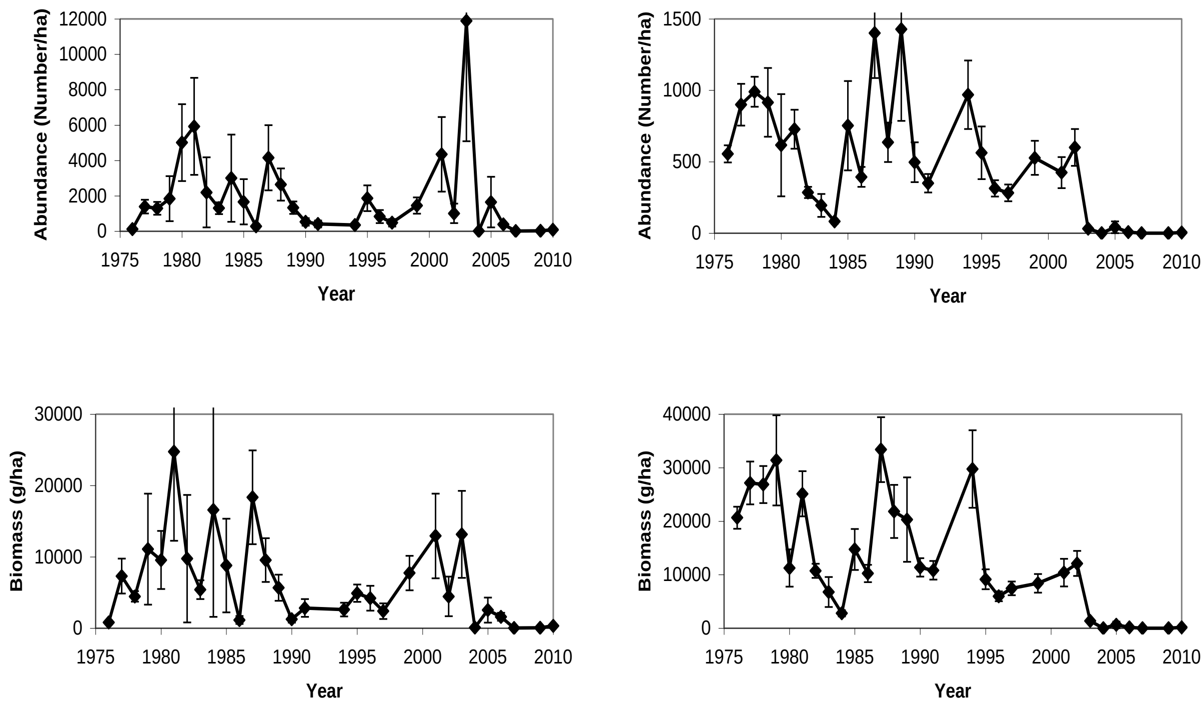

Figure 2. Density of young-of-the-year (YOY: left panels) and adult (YAO: right panels) alewives as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2010. 1976-1991 estimates were corrected using fishing power corrections developed by Adams et al. (2009). Error bars are 95% confidence intervals.

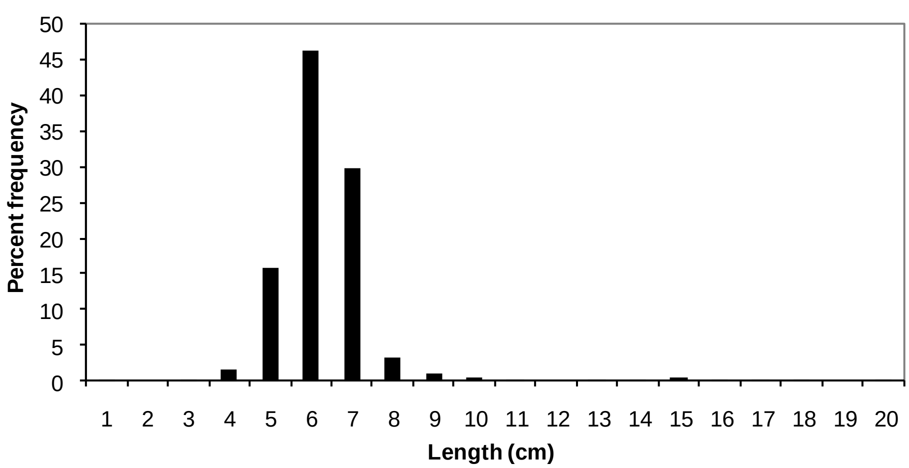

Figure 3. Size structure of Lake Huron alewives, 2010.

