**Great Lakes Prey Fish Populations:**
**A Cross-Basin Overview of Status and Trends**
**from Bottom Trawl Surveys, 1978-2011**[1]

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The assessment of prey fish stocks in the Great Lakes have been conducted annually with bottom trawls since the 1970s by the Great Lakes Science Center, sometimes assisted by partner agencies. These stock assessments provide data on the status and trends of prey fish that are consumed by important commercial and recreational fishes. Although all these annual surveys are conducted using bottom trawls, they differ among the lakes in the proportion of the lake covered, seasonal timing, bottom trawl gear used, 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, direct comparison of prey fish catches among lakes is not straightforward. However, all of the assessments produce indices of abundance or biomass that can be standardized to facilitate comparisons of status and trends across all the Great Lakes. In this report, population indices were standardized to the highest value for a time series within each lake for the following important prey species in the Great Lakes: cisco (*Coregonus artedi*), bloater (*C. hoyi*), rainbow smelt (*Osmerus mordax*), and alewife (*Alosa pseudoharengus*). Indices were also provided for round goby (*Neogobius melanostomus*), an invasive fish presently becoming established throughout the basin. These standardized indices represent the best available long-term indices of relative abundance for these fishes across all of the Great Lakes. In this report, these standardized indices are presented in graphical form along with synopses to provide a short, informal cross-basin summary of the status and trends of prey fishes. In keeping with this intent, tables, references, and a detailed discussion were omitted.

For each lake, standardized relative indices for biomass of age-1 and older fishes and numeric density of recruits were calculated as the observed value divided by the maximum value observed in the times series. Recruitment indices of year-class strength reliably reflect the magnitude of the cohort recruited at subsequent ages. Differences in the timing of

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surveys across lakes and differences in methodology to distinguish age classes resulted in adopting different fish age-classes to index year-class strength for each species. Year-class strengths were based on aged cisco, bloater, and smelt in Lake Superior and alewife in Lake Michigan. For other species and lakes, age-classes were assigned based on fish length cut-offs. Depending on the lake and species, year class strengths were assessed from densities of age-0, age-1, or age-3 fish.

The Kendall coefficient of concordance (*W*) was calculated to determine if the time series of relative abundances for a given species was statistically "concordant" across lakes. *W* can range from 0 (complete discordance or disagreement) to 1 (complete concordance or agreement). The *P*-value for *W* provides the probability of agreement across lakes.

When making statistical comparisons of trends among lakes, data were restricted to years when all or a group of lakes were sampled. For all lakes, data from 1992, 1993, 1998, and 2000 were omitted from statistical comparisons because missing or atypical data were collected in one or more lakes. Comparisons with Lake Erie were restricted to 1990-2010, years when surveys with a consistent sample design were conducted. Beginning with our 2010 report, a complete series of catch data from Lake Huron was made available for comparison with other lakes because fishing power corrections to the Huron data were developed to account for the use of a larger bottom trawl to conduct surveys during 1992-2011. Assessment of cross-basin trends for round gobies begins with 1994, the first year that these fish were detected in bottom trawl surveys in the Great Lakes.

## Relative Biomass, Age-1 and Older Coregonids

Across the three upper Great Lakes, biomass of age-1 and older coregonids (cisco and bloater in Lake Superior and bloater in Lakes Michigan and Huron) shared common trends (Fig. 1), resulting in a 72% concordance among all time series ($W = 0.72$; $P < 0.0001$). In all lakes, biomass was relatively high from the mid-1980s through the mid-1990s Following peaks in the mid-1980s through the mid-1990s, coregonid biomass declined to historically low levels by 2008-2009 in Lakes Superior, Michigan, and Huron. In 2009, cisco and bloater biomass dropped to near-zero in Superior, the lowest values since 1978, but by 2011 biomass increased slightly to 4% and 7% of peak values, respectively, due to the recruitment and growth of weak 2009 year classes (Fig. 5). In Lake Michigan, bloater biomass increased from a record low of < 1% of peak level in 2008 to 3% in 2010 and then declined back to 1% in 2011. In contrast, bloater in Lake Huron rebounded following a record low of < 1% in 2008 to 45% of peak biomass in 2011, due to the recruitment and growth of strong 2005 and 2007 year classes (Fig. 5). Bloater were absent from survey catches in Lakes Erie and Ontario and cisco were rarely encountered in any other Great Lake than Superior.

