Status and Trends of Pelagic Prey Fish in Lake Huron, 2007

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Abstract

The USGS Great Lakes Science Center conducted annual acoustic/midwater trawl surveys of Lake Huron from 2004-2007. The 2007 survey was conducted during September and October, and included transects in Lake Huron's main basin, Georgian Bay, and North Channel. Main basin estimates of pelagic fish density were similar during all four years. Biomass estimates were significantly lower during 2006 compared to other years, but all annual estimates ranged between 3.5 and 8.8 kg/ha. During 2004-2007 alewife were virtually absent, and rainbow smelt and bloaters comprised the majority of pelagic biomass. However, emerald shiners *Notropis atherinoides* were prominent in 2006, while cisco *Coregonous artedi* were prominent in 2007. Ciscoes were absent in trawl catches in 2004-2006, but comprised about 30% of main basin pelagic fish biomass in 2007 due to their large size compared to other species. As with previous surveys during 2004 and 2005, pelagic fish density and biomass in the North Channel was significantly higher than Georgian Bay and the main basin. Native species now comprise the majority of the main basin biomass.

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. While data from bottom trawl surveys appeared to reflect broad-scale changes in the fish community, 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 first conducted during the 1970's (Argyle 1982), but the first lake-wide survey that included multiple transects in all of Lake Huron's distinct basins was conducted in 2004 and 2005 (Warner et al. 2005, Schaeffer et al. 2006). The main basin only was sampled during 2006 (Schaeffer et al. 2007), but support from the Ontario Ministry of Natural Resources (OMNR) allowed all basins to be sampled during 2007.

In this report, we focus on main basin trends (2004-2007), and among-basin differences in fish communities observed during 2007.

Methods

The 2007 survey used a stratified and randomized systematic design with random and systematically selected parallel transects in five regions (strata): eastern main basin (ME), western main basin (MW), southern main basin (SB), Georgian Bay (GB), and the North Channel (NC)(Figure 1). The first transect in each stratum was chosen randomly, additional parallel transects were spaced evenly and parallel to the first in an effort to maximize spatial coverage. Effort (transects per strata) was allocated based on stratum area and the mean of standard deviations of total biomass in each stratum in previous years (Adams et al. 2006). For analysis, each transect was apportioned into 1,000 m long sampling units consisting of multiple 10-m depth layers.

Acoustic data were collected during 2004, 2005, and 2007 with a Biosonics split-beam 120 kHz echosounder deployed through a sonar tube from the R/V Sturgeon. Sampling in those years occurred in September through October. During 2006, August sampling was performed with the R/V Grayling using a 70 kHz echosounder and a transducer deployed via a towfish. In all years, sampling began 1 hour after sunset and ended 1 hour before sunrise. Echo integration thresholds of -80 dB were used throughout the surveys.

Species and size composition data were collected using 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, and we attempted to obtain multiple tows per transect so that data were available from all depth zones. Trawl depth was monitored using a Netmind^{TM} system. Most midwater trawl tows were of 10 minutes duration, although tow times were extended up to 20 minutes if few fish were present. Temperature profiles were obtained using a bathythermograph at the halfway point on each acoustic transect.

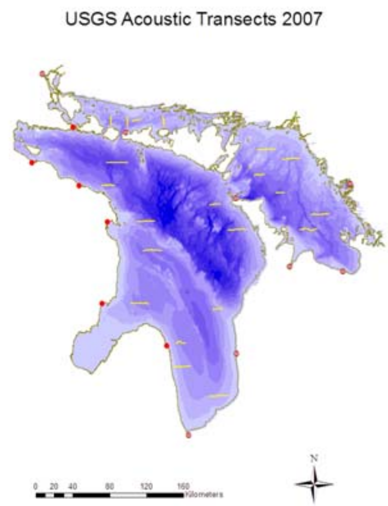

Figure 1. Map of Lake Huron showing acoustic regions, transects, and trawl locations.