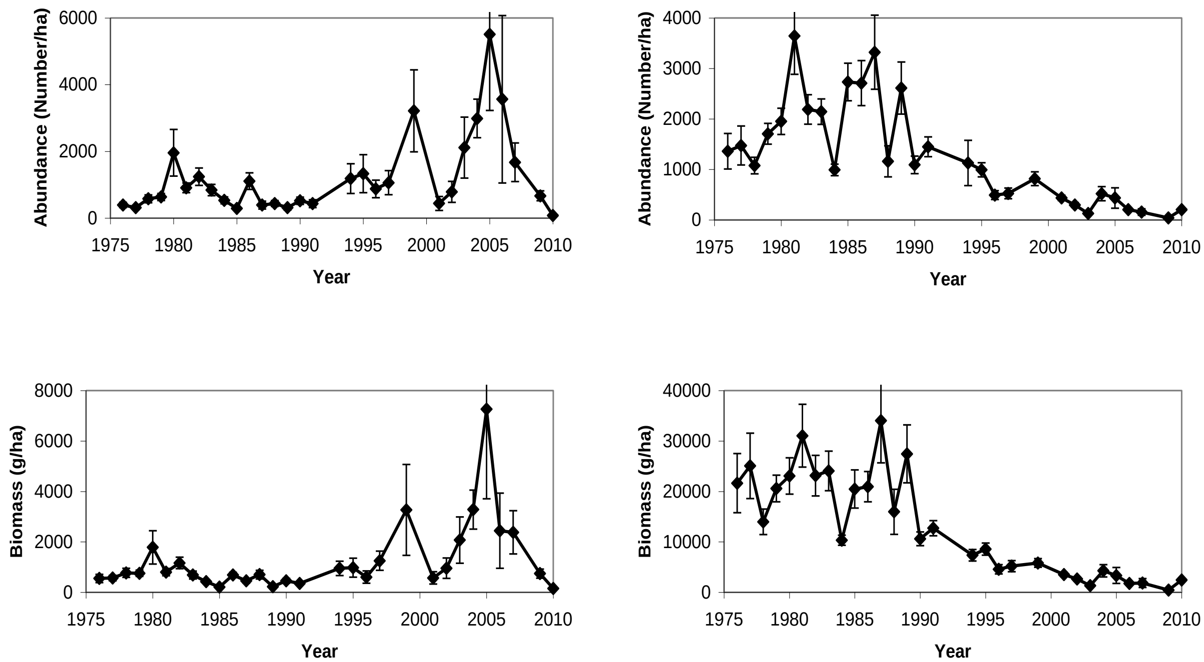

Figure 4. Density of young-of-the-year (YOY: left panels) and adult (YAO: right panels) rainbow smelt as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2010. 1976-1991 estimates for YAO were corrected using fishing power corrections developed by Adams et al. (2009); YOY data are uncorrected. Error bars are 95% confidence intervals.

