Great Lakes Prey Fish Populations:
A Cross-Basin View of Status and Trends in 2005[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 manner in which the trawl is towed (across or along bottom contours). Because each assessment is unique in one or more important aspect(s), 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. Herein we present indices of abundance, standardized to the highest value for a time series within each lake, for important prey fishes in the various Great Lakes: lake herring (*Coregonus artedi*), bloater (*C. hoyi*), rainbow smelt (*Osmerus mordax*), and alewife (*Alosa pseudoharengus*). We also provide indices for round goby (*Neogobius melanostomus*), a new invasive fish presently spreading throughout the basin.

To determine whether basin-wide trends were apparent for each species, we first ranked standardized index values within each lake. When comparing indices 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 indices 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 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 are intended to 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.

[1] Distributed at: Upper and Lower Lakes Committee Meetings
Great Lakes Fishery Commission
Windsor, Ontario
March 20-24, 2006

Age-1 and Older Coregonids

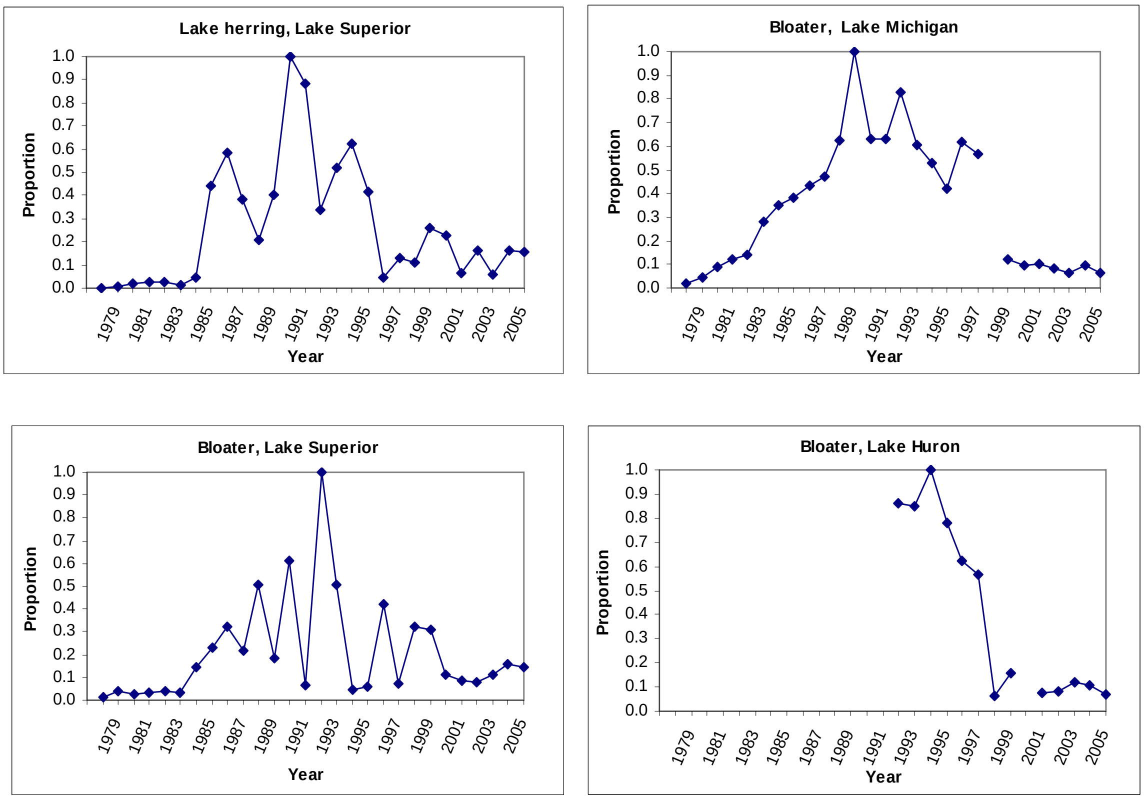

Figure 1. – Standardized indices of biomass for age-1 and older lake herring in Lake Superior and for age-1 and older bloater in lakes Superior, Michigan, and Huron, 1978-2005. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2005. Data from 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 74% agreement among the entire time series for bloaters in Lake Michigan, bloaters in Lake Superior, and lake herring in Lake Superior during 1978-2005 ($W = 0.74$; $P < 0.001$). 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 still significant concordance among the four lakes ($W = 0.51$; $P < 0.05$). 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 increased modestly in Lake Superior, due to recruitment of fish from the 2003 year-class. 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

