Sub-Indicator: Native Prey Fish Diversity

Overall Assessment

Status: Fair

10-Year Trend: (2011-2020): Undetermined
Long-term Trend (1973-2020): Undetermined

Rationale: Great Lakes prey fish diversity status remains 'Fair', but individual lake status varies from 'Good' in Lake Superior to 'Fair' in the remaining four lakes (Table 1). Lake Superior was the only lake where both prey fish diversity and the percent native species were categorized as 'Good'. Lake Erie prey fish status improved in this reporting cycle since the percent of native prey fishes increased to 'Fair' (Table 1). For the first time in this analysis, Lake Ontario's prey fish community diversity improved to 'Good', however since the percent native remained 'Poor' the overall status was 'Fair' (Table 1).

The long-term trend was 'Undetermined' because while six of the possible ten metrics (two per lake) were 'Unchanging', three were determined to be 'Improving', while one was 'Deteriorating' (Table 2). The 10-year trends were similarly diverse and resulted in an 'Undetermined' overall characterization (Table 2).

Prey fish biomass trends are not specifically graded in this indicator; however, these trends have generally declined or remained low, as oligotrophication continues in all main-lake habitats other than western Lake Erie, and native and stocked predator populations naturally have reduced prey fishes. Prey fish communities are driven by changing ecosystem conditions including productivity, fluctuating predator populations, climate, and non-native species. These factors are generally changing in similar directions across the region. However, because each lake is unique in its nutrient concentrations, morphometry, hydrology, and fish communities, the prey fish communities in each lake respond differently to ecosystem drivers (Figure 1).

Lake-by-Lake Assessment

Lake Superior

Status: Good

10-Year Trend (2011-2019): Unchanging

Long-term Trend (1978- 2019): Unchanging

Rationale: The Lake Superior prey fish community is categorized as 'Good', with individual metrics classified as 'Good' (proportion native species) and 'Good' (diversity). Lake Superior is the least anthropogenically-altered Great Lake and its prey fish community metrics reflect this more pristine state. Native species dominate a diverse prey fish community as measured by prey fish biomass and the Shannon Diversity Index (Tables 1 and 2, Figure 1). The percentage of the fish community biomass comprised of native species has averaged >80% over the long term and 82% over the past nine years (2011 – 2019). While Lake Superior prey fish metrics have been 'Unchanging', there are concerns among fish managers over population declines of coregonine species like Bloater (*Coregonus hoyi*), Cisco (*Coregonus artedi*), and Kiyi (*Coregonus kiyi*) which support significant commercial fisheries and are prey for Lake Trout (*Salvelinus namaycush*). Lake Superior prey fish data from 2020 were incomplete because COVID-19 precautions prevented sampling, and therefore community indices for that year were not calculated.

Lake Michigan

Status: Fair

10-Year Trend (2011-2020): Unchanging

Long-term Trend (1973-2020): Unchanging

Rationale: The Lake Michigan prey fish community is categorized as 'Fair', with individual metrics classified as 'Good' (proportion native species) and 'Fair' (diversity) (Table 1). This is identical to the status reported in 2019. When examined over the past ten years, trends in both the diversity index and the percent native species have improved since the previous assessment, shifting from 'Deteriorating' to 'Unchanging' and 'Unchanging' to 'Improving', respectively (Table 2). This in turn has improved the status of the overall 10-year trend to 'Unchanging'. While prey fish diversity has been 'Improving' over the longer time scale, the lack of directional change in the percent native metrics still results in an 'Unchanging' long-term trend (Table 2).

Lake Huron

Status: Fair

10-Year Trend (2011-2020): Unchanging

Long-term Trend (1976-2020): Undetermined

Rationale: The Lake Huron prey fish community is categorized as 'Fair', with the proportion of native species classifieds as 'Good' and diversity categorized as 'Fair' (Table 1). Over the 10-year period these metrics were unchanging; however, over the long term the percent native has 'Improved' while the diversity has 'Deteriorated,' resulting in an overall trend of 'Undetermined' (Table 2). The declining diversity trend in Lake Huron is driven primary by the shift from non-native Alewife (*Alosa pseudoharengus*) and Rainbow Smelt (*Osmerus mordax*) in the 1970s through 2000, to a community dominated by a single native species (Bloater). Long-term, consistent observations on prey fishes in the St Mary's River were not available for comparison.

