The Great Lakes Science Center (GLSC) has conducted daytime bottom trawl surveys in Lake Michigan during the fall annually since 1973. From these surveys, the relative abundance of the prey fish populations are measured, and estimates of lake-wide biomass available to the bottom trawls (for the region of the main basin between the 5-m and 114-m depth contours) can be generated (Hatch et al. 1981; Brown and Stedman 1995). Such estimates are critical to fisheries managers making decisions on stocking and harvest rates of salmonines and allowable harvests of fish by commercial fishing operations.

The basic unit of sampling in our surveys is a 10-minute tow using a bottom trawl (12-m headrope) dragged on contour at 9-m (5 fathom) depth increments. At most survey locations, towing depths range from 9 or 18 m to 110 m. Age determinations are performed on alewives and bloaters from our bottom trawl catches (TeWinkel et al. 2002; Madenjian et al. 2003). Although our surveys have included as many as nine index transects in any given year, we have consistently conducted the surveys at seven transects. These index transects are situated off Manistique, Frankfort, Ludington, and Saugatuck, Michigan; Waukegan, Illinois; and Port Washington and Sturgeon Bay, Wisconsin (Figure 1). All seven index transects were completed in 2004.

Lake-wide estimates of fish biomass require (1) accurate measures of the surface areas that represent the depths sampled and (2) reliable measures of bottom area swept by the trawl. A complete Geographical Information System (GIS) based on depth soundings at 2-km intervals in Lake Michigan was developed as part of the acoustics study performed by Argyle et al. (1998). This GIS database was used to estimate the surface area for each individual depth zone surveyed by the bottom trawls. For 2004, we obtained a more accurate estimate of surface area in the 46-m depth zone, which will slightly modify our historical lake-wide biomass estimates. Trawl mensuration gear that monitored net configuration during deployment revealed fishing depth (D, in meters) to influence the bottom area swept by the trawl. Since 1998, we have corrected the width (W, in meters) of the area sampled according to $W = 9.693 - 43.93/D$, as well as the actual time (AT, in minutes) spent on the bottom according to $AT = \text{tow time} - 3.875 + D^{0.412}$ (Fleischer et al. 1999). These relationships, along with boat speed, were used to estimate bottom area swept.

Beginning this year, we have made several changes in our reporting of the bottom trawl survey data. To better facilitate comparison of our estimates of fish abundance in Lake Michigan with abundance estimates in other lakes and with hydroacoustic estimates of abundance, we have opted to report fish density, expressed both as number of fish per hectare (ha) and kg of fish per ha, rather than catch per tow. A weighted mean fish density over the entire range of depths sampled (within the 5-m to 114-m depth contours) was estimated by first calculating mean density for each of the depth zones, then weighting each depth zone mean density by the respective proportion of lake surface area assigned that depth zone. Beginning this year, estimates of variability in estimates of mean fish density and lake-wide biomass are also reported. Standard error (SE) of mean fish density was estimated by weighting the variances of fish density in each of the depth zones by the appropriate weight (squared proportion of surface area in the depth zone), averaging the weighted variances over all depth zones, and taking the square root of the result.