All fish were identified, counted, and weighed in aggregate (g) by species. Up to 100 randomly selected individuals were measured (mm) per tow, and weighed in aggregate (g). Individual alewives, rainbow smelt, and bloaters were assigned to age categories representing age-0 or yearling/adult based on total length (alewife <100 mm, ≥ 100 mm; rainbow smelt <90 mm, ≥ 90 mm; bloater < 120 mm, ≥ 120 mm).

Acoustic data were analyzed using Echoview 4.0, which provided fish density estimates for each sampling unit. Fish density was calculated as

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

where ABC was the area backscattering coefficient ($m^2 \cdot m^2$) and σ was the mean backscattering cross section (m^2) of all targets between -60 and -30 dB.

The lower threshold 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, Parker Stetter 2006).

Density of individual species was estimated as the product of acoustic fish density and the proportion of each species by number in the midwater trawl catches at that location. Total density per species was subdivided into small and large size-classes by multiplying total density by the numeric proportions of each size group. Average weights of size groups of each species were calculated for each species captured in trawl tows.

Trawl data were linked geographically with acoustic data; catch composition data were applied to the acoustic data from the same transect, layer, and bottom depth where possible. However, few acoustic sampling units had trawl data. In those cases we used catch data from the same depth layer and bottom depth range within the stratum. If species and size composition data were still lacking, we assigned averages of 1) region, depth, and bottom depth, 2) depth and bottom depth, or) 3 depth within the remainder of the lake. However, we assumed that all targets at depths ≥ 40 m were large bloater or large rainbow smelt and estimated their mean mass through a mass-target strength equation (Fleischer et al. 1997 for bloater) or we predicted mass from mean lengths that were predicted with a target strength-length equation (Rudstam et al. 2003). This eliminated a bias inherent with deep midwater trawl tows- the capture of non-target species when the trawl is descending and ascending.

Biomass ($kg \cdot ha^{-1}$) was estimated as the product of total density (estimated acoustically) by the numeric proportions of each size class of each species and its average weight in the trawls. Mean and relative standard error (RSE= (SE/mean) ·100) for density and biomass in the survey area were calculated for each species (SAS Institute Inc, 2007). Mean density and biomass estimates were estimated for each transect, weighted for transect length. Annual and regional differences in abundance were compared using ANOVA, with alpha set at 0.05 as the significance level and the assumption that data were independent. Tukey's multiple comparison test was used to evaluate significance of differences among regions or years. Chi-square tests were used to examine differences in species composition among basins.

Relative standard errors (RSE) were calculated for each annual density and biomass estimate:

$$RSE = \frac{se}{\overline{\chi}} \bullet 100$$

Where *se* is the standard error of $\overline{\chi}$, a mean density or biomass estimate for a particular species. High *RSE*s occur when data are more variable. *RSE*s were only calculated in years when a species was captured.

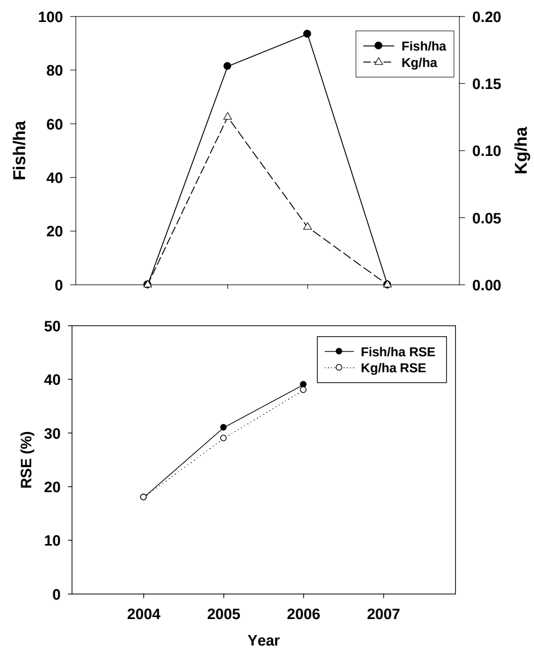

Figure 2. Acoustic estimates of age-0 alewife density and biomass in Lake Huron's main basin, 2004-2007 (upper panel), and relative standard error of density estimates (lower panel).

