Lake Huron Committee
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Status of Pelagic Prey Fish in Lake Huron in 1997 and 2004

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ABSTRACT

To provide annual estimates of prey fish biomass in Lake Huron, acoustic surveys were conducted in the fall during the years 1997 and 2004. The survey conducted in 1997 was limited to areas <150 m deep, but in 2004 a more extensive survey was conducted. Midwater trawling during the surveys provided measures of species and size composition of the fish community for use in scaling acoustic data and providing species-specific abundance estimates. Bloaters (*Coregonus hoyi*) were the dominant component of acoustic biomass in both years, but rainbow smelt (*Osmerus mordax*) were numerically dominant in both years. Alewives (*Alosa pseudoharengus*) made up ~5% of biomass in 1997 and less than 0.05% in 2004 Acoustic estimates of total biomass, rainbow smelt biomass, and bloater biomass were significantly higher in 1997 than in 2004. This difference was not the result of limited spatial coverage. Total biomass estimated from the acoustic survey in 2004 was similar to the USGS bottom trawl survey estimate. The decline in biomass between 1997 and 2004 was of similar magnitude for both surveys. The Lake Huron preyfish community continues to be dominated by the native bloater. Density and biomass did not vary significantly among regions in 1997. In 2004, significant regional variation in rainbow smelt and YOY bloater density and biomass was observed; decreased abundance may have contributed to greater patchiness. It is unclear how biomass estimates presented here compare to recent salmonine consumption rates, but it is evident that preferred prey (alewife) is not abundant enough to support predator demand.

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The U.S. Geological Survey Great Lakes Science Center has conducted surveys of forage fish abundance in Lake Huron since the early 1970s. These surveys have primarily been conducted using bottom trawls. However, the Great Lakes Science Center also has a history of using acoustics as a tool in the Great Lakes acoustic surveys (Argyle 1992). On Lake Huron, fishery surveys were conducted in the late 1970s (Argyle 1982), 1997, and 2004. Data were readily available for the survey in 1997 as well as 2004. The focus of this report was the integration of data from acoustic surveys of Lake Huron conducted in 1997 and 2004 for establishment of a time series of biomass estimates.

Monitoring of trends in preyfish biomass can be an important tool in the management of stocked salmonines in the Great Lakes (Madenjian et al. 2005a). The dynamic nature of the Lake Huron food web and the potential for high levels of salmonine predation on YOY and yearling alewives warrant an increased focus on abundance, distribution, and survival of alewives throughout all stages of life. The primary factors affecting alewife recruitment to age three (also recruitment to the bottom trawl) in Lake Michigan have been summer water temperature and predation by salmonines during the spring and summer of the first year of life (Madenjian et al. 2005a). However, other factors may influence survival earlier in life (O'Gorman and Lantry 2004).

Acoustic surveys may provide a more appropriate tool for the study of young fish than other methods. Acoustic surveys in Lake Michigan provided much higher estimates of juvenile preyfish abundance in Lake Michigan during 2001-2004 (Warner et al. 2005) than bottom trawling, suggesting that acoustic surveys are more appropriate for young fish than bottom trawl surveys in Lake Michigan. Similar conclusions were reached by Argyle et al. (1998) and Fabrizio et al. (1997) for Lake Michigan. By extension, the same may be true in Lake Huron.

METHODS

Sampling Design

Acoustic survey design has developed a great deal in the past ten years with a focus on understanding the assumptions and biases of different designs (Rivoirard et al. 2000). Classical variance estimates are biased if sample sites are not randomly selected (Rivoirard et al. 2000), but in practice this randomization can be difficult to achieve. The survey conducted in 1997 was a quasi-random (with transects located near ports) design consisting of 15 transects between the 10-150 m depth contours. Each transect was broken into horizontal segments corresponding to 10-m bottom depth intervals. These intervals were split into 5-m depth layers. The initial design was stratified by bottom contour.