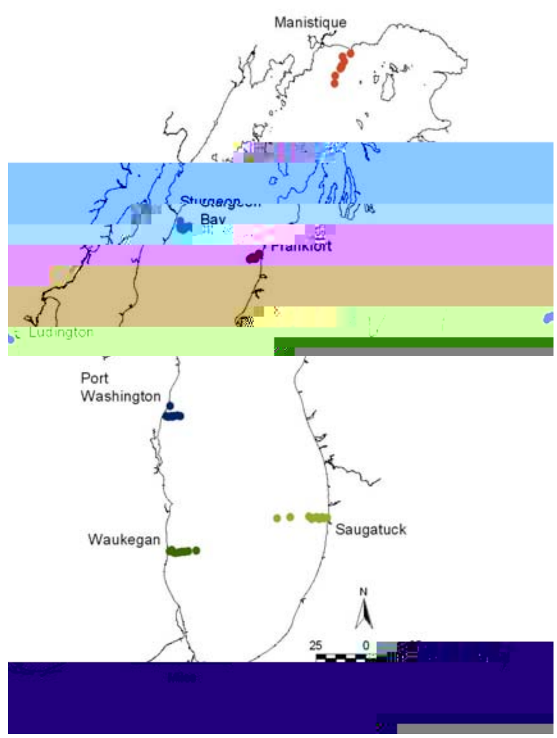


Figure 1. Established sampling locations for GLSC bottom trawls in Lake Michigan.

Relative standard error (RSE) was calculated by dividing SE by mean fish density and then multiplying this ratio by 100 to yield a percentage. SE and RSE for the estimate of lake-wide biomass were calculated in a manner analogous to that for calculating SE and RSE for the estimate of mean fish density.

ABUNDANCE

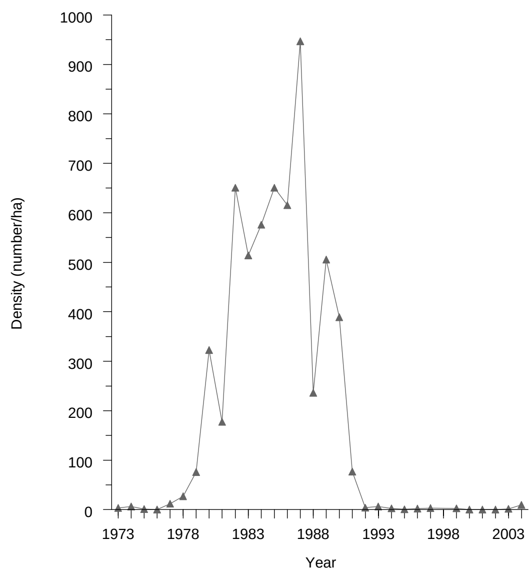
By convention, we classify "adult" prey fish as those individuals age 1 or older. Life stage classification was assigned based on length-frequency, where alewives greater ≥ 100 mm, rainbow smelt ≥ 90 mm, and bloaters ≥ 120 mm were classified as "adults". Unless otherwise stated, all length measurements refer to total length.

Catches of small alewives, bloaters, and rainbow smelt are not necessarily reliable indicators of future year-class strengths for these populations, because their small size and position in the water column make them less vulnerable to bottom trawls. Nevertheless, during the bloater recovery in Lake Michigan that began in the late 1970s, our trawling survey indicated that the lake contained unusually-high abundances of age-0 bloaters, so there is some correspondence between our bottom trawl catches of age-0 prey fish and their actual abundance in the lake.

<u>Alewife</u> – Since its establishment in the 1950s, the alewife has become a key member of the fish community. The alewife has remained the most important constituent of salmonine diet in Lake Michigan for the last 35 years (Jude et al. 1987; Stewart and Ibarra 1991; P. Peeters, Wisconsin Department of Natural Resources, Sturgeon Bay, WI, personal communication; R. Elliott, U. S. Fish and Wildlife Service, Green Bay, WI, personal communication). Most of the alewives consumed by salmonines in Lake Michigan are eaten by chinook salmon (Madenjian et al. 2002). A commercial alewife harvest was estabstate by satate bA coA co co.4(19rlsne)Ss-7.8n.l alewil-31g9ybA cn b950s, t

2004 suggested that adult alewives were patchier

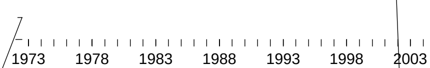
Bloater - Bloaters are eaten by salmonines in Lake Michigan, although not to the extent that adult alewives are consumed. Over 30% of the diet of large (≥ 600 mm) lake trout at Saugatuck and on Sheboygan Reef was composed of adult bloaters during 1994-1995, although adult bloaters were a minor component of lake trout diet at Sturgeon Bay (Madenjian et al. 1998). When available, juvenile bloaters have been a substantial component of salmon and nearshore lake trout diets, particularly for intermediate-sized fish (Elliott 1993; Rybicki and Clapp 1996). The bloater population in Lake Michigan also supports a valuable commercial fishery.