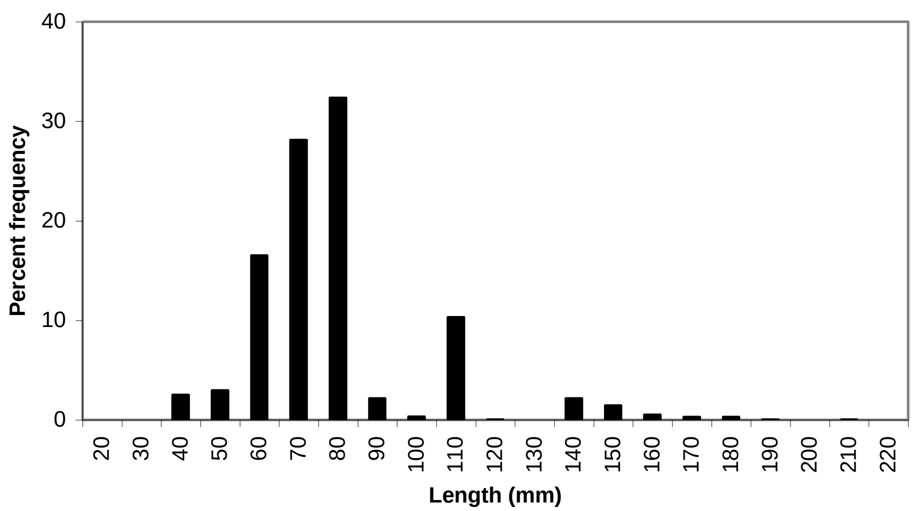

Figure 5. Length-frequency distribution of rainbow smelt collected in bottom trawls from Lake Huron during fall 2010.

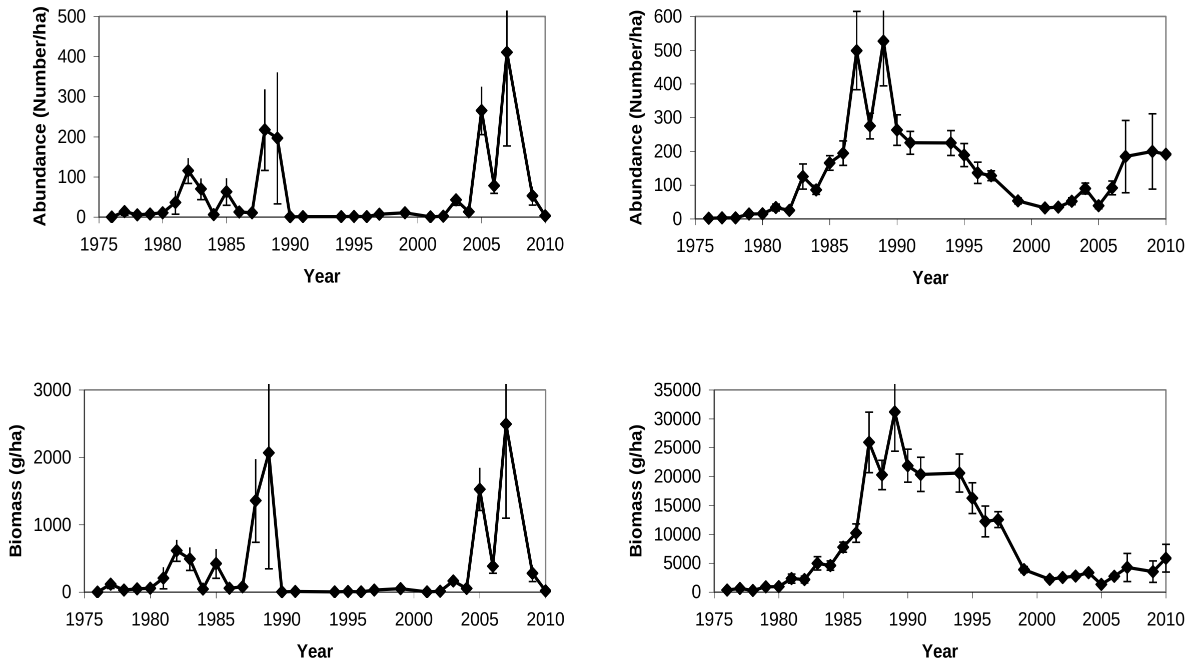

Figure 6. Density of young-of-the-year (YOY: left panels) and adult (YAO: right panels) bloater as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2010. 1976-1991 estimates were corrected using fishing power corrections developed by Adams et al. (2009). Error bars are 95% confidence intervals.

