Status and Trends of the Lake Huron Offshore Demersal Fish Community, 1976-2009[1]

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Abstract

The U SGS 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 additional sampling near Goderich, Ontario, since 1998. This is the first time that the entire time series of abundance and biomass estimates for Lake Huron have been presented since the sampling gear was changed in 1992. The 2009 fall bottom trawl survey was carried out between 18 October – 4 November 2009. The 2009 main basin prey fish biomass estimate for Lake Huron was 16.53 kt, the 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 2009 were the lowest observed in the time series, and populations were dominated by small fish. Adult bloater densities in Lake Huron have been increasing in recent years, but the 2009 biomass estimate was less than that estimated by the last full survey in 2007. Biomass estimates for trout-perch, ninespine sticklebacks, and slimy and deepwater sculpins in 2009 were the lowest observed in the time series. The 2009 biomass estimate for round goby was the lowest since 1998, the year after the species was first captured in the survey. Lake whitefish abundance and biomass remain depressed compared to the 1990s, but biomass appears to be increasing. No wild juvenile lake trout were captured in the 2009 survey for the first time since 2004. Relatively large numbers of juvenile walleye were captured near Au Sable Point in 2009, the first time that walleye in this size range have been captured since the inception of the survey.

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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 *Coregonus clupeaformis* and Chinook salmon *Oncorhynchus tshawytscha* 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 *Neogobius melanostomus*, and the collapse of the offshore demersal fish community (Riley et al. 2008).

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 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), but we also describe trends in catches of other important species. Until recently, analysis of the complete time series of data for Lake Huron has been precluded due to a change in sampling gear that occurred in 1992. For the first time since 1992, this report examines data collected over the entire usable time series, from 1976-2009.

Methods

The USGS Great Lakes Science Center (GLSC) has monitored fish abundance annually from 1973-2006 using 12 m headrope (1973-1991) and 21 m headrope (1992-2006) 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.

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 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 both the actual time on bottom and the trawl width for each trawl increased with depth (Adams et al. 2009). Relative abundance was standardized to density as

$$D = \frac{10000N}{T'SW},$$

where D is the density (in number/ha), 10,000 is the area conversion (in m^2/ha), N is the catch (in number), T' is the actual time on bottom (in min), S is the towing speed (in m/min), and W is the trawl width (in m). Biomass (in kg/ha) was calculated using the same approach, replacing the catch in number with the catch in kg. Lakewide biomass was estimated as the sum of the biomass of the common species sampled in the survey, weighting by the surface area of the main basin of Lake Huron in each depth range, 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 previous reports, a constant length cutoff was used in all years; here we apply year-specific length cutoffs for 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 to the density and biomass estimates of alewife, rainbow smelt (YAO only), bloater, and lake whitefish *Coregonus clupeaformis*, 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; these data were not used here because the distribution of many offshore species in the Great Lakes is highly seasonally variable (Wells 1968; Argyle 1982) 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 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 among habitats. 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.

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 these data may not fully characterize the offshore demersal fish community. Despite the foregoing constraints, however, these data are currently the best available to assess the Lake Huron offshore demersal fish community.

Results

The 2009 Lake Huron fall bottom trawl survey was carried out during 18 October – 4 November. A total of 44 trawl tows were completed and all ports were sampled. The lake remained stratified during the survey. Eighteen species were captured in the 2009 survey: rainbow smelt, alewife, bloater, deepwater sculpin, trout-perch, lake whitefish, ninespine stickleback, slimy sculpin, lake trout, walleye *Sander vitreus*, spottail shiner *Notropis hudsonius*, round goby, yellow perch *Perca flavescens*, common carp

Cyprinus cyprinus, round whitefish *Prosopium cylindraceum*, 3-spine stickleback *Gasterosteus aculeatus*, sea lamprey *Petromyzon marinus*, and gizzard shad *Dorosoma cepedianum*.

Alewife, rainbow smelt, and bloater

Alewife abundance in Lake Huron remained low in 2009. Adult alewife density was the second-lowest observed (after 2004) and biomass was the lowest observed in the time series (Fig. 2). Age-0 alewife density and biomass showed a slight increase in 2009, but remain near the all-time low for the time series (Fig. 2). The majority of the alewives captured were less than 90 mm (Fig. 3).

