Great Lakes Prey Fish Populations:
A Cross-Basin Overview of Status and Trends
Based on Bottom Trawl Surveys, 1978-2012[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 principal prey species: 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 that has proliferated throughout the basin over the past 18 years. 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, standardized indices are presented in graphical form along with synopses to provide a short, informal cross-basin summary of the status and trends of principal prey fishes. In keeping with this intent, tables, references, and a detailed discussion were omitted.

For each lake, standardized relative indices of biomass for age-1 and older fishes and numeric density for recruits were calculated as the observed value divided by the maximum value observed in the times series. Year-class strength expressed as density of juvenile fish reflects the magnitude of the cohort recruited at subsequent ages. Differences in the timing of surveys across lakes and differences in methodology used to distinguish juvenile age classes resulted in adopting different age-classes (age-0, age-1, age-3) to index year-class strength for each species and lake. Year-class strengths were based on age-correlated size classes of 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.

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 3 or more lakes. *W* can range from 0 (complete discordance or disagreement) to 1 (complete concordance or agreement). For comparisons between two lakes, Spearman's correlation *r* was used assess concordance of ranks, ranging from 0 (complete discordance or disagreement) to 1 (complete concordance or agreement). The *P*-value for *W* and *r* provides the probability of agreement of trends among lakes.

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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 the 2010 report, a complete series of 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. Beginning with this report, a complete series of data from the Lake Erie was made available due to the inclusion of data from Pennsylvania waters. 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.

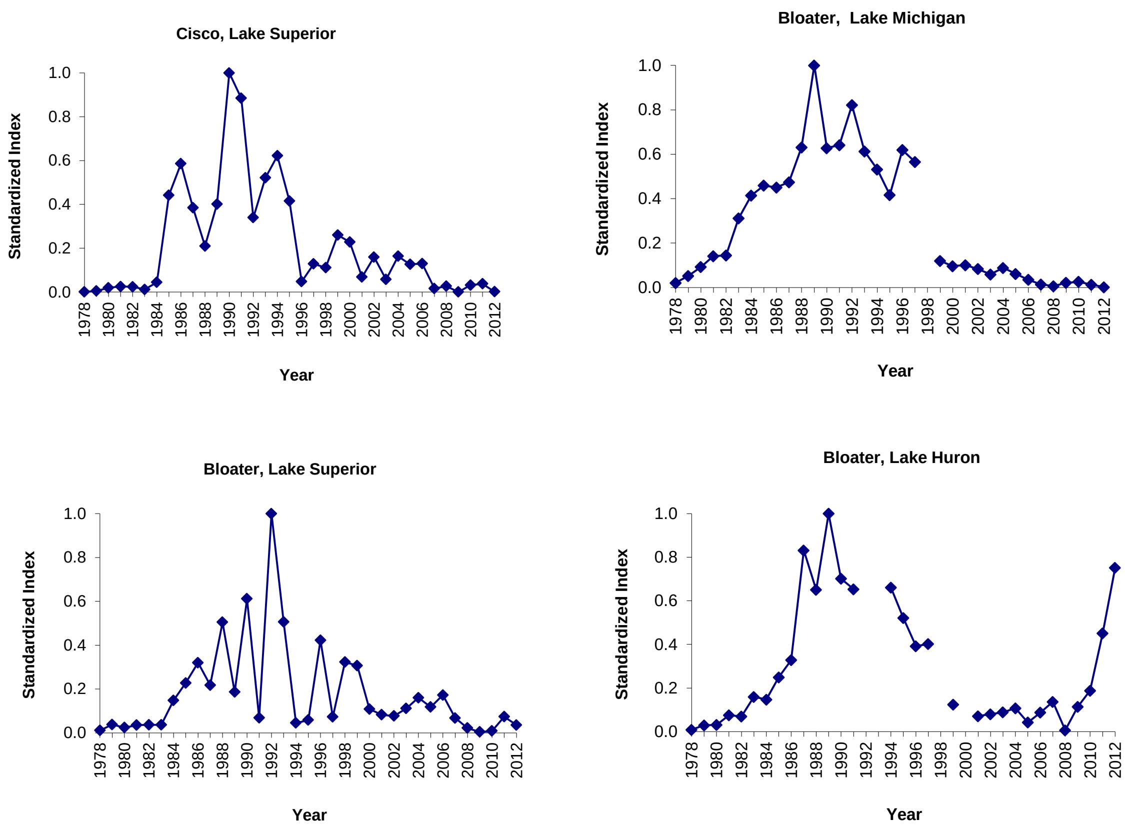

Figure 1. – Standardized indices of biomass for age-1 and older cisco in Lake Superior and for age-1 and older bloater in Lakes Superior, Michigan, and Huron, 1978-2012.