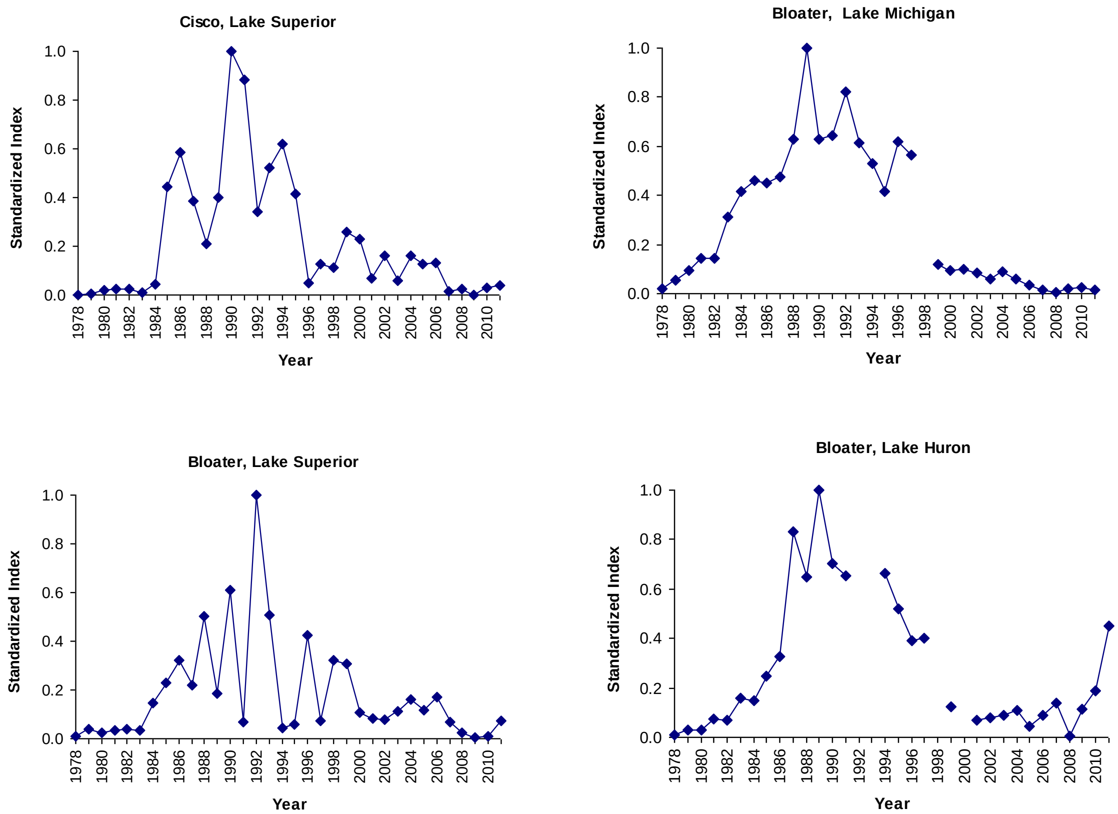


**Figure 1.** – Standardized indices of biomass for age-1 and older cisco in Lake Superior and for age-1 and older bloater in Lakes Superior, Michigan, and Huron, 1978-2011.

## Relative Biomass, Adult Alewife

Trends in relative biomass of adult alewife across Lakes Michigan, Huron, and Ontario were variable, though biomass was higher early in the time series and lower in more recent years (Fig. 2). For all three lakes, there was moderate (62%) concordance among the time series ($W = 0.62$; $P < 0.004$). In Lake Michigan, relative biomass of adult alewife was high in the early 1980s and rapidly declined to 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 2004-2011, achieving the lowest level in the time series in 2010 and second lowest in 2011. Similarly, relative biomass of alewife in Lake Huron was high in the beginning of the time series, declined to low levels in the mid-1980s, but unlike Lake Michigan, fluctuated widely in the late 1980s – mid 1990s with peaks in 1987 and 1994 and an intervening low in 1990-1991. After 1994, biomass declined to 18% of peak abundance in 1996, rebounded to 36% in 2002 and afterwards declined to near-zero levels in 2004-2011, achieving record lows in 2004, 2008, and 2009. 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 declined in 2006. In 2008-2009, biomass recovered to 35% of peak abundance, fell to a record low in 2010 and recovered to 17% in 2011. Alewife is a rare species in Lake Superior and survey data for alewife in Lake Erie were not available for this comparison.