Adult (YAO) rainbow smelt density continued to decline in Lake Huron, reaching the lowest abundance and biomass observed in the time series in 2009 (Fig. 4). YOY rainbow smelt abundance and biomass were also reduced compared to recent years, with the lowest abundance and biomass estimates observed since 2002. The rainbow smelt population in Lake Huron was dominated by age-0 fish in 2009, with less than one percent of the population larger than 100 mm (Fig. 5).

Adult (YAO) bloater densities in Lake Huron have been increasing in recent years, and the 2009 abundance estimate was the highest observed since 1995, although the biomass estimate was smaller than 2007 (Fig. 6). YOY bloater abundance was lower then observed since 2005, but was higher than most years in the 1990s (Fig. 6). More than 20 percent (21.4%) of bloaters captured in the 2009 survey were greater than 100 mm (Fig. 7).

Other prey species

Abundance and biomass estimates for slimy and deepwater sculpins in Lake Huron were the lowest observed in the time series (Fig. 8). The 2009 abundance estimate for deepwater sculpins represented four percent of the previous low estimate (2007) and <0.04 percent of the maximum estimate (1995). Slimy sculpins have not been captured in the Lake Huron bottom trawl survey since 2006.

The 2009 abundance estimate for ninespine stickleback was the third-lowest in the time series, while the biomass estimate was the lowest (Fig. 9). Trout-perch abundance was the second-lowest estimate in the time series; biomass was the lowest (Fig. 9). The 2009 biomass estimates for ninespine stickleback and trout-perch were 2.8 percent and 1.1 percent of the maximum estimates for those species, respectively. The 2009 abundance and biomass estimates for round goby were the lowest since 1998, the year after the species was first captured in the survey (Fig. 10).

Lakewide prey biomass

The total main basin prey biomass estimate (5 - 114 m) was 16.53 kt, the lowest estimate in the time series (Fig. 11). This estimate is less than half (45.7%) of the biomass estimated in the last complete survey in 2007, and represents 4.5 percent of the maximum biomass estimated in 1987. Approximately 69 percent of the 2009 biomass estimate was made up of YAO bloater.

Other species of interest

Lake whitefish abundance and biomass remain depressed compared to the peak values observed in the early 1990s, but biomass has increased in the past few years (Fig. 10). No wild juvenile lake trout were captured in the 2009 survey for the first time since 2004 (Fig. 12). Relatively large numbers of juvenile walleye were captured near Au Sable Point in 2009 (Fig. 13). This is the first time that walleye in this size range (110 - 120 mm) have been captured since the inception of the survey.

Discussion

The abundance of prey fish in Lake Huron has continued to decline since the collapse of the offshore demersal fish community was reported (Riley et al. 2008). The estimated lakewide biomass of prey fish in 2009 was the lowest recorded since the survey began, and is less than half of that estimated in the last complete survey in 2007. The estimated biomass of YAO alewife and rainbow smelt in 2009 were the lowest observed in the time series, and the existing populations were dominated by small fish. The reduction in 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.

YAO bloater are the only prey species in Lake Huron to show a positive trend in abundance in recent years. YAO bloater abundance has increased since approximately 2001, and the 2009 abundance estimate was the highest observed since 1995. Because the majority of YOA bloater were relatively small, however, the 2009 biomass estimate was lower than that observed in 2007. The abundance of this native species appears to be approaching the levels observed in the 1980s and 1990s, but biomass does not.

All three of the primary prey fish species in Lake Huron (alewife, rainbow smelt, and bloater) 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.

Sculpins, 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 2009 were the lowest observed in the time series, suggesting that these species will not compensate for low abundance of the primary prey species. 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 other factor, such as fish movement due to temperature or currents. As these species are all benthic feeders, these observations may be related to changes in the benthic environment associated with the invasion of dreissenid mussels, which occurred previous to these anomalously high observations.

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 reached the lowest level observed since 1976. 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 fall survey in 2004, the year after the alewife population collapsed (Riley et al. 2007). Catches have generally declined since then, and 2009 was the first year since 2004 that none were captured by the survey. This suggests that the conditions that were conducive to natural reproduction of lake trout in Lake Huron may have been temporary, and that widespread natural reproduction of lake trout may no longer be occurring in Lake Huron. We note, however, that this survey was not designed to sample lake trout fry, 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. Moreover, juvenile lake trout may be experiencing higher predation rates in recent years due to the lack of other prey species in the lake.

The reproductive success of walleye in Saginaw Bay has increased greatly since approximately 2003 (Fielder et al. 2007). Juvenile walleye were captured in 2009 for the first time in the history of the Lake Huron fall survey, suggesting that juvenile walleye may now be using offshore areas of the lake near Saginaw Bay as nursery habitat. Catches from future surveys will determine if this is a continuing trend.

