Lake Michigan Committee
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Status and Trends of Prey Fish Populations in Lake Michigan, 1999[1]

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Abstract

The Great Lakes Science Center 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 information on relative abundance and species composition, age and size structure within the populations, and condition of individual fishes, especially for those species important as prey, are critical to fisheries managers making decisions on stocking rates of salmonines and allowable harvests of valuable fish by commercial fishing operations. The 1999 survey was completed with tows made at the established index locations in Lake Michigan by the *R/V* Grayling; problems in trawl technique that affected the 1998 catch rates for the various species were corrected. In 1999, bloaters still dominated the prey fish biomass in Lake Michigan, however at a much lower level than has been observed in recent years. Bloaters composed 30% (45,541 t), alewives 27% (41,580 t), rainbow smelt 3% (4,530 t), and sculpins 28% (slimy sculpins 4,043 t; deepwater sculpins 40,315 t) of the estimated total prey fish biomass. The decline in bloater biomass to the lowest levels since the 1980's was expected due to consistently poor recruitment throughout the 1990's. During the last decade, alewife biomass has fluctuated with no consistent trend. Recent increases in alewife biomass are chiefly due to strong 1995 and 1998 year-classes. Rainbow smelt populations have declined to remain at levels at about 25% of the 1980-1989 average biomass. Deepwater sculpin biomass has been consistent over time, with a gradual increase in recent years. Burbot have demonstrated resurgence in their populations from the 1980s to the early 1990s, but have peaked and subsequently declined or leveled off. Zebra mussel populations have expanded and now are encountered in densities to sufficiently contribute to the bottom trawl catches at most sites.

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The Great Lakes Science Center 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 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. During 1973-1993, the shallowest tows were at 18 m and the deepest tows were at 91 m. Since 1994, depths surveyed were expanded to include tows at 9 m and 110 m. Although our surveys have included as many as nine index locations in any given year, we have consistently conducted the surveys at seven index locations. These index locations include Manistique, Frankfort, Ludington, and Saugatuck, Michigan; Waukegan, Illinois; and Port Washington and Sturgeon Bay, Wisconsin (Figure 1).

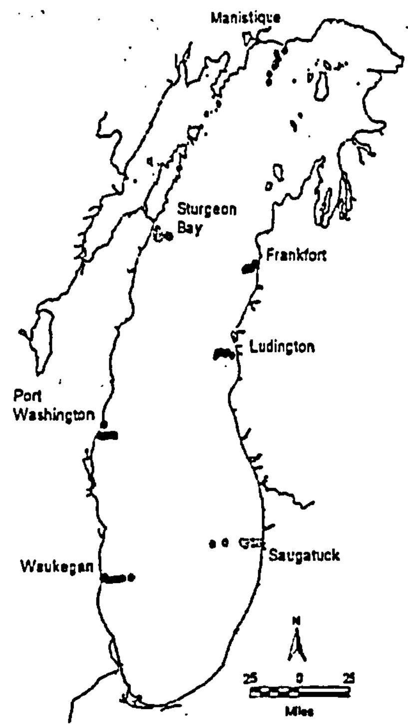

Figure 1. Sampling locations for bottom trawls completed in fall 1999 on Lake Michigan. Each trawl site is marked by color-coded circles with respect to each index location or port.

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 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 measures of Lake Michigan surface area and depth profile data, 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 calculate the surface area accurately for each individual depth zones 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 strength 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 25 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.

