**Status and Trends of Pelagic Prey Fish in Lake Huron's Main Basin, 2006**

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**Abstract**

The USGS Great Lakes Science Center conducted acoustic and midwater trawl surveys of Lake Huron in 1997, 2004, 2005, and 2006. The 2006 survey was conducted during August and was comprised of Lake Huron's main basin. Main basin estimates of pelagic fish density were higher in 2006, primarily due to increased age-0 rainbow smelt *Osmerus mordax* abundance. However, biomass estimates were lower than in 2004 and 2005 due to lower abundance of adult rainbow smelt and adult bloaters *Coregonus hoyi*. Alewife *Alosa pseudoharengus* density and biomass remained low; alewife densities were 56 fish·ha$^{-1}$ and all alewives captured in trawls were age-0's. Emerald shiner *Notropis atherinoides* density and biomass increased substantially throughout the main basin in 2006, and they comprised about 25% of pelagic biomass. Increased emerald shiner biomass did not offset decreases in other species, and total pelagic fish biomass estimates during 2006 were 69% lower compared with 2004. Results of the acoustic survey were consistent with observations of low prey abundance in bottom trawl surveys, and suggest that overall prey availability in the main basin may be at an all time low since inception of annual surveys in 1973.

## Introduction

The U.S. Geological Survey's (USGS) Great Lakes Science Center (GLSC) has conducted surveys of Lake Huron's fish community since the 1970's. These surveys were conducted primarily with bottom trawls. Data from bottom trawl surveys appeared to reflect broad-scale changes in the fish community, but acoustic surveys were implemented because the bottom trawl surveys did not sample all bottom types or areas deeper than about 100 m, and no single gear is adequate for sampling pelagic fish (Fabrizio et al. 1997).

Acoustic surveys were conducted during the 1970's (Argyle 1982), and lake-wide surveys that included all of Lake Huron's distinct basins were conducted during 1997, 2004, 2005, and 2006 (Warner et al. 2005, Schaeffer et al. 2006). Recent improvements in acoustic technology and a new USGS research vessel allowed GLSC to conduct lake-wide surveys in both 2004 and 2005. Our objective was to estimate density and biomass of three pelagic species: alewife, rainbow smelt, and bloater.

For the 2006 report, we made two changes in methodology. First, assignment of species/size composition at depths ≥ 40 m is now based on the assumption that fish at these depths are bloater and that the best way to estimate their mean mass is using mean target strength (TS) (TeWinkel and Fleischer 1999). Second, the technique for merging acoustic and trawl data was refined to more closely match acoustic density estimates and the closest available trawl data.

## Methods

The 2006 survey used a stratified and randomized systematic design with evenly-spaced, randomly-selected parallel transects in three regions (strata): eastern main basin, western main basin, and southern main basin, (Figure 1). The North Channel and Georgian Bay could not be sampled due to vessel breakdown of the R/V Sturgeon, which was to sample those areas.

Effort in each stratum was approximately proportional to its area. For analysis, each transect was divided into 1,000 m long sampling units consisting of multiple 10-m depth layers. This approach balanced the need for capturing spatial variability while obtaining enough data to estimate fish density.

Acoustic data were collected in August with a Biosonics 70 kHz split beam echosounder (half-power beam width =5.4° ). In 2004-2005, we used a 120 kHz split beam echosounder (half-power beam width = 6.8°). In 2004 and 2006, the transducer was deployed at a depth of ~ 1 m using a towfish. In 2005, the transducer was deployed at a depth of 1-2 m using a sonar tube attached to the side of the vessel or suspended in a sonar tube. Sampling was initiated 1 hour after sunset and ended 1 hour before sunrise.

Species and size composition data were collected by a 15-m headrope midwater trawl with a fishing area of 63 $m^2$ and 6.35 mm cod end mesh. Tow locations and depths were chosen to target fish aggregations, but we attempted to obtain three tows per transect so that data were available from the epilimnion, metalimnion, and hypolimnion. Trawl depth was monitored using a Netmind$^{TM}$ system. Most midwater trawl tows were 10 minutes long, although tow times were extended up to 20 minutes if few fish were present. Temperature profiles were obtained using a bathythermograph after each trawl tow.

All fish were identified, counted, and weighed in aggregate (g) by species. Up to 100 randomly selected individuals were measured (mm) per tow, and samples were frozen in water for measuring individual lengths and weights in the laboratory. Individual alewives, rainbow smelt, and bloater were assigned to size categories (age-0, yearling and older) based on total length (alewife <100 mm, ≥ 100 mm; rainbow smelt <90 mm, ≥ 90 mm; bloater < 120 mm, ≥ 120 mm).

