Preyfish Populations

Formerly Indicator #17

Overall Assessment

Status: Mixed

Trend: Deteriorating

Rationale: In all five Laurentian Great Lakes, preyfish biomass has decreased since 1988. This decrease in preyfish biomass may be partly attributable to predation by piscivorous fish populations. However, other factors likely contributed to the decrease in preyfish biomass, including variation and gaps in recruitment of ciscoes, shifts of fish populations to waters deeper than those sampled by bottom trawl surveys, declines in offshore primary productivity and phosphorous levels, and negative effects induced by dreissenid mussel and *Bythotrephes* invasions. Expansion of non-native gobies in demersal habitats of the lower lakes is symptomatic of a change in the food web. Assessing and quantifying bottom-up effects on preyfish biomass will require additional years of surveillance, across-lake comparisons, and food-web analyses. Because Lake Superior has not been successfully invaded by dreissenid mussels, Lake Superior can serve as a control lake when attempting to assess the effects of dreissenid mussels on food webs and preyfish populations.

Lake-by-Lake Assessment

Lake Superior

Status: Mixed

Trend: Improving

Rationale: Abundance of preyfish populations, dominated by native coregonids, continues to fluctuate with a downward trend that sharply steepened in 2009. The decline in preyfish populations since the early 1990s is attributed to recruitment variation and predation by recovered lake trout populations. Non-native rainbow smelt remains as a principal component of preyfish assemblage. Round gobies are present though rare in western Lake Superior and Eurasian ruffe, though uncommon, continues to colonize inshore waters and embayments.

Lake Michigan

Status: Mixed

Trend: Deteriorating

Rationale: Several preyfish populations (i.e., alewife, bloater, rainbow smelt, deepwater sculpin) are near historic lows, while densities of non-native round goby are increasing. The decline in *Diporeia* and expansion of dreissenids, particularly quagga mussels, to deeper waters signal a shift in food web toward greater biomass in the benthic food web relative to the pelagic one; further community change is expected.

Lake Huron

Status: Mixed

Trend: Deteriorating

Rationale: Non-native preyfish populations are at historic lows and native bloater has become the dominant prey species. The decline in *Diporeia* and colonization of dreissenids signals a shift in food web toward a benthic organization and further community change.

Lake Erie

Status: Mixed

Trend: Deteriorating

Rationale: Preyfish (spiny-rayed and softfin fish species) populations have increased since the early1990s but have fluctuated considerably. Biomass of clupeids has declined since 2001. Non-native round goby populations expanded rapidly after 1994, peaked in 2007, and afterwards declined by 90%. The colonization of dreissenid mussels has resulted in major changes in the food web.

Lake Ontario

Status: Mixed

Trend: Deteriorating

Rationale: Non-native preyfish populations have fluctuated about historic lows and non-native alewife remains the dominant prey species. Abundance of non-native round goby has declined sharply since 2008. Colonization of offshore waters by dreissenids has increased energy flow from the pelagia to the lake bottom. Catches of native deepwater sculpin, a population thought to be extirpated from Lake Ontario, have increased steadily in catches taken at depths > 70 m since 2005. Native deepwater ciscoes have not been reported in the lake since 1983; however, initial restoration efforts have begun. A new invasive invertebrate, *Hemimysis anomala,* was discovered in 2006 and has become widely established in nearshore waters. Thus far, its impacts on the lake ecosystem appear to be minimal.

Purpose

- To assess the abundance and diversity of preyfish populations
- To infer the stability of predator species necessary to maintain the biological integrity of each lake

Ecosystem Objective

The importance of preyfish populations to support healthy, productive populations of predator fishes is recognized in the Fish Community Goals and Objectives (FCGOs) for each lake. For example, the Fish Community Objectives (FCOs) for Lake Michigan specify that in order to restore an ecologically balanced fish community, a diversity of prey species at population levels matched to primary production and predator demands must be maintained. This indicator also relates to the 1997 Strategic Great Lakes Fisheries Management Plan Common Goal Statement for Great Lakes fisheries agencies.