The survey approved by the Lake Huron Technical Committee in summer 2004 and carried out in fall 2004 was a stratified and randomized systematic design with 21 evenly spaced parallel transects in five strata (North Channel, main basin west, main basin east, south main basin, and Georgian Bay, Figure 1) covering depths between 12 and 215 m. This type of design has been recommended for surveys of open seas (Simmonds et al. 1992; Rivoirard et al. 2000).

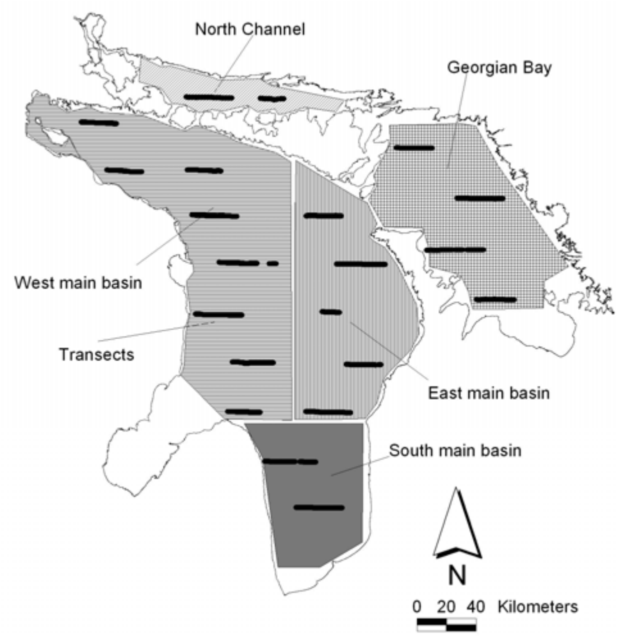

Figure 1. Map of Lake Huron showing strata and transects implemented in the 2004 acoustic survey.

Effort in each stratum was allocated based on the area of the stratum and the availability of ports. Each transect was broken into elementary horizontal sampling units (ESU) that were ~500m long. Each ESU consisted of multiple 10-m deep layers. This segmentation was chosen to achieve a balance between capturing spatial variability in density and size with obtaining enough pings and targets to estimate density. Transects surveyed in 1997 were re-analyzed with the same stratification and analytical methods used in 2004.

Data Collection and Processing

Acoustic sampling was conducted aboard three different vessels including the S/V Steelhead (Michigan Department of Natural Resources) and R/V Grayling (USGS) in 1997 as well as the R/V Sturgeon (USGS) in 2004. Acoustic data were collected with Biosonics dual (1997) and split beam (2004) 120 kHz echosounders. The dual beam transducers (7 x 18° half-power beam widths) were housed in the sea chests of the S/V Steelhead and R/V Grayling, with sound energy transmitted through a rubber-compound window. This window has little effect on beam transmission or receive-sensitivity at the frequency used for this survey (Fleischer et al. 2002). The split beam transducer (6.8° half-power beam width) was deployed on a towfish suspended abeam ship from a crane and towed at a depth of ~ 1 m. The acoustic systems were calibrated during the survey in the field according to methods described in Foote et al. (1987) and MacLennan and Simmonds (1992). The calibration utilized a tungsten carbide sphere with theoretical TS of –40.6 dB. Calibration offsets were applied to echo integration and target strength data during processing. An echo integration threshold of -80 dB was applied during data collection and analyses

Midwater trawling was used to identify species and size composition in fish aggregations observed with echosounders and to provide size composition data. Tow locations and depths were chosen to target observed fish aggregations while sampling. Tow duration varied from 10-40 minutes depending on visual indications of fish density. Most tows were at a specific depth, but three tows in 2004 were stepped oblique. In 1997 two different trawls were used. A trawl with an 8-m headrope, 25 m^2 fishing area, and 6.35 mm cod end mesh was used on the S/V Steelhead. A trawl with a 28-m headrope, 100 m^2 fishing area, and 6.35 mm cod end was used on the R/V Grayling in 1997. In 2004, a trawl with a 15 m headrope, 63 m^2 fishing area and 6.35 mm cod end was used on the R/V

