Lake Michigan Committee
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Status of Pelagic Prey Fishes and Pelagic Macroinvertebrates in Lake Michigan, 2008

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ABSTRACT

Acoustic surveys were conducted in late summer/early fall during the years 1992-1996 and 2001-2008 to estimate pelagic prey fish biomass in Lake Michigan. Midwater trawling during the surveys provided a measure of species and size composition of the fish community for use in scaling acoustic data and providing species-specific abundance estimates. In 2005, we began sampling *Mysis diluviana* during the survey. The 2008 survey provided data from 24 acoustic transects (734 km), 33 midwater tows, and 39 mysid tows. Mean total prey fish biomass was 15.3 kg/ha (relative standard error, RSE = 7.6%) or ~82 kilotonnes (kt, 1,000 metric tons), which was 1.9 times higher than the estimate for 2007 but 78% lower than the long-term mean. The increase from 2007 was because of increased biomass of age-1 and age-3 alewife. The 2008 alewife year-class contributed ~12% of total alewife biomass (11.0 kg/ha, RSE = 9.0%), while the 2007 and 2005 alewife year-classes contributed ~33% and 35%, respectively. In 2008, alewife comprised 72% of total biomass, while rainbow smelt and bloater were 11 and 17% of total biomass, respectively. Rainbow smelt biomass in 2008 (1.6 kg/ha, RSE = 10.6%) was identical to the biomass in 2007 (1.6 kg/ha). Bloater biomass was again much lower (2.6 kg/ha, RSE = 15.2%) than in the 1990s, but mean density of small bloater in 2008 (534 fish/ha, RSE = 10.9) was the highest observed in any acoustic survey on record. Prey fish biomass remained well below the Fish Community Objectives target of 500-800 kt and only alewife and small bloater are above or near long-term mean biomass levels. *Mysis diluviana* remains relatively abundant. Mean density ranged from 185 ind./m^2 (RSE = 6.8%) in 2005 to 112 ind./m^2 (RSE = 5.1%) in 2007, but there was not a statistically significant difference among years.

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In light of changes in the Lake Michigan food web during the last 40 years (Madenjian et al. 2002) and the continuing anthropomorphic influences through introduction of exotic species, pollution, fishing, and fish stocking, regular evaluation of long-term data on prey fish dynamics is critical. The traditional Great Lakes Science Center (GLSC) prey fish monitoring method (bottom trawl) is inadequate for fish located off bottom (Fabrizio et al. 1997). In particular, bottom trawls do not adequately sample young-of-the-year alewives (*Alosa pseudoharengus*), rainbow smelt (*Osmerus mordax*), or bloater (*Coregonus hoyi*). Alewives are the primary prey of introduced salmonines in the Great Lakes (Stewart and Ibarra 1991; Elliot 1993; Rybicki and Clapp 1996; Warner et al. 2008), and, as such, constitute an important food web component. Alewife dynamics typically reflect occurrences of strong year-classes and total alewife density is highly correlated with the density of alewife ≤ age 2 (Warner et al. 2008). Much of the alewife biomass will not be recruited to bottom trawls until age–3, but significant predation by salmonines may occur on alewives ≤ age 2 (Warner et al. 2008). Because of the ability of acoustic equipment to count organisms far off bottom, this type of sampling is ideal for highly pelagic fish like age 0 alewives, rainbow smelt, and bloater and is a valuable complement to bottom trawl sampling.

METHODS

Sampling Design

The initial Lake Michigan survey adopted by the Lake Michigan Committee (Fleischer et al. 2001) was a stratified quasi-random design with three strata (north, south-central, and west) and unequal effort allocated among strata. The location of strata and number of transects within each stratum was determined from a study of geographic distribution of species and the variability of fish abundance within the strata (Argyle et al. 1998). A modified stratification (Figure 1) was developed in 2004 (Warner et al. 2005), which included two additional strata (north and south offshore). The initial three strata were retained, but their size was modified based on data collected in 2003 as well as NOAA CoastWatch Great Lakes node maps of sea surface temperature from 2001-2003. In 2007-2008, the number of transects in each stratum was optimized based on stratum area and standard deviation of total biomass using methods in Adams et al. (2006).

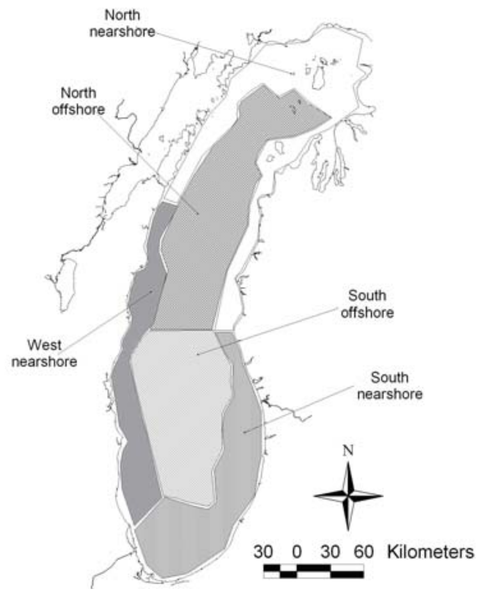

Figure 1. Map of Lake Michigan showing strata used in design and analysis of the lakewide acoustic survey conducted in 2008.