Lake Erie

Status: Fair

10-Year Trend (2011-2020): Deteriorating

Long-term Trend (1990-2020): Unchanging

Rationale: The Lake Erie prey fish community status was classified as 'Fair, as both the percent native species and diversity metrics were classified as 'Fair' (Table 1). This is a change from the previous reporting period when the percent native species value fell in the 'Poor' category. Native species typically make up less than 50% of the Lake Erie prey fish community and while the proportion native has varied over time, it has not trended in a particular direction (Figure 1, Table 2). Lake Erie prey fish diversity values are among the highest in the Great Lakes, but they have declined slightly in the past 10 years (Figure 1, Table 2). Much of the changes in both metrics result from annual variability or declines in Emerald Shiners (*Notropis atherinoides*), Yellow Perch (*Perca flavescens*), Spottail Shiner (*Notropis hudsonius*) and Trout-perch (*Percopsis omiscomaycus)*. The classifications for Lake Erie are based on lake-wide assessment trends and may not accurately reflect regional prey fish population status or trends. Lake Erie prey fish surveys results are presented as density, as opposed to biomass, which can result in greater variability in the metrics used in this report. Long-term, consistent observations for prey fishes in the St Clair-Detroit River or upper Niagara River were not available for comparison.

Lake Ontario

Status: Fair

10-Year Trend: Improving

Long-term Trend (1978 - 2020): Unchanging

Rationale: Lake Ontario prey fish percent native status was 'Poor', but the diversity index was 'Good', resulting in an overall status of 'Fair' (Table 1). Both the diversity index and proportion of native species were 'Improving' over the past 10 years (Table 2). These recent increases caused the long-term trend for these indicators to shift from previously 'Deteriorating' to now 'Unchanging'. Lake Ontario prey fish diversity is the lowest in the Great Lakes because Alewife continue to dominate the assemblage. However, as Alewife abundance has recently declined and Round Goby (*Neogobius melanostomus*) and Deepwater Sculpin (*Myoxocephalus thompsonii*) remain abundant, the community diversity improved. The increased proportion of Deepwater Sculpin also caused the proportion of native species trend to be 'Increasing'. Concerns over Alewife abundance declines have caused reductions in sport fish stockings. Prey fish data from 2020 was incomplete (COVID-19 precautions prevented sampling) and therefore community indices for that year were not calculated. Long-term, consistent observations on prey fishes in the lower Niagara River or St. Lawrence River were not available for comparison.

Status Assessment Definitions

Good: The average percent by biomass (or density) of native prey fish in the total prey fish catch is at or above 75% and the diversity index value is greater than or equal to 75% of the maximum diversity index value observed in the time series.

Fair: The average percent by biomass (or density) of native prey fish in the total prey fish catch is at or above 25% and the diversity index value is greater than or equal to 25% of the maximum diversity index value observed in the time series.

Poor: The average percent by biomass (or density) of native prey fish in the total prey fish catch is below 25% and the diversity index value is below 25 % of the maximum diversity index value observed in the time series.

Undetermined: Data are insufficient to assess the metrics.

If the two metrics status categories differ, the lake status will either be the average or conservatively be the lower of the two categories. For example, a status of 'good' for percent native and 'fair' for diversity will result in a status categorization of 'fair'. A status of 'good' and 'poor' results in an overall status of 'fair'.

Trend Assessment Definitions

Trends at 10-year and long-term timescales are evaluated for each metric using linear models with yearly observations. If trends are significant, positive, or negative, with a *P*-value of 0.10 or lower the trend is reported; otherwise the trend is considered Unchanging. If the trends of the two metrics differ the overall trend will conservatively be categorized as the 'lesser' of the two metrics (e.g. one metric Improving and the other Unchanging results in a classification of Unchanging). If individual metric trends are opposite (e.g. Improving and Deteriorating) the overall trend is Undetermined.