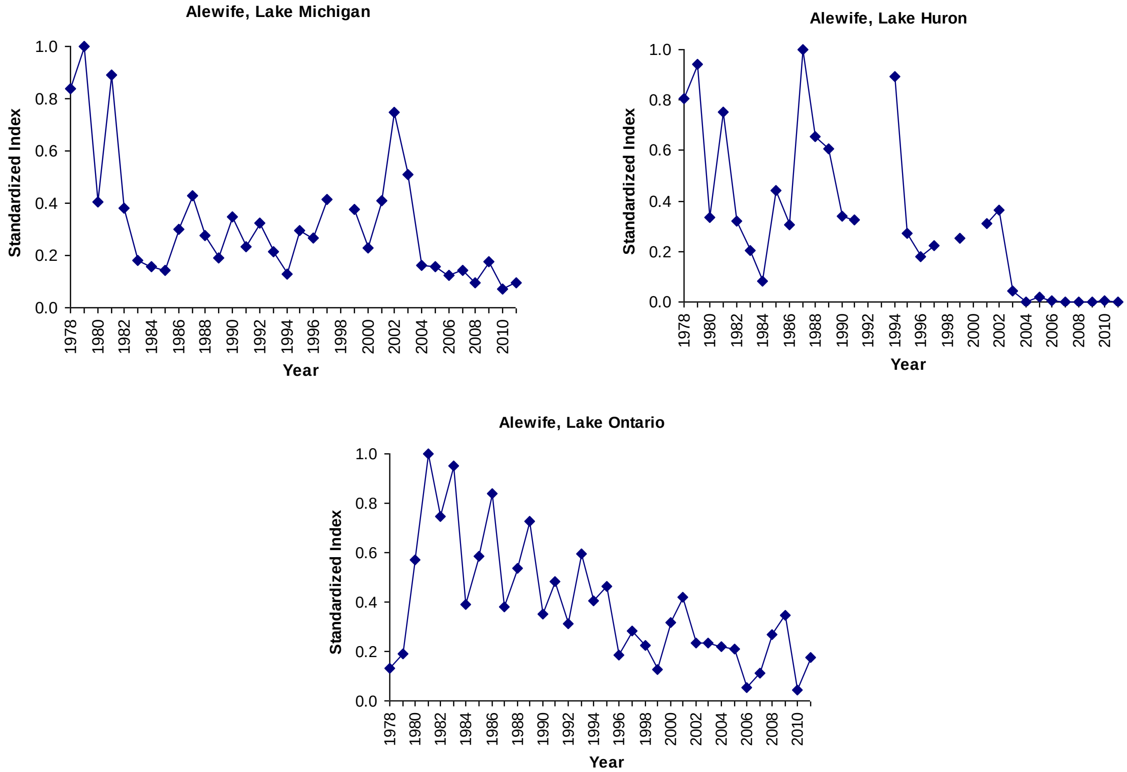


**Figure 2.** – Standardized indices of biomass for age-1 and older alewife in Lakes Michigan, Huron, and Ontario, 1978-2011.

## Relative Biomass, Age-1 and Older Rainbow Smelt

Lakes Superior, Michigan, Huron, and Ontario showed a common trend of fluctuating but declining relative biomass of age-1 and older rainbow smelt during 1978-2011 (Fig. 3; $W = 0.78$; $P < 0.0001$). Relative biomass was at or near record lows in 2002-2004 in Lake Superior, increased to 13-16% of peak biomass in 2005-2007, declined to 7-11% between 2008 and 2011. Similarly, relative biomass in Lake Michigan was near record lows during 2001-2003, rose nearly 4-fold in 2005, and then dropped to a record low of 1% of peak biomass in 2008 and increasing slightly in 2009-2010 to 3-4% of peak biomass only to fall to near record low of 2% in 2011. Mirroring the pattern in Michigan, relative biomass in Lake Huron declined to near-record lows in 2002-2003, increased to 13% of peak biomass in 2004 and then declined to record lows in 2008-2009, followed by a slight increase to 6-7% of peak biomass in 2010 and 2011. A similar pattern was observed in Lake Ontario with near record low biomass in 2003, a small increase in 2004 and a decline to record low biomass in 2008 followed by a modest increase to 15% of peak biomass in 2010, but falling to 7% in 2011. Survey data for age-1 and older rainbow smelt in Lake Erie were not available for this comparison.

