

Status and Trends of Pelagic Prey Fish in Lake Huron, 2005: Results From a Lake-Wide Acoustic Survey

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Abstract

The USGS Great Lakes Science Center conducted acoustic/midwater trawl surveys of Lake Huron in 1997, 2004, and 2005. The 2005 survey was conducted during September-October, and included transects in Lake Huron's main basin, Georgian Bay, and the North Channel. Estimates of pelagic fish density were higher in 2005 than 2004, primarily due to increased rainbow smelt abundance in the North Channel and a lake-wide increase in age-0 bloater abundance. However, biomass estimates did not differ significantly between the two years, and were lower than estimates from the initial survey in 1997. Alewife density and biomass remained low; alewife density in 2005 was about 1 fish per hectare, compared with a density of 580 fish per hectare in 1997. Slight increases in the density of sticklebacks and emerald shiners during 2005 did not contribute substantially to pelagic fish biomass. Between 1997 and 2004-05, Lake Huron's pelagic fish biomass decreased from about 150 kg per hectare to 10-20 kg hectare. This was due to almost complete disappearance of alewife and a change in age and size structure in the bloater population from dominance by adults to increased prevalence of smaller or younger bloaters. Rainbow smelt density varied among regions and North Channel density and biomass may have been higher than overall lake-wide densities observed during 1997. Lake Huron appears to have lost a substantial amount of pelagic fish biomass between 1997 and 2004-05. Results of the acoustic survey support observations of lower prey abundance observed in bottom trawl surveys, but suggest that overall prey availability remains higher in Georgian Bay and the North Channel than in the main basin.

Introduction

The U.S. Geological Survey's Great Lakes Science Center 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), but the first lake-wide surveys that included all of Lake Huron's distinct basins were conducted during 1997 and 2004 (Warner et al. 2005). Recent improvements in acoustic technology and a new USGS research vessel allowed GLSC to conduct lake-wide surveys in both 2004 and 2005.

Methods

The 2005 survey used a stratified and randomized systematic design with evenly-spaced, randomly-selected parallel transects in five regions (strata): eastern main basin (ME), western main basin (MW), southern main basin (SB), North Channel (NC) and Georgian Bay (GB) (Figure 1). Effort was allocated based on stratum area and port availability. For analysis, each transect was apportioned into 500 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 with a Biosonics split-beam 124 kHz echosounder. The transducer was deployed through a sonar tube extending through the ship's hull. Species and size composition data were collected by a 15-m headrope midwater trawl having a fishing area of 63 m² 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™ system. Most midwater trawl tows were of 10 minutes duration, although tow times were extended up to 40 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). 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.

Acoustic data were analyzed using Echoview 3.25, which provided fish density estimates for each sampling unit. Density estimates were made for two groups of targets: all targets (fish and invertebrates), and those that corresponded to fish targets. Density was calculated as

$$Density(fish \cdot ha^{-1}) = 10^4 \cdot \frac{ABC}{\sigma}$$

where ABC was the area backscattering coefficient (m² · m²) and σ was the mean backscattering cross section (m²) of all targets between -76 and -20 dB.

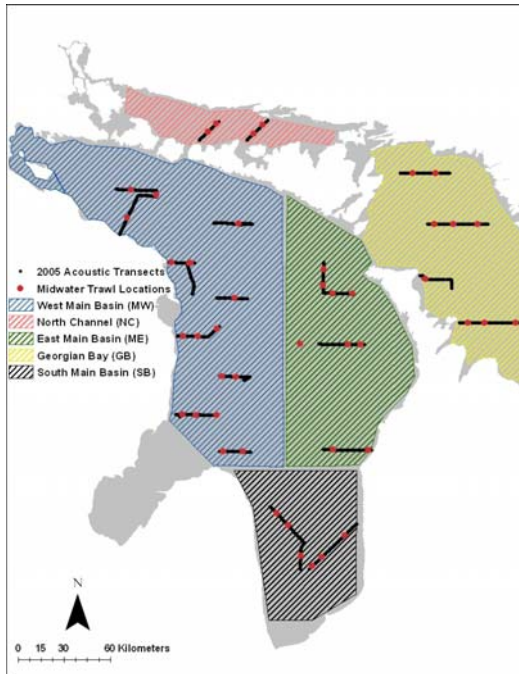


Figure 1. Map of Lake Huron showing acoustic regions, transects, and trawl locations.