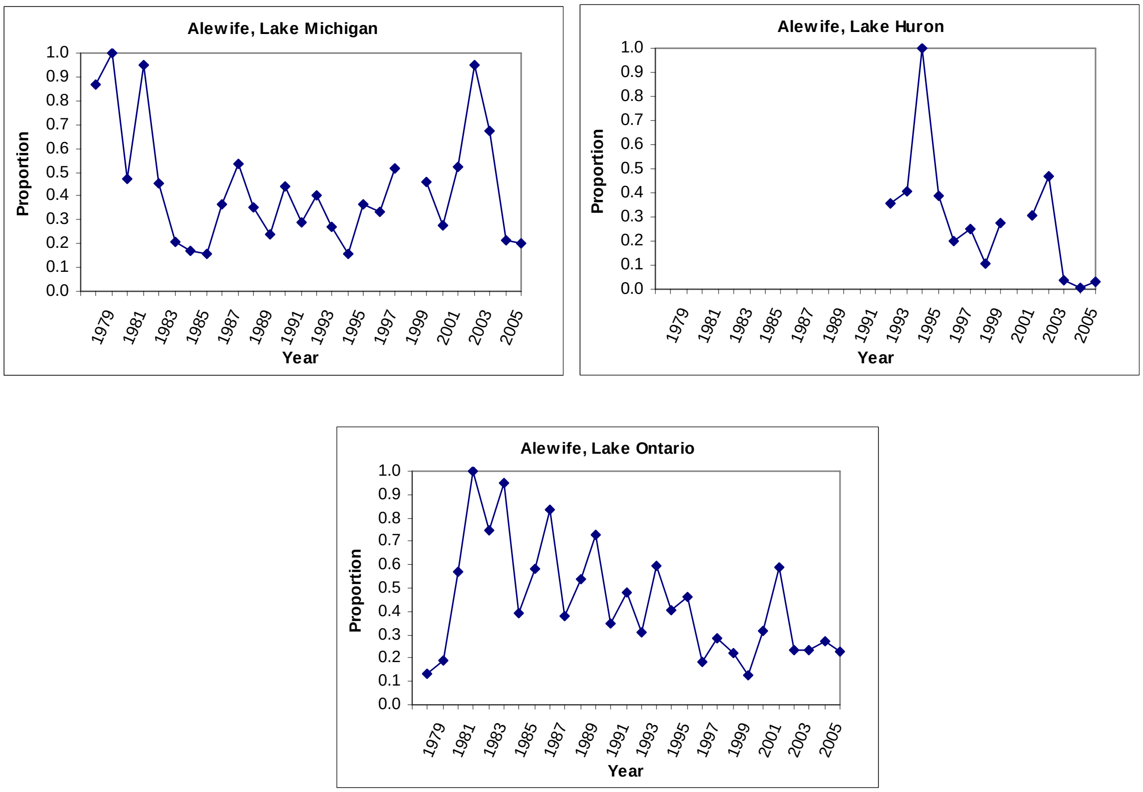

Figure 2. – Standardized indices of biomass for adult alewife in lakes Michigan, Huron, and Ontario, 1978-2005. Adult alewife are those fish that have completed two or more growing seasons; i.e. age 1 when surveys are conducted in fall (lakes Michigan and Huron) and age 2 when surveys are conducted in spring (Lake Ontario). Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2005. Data from 1998 in Lake Michigan are unreliable due to a faster than normal towing speed.