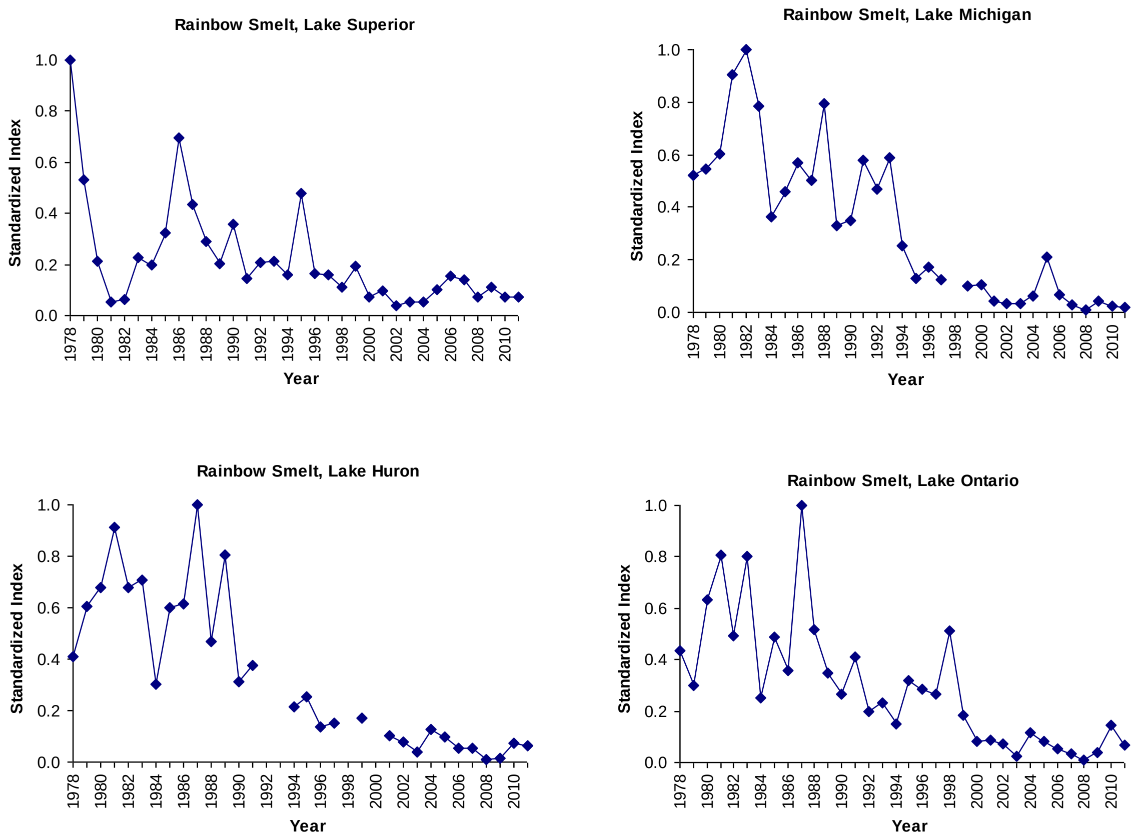


**Figure 3.** – Standardized indices of biomass for age-1 and older rainbow smelt in Lakes Superior, Michigan, Huron, and Ontario, 1978-2011.

## Relative Abundance, Age-0 and older Round Goby

Expansion of round goby populations varied among lakes, from complete in Lake Erie, to none in Lake Superior (Fig. 4). Although a single round goby was caught in a bottom trawl in Lake Superior in 2005 near the entry to the Duluth-Superior harbor, that catch was not made during the annual spring bottom trawl assessment; to date, no gobies have been caught in any annual spring bottom trawl assessments in Lake Superior. Moderate agreement in biomass trends ($W = 0.63$; $P < 0.001$) was observed among lakes where round goby has become established (Lakes Michigan, Huron, Erie, and Ontario). Greater agreement in trends among lakes was hindered by the desynchronized expansion of round goby populations, with the earliest occurring in Lake Erie, followed by Lake Huron and then by Lakes Ontario and Michigan. In 2011, biomass peaked in Lake Huron, declined sharply in Lake Michigan, and rebounded moderately in Lakes Erie and Ontario. These recent mixed results yield an unclear picture of the current state of goby populations across the Great Lakes; they may have reached equilibrium in Lake Erie, may still be expanding in Lake Huron, but the direction of trends in Lakes Michigan and Ontario remains uncertain.