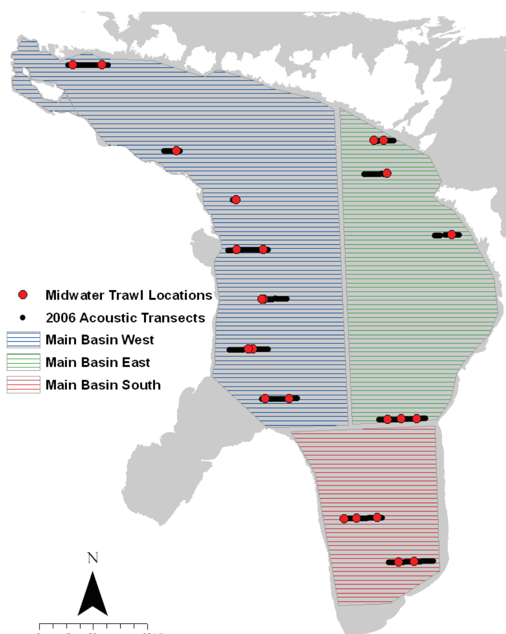


*Figure 1. Map of Lake Huron showing acoustic regions, transects, and trawl locations.*

Trawl and acoustic data at water column depths <40m were linked in steps ranging from fine-scale to coarse-scale. First, acoustic data were categorized by transect, depth layer (10m bins) and bottom depth (10m bins). Second, trawl data were matched to acoustic data cells by transect, depth layer, and bottom depth category. This provided essentially a one-to-one match by location. Subsequent steps involved aggregation of trawl data by averaging 1) stratum, depth layer, and bottom depth, 2) depth layer and bottom depth, 3) depth layer, and 4) coarse depth layers corresponding to epilimnion (0-20 m depths), metalimnion (20-50 m depths), and hypolimnion (depth ≥50 m). For depths ≥40 m, we assumed that acoustic targets were large bloater (TeWinkel and Fleischer 1999). Mean mass of bloater in these cells was estimated using the mass-target strength (TS) equation of Fleischer et al. (1997). This reduced bias in species composition of deep tows when surface dwelling species were captured during trawl set and haulback.

*Estimates of Abundance*

Acoustic density estimates for each transect were made for two groups: all targets and those that corresponded to fish targets. An estimate of absolute density (including all targets) was made using the formula

$$(1)\ Total\ density\ (\#\cdot ha^{-1}) = 10^4 \times \frac{ABC}{\sigma}$$

where $10^4$ = conversion factor ($m^2$/ha), *ABC* = area backscattering coefficient (unitless) and σ = the mean backscattering cross section ($m^2$) of all targets between -70 and -30 dB, a range including all fish catchable with our trawl. The estimate from equation 1 gives the density for all targets, potentially including invertebrates such as *Mysis relicta*, because aggregations of *Mysis* have target strengths similar to individual age-0 rainbow smelt (-70 to -64 dB, Rudstam et al. 2003; D.M. Warner, unpublished data). To maintain consistency with acoustic surveys of Lake Michigan in the 1990s (Argyle et al. 1998), targets <-60 dB were excluded. To accomplish this, density of fish targets was estimated by multiplying total density (equation 1) by the proportion of the total number of targets that were between -60 and -30 dB. The lower threshold of -60 dB should have included targets corresponding to the smallest age-0 alewives (2-3 cm) at most orientations based on in situ TS-length relations (-60 to -52 dB) published by Warner et al. (2002). However, this threshold likely underestimated rainbow smelt density given expected target strengths published by Rudstam et al. (2003).

Numeric densities (fish/ha) of the different species were estimated as the product of acoustic fish density and the proportion by number of each species and size group in the trawl. Total alewife, smelt, and bloater density was subdivided into size-specific density by multiplying total density for these species by the numeric proportions in each size group. Biomass (kg/ha) for the different groups was then estimated as the product of density and species or size-specific mean mass as determined from trawling and weight-length equations (except as described above for depths ≥40 m). Mean and relative standard error (RSE = 100*SE/mean) for density and biomass in the survey area were estimated using stratified cluster analysis methods featured in the statistical routine SAS PROC SURVEYMEANS (SAS Institute Inc. 2004). Cluster sampling techniques are appropriate for acoustic data, which represent a continuous stream of autocorrelated data (Williamson 1982; Connors and Schwager 2002). Density and biomass values for each elementary sampling unit (ESU) (a 1,000 m interval within a transect) in each stratum were weighted by dividing the stratum area (measured using GIS) by the number of ESUs in the stratum. Annual differences in abundance were compared using ANOVA, with alpha set at 0.05. Tukey's multiple comparison test was used to evaluate significance of differences among regions and years.

