[illegible] an C[illegible]

[illegible] March[illegible]

S [illegible] 2007[1]

[illegible] P. Ma[illegible] ian, David [illegible] esorcie, and Jean V[illegible]

Ann[illegible]

[illegible] ence Center (GLSC) has cond[illegible] de surveys of the fish communi[illegible] nce 1973 using standard 12-m [illegible] awls towed along contour at dept[illegible] index transects. The resulting [illegible] a on relative abundance, size stru[illegible] shes are used to estimate various population parameters that are in tu[illegible] managing Lake Michigan fish [illegible] ks. All seven established index tr[illegible] in 2007. The survey pr[illegible] lative abundance and biomass [illegible] epth contours of the la[illegible] ke-wide) for prey fish popu[illegible] nd the introduced [illegible] ls and round gobies. [illegible] stimated at 11[illegible] = 1000 metric tons), [illegible] e biomass [illegible]) and rainbow smel[illegible] vely, lo[illegible] ss has declined [illegible] e lo[illegible] melt lake-wid[illegible] er sculpin [illegible] g no[illegible] en decre[illegible] slimy sc[illegible] ncrea[illegible] kt in 200[illegible] k [illegible] in 2007 (2.37 [illegible] 1973-1995. Burb[illegible] ren[illegible] ter a record-high 200[illegible] low pe[illegible] latively high (4.7 fish per [illegible] 04 period. [illegible] ssenid mussels appeared to be [illegible] increasing [illegible] 3-2006. Round goby abundance [illegible] 006 to 1.0 [illegible] Overall, the total lake-wide prey fis[illegible] e, bloater, [illegible] water sculpin, slimy sculpin, and ninespi[illegible] kt, which [illegible] rved since the survey began in 1973.

---

[1] Great Lakes Fishery Commission
Lake Michigan Committee Meeting
Niagara Falls, Ontario
March 20, 2008

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 (using otoliths) and bloaters (using scales) from our bottom trawl catches (Madenjian et al. 2003; Bunnell et al. 2006a). 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 transects are situated off Manistique, Frankfort, Ludington, and Saugatuck, Michigan; Waukegan, Illinois; and Port Washington and Sturgeon Bay, Wisconsin (Figure 1). All seven transects were completed in 2007.

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

c7.8(p)-5.risatiote h (ati(tima.8(of fing)]TJ0 -1.153 TD0.9005 Tc4320602 Twab soa[(guwtoltab s

trout, and yellow perch (Smith 1970; Wells and McLain 1973; Madenjian et al. 2005c; Bunnell et al. 2006b). Additionally, 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 harvest was established in Wisconsin waters of Lake Michigan in the 1960s 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 annual alewife harvest declined from about 7,600 metric tons in 1985 to an incidental harvest of only 12 metric tons after 1990 (Mike Toneys, Wisconsin Department of Natural Resources, Sturgeon Bay, personnel communication). There is presently no

1990s was strongly linked to the dreissenid mussel invasion of the lake (Nalepa et al. 2006).

next 3 to 5 years should allow for testing of this hypothesis.

Numeric density of deepwater sculpins in Lake Michigan decreased from 626 fish per ha in 2006 to 247 fish per ha in 2007 (Figure 6a). Similarly, biomass density of deepwater sculpins in Lake Michigan decreased from 6.5 kg per ha in 2006 to 2.4 kg per ha in 2007 (Figure 6b). These substantial declines may possibly have been due to the bulk of the deepwater sculpin population moving to water deeper than 110 m by 2007 (Madenjian and Bunnell 2008). Neither numeric density nor biomass density of deepwater sculpins had trended downward during 1990-2006 (Figure 6). RSE for deepwater sculpin numeric density was 35% in 2007, which follows a general trend of slightly increasing RSE since 1983 (Figure 3b).

Numeric density of slimy sculpins in Lake Michigan decreased from 701 fish per ha in 2006 to 204 fish per ha in 2007 (Figure 6a). Reasons for this substantial decrease were not clear, but similarly proportioned declines also occurred in 1977 and 2001. RSE for slimy sculpin numeric density was 20% in 2007, which was lower than its average RSE of 38% from 1973-2007 (Figure 3b). Overall, slimy sculpin numeric density showed an increasing trend from the mid 1980s to 2007. This increase was likely attributable to greater emphasis on stocking lake trout on offshore reefs beginning in 1986 (Madenjian et al. 2002). *Diporeia* has dominated the diet of slimy sculpins in Lake Michigan since the 1970s (Madenjian et al. 2002), and *Diporeia* abundance in Lake Michigan has declined during the 1990s and 2000s (Nalepa et al. 2006). The effect of the decrease in *Diporeia* abundance on the slimy sculpin population remains to be determined.