The results of this survey indicate that the abundance and biomass of prey species in the main basin of Lake Huron remain are at the lowest levels observed since the inception of the survey. The continuing decline in 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. Bottom trawl sampling locations in Lake Huron, 2009.

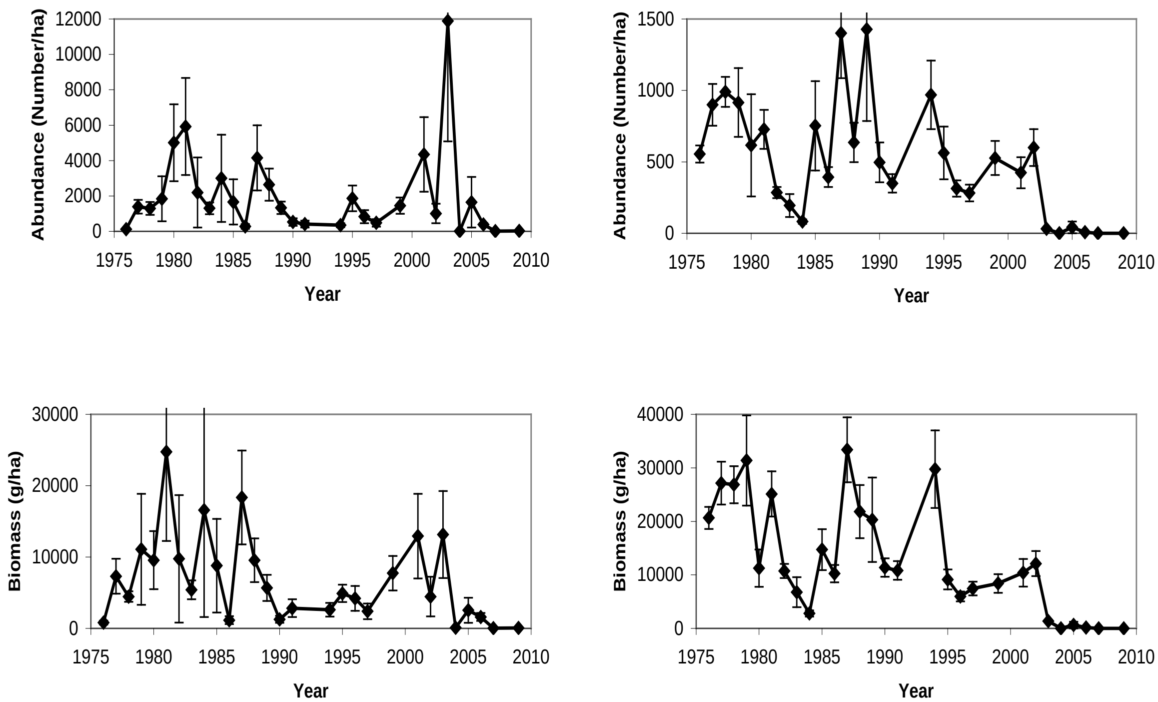

Figure 2. Density of young-of-the-year (YOY: left panels) and adult (YAO: right panels) alewives as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2009. 1976-1991 estimates were corrected using fishing power corrections developed by Adams et al. (2009). Error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

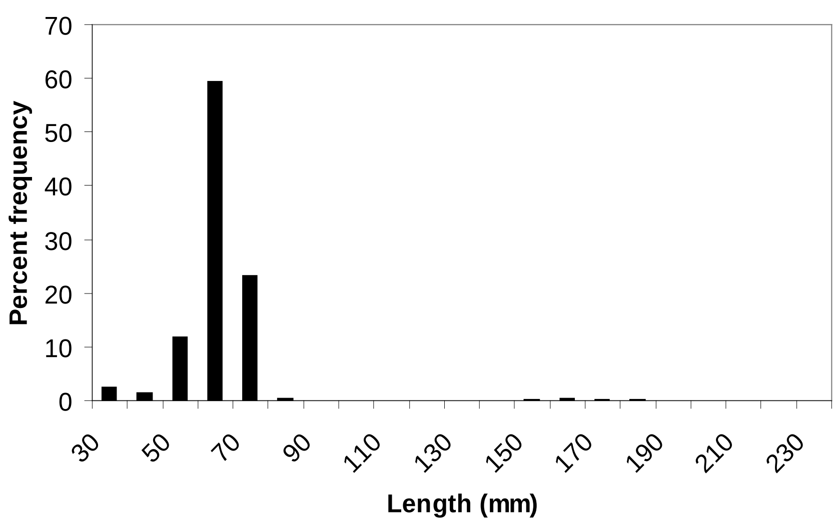

Figure 3. Length-frequency distribution of Lake Huron alewives, 2009.

