Lake Superior Committee
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Status and Trends of Prey Fish Populations in Lake Superior, 2008[1]

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Abstract

The Great Lakes Science Center has conducted annual daytime bottom trawl surveys of the Lake Superior nearshore (15-80 m bathymetric depth zone) every spring since 1978 to provide a long-term index of relative abundance and biomass of the fish community. Between May 5 and June 14, 2008, 58 stations were sampled around the perimeter of the lake with 12-m wide bottom trawls. Trawls were deployed cross-contour at median start and end depths of 17 and 55 m, respectively. The lakewide mean relative biomass estimate for the entire fish community was 4.61 kg/ha which was similar to that measured in 2007, 4.81 kg/ha. Dominant species in the catch were lake whitefish, rainbow smelt, longnose sucker and cisco, which represented 49, 18, 11, and 7 % of the total community biomass, respectively. Compared to 2007 levels, lake whitefish and cisco biomass increased 35% and 55%, respectively, while bloater and rainbow smelt biomass declined 69% and 41%, respectively. Increased biomass of lake whitefish and decreased biomass in bloater represent trends observed since 2007; however, reversed trends in biomass were observed for cisco and rainbow smelt. Year-class strength for the 2007 cisco cohort (0.20 fish/ha) was below the long-term (1977-2007) average (73.31 fish/ha), as was year-class strength for the 2007 bloater cohort (0.33 fish/ha) compared to the long-term average (11.11 fish/ha). Smelt year class strength (226.26 fish/ha) continues a trend of increasing strength from a 31-year low of 56.75 fish/ha in 2001 and was above the long-term average of 193.81 fish/ha. The 2008 cisco age structure was dominated by age 5 and older fish, which accounted for 82% of the mean relative density. Wisconsin waters continue to be the most productive (mean total community biomass of 17.09 kg/ha), followed by western Ontario (5.40 kg/ha), eastern Ontario (3.08 kg/ha), Michigan (2.82 kg/ha), and Minnesota (0.89 kg/ha).

Densities of small (< 226 mm), intermediate (226-400 mm) and large (>400 mm) hatchery lake trout continued a pattern of decline observed since 1993-1996 to 0.04, 0.03 and 0.01 fish/ha in 2008, respectively. Densities of small and large wild (lean) lake trout continued a decreasing trend observed since 1996-1998. From 2007 to 2008, density of small lean lake trout declined from 0.29 to 0.15 fish/ha, the lowest value since 1978. Density of large lean lake trout has been relatively stable since 1986 but more recently density declined from 0.43 fish/ha in 2006 to 0.10 fish/ha in 2008. Density of intermediate size lean lake trout showed a small increase from 0.31 in 2007 to 0.41 fish/ha in 2008. Siscowet lake trout have shown a pattern of variable but increasing density since 1980. Since 2006, densities of small and intermediate size siscowet lake trout have increased from 0.10 to 0.12 and 0.08 to 0.15 fish/ha, respectively. Densities of large siscowet lake trout have fluctuated between 0.10 and 0.07 fish/ha since 2000. In 2008 the proportions of total lake trout density that were hatchery, lean and siscowet were 8, 60, and 32%, respectively.

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Introduction

The Great Lakes Science Center's Lake Superior Biological Station (LSBS) conducts an annual daytime bottom trawl survey every spring in Lake Superior. The survey is intended to provide a long-term index of relative abundance and biomass of Lake Superior's fish community in nearshore waters. The survey began in 1978 in United States (U.S.) waters with 43-53 stations and was expanded in 1989 to include Canadian waters, increasing the total sampling effort to 76-86 stations. In 2005, the number of stations sampled lake-wide was reduced to 51 after it was found that this smaller sample yielded similar estimates of relative biomass of major species (Stockwell et al. 2006a). In this report, we update the time series of relative density and biomass with data collected in 2008 from 58 stations.

Methods

Spring Survey

The annual spring daytime bottom trawl assessment dates back to 1978 and was designed to provide relative abundance measures for the fish community in the nearshore waters of Lake Superior (15-80 m bathymetric depth, 16% of the lake area). We have previously demonstrated the inherent sampling biases in day bottom trawl sampling, particularly in under representing abundance of adult cisco *Coregonus artedi* (Stockwell et al. 2006b, 2007b; Yule et al. 2008a). Moreover, our sampling does not assess the fish community of the inshore zone (0-15 m depth) nor the offshore zone (> 80 m), these zones representing approximately 7 and 77% of the lake area, respectively. Despite these limitations, the survey results provide reliable measures of long-term trends in fish community structure and relative abundances of resident species (Gorman and Hoff 2009). We have begun development of a new sampling design for the nearshore and offshore zones that addresses the limitations of the present survey design; implementation is expected in 2011-2012. The new design will remain compatible with the historic survey and will integrate day and night bottom trawl sampling and hydroacoustics. No plans yet exist for assessing the fish community of the inshore zone, but this is an subject of active research by us and we are evaluating the efficacy of several sampling methodologies.

