Status and Trends of the Lake Huron Deepwater Demersal Fish Community, 2007[1]

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Abstract

The U.S.G.S. Great Lakes Science Center has conducted trawl surveys to assess annual changes in the fish community of Lake Huron since 1973. Since 1992, surveys have been carried out using a 21 m wing trawl towed on-contour at depths ranging from 9 to 110 m on fixed transects. Sample sites include five ports in U.S. waters with less frequent sampling near Goderich, Ontario. The 2007 fall prey fish survey was carried out between October 15 and November 4, 2007 and sampled all five U.S. ports and Goderich, Ontario. The alewife population remained at low levels after collapsing in 2004. Adult and age-0 alewife density and biomass declined from 2006 levels and remain near the historical low observed in 2004. Density and biomass of adult and juvenile rainbow smelt showed only a slight increase from 2006 levels despite record-high abundance of juveniles observed in 2005 suggesting recruitment was limited. Juvenile rainbow smelt abundance in 2007 remained slightly higher than the long-term mean for the time series since 1992. Numbers of adult bloater increased in 2007 approaching the high levels observed in the early 1990s showing evidence of recruitment, but biomass remains low due to the small size distribution of the new recruits. Juvenile bloaters remained ubiquitous with abundance surpassing the previous record high observed in 2005. Abundances for most other prey species were similar to the low levels observed in 2005 and 2006. We captured 11 wild juvenile lake trout in 2007; this represents the fourth consecutive year that substantial numbers of wild lake trout were captured in the survey. Benthic macroinvertebrates have been sampled during the fall survey since 2001. Density of benthic macroinvertebrates showed an increase from 2005-2006 values due largely to increases in oligochaete and quagga mussel densities. Prey biomass available to the bottom trawl increased slightly from 2006 levels due to increases in bloater and rainbow smelt biomass. However, total prey biomass remains near the all-time low observed in 2006. The prey available to salmonids during 2008 will be small rainbow smelt and small bloaters. Predators in Lake Huron will continue to face potential prey shortages.

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Introduction

The Great Lakes Science Center (GLSC) has conducted annual bottom trawl surveys on Lake Huron since 1973. These surveys are used to examine relative abundance, size and age structure, and species composition of the prey fish community. Estimates of lake-wide (i.e., between 5- and 114-m depth contours) prey fish biomass available to the trawl are also generated. Sampling was conducted with a 12-m bottom trawl during 1973-1991, but in 1992 the gear was changed to a 21-m wing trawl to improve biomass estimates of pelagic prey species and to reduce apparent size selectivity. This report focuses on data collected during 1992-2007 using the 21-m wing trawl. Sampling was conducted annually during this time period, except during 2000 when sampling did not occur due to vessel navigation system breakdown.

Methods

Trawl sampling is performed annually at five ports in U.S. waters: De Tour, Hammond Bay, Alpena, Au Sable Point (Tawas), and Harbor Beach (Figure 1). At each port, 10-minute on-contour trawl tows are made on approximate 9 m depth intervals at fixed transects from 9 to 110 m in depth. The 27, 37, 46, 55, 64, and 73 m depths are common to all ports, but the number of shallower and deeper tows varies among ports due to variation in bathymetry and bottom composition. Sampling also occurred at Goderich, Ontario during 1998, 1999, and 2003-2007 using the same trawling regime as U.S. ports (Figure 1).

Tow times and speeds were constant, but true time-on-bottom increases with depth, and catches C_i were standardized among tows using the formula:

$$C_i = N_i * \left(\frac{10}{t(0.004d + 0.8861)} \right)$$

where N_i is the number of fish of species *i* captured in a single tow, *t* is tow time (usually 10 minutes), and *d* is depth (m). Density (D_i) was calculated for each species by dividing C_i by area swept, expressed as number · Ha^{-1}.

Annual numeric density (A_i) was defined as mean number · Ha^{-1} of each species:

$$A = \frac{\sum_{i=1}^{n} D_i}{n}$$

where D_i is the density of species *i* from each trawl tow, and *n* is total number of tows performed.

Variability associated with *A* was estimated using Relative Standard Error (*RSE*):

$$RSE_{\mathrm{i}} = 100 \times \left(\frac{se}{A_i} \right)$$

where *se* represents the standard error of *A* (mean density). An RSE of 100% indicates the standard error was equal to the estimated mean.

For analysis of recruitment trends, mean density was apportioned into age-0 and adult fish based on length frequency data from all tows where a species was captured. We used 100 mm TL as a demarcation between juvenile and older fish for alewife, 90 mm for rainbow smelt, and 120 mm for bloater based on archived historical age data.

Swept area biomass estimates for Lakes Huron and Michigan (Madenjian et al. 2008) are now calculated in the same manner. In both lakes, only depth contours sampled by trawling (i.e., 5 to 114 m depth) are considered. The Lake Huron acoustic survey estimates lakewide biomass in deeper waters (see Schaeffer et al. 2007). In this report, lakewide biomass B_i of each major prey fish species $_i$ was calculated from trawl biomass per tow:

$$B_i = \sum_{s=0}^{s=110} \frac{W_{is} a_s}{n}$$

where B_{i} is biomass of species *i*, W_{is} represents mean biomass (kg · Ha^{-2}) of each species within each depth stratum *s*, a_s represents the weighted area (Ha^2) of individual strata *s*, and n represents the number of depth strata. W_i was derived for each species *i* by calculating its total weight within each depth stratum and dividing by area swept by the trawl.

Benthic macroinvertebrate samples were collected at each U.S. port during 2001 through 2004 and all U.S. ports plus Goderich, ON in 2005-2007. Three replicate grabs were made with a Ponar dredge (484 cm^2 mouth) at 27 m, 46 m, and 73 m depths. Samples were washed onto 0.5 mm benthos sieves and preserved in 5% formalin. We calculated mean density of major invertebrate groups representing common prey types for fish.

