Status and Trends of Pelagic Prey Fishes in Lake Huron, 2012[1]

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Abstract

The USGS Great Lakes Science Center (GLSC) conducted acoustic/midwater trawl surveys of Lake Huron during 1997 and annually during 2004-2012. The 2012 survey was conducted during September and October, and included transects in Lake Huron's Main Basin, Georgian Bay, and North Channel. Pelagic fish density (638 fish/ha) was lower in 2012 compared to 2011, with density in 2012 only 34% of 2011. Total biomass in 2012 was 74% of the 2011 value. Alewife *Alosa pseudoharengus* remained nearly absent, and only one cisco *Coregonus artedi* was captured. Rainbow smelt *Osmerus mordax* density was only 31% of the 2011 density. Bloater *Coregonus hoyi* density was less than half the 2011 density, mostly as a result of lower density of small bloater. Density and biomass of large bloater in 2012 were similar to 2011 levels. During 2012 we observed significantly higher fish biomass in North Channel than in the Main Basin or Georgian Bay. Prey availability during 2013 will likely be similar to 2012. Lake Huron now has pelagic fish biomass similar to that observed in recent lakewide acoustic surveys of Lake Michigan and Lake Superior, but species composition differs in the three lakes. There is an increasing diversity and prevalence of native species gradient from Lake Michigan to Lake Superior, with Lake Huron being intermediate in the prevalence of native fish species like coregonines and emerald shiner *Notropis atherinoides*.

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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.

Methods

The 2012 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 stratum) 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 10 m bottom contour intervals and 5-10 m layers (1997), 1,000 m distance intervals and 10 m layers (2004-2011), or 3,000 m long sampling units and 10-m depth layers (2012).

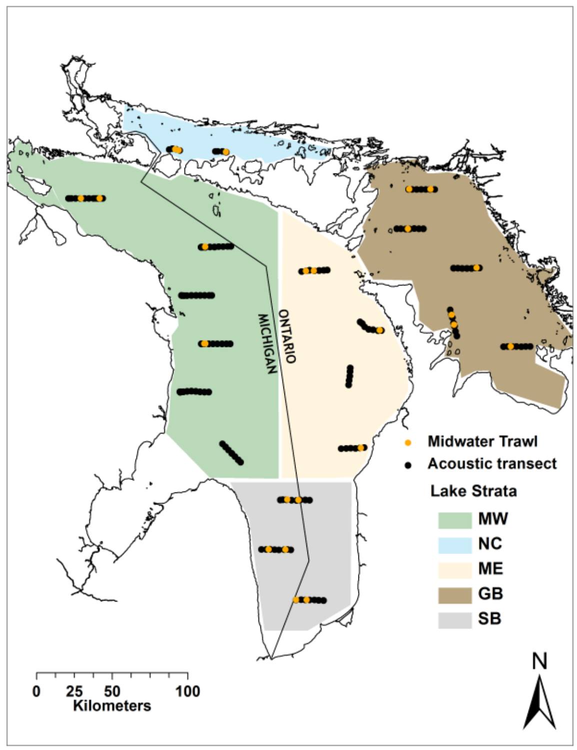

Figure 1. Hydroacoustic transects sampled during the 2012 lakewide acoustic/midwater trawl survey in Lake Huron.

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 was largely untested in the Great Lakes, but a transducer at that frequency was the only one available that passed field calibration tests. In 2010-2012, we used both a 38 and 120 kHz echosounder to facilitate future frequency comparisons, but with the exception of 2009, we present 120 kHz data only. Resulting fish density estimates were higher than expected and it was not clear how they compared to estimates from120 kHz. Subsequent to the 2009 survey, we collected data using both transducers and have found that a) density estimates from 38 kHz are higher than from 120 kHz, b) this difference does not vary among fish species, and c) fish density estimates from the two frequencies are highly correlated (r^2 =0.77). In order to provide estimates for 2009 that would have been equivalent to 120 kHz, we predicted the 2009 fish density estimates using the 38 kHz estimates and a regression model relating the two from data collected in subsequent years. As indicated, the estimates are highly correlated. Additionally, studentized residual plots indicated that the model was acceptable.