Sturgeon. Trawl depth was monitored using net mensuration systems (Simrad ITI in 1997 and NetMind in 2004). In 1997 fish were counted, weighed in species groups and measured in the field. Total catch weight was recorded as the sum of the species weights. In 2004 fish were frozen (in water) during the survey and measured (nearest mm) and weighed (nearest 0.1 g) in the laboratory. In all years lengths and weights of large catches (>100 fish) were taken from a random subsample. During data analysis, three species were divided into small and large groups corresponding to yearling-or-YOY and older animals. The separation points were between 89 and 90 mm for rainbow smelt, 119 and 120 mm for bloaters, and 109 and 110 mm for alewives. Tows were targeted at fish aggregations observed in echograms. Numbers of tows and transects in each region are shown in Table 1.

Table 1. Number of midwater tows and transects in each region during the acoustic survey 2004.

	Sample type	
Region[1]	Trawl	Acoustic
NC	2	2
MW	10	8
ME	7	5
SB	4	2
GB	8	4

[1]NC= North Channel, MW=west main basin, ME= east main basin, SB= south main basin, GB= Georgian Bay.

Catch and acoustic data were assigned to one of three depth layers (<20 m, 20-40m, and >40 m). The depth classification was loosely based on thermocline depth and patterns in distribution of fish. Trawl data were geographically linked with acoustic transect data; catch composition and sizes from each transect-layer combination were applied to the acoustic data from the same transect and layer where possible. Trawls were assigned to layers based on the mean headrope depth during the tow. In the case of stepped oblique tows, the tow was treated as two separate tows with identical catch composition and mean fishing depth equal to the mean headrope depth of each step. Catch composition, mean length, and mean mass were calculated for each layer of each 500 m transect segment from trawling conducted on that transect. When this was not possible, the stratum mean of trawl data for the respective depth layers was used. If data from a layer were absent from a stratum, the mean of the layer in the remainder of the lake was used.

Estimates of Abundance

Acoustic data analysis methods and software employed for analyses differed in the two years of sampling. Differences that did exist were not expected to influence conclusions drawn from data presented here. Details about software and analyses for 1997 data can be found in Argyle et al. (1998). For data collected in 2004, echo integration and target size analyses were conducted using Echoview 3.25. Acoustic density estimates for each transect were made for two groups of targets: all targets and those that corresponded to fish targets. An estimate of absolute density (including all targets) was made using the formula

(1)

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

where *ABC* = area backscattering coefficient ($m^2 \cdot m^2$) and σ = the mean backscattering cross section (m^2) of all targets between –76 and –20 dB. Single target detection parameters used in 1997 were equivalent to those used by Fleischer et al. (1997). Settings used in 2004 were similar and were equivalent to those used by Warner et al. (2002) to develop size-target strength relations for alewives. The density estimate from equation 1 provided density for all targets, potentially including invertebrates such as *Mysis relicta*, as aggregations of *Mysis* have TS similar to individual young-of-year (YOY) rainbow smelt (Rudstam et al. 2003; D. M. Warner, unpublished data). To maintain consistency with acoustic surveys of Lake Michigan in the 1990s (Argyle et al. 1998), targets <-60 dB were excluded. To accomplish this, density of fish targets was estimated by multiplying absolute density (equation 1) by the proportion of the total number of targets that were between –60 and –20 dB. This threshold should have included targets corresponding to the smallest YOY alewives (2-3 cm) at dorsal aspect based on in situ TS-length relations published by Warner et al. (2002). However, this threshold may have resulted in underestimation of rainbow smelt density given expected target strengths published by Rudstam et al. (2003).