Fish Data Collection and Processing

The lakewide acoustic survey has been conducted as a cooperative effort in most years. Sampling has been conducted between August and November, with acoustic data collection initiated ~1 hour after sunset and ending ~1 hour before sunrise. Several different vessels have been used (10-32 m in length) at speeds ranging from 5-11 km/hour. Different echosounders have been used through the years (Biosonics 102 dual beam, DE5000 dual beam, DT split beam, and DT-X split beam) However, acoustic data have always been collected using echosounders with a nominal frequency of 120 kilohertz. With the exception of one unit used in 2001, echosounders have been calibrated during the survey using methods described in Foote et al. (1987) and MacLennan and Simmonds (1992). Transducer deployment techniques have included a towfish, sea chests (Fleischer et al. 2002), hull mounting, and sonar tubes. Different deployment methods cause variation in the depth of the transducer, and sea chest, hull mount, and sonar tube methods result in a larger portion of the upper water column remaining unsampled because the transducer is deeper.

Midwater trawls were employed to identify species in fish aggregations observed with echosounders and to provide size composition data. Tows targeted aggregations of fish observed in echograms while sampling, and typically trawling locations were chosen when there was uncertainty about the composition of fish aggregations observed acoustically. A trawl with a 5 m headrope and 6.35 mm bar mesh cod end was fished from the S/V Steelhead in all years, while on the USGS vessel R/V Grayling, a variety of trawls were used (Argyle et al. 1998). On the USGS vessels R/V Siscowet, R/V Kiyi and R/V Sturgeon (2001 to present), a trawl with ~15 m headrope and 6.35 mm bar mesh cod end was used. In the 1990s, trawl depth was monitored using net sensors. Similar sensors were used in 2001-2005 (except 2002 on USGS vessel, 2001-2004 on MDNR vessel). In cases without trawl sensors, warp length and angle were used to estimate fishing depth.

Fish were measured as total length (TL, mm) either in the field or frozen in water and measured upon return to the laboratory. Lengths of large catches (> 100 fish) were taken from a random subsample. Fish were weighed in groups (total catch weight per species, nearest 2 g) in the field or individually in the laboratory (nearest 0.1 g). Total catch weight was recorded as the sum of weights of individual species. Rainbow smelt were assigned to two size categories (< 90 mm, ≥ 90 mm), while the size cutoff for bloater was < or ≥ 120 mm (Madenjian et al. 2008). Alewives were assigned to age classes using an age-length key based on sagittal otolith age estimates. Age-length keys were available for each year except 1992. The key for 1992 was constructed by averaging the 1991 and 1993 keys. Otoliths were aged by the same reader in all years except 1991.

Estimates of Fish Abundance

Transect data were subdivided into elementary distance sampling units (EDSU) consisting either of horizontal intervals between adjacent 10 m bottom contours that were 5 or 10 m deep (1990s) or of 1,000 m intervals that consisted of 10 m layers (2000s). Data collected at bottom depths > 100 m were defined as offshore strata. Data from the 1990s were analyzed using custom software (Argyle et al. 1998). Data collected from 2001-2007 were analyzed with Echoview 4.5 software.

An estimate of total fish density for data from 2001-2008 was made using the formula

$$(1)\ Total\ \ density\ \ (fish\ /\ ha) = 10^{4} \times \frac{ABC}{\sigma}$$

where 10^4 = conversion factor ($m^2 \cdot ha^{-1}$), *ABC* = area backscattering coefficient ($m^2 \cdot m^2$) and σ = the mean backscattering cross section (m^2) of all targets between -60 and -30 dB. Based on a target strength (TS) – length relationship for alewives (Warner et al. 2002), the applied lower threshold should have allowed detection of our smallest targets of interest (~20 – 30 mm age-0 alewife). This threshold may have resulted in underestimation of rainbow smelt density given expected target strengths (Rudstam et al. 2003).

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 (0-10, 10-20 m, etc., depending on headrope depth or 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 geographic stratum. If acoustic data still had no matching trawl data, we used a lakewide mean for each depth layer-bottom depth combination. For any cells still lacking trawl composition data, we assigned them lakewide means for each depth layer. Mean mass of species/size groups at depths < 40 m were estimated using weight-length equations from midwater trawl data. In 2001, trawl data were only available for the north nearshore and north offshore strata. To provide an estimate of species composition and size for other strata, the mean of catch proportions and sizes from 2002-2003 were used. 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, which was predicted using the TS-length equation of Rudstam et al. (2003). As recommended by the Great Lakes Acoustic SOP (Parker-Stetter et al. 2009 ; Rudstam et al. 2009), The N_v index of Sawada et al. (1993) was used 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 that mean TS in cells at or above 0.1 was 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.