In 2012, the survey was carried out jointly between GLSC and the United States Fish and Wildlife Service (USFWS). On the M/V *Spencer F. Baird*, USFWS used a 120 kHz split-beam echosounder (Simrad EK60) to sample 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 > -60 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 each scattering layer formed by fish, which often were in 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. Twenty six midwater tows were performed during 2012. 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. Based on age estimates for these species, the lengths approximate the lengths of the smallest age-1 fish of these species.

Acoustic data collected in 1997 were analyzed using custom software (Argyle et al. 1998). Data collected 2004 and later years 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 1000-3,000 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). The upper threshold excluded any fish much larger than our species of concern.

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 a technique described by Warner et al. (2009), with 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 (0-10, 10-20 m, etc., depending on headrope depth and upper depth of the acoustic cell), and by bottom depth. For acoustic cells without matching trawl data, we assigned the mean of each depth layer and bottom depth combination from the same transect. If acoustic data still had no matching trawl data, we assigned the mean of each depth layer and bottom depth combination within geographic strata. If acoustic data still had no matching trawl data, we used a lakewide mean for each depth layer. Mean mass of species/size groups at depths < 40 m were estimated using weight-length equations from midwater trawl data. For depths ≥ 40 m, we assumed that acoustic targets were large 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 large rainbow smelt and estimated mean mass from mean length, predicted using a TS-length equation (Rudstam et al. 2003).

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 weight predicted from mean length 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.

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 Sv noise at 1 m 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.

Results

<u>Alewife</u>

Since 2004, we have captured very few alewife, and almost all have been age-0 fish. During 2012, both alewife density and biomass remained low and represented 1.5 and 1.8% of the long-term mean, respectively (Figure 2). Alewife density in 1997, 2005, 2006, and 2008 was higher than all other years in the time series. However, we note that density differences, though large, 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. Temporal biomass differences were due in part to differences in size/age structure between 1997 and other years. In 1997 Age 1+ alewife were captured, but only age-0 alewife were captured during 2004-2012. Age-0 alewife biomass remains low and since 2004 they have never comprised more than 2.5 % of pelagic fish biomass. Alewife have shown no sign of returning to higher abundance. During 2012, only 9 of the 3,187 fish we captured in the midwater trawl were alewife; all were age-0 and most catches were comprised of single scattered individuals in the North Channel and southern Georgian Bay. The largest catch was 7 individuals taken in southern Georgian Bay. These results are consistent with the results from the annual bottom trawl survey (Roseman et al. 2013), which indicated that alewife abundance remains very low.

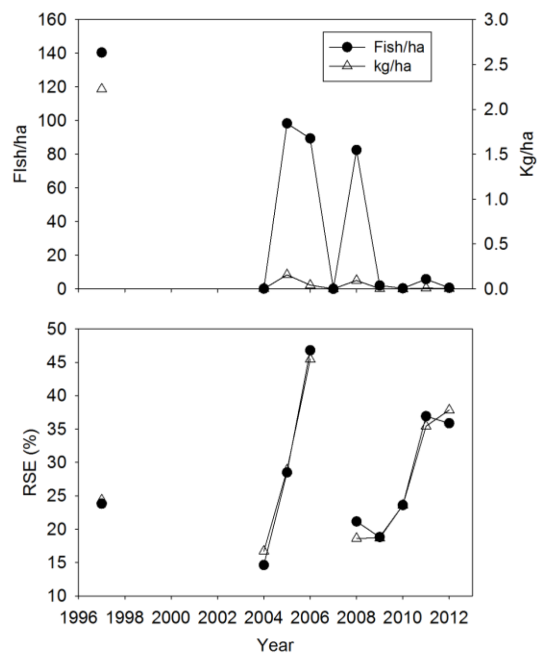

Figure 2. Acoustic estimates of alewife density and biomass in Lake Huron, 1997-2012 (upper panel), and relative standard error of density estimates (lower panel).

