Lake Michigan Committee
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Status and Trends of Prey Fish Populations in Lake Michigan, 2003[1]

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Abstract

The Great Lakes Science Center (GLSC) has conducted lake-wide surveys of the fish community in Lake Michigan each fall since 1973. These systematic surveys are performed using standard 12-m bottom trawls towed along contour at depths of 9 to 110 m at each of seven to nine index transects. The resulting data on relative abundance, size structure within the populations, and condition of individual fishes are used to estimate various population parameters that are in turn used by state and tribal agencies in managing Lake Michigan fish stocks. All seven established index transects of the lake-wide survey were completed in 2003. Alewife was the most abundant prey fish in Lake Michigan in 2003, with an estimated lake-wide biomass of 42.876 kilotonnes (kt) (1 kt = 1000 metric tons). Alewife catch was dominated by the 1998 year-class. Lake-wide biomasses of deepwater sculpin, bloater, slimy sculpin, and rainbow smelt were estimated at 32.787 kt, 20.682 kt, 2.385 kt, and 1.386 kt. Whereas bloater biomass continued its decline in 2003, alewife biomass has trended neither upward nor downward between the early 1980s and 2003. The decline in bloater biomass began in 1990 and can be chiefly attributed to consistently poor recruitment from 1992 through 2003. Rainbow smelt biomass declined during 1992-1997, and has remained low since 1997. Deepwater sculpin biomass has shown neither an increasing nor decreasing trend from 1990 to 2003. Burbot abundance decreased during 2001-2003. Slimy sculpin abundance appeared to be leveling off during 2000-2003, following an increase during 1990-2000. Yellow perch year-class strength was poor in 2003. Lake-wide biomass of dreissenid mussels decreased from 24.464 kt in 2002 to 13.756 kt in 2003. First catch of round gobies in the GLSC lake-wide survey of Lake Michigan was recorded in 2003.

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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 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 valuable fish by commercial fishing operations.

The basic unit of sampling in our surveys was 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. 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 2003.

The lake-wide estimates of fish abundance presented in this report differ in expansion technique, in calculation of area swept, and in surface area data applied to fish densities from those made in reports prior to 1998. For past estimates of total lake biomass, each of the seven transects was assigned a proportionate area of Lake Michigan, based on the statistical district system for reporting commercial catch that was established in the 1950s (Hatch et al. 1981). Catch in weight by prey species and life stage for a particular tow was then expanded based on the total area represented by a particular depth contour at that particular location. These expanded estimates were then summed for all of the depth-contour intervals and locations to yield estimates of lake-wide biomass available to the bottom trawl. Because of this fixed design, measures of precision are not available for these lake-wide estimates. However, to allow comparisons of the bottom trawl estimates as well as a measure of their precision, we considered each catch to be a representative sample of the fish populations from that particular depth stratum. The mean density (catch per unit area swept) for a given species and life stage for a particular depth contour was determined across each depth and expanded to the total lake area represented by the depth contour. These point estimates were summed to produce lake-wide biomass and variance estimates. We used the arithmetic mean to estimate the true population mean of each depth contour for expansion to total population size. This practice is appropriate for stratified random surveys based on sample survey theory and finite population theory and is common in stock assessment of fisheries (Smith 1990). Although distributions of fish abundance tend to be positively skewed, expectations can be taken without knowledge of distribution, as the expected (arithmetic) mean will tend toward normality even with non-normal frequency distributions (Cochran 1977). This design-unbiased property would also hold for the variance, and standard error estimates can be derived by assuming repeated sampling from the finite population.

Lake-wide estimates of fish biomass require (1) accurate measures of the surface areas that

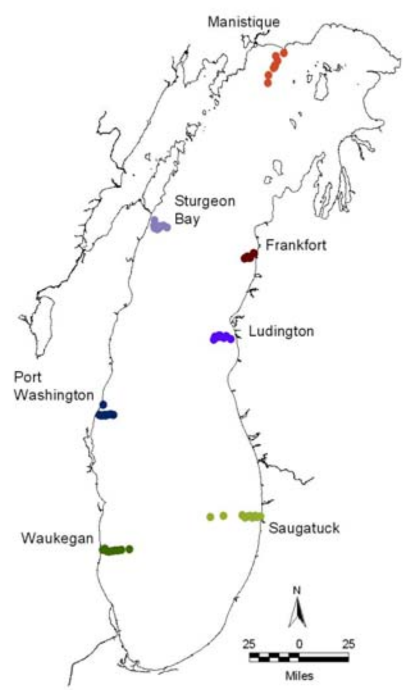

Figure 1. Established sampling locations for GLSC bottom trawls in Lake Michigan.