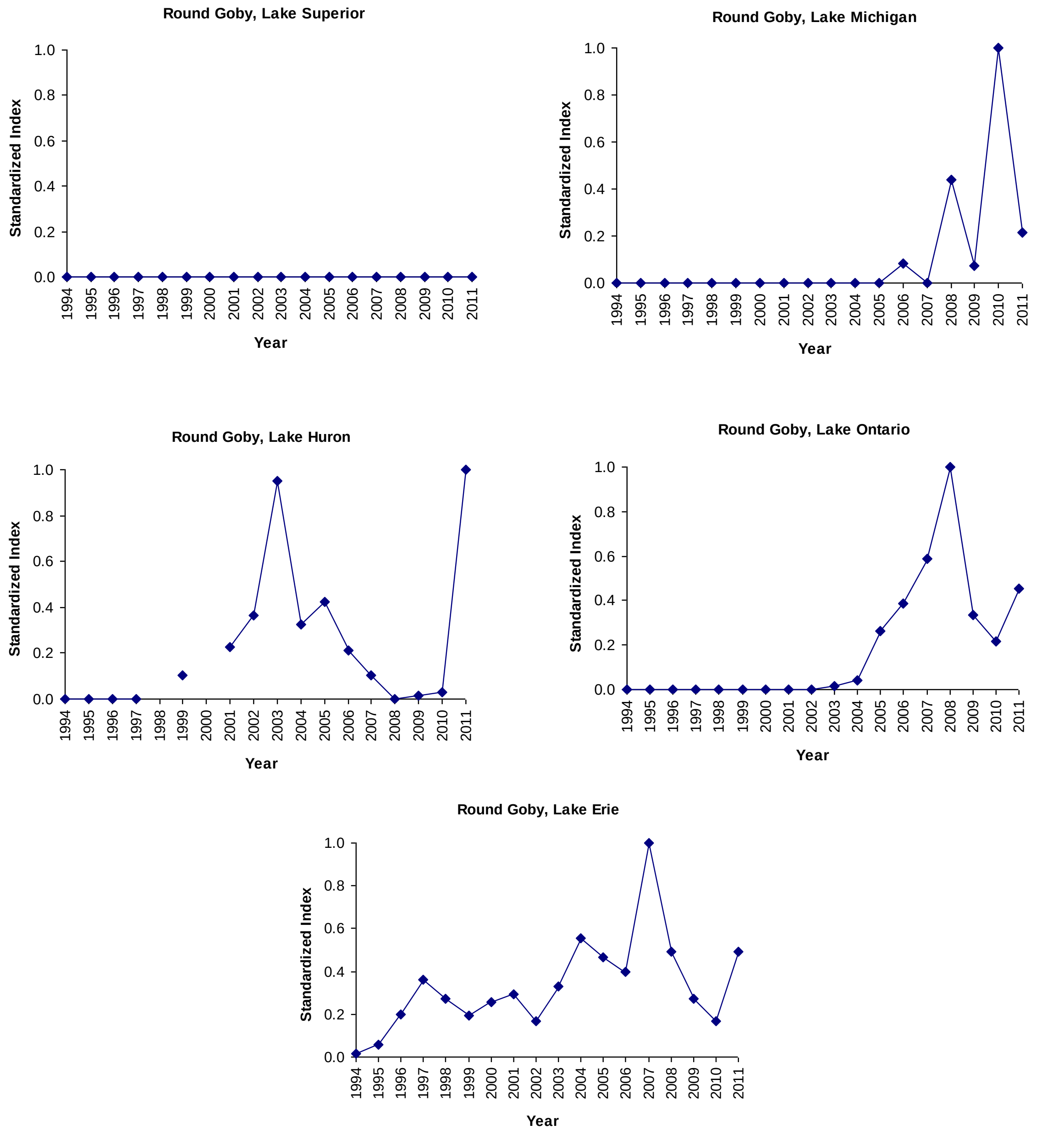


**Figure 4.** – Standardized indices of abundance for round goby in Lakes Superior, Michigan, Huron, Erie, and Ontario, 1994-2011. Indices are computed from number caught in Lake Erie and weight caught in all other lakes.

## Year-Class Strengths, Coregonids

Year-class strengths of coregonids showed moderate agreement ($W = 0.54$; $P < 0.001$) among Lakes Superior, Michigan, and Huron (Fig. 5). All lakes shared a general pattern of stronger year-classes in the 1980s and weaker year-classes in subsequent years. Stronger concordance was not observed because of the appearance of strong year-classes in Lake Huron in 2005 and 2007. Bloater were absent from survey catches in Lakes Erie and Ontario and cisco are rarely encountered outside of Lake Superior.