The 2007 Survey

The 2007 survey was carried out during October 15-November 4. Forty-five of the forty-eight planned trawl tows were completed; trawling could not be carried out at the 27 m transect at Detour and the 27 m transect at Thunder Bay due to commercial fishing gear. Survey logistics and bad weather prevented sampling the 91-m site at Harbor Beach. Fifty benthic samples were collected. The lake remained stratified for all ports with a deep (30-40 m) thermocline present.

A total of 18 fish species were collected in the survey (Appendix I) and seven invertebrate taxa were found in benthic samples. Common and scientific names of fishes are listed in Appendix I. Status and trends of common forage species are described below.

Figure 1. Sampling locations in Lake Huron, 2007.

Abundance, size, and age structure

Alewife- Similar to 2004-2006, alewives remain at low abundance in Lake Huron in 2007. Adult alewife density and biomass decreased slightly from the 2006 value and rivals the all-time low observed in 2004 (Figure 2). The RSE for adult alewife was about 40% in 2007, similar to values prior to 2004. The RSE value increased to 75% in 2004 and 85% in 2005 because of patchy alewife distributions in those years (Figure 2). Age-0 alewife abundance also declined in 2007, with densities close to the all-time low for the time series (Figure 3).

The alewife population collapse occurred during 2002-2004. During 2002, alewives of all sizes and ages were abundant due to a series of strong year classes that occurred in 1998, 1999, 2001, and 2002. However, high mortality of all sizes during 2002-2004 caused almost complete mortality of the 2002 year class, and substantial reduction in abundance of older fish. During 2003, the few remaining adults produced the largest year class in the time series (Figure 3), but age-0 alewives experienced almost complete mortality resulting in record-low densities during 2004.

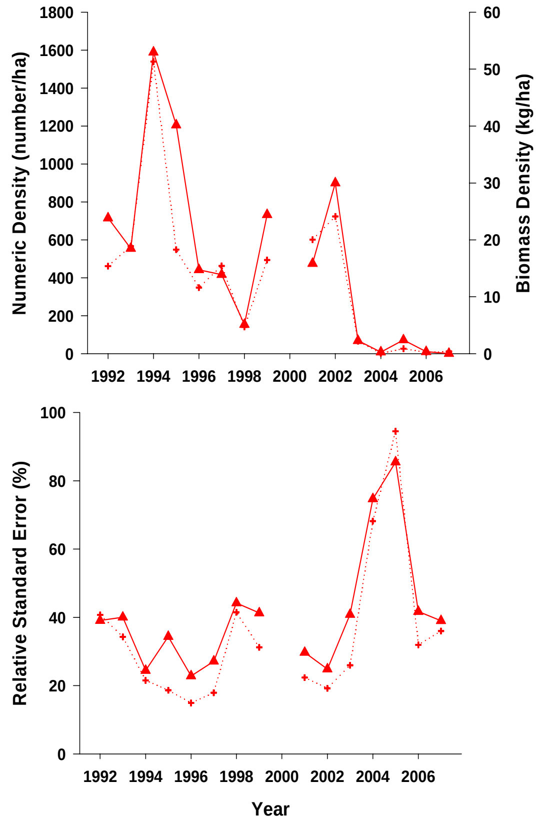

Figure 2. Density of adult alewives as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2007.

Recent alewife size and age structure reflected these conditions. Since 2003, alewife size distribution has been dominated by fish less than 100 mm TL (i.e. age-0 fish; Figure 4), whereas age-1 through age-5 fish were rare (Roseman et al. 2007). All alewives collected in 2007 were contributed to fatty acid and bioenergetics studies so no age estimates were derived for this year. Recent year-classes either failed to survive (2003) or were present at low densities (2004-2007). Currently, only low numbers of small alewives are available to predators.

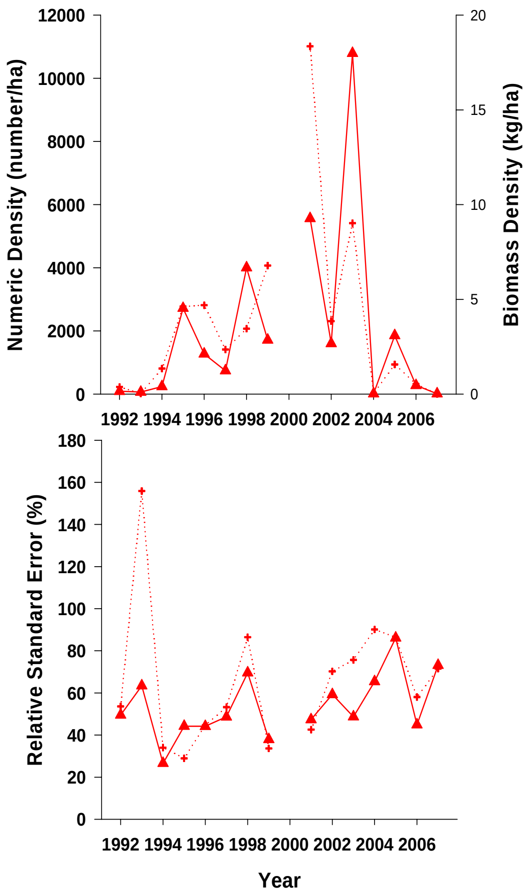

Figure 3. Density of age-0 alewives as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2007.