State of the Ecosystem

Background

The preyfish assemblage forms important trophic links in the aquatic ecosystem and constitutes the majority of the fish production in the Great Lakes. Preyfish populations in each of the lakes are currently monitored on an annual basis in order to quantify the population dynamics of these important fish stocks and to provide a better understanding of the processes that shape the fish community. Populations of lake trout, Pacific salmon, and other salmonids have been established as part of intensive stocking programs designed to rehabilitate or develop new sport fish populations and commercial fisheries. These economically valuable predator species sustain increasingly demanding and highly valued fisheries, and information on their status is crucial. In turn, these apex predators are sustained by preyfish populations. In addition, some preyfishes, such as the bloater and the cisco, which are native species, and the rainbow smelt, which is non-native, are also directly important to the commercial fishing industry. Therefore, it is very important that the current status and estimated carrying capacity of the preyfish populations be fully understood in order to fully address (1) lake trout restoration goals, (2) stocking projections, (3) present levels of salmonid abundance, and (4) commercial fishing interests.

The component of the Great Lakes fish communities that we classify as preyfish comprises species – including pelagic, benthopelagic and benthic species – that prey on invertebrates for their entire life history. As adults, most preyfish depend on diets of crustacean zooplankton and macroinvertebrates *Diporeia* and *Mysis*. Round gobies, which have invaded in the past ~15 years, also make use of dreissenid mussels as a primary diet component. This convention also supports the recognition of particle-size distribution theory and size-dependent ecological processes. Based on size-spectra theory, body size is an indicator of trophic level, and the smaller, short-lived fish that constitute the planktivorous fish assemblage discussed here are a discernable trophic group of the food web. At present, bloaters (*Coregonus hoyi*), cisco (*Coregonus artedi*), rainbow smelt (*Osmerus mordax*), alewife (*Alosa pseudoharengus*), and deepwater sculpins (*Myoxocephalus thompsonii*) constitute the bulk of the preyfish communities across the five lakes (Figure 1). In Superior, juvenile lake whitefish (*Coregonus clupeaformis*) is a principal prey species. Other species contributing a lesser extent to the preyfish assemblages include pygmy whitefish (*Prosopium coulteri*), ninespine stickleback (*Pungitius pungitius*), round goby (*Apollonia melanostoma*), trout-perch (*Percopsis omiscomaycus*), and slimy sculpin (*Cottus cognatus*). In Lake Erie, the preyfish community is unique among the Great Lakes in that it is characterized by relatively high species diversity. The preyfish community comprises primarily gizzard shad (*Dorosoma cepedianum*) and alewife (grouped as clupeids); emerald (*Notropis atherinoides*) and spottail (*N. hudsonius*) shiners; silver chub (*Hybopsis storeriana*); trout-perch (*Percopsis omiscomaycus*); round goby and rainbow smelt (grouped as soft-rayed); age-0 yellow perch (*Perca flavescens*) and white perch (*Morone americana*), and white bass (*M. chrysops*) (grouped as spiny-rayed).

The successful colonization of lakes Michigan, Huron, Erie, and Ontario by zebra mussel (*Dreissena polymorpha*) in the early 1990s and more recently the quagga mussel (*Dreissena bugensis*), has had a significant impact on the trophic structure of those lakes by sequestering energy and nutrients in the benthos and increasing water clarity of open waters. Only a handful of fish species (round gobies, lake whitefish, freshwater drum, lake sturgeon) consume dreissenid mussels. As a result, managers are concerned that expansion of dreissenids will reduce production of important pelagic preyfish species, because they can potentially reduce energy transfer from benthic to pelagic regions. As a result of profound ongoing changes in trophic structure in the lower Great Lakes, their ecosystems will continue to change, likely in unpredictable ways.