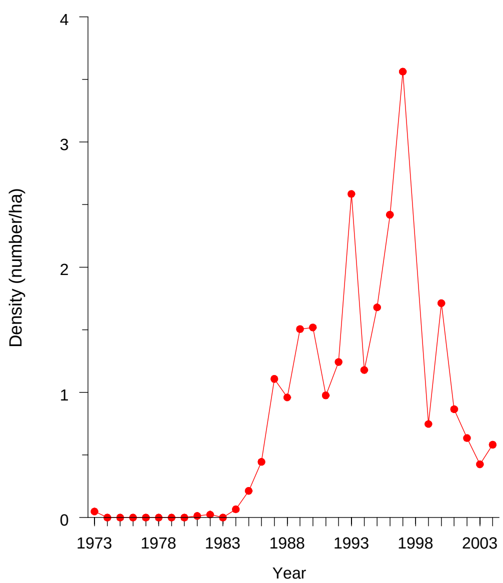
The overall trend in adult bloater density during 1989-2004 was a dramatic decline (Figure 2). This decline was attributable to relatively poor recruitment during 1992-2003 (Madenjian et al. 2002, 2004). Adult bloater density increased from 6.4 kg per ha in 2003 to 9.7 kg per ha in 2004 (Figure 2). Age-0 bloater density ranged from 0.2 to 6.5 fish per ha during 1992-2003, whereas age-0 bloater density ranged from 177 to 947 fish per ha between during 1980-1990 (Figure 7). In 2004, age-0 bloater density was 9.6 fish per ha, which was the highest value in the time series since 1991. Moreover, age-0 bloater density in 1977, the year in which the bloater recovery in Lake Michigan began (Eck and Wells 1987), was 11.8 fish per ha. Madenjian et al. (2002) have proposed that the Lake Michigan bloater population may be cycling in abundance, with a period of about 30 years. If bloater abundance is truly cyclical and year 2004 signaled the initiation of a bloater recovery, then age-0 bloater density average abundance of age-0 rainbow smelt during the 1990s (Figure 8). Age-0 smelt abundance substantially decreased from 161 fish per ha in 2003 to 23 fish per has in 2004 (Figure 8). Interpretation of the long-term time series for adult rainbow smelt density remains difficult.

<u>Sculpins</u> – The cottid populations in Lake Michigan proper are dominated by deepwater, and to a lesser degree, slimy sculpins. Spoonhead sculpins, once fairly common, suffered declines to become rare to absent by the mid 1970s (Eck and Wells 1987). Spoonhead sculpins are still encountered in Lake Michigan, but in small numbers (Potter and Fleischer 1992).

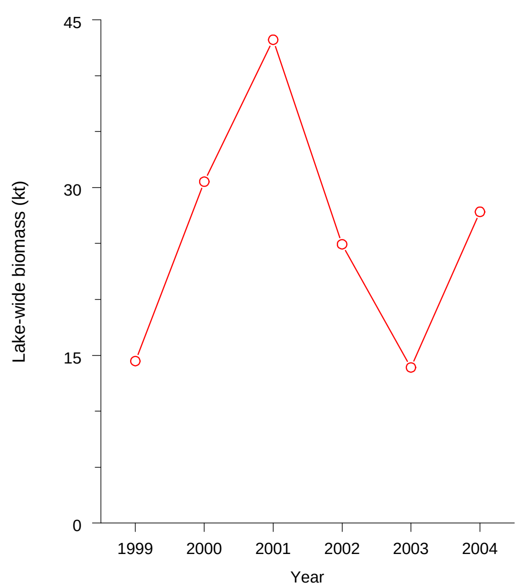
Slimy sculpin is a favored prey of juvenile lake trout in nearshore regions of the lake (Stewart et al. 1983; Madenjian et al. 1998). As lake trout grow, the importance of sculpins in lake trout diet decreases substantially so that sculpins form only a minor portion of adult lake trout diet. Deepwater sculpin is an important diet item for burbot in Lake Michigan, especially in deeper waters (Van Oosten and Deason 1938; Brown and Stedman 1995; Fratt et al. 1997).