Densities (fish/ha) of the different species were estimated as the product of total fish density and the proportion by number in the catch at that location. Total alewife, smelt, and bloater density was subdivided into size or age class-specific density by multiplying total density for these species by the numeric proportions in each age group. Biomass (kg/ha) for the different groups was then estimated as the product of density and species or age-specific mean mass as determined from fish lengths in trawls (except as described for depths ≥ 40 m).

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 the statistical routine 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 in each stratum were weighted by dividing the stratum area (measured using GIS) by the number of ESUs in the stratum.

A map of interpolated biomass (kg/ha) was created for all fish species age or size groups to present spatial patterns present during the survey in 2008. Biomass data were interpolated using second-power inverse distance weighting with a fixed search radius of 80,000 m and a minimum of 5 points included for each predicted 1,000 x 1,000 m cell.

Mysid Data Collection and Processing

In order to collect *Mysis diluviana*, vertical tows (1-3 m above bottom to the surface) were made at many (but not all) midwater trawl locations in 2005-2008 (Figure 2). In some cases, replicate tows were made. The nets used were conical and had a 1-m^2 opening area, net mesh of 1 mm, and cod end mesh of 0.252 mm. Tows were made no earlier than one hour after sunset and no later than one hour before sunrise. Vessel lights were extinguished at least 15 minutes prior to the tows, and the net was retrieved at a speed of ~0.5 m/s. Upon net retrieval, specimens were narcotized with an antacid solution and preserved in 100% ethanol. All specimens in each sample were enumerated in the laboratory.

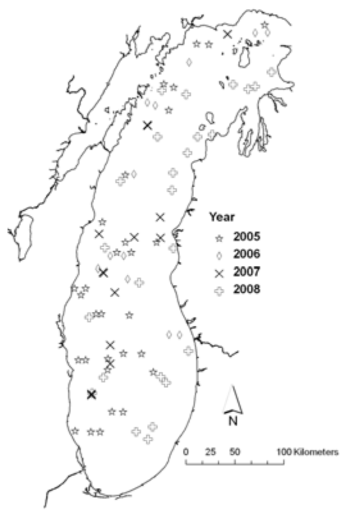

Figure 2. Locations of *Mysis diluviana* tows in 2005-2008.

Estimates of Mysid Abundance

Areal density (#/m^2) was estimated as the number of mysids in each tow assuming a net efficiency of 100%. In cases where replicate tows were made, the numbers per replicate were averaged. Because most of the variation in Lake Michigan mysid density can be explained by bottom depth (Warner et al. in review), it was necessary to account for the influence of bottom depth in estimates of lakewide abundance. To this end, lakewide abundance was estimated using a stratified estimator with bottom depth intervals (0-9, 10-19, 20-29 m, etc.) as strata. The area of these depth intervals was estimated using GIS software (excluding Green Bay and Grand Traverse Bay), and sample densities were assigned a weight estimated as the quotient of the number of samples in the individual strata and the area of the strata. To create a map of densities, mysid densities were interpolated using second-power inverse-distance weighting with a fixed search radius of 80,000 m and a minimum of five points were included for prediction at each location.

RESULTS

Alewife – Density of alewife in 2008 (1,638 fish/ha, RSE=10.5%) was 15% lower than the long-term (1992-2007) mean (± 95% confidence interval) of 1,929 ± 1,146 fish/ha. Age 0 density (1,031 fish/ha, RSE=13.9%, Figure 3), was 27% lower than the long-term mean (± 95% confidence interval) of 1,405 ± 883 fish/ha. Alewife biomass (11.0 kg/ha, RSE=9.0%) in 2008 was 33% lower than the long-term mean of 16.3 ± 12.3 kg/ha. Age 0 alewife made up 63% of alewife density in 2008, but made up only 12% of alewife biomass. Age 1 and older alewife (YAO) biomass was relatively constant from 2001-2007 (Figure 4) but tripled from 2007 to 2008. In 2008 the YAO group consisted of fish from the 2001 and 2002-2007 year-classes. The 2006 year-class was the second smallest observed at age-0 in 12 years of acoustic surveys, which explains the minor contribution (16.5%) it made to total alewife biomass in 2008. The 2005 year-class contributed 34.6% of YAO alewife biomass, while the 2007 year-class made up 32.7 %. The 2001-2004 year-classes contributed a total of 4.0% (Figure 5). The 2005 alewife year-class was the second largest since 1995 and made up the largest portion of

