Status and Trends of Pelagic Prey Fishes in Lake Huron, 2011[1]

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Abstract

The USGS Great Lakes Science Center conducted acoustic/midwater trawl surveys of Lake Huron during 1997 and annually during 2004-2011. The 2011 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 and biomass were higher in 2011 compared to 2010. Bloater *Coregonus hoyi* densities and biomass did not change between 2010 and 2011, but we observed increases in rainbow smelt *Osmerus mordax* (1.8x), and emerald shiner *Notropis atherinoides* (625x) biomass. Alewife *Alosa pseudoharengus* remained nearly absent, but ciscoes *Coregonus artedi* were captured in all four trawls on both North Channel transects. During 2011 we observed no significant differences in fish density or biomass among North Channel, Georgian Bay, or the main basin. That spatial pattern differed from patterns we found during 2004-2007 when biomass in the sub-basins was higher. Prey availability during 2012 will likely be higher than 2011 due to increases in rainbow smelt and emerald shiner. Lake Huron now has almost two times greater pelagic biomass than Lake Michigan, but species composition differed. Alewife predominated in Lake Michigan, while pelagic biomass in Lake Huron was comprised of rainbow smelt, bloater, and to a lesser extent, emerald shiner.

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Introduction

The U.S. Geological Survey's Great Lakes Science Center has conducted bottom trawl surveys of the Lake Huron fish community since the 1970's. While those data tracked broad-scale changes in the fish community, acoustic surveys were implemented because recent research has shown this method is better at assessing pelagic species, especially over rough bottoms (Fabrizio et al. 1997, Stockwell et al. 2007, Yule et al. 2008). Acoustic surveys were first conducted during the 1970's (Argyle 1982), but the first lake-wide survey that included all of Lake Huron's distinct basins was conducted in 1997. Annual surveys have been conducted since 2004; however, only the main basin was sampled during 2006, and 2009 data were likely not comparable to other years because the available transducer differed in frequency (38 kHz) from those used in other years (70 or 120 kHz). Consequently, 2009 data have been excluded from the time series.

Methods

The 2011 survey used a stratified and randomized systematic design with transects in five geographic strata: eastern Main Basin (ME), western Main Basin (MW), southern Main Basin (SB), Georgian Bay (GB), and the North Channel (NC) (Figure 1). Within each stratum, the first transect was selected randomly based on latitude or longitude; subsequent transects were spaced evenly around the first. Effort (transects per strata) was allocated based on stratum area and variability of total biomass in each stratum from previous surveys shown by Adams et al. (2006). For analysis, each transect was divided into 1,000 m long sampling units consisting of multiple 10-m depth layers.

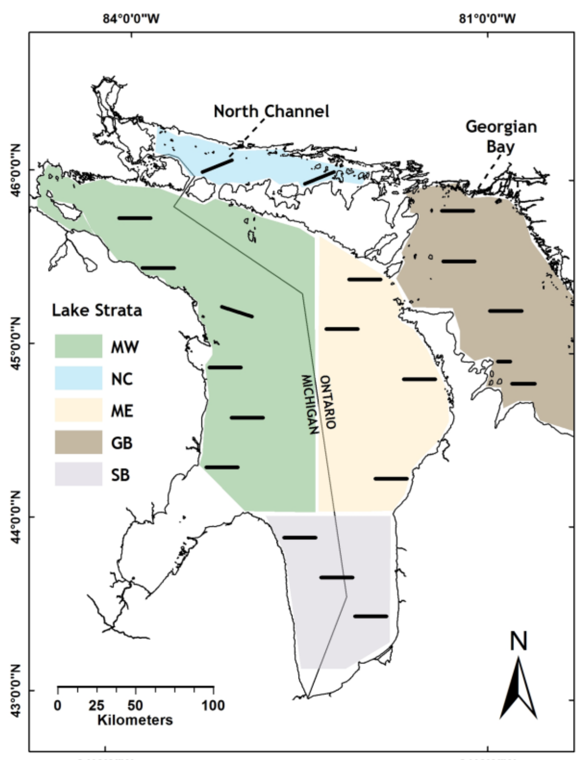

Figure 1. Hydroacoustic transects sampled during the 2011 lakewide acoustic/midwater trawl survey in Lake Huron.