represent the depths sampled and (2) reliable measures of bottom area swept by the trawl. The fish catch per unit effort (CPE) and biomass estimates presented in this report have taken advantage of improvements in the mapping of Lake Michigan, and the use of trawl mensuration gear to monitor net configuration during deployment. 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 accurately calculate the surface area for each individual depth zone surveyed by the bottom trawls. Furthermore, we determined that the bottom area swept by the trawl increased with depth as shown by the relations of net wingspread and difference in adjusted towing time (additional time net was on bottom) by the depth fished (Fleischer et al. 1999). The resulting predictive equations from our analysis were used to correct each tow to a standardized 10-minute tow and to compensate for the greater wingspread with depth.

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 than 100 mm, rainbow smelt greater than 90 mm, and bloaters greater than 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.

Alewife – Since its establishment in the 1950s and subsequent dominance, 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) and has been the focus of fisheries management issues in Lake Michigan. In addition, a commercial alewife harvest was established in Wisconsin waters of Lake Michigan in the 1960s when a trawl fishery was developed to make use of the then extremely abundant alewife that had become a nuisance and health hazard along the lakeshore. In 1986, a quota was implemented, and as a result of these rule changes and seasonal and area restrictions, the estimated alewife harvest declined from about 7,600 metric tons in 1985 to an estimated average annual incidental harvest of only 12 metric tons after 1990 (Mike Toneys, Wisconsin Department of Natural Resources, Sturgeon Bay, personnel communication). There is presently no commercial fishery for alewives in Lake Michigan.

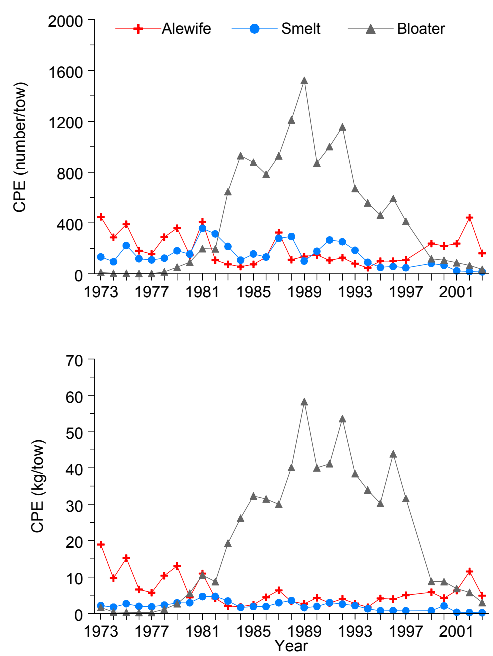

Figure 2. CPE of adult alewives, rainbow smelt, and bloaters as number (top) and weight (bottom) of fish per tow in Lake Michigan, 1973-2003.

Measured as number of fish per tow, relative abundance of adult alewives in Lake Michigan substantially decreased from 443 fish per tow in 2002 to 163 fish per tow in 2003 (Figure 2). Similarly, alewife abundance, on a weight basis, substantially decreased from 11.5 kg per tow in 2002 to 4.9 kg per tow in 2003 (Figure 2).

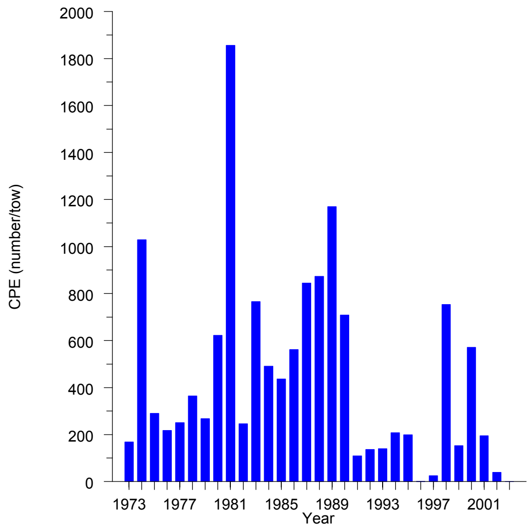

Figure 3. CPE of age-0 alewives in Lake Michigan, 1973-2003.