abundance, catches of burbot in the bottom trawls increased sharply from 1983 to 1990 (Figure 12). Burbot catch leveled off during 1990-2001, and then decreased during 2001-2003. The decrease in burbot density during 2001-2003 may have been partly due to increased predation by sea lampreys; lake-wide estimates of spawning sea lampreys in Lake Michigan tributaries increased during 2000-2003 (D. Lavis, U. S. Fish and Wildlife Service, Ludington, MI, personal communication). Burbot density increased from 0.43 fish per ha in 2003 to 0.58 fish per ha in 2004 (Figure 12).



Yellow perch The yellow perch population in Lake Michigan has supported valuable recreational and commercial fisheries (Wells 1977). GLSC bottom trawl surveys provide an index of age-0 yellow perch abundance, which serves as an indication of yellow perch recruitment success. According to the standard (reported in March 1990) in Indiana Harbor at Gary, Indiana. By 1990, adult mussels had been found at multiple sites in the Chicago area, and by 1992 were reported to range along the eastern and western shoreline in the southern two-thirds of the lake, as well as in Green Bay and Grand Traverse Bay (Marsden 1992). In 1999, catches of dreissenid mussels in our bottom trawls became significant and we began recording weights from each tow. Lake Michigan dreissenid mussels include two species: the zebra mussel and the quagga mussel. The quagga mussel is a more recent invader to Lake Michigan than the zebra mussel (Nalepa et al. 2001). According to the GLSC bottom trawl survey, lake-wide biomass of dreissenid mussels trended neither upward nor downward during 1999-2004 (Figure 14). Estimated lake-wide biomass of dreissenid mussels increased from 13.9 kt in 2003 to 27.8 kt in 2004. The dreissenid mussel invasions have been associated with the decline in the amphipod *Diporeia* in Lake Michigan, although the mechanism by which dreissenid mussels are negatively affecting *Diporeia* remains unidentified (Madenjian et al. 2002).



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Appendix 1. Mean density and lake-wide biomass estimates for various fishes and dreissenid mussels in Lake Michigan during 2004. Estimates based on the bottom trawl survey. Standard error enclosed in parentheses. NA denotes that estimate is not available.

Taxon	Density (number/ha)	Density (kg/ha)	Lake-wide biomass (kt)
age-0 alewife	9.18 (5.79)	0.043 (0.028)	0.152 (0.099)
adult alewife	123.43 (51.10)	3.853 (1.496)	13.568 (5.270)
age-0 bloater	9.59 (3.63)	0.079 (0.030)	0.277 (0.104)
adult bloater	114.36 (38.89)	9.667 (4.219)	34.043 (14.858)
age-0 rainbow smelt	23.47 (10.49)	0.021 (0.005)	0.074 (0.019)
adult rainbow smelt	50.44 (16.00)	0.505 (0.142)	1.780 (0.500)
deepwater sculpin	637.98 (237.41)	7.530 (2.091)	26.519 (7.364)
slimy sculpin	257.13 (64.56)	1.039 (0.307)	3.658 (1.082)
burbot	0.58 (0.25)	0.875 (0.356)	3.081 (1.255)
age-0 yellow perch	0 (0)	0.000 (0.000)	0.000 (0.000)
dreissenid mussels	NA	7.903 (1.074)	27.831 (3.781)