During 1997, 2004-2005 and 2007-2008 acoustic data were collected during September through early October with a Biosonics split-beam 120 (kHz) echosounder deployed through a sonar tube from the Research Vessel (R/V) Sturgeon or in a sea chest (1997). Split-beam echosounders were used in all years but 1997, when a Biosonics model 102-dual beam was used. During 2006, acoustic data were collected during August with a 70 kHz echosounder and a transducer deployed via a towfish from the R/V Grayling. During 2009 we used a 38 kHz echosounder deployed through a sonar tube. This frequency is largely untested in the Great Lakes to date, and tradeoffs between nearfield size and amount of backscatter relative to the precision of fish density estimates have not yet been evaluated (Parker-Stetter et al. 2009); however, a transducer with that frequency was the only one available that passed field calibration tests. In 2010, we used both a 38 and 120 kHz echosounder to facilitate future frequency comparisons, but present 120 kHz data only.

In 2011, the survey was carried out jointly between GLSC and the United States Fish and Wildlife Service (USFWS). USFWS used a 120 kHz split-beam echosounder (Simrad EK-20) aboard the M/V *Spencer F. Baird* and sampled 5 of 6 transects located in the MW stratum. GLSC sampled all other transects using the R/V *Sturgeon*.

In all years, sampling was initiated one hour after sunset and ended no later than one hour before sunrise. A threshold equivalent to an uncompensated target strength (TS) of -70 decibels (dB) was applied to S_v (volume backscattering strength) data, which resulted in exclusion of scattering of fish with compensated TS > -64 dB.

Species and size composition were determined using a 15-m headrope midwater trawl (USGS) or a 21-m headrope midwater trawl (USFWS). Tow locations and depths were chosen to target fish aggregations, but we attempted to collect multiple tows per transect when fish were present so that trawl data within a stratum were available from the epilimnion, metalimnion, and hypolimnion. Trawl depth was monitored using a Netmind™ system, a manual dive profiler (USGS), or a Simrad PI44 catch monitoring system (USFWS). Most midwater trawl tows were of 10 minutes duration, with tow times extended up to 20 minutes when few fish were present. Thirty one midwater tows were performed during 2011. Temperature profiles were obtained using a bathythermograph on each acoustic transect. All fish were identified, counted, and weighed in aggregate (g) by species. Up to 100 randomly selected individuals were measured (total length, mm) per tow. Individual fish were assigned to age categories (predominantly age-0, or predominantly age 1+) based on size using the following break points: alewife =100 mm; rainbow smelt = 90 mm; bloater = 120 mm.

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

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

where *ABC* was the area backscattering coefficient (m^2 / m^2) of each 10-m high by 1000-m long cell, and σ was the mean backscattering cross section (m^2) of all targets between -60 and -30 dB in each cell. The lower threshold should have included all age-0 alewives present (Warner et al. 2002), but may have underestimated age-0 rainbow smelt density (Rudstam et al. 2003).

Density (fish/ha) 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 age-0 and age-1+ age-classes by multiplying total density by the numeric proportions of each age group. Biomass (kg/ha) of each species was estimated as the product of density and size-specific mean mass estimated from fish lengths in trawls, and length-weight relationships.

In order to assign species and size composition to acoustic data, we used different approaches depending on the vertical position in the water column. For cells with depth < 40 m, midwater trawl and acoustic data were matched according to transect, depth layer, and bottom depth. For acoustic cells with no matching trawl data, we assigned the mean catch proportions of each depth layer and bottom depth combination from the same geographic stratum [lake region: main west (MW), main east (ME), southern basin (SB), Georgian Bay (GB), North Channel (NC)]. If acoustic data still had no matching trawl data, we used basin-wide mean catch proportions for each depth layer-bottom depth combination. Finally, for any cell still lacking trawl composition data, we assigned the lakewide mean catch proportions. Mean mass of species/size groups at depths < 40 m were estimated using length frequencies and weight-length equations from midwater trawl data. For depths ≥ 40 m, we assumed that acoustic targets were age-1+ bloater if mean TS was > -45 dB (Tewinkel and Fleischer 1999). Mean mass of bloater in these cells was estimated using the mass-TS equation of Fleischer et al. (1997). If mean TS was ≤ -45 dB, we assumed the fish were rainbow smelt and estimated mean mass from mean length, which was predicted using the TS-length equation of 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 and it allowed us to better characterize species composition in deep areas where fish tended to be close to the bottom and midwater trawling was unfeasible.

Biomass (kg/ha) was estimated as the product of total density (estimated acoustically) and the numeric proportions of each size class of each species and its respective 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. Mean density and biomass estimates for each basin were estimated from transect data weighted for transect length. Annual and regional differences in abundance were compared using ANOVA, with alpha set at 0.05. Tukey's multiple comparison tests were used to interpret significant differences among years within the main basin, and then among regions in 2011.