The trends in relative biomass of adult alewife varied across the lakes (Fig. 2). Lakes Ontario and Michigan were unrelated to one another during 1978-2005 ($\tau = -0.18$; $P = 0.21$). To include Lake Huron in the comparison, data were limited to 1992 to present and there was no agreement among the three lakes ($W = 0.45$; $P = 0.20$). 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 returned to low levels in 2004-2005. In Lake Huron, relative biomass of alewife peaked in 1994 and decreased to the lowest observed values in 2003-2005. In Lake Ontario, biomass of adult alewife was relatively high in the early 1980s but then gradually declined to a nadir in 1999, increasing somewhat thereafter. Despite the discordance among the basin-wide trends for the entire time series, it is worth noting that, in each lake, relative adult alewife biomass was at or near record lows in 2004-2005 after a brief surge upwards in 2001-2002 due to strong 1998 year-classes. 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

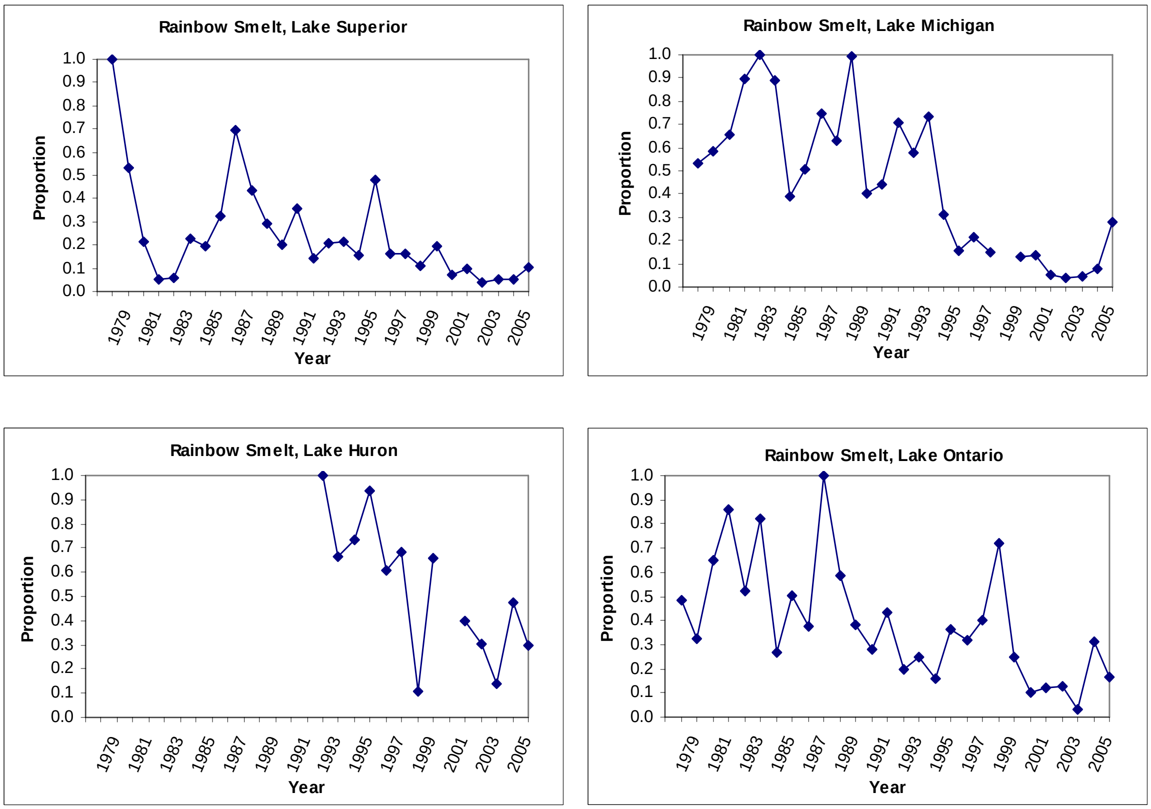

Figure 3. – Standardized indices of biomass for age-1 and older rainbow smelt in lakes Superior, Michigan, Huron, and Ontario 1978-2005. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2005. Data from 1998 in Lake Michigan are unreliable due to a faster than normal towing speed.