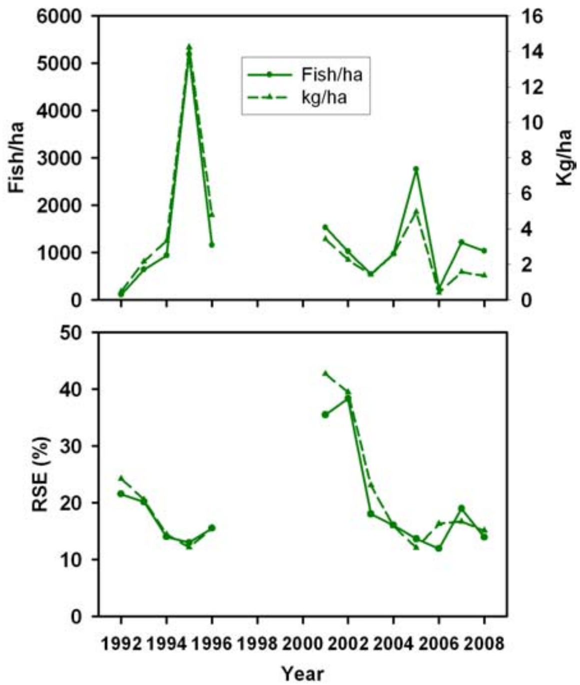

Figure 3. Acoustic estimates of age 0 alewife density and biomass in Lake Michigan,1992-2008 (upper panel) shown with relative standard error of the estimates (RSE, lower panel).

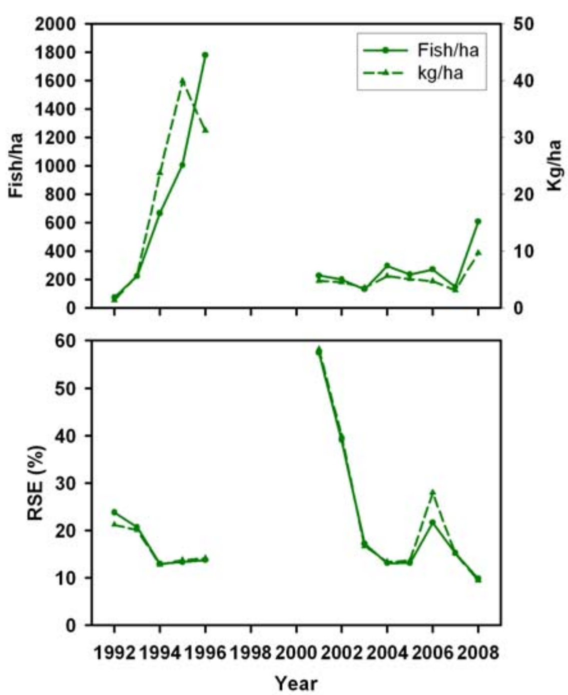

Figure 4. Acoustic estimate of yearling-and-older alewife density in Lake Michigan, 1992-2008 (upper panel) shown with relative standard error of the estimates (RSE, lower panel).

alewife biomass in 2008, supporting a previous report (Warner et al. 2006) that it was a strong year-class. Mean age of YAO alewife has declined from 4.3 years in 2003 to 1.7 years in 2008. Age-0 and YAO alewife exhibited somewhat different spatial distributions (Figure 6). The area from Whitefish Bay on the Door Peninsula northward had age-0 alewife biomass lower than the lakewide mean (1.3 kg/ha), as did the eastern half of the lake from Whitefish Bay southward to Little Sable Point. Most of the west-central and southern portion of the lake (south of

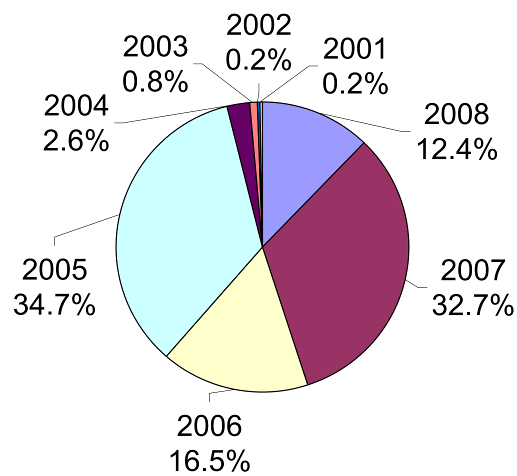

Figure 5. Percent contribution of alewife year-classes to alewife biomass during 2008. Labels show year class and percent of alewife biomass.

Muskegon) had biomass higher than the lakewide average, with the exception of areas between Muskegon and South Haven, MI as well as between Racine, WI and Chicago, IL. Four high-biomass patches that were over two times the lakewide average were observed, but these patches were relatively small (~625 km^2). Biomass of YAO alewife was below the lakewide average (9.4 kg/ha) throughout most of the central area of the lake as well as the eastern half of the northern two thirds. The area south of South Haven, MI had biomass higher than the lakewide mean, as did an area along the western shore to midlake from Sheboygan, WI to

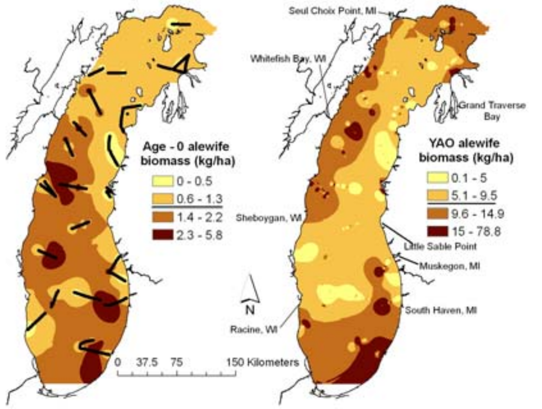

Figure 6. Map of 2008 Lake Michigan acoustic transects and interpolated alewife biomass estimated using acoustic data for age-0 (left panel) and YAO (right panel) alewife. Symbols in the left panel represent acoustic transects. The horizontal line in the legend separates categories that are below and above the lakewide mean biomass.