As recommended by the Great Lakes Acoustic SOP (Parker-Stetter et al. 2009, Rudstam et al. 2009), we used a number of techniques to assess or improve acoustic data quality. We used the N_v index of Sawada et al. (1993) to determine if conditions in each acoustic analysis cell were suitable for estimation of *in situ* TS. We defined suitability as an N_v value < 0.1 and assumed mean TS in cells at or above 0.1 were biased. We replaced mean TS in these cells with mean TS from cells that were in the same depth layer and transect with N_v < 0.1. To help reduce the influence of noise, we estimated noise at 1 m in the 20 log domain at each transect using either passive data collection or echo integration of data below the bottom echoes. We then used noise at 1 m to estimate noise at all depths, which we subtracted from the echo integration data. Additionally, we estimated the detection limit (depth) for the smallest targets we include in our analyses. Acoustic equipment specifications, software versions, single target detection parameters, noise levels, and detection limits can be found in Appendices 1 and 2.

Mean and relative standard error for density and biomass for the entire survey area (all three basins pooled) were estimated using stratified cluster analysis methods featured in the statistical routine SAS PROC SURVEYMEANS (SAS Institute Inc. 2007). 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) in each stratum were weighted by dividing the stratum area by the number of ESUs in the stratum.

Spatial coverage during 2011 was accomplished as planned and all scheduled transects were sampled.

Results- Main Basin

Alewife

Since 2004, we have captured very few alewives, and almost all have been age-0 fish. During 2011, both alewife density and biomass remained low (Figure 2). Main basin alewife density varied significantly among years (Tukey's test, two tests, $P < 0.05$). Alewife density in 1997, 2005, 2006, and 2008 was higher than all other years which had lower densities. However, we note that density differences, though significant, did not mean that alewife have been especially abundant in any survey year. During 1997, their year of highest abundance, they were only 3.1% of total fish density. Alewife biomass was significantly higher in 1997 compared with all other years in the series (Tukey's test, $P < 0.05$). Temporal biomass differences were due to differences in size/age structure between 1997 and other years. In 1997 Age 1+ alewife were captured, but age-0 alewife were captured during 2004-2011. Age-0 alewife biomass remains chronically low and since 2004 they have never comprised more than 2.5 % of main basin pelagic fish biomass. Alewife have shown no sign of returning to higher abundance. During 2011, only 25 of the 9903 fish we captured in the midwater trawl were alewife; all were age 0 and most catches were comprised of single scattered individuals in the northern main basin and northern Georgian Bay. The largest catch was 17 individuals taken near the straits of Mackinac.

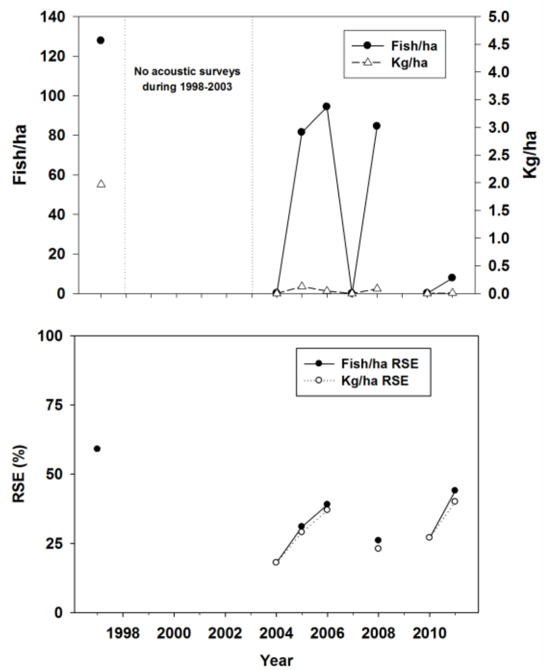

Figure 2. Acoustic estimates of alewife density and biomass in Lake Huron's Main Basin, 2004-2011 (upper panel), and relative standard error of density estimates (lower panel). Data from 2009 excluded.

Rainbow smelt

Main basin age-0 rainbow smelt density during 2011 was significantly higher compared with 2010.The highest density in the time series was 1997, followed by 2006 and 2011. All other years were significantly lower (Tukey's test, $P < 0.05$) (Figure 3). We also have observed few differences in age-0 biomass; in 1997 biomass was significantly higher than all other years, and 2011 values were higher than 2008-2010 (Tukey's test, $P < 0.05$). Age-0 rainbow smelt RSE values have generally increased through time and RSE values during 2011 were the highest in the time series. Age 1+ rainbow smelt density was highest in 1997, but 2011 densities were the second highest in the time series and differed from all other years in the time series except 2010 (Tukey's test, $P < 0.05$). Age 1+ rainbow smelt biomass remained unchanged between 2010 and 2011 (Figure 4). Their biomass was highest in 1997 compared to other years (Tukey's test, $P < 0.05$).