Results: Main Basin

<u>Alewife</u>

Alewives were an important prey species since their invasion, but have been scarce recently. Since 2004, we have captured few alewives, and of those nearly all were age-0 fish. We captured no alewives at all during 2007. Age-0 alewife density and biomass were significantly higher in 2005 and 2006 compared with other years, (Figure 2, Tukey's test, two tests, P<0.05) but both density and biomass were chronically low in the sense that alewives comprised no more than 2.0% of main basin pelagic fish biomass during 2004-2007. Furthermore, age-0 alewives appear to have low survival because we captured no adults in 2006 or 2007.

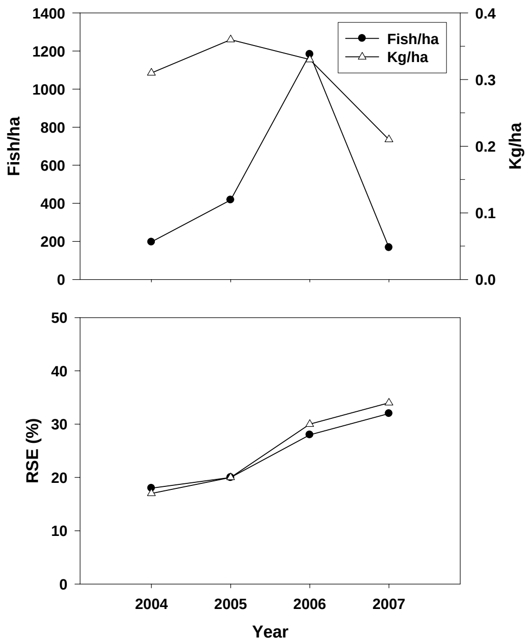

Figure 3. Acoustic estimates of age-0 rainbow smelt density and biomass in Lake Huron's main basin, 2004-2007, (upper panel), and relative standard error of estimates (lower panel).

Rainbow smelt

Main basin rainbow smelt density and biomass varied among years. Age-0 density was significantly higher during 2006 compared with other years; however, there were no differences in age-0 biomass among years in the time series (Tukey's test, two tests, density: P<0.05, biomass: P>0.05) (Figure 3). Both density and biomass of yearling and older smelt were significantly lower during 2006 compared with other years (Tukey's test, two tests, P<0.05) (Figure 4). Point estimates of density and biomass of yearling and older rainbow smelt increased during 2007 compared to 2006, but their biomass was still less than 1.5 kg/ha in 2007.

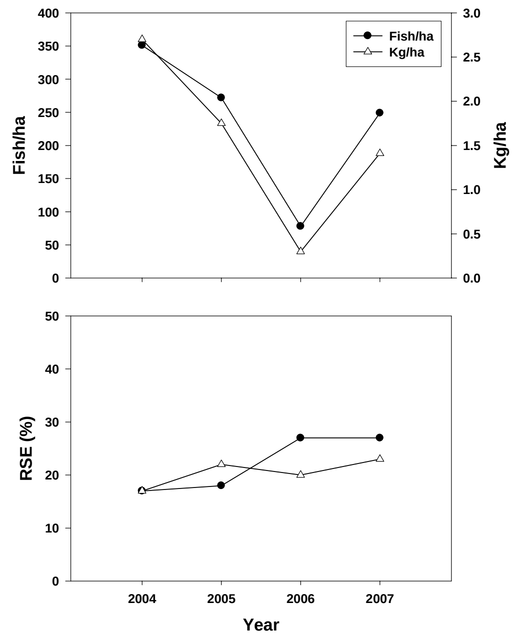

Figure 4. Acoustic estimates of yearling and older rainbow smelt density and biomass in Lake Huron's main basin, 2004-2007, (upper panel), and relative standard error of estimates (lower panel).