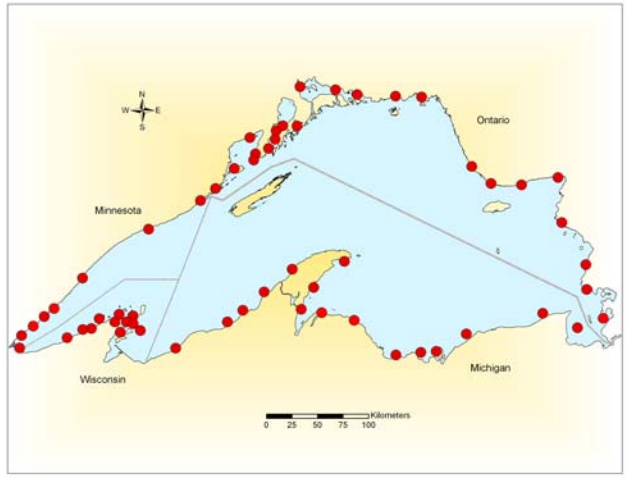

Figure 1. *Locations of 58 stations sampled during the 2008 annual spring bottom trawl survey in Lake Superior.*

A total of 58 stations distributed around the perimeter of Lake Superior were sampled with bottom trawls during daylight hours between May 5 and June 14, 2008 (Fig. 1). We were able to sample fish at 54 of the 58 stations that were identified in 2005 as adequate for estimating relative biomass of principal prey species in Lake Superior (Stockwell et al. 2006a). These 58 stations represented a subset of 85 stations sampled annually during 1978-2004. Four stations were added in 2008 because of favorable logistics.

Trawl samples were taken as a single cross-contour tow at each station. Median start and end depths for bottom trawl tows were 17 m (range 10-35 m, interquartile range 15-20 m) and 55 m (range 19-134 m, interquartile range 50-70 m), respectively. Median trawl tow duration was 24 minutes (range 8-62 minutes, interquartile range 19-30 minutes).

For each trawl tow, fish were sorted by species, counted, and weighed in aggregate by species to the nearest gram. Relative density (fish/ha) was estimated from sample counts and biomass (kg/ha) was estimated by aggregate weights expressed in kg divided by the number of hectares swept. These estimates were then modified by the station-specific weighting given in Stockwell et al. (2006a) to retain comparability with unweighted data prior to 2005. For important prey species (cisco, bloater *C. hoyi*, rainbow smelt *Osmerus mordax*, lake whitefish *C. clupeaformis*, year-class strength was estimated as the relative density (fish/ha) of age-1 fish, the first age-class that recruits to the bottom trawl in the spring. Densities of age-1 fish were estimated from densities of rainbow smelt < 100 mm, lake whitefish < 160 mm, cisco < 140 mm, and bloater < 130 mm. To be consistent with past reports and to more easily identify the year in which a cohort was produced, year-class strength is plotted against the year in which the cohort was produced (year sampled minus 1) and not the year the age-1 fish were caught. Standard errors (SE) for years prior to 2005 (the first year that sub-sampling of stations occurred) were calculated as SD/√n, where SD = the sample standard deviation and n = number of observations. Because weighted means were used after 2004, the denominator for calculating SE was the square root of the sum of the weights. The SE was standardized by the mean to generate relative standard error (RSE = SE/mean*100). An RSE of 100% indicates the standard error was equal to the estimated mean.

To determine the age structure of Lake Superior cisco in 2008, we used a length-age key to estimate relative density of each age-class as a function of length. To stratify sampling of fish for age determination, we divided Lake Superior into nine regions, and took a maximum of 10 cisco per 10-mm length bin for each region (50-400 mm range). Ages for all cisco were estimated from scales by a single trained reader; age estimates from otoliths were not available in 2008.

Because we were limited to application of scale age data in 2008, we recognized that the resulting estimate of age composition of cisco would likely be inaccurate as suggested by Yule et al. (2008b). To address this deficiency, we developed a statistical age key similar to that developed for rainbow smelt and cisco (Gorman 2007; Gorman et al. 2008) to estimate age composition of cisco. Reliable estimates of mean size at age are required to develop a statistical age key and we used age data based on scales and otoliths collected in 2000-2006. Because scales become less reliable as aging structures as coregonids mature (Aass 1972; Mills and Beamish 1980; Yule et al. 2008b), we used scales for fish < 250 mm and otoliths for fish ≥ 250 mm. Age estimates from otoliths were acquired by the crack and burn method (Schreiner and Schram 2001). Using this 2000-2006 age data, we generated size-at-age distributions for age classes 1 to 10 years. A default age key based on a composite catch curve and size-at-age distributions was then modified by weighting age classes by the relative abundance of their age-1 abundance. This weighted statistical age key was then applied to 2008 length-frequency distribution to estimate size-age specific density distributions.

