Great Lakes Prey Fish Populations: A Cross-Basin Overview of Status and Trends in 2008[1]

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Assessments of prey fishes in the Great Lakes have been conducted annually since the 1970s by the Great Lakes Science Center, sometimes assisted by partner agencies. Prey fish assessments differ among lakes in the proportion of a lake covered, seasonal timing, bottom trawl gear used, sampling design, and the manner in which the trawl is towed (across or along bottom contours). Because each assessment is unique in one or more important aspects, a direct comparison of prey fish catches among lakes is problematic. All of the assessments, however, produce indices of abundance or biomass that can be standardized to facilitate comparisons of trends among lakes and to illustrate present status of the populations. We present indices of abundance for important prey fishes in the Great Lakes standardized to the highest value for a time series within each lake: cisco (*Coregonus artedi*), bloater (*C. hoyi*), rainbow smelt (*Osmerus mordax*), and alewife (*Alosa pseudoharengus*). We also provide indices for round goby (*Neogobius melanostomus*), an invasive fish presently spreading throughout the basin. Our intent is to provide a short, informal report emphasizing data presentation rather than synthesis; for this reason we intentionally avoid use of tables and cited references.

For each lake, standardized relative indices for annual biomass and density estimates of important prey fishes were calculated as the fraction relative to the largest value observed in the times series. To determine whether basin-wide trends were apparent for each species, we first ranked standardized index values within each lake. When comparing ranked index values from three or more lakes, we calculated the Kendall coefficient of concordance (W), which can range from 0 (complete discordance or disagreement among trends) to 1 (complete concordance or agreement among trends). The P-value for W provides the probability of agreement across the lakes. When comparing ranked index values from two lakes, we calculated the Kendall correlation coefficient (τ), which ranges from -1 (inverse association, perfect disagreement) to 1 (direct association, perfect agreement). Here, the P-value for τ provides the probability of either inverse or direct

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association between the lakes. First, we present trends in relative biomass of age-1 and older prey fishes to show changes in populations within each lake. Then, we present standardized indices of numerical abundance of a single age class to show changes in relative year-class strength within each lake. Indices of year-class strength reliably reflect the magnitude of the cohort size at subsequent ages. However, because of differences in survey timing across lakes, the age class that is used for each species to index year-class strength varies across lakes and, just as surveys differ among lakes, methods for determining fish age-class differ also. For Lake Superior cisco, bloater, smelt, and Lake Michigan alewife, year- class strengths are based on aged fish and age-length keys, and for all other combinations of lakes and species, age-classes are assigned based on fish length cut-offs. Our intent with this report is to provide a cross-lakes view of population trends but not to propose reasons for those trends.