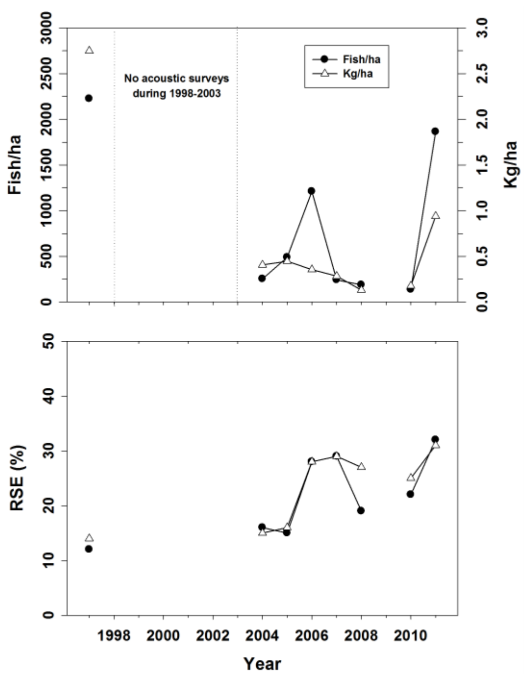

Figure 3. Acoustic estimates of age-0 (< 90 mm) rainbow smelt density and biomass in Lake Huron's Main Basin 2004-2011 (upper panel), and relative standard error of estimates (lower panel). Data from 2009 excluded.

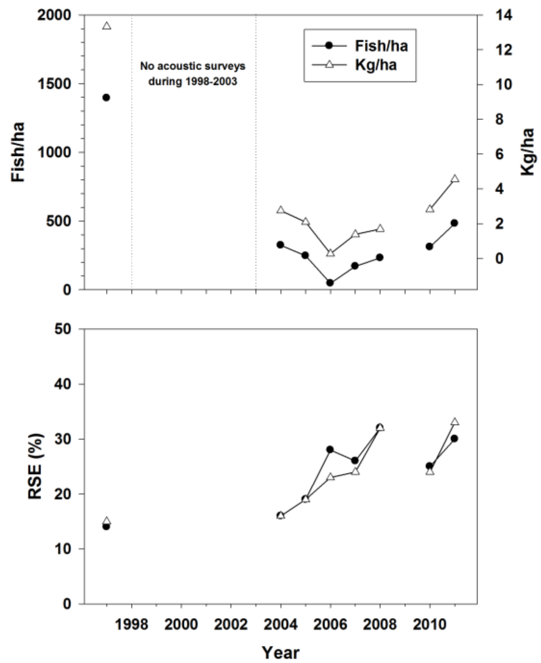

Figure 4. Acoustic estimates of age-1+ (> 90 mm) rainbow smelt density and biomass in Lake Huron's Main Basin 2004-2011 (upper panel), and relative standard error of estimates (lower panel). Data from 2009 excluded.

Bloater

Age-0 bloater density in the main basin was similar in 2011 compared with 2010 (Figure 5). There have been few temporal differences: density of age-0 bloater was significantly higher during 2008 compared with all other years, but their density during 2011 was significantly higher than the two lowest values in the time series (1997, 2004) (Tukey's test, $P < 0.05$). Age-0 bloater biomass showed no trend; values in 2008 were higher than all other years (Tukey's test, $P < 0.05$). Main basin density of age-1+ bloater were significantly lower during 2004 and 2005 compared with 1997 (these were lowest and highest values in the data series) but no other annual differences were detected (Tukey's test, two tests, $P < 0.05$) (Figure 6). Biomass of age-1+ bloater followed an identical trend (Tukey's test, $P < 0.05$).