Rainbow smelt

Rainbow smelt density and biomass decreased during 2012 compared to 2011 estimates. Age-0 rainbow smelt density decreased substantially and 2012 estimates were 13% of 2011 estimates, 16 % of the long-term mean, and the second lowest in the time series following 2010 (Figure 3). Abundance of age-0 rainbow smelt has been variable over the time series with the highest densities occurring during 1997, followed by 2006 and 2009.

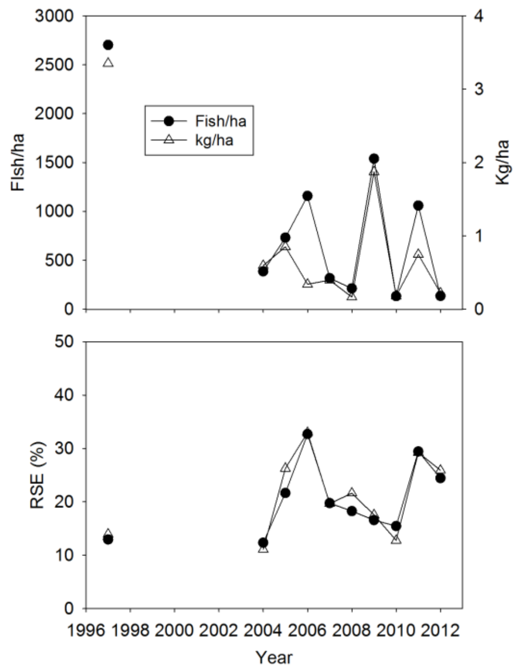

Figure 3. Acoustic estimates of age-0 (< 90 mm) rainbow smelt density and biomass in Lake Huron, 1997-2012 (upper panel), and relative standard error of estimates (lower panel).

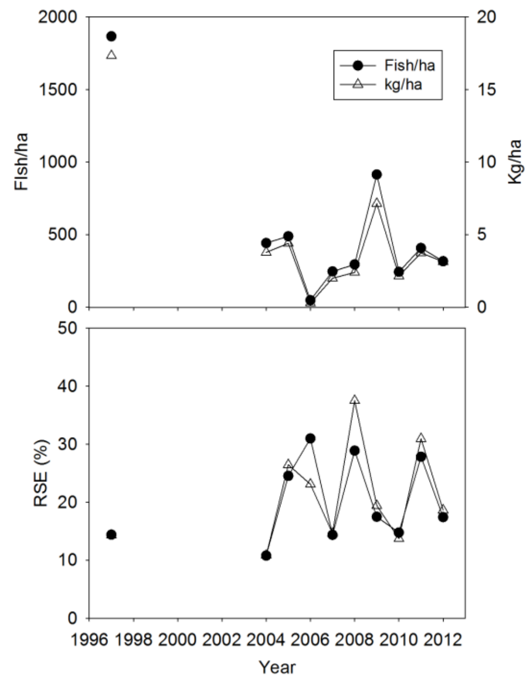

Figure 4. Acoustic estimates of age-1+ (> 90 mm) rainbow smelt density and biomass in Lake Huron, 1997-2012 (upper panel), and relative standard error of estimates (lower panel).

Consistent with low densities observed in 2012, age-0 rainbow smelt biomass was low and 29% of 2011 estimates and 25% of the long-term mean. Only 2008 and 2010 had lower estimates of age-0 biomass. Age 1+ rainbow smelt biomass and density were similar in 2011 and 2012 (Figure 4). Density of age-1+ rainbow smelt during 2012 was 78% of 2011 estimates and 60% of the long-term mean. Age-1+ rainbow smelt biomass in 2012 was 84% of 2011 estimates and 68% of the long term mean. Following the highest observed age-1+ abundance in 1997, estimates of rainbow smelt density and biomass were substantially lower during 2004-2012. Acoustic survey results indicate rainbow smelt density and biomass have shown no trend during 2004-2012. Density and biomass estimates from the bottom trawl survey in 2012 were similar to acoustic estimates (Roseman et al. 2013).