Lakes Superior, Michigan, and Ontario show a common trend of fluctuating but declining relative biomass of age-1 and older rainbow smelt during 1978-2005 (Fig. 3; $W = 0.66$; $P < 0.01$). For the shorter Lake Huron time series, rainbow smelt biomass declined sharply from the relatively high levels observed in 1992-1997 to record low levels in 2001-2005. Record low levels of relative biomass were also observed in 2002-2003 in lakes Superior, Michigan, and Ontario, and in 2005, Lake Michigan was the only lake with a meaningful increase in relative biomass of age-1 and older rainbow smelt. A comparison of trends across all four lakes in the shortened time series revealed significant agreement ($W = 0.71$; $P < 0.001$), similar to the trend with only three lakes. Survey data for age-1 and older rainbow smelt in Lake Erie were not available for this comparison.

Year-Class Strengths, Coregonids

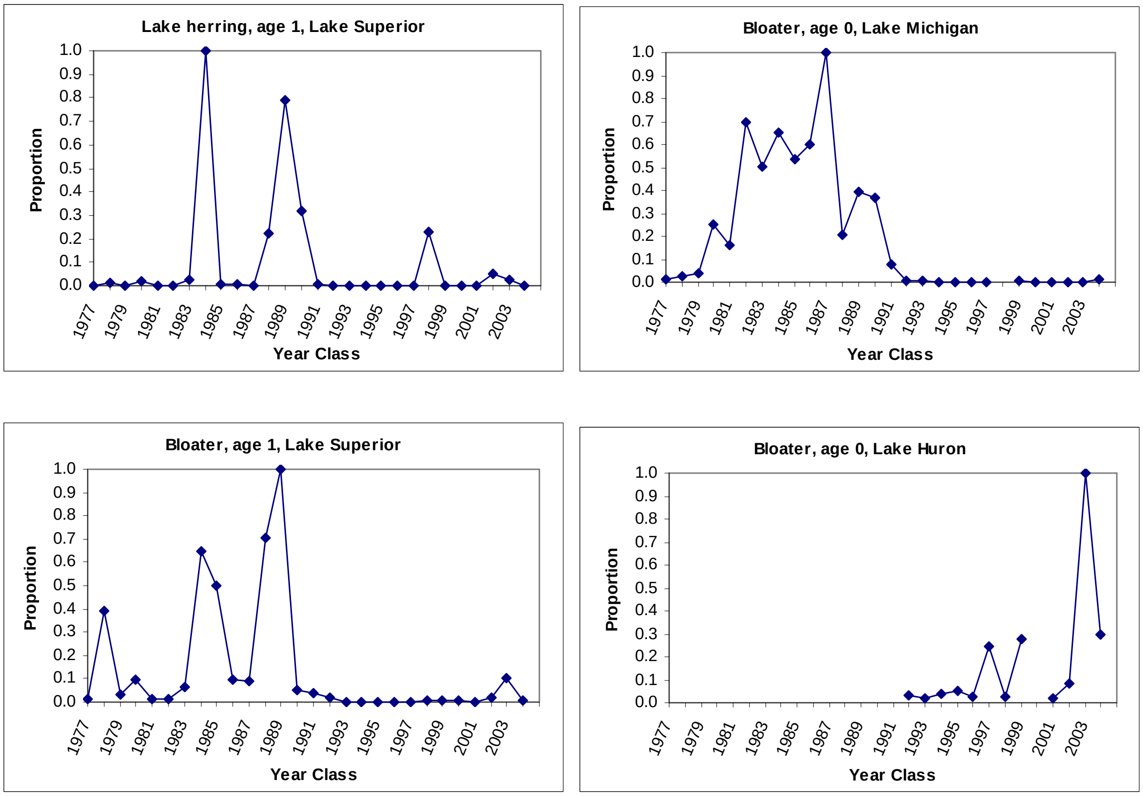

Figure 4. – Standardized indices of year-class strengths (age ≤1) for lake herring and bloater in lakes Superior, Michigan, and Huron, 1977-2005. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2005. Data from 1998 in Lake Michigan are unreliable due to a faster than normal towing speed.