Improving: The slopes for year in both metrics is positive ($P < .10$).

Unchanging: The slope for year is insignificant, and one is positive OR both slopes are insignificant ($P < .10$).

Deteriorating: The slopes for year in both metrics are negative OR one slope is non-significant and one is negative ($P < .10$).

Undetermined: If data are not sufficient, or if the metric trends differ (e.g. 'Improving' and 'Deteriorating')

Endpoints and/or Targets

Lake-specific committees create Fish Community Objectives (FCOs) that identify how Great Lakes fisheries are managed according to the Joint Strategic Plan (Great Lakes Fishery Commission, 1981). Most of these objectives do not specify numerical targets or endpoints for prey fishes. Instead the objectives generally seek to 'maintain prey fish diversity' or 'maintain and restore native forage fish species' and often attempt to balance prey fishes (or forage fishes) with primary production or predator demand. The portions of these FCOs that relate to prey fishes are listed below.

Lake Superior: Fish Community Goal – "*To rehabilitate and maintain a diverse, healthy, and self-regulating fish community, dominated by indigenous species and supporting sustainable fisheries*". Additional principals note: "*Preservation of indigenous species is of the highest concern*" (Horns et al. 2003).

Lake Michigan: Planktivore Objective – "*Maintain a diversity of planktivore (prey) species at population*

levels matched to primary production and to predator demands. Expectations are for a lakewide planktivore biomass of 0.5 to 0.8 billion kg." (Eshenroder et al. 1995).

Lake Huron: Prey Objective – "*Maintain a diversity of prey species at population levels matched to primary production and to predator demands. Emphasis is placed on species diversity and self-regulation of the fish community*" (DesJardine et al. 1995).

Lake Erie: Prey Fish Objective – "*Maintain a diverse, abundant prey-fish community that is capable of sustaining abundant warm-, cool-, and cold-water predators and that contributes to ecosystem function and sustainable human use. The LEC recognizes that it cannot directly manage prey-fish populations, even though they are essential to support the Lake Erie basin fisheries. The LEC especially values native prey species but recognizes that naturalized prey species can be an important part of the prey-fish community, predator diets, and targeted fisheries. Status indicator: Prey-fish populations support predator condition and growth rates near the long-term average*" (Francis et al., 2020).

Lake Ontario: Offshore Pelagic Zone Objective- "*Increase prey-fish diversity – maintain and restore a diverse prey-fish community that includes Alewife, Cisco (formerly Lake Herring), Rainbow Smelt, Emerald Shiner, and Threespine Stickleback (Gasterosteus aculeatus). Status and trend indicators are 1) maintaining or increasing populations and increasing species diversity of the pelagic prey fish community including introduced species (Alewife, Rainbow Smelt) and selected native prey fish species (Threespine Stickleback, Emerald Shiner and Cisco); and 2) increasing spawning populations of Cisco (formerly Lake Herring) in the Bay of Quinte, Hamilton Harbor, and Chaumont Bay*" (Stewart et al., 2017). The introductory material also notes: "*The LOC will continue with programs to protect and restore native species with an emphasis on... Cisco (Lake Herring), Round Whitefish (Prosopium cylindraceum), Deepwater Sculpin and deepwater coregonines*", such as Bloater.

Sub-Indicator Purpose

This sub-indicator attempts to quantify the status and trends of Great Lake's prey fish communities according to their diversity and the percent of the community comprised of native species, which are common elements identified in the lake-specific FCOs. Prey fish abundance indices are also reported for context on the state of Great Lakes ecosystems.

Ecosystem Objective

Ecosystem objectives for prey fishes vary across lakes, but at the lake level generally seek to maintain diverse prey fish communities, that support predator populations, are in balance with primary productivity, and in many cases favor native prey fishes (Desjardine et al., 1995; Eshenroder et al., 1995; Francis et al., 2020; Horns et al., 2003; Stewart et al., 2017). This sub-indicator results also inform '*forage fish*' elements of the " *Joint strategic plan for management of all great lakes fisheries, as revised, 10 June 1997*" (Great Lakes Fishery Commission, 2007). In addition, this sub-indicator supports the Great Lakes Water Quality Agreement's Annex 4 as they consider setting the Substance Objective (phosphorus targets) by illustrating how phosphorus concentrations influence "*fisheries productivity requirements*" (United States of America and Canada, 2012). This sub-indicator supports General Objective #5 of the 2012 Great Lakes Water Quality Agreement which states that the Waters of the Great Lakes should "support healthy and productive wetlands and other habitats to sustain resilient populations of native species