Bloater

Age-0 bloater density in 2012 was 22% of the 2011 value (Figure 5) and 27% of the long-term mean. Density has been highly variable and has shown no trend. Similarly, age-0 bloater biomass showed no trend. The estimate in 2012 was 15% of the 2011 estimate and 17% of the long-term mean. The density and biomass of large bloater has been somewhat less variable from year to year (Figure 6). Both density and biomass of large bloater showed an increasing trend from 2004-2008, followed by a decrease from 2009-2010 Density of large bloater in 2012 was similar to the estimates in 2010 and 2011 and was 60% of the long-term mean. Biomass of large bloater in 2012 was similar to biomass in 2011 and was 60% of the long-term mean. The acoustic estimate of large bloater biomass in 2012 was much lower than the bottom trawl estimate (Roseman et al. 2013), but results from both surveys suggest an increasing trend in biomass of large bloater since 2004.

Cisco

Cisco abundance has been very low in Lake Huron. Catches in midwater trawls are too sporadic to be able to use trawl proportions to apportion acoustic densities. For example, only one cisco was caught in 2012 and in six of the years from 2004-2012, zero or one

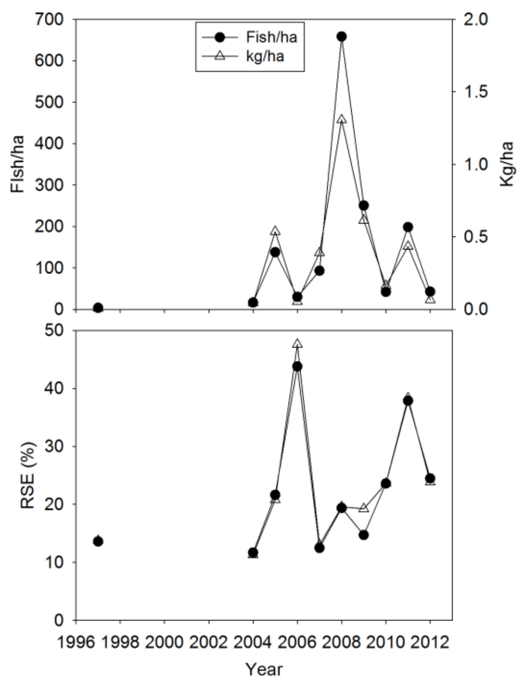

Figure 5. Acoustic estimates of age-0 (< 120 mm) bloater density and biomass in Lake Huron, 1997-2012 (upper panel), and relative standard error of estimates (lower panel).

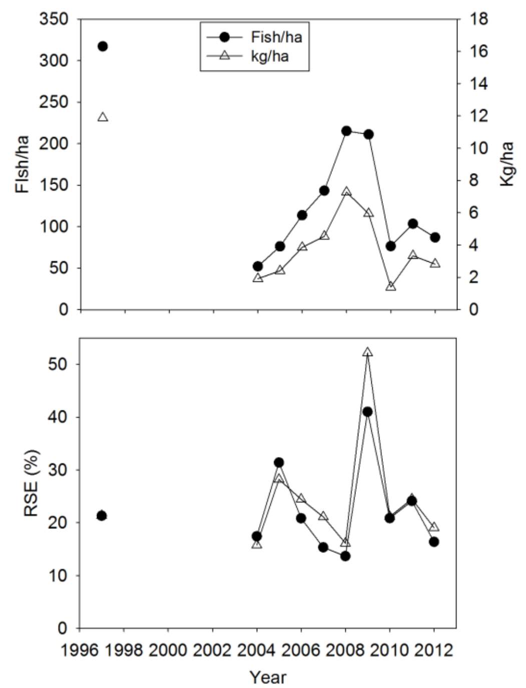

Figure 6. Acoustic estimates of age-1+ (> 120 mm) bloater density and biomass in Lake Huron, 1997-2012 (upper panel), and relative standard error of estimates (lower panel).