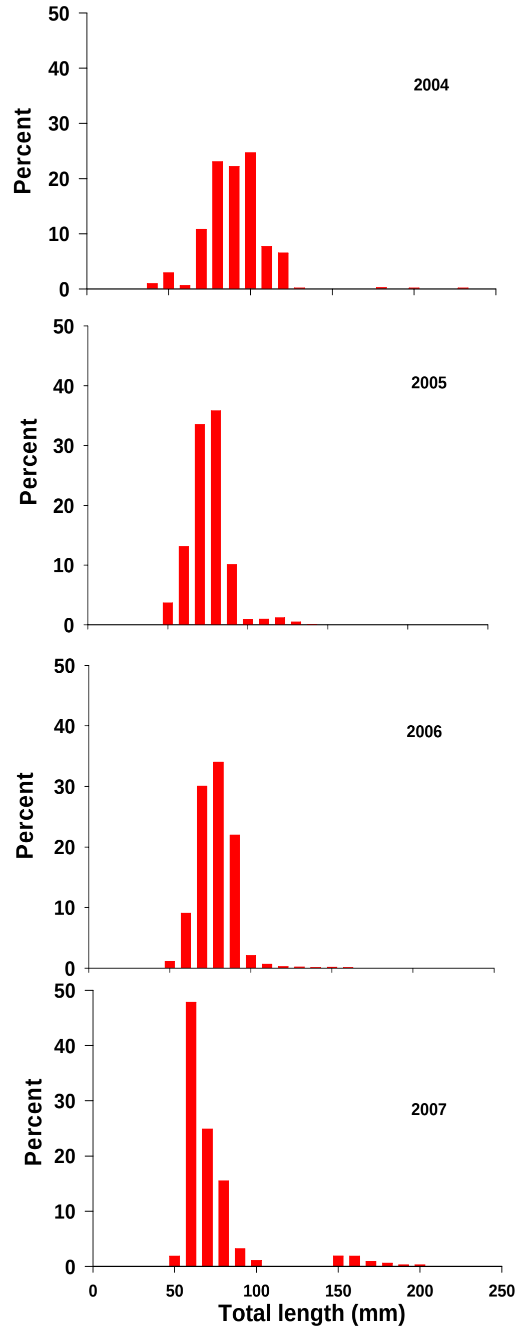

Figure 4. Size structure of Lake Huron alewives, 2004-2007. Percentages less than 1% are not visible.

Rainbow smelt- Adult rainbow smelt density showed only a small increase over 2006 despite record high levels of age-0 rainbow smelt in 2005 (Figures 5 and 6). In 2005, age-0 biomass was the highest on record since 1992 representing a doubling in density over 2004 estimates, but age-0 biomass declined by 85% in 2006 and increased only slightly in 2007 (Figure 6) and did not recruit to the adult stock. RSE for adult rainbow smelt in 2007 was between 30 and 45%, reflecting the relatively even spatial distribution of adult rainbow smelt observed in that year (Figure 5).

Similar to 2005 and 2006 (Roseman et al. 2007), the rainbow smelt population was dominated by age-0 fish in 2007 with less than 10% of the population larger than 100 mm (Figure 7). The low abundance of adult fish in 2007 suggests that the large numbers of small rainbow smelt observed in 2005 and 2006 did not translate into recruitment of larger rainbow smelt. In fact, the combined biomass for all age classes of rainbow smelt decreased by about 50% from 2005 to 2006-2007 despite the record-high density of age-0 fish observed in 2005.

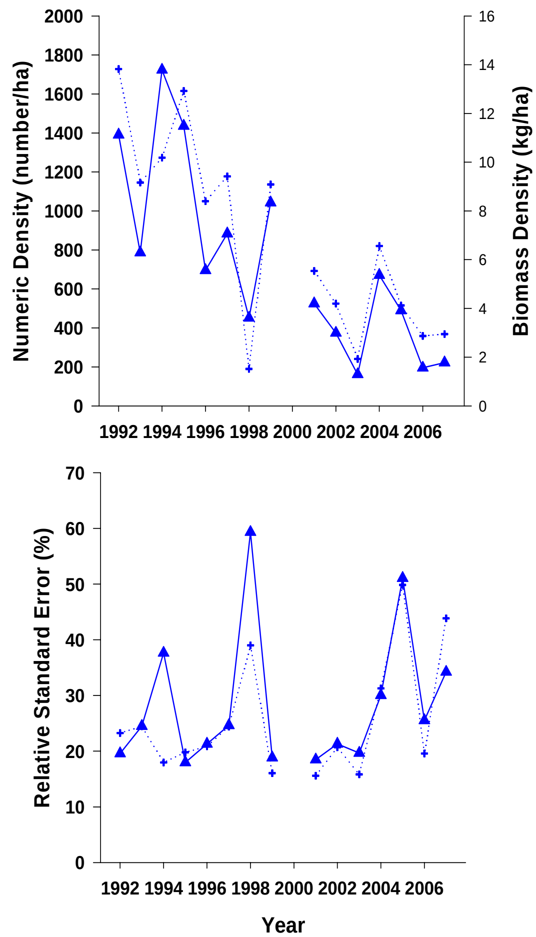

Figure 5. Density of adult rainbow smelt as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2007.

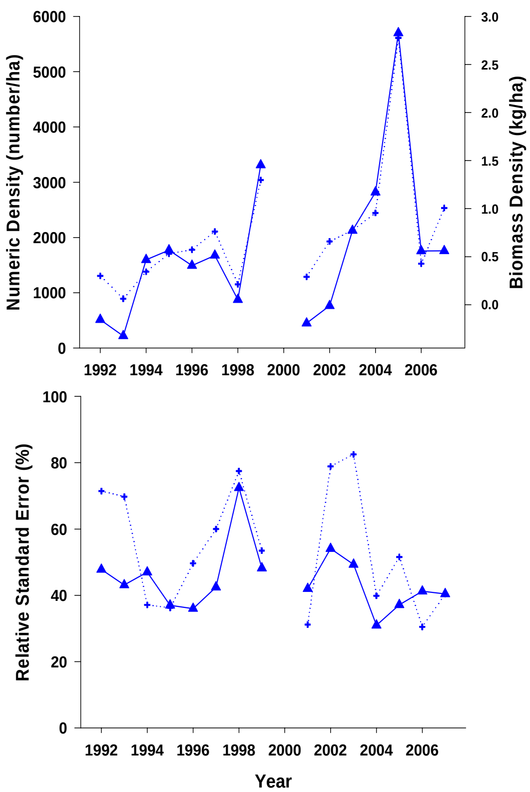

Figure 6. Density of juvenile rainbow smelt as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2007.