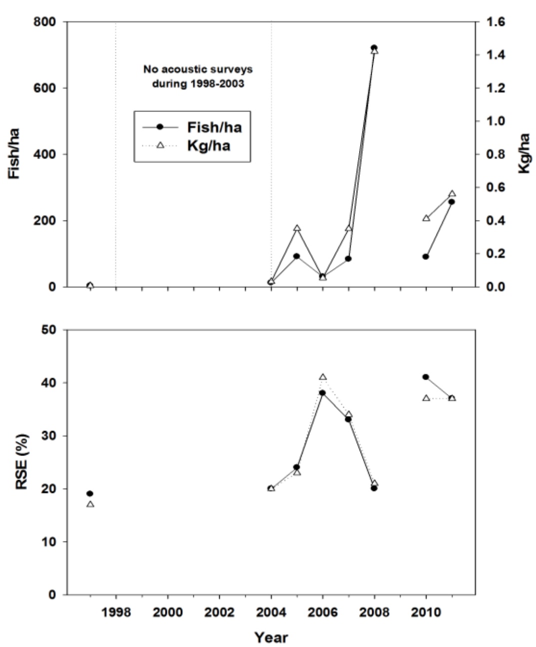

Figure 5. Acoustic estimates of age-0 (< 120 mm) bloater density and biomass in Lake Huron, 2004-2011 (upper panel), and relative standard error of estimates (lower panel). Data from 2009 excluded.

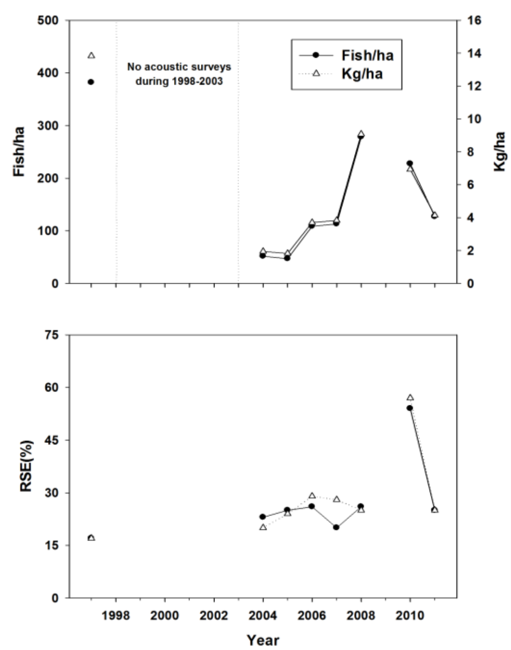

Figure 6. Acoustic estimates of age-1+ (> 120 mm) bloater density and biomass in Lake Huron, 2004-2011 (upper panel), and relative standard error of estimates (lower panel). Data from 2009 excluded.

Emerald shiner

Emerald shiner reappeared in higher densities during 2011 after being scarce during the previous three years (Figure 7). Emerald shiner densities differed significantly among years; they were highest during 2006 but we found no density differences among all other years (Tukey's test, $P<0.05$). Emerald shiner biomass followed a slightly different pattern. Biomass during 2006 and 2011 did not vary significantly, but those years were higher than all other years (Tukey's test, $P<0.05$). Emerald shiner were captured only in the SB and ME strata, and were not found in Georgian Bay or the North Channel. Despite this increase, they were a smaller proportion of main basin pelagic fish biomass during 2011 (2.4 %) than they were in 2006 (13.3%).

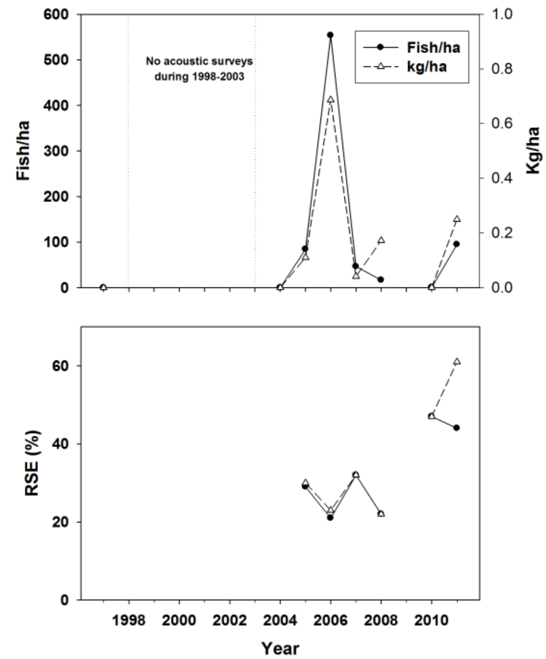

Figure 7. Acoustic estimates of emerald shiner density and biomass in Lake Huron's Main Basin, 2004-2011 (upper panel), and relative standard error of density estimates (lower panel). Data from 2009 excluded.