cisco were captured during acoustic surveys. GLSC sampling (all types) has captured only 108 cisco since 1980. In order to provide cisco density estimates for comparison with Lake Superior, we used the approach of Yule et al. (2006), who used acoustic target strength to identify targets as large cisco, with -35.6 dB as the lower limit to the target strength of large cisco (fish >250 mm). We used this approach with the caveat that not all of these targets are cisco and so the estimates are likely overestimates of cisco. We found that there has been no evidence of a trend in the density of large adult cisco-sized targets in the period 2004-2012. Mean density of targets >-36 dB in Lake Huron varied between 0.7 and 2.6 fish/ha with no discernible trend. Furthermore, this analysis showed that density of large cisco-sized targets in Lake Huron has been much lower than observed by Yule et al. (2013) during a lakewide acoustic survey of Lake Superior in 2011 (Figure 7).

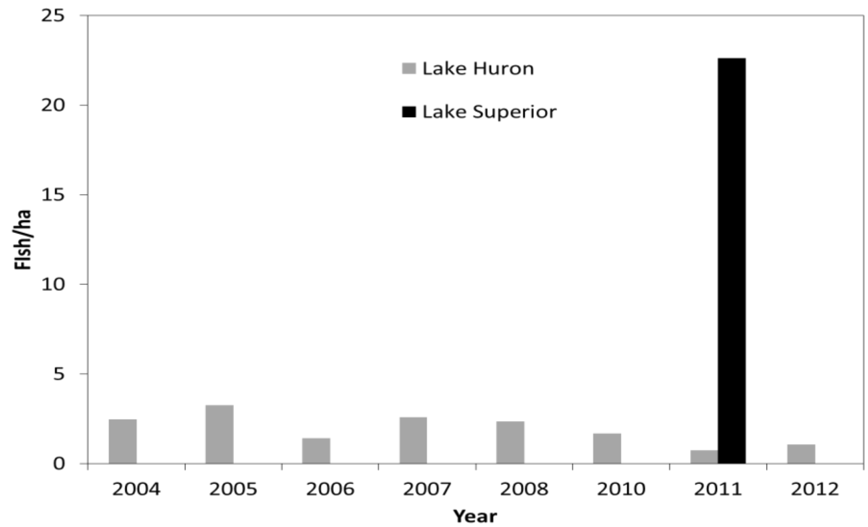

Figure 7. Density of large cisco-sized targets in Lake Huron during lakewide acoustic surveys in the years 2004-2012. The lakewide mean density from Lake Superior (Yule et al. 2013), estimated using the same methods, is shown for comparison.

Emerald shiner

Emerald shiner density and biomass in 2012 were much lower than in 2011 (Figure 8). Lakewide mean density was 26% of the 2011 value, while biomass was 7% of the 2011 value. Emerald shiner were captured only in the western portion of the Main Basin and were not observed in Georgian Bay or the North Channel. They were a small proportion (<1%) of pelagic fish biomass during 2012.

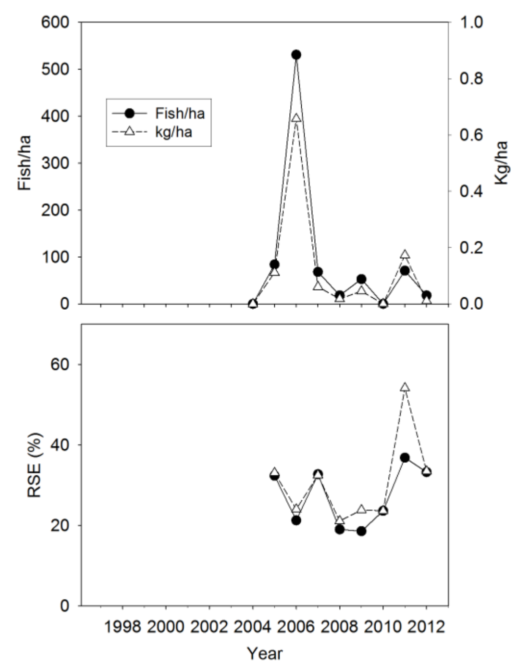

Figure 8. Acoustic estimates of emerald shiner density and biomass in Lake Huron, 1997-2012 (upper panel), and relative standard error of density estimates (lower panel).

