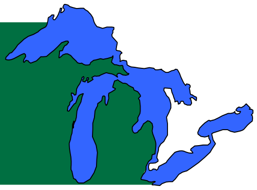

Great Lakes Prey Fish Populations: A Cross-Basin View of Status and Trends in 2006[1]

prepared by:
Robert O'Gorman, Owen Gorman, and David Bunnell
Deepwater Science Group
U.S. Geological Survey
Great Lakes Science Center
Ann Arbor, MI 48105

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, 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 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. In Lakes Superior and Ontario, age classes are assigned from aged subsamples whereas in the other lakes, year-class strengths and age classes are assigned from fish length. The only exception was for alewife on lakes Michigan and Huron, where ages were used to estimate year-class strength (Michigan, Huron) and age classes (Huron). Our intent with this report is to provide a cross-lakes view of population trends and not to determine reasons for those trends.

---

[1] Prepared for: Upper and Lower Lakes Committee Meetings
Great Lakes Fishery Commission
Ypsilanti, Michigan
March 19-23, 2007

Age-1 and Older Coregonids

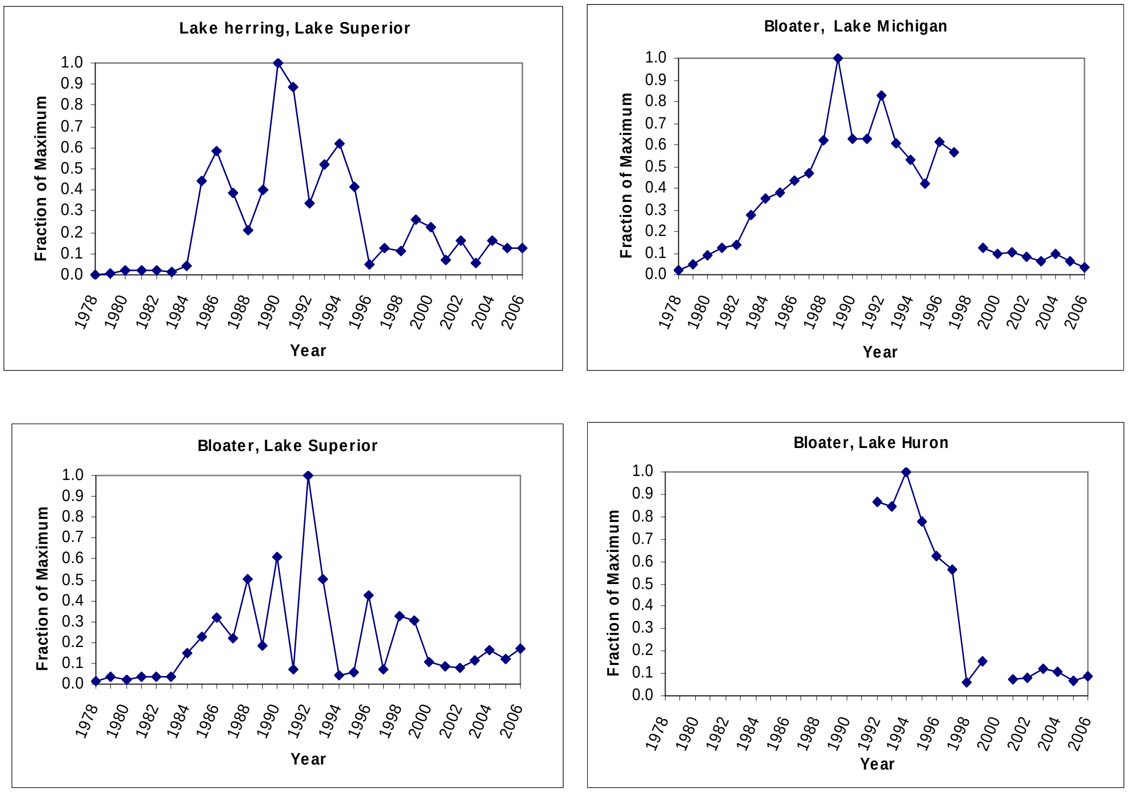

Figure 1. – Standardized indices of biomass for age-1 and older lake herring in Lake Superior and for age-1 and older bloater in lakes Superior, Michigan, and Huron, 1978-2006. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2006. Data from 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 73% agreement among the entire time series for bloaters in Lake Michigan, bloaters in Lake Superior, and lake herring in Lake Superior during 1978-2006 ($W = 0.73$; $P < 0.001$). 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 lakes ($W = 0.51$; $P < 0.02$). 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. 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