Relative Biomass, Age-1 and Older Coregonids

The three upper Great Lakes shared common trends in biomass of age-1 and older coregonids (cisco and bloater in Lake Superior and bloater in Lakes Michigan and Huron among the 1978-2012 time series (Fig. 1; $W = 0.69$; $P < 0.0001$). In all three lakes, biomass reached peak levels in the mid-1980s through the mid-1990s. Afterwards, coregonid biomass declined, reaching historically low levels by 2007-2009. In contrast, bloater in Lake Huron rebounded following a record low in 2008 to 75% of peak biomass in 2012, due to the recruitment and growth of strong 2005 and 2007 and moderate 2008 and 2011 year classes (Figs. 1, 5). The upturn in bloater biomass in Huron resulted in a modest decline in concordance among the lakes; down from 75% in 2008 to 69% in 2012. Bloater were absent from survey catches in Lakes Erie and Ontario and cisco were rarely encountered in any other Great Lake than Superior.

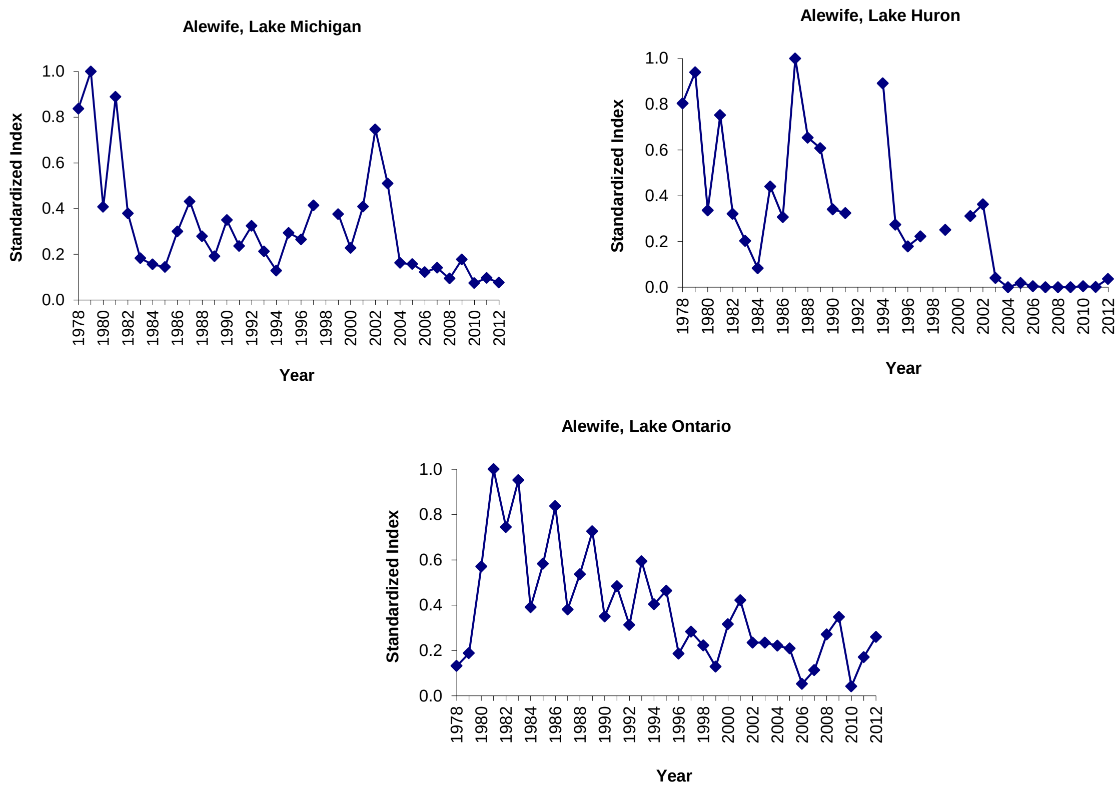

Figure 2. – Standardized indices of biomass for age-1 and older alewife in Lakes Michigan, Huron, and Ontario, 1978-2012.