Age-1 and Older Coregonids

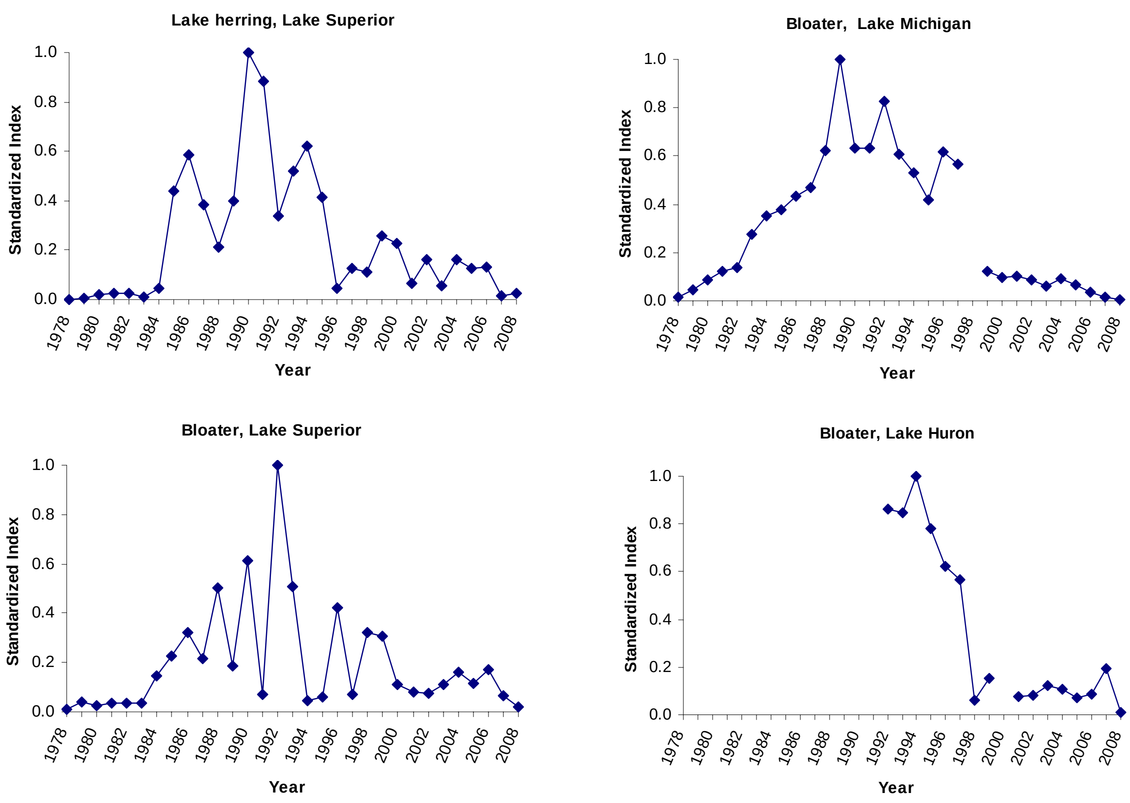

Figure 1. – Standardized indices of biomass for age-1 and older lake herring in Lake Superior and for age-1 and older bloater in lakes Superior, Michigan, and Huron, 1978-2008. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2008. Data from 1998 in Lake Michigan are unreliable due to a faster than normal towing speed.

Across the three upper Great Lakes, biomass of age-1 and older coregonids (lake herring, in Lake Superior and bloater in lakes Superior, Michigan, and Huron) was relatively high from the mid-1980s through the mid-1990s (Fig. 1). There was 75% agreement among the entire time series for bloaters in Lake Michigan, bloaters in Lake Superior, and lake herring in Lake Superior during 1978-2007 ($W = 0.75$; $P < 0.001$). To include Lake

Huron in the comparison, we used data only from 1992 to present; surveys in earlier years used a different net and no correction factor has been developed to extend the time series. Even in this shorter time series, there was significant concordance among the four species in the three lakes ($W = 0.60$; $P < 0.01$). Following the peaks in the mid-1980s through the mid-1990s, coregonid biomass has remained at low levels in lakes Huron and Michigan but has fluctuated 10-20% of peak levels in Lake Superior. In 2008, coregonid biomass dropped to < 3% of peak levels in the three lakes and was at the lowest levels since 1978 in lakes Huron and Michigan. Bloater were absent from survey catches in lakes Erie and Ontario and lake herring were rarely encountered in any lake other than Lake Superior.