Results

Cisco

Year-class strength for the 2007 cisco cohort was estimated at 0.20 fish/ha (Fig. 2A). This value was the sixth weakest recorded year-class strength observed over the 31-year survey and one of six year classes of ≤ 1 fish/ha observed since 1999. Year-class strength for the 2007 cohort in U.S. waters was 0.32 fish/ha and no yearling cisco were captured in Canadian waters. For comparison, the density of the strong 2003 year class was estimated at 182.25 fish/ha and moderate 2002 and 2005 year classes at 35.12 and 24.66 fish/ha, respectively (Fig. 2A). RSE estimated for the 2007 year class was 36% which is lower than the series average of 51% (Fig. 2B), a result of zero modal densities lake-wide. The RSE for cisco year-class strength (Fig. 2B) exceeded the level of precision (no greater than ± 30% of the mean) recommended by Walters and Ludwig (1981) for stock-recruit data sets.

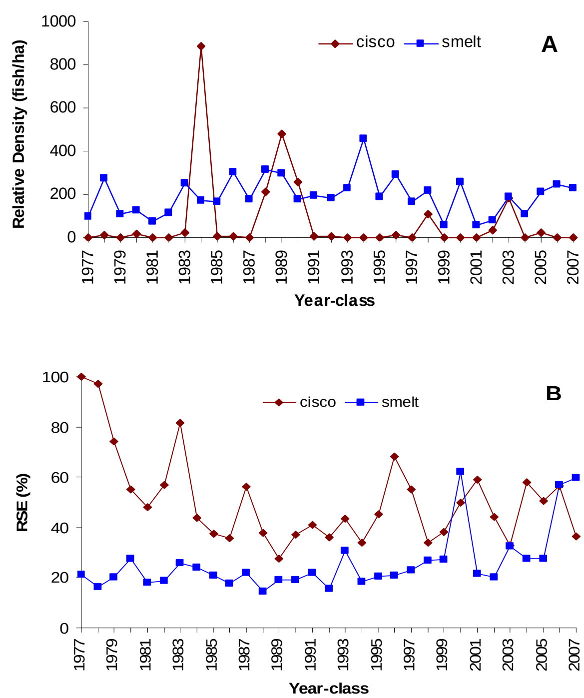

Figure 2. ***(A)*** *Year-class strength (number of age-1 fish/ha) for cisco and rainbow smelt for all nearshore sampling stations in Lake Superior for cohorts produced from 1977 to 2007. Only U.S. waters were sampled for the 1977-1988 year classes.* ***(B)*** *RSE (relative standard error) of year-class strengths.*

Mean relative biomass of age-1 and older cisco (0.31 kg/ha) in 2008 was higher than in 2007 (0.20 kg/ha) (Fig. 3A). This small increase in biomass did not change the downward trend in biomass observed since 2004-2006 when biomass averaged ≥ 1.80 kg/ha and is well below the long term 1978-2006 average of 2.90 kg/ha. The RSE of the 2008 estimate was 38% in 2008, which was lower than the survey average of 43% (Fig. 3B).

Trends in relative cisco biomass by jurisdiction from 2007 to 2008 were mixed: declines were observed in Michigan (0.25 to 0.02 kg/ha) and E. Ontario (0.12 to 0.01 kg/ha) while increases were recorded in Wisconsin (0.37 to 1.68 kg/ha), Minnesota (0.00 to 0.02 kg/ha) and W. Ontario (0.14 to 0.31 kg/ha; Figs. 4 and 5). Relative biomass estimates as a percent of long-term means were low in Wisconsin (26%), Minnesota (17%) and W. Ontario (17%) and very low in Michigan (0.6%) and E. Ontario (0.4%).

The mean relative density of all cisco showed a declining trend from 44.86 fish/ha in 2006 to 3.15 fish/ha in 2007 to 2.38 fish/ha in 2008. Age structure of cisco in 2008, expressed as the relative density of each age-class by length, is shown based on scale ages and a weighted statistical age-length

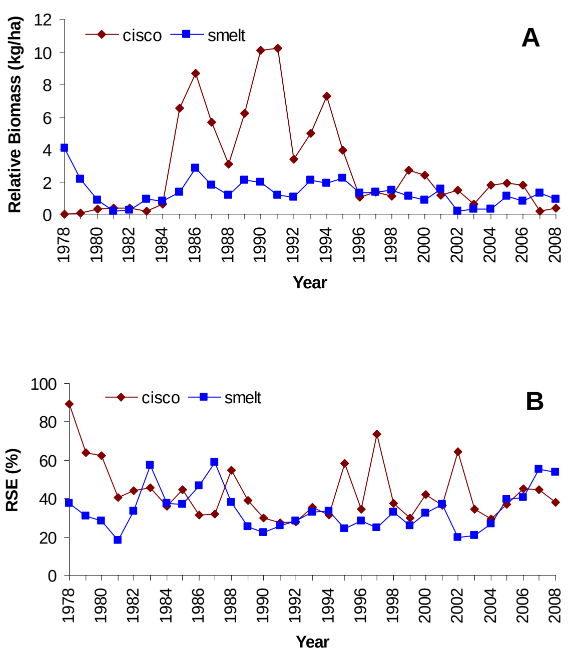

Figure 3. ***(A)*** *Mean relative biomass (kg/ha) of age-1 and older cisco and rainbow smelt for all nearshore sampling stations in Lake Superior, 1978-2008. Canadian waters were not sampled until 1989.* ***(B)*** *RSE (relative standard error) of mean biomass.*