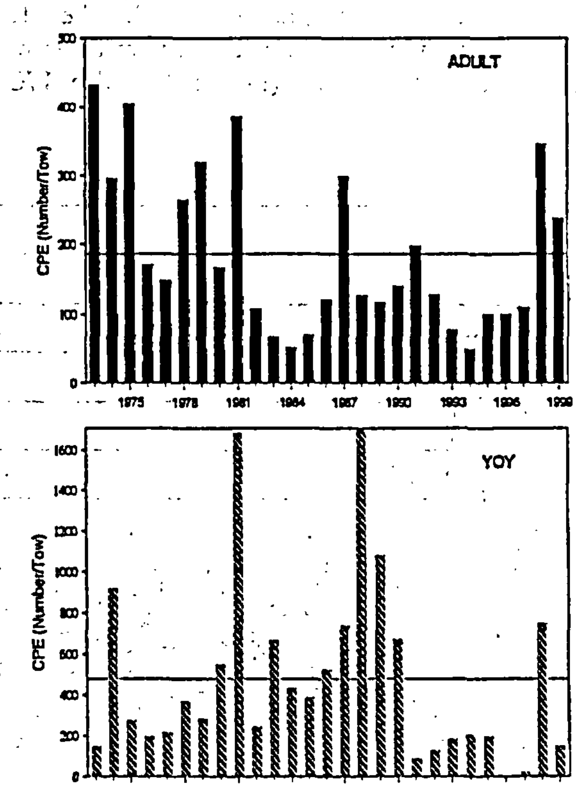

Figure 2. Number of adult alewives (upper panel) and YOY (lower panel) alewives per tow in Lake Michigan, 1973-1999. Horizontal lines indicates mean catch rate for the period. Note: the 1998 values may not fully represent abundance due to inconsistent trawl data.

The relative abundance of adult alewives in Lake Michigan has increased from 100 fish per tow in 1996 and 110 fish per tow in 1997 to 237 fish per tow in 1999 (Figure 2). The 1999 catch rate represents the highest adult alewife abundance in the last decade (1998 catches notwithstanding) to a level near the mean catch rate for the study period. From 1990 to 1997, there was no consistent upward or downward trend in adult alewife abundance in Lake Michigan. Rather, the abundance fluctuated about a mean level of approximately 112 fish per tow.

Catches of small alewives decreased from the notable 753 fish per tow in 1998 to 238 fish per tow in 1999, but remained at a level greater than recorded for the most recent years (Fig. 2). As an example, 1996 age-0 alewife abundance was unusually low at 1 fish per tow, and CPE for age-0 alewife was 25 fish per tow in 1997. The 1999 trawl catches of small alewives were comparable to catches in 1992-1995, but were still lower than the average levels observed for the entire study period (Fig. 2).

For alewives caught in 1999, the length distribution shows distinct modes at 85 mm, 120 mm and at 170 mm (Figure 3). The 170-mm modal length for the largest alewives in 1999 was an increase from 165 mm in 1998. These modal sizes, however, are still smaller than most previous year's values; typically, the modal length of adult alewives caught in Lake Michigan bottom trawls occurs at 175 to 185 mm (Figure 3).

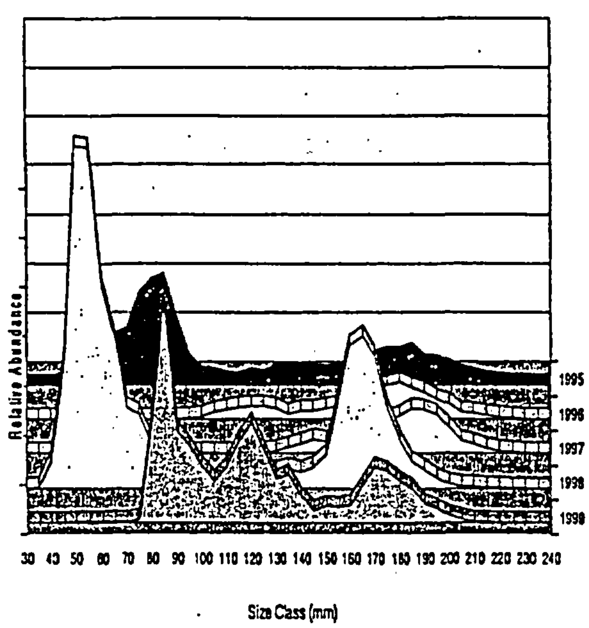

Figure 3. Length-frequency distributions of alewives caught in bottom trawls in Lake Michigan, 1995-1999.

Those smaller-sized fish that produced the modes at 120 mm and at 85 mm would normally correspond to yearling and young-of-year alewives, respectively. However, the age distribution of alewives shows all these fish to be yearlings (Fig. 4). These fish represent the 1998 year-class, which appeared to be a large year class composed of smaller-sized individuals (Fleischer et al. 1998). Over-winter survival of these fish was apparently better than expected (Brown 1972, O'Gorman and Schneider 1986), however, many of these fish are still atypically small. The older segment of the alewife population was dominated by age-4 individuals (Fig. 4), representatives of the 1995 year class. This cohort was shown to be exceptionally large in acoustic surveys by Argyle et al. (1998), and became fully recruited to the trawls at age 3. Annual growth of individuals from this dominant year-class is largely responsible for the shift in the modal size of the larger alewives.