Adult Alewife

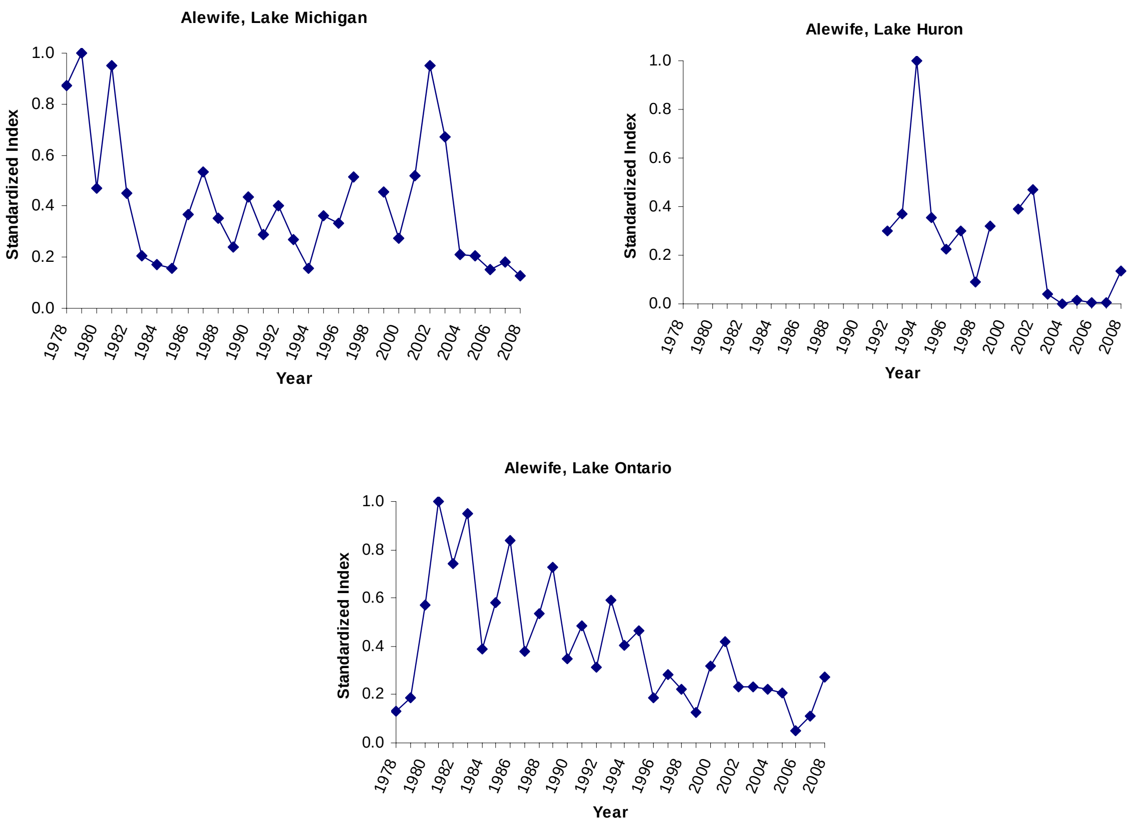

Figure 2. – Standardized indices of biomass for adult alewife in lakes Michigan, Huron, and Ontario, 1978-2008. Adult alewife are those fish that have completed two or more growing seasons; i.e. age 1 when surveys are conducted in fall (lakes Michigan and Huron) and age 2 when surveys are conducted in spring (Lake Ontario). Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2008. Data from 1998 in Lake Michigan are unreliable due to a faster than normal towing speed.

Trends in relative biomass of adult alewife varied across lakes (Fig. 2). Trends in Lakes Ontario and Michigan were unrelated to one another during 1978-2007 ($\tau = -0.02$; $P = 0.88$). To include Lake Huron in the comparison, data were limited to 1992 to present and there was a 64% agreement among the three lakes ($W = 0.64$; $P = 0.05$). In Lake

Michigan, relative biomass of adult alewife was high in the early 1980s and rapidly declined to much lower levels in the mid-1980s that persisted through the 1990s. Subsequently, relative biomass of alewife in Lake Michigan rebounded strongly in 2002-2003 and then dropped to low levels in 2004-2008, achieving the lowest level in the time series in 2008. In Lake Huron, relative biomass of alewife peaked in 1994 and decreased to the lowest observed values in 2003-2007, and then rebounded to 13% of peak value in 2008. In Lake Ontario, biomass of adult alewife was relatively high in the early 1980s but then gradually declined until 1996. During 1996-2005, biomass remained low except for a brief increase in 2000-2001 and then it declined to the lowest level observed in 2006. In 2007-2008, biomass recovered to 27% of its peak abundance. Alewife is a rare species in Lake Superior and survey data for alewife in Lake Erie were not available for this comparison.