There was significant agreement in year-class strengths of coregonids ($W = 0.67$; $P < 0.01$) in lakes Superior and Michigan (Fig. 4). In Lake Superior, year-class strengths of lake herring were highly variable, with the strongest year-classes produced in 1984 and in 1988-1990. Bloater year-class strengths were less variable, with a string of strong to moderate year-classes occurring during 1977-1990 in lakes Superior and Michigan. In recent years, moderate to strong year-classes of lake herring and bloater were produced in 2003-2004 in lakes Superior and Huron, but not in Lake Michigan. Perhaps owing to the recent absence of a strong bloater year-class in Lake Michigan, there was no agreement in trends of coregonid year-class strength among all lakes for year-classes produced after 1991 ($W = 0.42$; $P = 0.10$). Bloater were absent from survey catches in lakes Erie and Ontario and lake herring were rarely encountered in those lakes.

Year-Class Strengths, Alewife

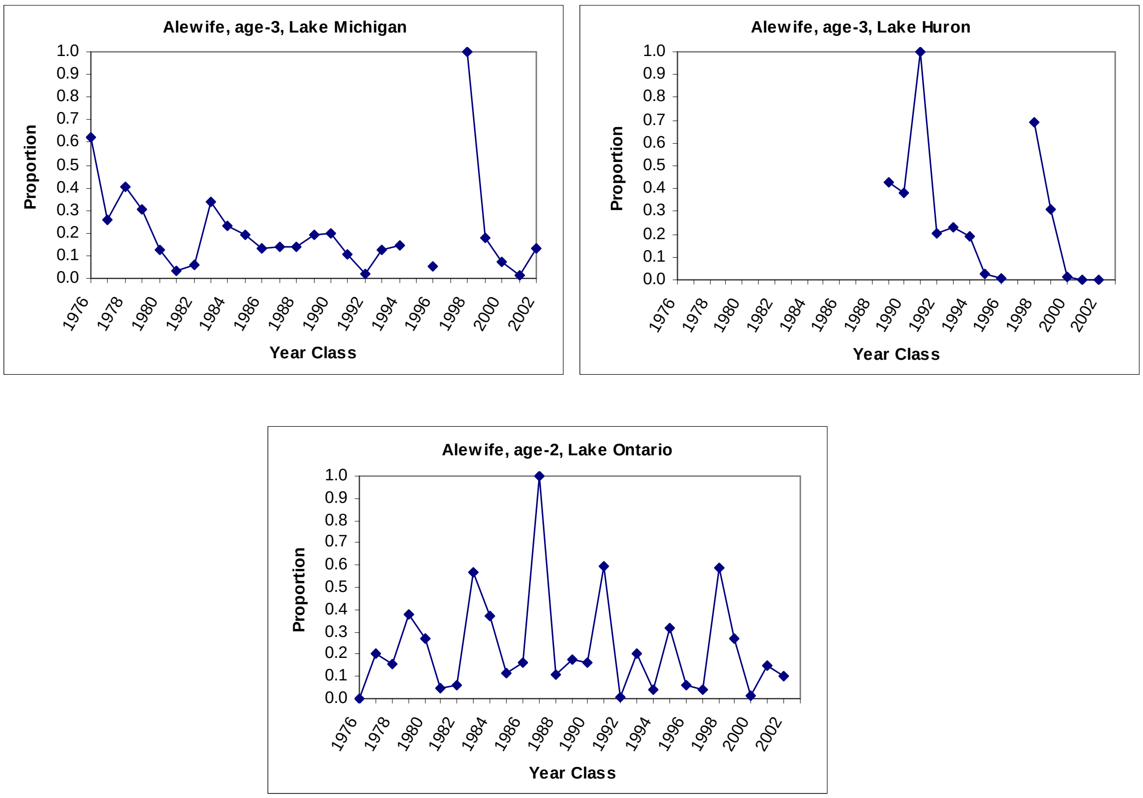

Figure 5. – Standardized indices of alewife year-class strengths measured at age 2 or 3, after the strength of the year class is set, in lakes Michigan, Huron, and Ontario, 1978-2005. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2005. Data from 1998 in Lake Michigan are unreliable due to a faster than normal towing speed.