Measure

The status and trends of prey fishes are based on the diversity and the percent of native species within the community. Community diversity is represented by the Shannon diversity index and the status of a period is a quantified against the maximum diversity value observed in the time series. Unfortunately, theoretical, or even widely agreed upon metrics or thresholds for what constitutes a prey fish community as 'good', 'fair', or 'poor' do not exist. Categorizing the state of prey fish communities is subjective and is influenced by an individual's perspective on the different ecosystem services the prey communities provide. For instance, while Lakes Erie and Ontario prey fish communities often exhibit low prey fish diversity or percent natives, these prey fish communities support the largest sport and commercial fisheries in the basin, providing provisioning and cultural ecosystems services to the region and nation. We recognize the metrics chosen to characterize prey fish status are imperfect and incomplete, but they serve as a starting point from which to understand differences among the lakes and time trends within a lake.

Prey fish abundance indices are also reported for context but are not a graded metric in this report because management actions for phosphorus reduction and predator abundance increases naturally reduce prey fish abundance. Energy properties of lake food webs require that prey fish biomass is negatively dependent on lake nutrient concentration and piscivorous fish abundance (Carpenter et al., 2001; Downing and Plante, 1993). Within the Great Lakes, resource management has, in most regions, successfully reduced phosphorus concentration below targets (Dove and Chapra, 2015) and restored piscivorous fish populations, both of which confound the utility of prey fish abundance as a graded metric.

Data used to calculate metrics are from bottom trawl surveys. These surveys have been generally conducted annually and consistently across time, sample across a wide range of available habitats and catch the most abundant prey fishes. Diversity and percent native metrics are based on biomass (kilograms per hectare) indices from bottom trawl catches, except for Lake Erie where data are represented by density indices (number per hectare). Data come from the USGS Great Lakes Science Center (GLSC), Ontario Ministry of Natural Resources, New York State Department of Environmental Conservation, Ohio Department of Natural Resources Division of Wildlife, and Pennsylvania Fish and Boat Commission. For Lakes Superior, Huron, Michigan and Ontario data are managed by the USGS GLSC. In Lake Erie data are managed and provided by the separate state, federal and provincial agencies. All data are provided at the whole-lake scale except for Lake Erie, which are provided at the basin scale and combined according to the proportional area of each of the three lake basins. Consistent annual or long-term data for prey fishes are not available for the connecting channel habitats.

Ecological Condition

Lake Superior, Status: Good, 10-year trend: Unchanging

Native species dominate the relatively diverse Lake Superior prey fish community (Figure 1). Rainbow Smelt are the only non-native species that substantially contributes to the Lake Superior bottom trawl catch (Vinson et al., 2020). Changes in Lake Superior prey fish metrics are primarily driven by fluctuations in coregonines (Bloater, Cisco, and Kiyi), Rainbow Smelt, and Lake Trout populations. Lake Trout are voracious predators of these prey species. These coregonine species are long-lived, up to 25 years, and exhibit high annual variability in survival to age-1, a.k.a., year class strength (Vinson et al., 2020). This year class strength variability leads to fluctuations in over-all prey fish biomass, which can be readily observed across the time series (Figure 2). Declining biomass over the past twenty years has resulted from poor and variable survival of coregonines to age-1 and is thought to be related to climate change and the reduction in winter ice cover in particular which leads to warmer spring and summer water temperatures, but the specific mechanism reducing survival has not been identified.