Cisco

Cisco were not caught in the main basin during 2011 (Figure 8). When present, they can comprise a significant proportion of pelagic biomass due to their large size, (Schaeffer and O'Brien 2009) but they have been captured rarely and seemed uncommon based on low densities of targets large enough to be cisco. However, during 2011 we captured 23 coregonids in the North Channel that were likely small cisco. They ranged from 82-204 mm total length (TL) and were taken in each of the four midwater trawl tows in the North Channel at fishing depths of 12-20 m over bottom depths of 32-46 m. Although small cisco and bloater are difficult to distinguish with certainty, the habitat in which they were collected was where we would expect cisco rather than bloater.

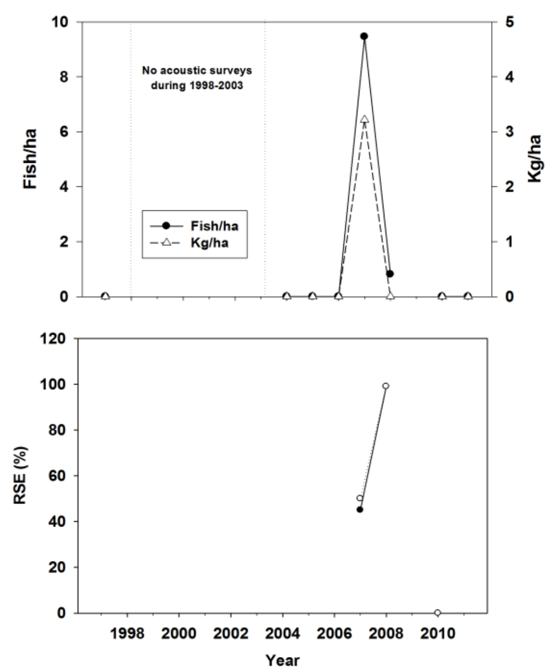

Figure 8. Acoustic estimates of cisco (2004-2007, 2010) and unidentified coregonid (2008) density and biomass in Lake Huron's Main Basin (upper panel), and relative standard error of estimates (lower panel). Data from 2009 excluded.

Main Basin Fish Community

Total main basin pelagic fish density was highest in 1997 compared to other years, but 2011 densities were higher than those observed in 2004, 2007, and 2010 (Tukey's test, $P<0.05$) (Figure 9). Total pelagic fish biomass was highest in 1997 compared to other years, but biomass estimates were similar among all other years (Tukey's test, $P<0.05$). This suggests that since 2004 Lake Huron has had a mean biomass of about 10.5 kg/ha, with biomass dominated by rainbow smelt and bloater (Figure 10). Assuming independence among years, there has been a temporal increase in both main basin density and biomass since 2004 (two regressions, $P<0.05$), primarily due to increase in the ME stratum (Figure 11).

Among-Basin Comparisons

Total pelagic fish biomass did not vary significantly among basins during 2011 (Tukey's test, $P>0.05$) (Figure 12), probably because individual transect biomass estimates had high variability that has increased through time. However, all three basins were similar in that they were dominated by rainbow smelt and bloater. The only substantive differences in species composition during 2004-2011 were observations of emerald shiners in the main basin only and cisco in the North Channel. Since 2004, both total density and biomass have increased in the main basin, declined in Georgian Bay, and

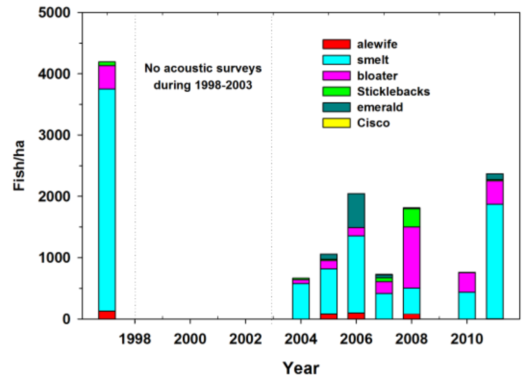

Figure 9. Acoustic estimates of total pelagic fish density in Lake Huron's main basin, 1997-2011. Data from 2009 excluded.

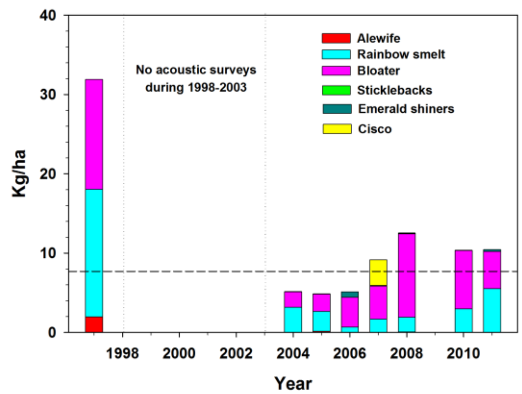

Figure 10. Acoustic estimates of total pelagic fish biomass in Lake Huron's main basin, 1997-2011. Dashed line is 2004-2011 mean. Data from 2009 excluded.