**Results**

**Alewife-**

Alewives were an important prey species historically, but were scarce during 2004-2006. Alewives were virtually absent during 2004, but densities increased in 2005 (Tukey's test, $P<0.05$) (Figure 2). Biomass estimates differed significantly among all years (Tukey's test, $P<0.05$) but alewives comprised no more than 6.0% of total pelagic fish biomass during 2004-2006.

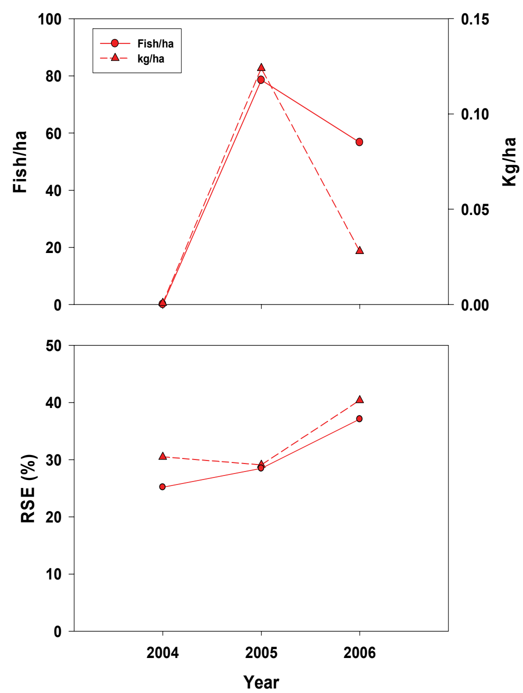


*Figure 2. Acoustic estimates of alewife density and biomass in Lake Huron, 2004-2006 (upper panel), and RSE of density estimates (lower panel).*

**Rainbow smelt-**

Main basin rainbow smelt density and biomass varied among years. Density of small rainbow smelt increased significantly during 2006 compared with 2004; however, there were no changes in biomass (Tukey's test, one of two tests, $P<0.05$) (Figure 3). In contrast, both density and biomass of large rainbow smelt decreased during 2006 (Tukey's test, two tests, $P<0.05$) Figure 4). This lead to an overall reduction in total rainbow smelt biomass from about 1.5 kg/ha to 0.4 kg/ha between 2005 and 2006.

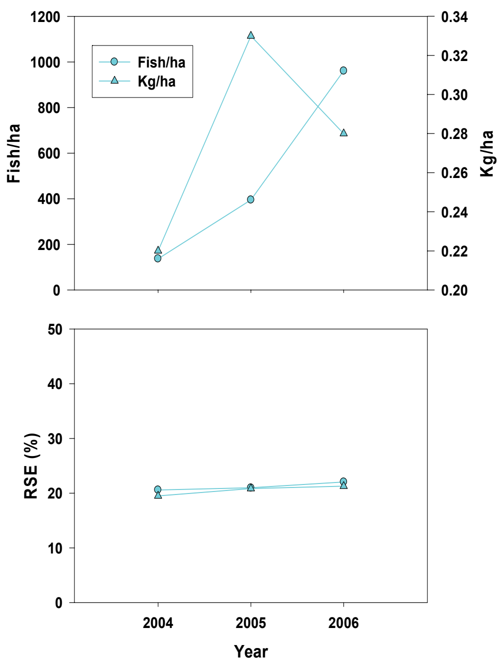


*Figure 3. Acoustic estimates of age-0 (<90 mm) rainbow smelt density and biomass in Lake Huron's main basin, 2004-2006, (upper panel), and RSE of estimates (lower panel).*

**Bloater**

During 2004-2006 there were no significant differences in total bloater densities among years (Tukey's test, $P<0.05$), but bloater biomass differed between 2004 and 2006 (Tukey's test, $P<0.05$, Figure 5).