Catch of age-0 alewives decreased from 39 fish per tow in 2002 to just 1 fish per tow in 2003 (Figure 3). During the 1990-2003 time period, highest age-0 abundances of alewives occurred during 1990, 1998, and 2000.

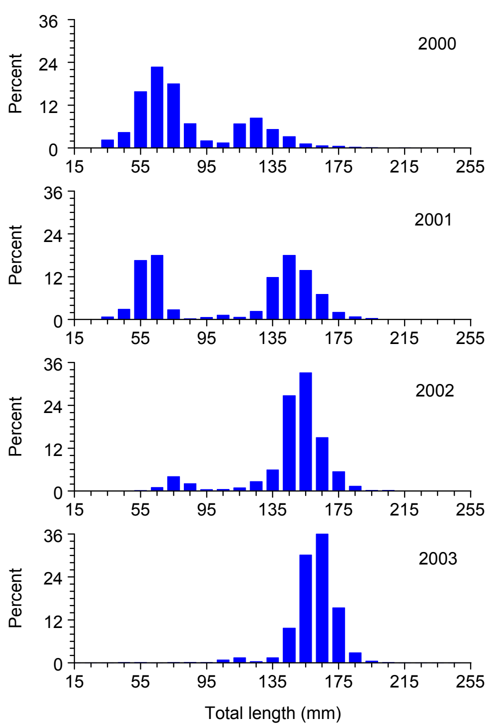

Figure 4. Length-frequency distributions of alewives caught in bottom trawls in Lake Michigan, 2000-2003.

Again, the 1998 year-class appeared to be an exceptionally strong one, as this year-class dominated the catch of adult alewives during 2003 (Figures 4 and 5). The 1998 year-class also dominated the catch of age-1 and older alewives during 1999-2002 as well (Madenjian et al. 2003).

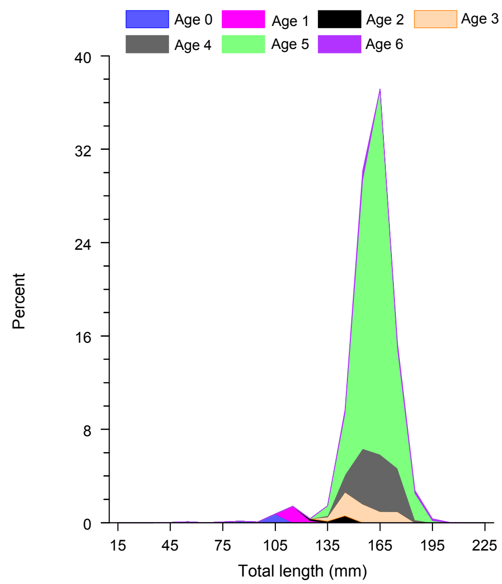

Figure 5. Age-length distribution of alewives caught in bottom trawls in Lake Michigan, 2003.

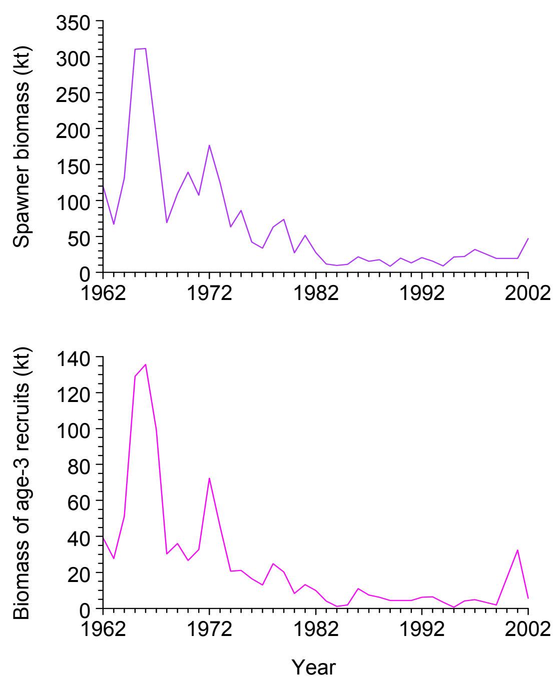

Figure 6. Annual lake-wide biomass estimates of spawner-size (≥ 150 mm in total length) and age-3 alewives during the fall in Lake Michigan, 1962-2002.