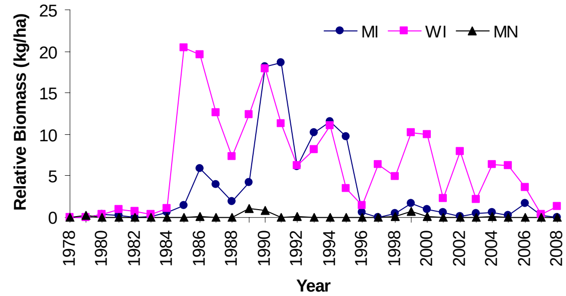

Figure 4. *Mean relative biomass (kg/ha) of age-1 and older cisco in Michigan (MI), Wisconsin (WI), and Minnesota (MN) nearshore waters of Lake Superior, 1978-2008.*

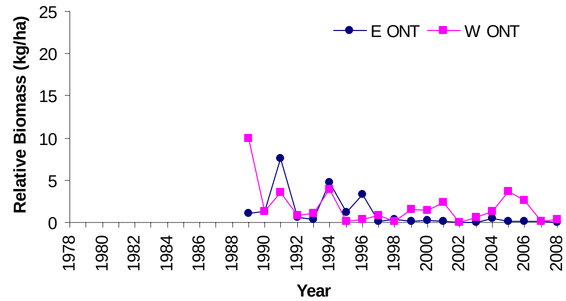

Figure 5. *Mean relative biomass (kg/ha) of age-1 and older cisco in eastern and western Ontario nearshore waters of Lake Superior, 1989-2008. Eastern and western Ontario waters are divided in the northeast corner of Lake Superior near Marathon, Ontario.*

key (Fig. 6). Differences in the two distributions are the result of systematic under-aging from scales (Yule et al. 2008b); there were too many fish ≥ age-4 classified as younger fish. Thus, we judged the distribution based on the weighted statistical age key to be more reliable for interpreting the 2008 cisco age structure (Fig. 6B). The 2008 cisco age structure was dominated by the 2003 year class (age-5) and older fish, which combined accounted for 82% of the mean relative density (Fig. 6B). The 1998, 2002, 2003, 2005 and the most recent 2007 cohorts accounted for 3, 33, 39, 6 and 9% of the mean relative density, respectively. Older cohorts (≥ age-7) represented 10% of the mean relative density (Fig. 6B).

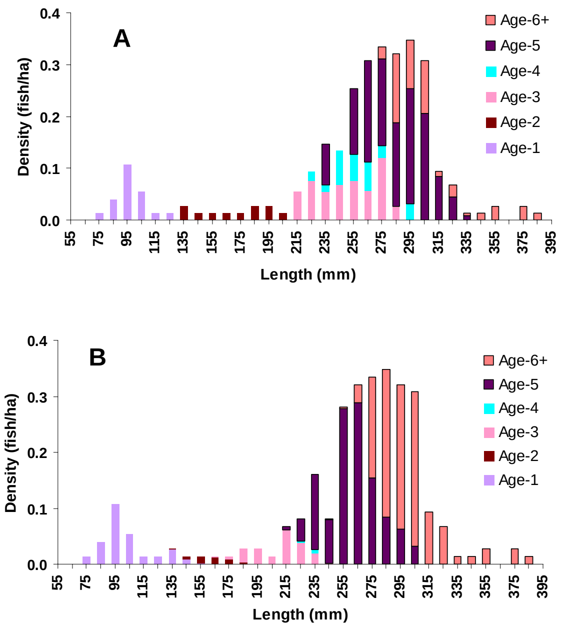

Figure 6. *Age-length distribution of cisco caught at all nearshore sampling stations in Lake Superior in 2008. Panel **A** shows the distribution based on a scale age key and panel **B** shows the distribution based on a weighted statistical age key.*

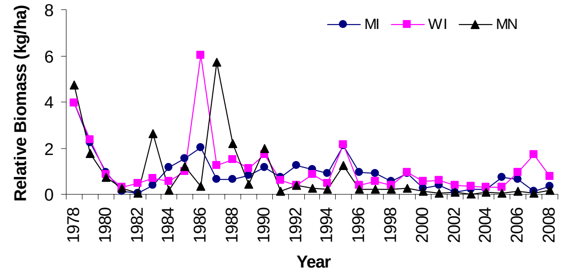

Figure 7. *Mean relative biomass (kg/ha) of age-1 and older rainbow smelt in Michigan, Wisconsin, and Minnesota nearshore waters of Lake Superior, 1978-2008.*

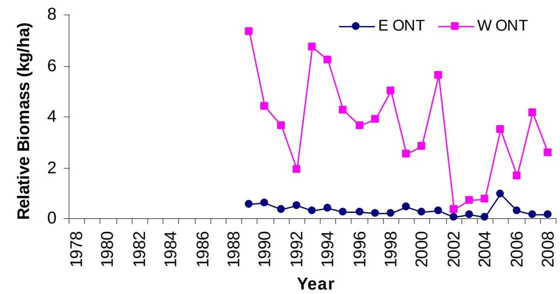

Figure 8. *Mean relative biomass (kg/ha) of age-1 and older rainbow smelt in eastern and western Ontario nearshore waters of Lake Superior, 1989-2008.*