Age-1 and Older Rainbow Smelt

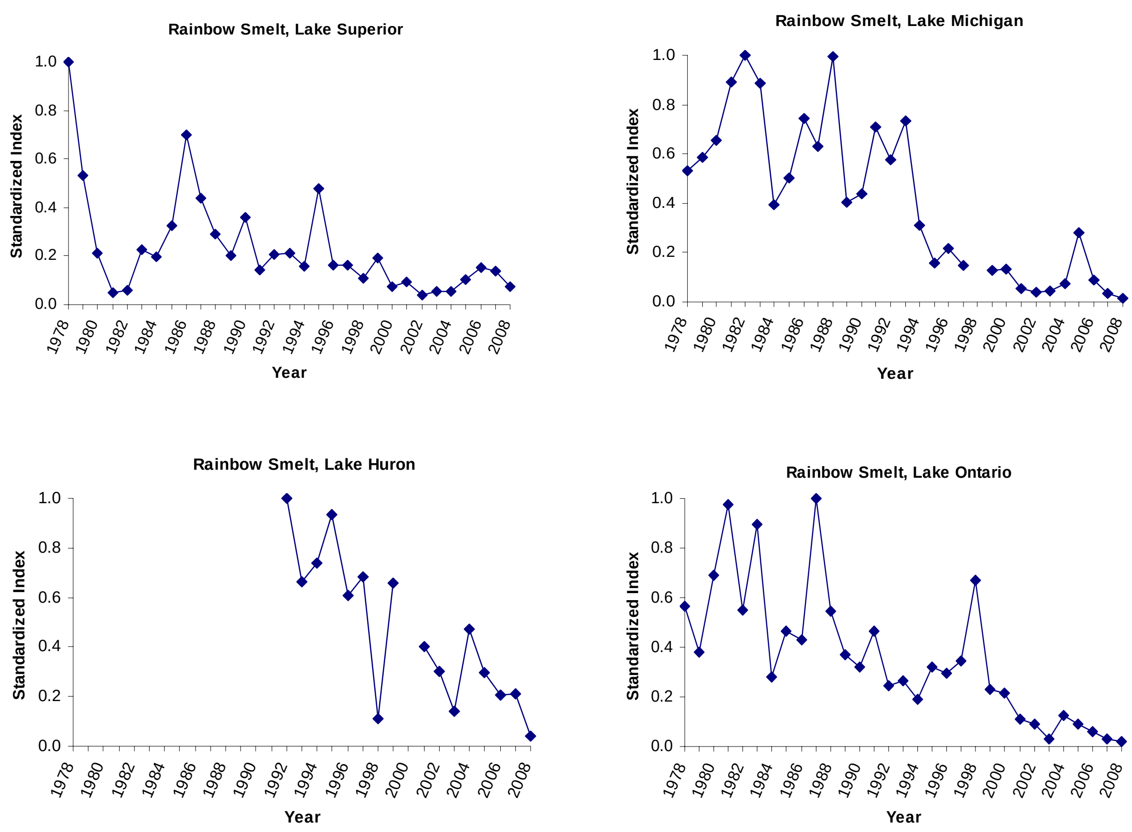

Figure 3. – Standardized indices of biomass for age-1 and older rainbow smelt in lakes Superior, Michigan, Huron, and Ontario, 1978-2008. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2008. Data from 1998 in Lake Michigan are unreliable due to a faster than normal towing speed.

Lakes Superior, Michigan, and Ontario showed a common trend of fluctuating but declining relative biomass of age-1 and older rainbow smelt during 1978-2008 (Fig. 3; $W = 0.74$; $P < 0.001$). Relative biomass was at or near record lows in 2002-2004 in Lake Superior, increased to 13-16% of peak biomass in 2005-2007 and then declined to 3% in

2008. In similar fashion, relative biomass was near record lows during 2001-2003 in Lake Michigan, rose nearly 4-fold in 2005, and then dropped to a record low of 1% of peak biomass in 2008. A similar pattern was followed in Lake Ontario with near record low biomass in 2003, a small increase in 2004 and a decline to record low biomass in 2008. For the shorter 1992-2008 Lake Huron time series, rainbow smelt biomass declined sharply from the relatively high levels observed in 1992-1997 to near-record low levels in 1998 and then fluctuated widely thereafter with a downward trend, with record low biomass observed in 2008. A comparison of trends across all four lakes in the shortened time series revealed significant agreement ($W = 0.82$; $P < 0.001$), similar to the trend across three lakes. In 2008 biomass was ≤ 7% of peak values in all lakes. Survey data for age-1 and older rainbow smelt in Lake Erie were not available for this comparison.