Lake Michigan, Status: Fair, 10-year trend: Unchanging

Consistent with previous reports, the status of Lake Michigan prey fish is "Fair" (Table 1). While individual metric scores are identical to the State of the Great Lakes Report 2019 (diversity index = "Fair"; percent native = "Good"), we note that limitations on the number of transects sampled in 2020 (3 of 7) due to restrictions resulting from the COVID-19 pandemic may introduce some bias. The diversity index was 0.69 in 2020, the second lowest on record (Figure 1). If the diversity index excluded 2020, the current overall status (based only on 2018, 2019) for Lake Michigan prey fish would be "Good". Similarly, a historically high proportion of native species, 98%, was recorded in 2020. However, this estimate is in general agreement with a high proportion of native species in the bottom trawl from the previous five years (mean 2015-2019 = 81%). Further, a comparison of 10-year trends for each metric to the 2019 report seems to suggest improving conditions in Lake Michigan; the diversity index has shifted from "Deteriorating" to "Unchanging" and the proportion of native species is now "Improving", resulting in a shift in the overall 10-year trend status from "Deteriorating" to "Unchanging' (Table 2, Figure 1). Declining results may be in partial conflict with stated Lake Michigan fish community objectives to maintain prey fish biomass (Eshenroder et al., 1995). Prey fish biomass, based on the fall bottom trawl survey continues to remain at historical lows (Figure 2) and has been dominated by one native species, Bloater, since 2015. This represents a dramatic shift in prey fish composition, since from 2011 to 2014 Alewife were the dominant prey fish species in all but one year. Declines in Alewife biomass relative to other species since the mid-2010s may be the result of changes in catchability in the bottom trawl survey (Tingley et al. 2021). Beyond top-down controls of predators on Alewife populations and reductions in catchability of some species (e.g., Alewife and Bloater), reductions in nutrient loading and concentration, changes in climate, and the proliferation of dreissenid mussels may contribute to the long-term downward trend in estimated prey fish biomass in Lake Michigan (Dove and Chapra, 2015; Rowe et al., 2017; Warner and Lesht, 2015).

Lake Huron Status: Fair, 10-year trend: Unchanging

The Lake Huron prey fish community has undergone a dramatic transformation since the late 1970s. In the 1970s, non-native Alewife and Rainbow Smelt dominated the prey fish community (Riley and Adams 2010). Declines in those non-native species and lake-wide recovery of Bloater (a native coregonid) during the 1980s resulted in a steady increase in the proportion of the community comprised of native species (Figure 1). Prey fish biomass in Lake Huron began a steady decline in the mid-1990s and reached a historic low in 2008 (Figure 2). As prey fish biomass decreased, the proportion of native species in the community initially dropped, but then quickly increased with decline of Alewife populations in the early 2000s. Loss of Alewife from the prey fish community has been attributed to physical factors including cold winters, reduced mineral nutrients, proliferation of dreissenid mussels, and predation from naturally-reproduced Lake Trout and Pacific Salmon (Collingsworth et al., 2014; Dunlop and Riley, 2013; Kao et al., 2016). Prey fish biomass over the last decade had remained near historic lows, and the community is dominated by native Bloater, which during 2018-2020 accounted for over 85% of prey fish biomass sampled in bottom trawls. Accordingly, species diversity in 2019 and 2020 were the third and fourth lowest values observed in the time series, and the four lowest diversity index values (2014, 2015, 2019, 2020) all have occurred in the past 5 years (Figure 1).

Lake Erie Status: Fair, 10-year trend: Deteriorating

The Lake Erie prey fish community has experienced substantial changes in the past 10 years (Figure 1). The percent native metric has varied and the diversity index has declined to lower catches of Emerald Shiners, Yellow Perch, Spottail Shiner and Trout-perch (Forage Task Group, 2021). Declines of these native species is most apparent in the central basin time series (Forage Task Group, 2021). Diversity is generally high, second only to Lake Superior among the five lakes, however this value has been declining slightly over the past 10 years (Figure 1, Table 2). Above-average reproductive success of Walleye has been observed over the past decade so that Lake Erie predator abundance is currently high and could partially explain some of the observed trends in Lake Erie prey fishes (Forage Task Group, 2021).