Alewife recruitment in Lake Michigan appeared to be most strongly influenced by predation by salmonines and water temperatures during spring and summer of the alewife's first year in the lake (Madenjian et al. 2004). Extraordinarily warm water temperatures during spring and summer of 1998 likely led to a moderately high recruitment of age-3 alewives in 2001, despite the high level of salmonine abundance (Figure 6; Madenjian et al. 2004).

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 the midlake 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.

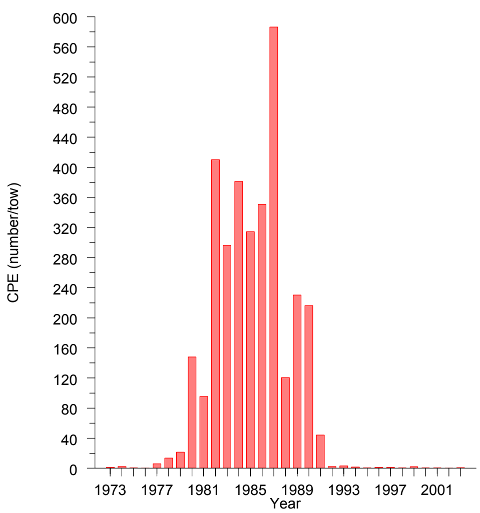

Figure 7. CPE of age-0 bloaters in Lake Michigan, 1973-2003.

Adult bloaters have decreased in abundance to only 35 fish per tow in 2003, a continuation of a trend of decreasing abundance in this species during the 1990s (Figure 2). The 2003 catch rate represents the lowest value since 1978. The decline in adult bloater abundance during the 1990s was expected because bloater recruitment was poor during 1992-2003 (Figure 7). Age-0 bloater abundance has ranged from 0.1 to 3.4 fish per tow during 1992-2003, with a catch of only 1.0 fish per tow in 2003. In contrast, age-0 bloater abundance ranged from 95 to 586 fish per tow during 1980-1990. Madenjian et al. (2002) have proposed that the Lake Michigan bloater population may be cycling in abundance, with a period of about 30 years. These cycles may be largely independent of human intervention or interactions with other fish populations.

Rainbow smelt – Adult rainbow smelt is an important diet item for intermediate-sized (400 to 600 mm total length) lake trout in the nearshore waters of Lake Michigan (Stewart et al. 1983; Madenjian et al. 1998). Overall, however, rainbow smelt are not consumed by Lake Michigan salmonines to the same extent as alewives. The rainbow smelt population supports commercial fisheries operated in Wisconsin and Michigan waters (Belonger et al. 1998; P. Schneeberger, Michigan Department of Natural Resources, Marquette, MI, personal communication).

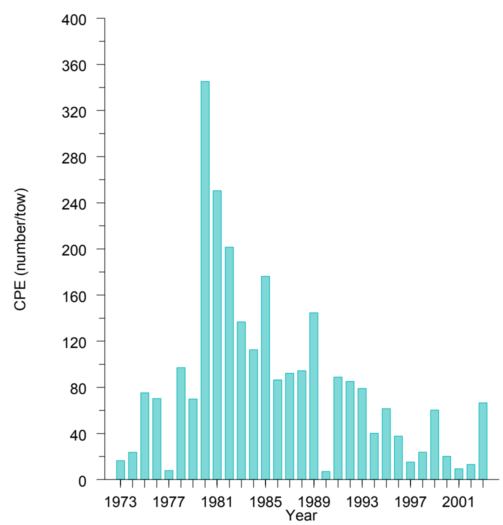

Figure 8. CPE of age-0 rainbow smelt in Lake Michigan, 1973-2003.