Year-Class Strengths, Coregonids

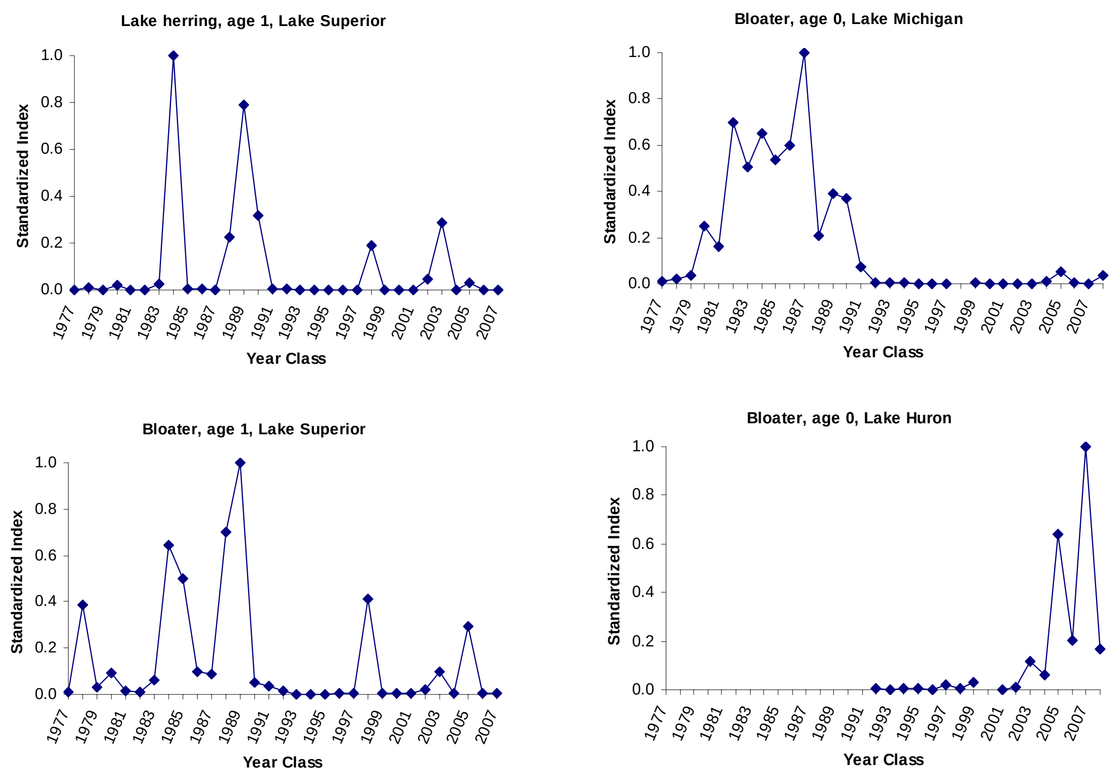

Figure 4. – Standardized indices of year-class strengths (age ≤1) for lake herring and bloater in lakes Superior, Michigan, and Huron, 1977-2008. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2008. Data from 1998 in Lake Michigan are unreliable due to a faster than normal towing speed.

There was significant agreement in year-class strengths of coregonids ($W = 0.68$; $P < 0.001$) in lakes Superior and Michigan over the time series (Fig. 4). In Lake Superior, year-class strengths of lake herring were highly variable, with the strongest year-classes produced in 1984, 1988-1990, 1998, and 2003. Bloater year-class strengths were less variable, with a series of strong to moderate year-classes occurring during 1977-1990 in lakes Superior and Michigan. In recent years, moderate to strong year-classes of bloater were produced in 2003-2005 in lakes Superior and Huron, but not in Lake Michigan. There was weak agreement in trends of coregonid year-class strength among all lakes for year-classes produced after 1991 ($W = 0.46$; $P < 0.05$). Bloater were absent from survey catches in lakes Erie and Ontario and lake herring were rarely encountered in those lakes.