Lake Ontario, Status: Fair, 10-year trend: Improving

The Lake Ontario prey fish community dynamics and total biomass continue to change over time (Figures 1, Figure 2). Alewife have historically dominated the prey fish community (>90% by biomass), which caused for low values of diversity and the percent native metrics. The long term declines in Alewife biomass mirror the trends in spring phosphorus concentration (Dove and Chapra, 2015; Weidel et al., 2020), while variable and declining Alewife recruitment appears related to nutrient declines and climate variation (O'Gorman and Stewart, 1999). Both the diversity and percent native metrics are increasing (Table 1), as the proportional role of Alewife has declined and Deepwater Sculpin and Round Goby populations comprise more of the community (Weidel et al., 2020). Alewife biomass declines since 2013 are due to below average reproduction (cold springs and winters), lower nutrient concentrations, and increased abundance of wild-reproduced Chinook Salmon that prey heavily on Alewife (Bishop et al., 2020; Murry et al., 2010; Weidel et al., 2020). Since 2016, fishery managers have reduced stocking numbers in an attempt to maintain balance between predators and available prey (Great Lakes Fishery Commission Lake Ontario Committee, 2016). Lake Ontario management agencies continue to stock Bloater reared from Michigan gametes and broodstock in an effort to diversify the native pelagic prey fish community. Despite relatively low numbers of Bloater stocked, these fish have been documented in lake wide trawl surveys (Weidel et al., 2020).

Linkages

Prey fish communities are influenced by primary production and invertebrates as well as by higher trophic levels including stocked and naturally-reproduced piscivores and avian predators. Physical process driven by climate and land use such as water temperature, water clarity, geomorphology and spawning habitat quality also influence prey fish community composition and abundance by modifying their behavior, growth dynamics, and spawning success.

- Nutrient inputs and internally recycled nutrients are the primary driver of Great Lakes primary productivity and therefore are also a strong driver of prey fish biomass. Nutrient concentration is often the primary determinant of how many prey fish a lake supports while climate, habitat, species introductions and predators determine which species comprise the community. Climate also influences productivity at given nutrient levels by changing the volume or depth of the warm surface layers within lakes (Rowe et al., 2017; Warner and Lesht, 2015).
- Zooplankton are the primary food of pelagic prey fishes while benthic invertebrates are primary food of benthic or demersal prey fishes.
- *Diporeia* spp. are a genus of native, deepwater amphipods that were historically an important food source for Great Lakes prey fishes. As a detritivore, the species feeds on freshly settled organic material such as diatoms, linking those energy sources to prey fishes (Nalepa et al., 2006).
- Dreissenid mussels provide food for some prey fishes such as Round Goby and also act to increase water clarity which can shift prey fish behavior and intensify predator – prey interaction strength (O'Gorman et al., 2000).
- Lake Trout, Walleye (*Stizostedion vitreum*), and the other Great Lakes piscivores are a dominate driver of prey fish biomass and community composition.
- Changes in climate influence Great Lakes water temperature, ice coverage, and other aspects of hydrodynamics, all of which have strong influences on prey fishes.
- Water temperature drives prey fish energetics, behavior and habitat and food availability which in turn influence prey fish abundance and community dynamics.
- Ice cover influences the quality of egg incubation for fishes with overwintering egg stages and larval fish habitat.
- Water levels influence the availability of nearshore habitats which can affect prey fishes spawning and nursery habitat availability.

Assessing Data Quality

The data quality assessments below are based on the consensus expert opinions of the primary and contributing authors.

Data Characteristics	Agree	Neutral or Unknown	Disagree	Not Applicable
Data are documented, validated, or quality-assured by a recognized agency or organization	X			
Data are from a known, reliable, and respected generator of data and are traceable to original sources	X			
Geographic coverage and scale of data are appropriate to the Great Lakes Basin		X		
Data obtained from sources within the U.S. are comparable to those from Canada			X	
Uncertainty and variability in the data are documented and within acceptable limits for this sub-indicator report		X		
Data used in assessment are openly available and accessible	Yes*	Data can be found here: https://www.sciencebase.gov/catalog/item/57e185c8e4b0908250033a54 https://www.sciencebase.gov/catalog/item/58e2940fe4b09da67996a821		

* USGS prey fish data from all lakes are available via links, however they may not always include the most recent year's data. Some Lake Erie prey fish data, from state and provincial agencies, is available upon request while open data access processes are under development.