Adult rainbow smelt abundance decreased from 19 fish per tow in 2002 to 16 fish per tow in 2003 (Figure 2). Ignoring the 1998 catch rate due to the gear deployment problems during that year, adult rainbow smelt abundance in 2003 was the lowest on record. Adult rainbow smelt abundance declined substantially from 1992 to 1997, and has remained low since 1997 (Figure 2). Causes for the decline remain unclear. Consumption of smelt by salmonines was higher in the mid 1980s than during 1992-1997 (Madenjian et al. 2002), yet adult smelt abundance remained high during the 1980s. Average abundance of age-0 rainbow smelt during 1973-1979 was not appreciably higher than average abundance of age-0 rainbow smelt during the 1990s (Figure 8). Age-0 smelt abundance substantially increased from 13 fish per tow in 2002 to 67 fish per tow in 2003 (Figure 8). Interpretation of the long-term time series for adult rainbow smelt abundance remains difficult.

Sculpins – 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).

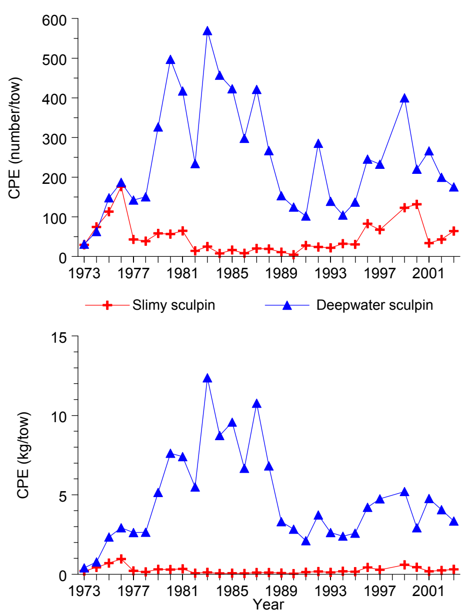

Figure 9. CPE of slimy sculpins and deepwater sculpins as number (top) and weight (bottom) of fish per tow in Lake Michigan, 1973-2003.

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 1937; Brown and Stedman 1995; Fratt et al. 1997).

Catches of deepwater sculpins in Lake Michigan decreased to 176 fish per tow in 2003, compared with 199 fish per tow in 2002 (Figure 9). From a standpoint of number of fish per tow, deepwater sculpin abundance has increased somewhat during 1990-2003. From a standpoint of kg of fish per tow, deepwater sculpin abundance has just increased slightly or leveled off between 1990 and 2003 (Figure 9). Leveling off of deepwater sculpin abundance during the 1990s coincided with a leveling off of burbot abundance.

Catches of slimy sculpins in Lake Michigan increased from 43 fish per tow in 2002 to 64 fish per tow in 2003 (Figure 9). Overall, slimy sculpin abundance showed an increasing trend during the 1990s. This increase in abundance may have actually begun in 1986, when an emphasis was first placed on stocking lake trout on offshore reefs rather than stocking lake trout in areas closer to shore in Lake Michigan. Slimy sculpin is a favored prey of juvenile lake trout. The GLSC bottom trawl survey does not cover the rocky, offshore reefs that have been heavily stocked with lake trout since 1986. Thus, the observed increase during the 1990s in slimy sculpin abundance detected in the GLSC bottom trawl survey was likely attributable to the emphasis on stocking lake trout on offshore reefs beginning in 1986 (Madenjian et al. 2002). The substantially lower slimy sculpin abundance during 2001-2003, compared with abundance during the late 1990s, may be attributable to the decline in *Diporeia* abundance. *Diporeia* has dominated the diet of slimy sculpins in Lake Michigan since the 1970s. Slimy sculpins inhabit shallower waters than deepwater sculpins, and therefore slimy sculpins may be more susceptible to the decline in *Diporeia* abundance, which has been most drastic in the nearshore waters of the lake (Nalepa et al. 2004), compared with deepwater sculpins. In addition, slimy sculpin abundance may be leveling off during the 2000s after showing a marked increase during the 1990s.

BIOMASS

We estimated a total lake-wide biomass of prey fish available to the bottom trawl in 2003 of 100.116 kilotonnes (kt) (1 kt = 1000 metric tons)

(Figure 10). This total prey fish biomass was the sum of the population biomass estimates for alewife, bloater, rainbow smelt, deepwater sculpin, and slimy sculpin. Alewives constituted 43% (42.876 kt), deepwater sculpins constituted 33% (32.787 kt), and bloaters constituted 21% (20.682 kt) of the total prey fish biomass in Lake Michigan in 2003.