Manistique, MI. Another area of higher-than-average biomass was observed in the northern lake from Seul Choix Point to the mouth of Grand Traverse Bay. Acoustic and bottom trawl survey results differed substantially for alewife biomass in 2008; Bunnell et al. (2009a) reported a 30% decrease in alewife biomass, while acoustic survey results indicate there was an increase of more than 135%. Differences between the surveys likely arose for two reasons. First, much of the increase observed in the acoustic survey was the result of growth of the 2007 year-class, which is not recruited to the bottom trawl. Second, the two surveys sample different areas and depth ranges, which can contribute to differences in biomass estimates stemming from patchiness of fish.

<u>Rainbow smelt</u> – Acoustic density and biomass estimates increased steadily from 2002-2006 (Figure 7), as did commercial catch per unit effort (Scott Nelson, GLSC, 1451 Green Road, Ann Arbor MI 48105,

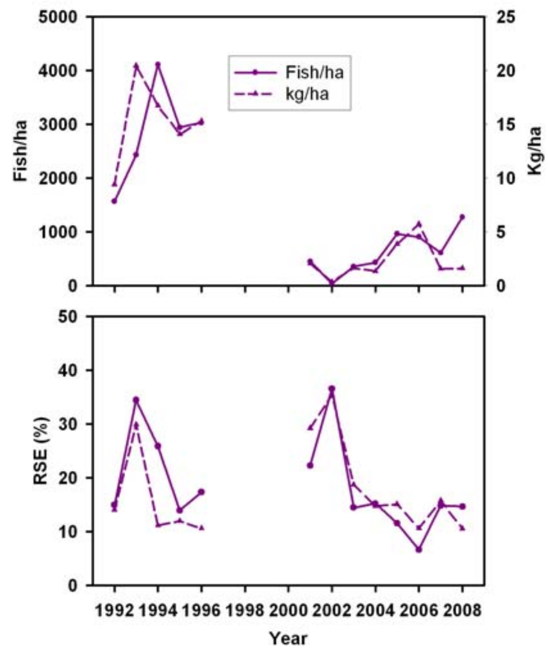

Figure 7. Acoustic estimates of rainbow smelt density and biomass in Lake Michigan in fall 1992-2008 (upper panel) shown with relative standard error of the estimates (RSE, lower panel).

unpublished data). Rainbow smelt density in 2008 (1,275 fish/ha, RSE=14.7%) was ~2 times higher than in 2007, but biomass of rainbow smelt (1.6 kg/ha, RSE=11.1%) was similar to 2007 and was 10.5% of total prey biomass. Rainbow smelt > 90 mm in length constitute roughly 31% of the population and 77% of rainbow smelt biomass. Acoustic survey results were consistent with bottom trawl results for 2008, as both surveys indicated there was an increase in rainbow smelt density but no change in biomass. The biomass of small and large rainbow smelt were distributed throughout the lake differently (Figure 8). Small rainbow smelt biomass was below the lakewide mean (0.36 kg/ha) in the northern half of the lake as well as much of the south-central portion between Evanston, IL to just north of Two Rivers, WI on the west shore and between South Haven, MI and Holland, MI on the east shore. Two large areas of higher-than average biomass were present. One was in the central portion of the lake spanning nearly the full extent of the Door Peninsula on the west shore and between Holland, MI and Manistee, MI on the east shore. The biomass of large rainbow smelt was below the lakewide mean (1.2 kg/ha) in the central portion of the lake as well as the eastern half from Little Sable Point, MI to Beaver Island. Biomass was higher than the lakewide mean elsewhere.

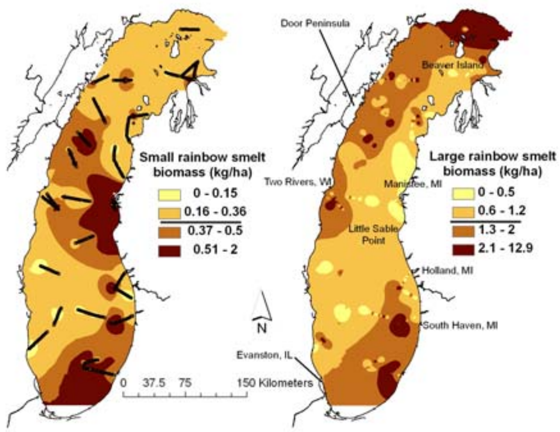

Figure 8. Map of interpolated rainbow smelt biomass estimated using acoustic data from Lake Michigan, August/September 2008. Symbols in the left panel represent acoustic transects. The horizontal line in the legend separates categories that are below and above the lakewide mean biomass.