Relative Biomass, Adult Alewife

Trends in relative biomass of adult alewife across Lakes Michigan, Huron, and Ontario were variable, though biomass was generally higher early in the time series and lower in more recent years (Fig. 2). For all three lakes, there was moderate concordance ($W = 0.62$; $P < 0.003$) among the 1978-2012 time series. 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 2004-2012, reaching the lowest levels in the time series in 2010 and 2012. Similarly, in Lake Huron, relative biomass of alewife 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 has declined step-wise since 1980. Alewife remains a rare species in Lake Superior and survey data for alewife in Lake Erie were not available for this comparison.

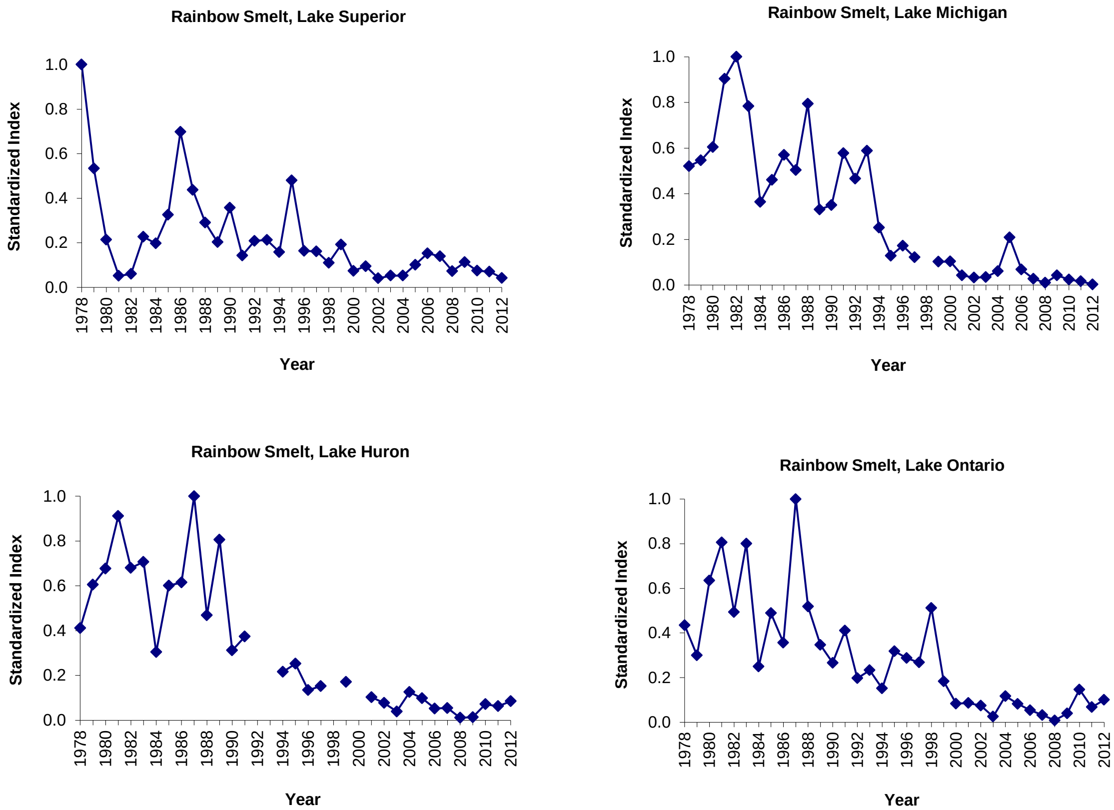

Figure 3. – Standardized indices of biomass for age-1 and older rainbow smelt in Lakes Superior, Michigan, Huron, and Ontario, 1978-2012.