Rainbow Smelt

Year-class strength of rainbow smelt decreased from 246.58 fish/ha for the 2006 cohort to 226.26 fish/ha for the 2007 cohort (Fig. 2A). Year-class strength for the 2007 cohort was greater (128%) than the average over the 31-yr survey period (193.81 fish/ha). RSE was relatively high (60%, Fig. 2B) relative to the 31-yr average (26%), likely caused by high variation in catches across jurisdictions. The 2007 year-class was stronger in Canadian waters (525.96 fish/ha) than in U.S. waters (55.24 fish/ha).

Mean relative biomass for age-1 and older rainbow smelt decreased 41% from 2007 (1.29 kg/ha) to 2008 (0.76 kg/ha; Fig. 3A) and was 57% of the 31-year mean of 1.33 kg/ha. Although biomass was lower in 2008, it is consistent with a recent trend of increasing biomass since 2005 and contrasts with a period of low biomass from 2002 to 2004. RSE for 2008 was 54%, which is within the 31 year survey range of 18-59% (Fig. 3B).

Relative biomass of rainbow smelt declined in Wisconsin waters from 1.70 kg/ha in 2007 to 0.77 kg/ha in 2008. In contrast, biomass increased in Michigan and Minnesota waters from 0.12 to 0.34 and 0.06 to 0.15 kg/ha, respectively (Fig. 7). Rainbow smelt biomass in W. Ontario waters decreased from 4.14 kg/ha in 2007 to 2.59 kg/ha in 2008 (Fig. 8) while biomass in E. Ontario waters increased slightly from 0.13 kg/ha in 2007 to 0.17 kg/ha in 2008.

Bloater

As in 2007, bloater year-class strength (0.3 fish/ha) remained low and contrasts sharply with the 2005 cohort (15.84 fish/ha; Fig. 9A) and is well below the 31-year average of 11.11 fish/ha. Year-class strength was greater in U.S. waters (0.49 fish/ha) compared to Canadian waters (0.09 fish/ha). RSE of bloater yearling density in 2008 was 56%, which is within the 31-year survey range of 22-65% (Fig. 9B).

Mean relative lake-wide biomass of age-1 and older bloater declined from 0.61 kg/ha in 2007 to 0.19 kg/ha in 2008 and contrasts with a recent peak of 1.36 kg/ha in 2006 (Fig. 10A). The 2008 relative biomass estimate is the lowest value observed since 1978 when it was 0.13 kg/ha. RSE for 2008 was 40%, which is within the 31-year survey range of 32-64% (Fig. 10B).

Between 2007 and 2008, bloater biomass declined slightly in Michigan from 0.68 to 0.64

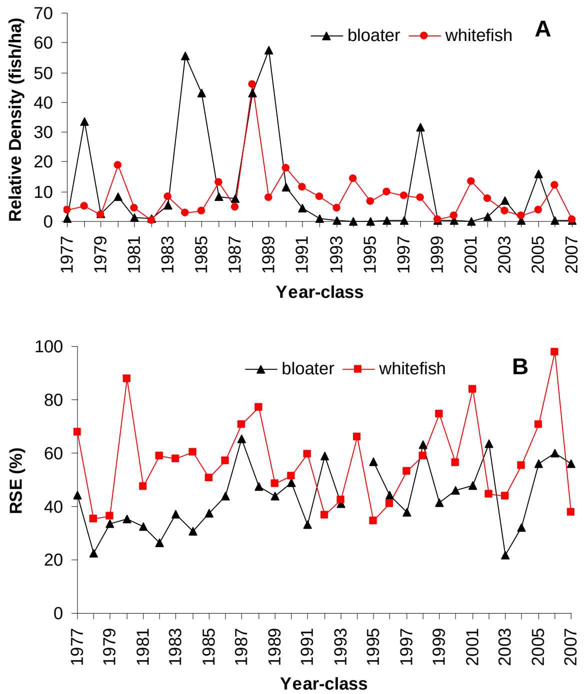

Figure 9. ***(A)*** *Year-class strength (number of age-1 fish/ha) for bloater and lake whitefish for all nearshore sampling stations in Lake Superior for cohorts produced from 1977 to 2007. Only U.S. waters were sampled for the 1977-1988 year-classes.* ***(B)*** *RSE (relative standard error) of year-class strengths.*

kg/ha and showed a sharp decline in Wisconsin from 1.54 to 0.29 kg/ha (Fig. 11). A small increase was observed in Minnesota (0.00 to 0.01 kg/ha; Fig. 11). Bloater biomass increased in W. Ontario (0.04 to 0.10 kg/ha) but decreased sharply in E. Ontario (0.68 to 0.02 kg/ha; Fig. 12).