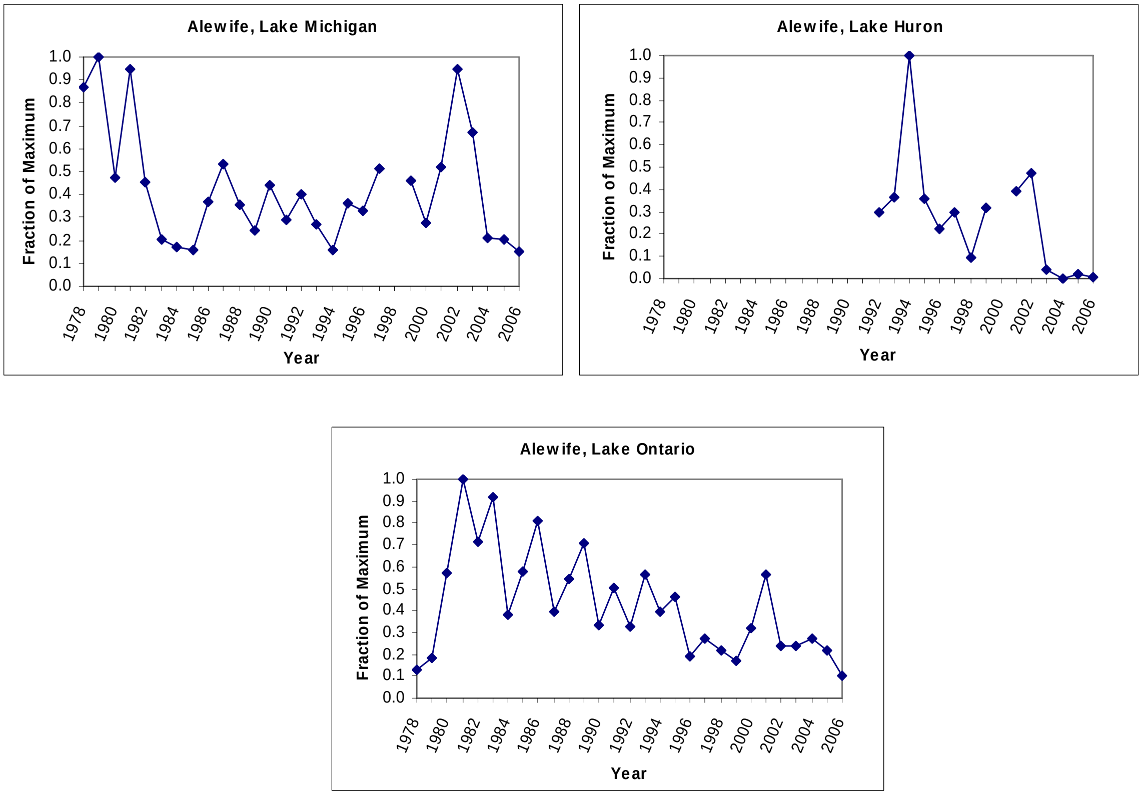

Figure 2. – Standardized indices of biomass for adult alewife in lakes Michigan, Huron, and Ontario, 1978-2006. Adult alewife are those fish that have completed two or more growing seasons; i.e. age 1 when surveys are conducted in fall (lakes Michigan and Huron) and age 2 when surveys are conducted in spring (Lake Ontario). Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2006. 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 1978-2006 ($\tau = -0.11$; $P = 0.44$). To include Lake Huron in the comparison, data were limited to 1992 to present and there was no agreement among the three lakes ($W = 0.57$; $P = 0.10$). 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 2004-2006. In Lake Huron, relative biomass of alewife peaked in 1994 and decreased to the lowest observed values in 2003-2006. 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 uptick in 2000-2001 and it declined to the lowest level observed in 2006. 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 2004-2006 after a brief surge upwards just a few years previously. 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