Year-Class Strengths, Alewife

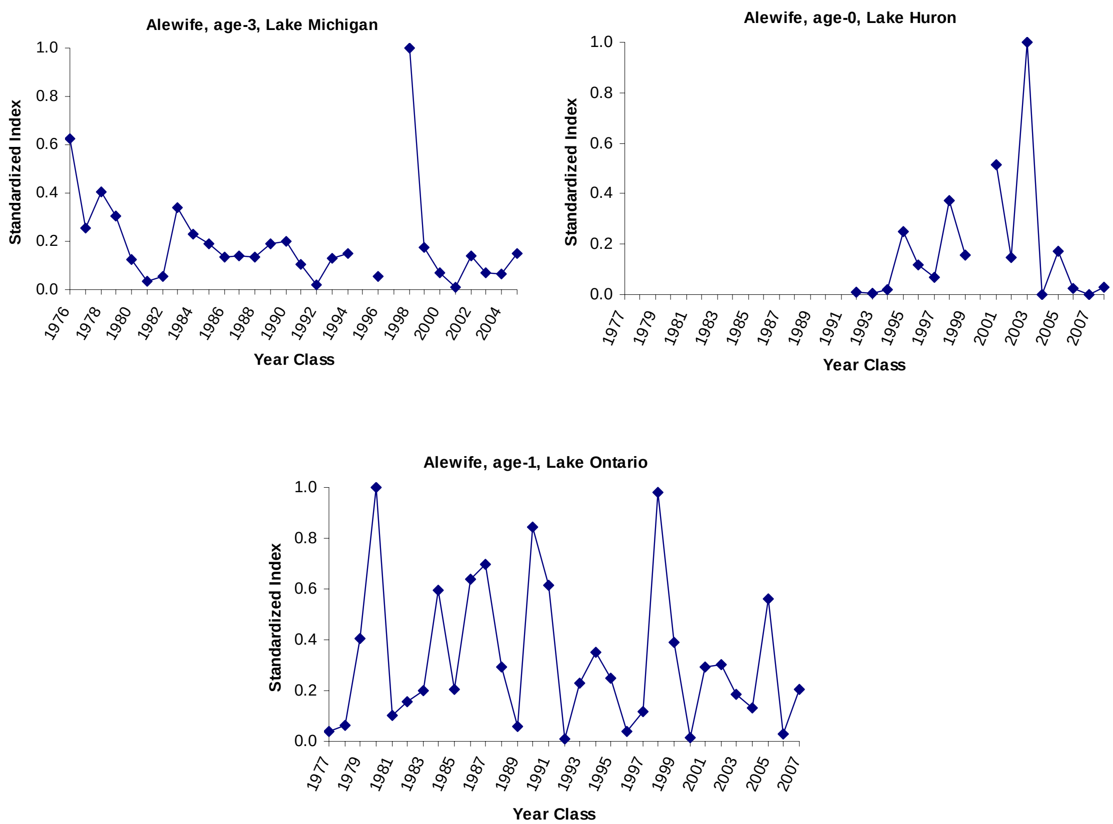

Figure 5. – Standardized indices of alewife year-class strengths measured at age 0, 1 or 3 (age of year-class strength is dependent on when alewife become fully vulnerable to survey on each lake) in lakes Michigan, Huron, and Ontario, 1978-2008. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2008. Data from 1998 and 2000 in Lake Michigan are not used because of either faster than normal towing speed (1998) or too few ports sampled (2000).

There was no agreement ($\tau = 0.23$; $P = 0.09$) in alewife year-class strength between lakes Michigan and Ontario for the 1977-2005 year-classes (Fig. 5). In Lake Michigan, strength of alewife year-classes was nearly constant from the late 1980s through the mid-1990s, whereas strength of alewife year-classes in Lake Ontario was highly variable during this same time period. To include Lake Huron in the comparison, data were limited to the 1992 to 2005 year-classes and there was weak agreement among the three lakes ($W = 0.67$; $P < 0.05$). Alewife is a rare species in Lake Superior and survey data for alewife in Lake Erie were not available for this comparison.