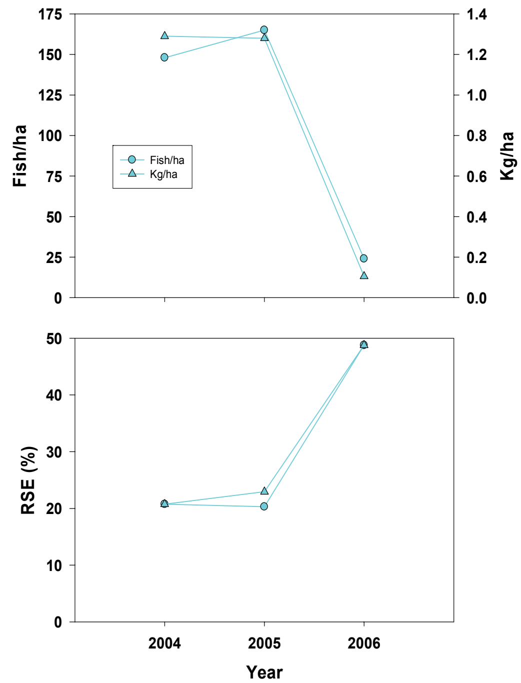


*Figure 4. Acoustic estimates of yearling and older (≥90 mm) rainbow smelt density and biomass in Lake Huron's main basin, 2004-2006, (upper panel), and RSE of estimates (lower panel).*

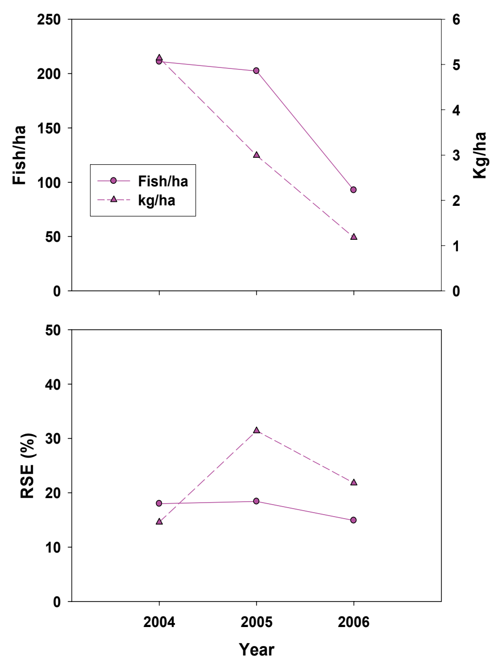


*Figure 5. Acoustic estimates of bloater density and biomass in Lake Huron's main basin, 2004-2006, (upper panel), and RSE of estimates (lower panel).*

**Emerald shiner**

Emerald shiners *Notropis atherinoides* were not observed in 2004, but were observed in both 2005 and 2006 (Figure 6). By 2006, emerald shiners had a basin-wide distribution, but with highest biomass in the Michigan waters (Figure 7). Decreases in RSE between 2005 and 2006 were likely the result of more widespread distribution and lower variation in density. Emerald shiners represented about 25% of the pelagic prey biomass during 2006.

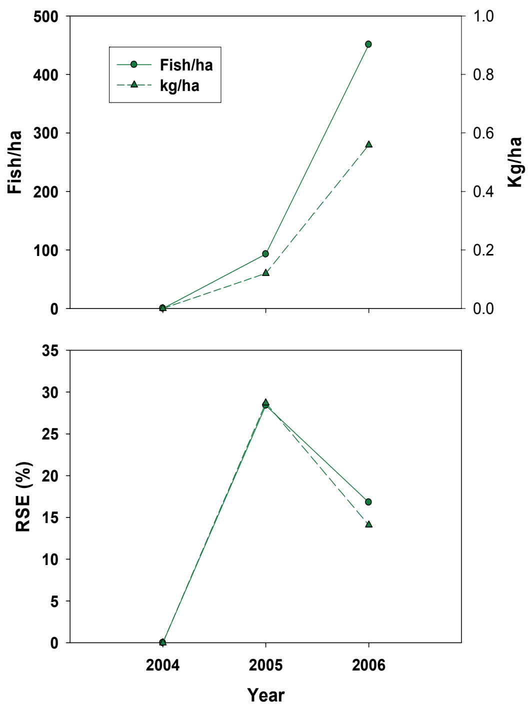


*Figure 6. Acoustic estimates of emerald shiner density and biomass in Lake Huron's main basin, 2004-2006, (upper panel), and RSE of estimates (lower panel).*

**Discussion**

Between 2004-2006, the pelagic fish community experienced changes in species composition, abundance, and size structure. Although total pelagic fish density increased, total pelagic biomass declined from 6.7 kg/ha in 2004 to about 2.1 kg/ha in 2006. This represents a 69% decrease, and occurred primarily due to reductions in average size of rainbow smelt and bloaters.