<u>Bloater</u> – Bloater continue to be present at low densities relative to the 1990s. However, mean density in 2008 (607 fish/ha, RSE = 9.9%) was the highest since 1996. The mean density of small bloater (<120 mm) was 534 fish/ha (RSE = 10.9%, Figure 9), the highest recorded in 13 years of acoustic sampling. In 2008, the mean density of large bloater was 74 fish/ha (RSE=15.4%). Mean biomass of large bloater in 2008 was 2.0 kg/ha (RSE=21.1%, Figure 10), which was similar to the 2001-2007 mean (1.7 kg/ha). It is not clear what led to the drastic decline in bloater abundance from the 1980s to present. Madenjian et al. (2002) proposed that bloater recruitment and abundance are regulated by internal cycling, and Bunnell et al. (2006) found that during periods of low abundance and recruitment, the sex ratio of bloater is predominantly female, while during periods of high abundance and recruitment sex ratio is more balanced. The sex ratio was more balanced in 2008 than in earlier years (J.D. Holuszko, unpublished data). It is possible that predation influences bloater abundance because juvenile bloater can at times be important in the diets of some predators (Elliot 1993; Rybicki and Clapp 1996; Warner et al. 2008). For example, Chinook salmon (*Oncorhynchus tshawytscha*) can consume bloaters and their abundance was probably well below the 1976-2004 average during 1992-1995 and

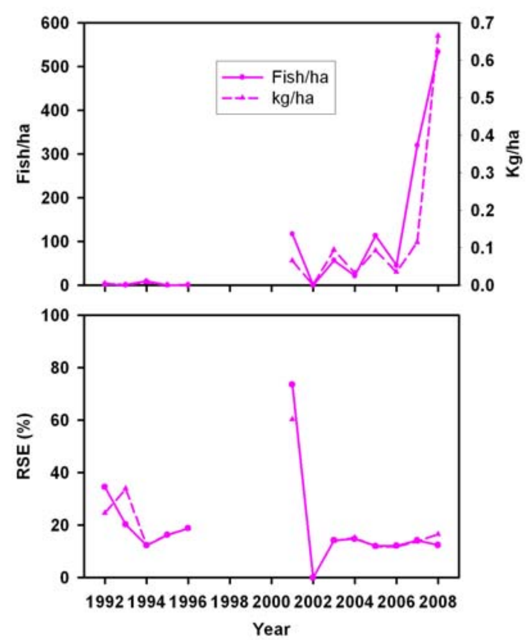

Figure 9. Acoustic estimates of small bloater density and biomass in Lake Michigan in fall 1992-2008 (upper panel) shown with relative standard error of the estimates (RSE, lower panel).

well above average in recent years (2000-2004). However, there is little evidence of consistent, substantial bloater consumption by Chinook salmon in data available for the period from 2001-2004 (Warner et al. 2008; R.M. Claramunt unpublished data). Seasonal predator diet data from a large portion of the lake might improve our understanding of the importance of bloater as prey. Bunnell et al. (2009a) reported from the bottom trawl survey that there was a 57% decrease in large bloater biomass from 2007 to 2008, while acoustic and midwater trawl data suggest there was no change relative to 2007. Two factors may have contributed to this difference. First, spatial distribution of bloater biomass

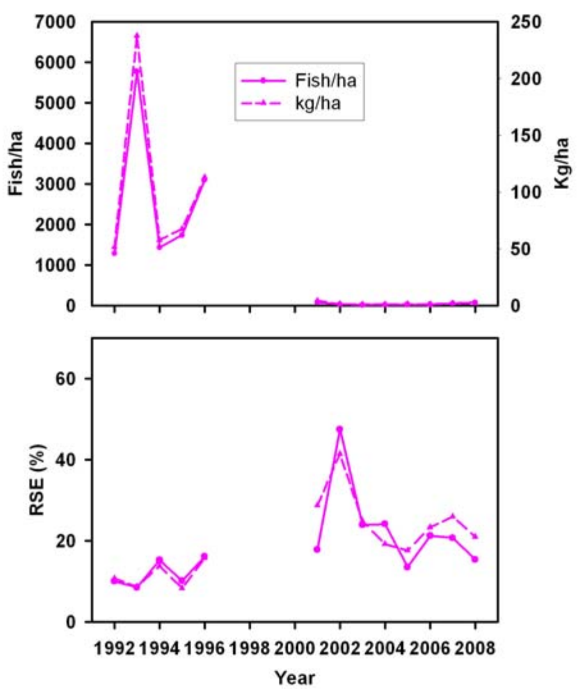

Figure 10. Acoustic estimates of large bloater density and biomass in Lake Michigan in fall 1992-2008 (upper panel) shown with relative standard error of the estimates (RSE, lower panel).