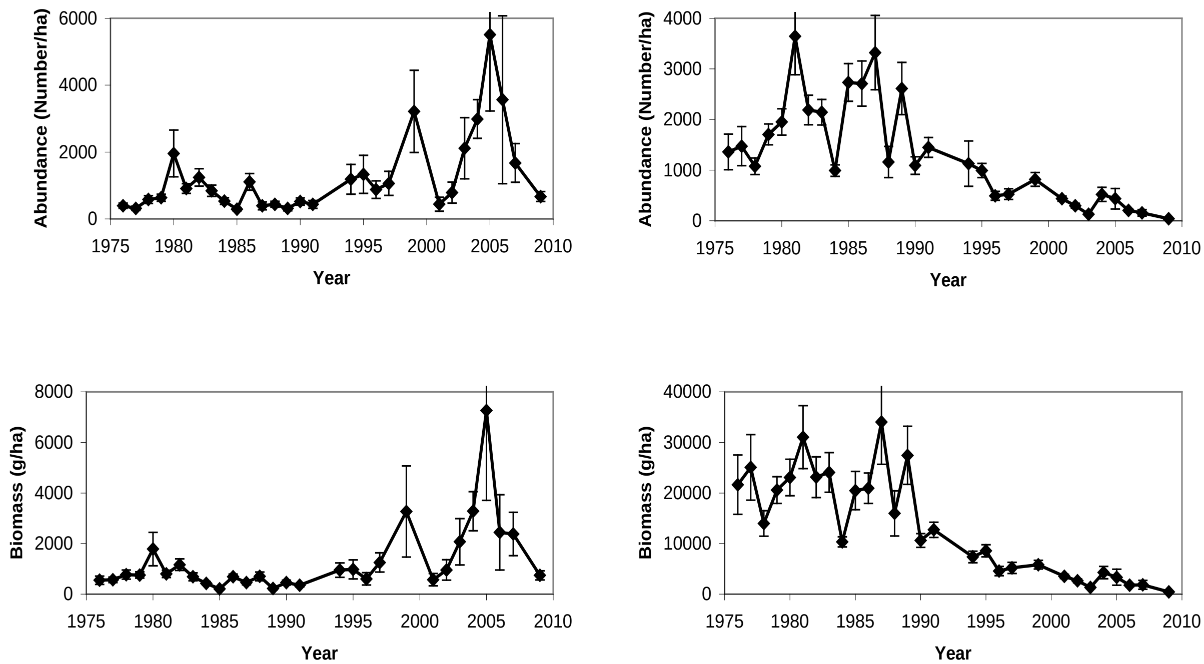

Figure 4. Density of young-of-the-year (YOY: left panels) and adult (YAO: right panels) rainbow smelt as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2009. 1976-1991 estimates for YAO were corrected using fishing power corrections developed by Adams et al. (2009);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

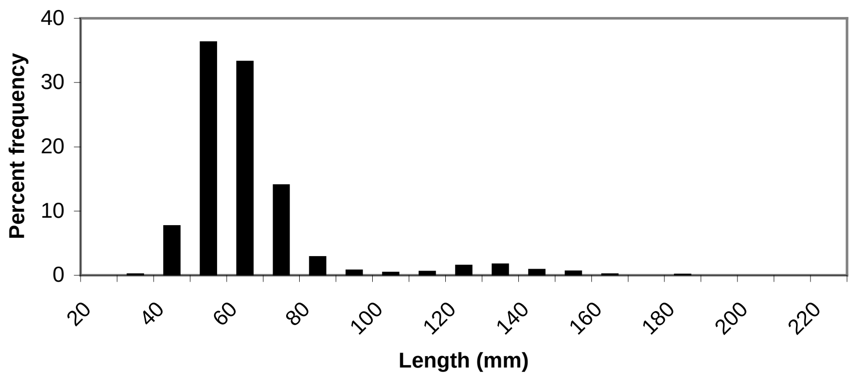

Figure 5. Length-frequency distribution of rainbow smelt collected in bottom trawls from Lake Huron during fall 2009.