State of Preyfish Populations

Lake Superior: Mixed, improving

Since 1994, biomass of the Lake Superior preyfish has declined compared to the peak years in 1986, 1990, and 1994, a period when cisco was the dominant preyfish species and wild lake trout populations were starting to recover (Gorman et al. 2011a). Since the early 1980s, the dynamics of preyfish biomass have been driven largely by variation in recruitment of age-1 cisco. Strong year classes in 1984, 1988-1990, 1998, and most recently 2003 were largely responsible for peaks in cisco biomass in 1986, 1990-1994, 1999, and 2004-2006. Prior to 1984, the non-native rainbow smelt was the dominant preyfish, but fluctuating population levels and recovery of native coregonids after 1984 resulted in reduced smelt biomass. Biomass of bloater and lake whitefish has increased since the early 1980s, and has been less variable than that of cisco. Since 2006, cisco and bloater abundance has declined sharply. During 2002 to 2004 and 2009-2010 rainbow smelt biomass declined to the lowest levels in the time series. There is strong evidence that declines in cisco, bloater, and rainbow smelt biomass are tied to increased predation by recovered lake trout populations. Other preyfish species, notably sculpins, burbot, and ninespine stickleback have declined in abundance since the recovery of wild lake trout populations in the mid-1980s. Thus, the current state of the Lake Superior preyfish community appears to be largely the result of recruitment variation in prey species, increased predation by recovered wild lake trout stocks, and to a lesser degree, the resumption of human harvest of lake trout, cisco, and lake whitefish.

Lake Huron: Mixed, deteriorating.

In the 1970-mid-1980s the Lake Huron preyfish community was dominated by exotic alewife and rainbow smelt. Following this early period, strong recruitment of native bloater stocks contributed as much 47% to preyfish biomass. After 1994 preyfish biomass trended downward and accelerated after 2002 when alewife stocks abruptly collapsed. The collapse of alewife stocks appears due to heavy salmonid predation by increased Chinook salmon abundance which was augmented by wild reproduction. Further decline of rainbow smelt and recruitment of bloater resulted in a preyfish community dominated by boater. From 2004 to 2010, U.S. Geological Survey (USGS) surveys captured increasing numbers of wild juvenile lake trout, signaling natural reproduction from recovering lake trout stocks. Meanwhile, salmon catch rates by anglers declined, as did average size and condition of those fish. Accompanying the decline in fish biomass and shift toward native fishes was a decline in lower trophic level productivity; the deepwater amphipod *Diporeia* has declined throughout Lake Huron's main basin, and the zooplankton community has changed so that it resembles the assemblage found in Lake Superior. The reasons triggering the shift toward a more oligotrophic state are not known, but a widely held hypothesis is that zebra and quagga mussels are shunting energy and nutrients into a benthic pathway and are no longer available to *Diporeia* and pelagic zooplankton and fish.

Lake Michigan: Mixed, deteriorating

Bloater abundance in Lake Michigan fluctuated greatly from 1973 to 2010, showing a strong expansion during the 1980s, and a rapid decline in the late 1990s (Madenjian et al. 2010). Bloater populations may have a cyclic pattern in year-class strength, with a period of about 30 years. The substantial decline in alewife abundance during the 1970s and early 1980s has been attributed to increased predation by salmon and trout. The Lake Michigan deepwater sculpin population exhibited a strong recovery during the 1970s and early 1980s, and this recovery has been attributed to the decline in alewife abundance. Alewives have been suspected of interfering with reproduction of deepwater sculpins by feeding upon deepwater sculpin fry. Slimy sculpin abundance appeared to be primarily regulated by predation from juvenile lake trout as it is a favored prey of juvenile lake trout. Temporal trends in abundance of rainbow smelt are difficult to interpret. Yellow perch may be showing early signs of a recovery in the main basin of Lake Michigan. The first catch of round gobies in the annual lakewide survey occurred in 2003, and round goby abundance in the main basin of the lake has increased during 2003-2010. Total preyfish biomass in Lake Michigan during 2007-2010 was at record low levels. Although this low abundance has been tied to the dreissenid mussel invasions, other explanations (including increased predation by Chinook salmon on alewives, shift of deepwater sculpin to deeper water, and a long-term cyclic pattern in bloater year-class strength) may to be more plausible. Assessing and quantifying the bottom-up effects on preyfish biomass will likely require additional years of surveillance, across-lake comparisons, and food-web analyses.