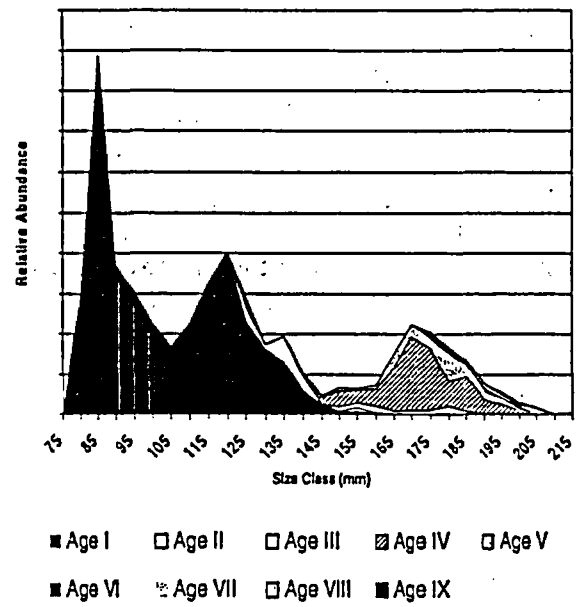

Figure 4. Age-length distribution of alewives caught in bottom trawls in Lake Michigan in 1999.

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 near shore lake trout diets, particularly for intermediate sized fish (Rybicki and Clapp 1996, Elliott 1993). The bloater population in Lake Michigan is also valuable to commercial fisheries.

Adult bloaters have decreased in abundance to only 119 fish per tow in 1999, a continuation of a trend of decreasing abundance in this species

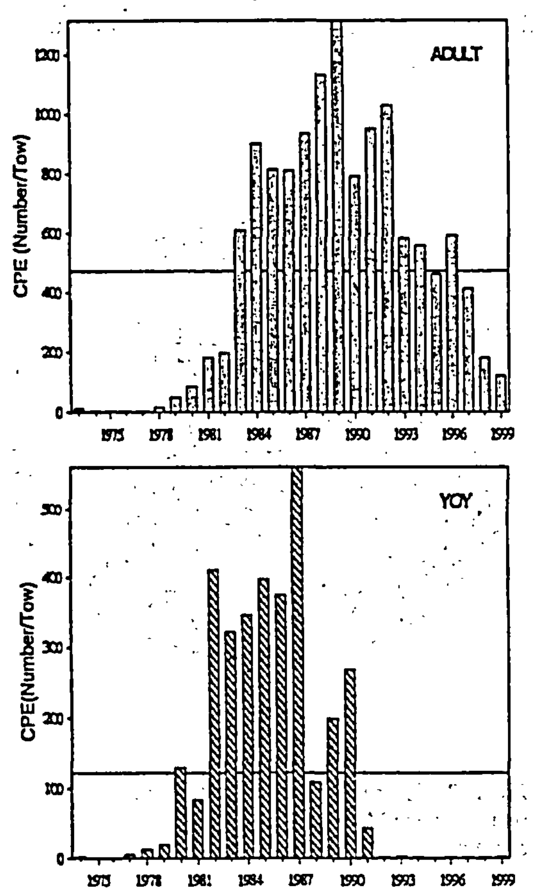

Figure 5. Number of adult bloaters (upper panel) and YOY (lower panel) bloaters per tow in Lake Michigan, 1973-1999. Horizontal lines indicates mean catch rate for the period. Note: the 1998 values may not fully represent abundance due to inconsistent trawl data.

during the 1990s (Fig. 5). The 1999 catch rate represents the lowest value since 1980. This decline is expected given the lack of recruitment in recent years and the shortage of younger age classes to contribute to the adult bloater population. Abundance of age-0 bloater increased from 0.7 fish per tow in 1998 to 2.2 fish in 1999 (Fig. 5), but is still well below the average catch for the study period. Bloaters have been shown to exhibit density-dependent growth and recruitment, with slower growth and low recruitment – an apparent response to the recent high population density in Lake Michigan; the relative abundance of females in the population has also increased throughout the past 10-15 years to more than 80% (TeWinkel et al. in press).