Among-Basin Comparisons

One factor that makes Lake Huron unique among the Laurentian Great Lakes is the presence of four large, distinct basins that make up significant portions of the total lake area. For example, Georgian Bay makes up approximately 25% of the total Lake Huron area and is 77% of the area of Lake Ontario. These basins differ in mean depth and area, and in past years, fish biomass (Warner et al. 2009). In 2012, pelagic fish biomass varied significantly among basins (Tukey's test, $P<0.05$), with biomass higher in the North Channel than in the Main Basin or Georgian Bay (Figure 9). In addition to differences in fish biomass, the three basins appear to have different temporal trends in biomass and they differ in community composition. In both Georgian Bay and the Main Basin, fish biomass has declined since 1997 (Figure 10) and remains low, while there is no evidence of a declining trend in North Channel. Community composition differences are predominantly the result of variation in the proportion of biomass made up by rainbow smelt and bloater. Most biomass in Georgian Bay has been in the form of rainbow smelt (53%), while most of the biomass in the Main Basin has been in the form of bloater (54%). North Channel, where rainbow smelt have made up 71% of biomass, has had even greater rainbow smelt dominance than Georgian Bay. To date, the only factor identified as having consistently influenced the biomass and community composition differences among these basins is bottom depth (Warner et al. 2009).

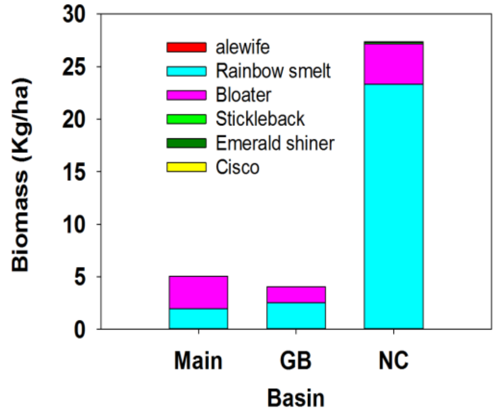

Figure 9. Acoustic estimates of total pelagic fish biomass among Lake Huron's three basins, 2012.