Lake Erie: Mixed, deteriorating
The preyfish community of Lake Erie has shown mixed trends in composition and abundance since 1987. In the mid-1990s, spiny-rayed and clupeid preyfishes declined in abundance while softfin preyfish increased. Abundance of spiny-rayed preyfish abundance increased after 1998 while abundance of clupeids declined after 2000. Abundance of softfin preyfish remained relatively stable from 1997 through 2010. These patterns have not been consistent across the three basins of Lake Erie. In the eastern basin, abundance of rainbow smelt (part of the soft-rayed group) declined since the late 1980s, however, this trend may have reversed after 2000 as abundance of smelt increased though with high inter-annual variation. Preyfish abundance in the central and western basins also declined since the late 1980s, the result of declines in abundance of age-0 white perch and rainbow smelt, although abundances of white perch and rainbow smelt increased after 2006. In 2004, 2008 and 2010, the clupeid preyfish component of the central and western basins declined to the lowest levels in the time series. Overlying trends in principal preyfishes was the proliferation of invasive, non-native species. By 1989 dreissenids had successfully colonized all three basins (Barbiero and Tuchman, 2004). Following the invasion of round goby in 1994 and their proliferation throughout the lake by the late-1990s, abundance declined sharply after 2007 (Gorman and Bunnell, 2011). The establishment of dreissenids in Lake Erie has affected nutrient and energy cycling (Culver and Conroy 2007) and changes in the preyfish community after 1989 may be at least partly attributable to their proliferation. The biomass estimates for western Lake Erie were based on data from bottom trawl catches, depth strata extrapolations (less than and greater than 6 m), and trawl net measurements using acoustic mensuration gear.

Lake Ontario: Mixed, deteriorating
The non-native alewife continues to dominate the preyfish community, but their populations remain at levels well below that of the early 1980s. The rainbow smelt population continues to decrease and has an abbreviated size structure suggestive of heavy predation pressure. Abundance of the non-native round goby appears to have stabilized at a biomass level similar to that of rainbow smelt. Frequent observations of round goby in sport fish diets suggest that it is an important link in moving energy from dreissenids to larger predators. Catches of deepwater sculpin, thought to be extirpated from the Lake, have steadily increased in depths greater than 70 meters since 2005. Current deepwater sculpin bottom trawl catches include a mix of age classes, suggesting conditions are favorable for recovery. Deepwater ciscoes, however, have not been reported in the lake since 1983 and the large area of the lake they once occupied may be devoid of fish for much of the year. Furthermore, dreissenid colonization in deeper waters is increasing the flow of energy from the open water to the lake bottom. Zooplankton density in surface waters remains low, likely a result of non-native *Bythotrephes* and *Cercopagis* predation. Dynamic changes in zooplankton density with water depth suggest that algal and zooplankton production around the thermocline may be important for supporting the native *Mysis diluviana* and preyfishes. The nearshore invasive shrimp, *Hemimysis*

anomala, discovered in the lake in 2006, has spread throughout the lake and is often found associated with rocky bottom types. Diet and energy tracer studies suggest *Hemimysis* consume a mix of near shore zooplankton and algae.

Pressures

The influences of predation by salmon and lake trout on preyfish populations appear to be common across all lakes. Additional pressures from dreissenid mussels which are linked to the collapse of *Diporeia,* are strong in all the Great Lakes except Lake Superior. Recent declines in preyfish abundance observed in lakes Ontario, Huron, and Michigan, suggest that dynamics of preyfish populations in those lakes may be driven by a combination of pressures from predation (top down) and benthification by dreissenid mussel proliferation (bottom up). Which of these pressures will have precedence in future years is unclear. Moreover, non-native zooplankters, *Bythotrephes* and *Cercopagis*, could negatively influence preyfish populations by competing for cladoceran and copepod zooplankton, if they are indeed limiting. A new invasive invertebrate *Hemimysis anomala*, now present in Lake Ontario, has the potential to further disrupt Great Lakes foodwebs,