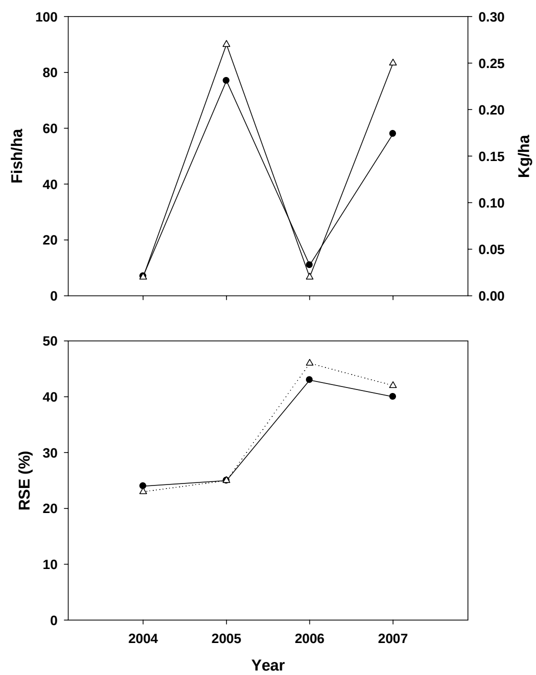

Figure 5. Acoustic estimates of age-0 bloater density and biomass in Lake Huron's main basin, 2004-2007, (upper panel), and relative standard error of estimates (lower panel).

Bloater

Age-0 bloater *Coregonus hoyi* densities varied among years (Tukey's test, *P*<0.05); their density was significantly higher in 2005 compared with other years (Figure 5). Age-0 bloater biomass was higher in 2005 and 2007 compared with 2004 and 2006 (Tukey's test, *P*<0.05). Higher biomass in 2007 without significant density increase was likely a result of slightly larger average size in 2007 compared with 2005.
We found no significant differences in yearling and older bloater density or biomass during 2004-2007 (Tukey's test, two tests, *P*<0.05). Densities ranged from about 50 to 100 fish/ha, and biomass ranged from 1.7 to 4.2 kg/ha (Figure 6).

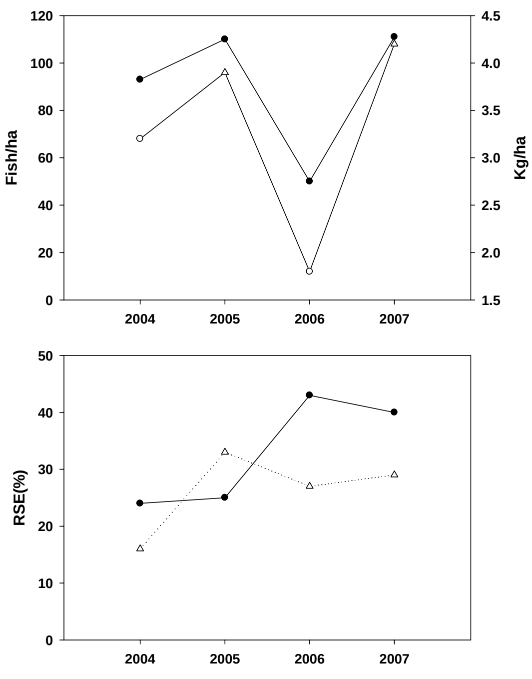

Figure 6. Acoustic estimates of yearling and older bloater density and biomass in Lake Huron, 2004-2007, (upper panel), and relative standard error of estimates (lower panel).

Emerald shiner

Emerald shiners *Notropis atherinoides* were not observed during 2004, but were collected during 2005-2007. Main basin density and biomass during 2007 was lower than in 2006 (Figure 6). Density varied significantly among years; density during 2006 was significantly higher than other years. (Tukey's test, *P*<0.05). (Figure 6). Increases in RSE between 2006 and 2007 indicated greater variation in density.