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). The rainbow smelt population supports commercial fisheries operated

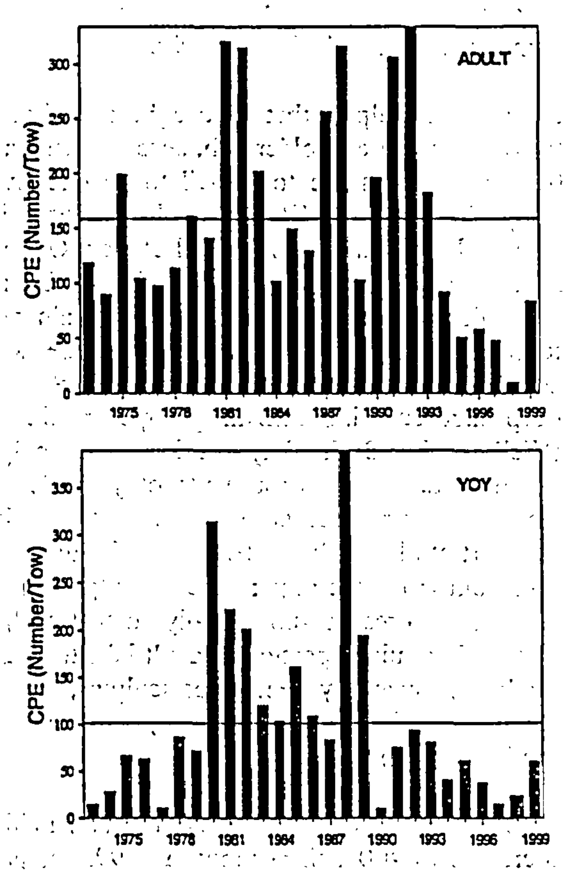

Figure 6. Number of adult (upper panel) and YOY (lower panel) rainbow smelt per tow in Lake Michigan, 1973-1999. Horizontal lines indicates mean catch rate for the period. Note: the 1998 values may not fully represent abundance due to inconsistent trawl data.

in Wisconsin and Michigan waters (Belonger et al. 1998; P. Schneeberger, Michigan Department of Natural Resources, Marquette, MI, personal communication).

Adult rainbow smelt abundance increased from 48 fish per tow in 1997 to 83 fish per tow in 1999 (the 1998 catch rate of 9 fish per tow, the lowest on record, was undoubtedly influenced by gear deployment problems that year) (Fig. 6). The CPE of age-0 rainbow smelt increased to 60 fish per tow in 1999 (Fig. 6). However, the CPEs for age-0 rainbow smelt have remained low throughout the 1990s and have been among the lowest levels since our Lake Michigan bottom trawling survey began in 1973 (Fig. 6).

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).

Most of the sculpins that are caught in the bottom trawls are age-1 and older fish, because many age-0 slimy sculpins are too small to be effectively sampled by the gear (R. Owens, U. S. Geological Survey, Lake Ontario Biological Station, Oswego, NY, personal communication). It is possible that age-0 deepwater sculpins may not be vulnerable to the gear due to their position in the water column; it is unknown whether the age-0 deepwater sculpins remain pelagic in the fall (Wells 1968). Both slimy and deepwater sculpins are important diet constituents of juvenile lake trout in some 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. Sculpins, especially deepwater sculpins, are also eaten by burbot in Lake Michigan (Brown and Stedman 1995).

Catches of deepwater sculpins in Lake Michigan increased to 400 fish per tow in 1999, compared to 232 fish per tow in 1997. The 1973-1997 average for deepwater sculpin abundance was about 270 fish per tow. Slimy sculpin abundance increased from 67 fish per tow in 1997 to 123 fish per tow in 1999. Slimy sculpins have never been as abundant as deepwater sculpins in Lake Michigan during our study period; the 1973-1997 average for slimy sculpin abundance was about 40 fish per tow.

BIOMASS

We estimated a total lake wide biomass of prey fish available to the bottom trawl in 1999 of 153,862 metric tons (t), as compared with 304,011 t in 1997. This total prey fish biomass was the sum of the population biomass estimates for alewife, bloater, rainbow smelt, deepwater sculpin, and slimy sculpin. In 1999, bloaters were still the dominant prey fish biomass in Lake Michigan, however at a much lower level than has been observed in recent years. Together, bloaters composed 30% (45,541 t), alewives 27% (41,580 t), rainbow smelt 3% (4,530 t), and sculpins 28% (slimy sculpins 4,043 t; deepwater sculpins 40,315 t) of the estimated total prey fish biomass (Fig. 7).