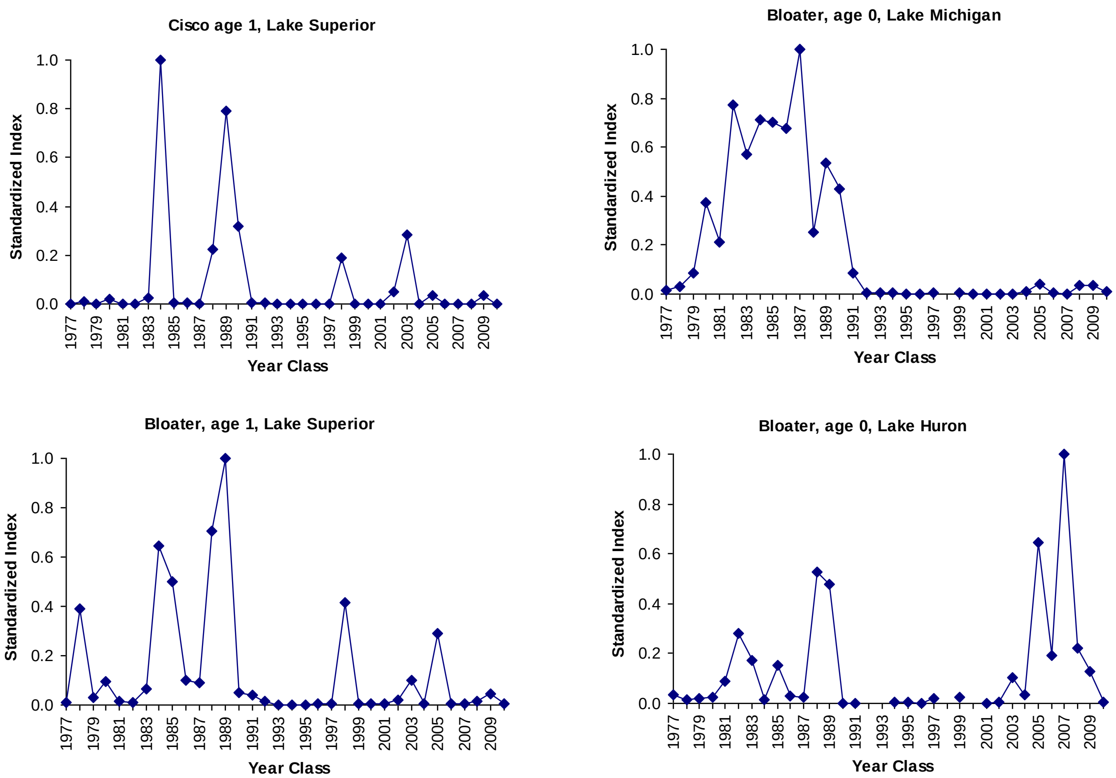


**Figure 5.** – Standardized indices of year-class strengths (age ≤1) for cisco and bloater in Lakes Superior, Michigan, and Huron, 1977-2010.

## Year-Class Strengths, Alewife

There was no agreement ($W$ = 0.45; $P$ = 0.12) in alewife year-class strength among Lakes Michigan, Huron, and Ontario for the 1977-2008 year-classes (Fig. 6). In all lakes, year-class strength was variable but at intermediate levels through the 1980s. Subsequently, Lakes Michigan, Huron, and Ontario produced large year-classes in 1998. Unfortunately, data for this year class was omitted from statistical comparisons because of anomalous data from Lake Huron. If data for this year-class was included in the statistical analysis, there may have been higher agreement across the basin. In Lake Michigan, year-classes subsequent to the strong 1998 year class were negligible. Lake Huron produced its strongest year-class in 2003, but was followed by negligible year-classes in 2004-2008. Alewife is a rare species in Lake Superior and survey data for alewife in Lake Erie were not available for this comparison.