Density (fish/ha) of the different species were estimated as the product of fish density and the proportion by weight in the catch at that location. Proportions by weight were used to reduce the influence of bycatch on catch composition. Bycatch typically occurs when a tow passes through an aggregation of numerically abundant but small fish near the surface during set or retrieval. Total density per species was subdivided into small and large fish density by multiplying total density by the numeric proportions of each species in each size group. Biomass (kg/ha) for the different groups was then estimated as the product of acoustic density and mean mass as determined from trawling. Mean and relative standard error (RSE = (SE/mean) x 100) for density and biomass in the survey area were estimated using stratified cluster analysis methods featured in SAS PROC SURVEYMEANS (SAS Institute Inc. 2004). Cluster sampling techniques are appropriate for acoustic data, which represent a continuous stream of autocorrelated data (Williamson 1982; Connors and Schwager 2002). Density and biomass values for each ESU (corresponding to a 500 m transect segment) in each stratum were weighted by dividing the stratum area (measured using GIS) by the number of ESUs in the stratum. The contribution of each stratum to the overall survey mean was dependent on the area of the stratum. To test for regional differences in abundance, regional means of density and biomass for alewife, rainbow smelt, and bloater were compared using ANOVA. Tukey's pairwise comparison tests were used to identify those regions that varied significantly where significant differences existed. These comparisons were made using transect means as individual sampling units within regions.

RESULTS

Abundance and biomass

Alewife – Alewives exhibited variable occurrence in the trawl catch, with alewives representing a larger component of the catch (by weight) in 1997 (mean=7.6%, RSE= 284%) than in 2004 (mean = 0.05%, RSE=483%).

Alewives (N=2) were the least common species observed in midwater tows in 2004 and were only captured in two tows (both in the North Channel), which was evidence of extreme patchiness and contributed to extremely high RSE and extreme uncertainty in the lakewide estimate (not different from zero). This patchiness occurred to some degree in both years, however. Mean total alewife density in 1997 was 580 fish/ha (RSE =19.5%), while in 2004 alewife density was extremely low at 0.26 fish/ha (RSE = 58.0%, Figure 2). Mean relative biomass of alewives in 1997 was 7.4 kg/ha (RSE=21.4%) and in 2004 mean biomass was 0.002 kg/ha (RSE = 89.0%, Figure 3).

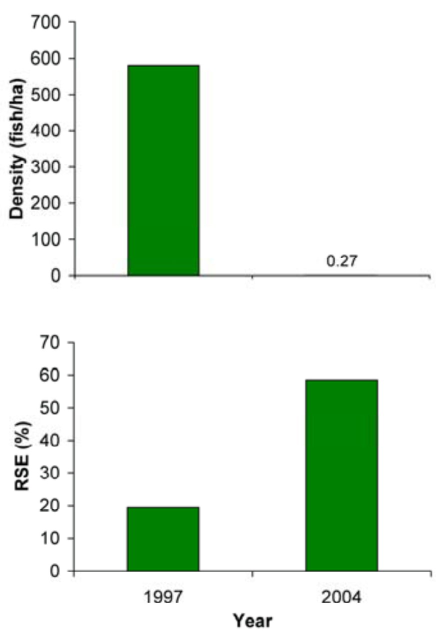

Figure 2. Mean total alewife density in Lake Huron in 1997 and 2004 (upper panel) with relative standard error of the estimates (lower panel).

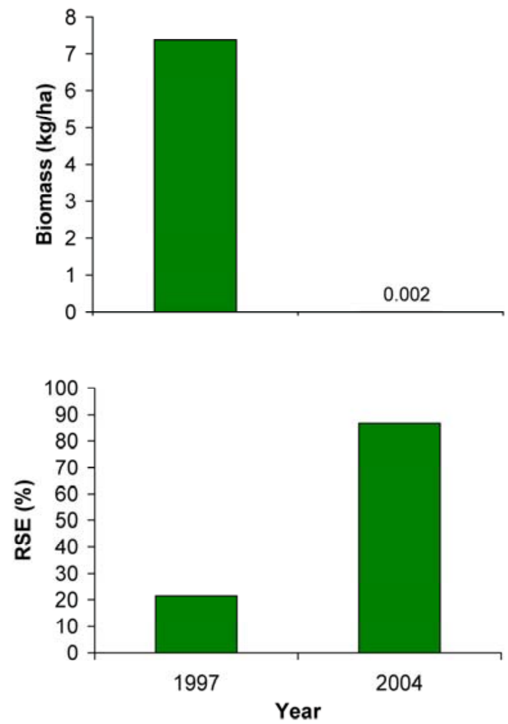

Figure 3. Acoustic estimates of alewife biomass in Lake Huron in 1997 and 2004 (upper panel) and relative standard error of the estimates (lower panel).