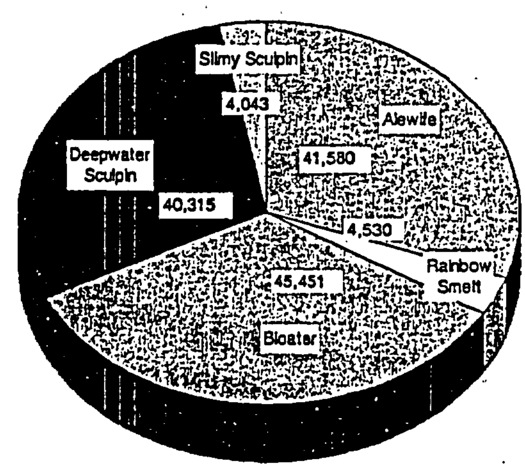

Figure 7. Estimated total biomass (metric tons) of prey fishes in Lake Michigan, 1999, based on bottom trawl surveys.

The overall decline in prey fish biomass in Lake Michigan is due mostly to the consistent decline of bloater biomass throughout the 1990s (Fig. 8). The current bloater biomass is at about 14% of the peak value in 1989. Rainbow smelt biomass has also declined from previous years, to current levels at about 25% of the 1980-1989 average (Fig. 8). Alewife biomass has declined during the 1970s, but fluctuated with no consistent trend between 1893-1999. Recent increases in biomass are chiefly due to strong 1995 and 1998 year-classes. Deepwater sculpin biomass has also been consistent, with a trend of gradual increase in recent years (Fig. 8).

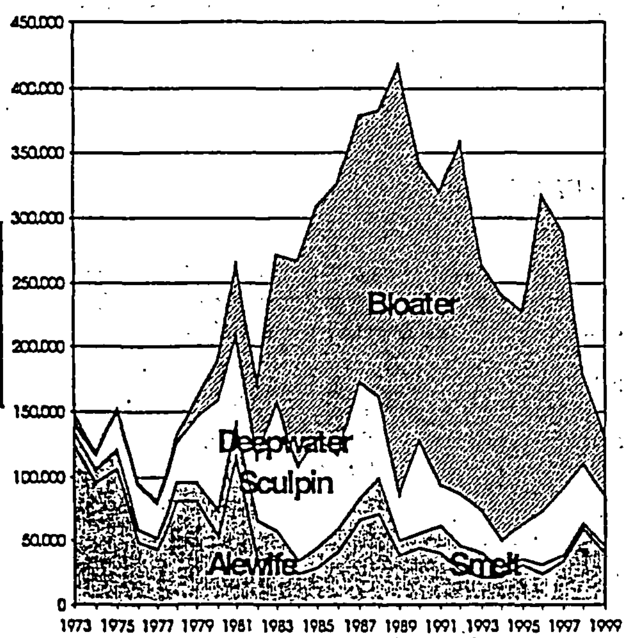

Figure 8. Trends in estimates of biomass for prey fishes in Lake Michigan, 1973-1999.

OTHER SPECIES OF INTEREST

Burbot – Burbot (*Lota lota*) are native to Lake Michigan and along with the lake trout, formed the original top predators in this lake. Though never of great commercial value, burbot were historically abundant as evidenced as by-catch to commercial fisheries. Trends in burbot populations, based on incidental catches to other species, showed declines similar to lake trout, and like the lake trout, appear to have been affected by sea lamprey (Smith 1972). After becoming scarce by the 1960's, burbot began to increase in the 1970's in an apparent response to sea lamprey control (Wells and McClain 1973, Eck and Wells 1987). The ecological conditions allowing, and the implications of the recovery and dominance of burbot in Lake Michigan are discussed by Eshenroder and Burnham-Curtis (1999).

The recovery of burbot is reflected in the trawl surveys where this species has demonstrated a dramatic resurgence in abundance in Lake Michigan. After a period of initial low abundance, catches of burbot in the bottom trawl surveys have increased markedly (Fig. 9). Burbot catches steadily increased during the 1980s and through the early 1990s. Catches peaked in 1997 and subsequently declined again in 1999 (1998 data not available) to suggest their numbers have leveled off. Burbot collected in the bottom trawls are typically large individuals (>350 mm TL); juvenile burbot, absent from the trawl collections, are apparently found shallower or in areas of bottom topography where trawls cannot be deployed.