This method provided density estimates for all targets, but we multiplied density by the proportion of targets between -60 and -20 dB to include only fish. This adjustment in target strength range should have included all age-0 alewives *Alosa pseudoharengus* present (Warner et al. 2002), but may have underestimated rainbow smelt *Osmerus mordax* density (Rudstam et al. 2003).

Density of individual species was estimated as the product of acoustic fish density and the proportion of each species by weight in the midwater trawl catches at that location. We used proportion by weight rather than number to reduce bias of bycatch on catch composition. Bycatch occurs when the trawl passes through aggregations of numerically abundant but small fish during deployment and retrieval. Total density per species was subdivided into age-0 and adult fish by multiplying total density by the numeric proportions of

each age group based on size (Schaeffer et al. 2004). Average weights of age-0 and adults of each species were calculated by dividing the number of individuals by weight for each size class of each species captured in each tow. Trawl biomass of each species in each tow was calculated as total density x average weight.

Trawl data were linked geographically with acoustic data; catch composition data were applied to the acoustic data from the same transect and layer where possible. However, not all acoustic sampling units had trawl data. In those cases we used the closest possible catch data, either from the same depth layer within the region, or the mean of that layer within the remainder of the lake. Biomass ($\text{kg}\cdot\text{ha}^{-1}$) was estimated as the product of total density by the numeric proportions of each species and its average weight within that sampling unit. Mean and relative standard error ($\text{RSE} = (\text{SE}/\text{mean}) \cdot 100$) for density and biomass in the survey area were calculated using stratified cluster analysis methods using SAS PROC SURVEYMEANS (SAS Institute Inc, 2005). This method is appropriate for acoustic data, which represent a continuous stream of autocorrelated data (Williamson 1982, Connors and Schwager 2002). Density and biomass estimates for each sampling unit were weighted by dividing stratum area (km^2) by the number of sampling units within that region. Regional differences in abundance were compared using ANOVA, with alpha set at 0.05 as the significance level. Tukey's multiple comparison test was used to evaluate significance of differences among regions or years. While we present summary data from the 1997 survey, the

focus of this report is on comparisons among 2004 and 2005 data, which represent consecutive lakewide comparisons.

Results

Alewife

Alewives were an important prey species historically, but were scarce during 2004 and 2005. Only two individuals were captured during 2004 (Warner et al. 2005), and we captured only 38 individuals during 2005. All were age-0 fish and alewives were present only in the Michigan waters of the western main basin.

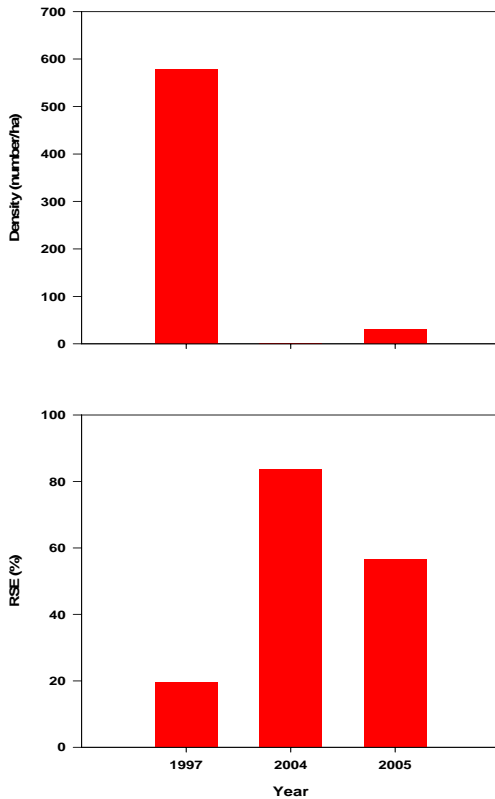


Figure 2. Acoustic estimates of alewife density in Lake Huron, 1997, 2004, and 2005 (upper panel), and relative standard error of density estimates (lower panel).