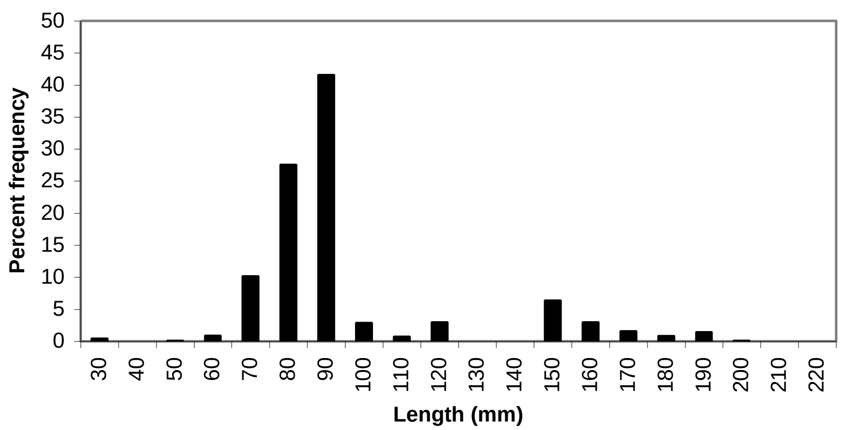

Figure 7. Length frequency distribution of bloaters collected in bottom trawls from Lake Huron, 2010.

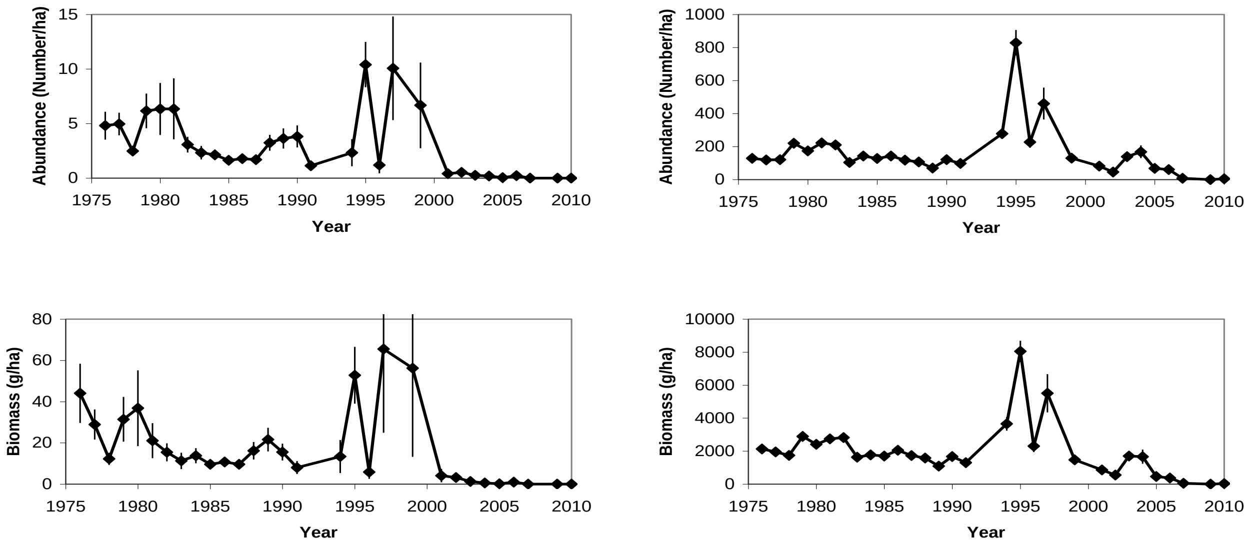

Figure 8. Density of slimy (left panels) and deepwater (right panels) sculpins as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2010. 1976-1991 estimates were corrected using fishing power corrections developed by Adams et al. (2009). Error bars are 95% confidence intervals.