Lake Whitefish

Lake whitefish year-class strength decreased from 12.27 fish/ha in 2007 to 0.54 fish/ha for the 2008 cohort (Fig. 9A). RSE for lake whitefish year-class strength was 38%, which is within the 31-year survey range of 35-98% (Fig. 9B). The 2007 year-class was stronger in U.S. (0.61 fish/ha) than in Canadian waters (0.44 fish/ha). Average year-class strength for lake whitefish over the 31-year survey period is 8.27 fish/ha.

Mean relative biomass for age-1 and older lake whitefish in all waters increased from 1.51kg/ha in 2007 to 2.04 kg/ha in 2008 (Fig. 10A). Overall, this estimate is consistent with a pattern of relatively little change in biomass since 1996. RSE for 2008 was 41%, which is within the 31-year survey range

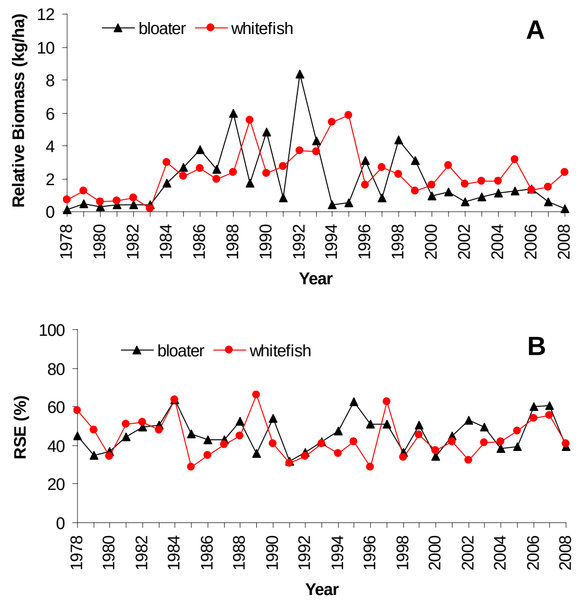

Figure 10. ***(A)*** *Mean relative biomass (kg/ha) of age-1 and older bloater and lake whitefish for all nearshore sampling stations in Lake Superior, 1978-2008. Canadian waters were not sampled until 1989.* ***(B)*** *RSE (relative standard error) of mean biomass.*

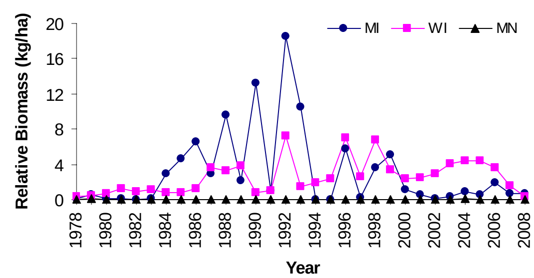

Figure 11. *Mean relative biomass (kg/ha) of age-1 and older bloater in Michigan, Wisconsin, and Minnesota nearshore waters of Lake Superior, 1978-2008.*

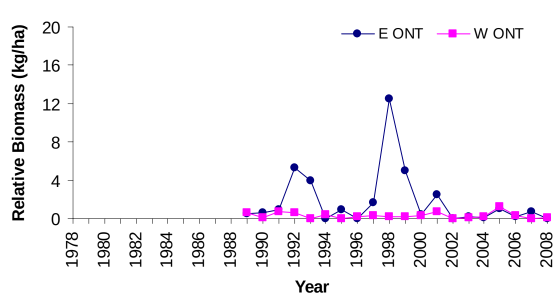

Figure 12. *Mean relative biomass (kg/ha) of age-1 and older bloater in eastern and western Ontario nearshore waters of Lake Superior, 1989-2008.*

of 29-66% (Fig. 10B).

Whitefish biomass increased across U.S. jurisdictions. In Wisconsin, biomass increased from 6.90 kg/ha in 2007 to 11.77 kg/ha in 2008, in Michigan from 0.38 to 1.05 kg/ha and in Minnesota from 0.00 to 0.63 kg/ha (Fig. 13). The 2008 survey represents only the second time that lake whitefish were caught in Minnesota waters since 1978. In Canadian waters, biomass decreased in W. Ontario from 0.49 to 0.38 kg/ha and E. Ontario from 0.34 to 0.26 kg/ha (Fig. 14).

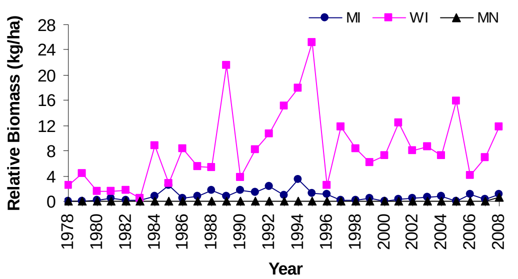

Figure 13. *Mean relative biomass (kg/ha) of age-1 and older lake whitefish in Michigan, Wisconsin, and Minnesota nearshore waters of Lake Superior, 1978-2008.*