<u>Rainbow smelt</u> – Rainbow smelt were the most common and widely distributed fish observed in the midwater tows, occurring in all but three of the 64 tows made during the 1997 and 2004 surveys combined. All of the tows from which rainbow smelt were absent were at fishing depths >50 m. In 1997 rainbow smelt made up 64.0% (RSE = 63.0%) of the catch by weight, whereas in 2004 this species made up 76.0% (RSE=49.4%) of the catch. The length distributions of rainbow smelt differed somewhat between years, with larger fish representing more of the catch in 1997 than in 2004 (Figure 4). Mean density of rainbow smelt in 1997 was 2,806 fish/ha (RSE=13.9%), with 44% (1,245 fish/ha) of the density occurring

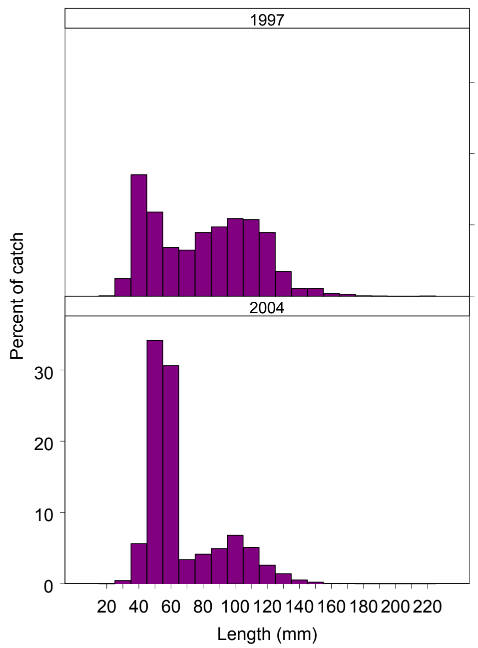

Figure 4. Length-frequency distribution of rainbow smelt caught in midwater trawls during acoustic surveys of Lake Huron in 1997 and 2004.

as small smelt (<90 mm). In 2004, mean density of rainbow smelt was 680 fish/ha (RSE=11.7%, Figure 5), ~24% of that observed in 1997. In 2004, fish <90 mm made up approximately 60% of the rainbow smelt density. Rainbow smelt biomass showed similar differences. In 1997, mean biomass of rainbow smelt was 13.2 kg/ha (RSE=13.7%). In 2004 mean biomass was 2.1 kg/ha (RSE=12.4%, Figure 6), just 16% of the biomass observed in 1997.

Bloater – Bloaters were the second most common species in the trawl catch and made up a similar proportion of the catch in both years. In 1997, bloaters were 27% of the catch (RSE=144%), while in 2004 they also made up 27% of the catch (RSE=141%).

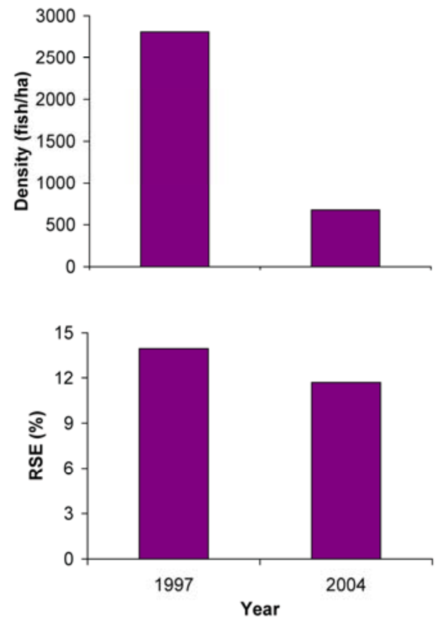

Figure 5. Acoustic estimates of density of rainbow smelt in Lake Huron in 1997 and 2004 (upper panel) and relative standard error of the estimates (lower panel).