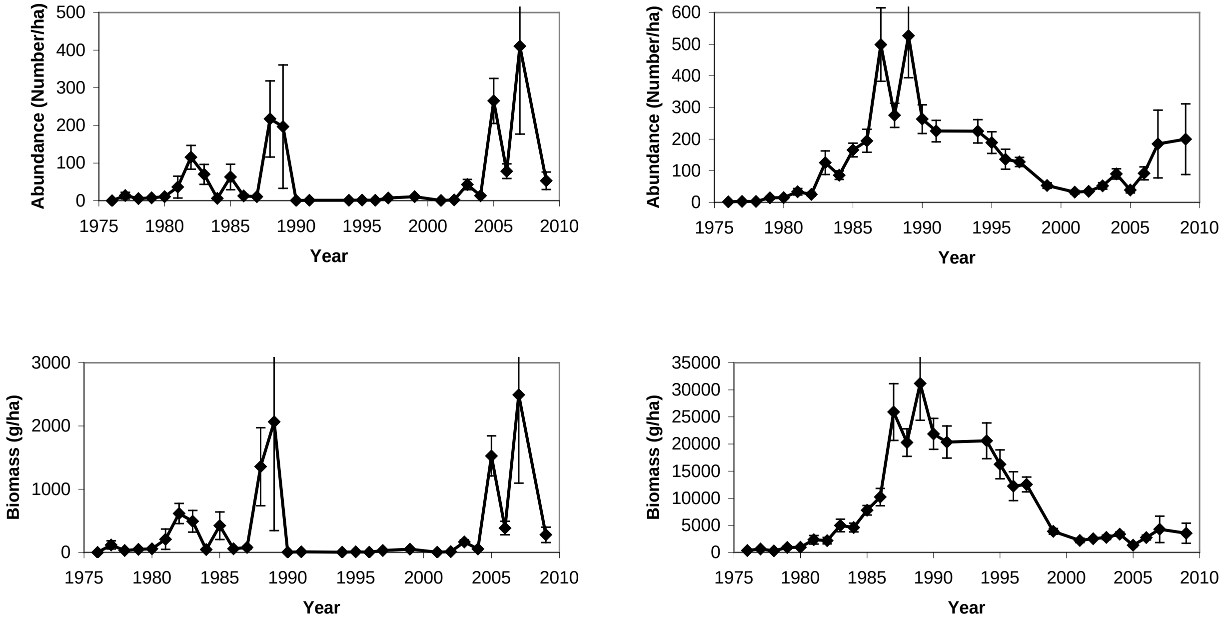

Figure 6. Density of young-of-the-year (YOY: left panels) and adult (YAO: right panels) bloater as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2009. 1976-1991 estimates were corrected using fishing power corrections developed by Adams et al. (2009). Error bars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

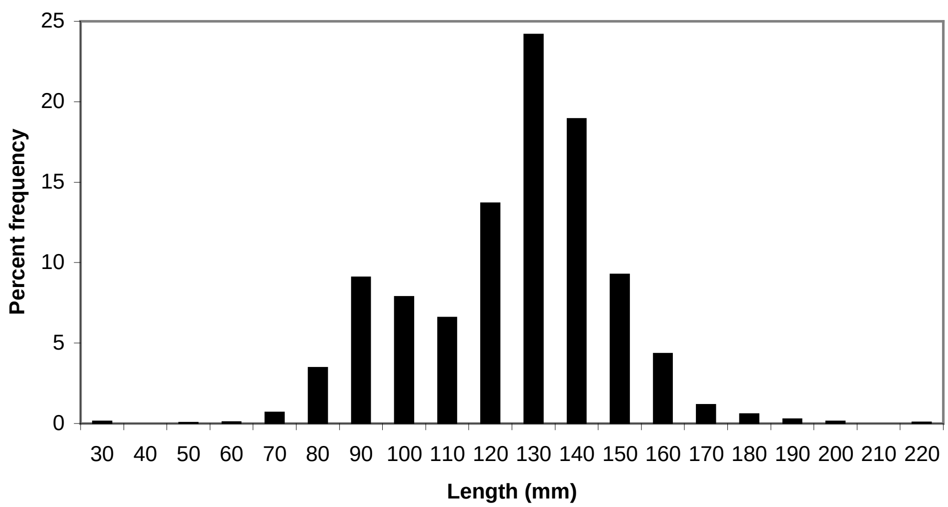

Figure 7. Length frequency distribution of bloaters collected in bottom trawls from Lake Huron, 2009.