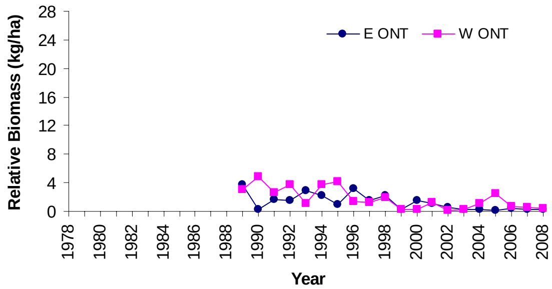

Figure 14. *Mean relative biomass (kg/ha) of age-1 and older lake whitefish in eastern and western Ontario nearshore waters of Lake Superior, 1989-2008.*

Other Species

Ninespine stickleback – Estimates of mean relative biomass for ninespine stickleback *Pungitius pungitius* showed a small decrease between 2007 (0.04 kg/ha) and 2008 (0.03 kg/ha; Fig. 15). Mean relative biomass for all waters since 1997 was 0.04 kg/ha whereas mean biomass between 1978 and 1996 was 0.21 kg/ha.

Sculpins – Mean relative biomass for all three sculpin species combined (spoonhead *Cottus ricei*, slimy *C. cognatus*, and deepwater *Myoxocephalus thompsoni*) followed a declining trend similar to that observed for ninespine sticklebacks since 1993 (Fig. 15). In the recent 2006-2008 interval, annual estimates of sculpin relative biomass have remained low (0.04 kg/ha). Deepwater sculpins were 51% of total sculpin biomass in 2008, followed by slimy (41%) and spoonhead (8%) sculpins. Although deepwater sculpins dominated the assemblage in 2006-2007, slimy sculpins were the dominant species in the group from 1978-2005, with the exception of 1984 when deepwater sculpins represented 55% of the biomass. Slimy sculpins averaged >68% of the total sculpin biomass across all years, but represented a higher percentage from 1978 to 1983 (81%) compared to 1984 to 2001 (64%) and 2002-2008 (36%).

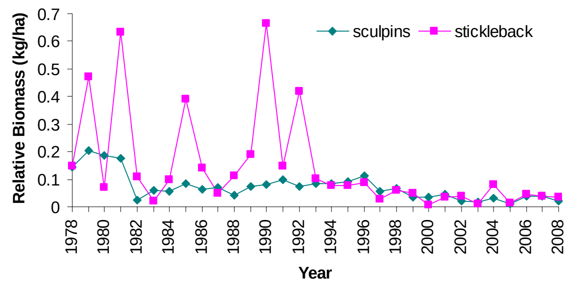

Figure 15. *Mean relative biomass (kg/ha) of age-1 and older ninespine stickleback and sculpins (slimy, spoonhead, and deepwater combined) for all nearshore sampling stations in Lake Superior, 1978-2008. Canadian waters were not sampled until 1989.*

Lake Trout – Because our bottom trawls capture a broad spectrum of lake trout *Salvelinus namaycush* sizes and life stages, biomass indices are sensitive to variable capture of large adult fish (Stockwell et al. 2007a). Therefore, as introduced in the previous report (Gorman et al. 2008), we summarized our lake trout data as density by size bins: small, < 226 mm (≤ ca., age-3), intermediate, 226-400 mm (ca., age 4-8), and large, > 400 mm (>ca., age-8). To dampen inter-annual variation in our density estimates, we expressed annual density using 2-year moving averages for hatchery and wild (lean) lake trout, and 3-year moving averages for siscowet lake trout.

Densities of small, intermediate and large hatchery lake trout continued a pattern of decline observed since 1993-1996 to 0.04, 0.03 and 0.01 fish/ha in 2008, respectively (Fig. 16).

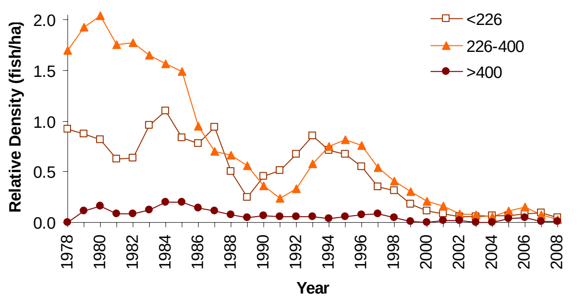

Figure 16. *Mean relative density (fish/ha) of age-1 and older hatchery lake trout for all nearshore sampling stations in Lake Superior, 1978-2008. Canadian waters were not sampled until 1989. Densities are shown for three length bins: <226 mm, 226-400 mm, and >400 mm TL.*

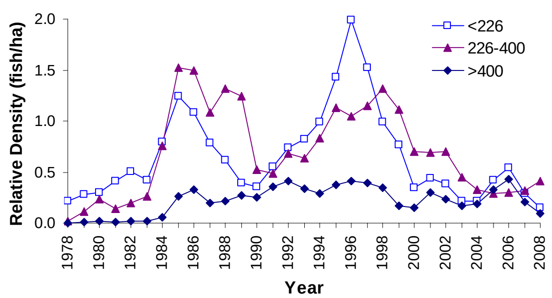

Figure 17. *Mean relative density (fish/ha) of age-1 and older wild (lean) lake trout for all nearshore sampling stations in Lake Superior, 1978-2008. Canadian waters were not sampled until 1989. Densities are shown for three length bins: <226 mm, 226-400 mm, and >400 mm TL.*