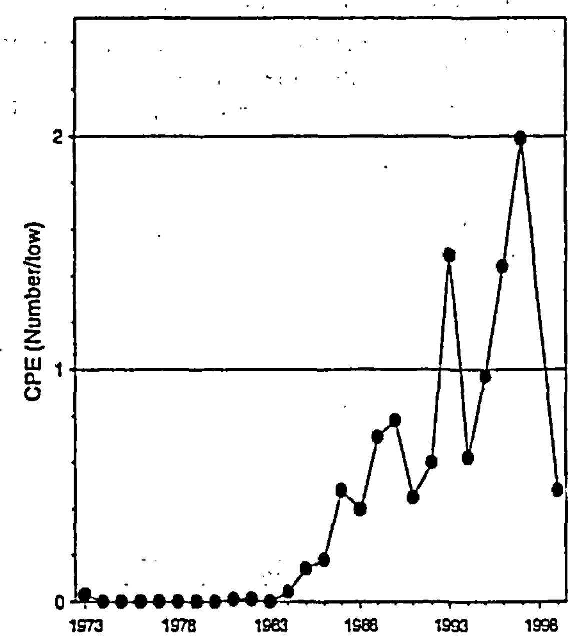

Figure 9. Trend in relative abundance of burbot from annual bottom trawl catches in Lake Michigan, 1973-1999.

Zebra 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), demonstrating their ability for rapid expansion. Based on environmental requirements such as temperature and water hardness, zebra mussels are anticipated to be able to colonize Lake Michigan and its watershed (Strayer 1992).

Up to now, the colonization and expansion of zebra mussels has gone largely unseen in our fish surveys as this bi-valve was observed only incidentally in our bottom trawls. However, in 1999, catches of zebra mussels became significant and we documented the catches from each tow (Fig. 10). Zebra mussels were found in

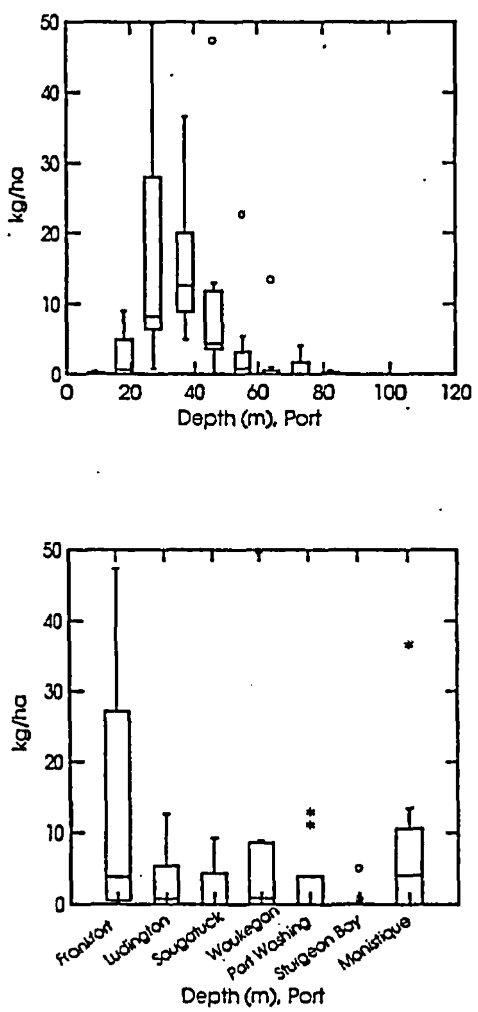

Figure 10. Densities of zebra mussels collected in bottom trawls in Lake Michigan, 1999

tows that ranged 9 to 82 m in depth, with their greatest concentrations at 27-46 m (Fig. 10). Geographically, zebra mussels were found at all ports, but with greatest densities in the north at Frankfort and at and Manistique. Aside from potential impacts on the food web in Lake Michigan (e.g. Madenjian 1995, Hoyle et al. 1999), the infestation of these mussels may also have ramifications on our ability to sample effectively. Fouling of bottom trawls may ultimately require conversion to a design to fish less heavy on bottom, which would necessitate comparison studies to quantify any changes in catchability to the previously established gear (O'Gorman et al. 1999).

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