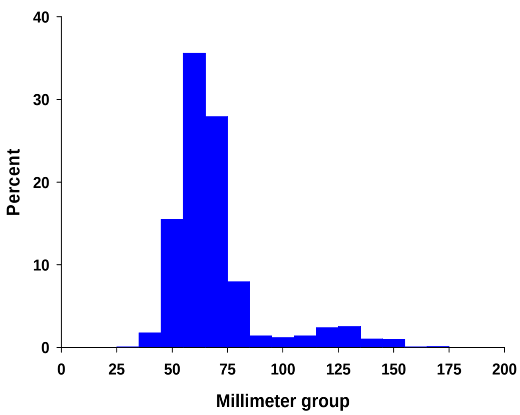

Figure 7. Length-frequency distribution of rainbow smelt collected in bottom trawls from Lake Huron during fall, 2007.

Bloater- Adult bloater density increased nearly four-fold compared to 2006 values and approached the abundances observed in the early 1990s, however biomass density of adult bloater only doubled (Figure 8) suggesting some recruitment occurred from the high abundance of small bloater observed in 2005 and 2006 and adult bloater were small (Figure 9). Abundance of small bloater increased to over 500/Ha surpassing the record-high levels observed in 2005 (Figure 9).

About 47% of bloaters captured during 2007 were less than 120 mm TL representing year-classes formed in 2006 and 2007. Abundance of larger bloater increased in response to the recruitment of some of the smaller fish observed in 2005 (Figure 10). Juvenile bloaters are pelagic and generally not susceptible to bottom trawls, so true year class strength may not be apparent until they become fully recruited to the trawl at age-3 or older (Wells 1968).

High densities of juveniles observed during 2003-2006 may represent a conservative estimate of the strength of these year classes. Nonetheless, juvenile bloater densities rarely exceeded 5 fish · Ha^{-1} during 1992-2002, but densities increased to approximately 60 fish · Ha^{-1} in 2003, 28 fish · Ha^{-1} in 2004, 320 fish · Ha^{-1} in 2005, and 105 fish · Ha^{-1} in 2006 (Figure 9).

The recurrence of higher-than-average densities of young fish suggests that adult bloater may be more abundant in the future, as seen with the increase observed in 2006-2007 (Figure 8). RSE values for both adult and juvenile bloaters typically fluctuate between 30 and 50 %, and 2007 results were similar to most previous years (Figures 8 and 9). Although bloater catches vary, their distribution with depth varies little from year to year.

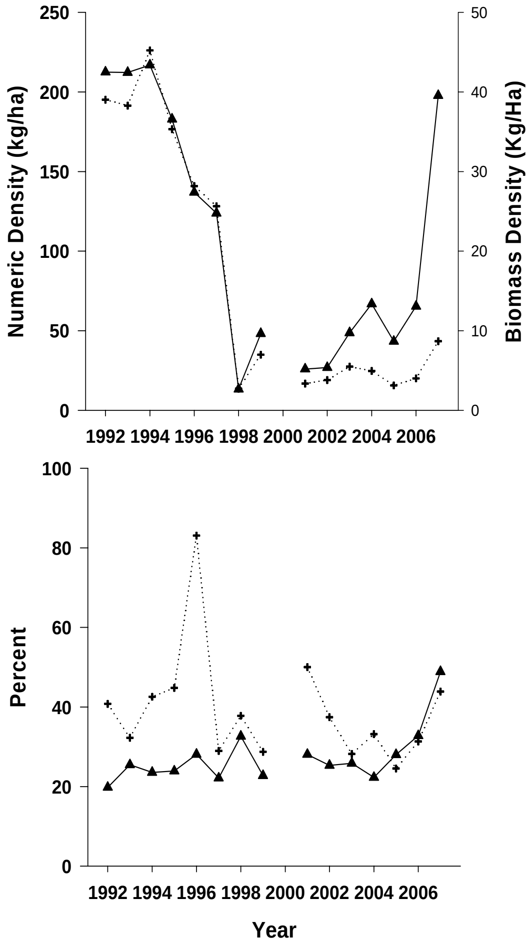

Figure 8. Density of adult bloaters as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2007.

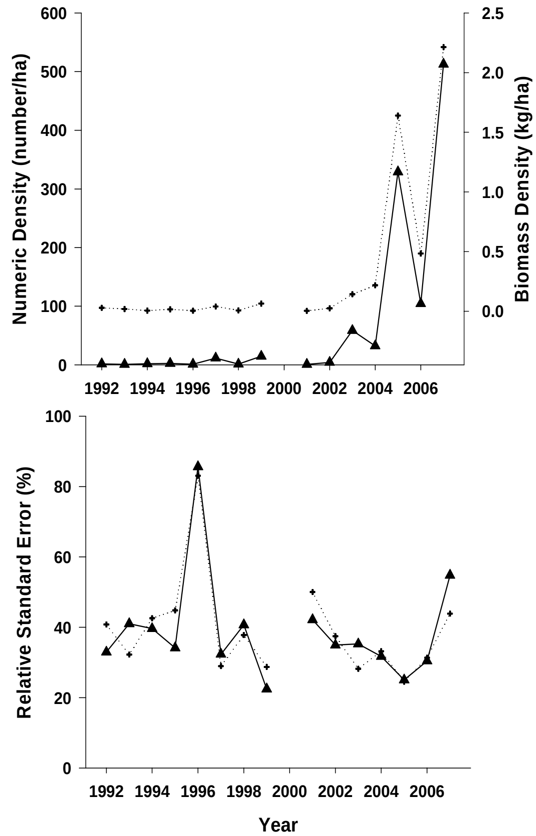

Figure 9. Density of juvenile bloaters as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2007.