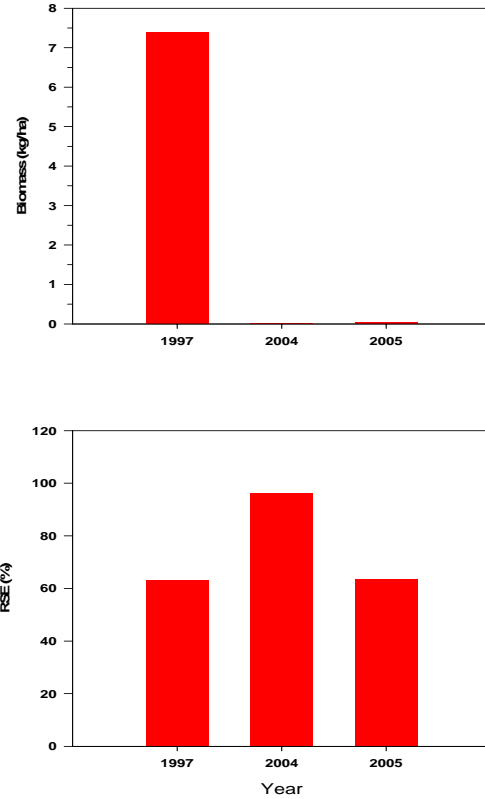


Figure 3. Acoustic estimates of alewife biomass in Lake Huron, 1997, 2004, and 2005 (upper panel), and relative standard error of density estimates (lower panel).

Alewife density and biomass did not differ significantly between 2004 and 2005 (ANOVA, $P < 0.05$), and their abundance was far lower than in 1997 (Figures 2, 3). Alewife biomass declined by over 99% between 1997 and 2004, and remained low during 2005.

Rainbow smelt

Rainbow smelt density and biomass varied among basins and years. Density was highest in the North Channel during both 2004 and 2005, and density in Georgian Bay was higher than the main basin during 2004 (Tukey's test, $P < 0.05$). Increases in density between

2004 and 2005 occurred primarily as a result of significant density increase in the North Channel between 2004 and 2005 (Figure 4).

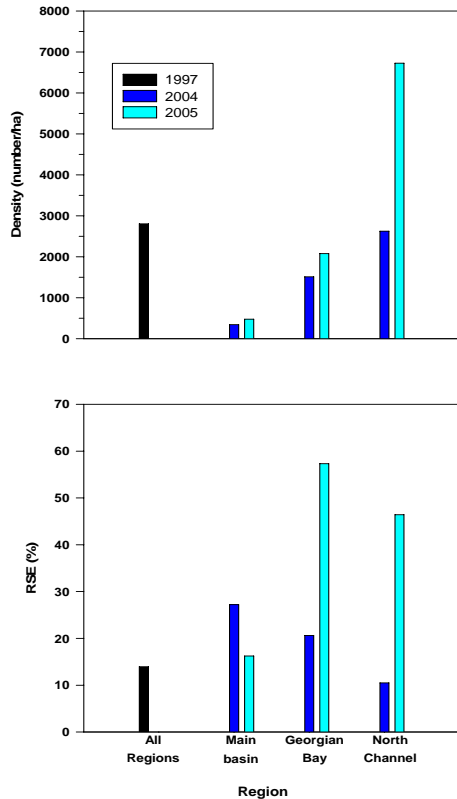


Figure 4. Acoustic estimates of rainbow smelt density by region in Lake Huron, 1997, 2004, and 2005 (upper panel), and relative standard error of density estimates (lower panel).