One of the most striking changes is the increase in density, biomass, and spatial distribution of emerald shiners. Emerald shiners are now found throughout the main basin, and now comprise a larger proportion of pelagic biomass than rainbow smelt (Figures 8, 9).

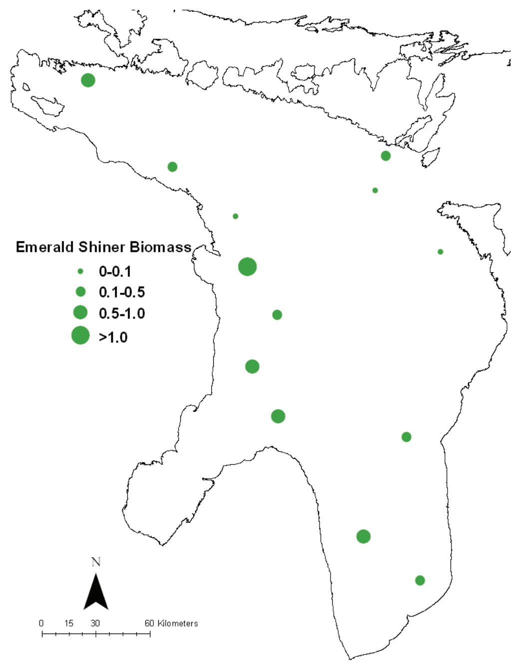


*Figure 7. Distribution of emerald shiner biomass (kg·ha$^{-1}$) in Lake Huron's ,main basin, 2004-2006.*

Increased emerald shiner density and biomass did not offset decreases in other species and total fish community biomass decreased.

Trends in prey fish abundance estimated by acoustics and midwater trawls agreed with those made from bottom trawl surveys. Bottom trawl estimates in 2006 show the Lake Huron alewife population to be well below the long-term average with a near-complete absence of large adults (Roseman et al. 2007).

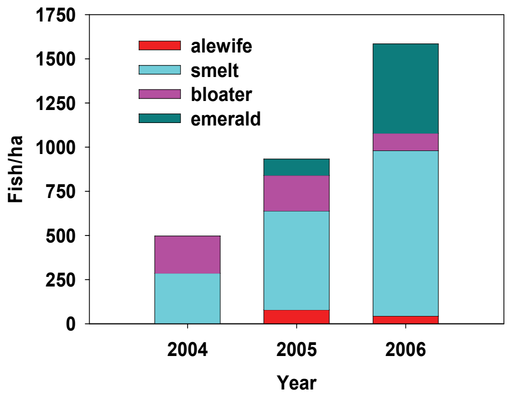


*Figure 9. Acoustic estimates of total pelagic fish density in Lake Huron's main basin, 2004-2006.*

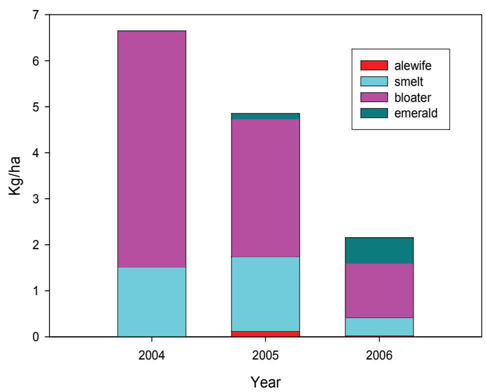


*Figure 8. Acoustic estimates of total pelagic fish biomass in Lake Huron's main basin, 2004-2006.*

Most remaining prey types are composed largely of very small individuals (age-0 rainbow smelt) or species not traditionally eaten by Pacific salmonines (bloaters, Diana 1990). The role of emerald shiners as a prey species remains unknown, and both the acoustic and bottom trawl surveys suggest that alewives remain scarce.

Main basin acoustic surveys during 2004-06 supported the observations from GLSC bottom trawl surveys by Schaeffer et al. (2005) and Roseman et al. (2006) that there has been a shift in main basin prey fish populations away from numerical dominance by alewife toward a lower-density prey fish community dominated by bloaters and emerald shiners. This change is consistent with fish community objectives for Lake Huron that call for restoration of native species (DesJardine et al. 1995), but is inconsistent with objectives that call for a prey community matched to primary production and predatory demand. While there have been no recent primary production estimates, prey availability is likely still too low to allow large numbers of salmonids to thrive.

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