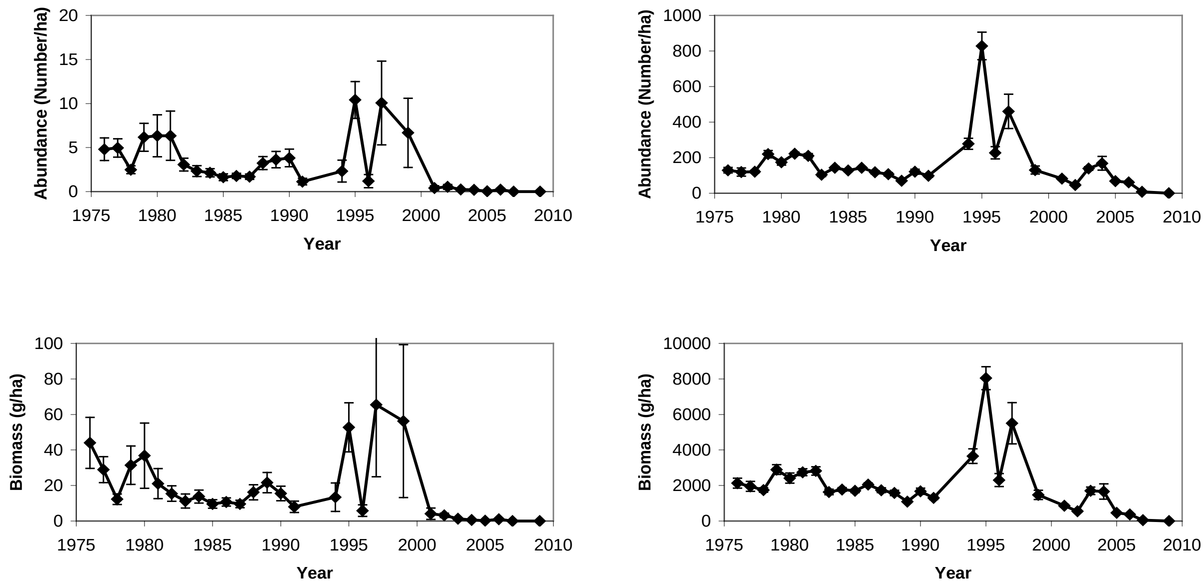

Figure 8. Density of slimy (left panels) and deepwater (right panels) sculpins as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2009. 1976-1991 estimates were corrected using fishing power corrections developed by Adams et al. (2009). Error bars are 95% confidence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

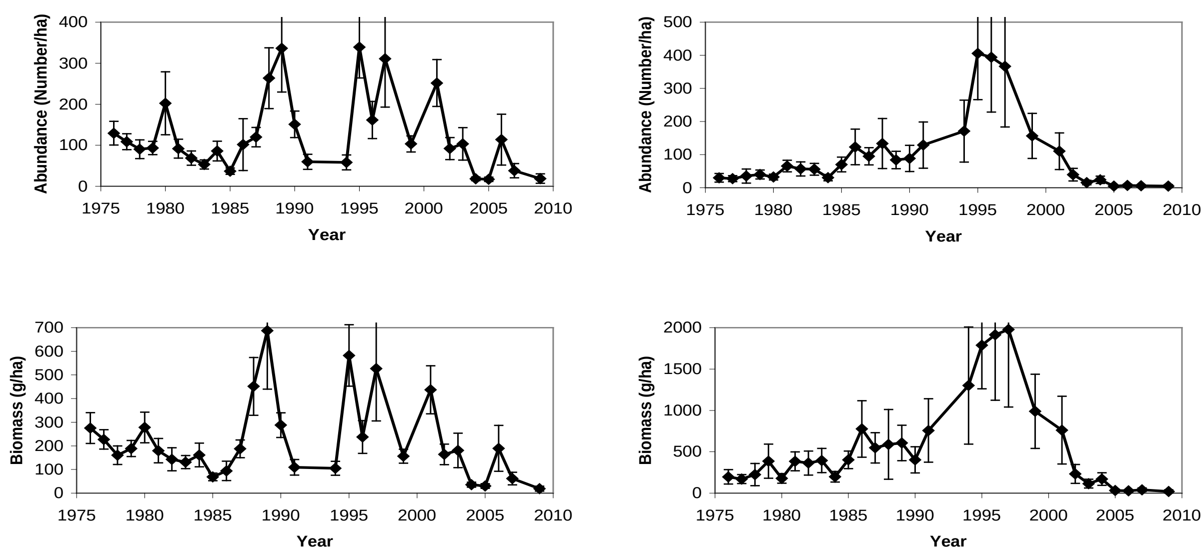

Figure 9. Density of ninespine stickleback (left panels) and trout-perch (right panels) as number (top panels) and biomass (bottom panels) of fish per hectare in Lake Huron, 1976-2009. Error bars are 95% confidence intervals.