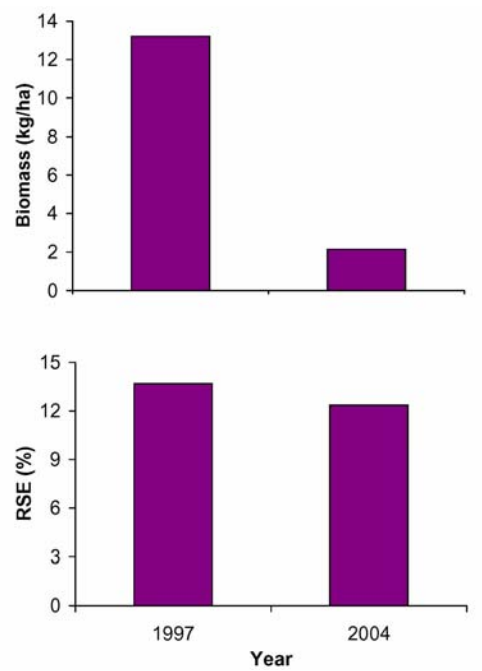

Figure 6. Acoustic estimates of biomass of rainbow smelt in Lake Huron in 1997 and 2004 (upper panel) and relative standard error of the estimates (lower panel).

Although the proportion of bloaters in the catch was similar in both years, bloater density and biomass were not. In 1997 mean bloater density was 1,485 fish/ha (RSE=13.4%), while in 2004 it was 175 fish/ha (RSE=21.0%, Figure 7). In 1997, the majority (99%) of bloater density was made up of fish >120 mm, while in 2004 only 80% of bloater density was attributed to fish >120mm. These differences were apparent in the length-frequency distributions (Figure 8). Bloater biomass was higher in 1997 (130 kg/ha, RSE =15.0%) than in 2004 (5.2 kg/ha, RSE=60.9%, Figure 9).

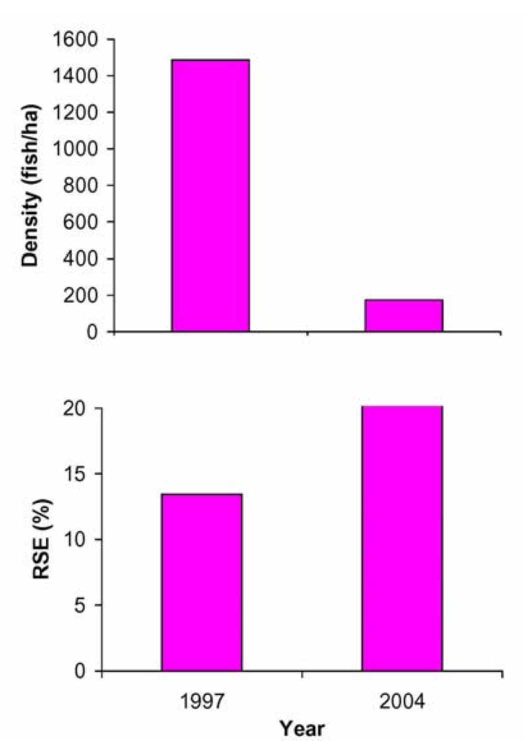

Figure 7. Acoustic estimates of density of bloater in Lake Huron in 1997 and 2004 (upper panel) and relative standard error of the estimates (lower panel).

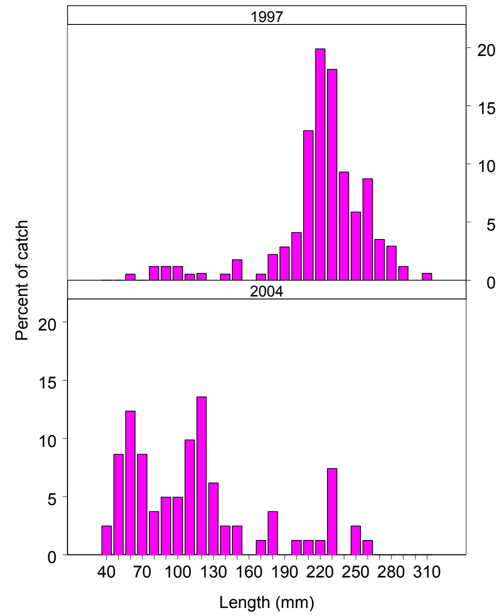

Figure 8. Length-frequency distribution of bloaters caught in midwater trawls during acoustic surveys of Lake Huron in 1997 and 2004.