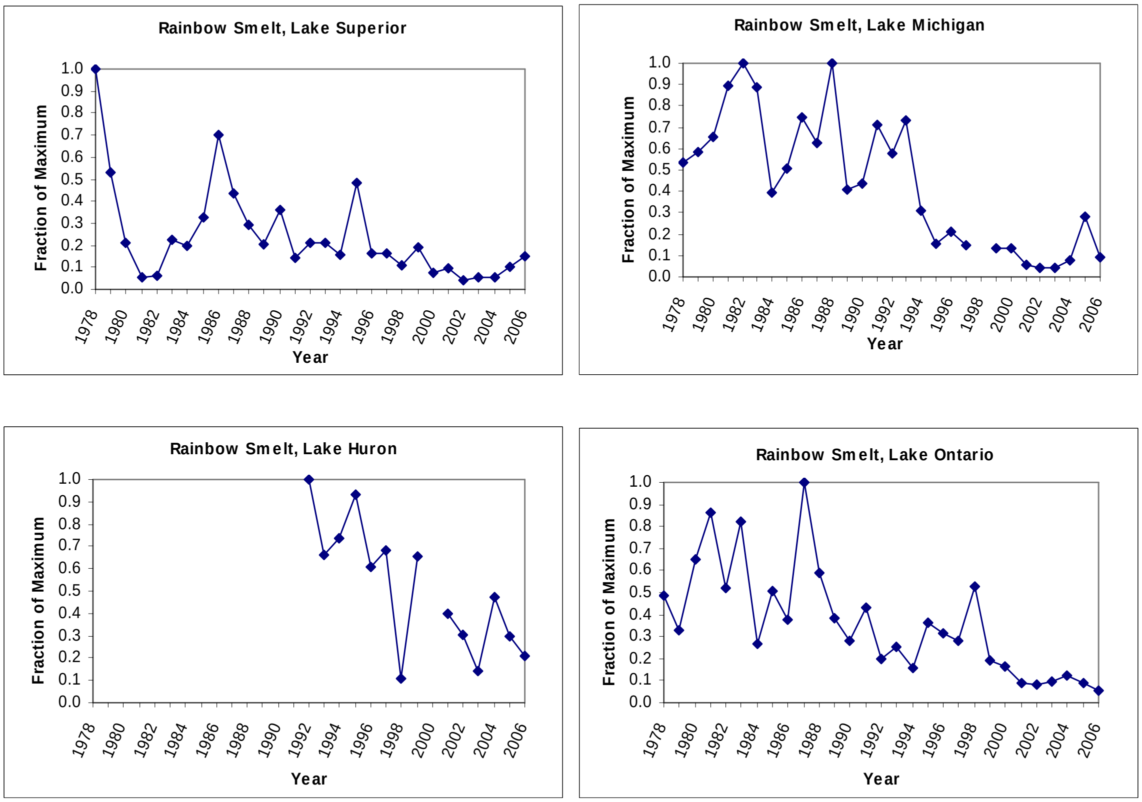

Figure 3. – Standardized indices of biomass for age-1 and older rainbow smelt in lakes Superior, Michigan, Huron, and Ontario, 1978-2006. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2006. Data from 1998 in Lake Michigan are unreliable 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 1978-2006 (Fig. 3; $W = 0.70$; $P < 0.001$). 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 1998 and fluctuated widely thereafter without returning to the high levels of the early 1990s. A comparison of trends across all four lakes in the shortened time series revealed significant agreement ($W = 0.79$; $P< 0.001$), similar to the trend with only three lakes. Record low levels of relative biomass were observed in 2002-2003 in lakes Superior and Michigan and in 2006 in Lake Ontario. In 2006, Lake Superior was the only lake with an increase in relative biomass of age-1 and older rainbow smelt. Survey data for age-1 and older rainbow smelt in Lake Erie were not available for this comparison.