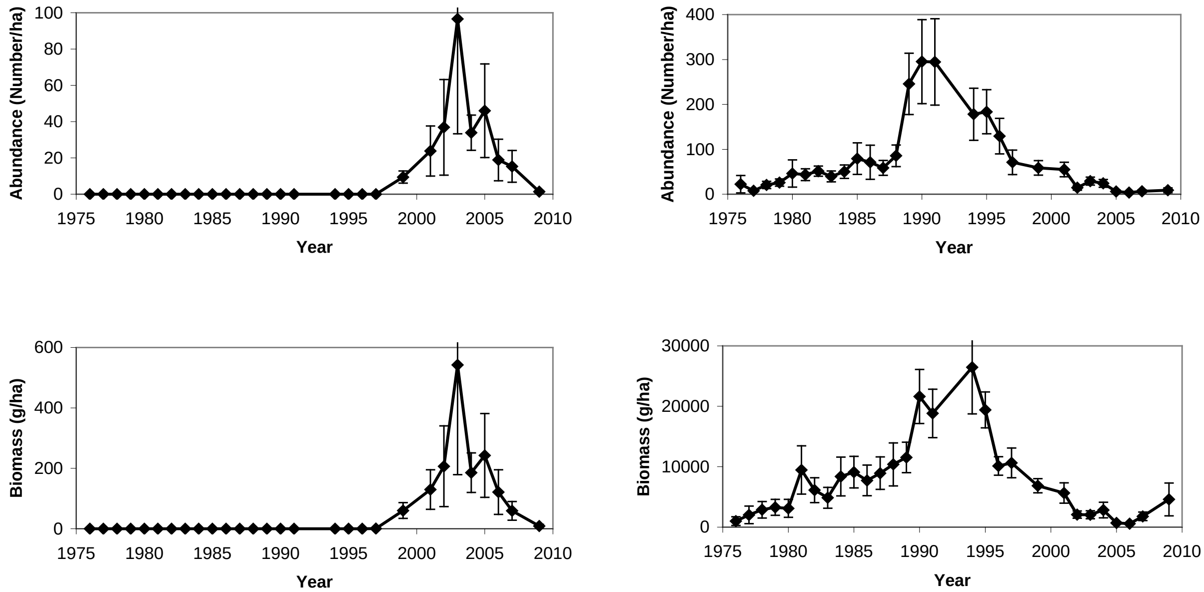

Figure 10. Density of round goby (left panels) and lake whitefish (right panels) as number (top panel) and biomass (bottom panel) of fish per hectare in Lake Huron, 1976-2009. Estimates for lake whitefish were corrected for the change in sampling gear. Error bars are 95% confidence intervals.