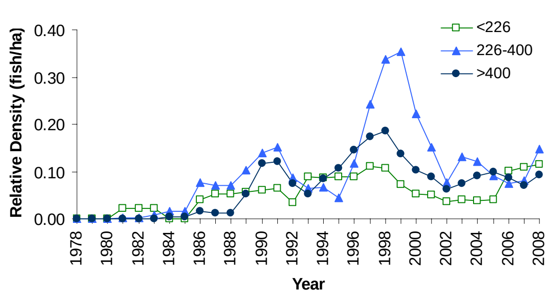

Figure 18. *Mean relative density (fish/ha) of age-1 and older siscowet lake trout for all nearshore sampling stations in Lake Superior, 1978-2008. Canadian waters were not sampled until 1989. Densities are shown for three length bins: <226, 226-400, and >400 mm TL.*

Densities of small and large wild lake trout continued a decreasing trend since 1996-1998 (Fig. 17). From 2007 to 2008, density of small lean lake trout declined from 0.29 to 0.15 fish/ha, the lowest value since 1978. Density of large lean lake trout has been relatively stable since 1986 but more recently density declined from 0.43 fish/ha in 2006 to 0.10 fish/ha in 2008. Density of intermediate size lean trout showed a small increase from 0.31 in 2007 to 0.41 fish/ha in 2008.

Siscowet lake trout have shown a pattern of variable but generally increasing density since 1980 (Fig. 18). Since 2006, densities of small and intermediate size siscowet lake trout have increased from 0.10 to 0.12 and 0.08 to 0.15 fish/ha, respectively. Densities of large siscowet lake trout have fluctuated between 0.10 and 0.07 fish/ha since 2000.

In 2008 the proportions of total lake trout density that were hatchery, lean and siscowet were 8, 60, and 32%, respectively.

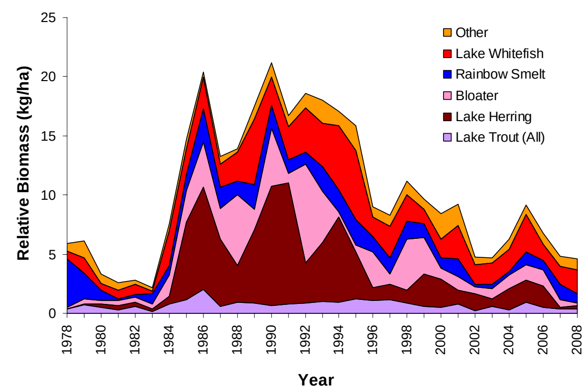

Figure 19. *Cumulative area plot of mean relative biomass (kg/ha) of the fish community caught in bottom trawls at all nearshore sampling stations in Lake Superior, 1978-2008. Canadian waters were not sampled until 1989.*

Lake Superior Fish Community

In 2008, cisco, rainbow smelt, bloater, and lake whitefish represented 71% of the total relative biomass for all nearshore waters. Since 2005, mean biomass of all fish species caught during the spring bottom trawl survey have declined 50%; from 9.13 kg/ha in 2005 to 6.80 kg/ha in 2006 to 4.81 kg/ha in 2007 and to 4.61 kg/ha in 2008 (Fig. 19). This decline followed two consecutive years of increased biomass (34% increase from 2003 to 2004 and 45% increase from 2004 to 2005). Similarly, community biomass increased in 2000-2001 and then declined sharply in 2002-2003. Decreased biomass in 2006 -2007 was a result of declines in estimated biomass of cisco, bloater, lake whitefish and lake trout. In 2008, biomass of bloater and rainbow smelt declined while biomass of lake whitefish and cisco increased. In 2008, principal species contributing to community biomass were lake whitefish (49%), rainbow smelt (18%), longnose sucker *Catostomus catostomus* (11%), cisco (7%), burbot *Lota lota* (6%), bloater (4%), and lean lake trout (4%). This structure contrasts with 2006 when cisco represented the highest percentage of biomass for any species (26%), followed by bloater (20%), lake whitefish (20%), and rainbow smelt (12%).

Changes in community structure and biomass over the 30-year times series was tied largely to changes in composition and abundance of major prey species (Gorman and Hoff 2009). Principal factors associated with changes in community structure have been recovery of lake trout, increased mortality of rainbow smelt, sustained recruitment of lake whitefish and variable recruitment of large year classes of cisco and bloater. Annual variation in biomass of prey species since 1984 has been driven largely by recruitment variation in cisco, bloater and lake whitefish. Recruitment of large year classes of cisco in 1984, 1988-1990, and 1998 resulted in subsequent increases in preyfish biomass (Fig. 19). Recruitment of the most recent large year class in 2003 yielded smaller and less sustained increases in biomass than previous ones. We suspect that the presence of recovered lake trout populations and attendant predation dampened this most recent recruitment event. In the future, we expect prey fish biomass to continue to fluctuate as a result of recruitment variation but in dampened cycles because of predation mortality.

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