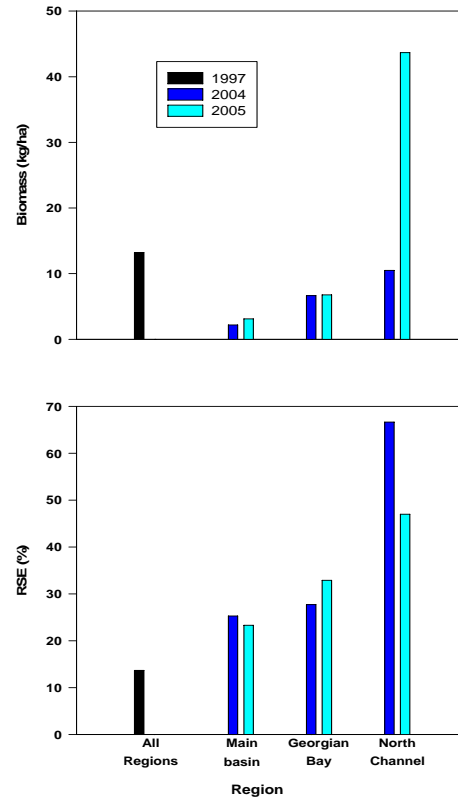


Figure 5. Acoustic estimates of rainbow smelt biomass by region in Lake Huron, 1997, 2004, and 2005 (upper panel), and relative standard error of density estimates (lower panel).

Rainbow smelt biomass followed a similar pattern; however, biomass was more variable than density because of changes in both density and average weight among years (Figure 5). Biomass estimates for the North Channel were 3.5 times higher than overall biomass in 1997, and were significantly higher than other areas during 2004 and 2005 (Tukey's test, $P < 0.05$). RSE actually declined in the main basin and North Channel suggesting that rainbow smelt were more evenly distributed in these regions during 2005, while increasing only slightly in Georgian Bay.

Length frequency distributions of rainbow smelt were consistent with

recent high recruitment; most fish were likely to be age-0 or age-1 (Figure 6).

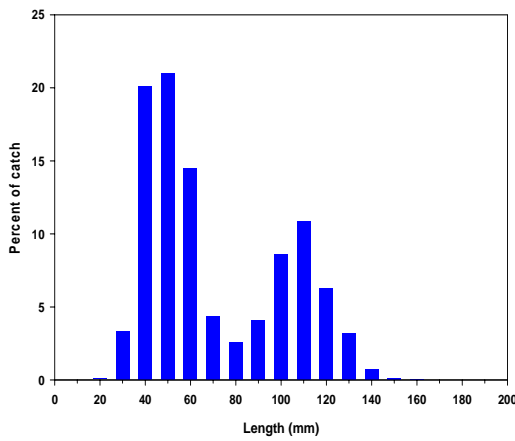


Figure 6. Length frequency distribution of rainbow smelt in midwater trawls performed in Lake Huron, 2005. All data pooled.

Bloater

During 2005 there were no significant differences in bloater *Coregonus hoyi* density or biomass among basins and years (Anova, two tests, $P>0.05$), but overall bloater density increased between 2004 and 2005 (Anova, $P<0.05$) (Figure 7). Density increase was the result of an apparent strong year class during 2005; catches of age-0 bloaters were the highest recorded since 1992 in the GLSC bottom trawl survey (Roseman et al. 2006). However, bloater biomass did not differ among years (ANOVA, $P>0.05$) (Figure 8) because smaller individuals (< 100 mm total length) predominated in trawl catches (Figure 9). Average size of an individual bloater decreased from 42 g in 2004 to 18 g in 2005.

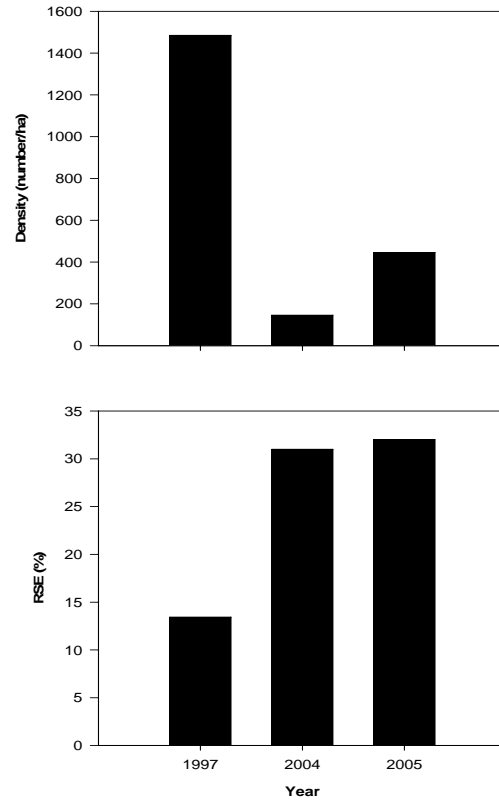


Figure 7. Acoustic estimates of bloater density in Lake Huron, 1997, 2004, and 2005 (upper panel), and relative standard error of density estimates (lower panel).