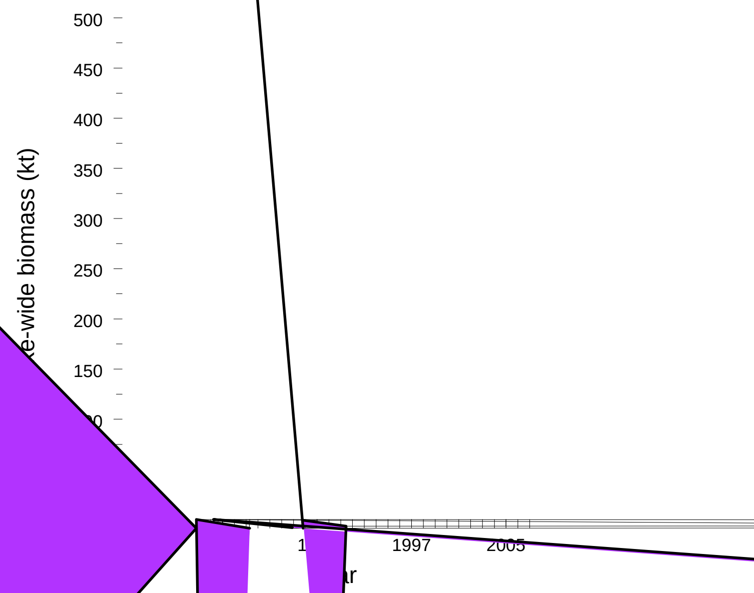
Analysis of bottom trawl survey data indicated that alewives interfering with deepwater sculpin reproduction and predation by burbot on deepwater sculpins are the most important factors affecting deepwater sculpin abundance in Lake Michigan (Madenjian et al. 2005c). The survey data provided no evidence that slimy sculpins negatively affected deepwater sculpin abundance.

<u>Ninespine stickleback</u> – Given the increasing abundance of ninespine stickleback in Lake Michigan and its occasional occurrence in the diets of salmonines and lake trout, we added this species to our annual report. Two stickleback species occur in Lake Michigan. Ninespine stickleback is native, whereas threespine stickleback is non-native and was first collected in the GLSC bottom trawl survey during 1984 (Stedman and Bowen 1985). Ninespine stickleback is generally captured in greater densities than the threespine, especially in recent years. Relative to other preyfishes, ninespine sticklebacks are of minor importance to lake trout and other salmonines. In northern Lake Michigan, for example, sticklebacks occur infrequently in the diet of lake trout (Elliott et al. 1996). Numeric density of ninespine stickleback 1

h coincided with their increase in

ide biomass of prey
l in 2007 of 31.04
tons) (Figure 8,
ass was the
nates for
pwater
ack.

e Michigan has
, and is largely a
decrease in bloater
current bloater biomass
value in 1989. Total prey
rease slightly between 2000
increase in alewife biomass, in
exceptionally large 1998 alewife
gure 9). The decline in total prey
ass between 2002 and 2005 was
y driven by a decrease in alewife biomass.
decline between 2005 and 2007, however,
s largely due to a continued decrease in lake-
wide biomass of bloater and a substantial drop in
deepwater sculpin lake-wide biomass between
2006 and 2007. The total lake-wide biomass of
prey fish available to the bottom trawl in 2007 was the lowest biomass recorded in our time series.



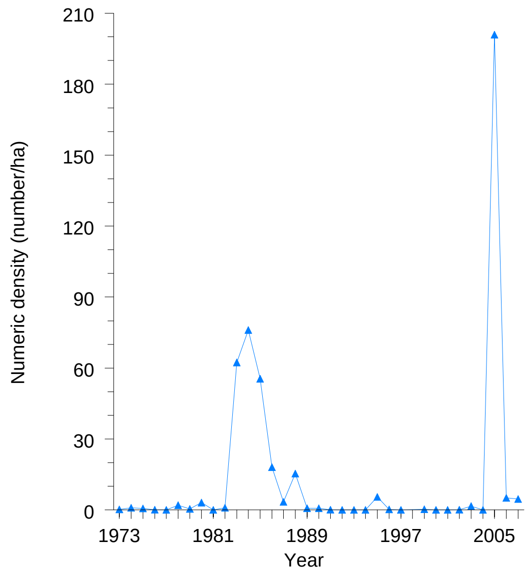
OTHER SPECIES OF INTEREST

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.

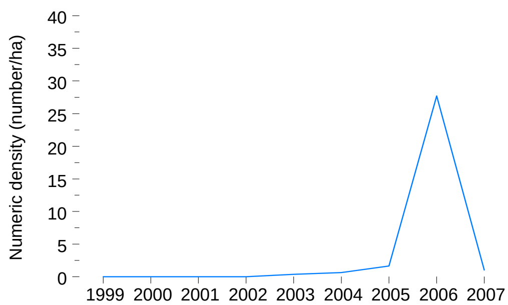
Burbot collected in the bottom trawls are typically large individuals (>350 mm TL); juvenile burbot apparently inhabit areas not covered by the bottom trawl survey.