There was weak agreement ($\tau = 0.30$; $P = 0.04$) in alewife year-class strength between lakes Michigan and Ontario for the 1976-2002 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 1989 to 2002 year-classes and there was considerable agreement among the three lakes ($W = 0.74$; $P < 0.02$), perhaps owing to the 1998 year-class that was strong in all lakes. 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

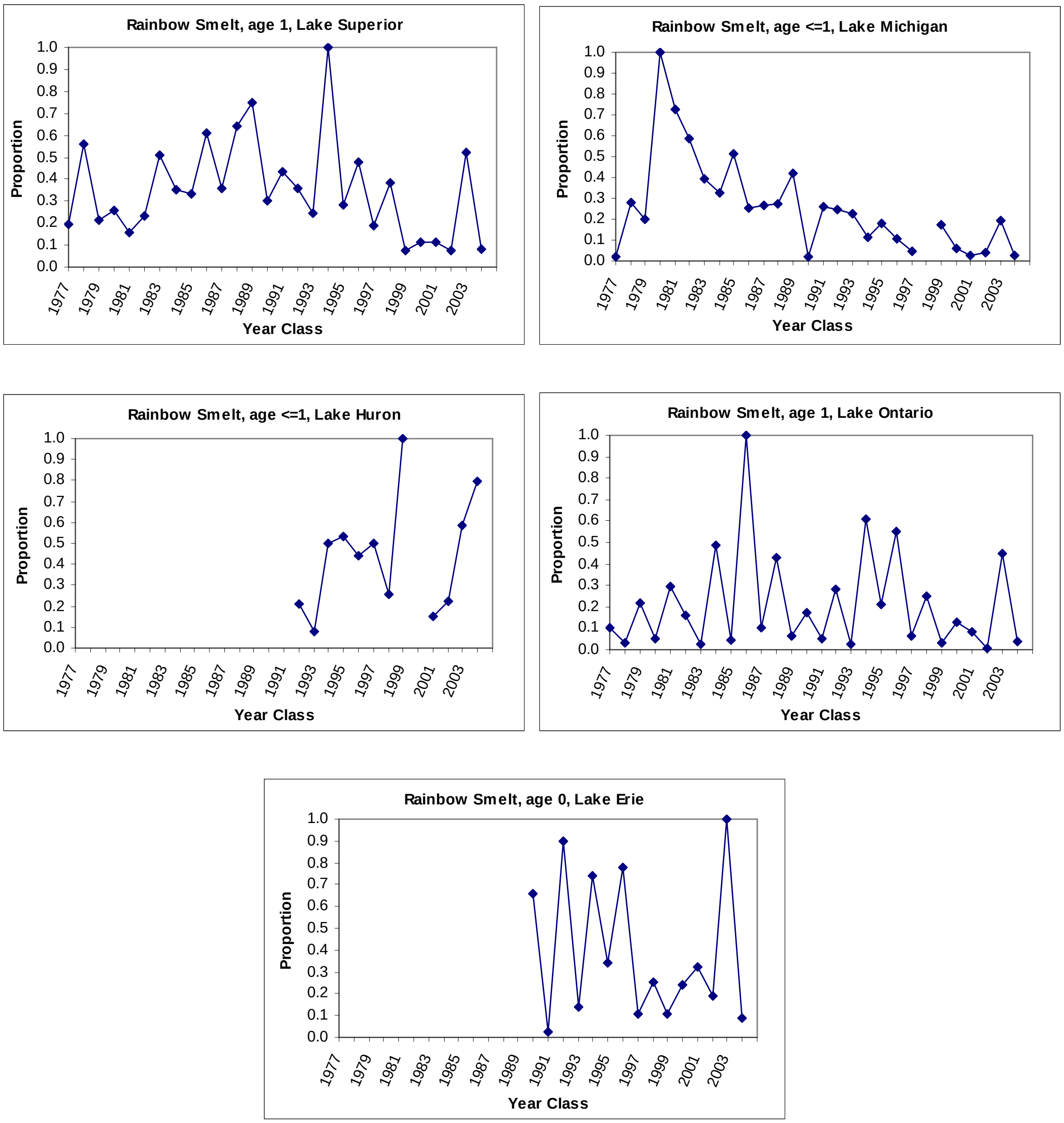

Figure 6. – Standardized indices of rainbow smelt year-class strengths measured at age 1, after the strength of the year-class is set in lakes Superior and Ontario and at age 0, after the strength of the year-class appears to be set in lakes Michigan and Huron, 1977-2005. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2005. Data from 1998 in Lake Michigan are unreliable due to a faster than normal towing speed.

Weak agreement in rainbow smelt year-class strength trends was present among lakes Superior, Michigan, and Ontario for the 1977 – 2004 year-classes ($W = 0.51$; $P < 0.03$) (Fig. 6). In Lake Superior, year-class strengths varied from moderate to strong during 1977-1996 and subsequently declined to weak levels in 1999-2002. In Lake Michigan, year-class strengths appear to have steadily declined since 1980. In Lake Ontario, year-class strengths have fluctuated without a discernable trend although there is a clear saw-tooth pattern to the plot of year-class strengths caused by the annual alternation of strong and weak year-classes. An alternating pattern of year-class strength is typically driven by cannibalism of age-0 fish by age-1 fish. To include Lake Huron and Lake Erie in our analysis, we could use only the 1992-2004 year-classes. Again, we observed some agreement among the year-class strength trends ($W = 0.46$; $P < 0.02$). The 2004 year-class was weak in all lakes except for Lake Huron.