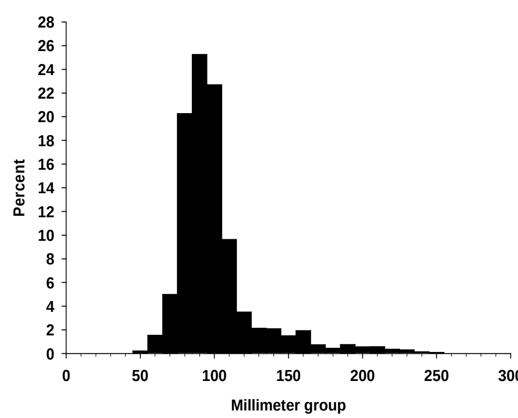

Figure 10. Length frequency distribution of bloaters collected in bottom trawls from Lake Huron, 2007.

<u>Sculpins, sticklebacks, and troutperch</u>- Sculpin abundance in Lake Huron has fluctuated widely since 1992 but has been depressed since 1998 (Figure 11). Deepwater sculpins comprise most of the total sculpin catch, while slimy sculpins are only a minor component of the deepwater fish community and were seen in low numbers in 2007. Deepwater sculpin abundance decreased from levels observed in 2006 and remains at near record-low levels. RSE for deepwater sculpins remains at relatively high levels (40 to 60%) because deepwater sculpin distributions have become patchier during recent surveys, restricted to offshore and northern sample sites.

Density and biomass of ninespine sticklebacks decreased by about 50% from levels observed in 2006 (Figure 12). Ninespine stickleback abundance has varied considerably since 1992 and low densities have been observed previously (1992-94 and 1998-99). However, the recent trend since 2001 is downward, and indicates that sticklebacks will not contribute to the fish community as an alternative prey species.

Troutperch density and biomass also continue a five-year overall decline. Their overall abundance remains low for the time series (Figure 13). As with sticklebacks, troutperch will not be an important alternative prey species in 2007.

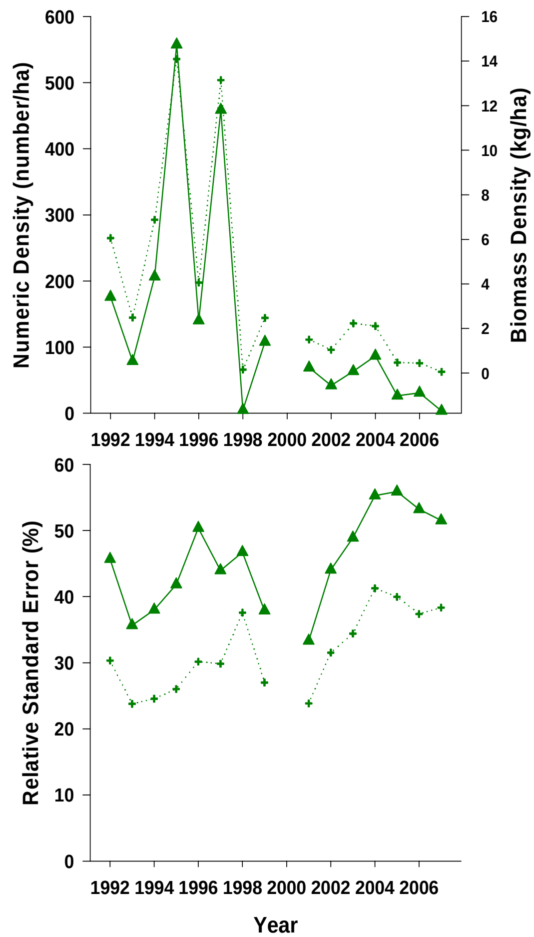

Figure 11. Density of deepwater sculpins as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2007.

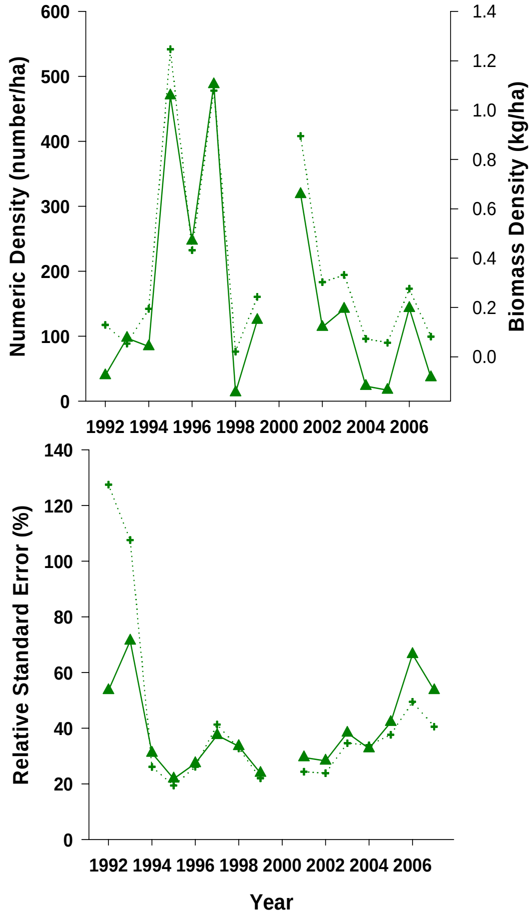

Figure 12. Density of ninespine sticklebacks as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2007.