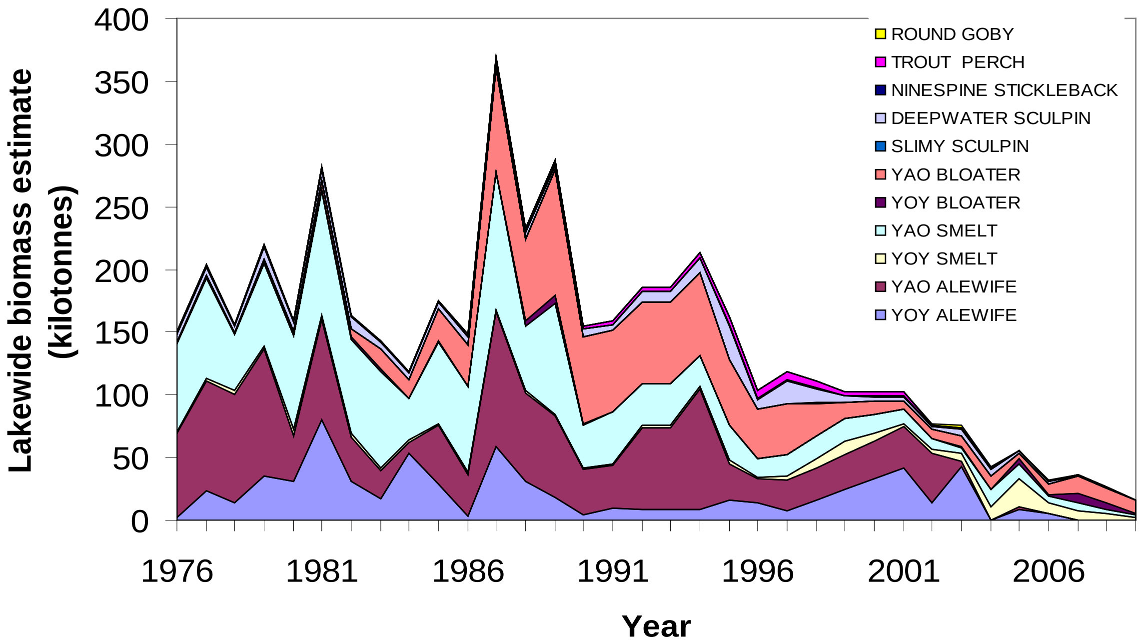

Figure 11. Offshore demersal fish community biomass in the main basin of Lake Huron, 1976-2009. Valid data were not collected in 1992, 1993, 1998, 2000, and 2008; biomass estimates for those years represent interpolated values.

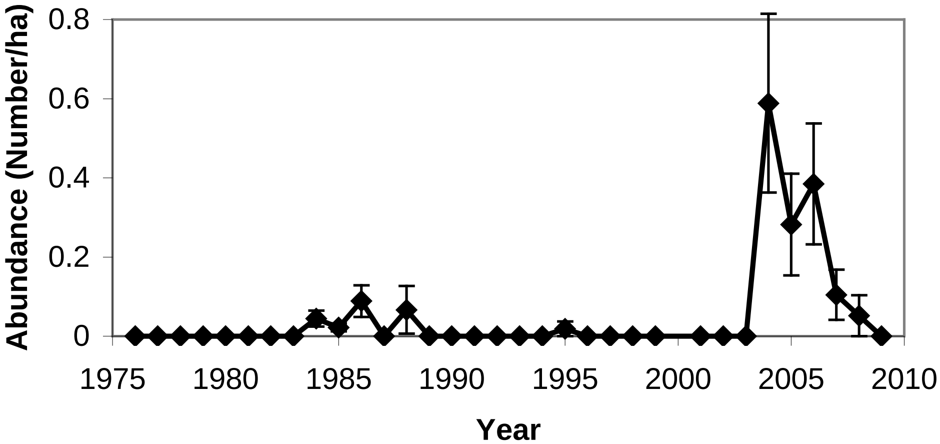

Figure 12. Density of wild juvenile lake trout collected in fall bottom trawls from Lake Huron 1976-2009. Error bars are 95% confidence intervals.

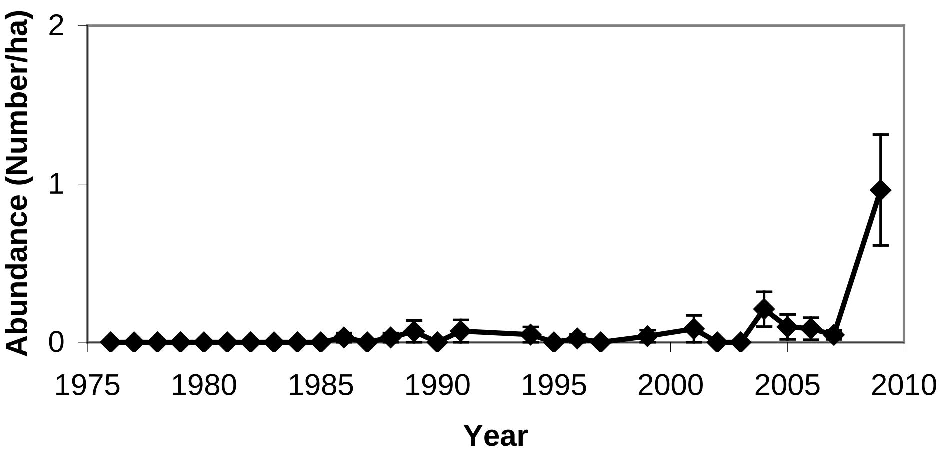

Figure 13. Density of walleye collected in fall bottom trawls from Lake Huron 1976-2008. Error bars are 95% confidence intervals.