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 1978-2012 (Fig. 3; $W = 0.79$; $P < 0.0001$). In Lake Superior, relative biomass was at or near-record lows in 2002-2004, recovered to 15% of peak biomass by 2006, and then declined afterwards, reaching a near-record low in 2012. Similarly, relative biomass in Lake Michigan was near record lows during 2001-2003, rose nearly 4-fold in 2005, and then dropped to record lows in 2007-2012. Mirroring the Michigan pattern, relative biomass in Lake Huron declined to near-record lows in 2002-2003, increased to 13% in 2004 and then declined to record lows in 2008-2009, but differing from the Michigan pattern, biomass increased to 6-8% of peak biomass in 2010-2012. A similar pattern was observed in Lake Ontario where biomass reached a near-record low in 2003 and was followed by two cycles of weak recovery and decline. The low level of biomass in 2012 represents a modest recovery from a record low biomass in 2008. Survey data for age-1 and older rainbow smelt in Lake Erie were not available for this comparison.

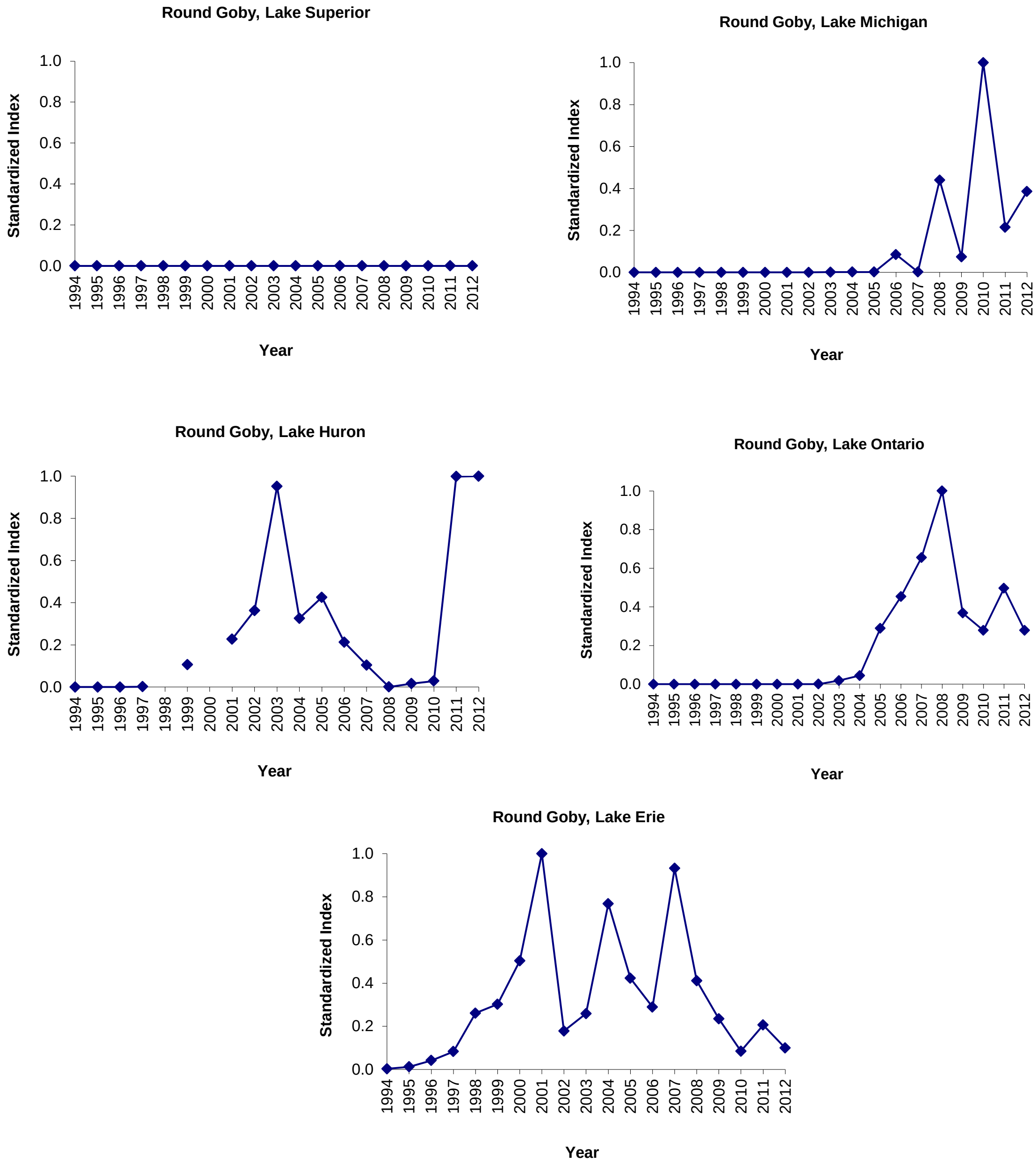

Figure 4. – Standardized indices of abundance for round goby in Lakes Superior, Michigan, Huron, Erie, and Ontario, 1994-2012. Indices are computed from number caught in Lake Erie and weight caught in all other lakes.

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 ($W = 0.57$; $P < 0.003$) was observed among lakes where round goby has become established (Lakes Michigan, Huron, Erie, and Ontario). Agreement in trends among lakes was hindered by the desynchronized expansion of round goby populations. The first records occurred in Lake Erie, followed by Lake Huron and then by Lakes Ontario and Michigan. In 2012, biomass remained at peak levels in Lake Huron, increased slightly in Lake Michigan, and declined 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 appear to 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.

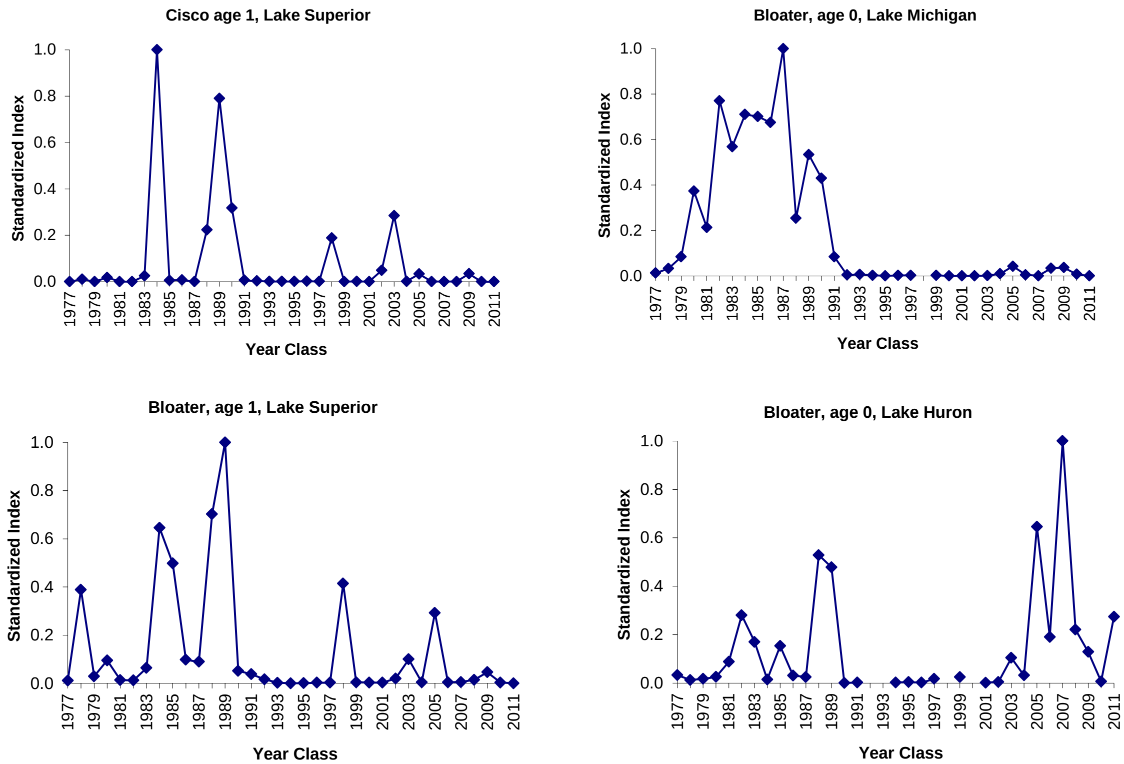

Figure 5. – Standardized indices of densities of age ≤ 1 coregonids (cisco and bloater) in Lakes Superior, Michigan, and Huron, 1977-2011.