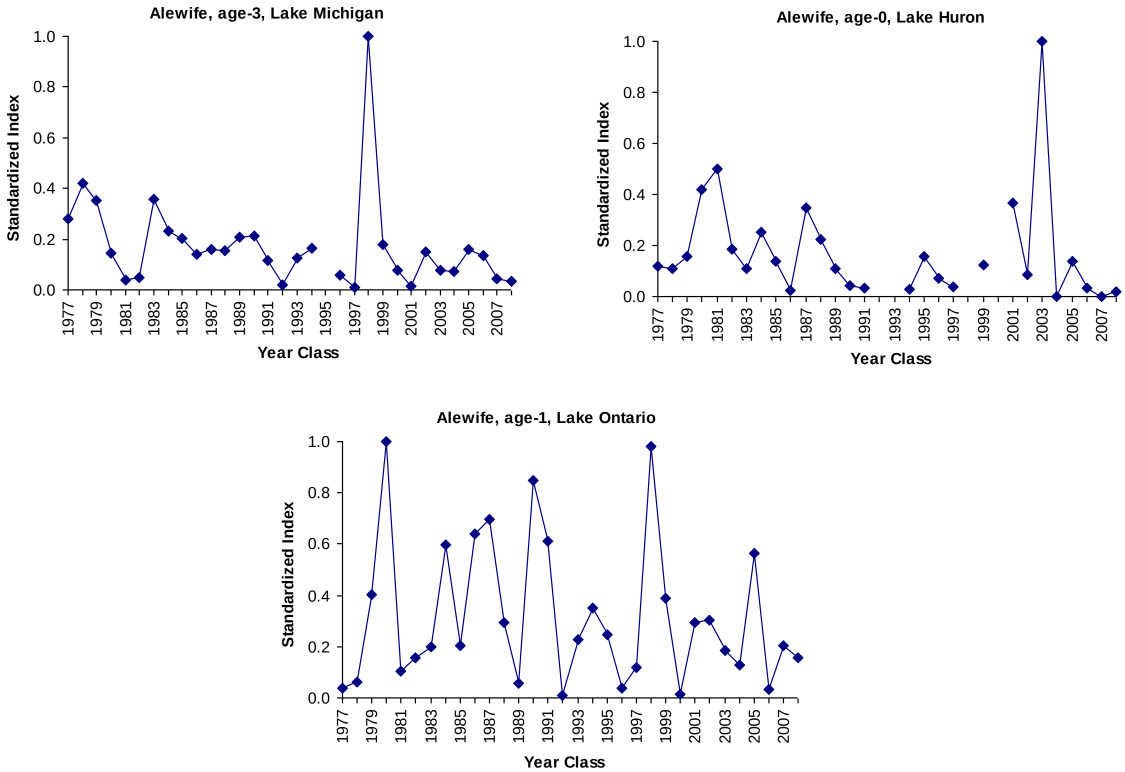


**Figure 6.** – Standardized indices of alewife year-class strengths measured at age 0, 1 or 3 (age of year-class strength is dependent on when alewife become fully vulnerable to survey on each lake) in Lakes Michigan, Huron, and Ontario, 1977-2008.

## Year-Class Strengths, Rainbow Smelt

Marginal concordance was observed among rainbow smelt year-classes in Lakes Superior, Michigan, Huron, and Ontario from 1977 to 2010 ($W = 0.37$; $P = 0.05$) (Fig. 7). 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 2003-2009 and reached a record low in 2010. In Lake Michigan, year-class strengths appear to have declined steadily from 1980 to 1997 and thereafter remained weak except for the moderately strong year classes in 2005 and 2008. In contrast, year-class strengths in Lake Huron were moderate to weak over the first 26 years of the 33-year time series, and then increased rapidly to a peak in 2005 followed by a steep decline to record lows in 2008 and 2010. In Lake Ontario, prior to 1999, year-class strength exhibited a clear "saw-tooth" pattern caused by alternating strong and weak year-classes. This pattern was not discernible during 1999-2010 due to a succession of weak year classes. To include Lake Erie in our analysis, our comparison was restricted to the 1990-2009 year-classes. After including Lake Erie, concordance in trends in year-class strengths among all lakes remained marginal ($W = 0.33$; $P = 0.05$). Lake Erie, year class strengths have varied widely showing a repeating pattern of being up for a year or two then down for the next few years. The 2009 and 2010 year-classes were relatively weak in all Great Lakes.