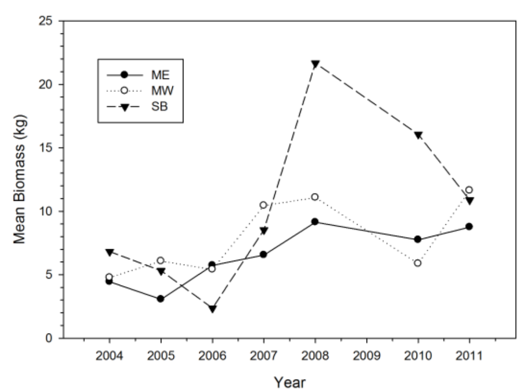

Figure 11. Acoustic estimates of total pelagic fish biomass among three geographic strata within Lake Huron's Main Basin, 2004- 2011.

remained unchanged in the North Channel (three basins, two variables, four of six regressions significant, $P < 0.05$).

Among Lake Comparisons

During 2011, Lake Huron's mean pelagic biomass (all transects in all basins combined) was 8.52 kg/ha, while Lake Michigan's mean pelagic biomass was 4.8 kg/ha (Figure 13). Alewife biomass was significantly higher in Lake Michigan, but rainbow smelt, bloater, and total pelagic fish biomass was significantly higher in Lake Huron (ANOVA, 4 of 4 tests significant, $P < 0.05$). Overall, Lake Huron pelagic biomass estimates were about 1.8 times greater than those obtained in Lake Michigan. We note that the among-lake comparison compared all Lake Michigan transects with all Lake Huron transects from all basins. Since there were no significant differences in among-basin biomass in Lake Huron, this suggests that the among-lake differences during 2011 were not an artifact of among-basin variation.

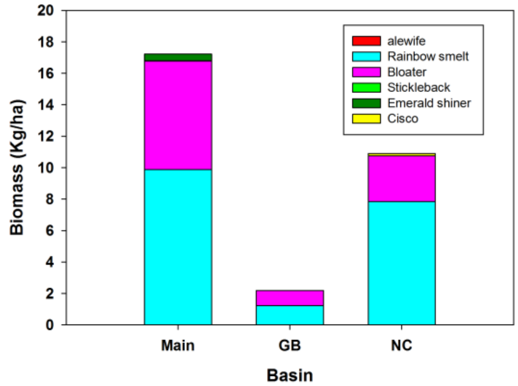

Figure 12. Acoustic estimates of total pelagic fish biomass among Lake Huron's three basins, 2011.

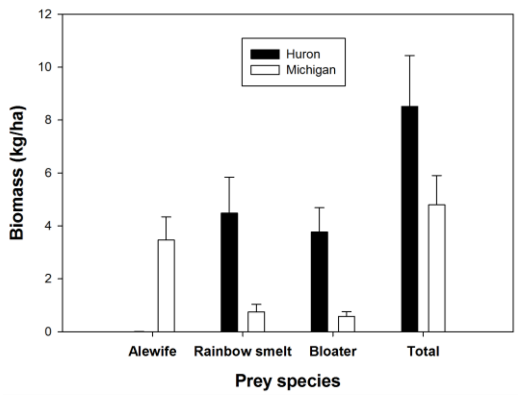

Figure 13. Lakewide mean pelagic biomass and 95% confidence intervals for Lakes Michigan and Huron, 2011. Lake Huron estimates include data from all three basins (Main, North Channel, and Georgian Bay). Lake Huron alewife biomass was too small to be visible.

Discussion

Pelagic fish biomass showed almost no change in Lake Huron's main basin from 2010 to 2011, but biomass is now about 1.8 times higher than that of Lake Michigan as a result of large decrease in Lake Michigan between 2010 and 2011 (Warner et al. 2012). We found no biomass differences among the three basins (main, Georgian Bay, and North Channel). The community in all three basins remains dominated by rainbow smelt and bloater, with lower densities of emerald shiners (main basin only) and cisco (North Channel only). Alewife were again scarce and show no sign of recovery to their former abundance.