Year-Class Strengths, Coregonids

Year-class strengths of coregonids showed moderate agreement ($W = 0.52$; $P < 0.001$) 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. Trends in year-class strengths of coregonids among the three upper Lakes showed higher concordance before the appearance of a succession of strong and moderate year-classes in Lake Huron in 2005-2011 (1977-2004; $W = 0.57$; $P < 0.0004$). Bloater were absent from survey catches in Lakes Erie and Ontario and cisco are rarely encountered outside of Lake Superior.

Year-Class Strengths, Alewife

Using relative abundances of alewife at age-3 in Lake Michigan, age-0 in Lake Huron, and age-1 in Lake Ontario to assess year-class strengths, there was no agreement in trends ($W = 0.43$; $P = 0.13$) among the Lakes for 1977-2009 year-classes (Fig. 6). Agreement became significant if abundances of alewife at age-0 in Lake Michigan (1978-2011 year classes) were substituted in the comparison ($W = 0.49$; $P < 0.05$). Comparison of relative abundances of age-0 (1978-2011 year classes) alewife in Lakes Michigan and Huron was also significant ($r = 0.45$; $P < 0.05$). However, paired comparisons of relative abundances of age-1 alewife in Lake Ontario with age-0 alewife in Lakes Michigan and Huron showed no agreement ($r = 0.21, 0.20$; $P > 0.18, 0.19$, respectively).