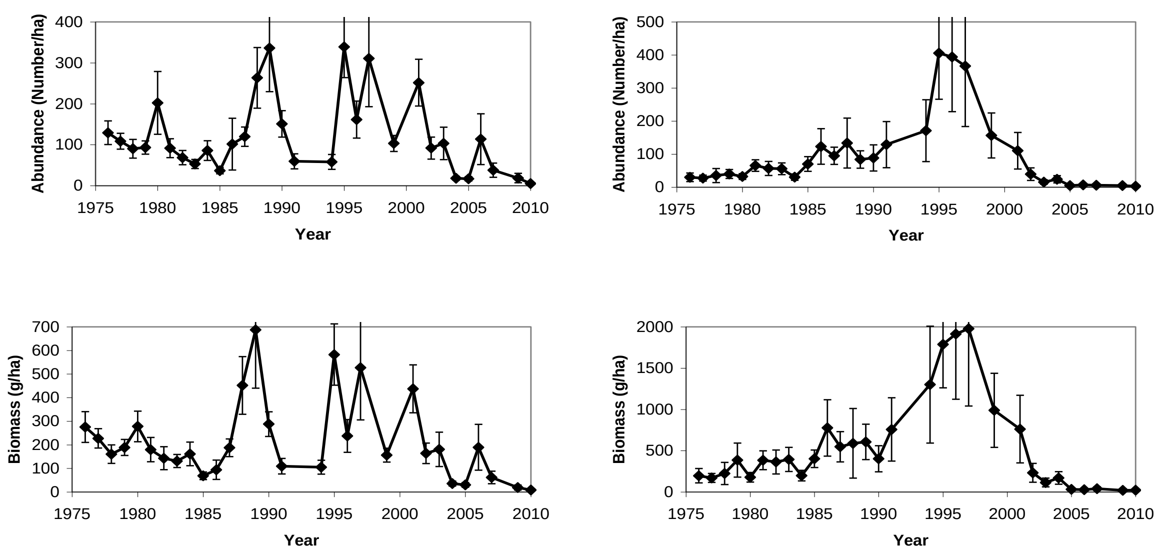

Figure 9. Density of ninespine stickleback (left panels) and trout-perch (right panels) as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2010. Error bars are 95% confidence intervals.

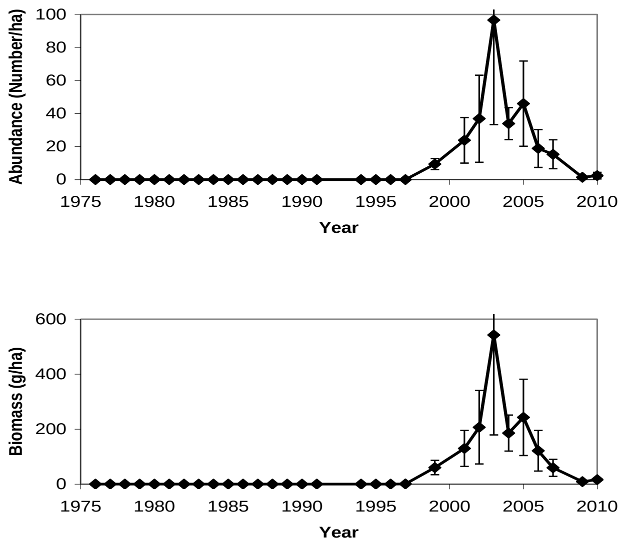

Figure 10. Density of round goby as number (top panel) and biomass (bottom panel) of fish per hectare in Lake Huron, 1976-2010.