Year-Class Strengths, Coregonids

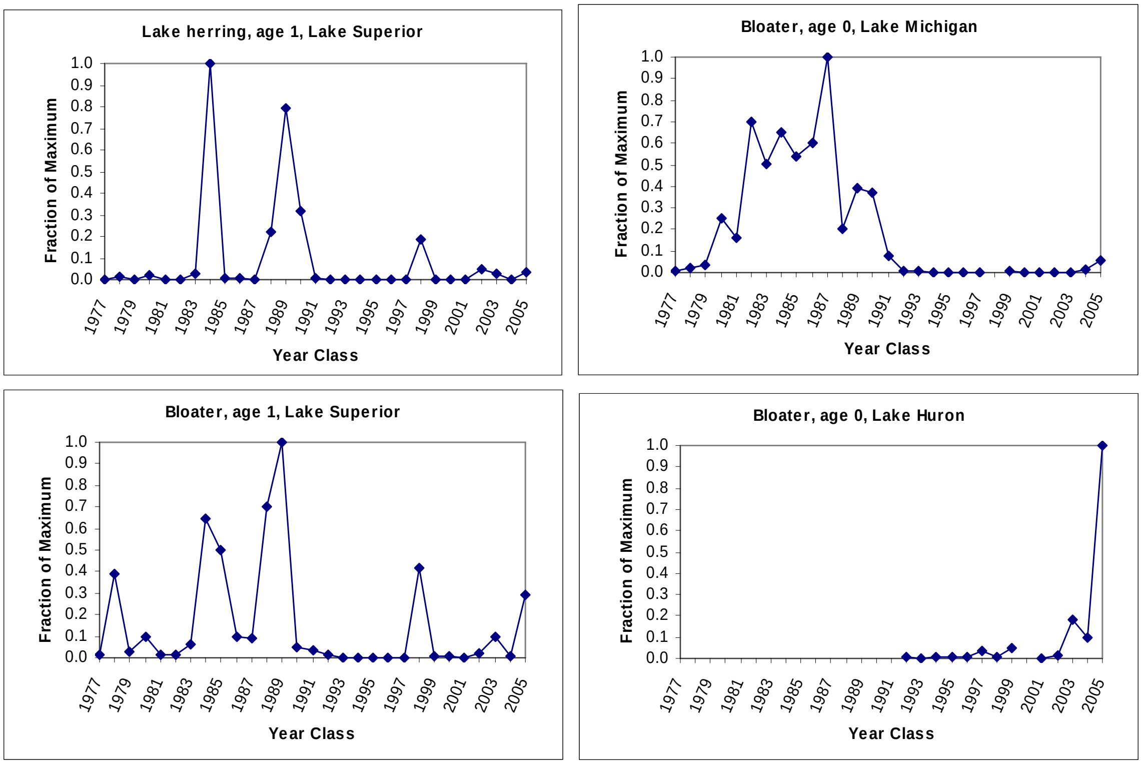

Figure 4. – Standardized indices of year-class strengths (age ≤1) for lake herring and bloater in lakes Superior, Michigan, and Huron, 1977-2006. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2006. Data from 1998 in Lake Michigan are unreliable due to a faster than normal towing speed.

There was significant agreement in year-class strengths of coregonids ($W = 0.68$; $P < 0.01$) 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 bloater were produced in 2003-2005 in lakes Superior and Huron, but not in Lake Michigan. There was agreement in trends of coregonid year-class strength among all lakes for year-classes produced after 1991 ($W = 0.54$; $P < 0.02$). Bloater were absent from survey catches in lakes Erie and Ontario and lake herring were rarely encountered in those lakes.