Year-Class Strengths, Rainbow Smelt

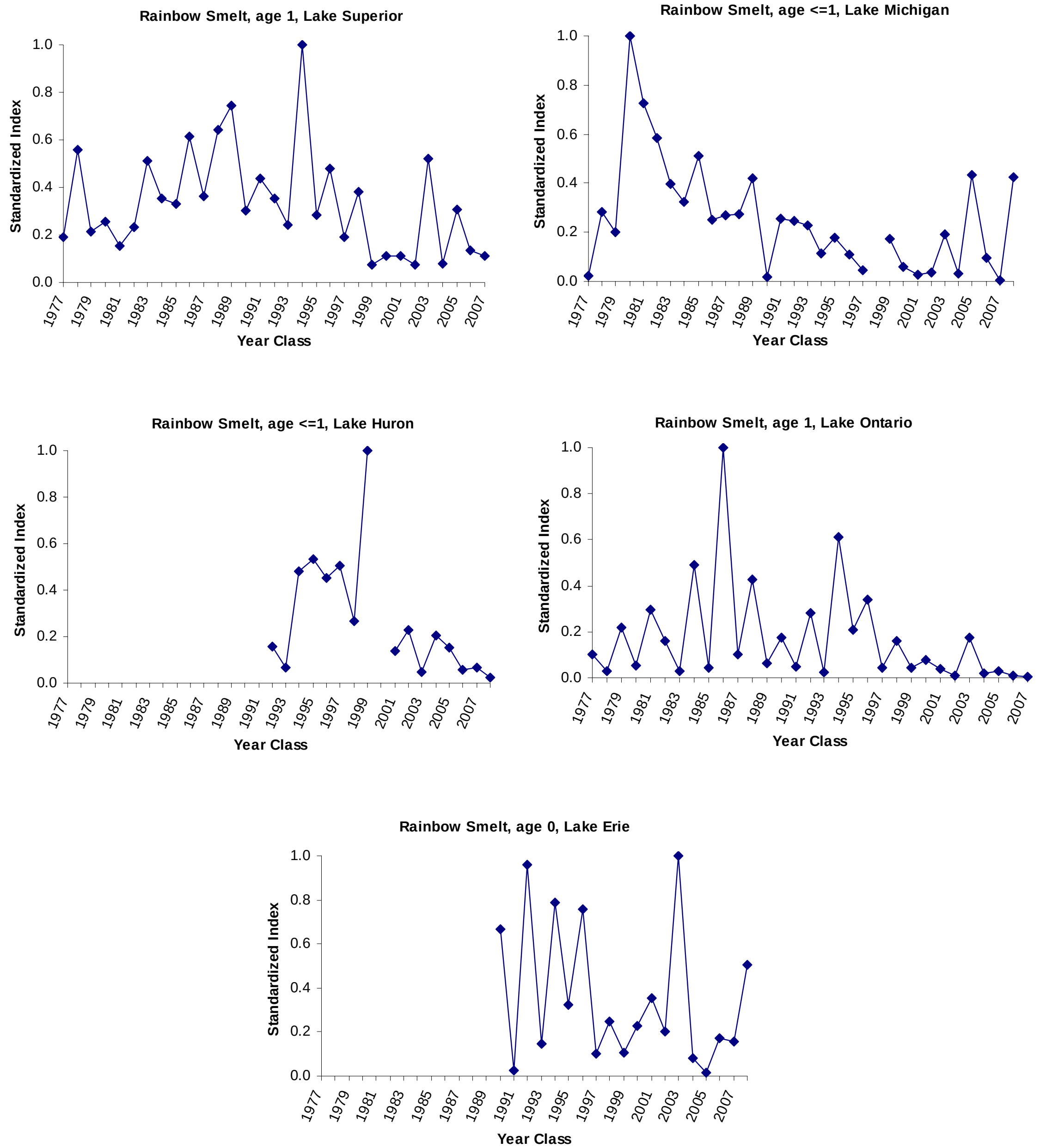

Figure 6. – Standardized indices of rainbow smelt year-class strengths measured at age 1, after the strength of the year-class is set in lakes Superior and Ontario and at age 0, after the strength of the year-class appears to be set in lakes Michigan and Huron, 1977-2008. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2008. Data from 1998 in Lake Michigan are unreliable due to a faster than normal towing speed.

Concordance was present among rainbow smelt year-classes in lakes Superior, Michigan, and Ontario from 1977 to 2007 ($W = 0.60$ $P < 0.01$) (Fig. 6). In Lake Superior, year-class strengths varied from moderate to strong during 1977-1996, subsequently declined to weak levels in 1999-2002, and varied from weak to moderate in 2003-2007. In Lake Michigan, year-class strengths appear to have steadily declined from 1980 to 1997 and thereafter remained weak except for the punctuation of moderately strong year classes in 2005 and 2008. In Lake Ontario, prior to 1999, the plot of year-class strength has a clear saw-tooth pattern caused by the annual alternation of strong and weak year-classes. This pattern was not discernible during 1999-2007 due to a succession of weak year classes. To include Lake Huron and Lake Erie in our analysis, we could use only the 1992-2007 year-classes. Again, we observed agreement among the year-class strength trends (W = 0.46; $P < 0.02$). The 2007 year-class was relatively weak in all the lakes and the 2008 year class was weak in Huron but moderate in Michigan and Erie.