Age-0 and older Round Goby

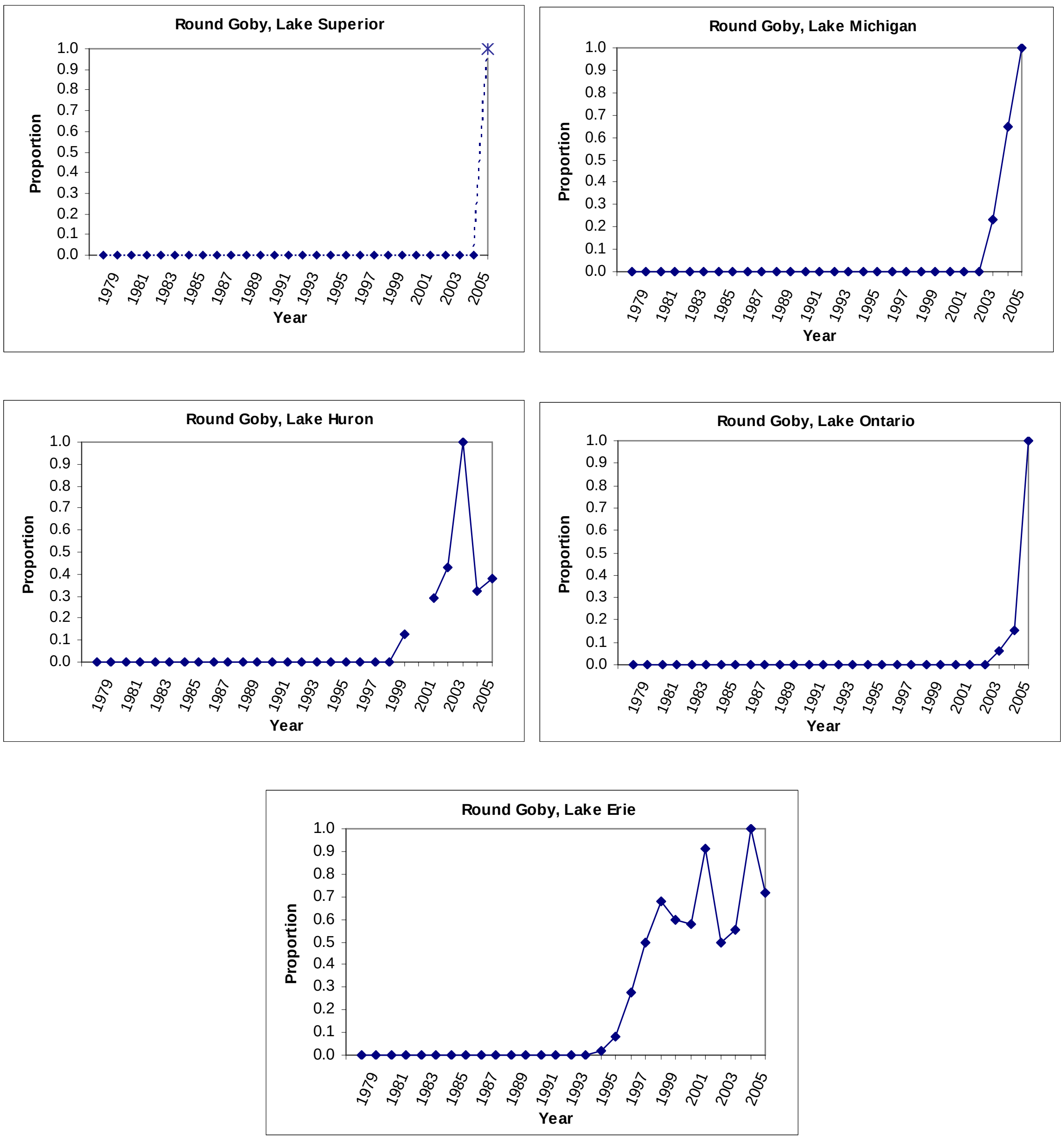

Figure 7. – Standardized indices of abundance for round goby in lakes Superior, Michigan, Huron, Erie, and Ontario, 1978-2005. Indices computed from number caught in Lake Erie and weight caught in all other lakes. A single round goby was caught in Lake Superior in 2005 near the entry to Duluth-Superior harbor.

The stage of round goby population expansion, as judged from surveys in offshore waters, varies among lakes from complete in Lake Erie to beginning in Lake Superior. In lakes Michigan and Ontario, population expansion is ongoing and biomass is likely to continue increasing in the near 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 for round gobies owing to too few years of data.

Summary

Although the fishery assessment surveys in each lake differ, comparing standardized abundance indices 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 cross-lake trends in biomass of adult alewife were apparent. There was, however, weak basin-wide concordance in the strengths of alewife year-classes. In addition, rainbow smelt year-class strengths demonstrated weak agreement across the basin. Trends in year-class strengths of coregonids were dependent on the suite of year-classes and lakes that were included in the analysis: strong agreement in year-class strengths between lakes Superior and Michigan when analyzing all year-classes (1977-2004), but no agreement in year-class strengths when comparisons were restricted to recent year-classes (1992-2004) to allow inclusion of Lake Huron. In conclusion, we found that the biomasses of age-1 and older coregonids, alewife, and rainbow smelt recorded in 2005 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. Round gobies are now established in the lower lakes and are well-integrated into the food webs of these lakes. The appearance of a round goby in the spring 2005 assessment in Lake Superior should be viewed with some concern, considering the impact that gobies have had on fish communities of the lower Great Lakes.

Acknowledgements

The New York State Department of Environmental Conservation participated in the collection of data from Lake Ontario. For Lake Erie, data used to characterize year-class strength of rainbow smelt and round goby population trends were collected by the Ohio Department of Natural Resources, Pennsylvania Fish and Boat Commission, New York State Department of Environmental Conservation, and Ontario Ministry of Natural Resources.