Management Implications

Recognition of significant predation effects on preyfish populations, particularly alewife, has resulted in recent salmon stocking cutbacks in Lake Michigan and Lake Huron and only minor increases in Lake Ontario. However, alewife have exhibited the ability to produce strong year classes from small adult stocks when climatic conditions are favorable such that the continued judicious use of artificially propagated predators may be necessary to avoid domination by alewife. For example, the 2010 year-class of alewife in Lake Michigan was among the largest ever recorded in the 15-year history of the acoustic survey. On the other hand, the continued low abundance of alewife in Lake Huron since their collapse in 2003 suggests that the ability to produce strong year-classes from small stock sizes is not inevitable, however, it is unclear whether poor biotic and abiotic conditions for alewife larvae or strong predatory pressure on age-0 alewife are responsible for the absence of an alewife recovery in Lake Huron. Continued strong predation pressure on alewife in Lake Huron may be preventing adults from reaching a threshold population size needed to generate a large year class. Thus, alewife stocks in Lake Huron may be trapped in a "predator pit" (J. Bence, personal communication). Stocking of predators is not an option in Lake Superior where lake trout and salmon are almost entirely lake-produced. This scenario reinforces the need to avoid further introductions of non-native species into the Great Lakes ecosystems.

Comments from the Authors

In order to restore an ecologically balanced fish community, a diversity of prey species at population levels matched to primary production and predator demands must be maintained. However, the current mix of native and naturalized prey and predator species, and the contributions of artificially propagated predator species into the system, confound any sense of balance in any lakes other than Lake Superior. The metrics of ecological balance as the consequence of fish community structure are best defined through food-web interactions. It is through understanding the exchanges of trophic supply and demand that the fish community can be described quantitatively and ecological attributes such as balance can be better defined and the limits inherent to the ecosystem be realized.

Currently, new efforts to develop food web models are underway in all the Great Lakes. Ecosystem models (Ecopath with Ecosim) have been developed in all of the Great Lakes in recent years, and this synthesis of data across trophic levels will provide new insights into the important ecological drivers within each lake as well as the key differences across the Great Lakes. Because full development of these models is hindered by a lack of data, USGS plans to intensively sample multiple trophic levels in each of the Great Lakes over 2010-2014. This work will be conducted in coordination with intensive monitoring of lower trophic level communities in each lake by USEPA and Environment Canada. This work is above and beyond the long-term annual monitoring of fish communities. In addition, over the past decade or so, fisheries scientists have begun to recognize the sampling limitations of traditional capture techniques (day bottom trawling), and have added complementary night bottom trawling, midwater trawling, and acoustic techniques to more accurately estimate abundance of preyfish in the Great Lakes (Stockwell et al. 2006, 2007; Yule et al. 2007, 2008). Though not an assessment panacea, hydroacoustics have provided additional insights and have demonstrated utility in yielding more accurate estimates of preyfish biomass.

Long-term preyfish assessment data for Lake Superior is presently restricted to the nearshore waters (15-80 m depth) which constitute only ~16% of the Lake surface area. Offshore waters (>80 m depth) constitute ~77% of the Lake surface area and remain poorly studied. Surveys of offshore waters conducted during 2001-2010 revealed a preyfish assemblage dominated by adult cisco, kiyi (*C. kiyi*) and deepwater sculpin and the dominant predator is siscowet lake trout (Gorman et al. 2011a). Given the large area of offshore habitat in Lake Superior, consideration of trends in the offshore fish assemblage should be addressed to assess the state of the lake-wide fish community. Research on the offshore fish community since 2005 has shown that the offshore food web is distinct from the nearshore foodweb (Stockwell et al. 2010a,b; Gamble et al. 2011a,b). Studies of diel movement of Lake Superior fishes demonstrate that approximately 80% of the fish community biomass undergoes diel vertical migration, effectively linking benthic and pelagic zones of the lake (Gorman et al. 2011b). Trophic transfers between nearshore and offshore waters may be facilitated by seasonal movement of fish, primarily cisco. These findings have spurred the development of a new annual assessment program which will incorporate sampling in both nearshore and offshore waters.