may have been such that many higher-biomass areas were only sampled acoustically (Figure 11). Spatial patterns for biomass of small and large bloater differed. The highest biomass of small bloater was in western and southern parts of the lake, while the highest biomass of large bloater was in the southern portion of the lake south of Milwaukee, WI, off the Holland and Grand Haven, MI areas, and in the northern portion of the lake in a band between Point Betsie and Washington Island. Second, it is not clear when bloater become demersal and are fully recruited to the bottom trawl. Wells and Beeton (1963) suggested that the switch from pelagic to demersal occurred at age-3, while Crowder and Crawford (1984) suggested the switch occurred by age-1 in 1979-1980. Scale age estimates for bottom trawl-caught fish in 2007 indicate that many large bloaters are ≤ age-2 (J.D. Holuszko, unpublished data) which suggests many bloaters may not be recruited to the bottom trawl.

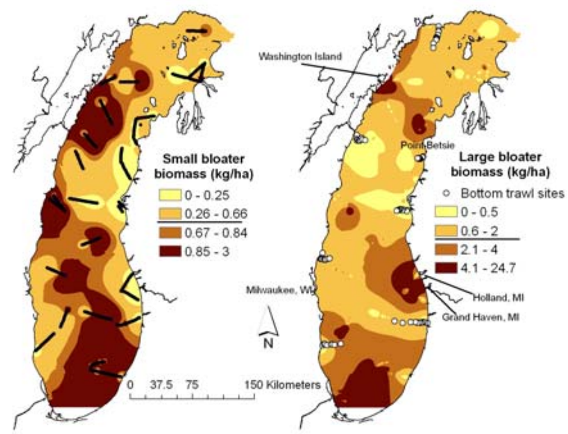

Figure 11. Map of interpolated bloater biomass estimated using acoustic data from Lake Michigan, August/September 2008. Symbols in the left panel represent acoustic transects. Symbols in the right-hand panel represent locations from bottom trawl survey. The horizontal line in the legend separates categories that are below and above the lakewide mean biomass.

<u>*Mysis diluviana*</u> –Estimates of *Mysis diluviana* density were available from 30, 12, 16, and 27 sites in 2005, 2006, 2007, and 2008, respectively. Mean density ranged from 185 ind./m^2 (RSE = 6.8%) in

2005 to 112 ind./m^2 (RSE = 5.2%) in 2007, with a mean of 119 ind./m^2 (RSE = 10.6%) in 2008. Although density decreased from 2005 to 2008, there were not statistically significant differences in density among years based on results of general linear models ANOVA (P = 0.37, F = 1.1, df = 3, 81, and 84). The mean density observed in 2008 was similar to that observed in 2000 (Pothoven et al. 2004) and 2007. These results are consistent with the conclusions of Warner et al. (in review), who found that recent densities and as well mysid bathymetric distribution were statistically indistinguishable from those observed in the late 1980s (Lehman et al. 1990), and densities were similar to those reported by Pothoven et al. (2004). Warner et al. (in review) also found that mysid density was much higher in Lake Michigan than in Lake Huron. Our results as well as the results of Pothoven et al. (2004) suggest that densities in 2005 may have been unusually high and that values observed in 2000 and 2006-2008 are more typical. One caveat regarding comparisons with data from Lehman et al. (1990) is that even though their data represented the first synoptic surveys of mysids in Lake Michigan, there were typically few (6-8) stations sampled in each year. In 2008, density was higher than the lakewide average in two large areas (Figure 12). The first was in northern areas between Ludington, MI and the tip of the Door Peninsula (Figure 12). The second was roughly the southern third of the lake excluding an area in the southwest corner to the area near Grand Haven, MI.

CONCLUSIONS

As with any survey, it is important to note that trawl or acoustic estimates of fish biomass are potentially biased and, when possible, we should describe the effects of any bias when interpreting results. With acoustic sampling, areas near the bottom (bottom 0.3-1 m) and the surface (0-3 m) are not sampled well or at all. The density of fish in these areas is unknown. Time limitations preclude the use of upward or side-looking transducers. If one assumes that fish available to a bottom trawl with ~ 1 m fishing height at night are not available to acoustic sampling, it is doubtful that the bottom deadzone contributes much bias for alewife and rainbow smelt because of their pelagic distribution at night. In Lake Michigan, day-night bottom trawling was conducted at numerous locations and depths in 1987 (Argyle 1992), with day and night tows occurring on the same day. After examining these data we found that night

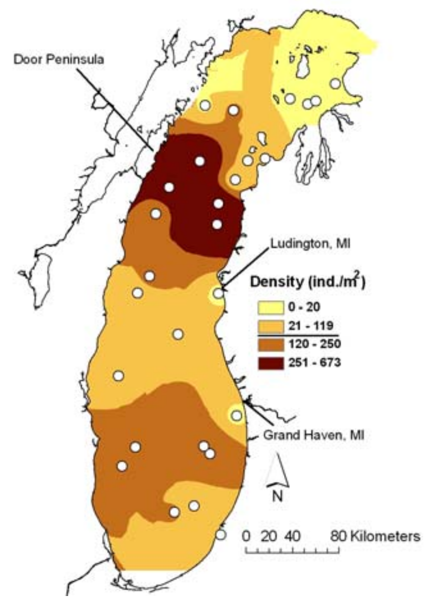

Figure 12. Map of interpolated *Mysis diluviana* density (ind./m^2) estimated using samples from Lake Michigan, August 2008. Symbols represent actual sample locations. The horizontal line in the legend separates categories that are below and above the lakewide mean biomass.