Burbot numeric density in 2007 (0.49 fish per ha) was similar to that of 2006 (0.44 fish per ha) (Figure 10). After a period of low numeric density in the 1970s, burbot showed a strong recovery in the 1980s. Densities increased through 1997, although we interpret the trend as a leveling off between 1990 and 2001. Since 2001, however, burbot densities decreased, perhaps partly due to increased predation by sea lampreys. Lake-wide estimates of spawning sea lampreys have generally been increasing since 2000 (D. Lavis, U. S. Fish and Wildlife Service, Ludington, MI, personal communication).

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 numeric density, which serves as an indication of yellow perch recruitment success. The 2005 year-class of yellow perch was the largest ever recorded (Figure 11). This huge year-class was likely attributable to a sufficient abundance of female spawners and favorable weather. Numeric density of the 2007 year-class was 4.7 fish per ha, which was relatively high compared with most year-classes between 1989 and 2007 (Figure 11). Most researchers believe that the poor yellow perch recruitment that occurred during 1989-2000 (Figure 11) was a combination of several factors, including poor weather conditions, low abundance of female spawners, and possibly a low availability of zooplankton for yellow perch larvae (Makauskas and Clapp 2000).



Round goby 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 were captured by Michigan DNR personnel in the southern main basin of the lake as early as 1997 (Clapp et al. 2001). Round gobies were first caught in the GLSC bottom trawl survey in 2003. Round goby numeric density increased exponentially during 2003-2006, attaining a level of 27.7 fish per ha in 2006 (Figure 12a). However, numeric density suddenly dropped to 1.0 fish per ha in 2007. Round gobies have been caught at all transects except at Frankfort and at Port Washington. With additional years of continued surveillance, results from the GLSC bottom trawl survey 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, biomass density of dreissenid mussels was highest in 2007 (Figure 12b), exhibiting a 16% increase over the 2006 level. Biomass density of dreissenid mussels increased exponentially during 2003-2006, and this increase was likely due to the greater proportion of quagga mussels in Lake Michigan (T. Nalepa, NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, MI, personal communication). Relative to the zebra mussel, quagga mussels can reproduce at lower temperatures (Roe and MacIsaac 1997) and, in turn, greater depths. As a result the distribution of dreissenid mussels has increased, likely as a result of the quaggas (Bunnell et al., in review).



Management Reports, Wisconsin Department of Natural Resources. Lake Michigan Committee Meetings, Great Lakes Fishery Commission, Thunder Bay, Ontario, March 16-17, 1998.

Brown, E. H., Jr., and R. M. Stedman. 1995. Status of forage fish stocks in Lake Michigan, 1994. Pages 81-88 in Minutes of Great Lakes Fishery Commission, Lake Michigan Committee Meeting, Milwaukee, Wisconsin, March 29-30, 1995.

Bunnell, D. B., C. P. Madenjian, and T. E. Croley II. 2006a. Long-term trends of bloater recruitment in Lake Michigan:

of the benthic amphipod *Diporeia* spp. in Lake Michigan: is there evidence for food limitation? Can. J. Fish. Aquat. Sci. 63:872-890.

Potter, R. L. and G. W. Fleischer. 1992. Reappearance of spoonhead sculpins (*Cottus ricei*) in Lake Michigan. J. Great

Appendix 1. Mean numeric and biomass density, as well as lake-wide biomass (defined as biomass available to the bottom trawls for the region of the main basin between the 5-m and 114-m depth contours) estimates for various fishes and dreissenid mussels in Lake Michigan during 2007. Estimates are based on the bottom trawl survey. Standard error enclosed in parentheses. NA denotes that estimate is not available.

Taxon	Numeric density (fish per ha)	Biomass density (kg per ha)	Lake-wide biomass (kt)
age-0 alewife	5.28 (5.12)	0.028 (0.027)	0.099 (0.095)
adult alewife	141.54 (71.96)	3.287 (1.760)	11.575 (6.198)
age-0 bloater	1.02 (0.38)	0.009 (0.003)	0.030 (0.011)
adult bloater	37.00 (14.86)	1.522 (0.618)	5.360 (2.177)
age-0 rainbow smelt	4.49 (1.81)	0.007 (0.002)	0.024 (0.008)
adult rainbow smelt	27.46 (8.03)	0.244 (0.074)	0.858 (0.261)
deepwater sculpin	247.06 (86.38)	2.422 (0.767)	8.529 (2.702)
slimy sculpin	204.07 (40.85)	0.624 (0.122)	2.199 (0.431)
ninespine stickleback	373.66 (189.94)	0.674 (0.325)	2.372 (1.145)
burbot	0.49 (0.21)	0.541 (0.250)	1.905 (0.882)
age-0 yellow perch	4.68 (4.68)	0.002 (0.002)	0.006 (0.006)
round goby	1.02 (0.83)	0.006 (0.004)	0.022 (0.013)
dreissenid mussels	NA	69.716 (29.195)	245.515 (102.813)