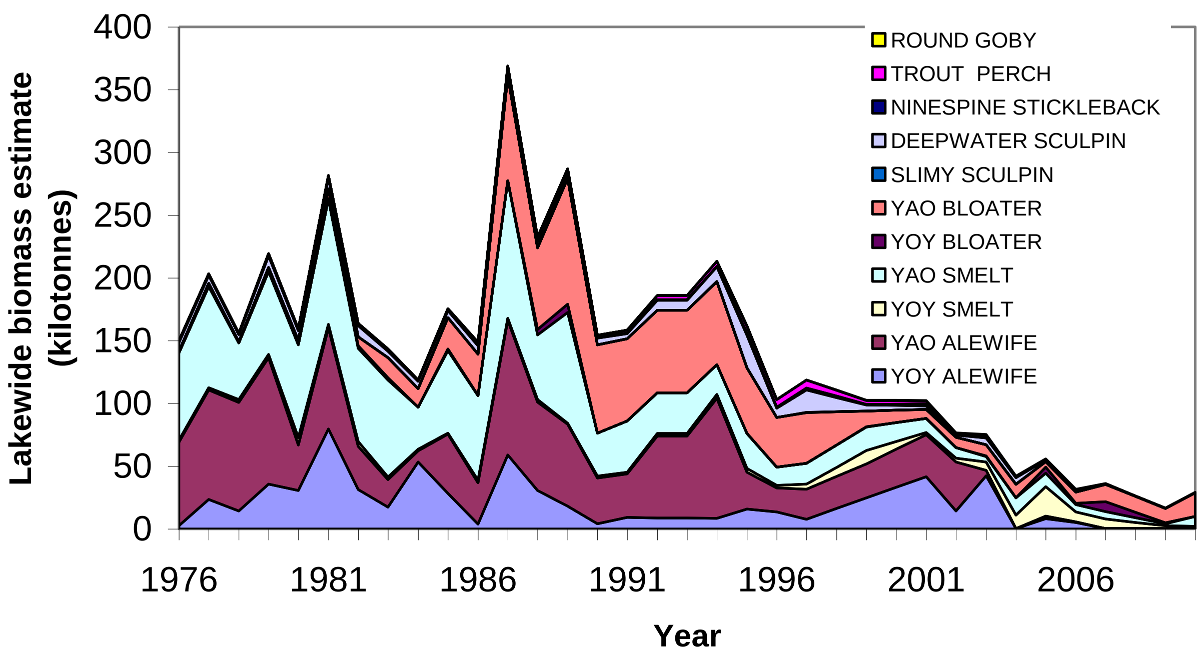

Figure 11. Offshore demersal fish community biomass in the main basin of Lake Huron, 1976-2010. Valid data were not collected in 1992, 1993, 1998, 2000, and 2008; biomass estimates for those years represent interpolated values.

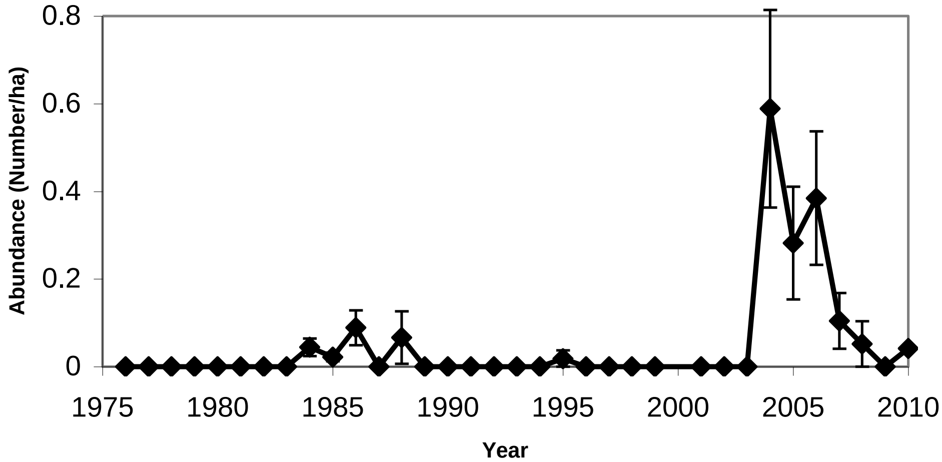

Figure 12. Density of wild and stocked lake trout collected in fall bottom trawls from Lake Huron 1976-2010. Error bars are 95% confidence intervals.