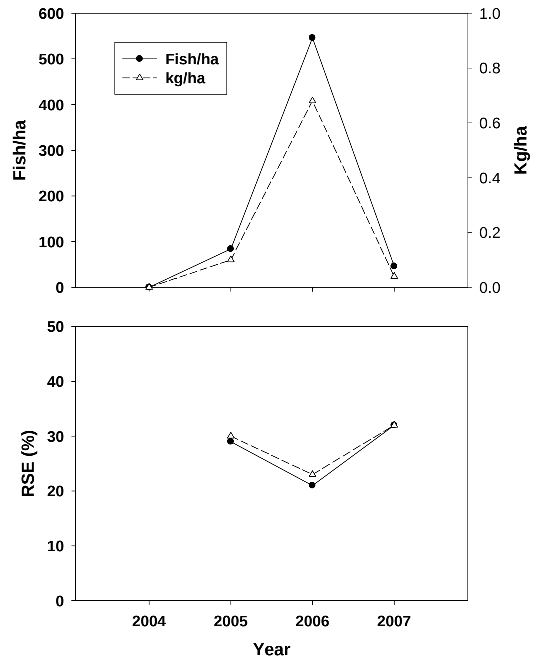

Figure 7. Acoustic estimates of emerald shiner density and biomass in Lake Huron, 2004-2007, (upper panel), and relative standard error of estimates (lower panel).

biomass in 2006 was lower compared to other years (Tukey's test, two tests, $P<0.05$) (Figures 9, 10) .

Cisco

Ciscoes were absent from our survey during 2004-2006 and were collected for the first time during 2007. Adults were collected by the trawl in both in the main basin and Georgian Bay. Main basin cisco densities were over eight fish/ha, and their biomass of 2.7 kg/ha comprised 30% of main basin pelagic fish biomass (Figure 8).

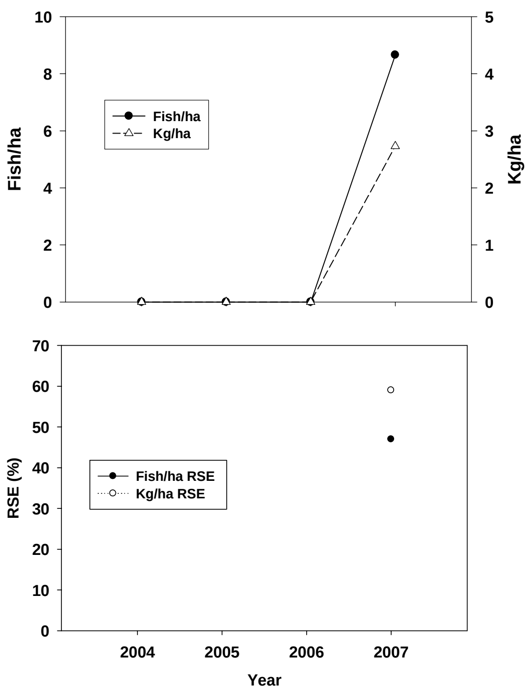

Figure 8. Acoustic estimates of cisco density and biomass in Lake Huron, 2004-2007, (upper panel), and relative standard error of estimates (lower panel).

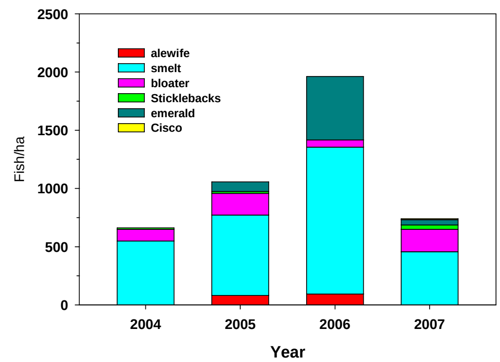

Figure 9. Acoustic estimates of total pelagic fish density in Lake Huron's main basin, 2004-2007.

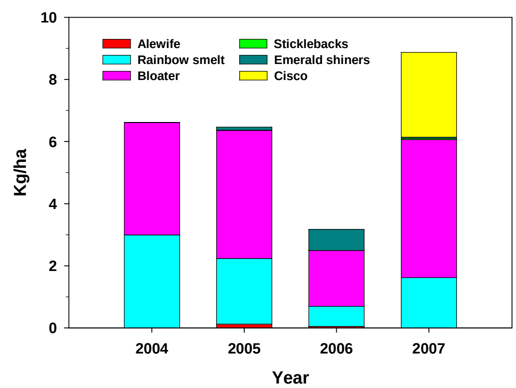

Figure 10. Acoustic estimates of total pelagic fish biomass in Lake Huron's main basin, 2004-2007.