The native deepwater demersal preyfish community in Lake Huron was historically dominated by deepwater ciscoes, sculpins, and cisco, with ninespine sticklebacks and trout-perch also present. By the 1950s, the native community was disrupted by introductions of alewife and rainbow smelt and was dominated by non-native invasive species. More recently, introductions of dreissenid mussels, predatory zooplankters (*Bythotrephes* sp. and *Cercopagis* sp.), and round gobies have further affected this community, which was in a state of collapse by 2006 (Riley et al. 2008). The total estimated lakewide offshore demersal prey biomass in Lake Huron (from bottom trawling) has continued to decline, and was at the second-lowest level recorded in 2010 (29.1 Kt; Roseman et al. 2011), approximately 12 percent of the highest estimate (242.5 Kt) recorded in 1987. Invasive alewife populations collapsed in 2003 and estimated biomass of this species has remained very low, but there are indications that rainbow smelt and bloater abundance are beginning to rebound. In particular, bloater abundance appears to be approaching the levels observed in the 1980s and 1990s, but biomass remains lower due to a relative lack of larger fish. In recent years biomass estimates for sculpins, sticklebacks, and trout-perch were near the lowest levels observed in the time series, indicating that benthic offshore conditions in Lake Huron may have changed in a way that does not favor previous population levels (Roseman et al. 2011). Round gobies have declined to relatively low abundance (Roseman et al. 2011). Changes in habitat use and fish schooling suggest that large-scale changes may be occurring in the benthic environment (Dunlop et al. 2009; Riley and Adams 2010). Abundance of *Diporeia* has declined sharply to low densities throughout the lake (Nalepa et al. 2007), and recent work suggests that invasive

Bythotrephes may consume large amounts of zooplankton (Bunnell et al. 2011). Recent changes in fish populations may stem from restructured food webs which in turn may be related to the effects of invasive species. Continuing low levels of preyfish abundance may have serious implications for the growth, condition, and survival of predatory fish in the lake.

Protecting or re-establishing rare or extirpated members of the once prominent native preyfish communities, most notably the various members of the whitefish family (*Coregonus* spp.), should be a priority in all the Great Lakes, but especially so in Lake Ontario where vast areas of the lake once occupied by extirpated deepwater ciscoes are devoid of fish for much of the year. Lake Superior, whose preyfish assemblage is dominated by indigenous species and retains a full complement of ciscoes, should be examined more closely to better understand the trophic ecology of its more natural system.

With the continuous nature of changes that seems to characterize the preyfish populations of the Great Lakes, and the lower trophic levels on which they depend, the appropriate frequency to review this indicator should be on a 3-year basis.

Assessing Data Quality

Insert “x” under the statement that best corresponds with each data characteristic

Data Characteristics	Strongly Agree	Agree	Neutral or Unknown	Disagree	Strongly Disagree	Not Applicable
1. Data are documented, validated, or quality-assured by a recognized agency or organization	X					
2. Data are traceable to original sources		X				
3. The source of the data is a known, reliable and respected generator of data	X					
4. Geographic coverage and scale of data are appropriate to the Great Lakes basin				X		
5. Data obtained from sources within the U.S. are comparable to those from Canada			X			
6. Uncertainty and variability in the data are documented and within acceptable limits for this indicator report	X					
Clarifying Notes:						

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List of Figures

Figure 1. Preyfish trends based on annual bottom trawl surveys.

All trawl surveys were performed by USGS - Great Lakes Science Center, except for Lake Erie, which was conducted by the USGS, Ohio Division of Wildlife and the Ontario Ministry of Natural Resources (Lake Erie Forage Task Group), and Lake Ontario, which was conducted jointly by USGS and the New York State Department of Environmental Conservation.