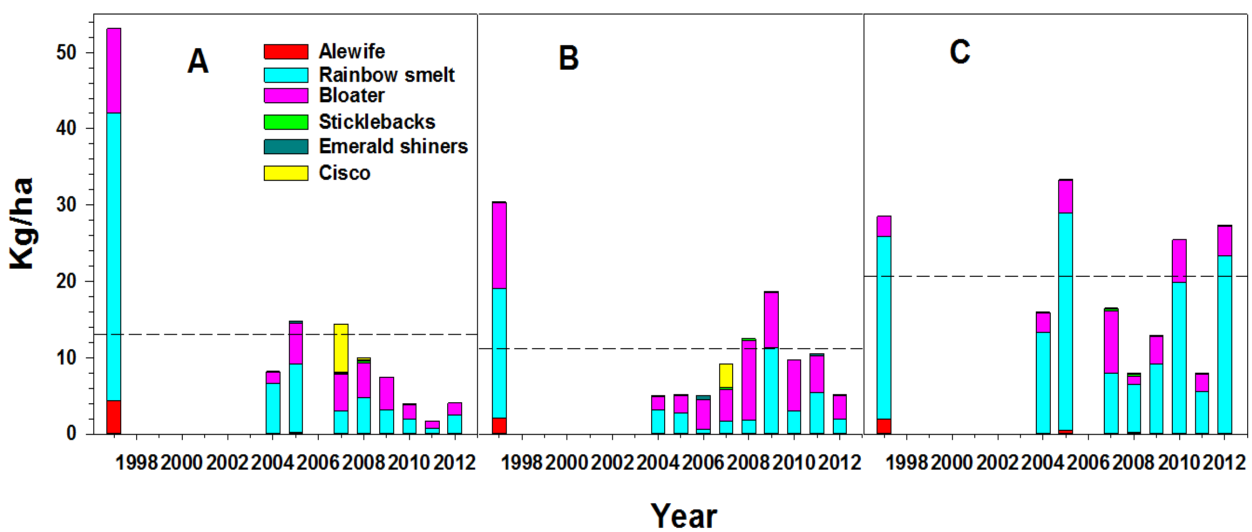

Figure 10. Pelagic fish biomass in the three basins of Lake Huron, 1997-2012. A= Georgian Bay, B=Main Basin, and C = North Channel. Horizontal lines denote 1997-2011 means.

Discussion

Acoustic estimates of pelagic fish biomass in Lake Huron have shown no consistent trend between 2004 and 2012 (Figure 11). However, biomass remains much lower than in 1997. Most of this decrease in biomass is the result of decreased abundance of rainbow smelt and bloater.

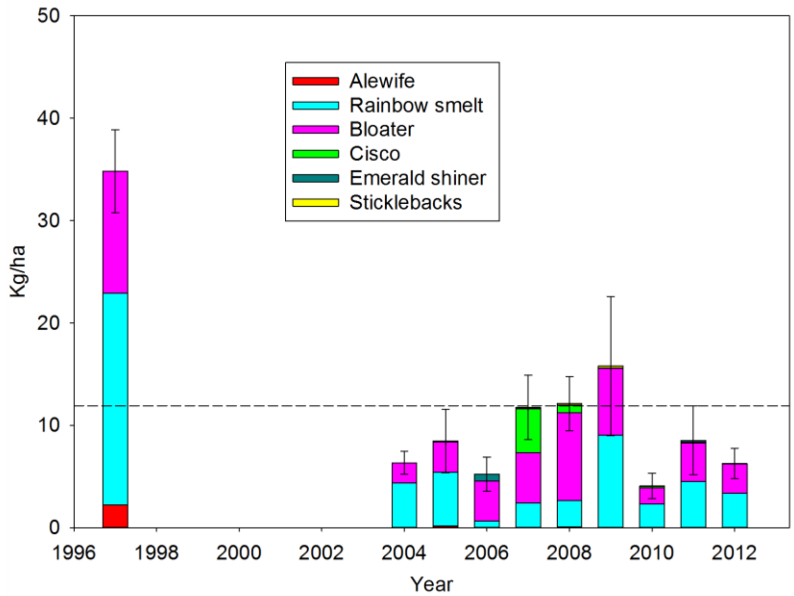

Figure 11. Lakewide mean pelagic fish biomass in Lake Huron, 1997-2012. Error bars are 95% confidence intervals. The horizontal line denotes the 1997-2011 mean.

During 2013, forage availability for piscivores will likely be similar to that seen in other recent years. Alewife remain rare, and there has been no trend in pelagic biomass since 2004. The Lake Huron forage base still remains low compared to previous decades when alewife, rainbow smelt, and bloater were likely more abundant. Lakewide pelagic biomass in Lake Huron in 2012 (6.3 kg/ha) was similar to biomass in Lake Michigan (6.4 kg/ha, Warner et al. 2013) as well as Lake Superior in 2011 (6.8 kg/ha, Yule et al. 2013). There is, however, a key difference between the three lakes. In Lake Michigan, alewife are still prevalent in that they comprise about 77% of the pelagic biomass, while in the other two lakes, the biomass of this species is negligible. Additionally, native coregonines and other species are extremely rare or absent in Lake Michigan. Both Huron and Superior have much greater contribution to density and biomass from native species. In the case of Lake Superior, kiyi (*Coregonus kiyi*) are numerically dominant, while cisco (*Coregonus artedi*) make up most of the biomass (Yule et al. 2013). In Lake Huron, rainbow smelt are numerically dominant, while rainbow smelt and bloater have been alternating roles as the dominant contributor to total biomass. Additionally, there have been relatively consistent (but low) catches of emerald shiner and cisco in Lake Huron midwater trawling. In the case of emerald shiner, it is likely that their reappearance was the result of a release from predation on fry following the collapse of alewife (Madenjian et al. 2008; Schaeffer et al. 2008). The alewife collapse likely had a similar effect on lake trout (*Salvelinus namaycush*), an important native species that appears to have an influence on rainbow smelt abundance through predation (O'Brien 2010). While the results of this survey indicate clearly that cisco have not been restored to Lake Huron given the a) cisco-sized target densities have averaged <10% of densities in Lake Superior and b) midwater trawl catches remain limited to few fish, it is not clear why this species remains at such low densities nor is it clear what a reasonable density for Lake Huron might be.