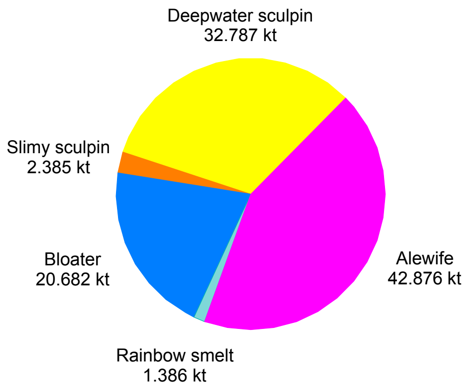

Figure 10. Estimated lake-wide biomass of prey fishes in Lake Michigan, 2003, based on bottom trawl surveys.

Total prey fish biomass in Lake Michigan has shown a declining trend during 1989-2003, and this decline is mainly attributable to the tremendous decrease in bloater biomass (Figure 11). The current bloater biomass is about 6% of the peak value in 1989. Total prey fish biomass did increase slightly between 2000 and 2002, and this slight increase was due to an increase in alewife biomass (Figure 11). Apparently, the 1998 alewife year-class was an exceptionally large one. Nonetheless, alewife biomass declined during the 1970s, but fluctuated with no consistent trend during 1982-2003. Long-term trends in alewife biomass suggested that the salmonine stocking program was not only effective in reducing alewife abundance in Lake Michigan, but also effective in maintaining relatively low alewife abundance for the last 20 years (Madenjian et al. 2002). Rainbow smelt biomass declined between 1992 and 1997, and has remained low from 1997 to 2003. Deepwater sculpin biomass has fluctuated without trend during 1990-2003 (Figure 11).

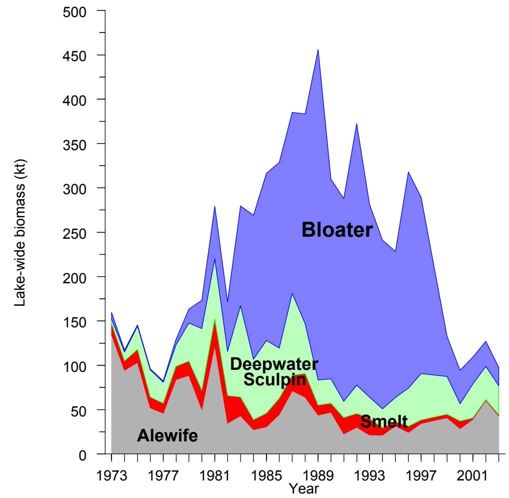

Figure 11. Estimated lake-wide biomass of prey fishes in Lake Michigan, 1973-2003, based on bottom trawl surveys.

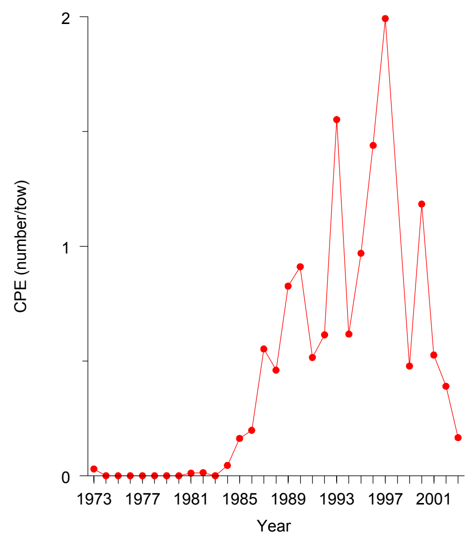

Figure 12. CPE of burbot in Lake Michigan, 1973-2003.

OTHER SPECIES OF INTEREST

Burbot – Burbot and lake trout represent the native top predators in Lake Michigan. The decline in burbot abundance in Lake Michigan during the 1950s has been attributed to sea lamprey predation (Wells and McLain 1973). Sea lamprey control was a necessary condition for recovery of the burbot population in Lake Michigan, however Eshenroder and Burnham-Curtis (1999) proposed that a reduction in alewife abundance was an additional prerequisite for burbot recovery.

Burbot collected in the bottom trawls are typically large individuals (>350 mm TL); juvenile burbot apparently inhabit areas not covered by the bottom trawl survey.