Year-Class Strengths, Alewife

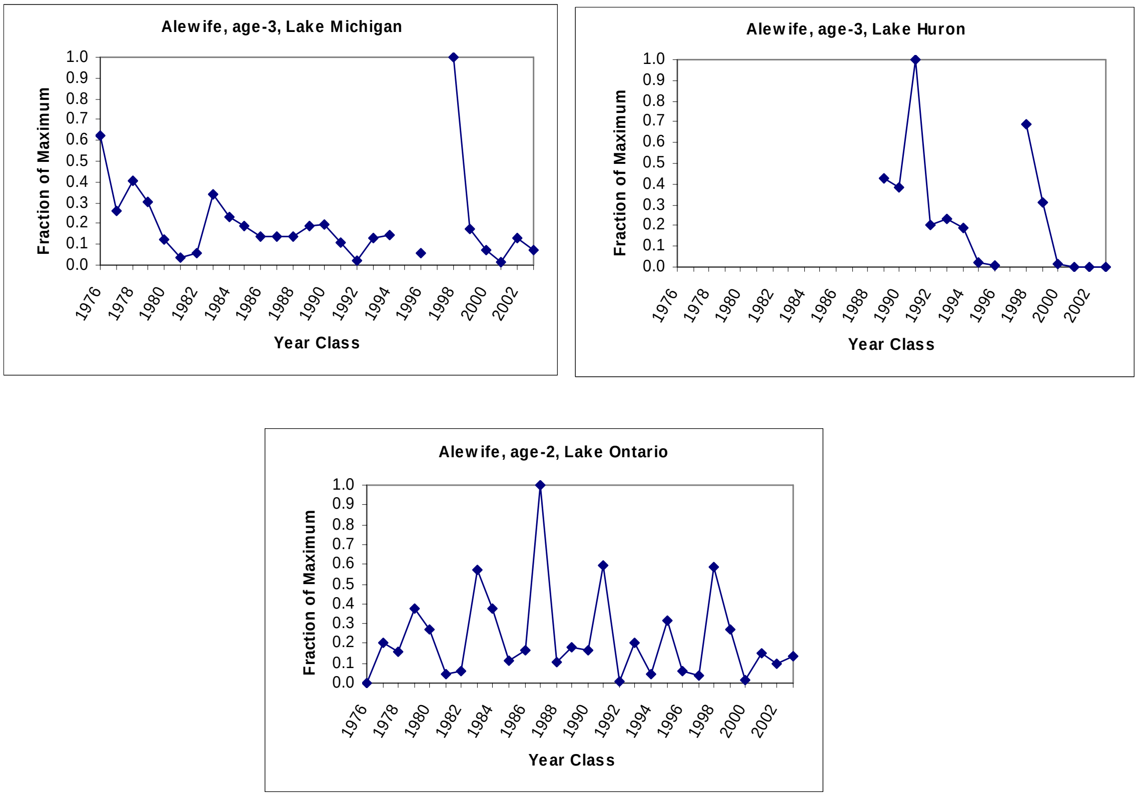

Figure 5. – Standardized indices of alewife year-class strengths measured at age 2 or 3, after the strength of the year class is set, in lakes Michigan, Huron, and Ontario, 1978-2006. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2006. 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 weak agreement ($\tau = 0.32$; $P = 0.02$) in alewife year-class strength between lakes Michigan and Ontario for the 1976-2003 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 2003 year-classes and there was considerable agreement among the three lakes ($W = 0.74$; $P < 0.01$), 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