We excluded data from 2009 because that year a 38 kHz transducer was the only one that passed field calibration tests prior to the survey. Subsequent sampling during 2010 with paired transducers (38 kHz and 120 kHz) operating simultaneously suggests greater differences between 38 and 120 kHz fish scattering than anticipated (GLSC, unpublished data). During 2011, we again sampled with paired transducers to collect data to determine if 2009 results can be rescaled given differences in scattering intensity so that those density and biomass estimates can be included in the time series.

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 sample nearshore zones and large shallow 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 small fishes than offshore waters (Fielder and Thomas 2006, Höök et al. 2001, Klumb et al. 2003).

We used size to assign age and assumed no overlap in age among size classes. This assumption was likely violated, especially for rainbow smelt. While this might have slight effects on our estimates of age-0 and age-1+ density and biomass, it would have no impact on our estimates of total density, and it would not change our conclusions that rainbow smelt densities and biomass were higher in 2011 compared with 2010.

The 2011 survey was successful largely due to the use of multiple vessels. This allowed us to complete all transects, and to provide a lakewide survey with data collected within a shorter temporal window. While logistically challenging, use of multiple vessels has been used successfully on Lake Michigan since the mid-1990's (David Warner, GLSC, personal communication) and has contributed to the development of a consistent long-term data series that has been used widely in management decisions. The advantages of a multi-vessel approach were demonstrated clearly on Lake Huron during 2011.

Results of our acoustic survey were in general agreement with those of the concurrent bottom trawl survey, with some key differences. Riley et al. (2012) concluded that alewife density was among the lowest recorded in the bottom trawl time series, and our results were similar. They found lower densities of age 1+ rainbow smelt, while we reported an increase between 2010 and 2011. However, both surveys agreed that age-0 rainbow smelt were more abundant this year compared to last year. They found that bloater density and biomass had increased, while we found no change between 2010 and 2011. Their results were similar to ours in that bloater increase was due to higher catches in southern Lake Huron, and we also have observed higher catches in the same areas since 2008. Other species were not comparable because bottom trawls are unlikely to sample highly pelagic species such as emerald shiner, while midwater trawls are unlikely to sample demersal species.

During 2012, forage availability for piscivores will likely be similar to that seen in other recent years. Alewife remain rare, and there has been little change in pelagic biomass since 2004. The Lake Huron forage base still remains low compared to previous decades when both alewife and rainbow smelt were likely more abundant, and in 2011 biomass was only about one third of that estimated in 1997. The most important finding during 2011 was that lakewide pelagic biomass is now about 1.8 times higher in Lake Huron compared to Lake Michigan, and Lake Michigan's lakewide pelagic biomass is similar to estimates obtained from Lake Huron during 2004-2005 when we observed the lowest biomass estimates in the time series. There is, however, a key difference between the two lakes. In Lake Michigan, alewife are still prevalent in that they comprise about 72% of the pelagic biomass. In Lake Huron, alewife were nearly absent during low-biomass years. Thus, preferred prey of salmonids are still available in Lake Michigan, albeit at lower levels than in the past. Acoustic sampling in both lakes during 2012 will be important to examine the ramifications of lower biomass in Lake Michigan, and to determine if Lake Huron continues its trend of biomass increase since 2004.

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Appendix 1. Single target detection parameters used in acoustic data analyses in 2011.

Parameter	Value
TS threshold (dB)	-77
Pulse length determination level (dB)	6
Minimum normalized pulse length	0.8
Maximum normalized pulse length	1.5
Maximum beam compensation (dB)	6
Maximum standard deviation of minor-axis angles	0.6
Maximum standard deviation of major-axis angles	0.6

Appendix 2. Noise levels (mean and range of Sv and TS at 1 m), detection limits, and acoustic equipment specifications in Lake Huron, 2011, for the R/V Sturgeon.

Vessel	R/V Sturgeon	M/V Spencer Baird
Collection software	Visual Acquisition 5.1	ER60 2.2
Transducer beam angle (3dB)	8.2º split beam	6.5º split beam
Frequency (kHz)	120	120
Pulse length (ms)	0.4	0.256
Mean of Sv noise at 1 m (dB)	-133.40[1]	-124.18[1]
Mean of TS noise at 1 m (dB)	-160.00	-150.8
2 way equivalent beam angle	-19.34	-20.10
Detection limit (m) for -64 dB target[2]	101	60

[1] Mean of values estimated by integrating passive data collected on each transect or integrating below bottom.

[2] Assuming 3 dB signal-to-noise ratio, 6 dB maximum beam compensation, and 6dB pulse length determination level.