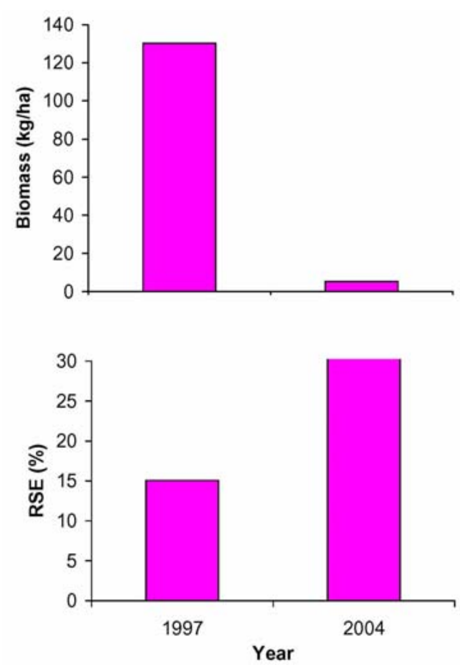

Figure 9. Acoustic estimates of biomass of bloater in Lake Huron in 1997 and 2004 (upper panel) and relative standard error of the estimates (lower panel).

Distribution

Mapping of fish density and biomass indicated that estimates of abundance varied widely among regions (Figure 10). However, ANOVA analyses revealed that alewife, rainbow smelt, bloater, and total density and biomass did not vary significantly among regions in 1997 (P>0.05) even though higher values were observed in North Channel and Georgian Bay. In 2004, density and biomass of rainbow smelt and YOY bloater did vary significantly among regions. For rainbow smelt, density in North Channel was significantly higher than in any other region (P<0.05, Figure 10), and density in Georgian Bay was significantly higher than any region except North Channel (P<0.05). Comparisons of rainbow smelt biomass revealed that biomass in North Channel was significantly higher than in any other region (P<0.05) and biomass in Georgian Bay was significantly higher than in the east main basin (P<0.05) (Figure 11). Density of YOY bloater in North Channel and the south main basin was significantly higher than in the main east and west basins (P<0.05). Biomass of YOY bloater was significantly higher in the south main basin than in any other region (P<0.05).

CONCLUSIONS

Although data presented here only represent two years of acoustic surveys, there are some patterns that are evident and conclusions that can be drawn when the data are examined relative to other surveys (e.g bottom trawl). The most striking observation was the 92% decrease in total preyfish biomass from 151 kg/ha in 1997 to 7.4 kg/ha in 2004. This decrease in biomass was accompanied by changes in community

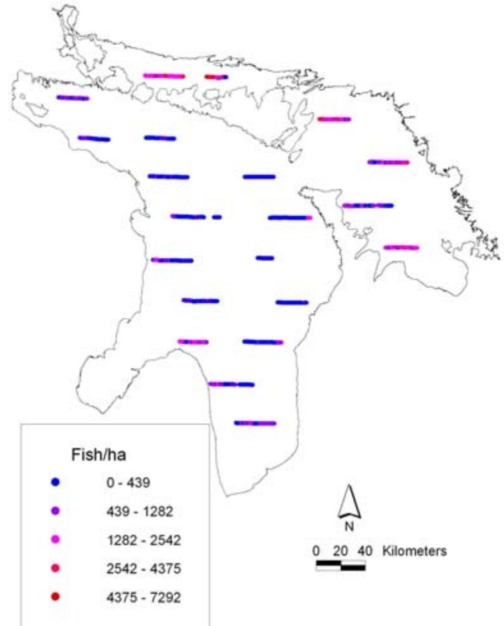

Figure 10. Map of Lake Huron showing along-transect densities of rainbow smelt observed during the 2004 acoustic survey.