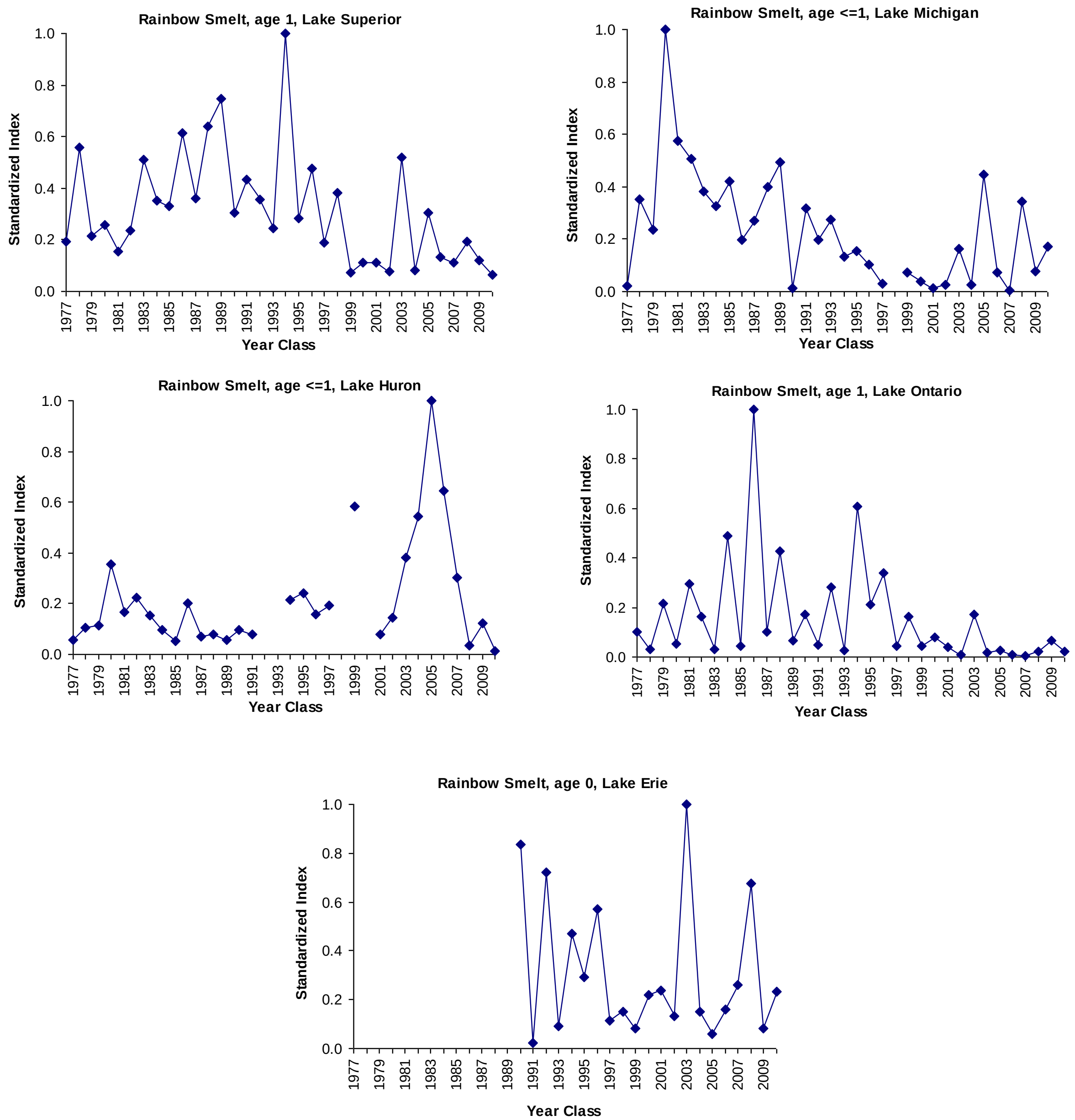


**Figure 7.** – Standardized indices of rainbow smelt year-class strengths measured at age 1, after the strength of the year-class is set in Lakes Superior and Ontario and at age 0, after the strength of the year-class appears to be set in Lakes Michigan and Huron, 1977-2010.

## Summary

There was basin-wide agreement in the trends of age-1 and older biomass for all species, with the highest concordance occurring for coregonids and rainbow smelt, and weaker concordance for alewife. 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. Alewife biomass was generally higher from the early 1980s through 1990s across the Great Lakes, but since the early 1990s, trends have been divergent across the lakes, though there has been a downward trend in all lakes since 2005. In general, year-class strength patterns were less concordant across the basin and only coregonids showed statistical agreement.

Low levels of biomass of age-1 and older coregonids, alewife, and rainbow smelt across the Great Lakes in 2011 continue a declining trend in prey fish biomass since 1990. Bloater in Lake Huron represents a notable exception to this pattern where they rebounded to 45% of peak biomass in 2011. Patterns of round goby biomass have been highly variable across lakes Michigan, Huron and Ontario, making it difficult to discern whether the populations have reached some level of equilibrium (as is apparent in Lake Erie) or whether they are still expanding or perhaps declining as round gobies become increasingly incorporated in piscivore diets. There was an absence of round goby in spring bottom trawl assessments in Lake Superior, but their presence in the harbors and embayments of Duluth and Thunder Bay (U.S. Geological Survey and Ontario Ministry of Natural Resources, unpublished data), suggests that there is potential for future colonization.

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