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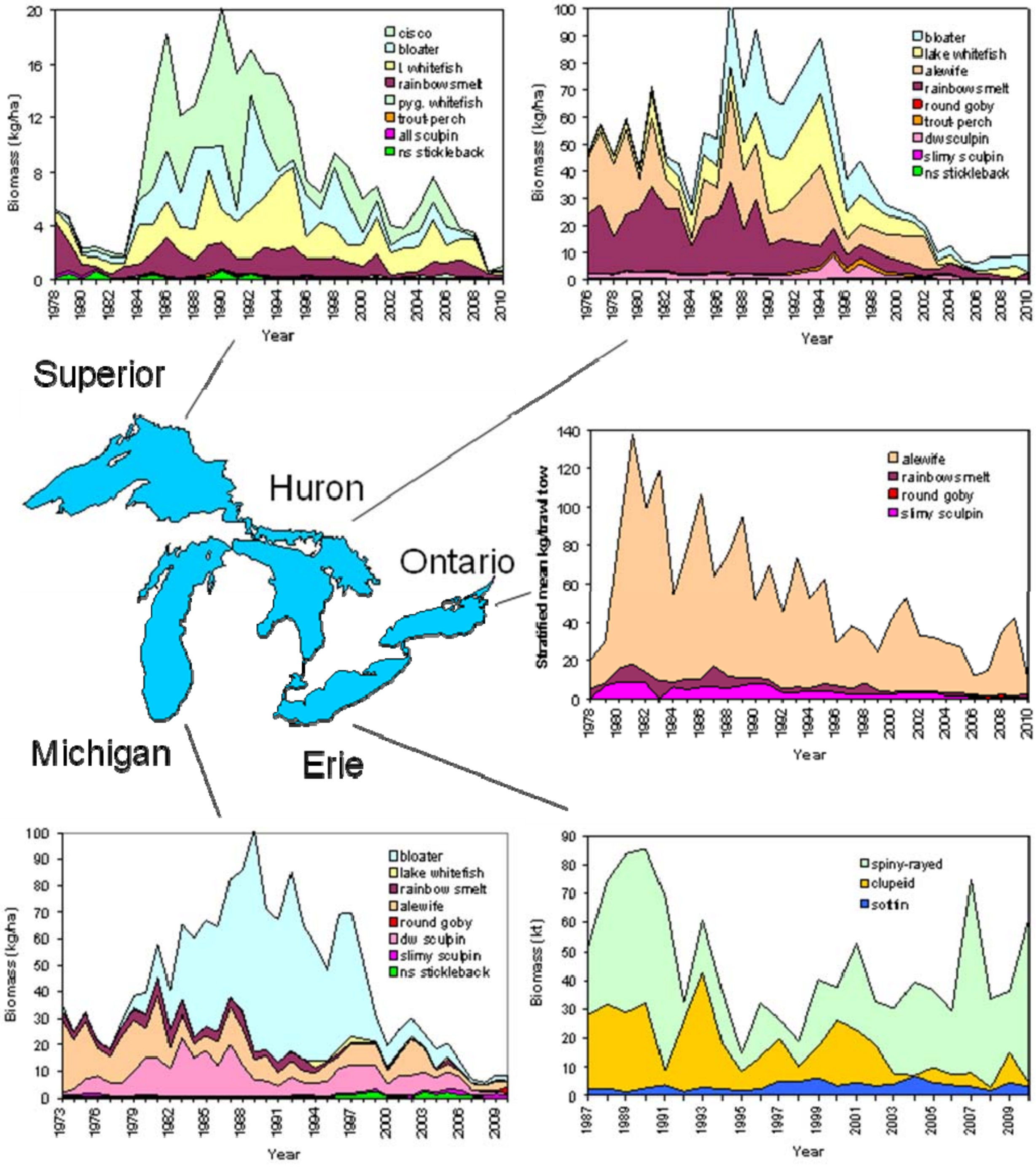

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