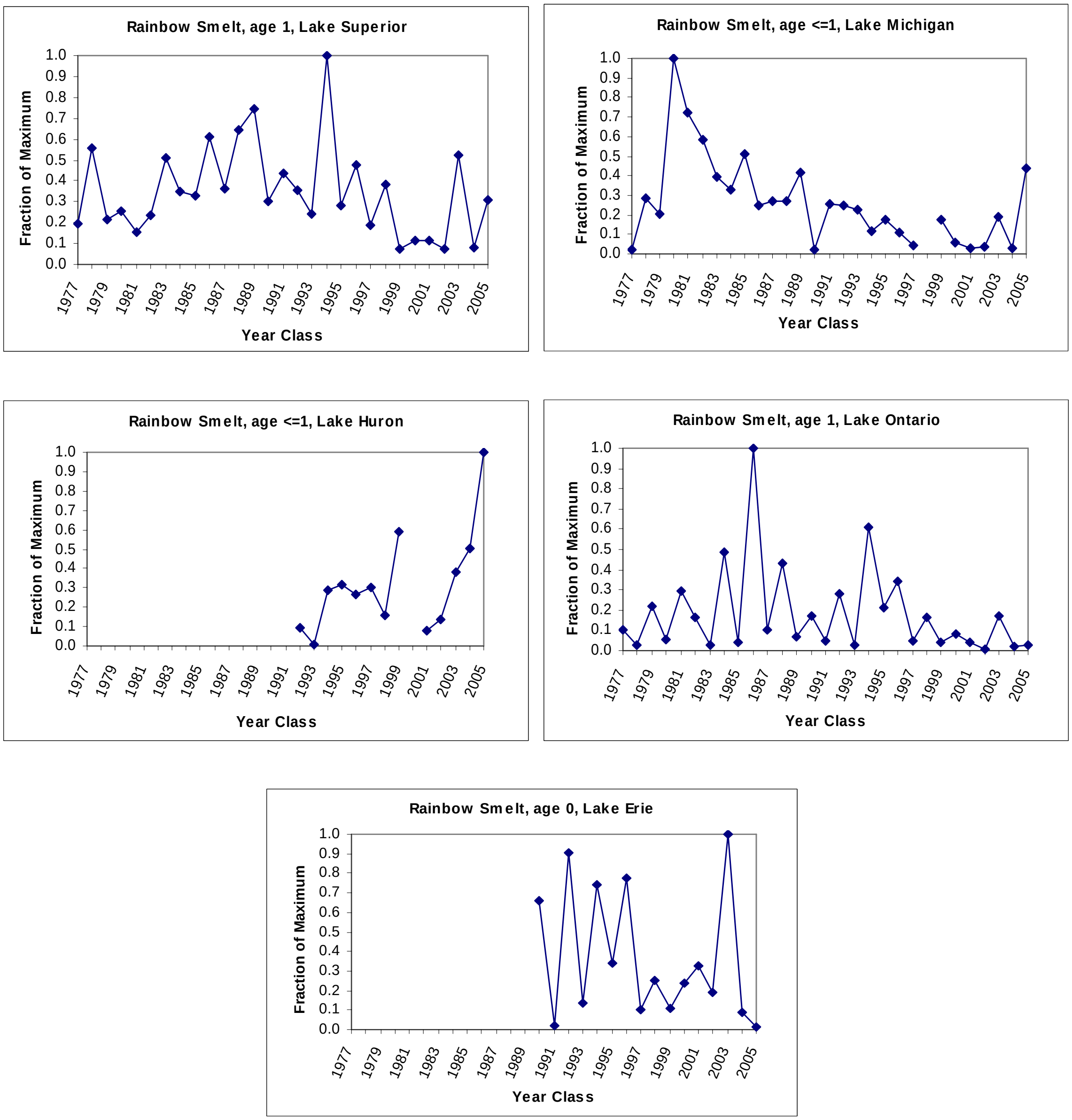

Figure 6. – Standardized indices of rainbow smelt year-class strengths measured at age 1, after the strength of the year-class is set in lakes Superior and Ontario and at age 0, after the strength of the year-class appears to be set in lakes Michigan and Huron, 1977-2006. Lake Huron was not sampled in 2000 and the sampling gear used prior to 1992 differed from that used during 1992-2006. Data from 1998 in Lake Michigan are unreliable due to a faster than normal towing speed.

Weak agreement in rainbow smelt year-class strength was present among lakes Superior, Michigan, and Ontario for the 1977 – 2005 year-classes ($W = 0.53$; $P < 0.05$) (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 2003-2005. In Lake Michigan, year-class strengths appear to have steadily declined from 1980 to 1997 and thereafter remained weak until 2005 when a moderately strong year class was produced. 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 1999-2005 due to a succession of weak year classes. To include Lake Huron and Lake Erie in our analysis, we could use only the 1992-2005 year-classes. Again, we observed weak agreement among the year-class strength trends ($W = 0.41$; $P < 0.05$). The 2005 year-class was weak in lakes Ontario and Erie, moderate in lakes Michigan and Superior, and exceptionally strong in Lake Huron.