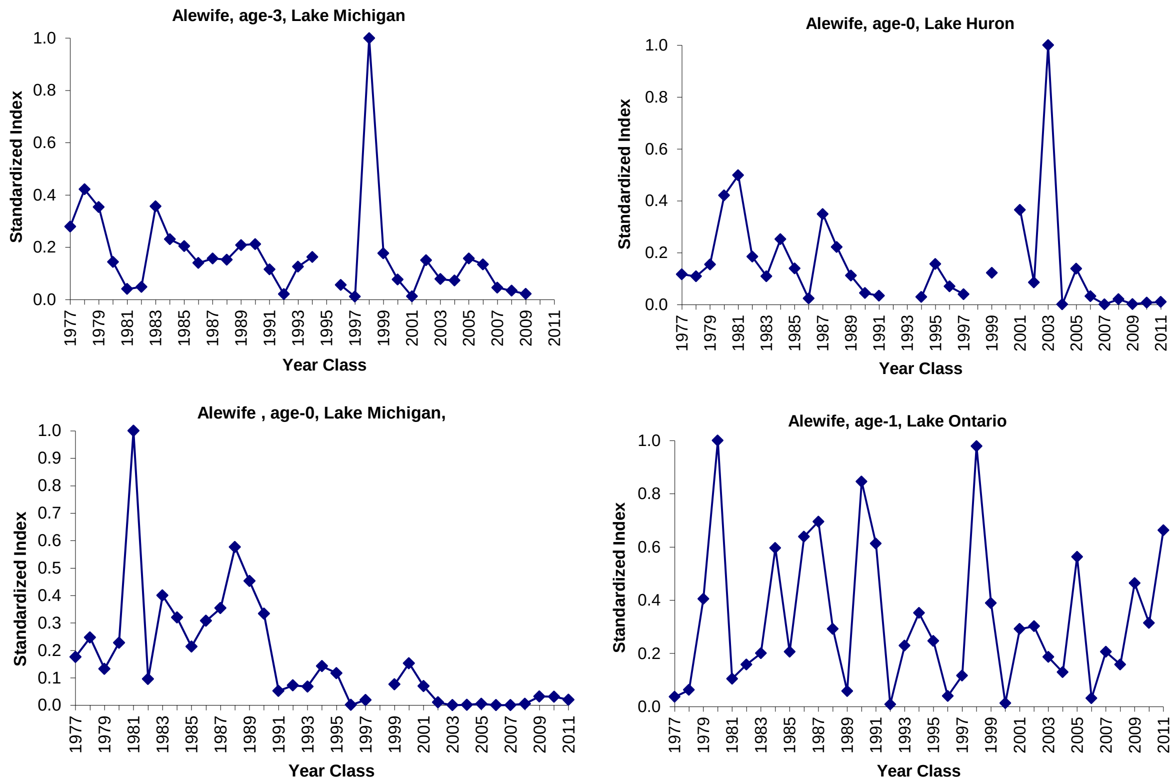

Figure 6. – Standardized indices of alewife densities measured at age 0, 1 or 3 in Lakes Michigan, Huron, and Ontario, 1977-2011.

Comparisons of recruitment trends in alewife at different ages are problematic because abundances at age-0, age-1, and age-3 are affected by differential survivorship. Thus it is not surprising that comparison of trends in year-class strength of alewife across the three lakes showed no agreement when these ages were considered. Paired comparisons showed moderate agreement between Lakes Michigan and Huron but no agreement with trends in Lake Ontario. Trends in year-class strength in Ontario were highly variable with no discernible trends. In Lakes Michigan and Huron, year-class strength was variable but at intermediate levels through the 1980s. Subsequently, a large year-class was produced in both lakes in 1998, but unfortunately data for this year class were omitted from the analysis because of anomalous sampling. If data for this year-class were included in the statistical analysis, there would have been higher agreement between the two Lakes. In Lake Michigan, year-classes subsequent to the strong 1998 year class were negligible. Lake Huron produced its strongest year-class in 2003, but subsequent year-classes were negligible. 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

Trends in rainbow smelt year-classes across Lakes Superior, Michigan, Huron, and Ontario from 1977 to 2012 showed no agreement (W = 0.33; P = 0.11) (Fig. 7). When the comparison was limited to Lakes Superior, Michigan, and Huron, the agreement was significant (W = 0.59; P < 0.006). Paired comparisons among the three lakes showed that only Lakes Superior and Michigan were in agreement (r = 0.49; P < 0.01). 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