<u>Round gobies</u>- Round gobies were first encountered in the trawl survey during 1997 and increased in abundance steadily until 2003; however, their abundance declined in 2004 and has remained at below 40 fish · Ha^{-1} in 2005-2007. Numeric and biomass density of round gobies decreased in 2007 (Figure 14).

As in previous years, we collected round gobies at depths up to 73 m, indicating that their distribution extends well offshore. Round gobies were collected at all ports except Hammond Bay and DeTour in 2007.

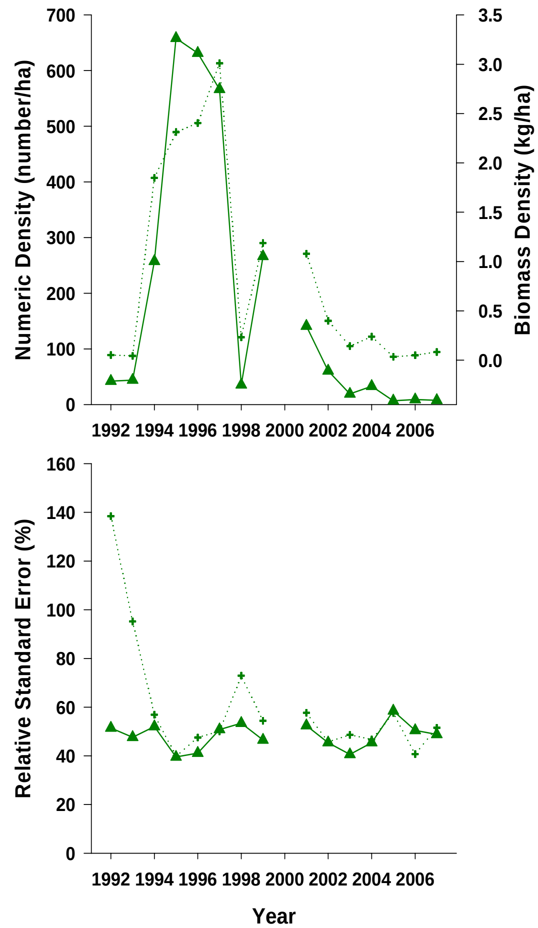

Figure 13. Density of troutperch as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2007.

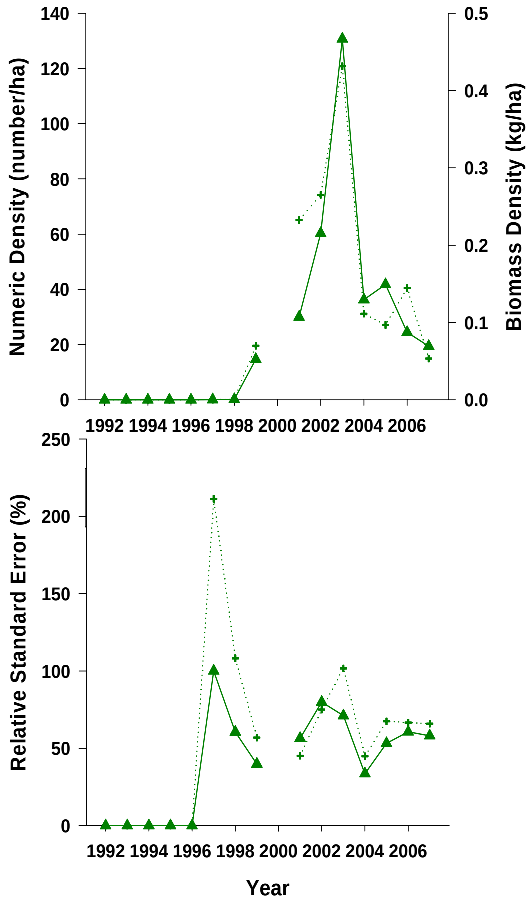

Figure 14. Density of round gobies as number (solid line) and weight (dotted line) of fish per hectare (top panel) and relative standard error (bottom panel) in Lake Huron, 1992-2007.

Lake trout- Collection of wild juvenile lake trout continued in 2007. These fish were identified as naturally-spawned because they lacked fin clips and were far smaller during October than even the smallest hatchery lake trout that were stocked earlier that year. Eleven wild lake trout were collected at the 37 and 46 m sites at Detour in 2007 and wild yearling and older fish were collected from Hammond Bay and Harbor Beach suggesting that survival of wild fish is occurring. Overall lake-wide mean density of wild lake trout was low at about 0.27 fish · Ha^{-1} in 2007. Collections of stocked lake trout have declined in recent years (Figure 15).

Wild age-0 lake trout have been collected in mid-lake surveys of Six-Fathom Bank (Desorcie and Bowen 2003), and this is the fourth consecutive year that significant numbers of wild lake trout have been collected during this survey (Figure 15). Collections of age-0 lake trout in recent years indicate that widespread reproduction is occurring in the main basin (Riley et al. 2007).

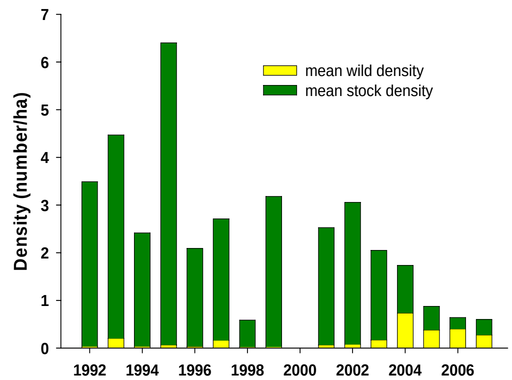

Figure 15. Density of wild and stocked lake trout collected in fall bottom trawls from Lake Huron 1992-2007.