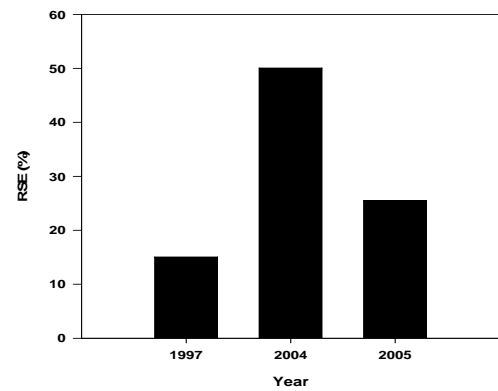
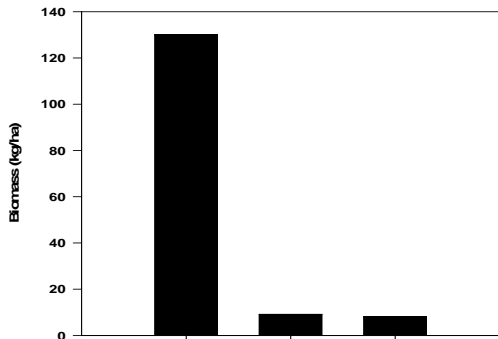


Figure 8. Acoustic estimates of bloater biomass in Lake Huron, 1997, 2004, and 2005 (upper panel), and relative standard error of density estimates (lower panel).

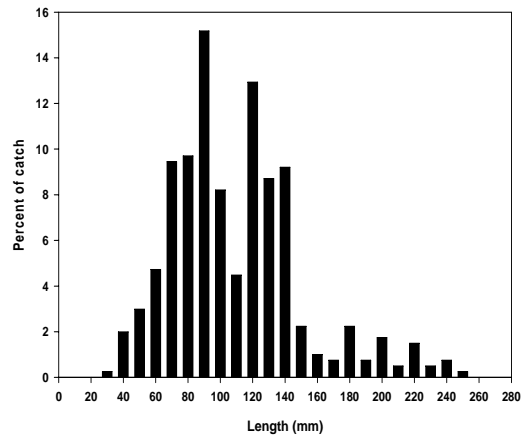


Figure 9. Length frequency distribution of bloaters in midwater trawls performed in Lake Huron, 2005. All data pooled.

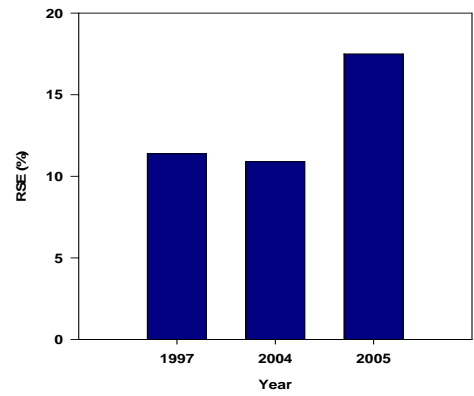
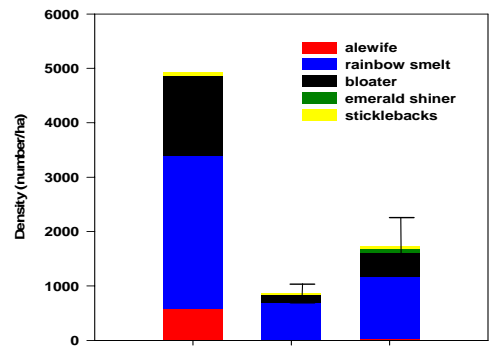


Figure 10. Acoustic estimates of total fish density in Lake Huron, 1997, 2004, and 2005 (upper panel), and relative standard error of density estimates (lower panel).