After a period of initial low abundance, catches of burbot in the bottom trawls increased sharply from 1983 to 1990 (Figure 12). Burbot catch leveled off during 1990-2002. Burbot abundance decreased from 0.39 fish per tow in 2002 to 0.17 fish per tow in 2003, and causes for this marked decline are unclear.

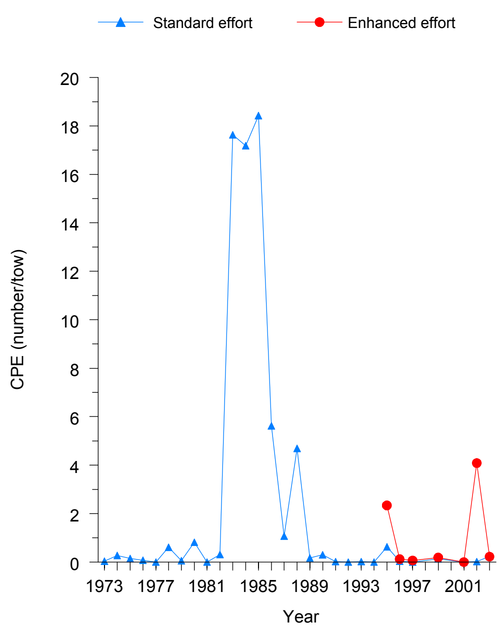

Figure 13. CPE of age-0 yellow perch in Lake Michigan, 1973-2003.

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 trawl series, recruitment success was poor in most years during 1989-2003 (Figure 13). Beginning in 1995, three additional trawl tows (at depths of 5, 13, and 22 m) were added to the Saugatuck transect to enhance the sampling effort for age-0 yellow perch. According to both the standard and enhanced-effort series, age-0 yellow perch abundance was very low in 2003 as only 0.2 fish per tow were caught. Most researchers believe that a combination of several factors are responsible for this prolonged period of low recruitment success; these factors include poor weather conditions in some years, a low abundance of female spawners in some years, and possibly a low availability of zooplankton for yellow perch fry in some years (Makauskas and Clapp 2000).

Round goby – The first catch of round gobies in the GLSC bottom trawl survey of Lake Michigan occurred in 2003. In total, 23 round gobies were caught during the 2003 survey. Catches were limited to the Manistique and Saugatuck transects at depths ranging from 9 to 27 m. Round goby total lengths ranged from 57 to 161 mm.

The round goby is an invader from the Black and Caspian seas. Round gobies have been observed in bays and harbors of Lake Michigan since 1993, and round gobies have been captured by Michigan DNR personnel in the southern main basin of the lake as early as 1997 (Clapp et al. 2001). With additional years of continued surveillance, results from the GLSC bottom trawl survey should prove useful in detecting significant effects of round gobies on the Lake Michigan fish community.

Dreissenid mussels – The first zebra mussel noted in Lake Michigan was found in May 1988 (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 catches from each tow. Lake Michigan dreissenid mussels included 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 increased from 14 kt in 1999 to 43 kt in 2001, but then decreased to 14 kt by 2003 (Figure 14). The zebra mussel invasion has been associated with the decline in the amphipod *Diporeia* in Lake Michigan, although the mechanism by which zebra mussels are negatively affecting *Diporeia* remains unidentified (Madenjian et al. 2002).

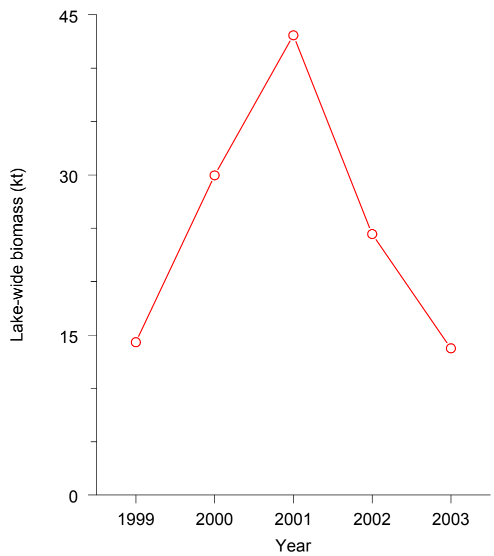

Figure 14. Estimated lake-wide biomass of dreissenid mussels in Lake Michigan, 1999-2003, based on bottom trawl surveys.

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