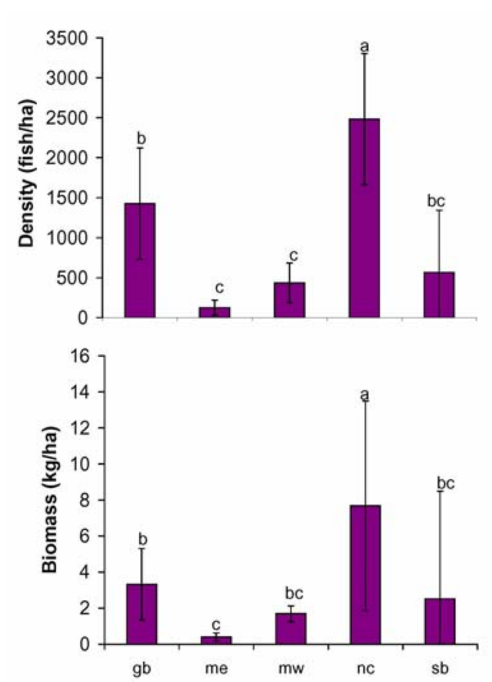

Figure 11. Mean (±95% CL) density and biomass of rainbow smelt in different regions of Lake Huron in 2004. Bars that share the same letter are not significantly different.

composition. Bloaters made up a similar proportion of total biomass in 1997 (86%) and 2004 (71%), but there was nearly a 100% decrease in the percentage of biomass made up of alewives and a 330% increase in the percentage made up by rainbow smelt. Similar changes were also observed in the USGS bottom trawl survey (Schaeffer et al. 2005), but the decrease in total biomass from 1997 to 2004 was ~78% as measured by bottom trawling.

Comparison of Lake Huron survey results with data from Lake Michigan revealed both similarities and differences. Prey biomass has also decreased in Lake Michigan in the same time period (Madenjian et al. 2005b; Warner et al 2005). Bottom trawl estimates of total relative biomass in Lake Huron exhibited a decline of ~62% from 2001-2004 (Schaeffer et al. 2005), which was similar in magnitude to the 67% decrease observed by Warner et al. (2005) in Lake Michigan acoustic data for the same years. Combined biomass of adult alewives, rainbow smelt, and bloaters from the USGS Lake Huron bottom trawl survey in 2004 (11.0 kg/ha) was similar to that observed in the 2004 acoustic survey (95% CI = 1.4-12.0 kg/ha). Key differences in these surveys are that the bottom trawl estimate is for trawlable areas, excludes Georgian Bay and North Channel, and excludes areas with depths greater than 110 m. The acoustic survey conducted in 2004 was assumed to be representative of an area of ~ 46,770 km^2 or ~85% of the lake surface area exclusive of Saginaw Bay, Thunder Bay, a portion of the shallow (<13 m) south main basin, and shallow areas (<17 m) of Georgian Bay and North Channel.

The acoustic surveys in Lakes Huron and Michigan in 2004 represented the most extensive coverage of these lakes in a given year. Given the similarities in the surveys, comparisons of relative biomass are possible. Total relative biomass in Lake Huron (7.4 kg/ha) was similar to that in Lake Michigan (6.7 kg/ha) in 2004. The relative biomass of alewives in Lake Huron (0.002 kg/ha) was lower than in Lake Michigan (5.1 kg/ha), but the fact that only two alewives were caught in Lake Huron contributed to very high uncertainty in the estimate. Rainbow smelt biomass in Lake Huron (2.14 kg/ha) was 3.7x that in Lake Michigan (0.58 kg/ha). Bloater biomass in Lake Huron (5.2 kg/ha) was 5.4x that in Lake Michigan (0.97 kg/ha). Although the two lakes have similar total preyfish biomass, the Lake Huron community remains different and is dominated by bloater, a native species. It is unclear how 2004 estimates of biomass presented here compare to salmonine consumption rates, but the biomass of preferred prey of salmonines (alewife) was almost certainly too low to support maintenance of the present predator biomass in Lake Huron. Whether or not salmonines will switch to other prey like bloater remains to be seen.

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