This survey, as with any other type of fishery survey, includes assumptions about the sampling and data analysis techniques. For example, we assumed that the areas sampled were representative of the lake as a whole. This survey sampled 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 high rates of pelagic fish production (Fielder and Thomas 2006, Höök et al. 2001, Klumb et al. 2003), but could not be sampled safely due to the draft of our research vessel (3 m). However, in order to have the effect of increasing lakewide means appreciably, the densities in these shallow areas would have to have been much higher than observed in the rest of the lake because this shallow part of the lake is small in comparison to the area of the rest of the lake. We used an optimal allocation scheme (Adams et al. 2006) to allocate transect effort, with the number of transects allocated to the different strata determined by weighting the variability in acoustic estimates from recent years by the area of the strata. We also attempted to conduct enough midwater tows to achieve an acceptable degree of confidence in community composition following guidelines in Warner et al. (2012).

An additional assumption was that fish size was a reasonable proxy for fish age. 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 for a species.

Comparison of the acoustic and bottom trawl estimates of bloater biomass revealed a large difference in these estimates for 2012. While this difference may be disconcerting to some, a number of factors must be considered in interpreting this comparison. First, it is important to reiterate that when considering data since 2004, both surveys indicate there is an increasing trend in large bloater biomass and both surveys suggest that this increase was a result of high biomass of small bloater between 2005 and 2009. This is in contrast to Lake Michigan, where large numbers of young produced in 2007-2009 have not resulted in increased abundance of large bloater (Warner et al. 2013). Second, the bottom trawl estimate was driven in large part by relatively few tows with very high catches. Third, a number of factors could have led to differences in the results of the acoustic and bottom trawl surveys. Differences in biomass may arise from differences in survey timing, locations sampled, and sample size. Differences in survey timing may be quite important, as there is significant temporal variability at very small temporal scales in fish density at a given site. For example, two replicate bottom tows at the same site in

Lake Huron <45 minutes apart in July 2012 had bloater catches that varied 63-fold, and two replicate bottom tows in Lake Michigan in September 2010 had bloater catches that varied 135-fold (D.M. Warner, unpublished data). Furthermore, the tow with the highest catch can be the second tow. Given this variation in replicate bottom trawl catches, it is reasonable to expect differences in estimates that are generated from samples taken up to 30 days apart. Finally, as with acoustic sampling, there are many caveats to consider with bottom trawling. For example, Kotwicki et al. (2013) concluded that catchability of semipelagic fish varies temporally, spatially, and with fish density, which could influence the biomass estimates in ways that acoustic data may not.

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Appendix 1. Single target detection parameters used in acoustic data analyses in 2012.

Parameter	Value
TS threshold (dB)	-77
Pulse length determination level (dB)	6
Minimum normalized pulse length	0.7
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, detection limits, and acoustic equipment specifications in Lake Huron, 2012, for the R/V Sturgeon and M/V Spencer Baird.

Vessel	R/V Sturgeon	M/V Spencer Baird
Collection software	Visual Acquisition 6.0	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
Sv noise at 1 m (dB)	-132	-123
TS noise at 1 m (dB)	-158	-150
2 way equivalent beam angle	-19.34	-20.10
Detection limit (m) for -60 dB target[1]	105	75

[1] Assuming 10 dB signal-to-noise ratio.