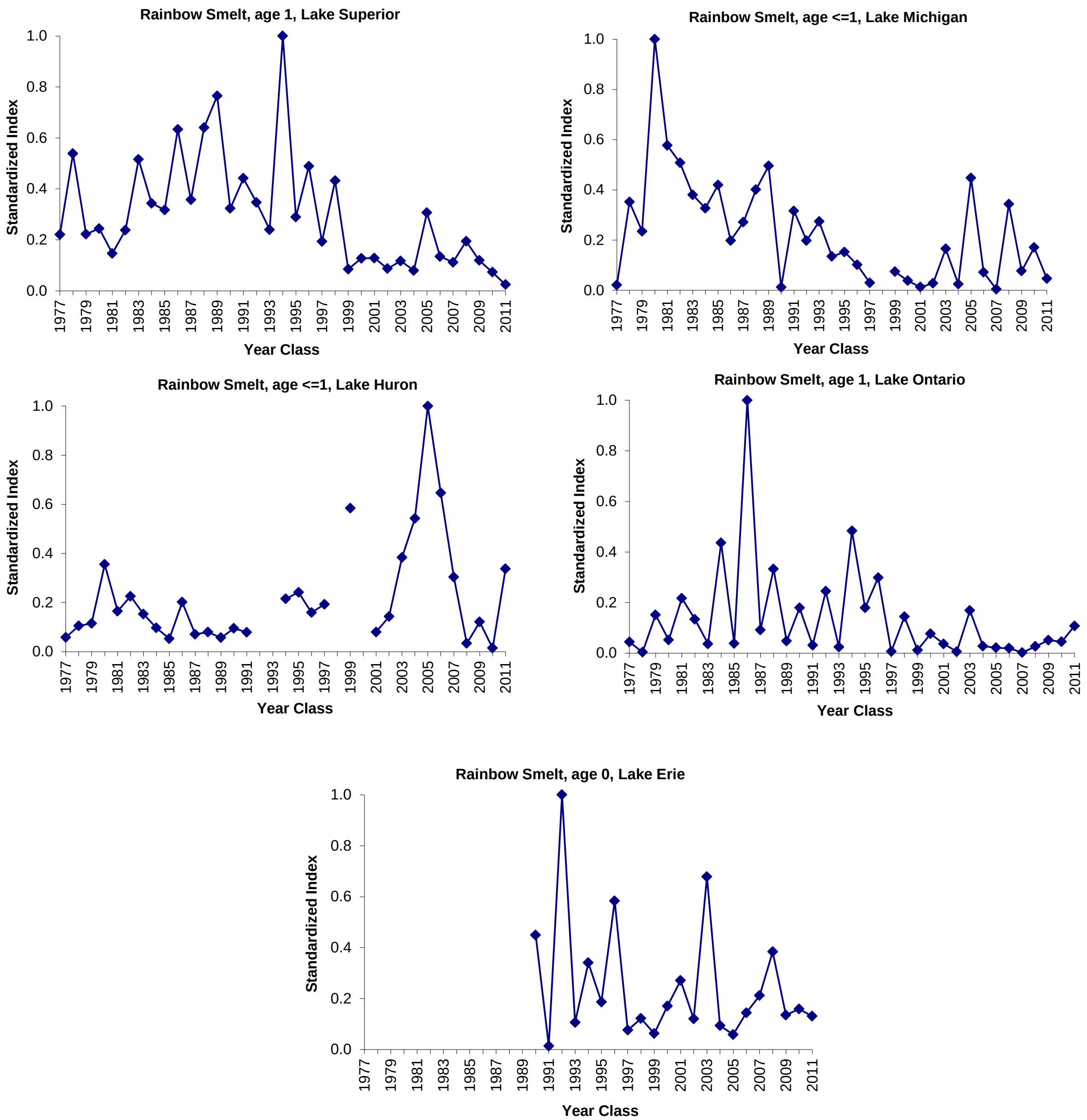

Figure 7. – Standardized indices of rainbow smelt densities measured at age-1 in Lakes Superior and Ontario and at age-0 in Lakes Michigan and Huron, 1977-2011.

2003-2009 and reached a record lows in 2010 and 2011. In Lake Michigan, year-class strengths 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 and then rebounded to 34% of the record in 2011. 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 1999-2011 due to a succession of weak year classes. To include Lake Erie in our analysis, the comparison was restricted to the 1990-2011 year-classes. After including Lake Erie, concordance in trends in year-class strengths among all lakes remained insignificant ($W = 0.28$; $P = 0.13$) and paired comparisons showed agreement only between Lakes Erie and Ontario ($r = 0.57$; $P < 0.05$). Agreement between Lakes Erie and Ontario was caused by concordance in up and down patterns of year-class strengths between 1990 and 2005 (Fig. 7).

Summary

There was basin-wide agreement in the trends of age-1 and older biomass for all prey 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 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. The exception to this pattern of decline was Lake Huron, which has shown resurgence in biomass of bloater, achieving 75% of its maximum record in 2012 due to recruitment of a succession of strong and moderate year classes that appeared in 2005-2011.

In general, trends in year-class strength were less concordant across the basin and only coregonids showed statistical agreement across the upper Great Lakes. The appearance of strong and moderate year-classes of bloater in Lake Huron in 2005- 2011 countered the trend of continuing weak year-classes of coregonids in Lakes Michigan and Superior. There was no agreement in cross-basin trends in year-class strength for rainbow smelt and alewife, but there was agreement between pairs of lakes. Lakes Michigan and Superior showed concordant trends in year-class strength of rainbow smelt as did Lakes Erie and Ontario. Lakes Michigan and Huron showed agreement in trends of age-0 alewife.

Although there was statistical agreement in trends of round goby biomass among lakes where this species has successfully invaded (Michigan, Huron, Erie and Ontario), temporal patterns of abundance in each lake were different. Gobies appear to have reached some level of equilibrium in Lake Erie while they may be peaking in Lake Huron. Declining biomass in Lakes Michigan and Ontario in recent years may signal a trend toward equilibrium. Trends toward lower equilibrium levels have corresponded with evidence that round gobies have become increasingly incorporated into piscivore diets, e.g., lake trout, walleye, smallmouth bass, yellow perch, and burbot. Round gobies continue to be absent from 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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