Biomass Estimates- Total main basin prey biomass for the area between 5 and 114 m increased from 32 kilotonnes in 2006 to 40 kilotonnes in 2007 (Figure 16) but remains far below levels observed when alewives dominated the forage fish community. The increase observed in 2007 is due to the moderate increases in bloater and rainbow smelt. Biomass of other species did not change appreciably, indicating that no species has begun to replace lost alewife production, at least in the offshore environment. These fish should contribute to an increase in overall biomass in future years as young fish continue to grow and move into the adult stock.

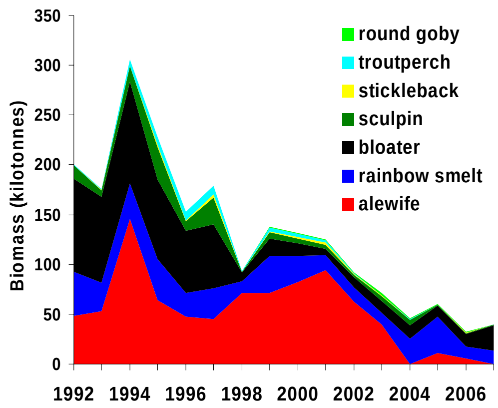

Figure 16. Prey fish community biomass (Kilotonnes) in main basin waters of Lake Huron, 1992-2007. No sampling occurred during 2000; biomass estimates for that year represent interpolated values.

Benthic Invertebrates- Density of benthic invertebrates was at an all-time low in 2005 and increased slightly in 2006-2007 due to increases in oligochaete densities and recruitment of quagga mussel (*D. bugensis*) young-of-the-year (Figure 17). Densities of *Diporeia* spp., chironomids and sphaerid clams remained near levels observed in 2005.

Density of *Diporeia* spp. has shown a continuing decline in abundance since sampling began in 2001 and densities in 2005 - 2007 are the lowest observed. *Diporeia* spp. were not collected in samples taken at 27 m and 46 m stations in 2007 (Figure 18).

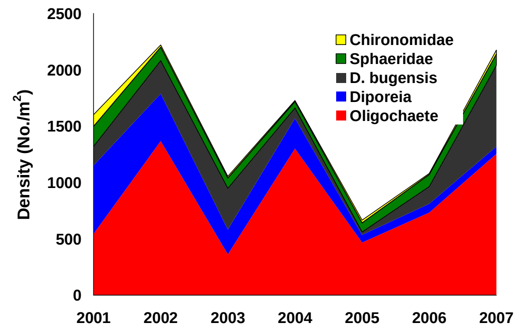

Figure 17. Mean density of benthic macroinvertebrates collected from five U.S. ports in western Lake Huron (2001-04) and five U.S. ports plus Goderich, ON (2005-07). Data include all depths pooled**.**

Overall mean quagga mussel density increased in 2007, but remains below the peak abundance observed in 2002 and 2003 although abundance at deeper stations is increasing (Figure 19).

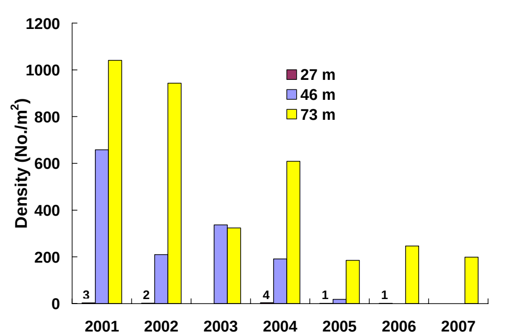

Figure 18. Mean density of *Diporeia* spp. at 27 m, 46 m, and 73 m depth strata determined from collections at five U.S. ports in western Lake Huron (2001-04) and five U.S. ports plus Goderich, ON (2005-07).

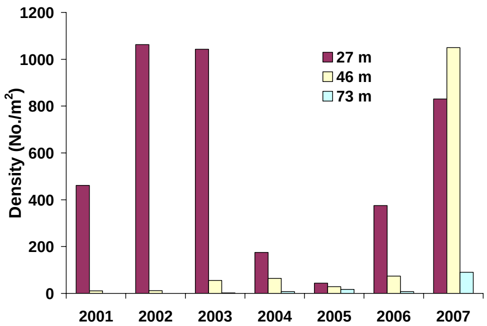

Figure 19. Mean density of quagga mussels *Dreissena bugensis* at three depth strata as determined from samples collected from five U.S. ports in western Lake Huron (2001-04) and five U.S. ports plus Goderich, ON (2005-07).

Discussion

Prey fish populations in Lake Huron remain in a depressed state since the collapse of alewife populations in 2003. Collections made in 2007 showed an overall increase in total prey biomass but this was largely constituted by high numbers of small bloater and evidence of bloater recruitment. Alewife density remains near the all-time low for the time series observed in 2004. Abundance of juvenile rainbow smelt was at an all-time high for this survey in 2005, but recruitment of these small fish contributed little to lakewide biomass estimates in 2006 or 2007. While a reduction in the abundance of an exotic species is consistent with fish community objectives for Lake Huron (DesJardine et al. 1995), prey availability, ecosystem stability, and sustainability of the Chinook salmon *Oncorhynchus tshawytscha* sport fishery remain as concerns for fisheries managers and stakeholders.

Prey availability for piscivores will likely be low during 2008 because no species has replaced alewife in either numbers or biomass. While density of bloaters nearly doubled and rainbow smelt increased by about 15% between 2006 and 2007, overall prey biomass remained low compared to previous years (1992-2001) and showed only a slight increase in 2007.

Rainbow smelt density and biomass increased in 2005 showing the strongest year-class produced in the fourteen year time series. However, rainbow smelt biomass declined in 2006 and increased only slightly in 2007 suggesting that survival of young fish from the record year-class observed in 2005 was minimal. The lake-wide population of rainbow smelt remains dominated by small fish. Similar to observations in 2005 and 2006, most rainbow smelt collected in 2007 were less than 100 mm TL.