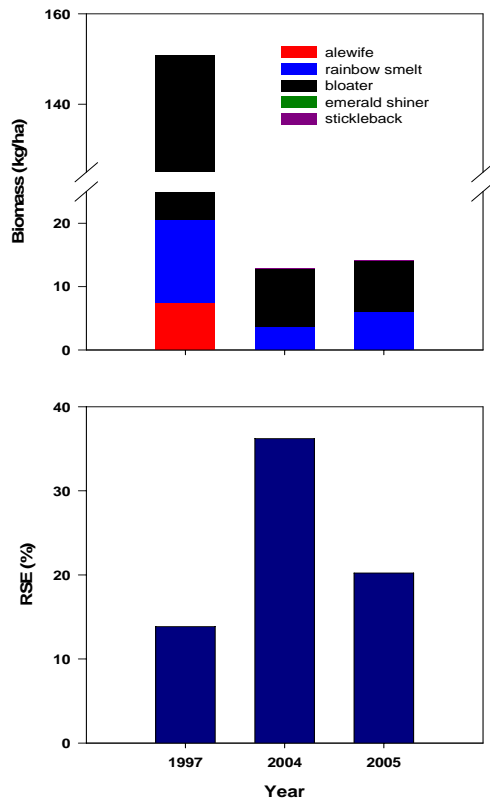


Figure 11. Acoustic estimates of total pelagic fish biomass in Lake Huron, 1997, 2004, and 2005 (upper panel), and relative standard error of biomass estimates (lower panel).

Fish community

Between 1997 and 2004-05 the pelagic fish community experienced changes in species composition, abundance, and size structure that led to an approximate 66% decrease in total fish density (Figure 10). The decrease was due to loss of alewife and decreased abundance of rainbow smelt and bloaters. Slight increases in ninespine and threespine stickleback (*Pungitius pungitius*, *Gasterosteus aculeatus*) abundance and the appearance of emerald shiners *Notropis atherinoides* during 2005 did not offset the decrease.

Pelagic fish biomass decreased by about 90% between 1997 and 2004-05 (Figure 11). Part of the decrease was due to reduced pelagic fish density, but the trend was exacerbated by reductions in the size or age structure of bloaters. In 1997, bloaters were nearing the end of a population peak that began during 1988-1992, but adults in the length range of 250-300 mm were still abundant (Schaeffer 2004). During 2004-05 all bloaters were less than 250 mm TL, and 90% were less than 150 mm TL.

Discussion

We found decreased abundance and biomass between 1997 and 2004-05 for all pelagic fish species except sticklebacks and emerald shiners. Density and biomass estimates were similar and spatially consistent between 2004 and 2005; the only differences among years were increased abundance of rainbow smelt in the North Channel, and increased density of small bloaters due to an apparent strong year class.

Density estimates in this report are similar to previous reports, but our biomass estimates for most species were 1 to 5 kg·ha⁻¹ higher than previous estimates (Warner et al. 2005) because we calculated average weights of each species from each individual in each trawl tow rather than averaged mean weights. We believe that this approach better encompasses observed spatial variability in size, but it did result in higher biomass estimates and RSE's. However, this change would not affect our conclusions that pelagic biomass has declined.

This survey sampled offshore areas of Lake Huron from 15 to 250 m in depth. This depth range encompassed about 85 % of the total surface area of Lake Huron. However, this survey did not address nearshore zones and large embayments, especially Thunder Bay, Saginaw Bay, and Parry Sound. These areas could be responsible for a substantial amount of pelagic fish production, but could not be sampled safely due to the draft of our research vessel (3 m). We believe that our biomass estimates would have been higher had these areas been included because nearshore areas are well known as nursery habitats (Höök et al. 2001, Klumb et al. 2003).