Age-0 and older Round Goby

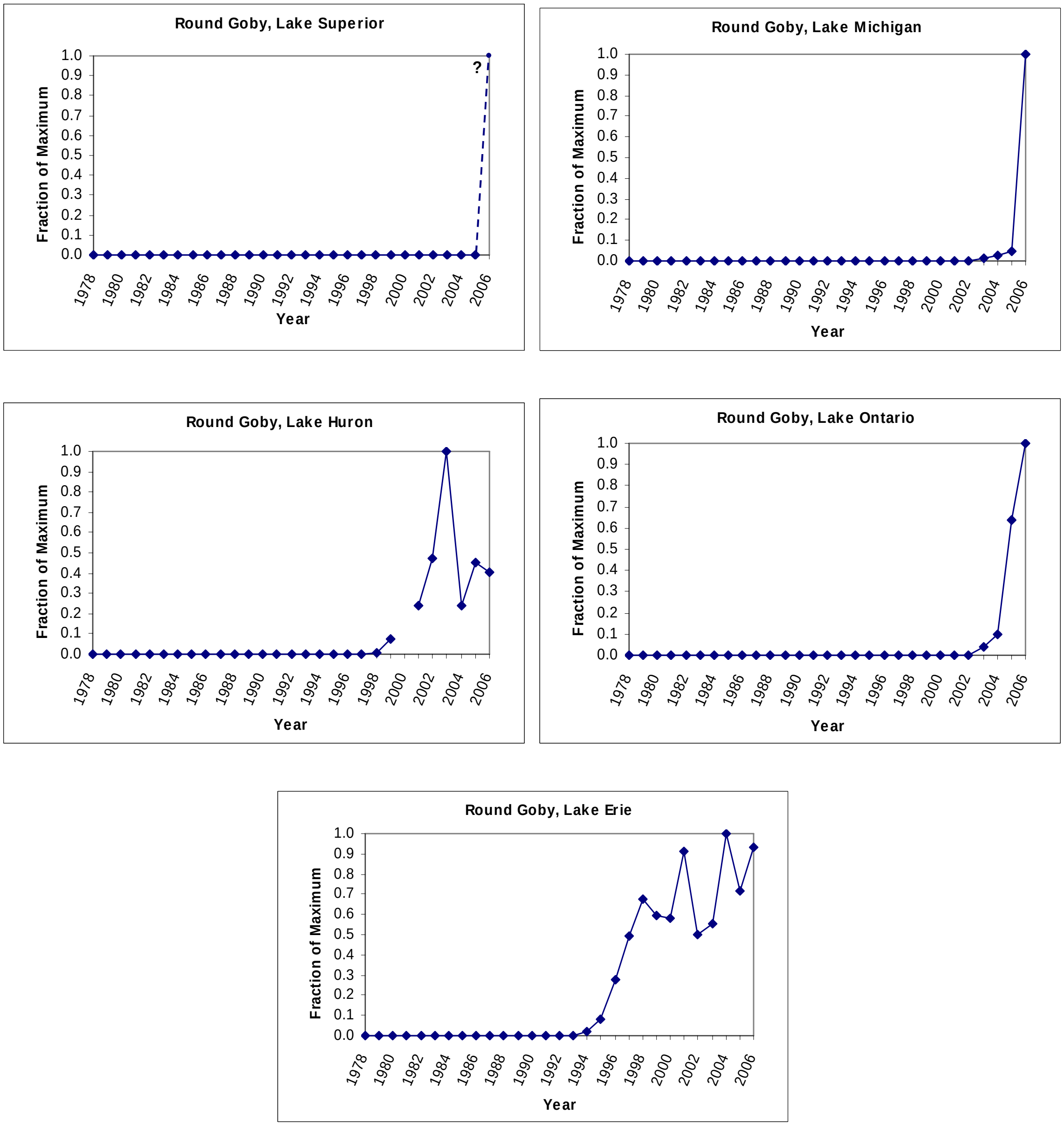

Figure 7. – Standardized indices of abundance for round goby in lakes Superior, Michigan, Huron, Erie, and Ontario, 1978-2006. Indices computed from number caught in Lake Erie and weight caught in all other lakes. Although a single round goby was caught in Lake Superior in 2005 near the entry to Duluth-Superior 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 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 although in recent years adult alewife biomass has been near or at record lows in lakes Michigan, Huron, and Ontario. There was basin-wide concordance in the strengths of alewife year-classes beginning with the 1989 year-class. 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 (1977-2005) and moderate agreement in year-class strengths when comparisons were restricted to recent year-classes (1992-2005) 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 2006 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 is now firmly established in the lower lakes and well-integrated into the food webs of these lakes. The absence of round goby in the spring assessments in Lake Superior, even though they have been recorded in and around harbors, suggests that colonization will proceed slowly in Superior.

The bottom trawls used to collect these data are reliable tools for measuring relative fish abundance near bottom. Inter-annual variation in the proportion of a fish population near 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

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.