Main Basin Fish Community

We found few differences in total density or biomass among years. Main basin fish density did not vary during 2004-2007, and the only significant difference in fish biomass was that

Among-Basin Comparisons

During 2007 we observed differences in fish density and biomass among Lake Huron's three basins, with a pattern similar to that observed in 2004 and 2005 (Warner et al. 2006, Schaeffer et al. 2007).

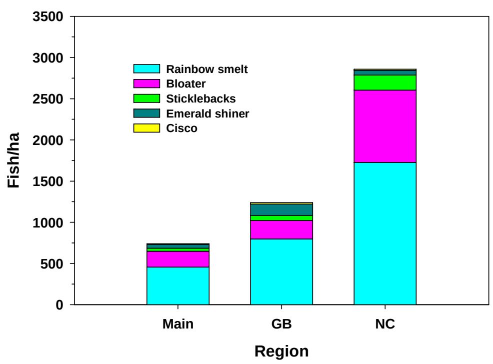

Figure 10. Acoustic estimates of total pelagic fish densities in Lake Huron's main basin (Main), Georgian Bay (GB) and North Channel (NC).

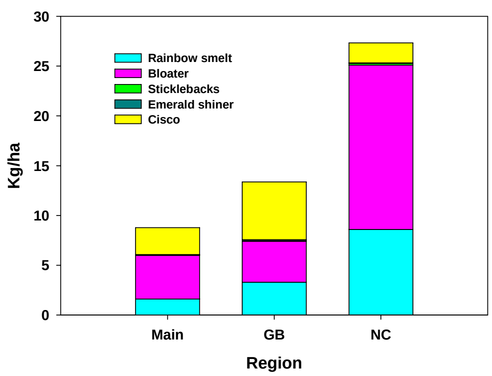

Figure 11. Acoustic estimates of total pelagic fish biomass in Lake Huron's main basin (Main), Georgian Bay (GB) and North Channel (NC).

In 2004 and 2005, we saw significant differences in both pelagic fish density and biomass among all three basins, with highest values in the North Channel, lowest values in the main basin, and intermediate estimates in Georgian Bay. In 2007, North Channel density and biomass estimates were significantly higher than other basins, but there were no significant differences between Georgian Bay and the main basin (Figures 10, 11).

Discussion

We observed few significant changes in the pelagic density or biomass of Lake Huron's main basin during 2004-2007. Total fish density did not vary among years. Biomass was significantly lower during 2006 compared with other years, but varied only between about 3.5 and 8.8 kg/ha. We did observe consistent differences among basins, with the North Channel always having significantly higher fish density and biomass than the other two basins. We also observed changes in species composition. In 2006 we observed substantial increases in emerald shiners, while in 2007 we saw appearance of ciscoes for the first time in our surveys.

The increase in ciscoes was consistent with fish community objectives that call for their restoration (Desjardine et al. 1995), increased interest in ciscoes as a food resource for salmonids, and as a species sought by sport, commercial, and tribal fishers. However, their density and biomass estimates must be interpreted with extreme caution.

Ciscoes were rare in our trawl catches; we captured one individual in the main basin, six individuals in Georgian Bay, and none in the North Channel. They achieved prominence in biomass estimates because 1) overall fish biomass in Lake Huron is low, and 2) ciscoes were large bodied compared to other species. The adults we captured had an average weight of 338 g; individual ciscoes weighed 15 to 40 times more than individual adult rainbow smelt and adult bloaters. Because biomass was the product of density and mean weight, even low cisco densities made substantial contributions to biomass estimates because they were large compared to other species. Cisco presence in the North Channel where none were captured was an avowed bias, and occurred because some acoustic cells there were populated with trawl data derived from means from all trawls across all basins. While that approach was consistent with our primary goal of estimating total lakewide fish density and biomass, it was also sensitive to the problem of cross-basin inclusion of ciscoes as well as large size of ciscoes compared with other fishes.