Trends in prey fish abundance estimated by acoustics and midwater trawls agreed with those made from bottom trawl surveys. Bottom trawls estimates in 2004 and 2005 show the Lake Huron alewife population to be well below the long-term average with a near-complete absence of large adults (Schaeffer et al. 2005, Roseman et al. 2006). Also in agreement with this report, the bottom trawl survey showed young rainbow smelt and bloater to be at all-time high abundances in 2005 (Roseman et al. 2006).

Although pelagic fish biomass declined by about 90% between 1997 and 2004-05, overall prey availability for salmonids was probably not reduced by the same percentage because most of the biomass decline was due to the loss of large adult bloaters, which may not have been important as prey (Diana 1990). However, prey availability for salmonids is undoubtedly much lower now than in 1997 because of overall reduced prey abundance, particularly the

disappearance of alewife. Density of bloaters and rainbow smelt increased between 2004 and 2005 but remained lower than 1997 estimates, and smaller prey size distributions may exacerbate the current situation of low prey density.

This survey has led us to ask two substantive questions that remain unanswered. First, why are fish densities higher in North Channel and Georgian Bay compared to the main basin? These basins may have higher recruitment or better survival than the main basin, possibly due to fewer predators. However, we presently do not understand the reason for the observed differences. Differences in pelagic fish density among basins are potentially important because rainbow smelt biomass in the North Channel during 2005 ($43.6 \text{ kg}\cdot\text{ha}^{-1}$) was higher than biomass of alewife and rainbow smelt observed in the main basin in 1997 ($20.6 \text{ kg}\cdot\text{ha}^{-1}$). The apparent prey shortage in the main basin does not seem to be as severe in the North Channel or portions of Georgian Bay, assuming that piscivores can utilize rainbow smelt effectively.

The second question is this: Why is preyfish biomass in 2004-05 an order of magnitude lower than in 1997? During 1997 Lake Huron supported a pelagic fish biomass of about $150 \text{ kg}\cdot\text{ha}^{-1}$. In 2004-05 it supported a pelagic fish biomass of only 10 to $20 \text{ kg}\cdot\text{ha}^{-1}$. We offer three hypotheses. Our first hypothesis is that predatory demand by piscivores is so high that most fish production is being consumed. Our findings are consistent with estimates of predatory demand estimated by Dobiesz and Bence (2003) who found that total main basin predatory demand by

piscivores was increasing, and converging on prey fish production estimated from bottom trawls. Their estimate may have been conservative because of the recent discovery that naturally recruited Chinook salmon comprised the majority of the sport harvest during 2000-2003 (James Johnson¹, Michigan Department of Natural Resources, unpublished data; David Gonder², Ontario Ministry of Natural Resources, unpublished data). If the Chinook salmon population increased due to a combination of stocking and wild recruitment, predatory demand could have consumed at least part of the missing pelagic fish biomass.

A second hypothesis is that pelagic fish production is now lower because of food web disruptions, including loss of the deepwater amphipod *Diporeia*, or possibly the shunting of energy into Dreissenids that are consumed by benthivores including non-native round gobies (Ray and Corkum 1997, French and Jude 2001). While changes in the density of invertebrate populations are reasonably well documented (Barton 1984, Nalepa et al. 2005, Roseman et al. 2006), we know of no system-wide estimates of energy flow that would enable us to calculate the magnitude of those effects. Further studies on the proportion of primary production sequestered by Dreissenid mussels are needed to more fully understand possible food web disruptions.

A third hypothesis is predation by double-crested cormorants *Phalacrocorax auritus*. We believe that this hypothesis can be rejected as a major factor. While double-crested cormorants may have strong effects on nearshore fish populations (Belyea et al.

2000), the majority of the decline in biomass was due to loss of adult bloaters that inhabit depths that were too deep and further offshore than habitats where double-crested cormorants could pursue prey (Stapanian et al. 2002). While we can not rule out cormorant effects on alewives and rainbow smelt during spring spawning in shallow water, the highest fish densities we observed were in the North Channel, which had high cormorant nest density and the greatest spatial exposure to cormorant foraging (Weseloh et al. 2002). If cormorants had an effect on offshore fish populations, we would have expected it there.

Lake-wide acoustic surveys during 2004-05 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 rainbow smelt and native species, especially bloater. While these changes are 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.

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