Age-0 and older Round Goby

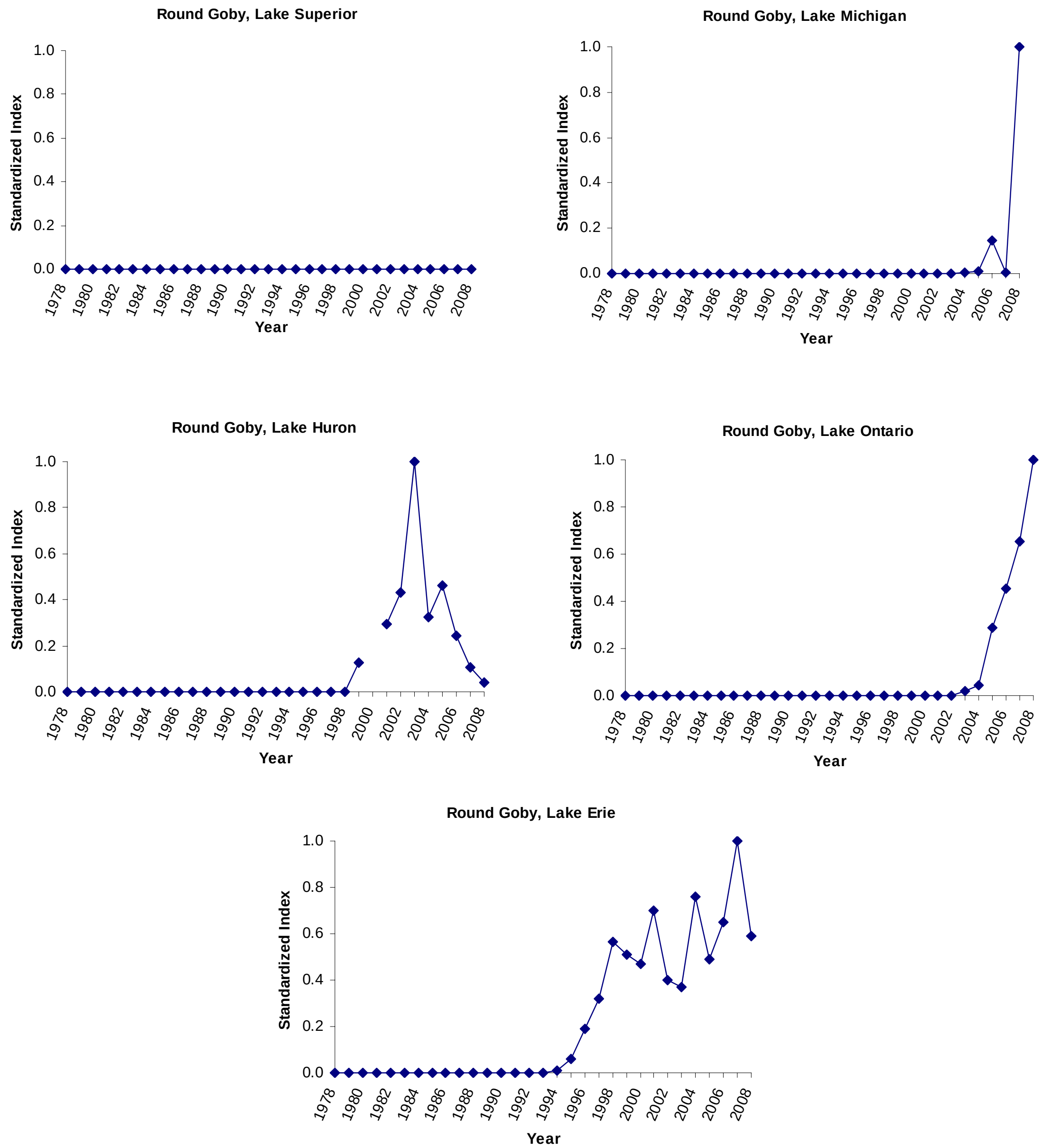

Figure 7. – Standardized indices of abundance for round goby in lakes Superior, Michigan, Huron, Erie, and Ontario, 1978-2008. Indices computed from number caught in Lake Erie and weight caught in all other lakes. Although a single round goby was caught in Lake Superior in 2005 near the entry to Duluth-Superior harbor, the catch was not made during the annual assessment and goby have not as yet been caught during that assessment.

The stage of round goby population expansion, as judged from surveys in offshore waters, varies among lakes from complete in Lake Erie to pending in Lake Superior (Fig. 7). In lakes Michigan and Ontario, population expansion is ongoing and biomass is likely to continue increasing in the future. In Lake Huron, the upward trajectory of round goby biomass appears to have halted after peaking in 2003. We did not use statistical analyses to compare round goby population trends among lakes owing to too few years of data.

Summary

Comparing standardized abundance indices across lakes enabled the detection of basin-wide trends in the population dynamics of prey fishes. We found basin-wide agreement in the trends of age-1 and older coregonids and rainbow smelt biomass. For coregonids, the highest biomass occurred from the mid 1980s to the mid 1990s. Rainbow smelt biomass has declined slowly and erratically during the last quarter century. Conversely, no synchrony in biomass trends of adult alewife were apparent between lakes Michigan and Ontario for the entire time series, although weak concordance was observed across lakes Michigan, Ontario, and Huron since 1992. With respect to year-class strength, a similar pattern to that observed for alewife occurred: discordance for lakes Michigan and Ontario for the entire time series, and weak agreement in trends across the basin since 1992. Rainbow smelt and coregonid year-class strength exhibited concordance across the basin. In conclusion, we found that the biomasses of age-1 and older coregonids, alewife, and rainbow smelt recorded in 2008 were at very low levels compared to previous years in the time series and fit a trend of declining biomass of prey fish across the Great Lakes since 1990. The only exception to this trend was the round goby, which has increased in abundance/biomass during the past decade in the lower lakes. The absence of round goby in spring bottom trawl assessments in Lake Superior, but their presence in the harbors and embayments of Duluth and Thunderbay (U.S. Geological Survey and Ontario Ministry of Natural Resources, unpublished data), suggests that the potential for future colonization of the main body of the lake remains.

The bottom trawls used to collect these data are reliable tools for measuring relative fish abundance near the lake bottom. Inter-annual variation in the proportion of a fish population collected near the lake bottom will, of course, result in some measurement error. The types, sizes, and numbers of fish caught by the trawl are influenced by many variables, such as dimensions of the net and speed at which it is towed. Nonetheless, we believe that the information presented in this report is the best available, long-term index of relative abundance for these selected fish in the Great Lakes.

Acknowledgements

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