We evaluated severity of this bias by using a different method of estimating cisco densities. We reanalyzed just the acoustic data using a target strength threshold of -35.0 dB. That was close to the value suggested by Yule et al. (2006) as a method of counting only fish large enough to represent ciscoes in acoustic density estimates. This approach allowed us to eliminate any influence of averaging the trawl data. We found cisco densities of 8 ciscoes/ha in the main basin, which was similar to our main-basin estimates based on both acoustics and trawling (8.8 ciscoes/ha). In Georgian Bay, we found 28 ciscoes/ha, which was higher than our acoustic/midwater trawl estimate of 16.8 ciscoes/ha. In contrast our acoustic/midwater trawl estimates of North Channel ciscoes were much higher than target strength based density estimates: 13.8 ciscoes/ha versus only 0.28 ciscoes/ha.

These results suggest that our cisco density estimates are likely too high in the main basin and North Channel, but for different reasons. In the main basin, both methods produced similar densities, but it is unlikely that all large fish observed on the echosounder were ciscoes, and some targets could have been lake whitefish *Coregonus clupeaformis* or salmonids. However, they were not captured in our trawl. In the North Channel, cisco densities based on trawl data were higher than the number of ciscoes actually observed with the echosounder. There, cisco densities were likely overestimated as a result of our computational technique.

Uncertainties regarding cisco density stemmed from their large size and few trawls relative to a large number of acoustic cells that required us to pool spatially segregated catch data to estimate lakewide species composition. These factors have contributed to uncertainty even in intensive acoustic studies performed over smaller spatial scales (Yule et al. 2006). However, disparity between acoustic densities and trawl catches is most severe when ciscoes are at low density; at higher densities disparities are lower (Daniel Yule, GLSC, unpublished data). Thus, both approaches should be robust in tracking increases in the cisco population. Despite these uncertainties, our results suggest that:1) ciscoes have increased in Lake Huron, 2) the range of densities we calculated are lower than those observed in Lake Superior (78/ha) (Yule et al., in press) , and 3) ciscoes could dominate pelagic biomass even at relatively low densities.

This survey sampled offshore areas of Lake Huron from 10 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 may have been higher had these areas been included because nearshore areas are well known as nursery habitats and could have supported higher densities of age-0 fishes than offshore waters (Höök et al. 2001, Klumb et al. 2003).

Species identification occurred in the field, and in Georgian Bay we captured small coregonids in two trawl tows that sampled the thermocline. These fish were identified as bloaters, but some could have been ciscoes because there is no completely reliable way to tell the two species apart in the field. This would probably not have altered our density estimates because ciscoes appeared to be rare compared to other species. It would have reduced cisco biomass estimates by lowering the average weight of ciscoes and reducing their biomass. This problem is likely to worsen if ciscoes become more abundant, and may require development of density and biomass estimates for juvenile coregonids in cases where identification is uncertain.

One of the more surprising aspects of our survey was the finding that there have been no significant changes in main basin pelagic fish density or biomass during 2004-2007 despite changes in species composition that included resurgence of emerald shiners in 2005 and 2006 (Schaeffer et al., in press), and the appearance of ciscoes during 2007. While increases in emerald shiners and ciscoes are consistent with fish community objectives that call for restoration of native species (Desjardine et al. 1995), their appearance has not yet resulted in biomass increase.

Low pelagic fish biomass appears to be a chronic problem in Lake Huron. While our data are not comparable directly to bottom trawl data, those surveys reported higher demersal fish biomass prior to 2004-2007 (Roseman et al. 2008). The reasons for apparent lower biomass are poorly understood, and both high predation rates and changes in lower trophic levels have been proposed as potential mechanisms. The relative importance of each factor is not known, but several current studies are attempting to quantify their importance. One consistent finding in our surveys is that pelagic fish density and biomass is higher in the North Channel compared with other basins. The reason underlying this difference is unknown, but we suggest that among-basin comparisons of Lake Huron's pelagic environment may be the key to understanding chronic and perplexing main basin trends.

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