bottom trawl estimates of alewife density in August/September 1987 were only 4% of day estimates (D.M. Warner, unpublished data). Similarly, night bottom trawl estimates of rainbow smelt density were ~3% of day estimates. Evidence suggests bloater tend to be more demersal; in Lake Superior, night acoustic/midwater trawl sampling may detect only 60% of bloater present (Yule et al. 2007). Day-night bottom trawl data from Lake Michigan in 1987 suggests that the availability of bloater to acoustic sampling ranges from 7-76%. Slimy sculpins (*Cottus cognatus*) and deepwater sculpins (*Myoxocephalus thompsonii*) are poorly sampled acoustically and we must rely on bottom trawl estimates for these species. Alewife and rainbow smelt (primarily age-0) may occupy the upper 3 m of the water column and any density in this area results in underestimation of water column and mean lakewide density. Depending on season, in inland New York lakes and Lake Ontario, 37-64% of total alewife catch in gill nets can occur in the upper-most 3 m (D.M. Warner, unpublished data). However, highest alewife and rainbow smelt catches and catch-per-unit-effort with midwater tows generally occur near the thermocline in Lake Michigan (Warner et al. 2008). Additionally, we assumed that all targets below 40 m with mean TS > -45 dB were bloater. It is possible that this resulted in a slight underestimation of rainbow smelt density. Use of *in situ* TS to estimate fish density could also lead to biased results if conditions are not suitable for measuring TS (Rudstam et al. 2009) and biased TS estimates are used. However, we identified areas where TS was biased and replaced these biased values with unbiased values from nearby areas in the same depth area. Of 7,302 acoustic analysis cells in 2008, only 178 (2 %) were identified as being unsuitable for estimation of in situ TS.

Prey fish biomass in Lake Michigan remains at levels much lower than in the 1990s, and the estimate of total lakewide biomass (81.6 kt) from acoustic sampling was the second highest since 2001. However, with the exception of alewife and small bloater, all the species or size categories we reported here were well below (>20 %) their long-term averages. The large difference in biomass from the 1990s resulted primarily from the decrease in bloater abundance, but alewife and rainbow smelt declined as well. Pelagic fish biomass was not evenly split among the species present in 2008 (Table 1), but increasing bloater biomass suggests that there may be some progress toward meeting the Fish Community Objectives (FCO, Eshenroder et al. 1995) of maintaining a diverse planktivore community. Bloater and emerald shiner (*Notropis atherinoides*) were historically important species, but bloater currently exist at low biomass levels and emerald shiner have never been detected in this survey. In Lake Huron, near-collapse of the alewife population in 2003-2004 was followed by resurgence in emerald shiner abundance in 2005-2006 (Schaeffer et al. 2008) and by increased abundance of cisco [*Coregonus artedi*, (Warner et al. in review)]. It appears that emerald shiners are suppressed by all but the lowest levels of alewife abundance.

Prey biomass available to the acoustic survey in 2008 (95% CI = 67.9 – 90.8 kt) was low relative to the FCO, which calls for maintenance of a diverse planktivore community at abundance levels matched to primary production and predator demand (500-800 kt). With sculpin biomass from the bottom trawl survey (Bunnell et al. 2009a) added to the acoustic biomass of other species, estimated lakewide biomass (76-99 kt) is still less than the FCO range. Fleischer et al. (2005) argued this FCO target range was attainable when bloater abundance was high, but was likely not sustainable. Although planktivorous fish biomass is low relative to the FCO and values observed in the past, it does appear that *Mysis diluviana*, one organism key to the evolution of (and perhaps restoration of) the native coregonine community (Eshenroder and Burnham-Curtis 1999) is probably at levels similar to pre-dreissenid years and is certainly present at levels similar to those observed prior to the recent expansion of dreissenid mussels described by Bunnell et al. (2009b).

Table 1. Biomass, RSE, and 95% CI for age-0, YAO, total alewife, rainbow smelt, and bloater estimated from acoustic and midwater trawl data collected in Lake Michigan in 2008.

Species	**Biomass (kg/ha)**	**RSE (%)**	**95% CI**
Age-0 alewife	1.4	15	(1.0,1.7)
YAO alewife	9.7	10	(8.1, 11.2)
Total alewife	11.0	9	(9.3, 12.7)
Rainbow smelt	1.6	11	(1.3, 1.9)
Bloater	2.6	15	(1.9, 3.3)
Total	15.3	8	(13.3, 17.3)

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