Data Limitations

Evaluating this sub-indicator using bottom trawl data from across the basin helps to maintain consistency in our comparisons, but differences in trawl surveys may influence our results. Prey fish survey designs differ because the five lakes vary in size, bathymetry, habitat suitable for trawling, fish communities, survey history, and management information needs. For instance, across all five lakes bottom trawl surveys vary in: seasonal timing (April – October), annual effort (0.8 – 18 trawls per 1000 km^2 lake area), bottom trawl types, and reported statistics (biomass vs density, whole-lake vs basin-specific). Differences among surveys do not necessarily invalidate the results presented here but they are important to consider when interpreting results.

Time series of bottom trawl data have historically been used to infer relative changes of a prey fish over time in a lake, but they may not catch all species in equal proportion to their abundance in the environment. Pelagic species may be underestimated by bottom trawling relative to more demersal, or bottom oriented species (Yule et al., 2008). For example in Lake Superior, acoustic surveys estimated substantially greater biomass of pelagic Kiyi and Cisco, than bottom trawls estimates from the same year (Yule et al., 2013). Similarly, in Lake Ontario, acoustic and midwater trawl observations suggest Cisco can be a greater portion of the fish community than bottom trawls have indicated (Holden et al., 2017; Weidel et al., 2017). Alewife abundance relative to other fishes may also be biased by trawl survey type or seasonal timing. In Lake Michigan, fall-collected bottom trawl Alewife biomasses are usually lower than September acoustic estimates from the same year (Bunnell et al., 2017; Warner et al., 2017), and in Lake

Ontario Alewife biomass is much higher in spring than fall-based surveys (Weidel et al., 2017). Efforts to understand potential biases in surveys will be critical for improving cross-basin prey fish comparisons such as those presented in this report.

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Pennsylvania Fish and Boat Commission
Michigan Department of Natural Resources
United States Fish and Wildlife Service

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Table 1. Status of Great Lakes prey fish communities in the current period (2018-2020) and previous reporting period (2015-2019) based on the percent native and the Shannon diversity index. For the percent native status, a categorization of good is for communities with 75% or more native species, while fair is above 25% and poor is below 25%. To attain as status of 'good' for the diversity index, the current period average indicator must be 75% or more of the maximum value observed in the time series. Similarly, the 'poor' status represents average values within the current period that are less than 25% of the maximum observed index value. If the metrics differ, they are averaged (good and poor yield fair) or if they are only more closely related the overall status is conservatively chosen as the lower metric (fair and poor yield poor). Metrics from 2020 were not available for Lake Ontario and Superior because precautions associated with COVID-19 pandemic prevented sampling therefore the current period represents 2018-2019.

Lake	Percent Native				Diversity Index				Overall
	Current	Previous	Max.	Status	Current	Previous	Max.	Status	Status
Superior	75	78	96	Good	1.7	1.9	2.2	Good	Good
Michigan	78	85	98	Good	1.2	1.2	1.7	Fair	Fair
Huron	77	70	90	Good	0.8	0.8	1.6	Fair	Fair
Erie	28	10	67	Fair	1.4	1.4	2.1	Fair	Fair
Ontario	11	5	15	Poor	0.7	0.4	0.8	Good	Fair

Table 2. Trend assessment for prey fish communities of the Great Lakes as determined by the community diversity index and proportion native species. A lake's metric was determined to be changing ('Improving' or 'Deteriorating') based on the slope (time) of a linear model with a p-value < 0.1. Asterisk denotes data from 2020 were not available for Lake Ontario and Superior because precautions associated with COVID-19 pandemic prevented sampling therefore the "10-year" trend represents data from 2011-2019.