Density of juvenile bloater was at a record-high level in 2007 and densities observed in 2003-2007 were well above the long-term average for the time series indicating formation of consecutive strong year-classes since the decline of alewives. While length-frequency analysis shows that some recruitment is occurring, it has not translated into a substantial increase in bloater biomass. Other potential prey species such as deepwater sculpins, ninespine sticklebacks, and trout-perch remain in low abundance and contribute little to overall prey biomass in Lake Huron. Information on predator-prey dynamics in Lake Huron is based on historic reports dating back nearly two decades so we can only speculate as to the role of predation (top-down effect) and food limitation (bottom-up effect) in limiting recruitment of forage fishes in Lake Huron. However, new research was initiated in 2007 by the UGSG Great Lakes Science Center, EPA, and other partners that examines these issues and will lead to a foodweb model for Lake Huron in the absence of alewives.

While the exact mechanisms of interactions (competition, predation, and thiamine) between alewives and other fishes in Lake Huron remain unclear, this survey has shown increases in abundance for several species having pelagic life history stages following the decline of alewives. Five consecutive years (2003-2007) of above average juvenile bloater densities have been observed; evidence of increases in bloater recruitment; and the highest juvenile rainbow smelt abundance in the 15-year time series. Other surveys have shown repeated record year-classes of walleye and yellow perch in Saginaw Bay associated with declines in alewives (Fielder et al. 2007). Additionally, in 2006 Schaeffer et al. (in press) found lake-wide high densities of emerald shiners in standard acoustic surveys of Lake Huron and evidence of cisco *Coregonus artedii* recruitment in Georgian Bay and the North Channel in 2007 (Schaeffer et al. 2008).

Declines in benthic macroinvertebrate abundance and increases in non-indigenous dreissenid mussels may be linked to declines in prey fish populations in Lake Huron. Trophic studies have shown that macroinvertebrates such as *Diporeia* and chironomids are important forage for various life stages of many fishes (Gordon 1961, McNickle et al. 2006). Growth and survival of fishes relying on macroinvertebrates as forage may be suppressed when invertebrate populations are low. Causes of recent observed declines in benthic invertebrates remain speculative, but most researchers agree that invasive species such as dreissenid mussels and round gobies add to the instability of benthic foodwebs and likely contribute to downward trends through competitive and predatory interactions (Nalepa et al. 2003, McNickle et al. 2006).

Our prey fish biomass estimate is conservative because the trawl does not sample the entire water column and pelagic individuals of any species are unlikely to be captured. For example, Argyle (1982) estimated that 20-30 % of forage fish were found in the pelagic zone (i.e., above the path of a bottom trawl) during day in Lake Huron, while Stockwell et al. (2006) suggest that bottom trawling provides biased estimates of adult cisco abundance in Lake Superior because many of the fish are pelagic and not susceptible to bottom trawls. Similarly, acoustic data collected during recent bottom trawling on Lake Huron suggest that up to 40% of identifiable targets may occur above the path of the trawl, but this varies considerably with depth (GLSC unpublished data). However, acoustic estimates and mid-water trawl surveys show fish in the pelagia are typically small (Warner et al. 2005, Schaeffer et al. 2006, 2007, 2008) and would likely contribute little to biomass estimates.

Moreover, biomass estimates assume that each tow is a representative sample from that depth stratum. This assumption was probably violated because trawls can only be made in areas with smooth substrates up to 110 m deep. These factors would all contribute to underestimation of true prey fish biomass. Catchability is also expected to vary with species, season, temperature, and water clarity, among other factors. Until research is conducted to estimate the catchability of different species to the Lake Huron fall bottom trawl survey, it should be noted that estimates of absolute abundance reported here are likely to be biased and should be interpreted with caution.

The continued depression of forage species biomass in the main basin of Lake Huron suggests that predators will continue to face potential prey shortages during 2008. Rainbow smelt and juvenile bloaters will be the only common pelagic prey and predation on these may limit their recruitment and reduce the possibility of future strong year-classes. Rainbow smelt and bloater are utilized as prey of salmonids (Diana 1990, Rybicki and Clapp 1996, Madenjian et al. 1998), but there are likely to be low numbers of large-sized prey items needed to sustain growth of large salmonids, especially adult lake trout (Martin 1966, Madenjian et al. 1998). Managers and anglers should expect slow growth of salmonids in 2008.

Acknowledgements

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Appendix I. List of species (common and scientific names) and mean densities (number/ha) collected during the 2007 Lake Huron fall bottom trawl survey.

Common name	**Scientific name**	**Density (No./ha)**
Rainbow smelt	*Osmerus mordax*	1980.01
Bloater chub	*Coregonus hoyi*	710.54
Ninespine stickleback	*Pungitius pungitius*	36.53
Yellow perch	*Perca flavescens*	30.54
Round goby	*Apollonia melanostoma*	19.42
Alewife	*Alosa pseudoharengus*	8.66
Trout perch	*Percopsis omiscomaycus*	7.60
Lake whitefish	*Coregonus clupeaformis*	7.20
Spottail shiner	*Notropis hudsonius*	5.55
Deepwater sculpin	*Myoxocephalus thompsonii*	3.41
White bass	*Morone chrysops*	1.88
Lake trout	*Salvelinus namaycush*	0.64
Gizzard shad	*Dorosoma cepedianum*	0.40
White perch	*Morone americanus*	0.31
Round whitefish	*Prosopium cylindraceum*	0.10
Walleye	*Sander vitreus*	0.06
Sea lamprey	*Petromyzon marinus*	0.03
Burbot	*Lota lota*	0.02