Lake	Indicator	Whole Time Series		Last 10 Years*	
		Years	Trend	Years	Trend
Superior	Diversity Index	1978-2019	Improving	2011-2019	Unchanging
	Percent Native	1978-2019	Unchanging	2011-2019	Unchanging
Michigan	Diversity Index	1973-2020	Improving	2011-2020	Unchanging
	Percent Native	1973-2020	Unchanging	2011-2020	Improving
Huron	Diversity Index	1976-2020	Deteriorating	2011-2020	Unchanging
	Percent Native	1976-2020	Improving	2011-2020	Unchanging
Erie	Diversity Index	1990-2020	Unchanging	2011-2020	Deteriorating
	Percent Native	1990-2020	Unchanging	2011-2020	Unchanging
Ontario	Diversity Index	1978-2019	Unchanging	2011-2019	Improving
	Percent Native	1978-2019	Unchanging	2011-2019	Improving

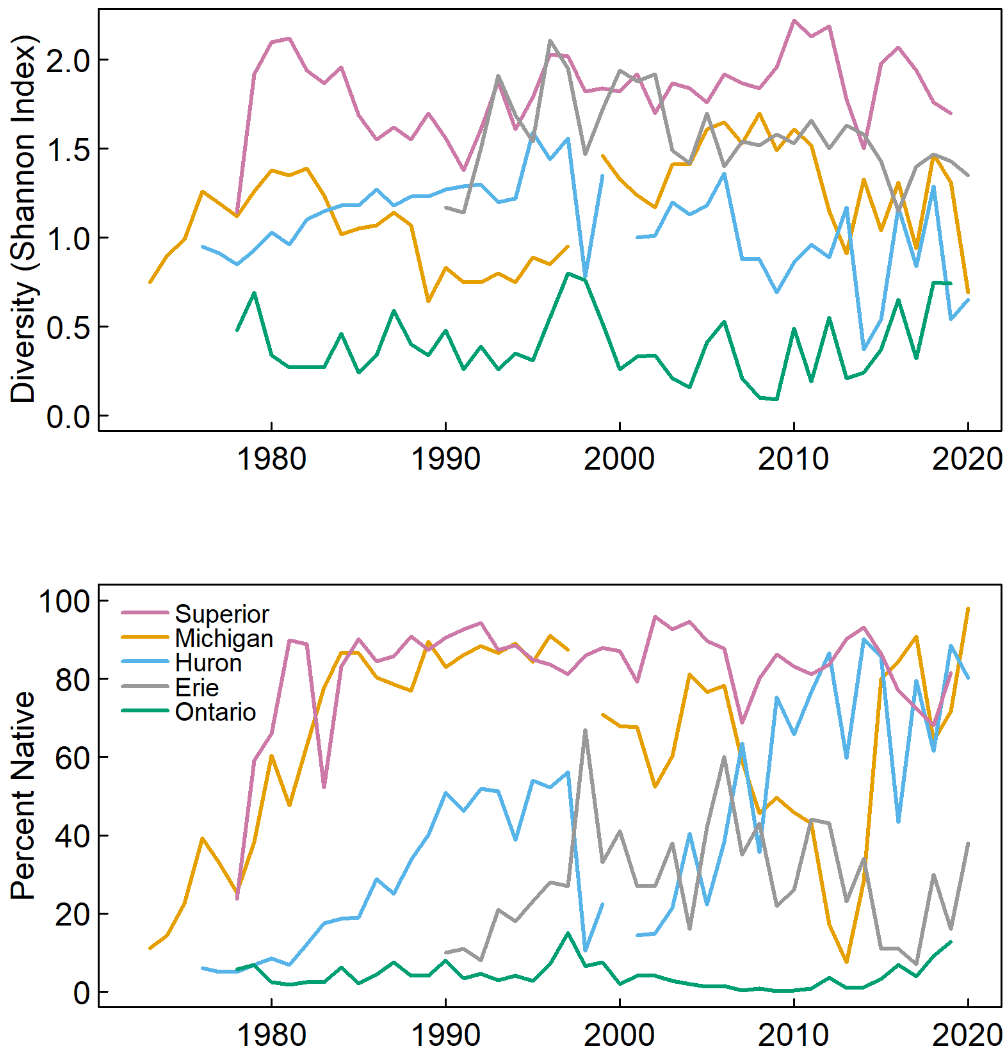

Figure 1. Shannon Diversity index values and proportion of native species of Great Lakes prey fish communities. Source: Data primarily derive from bottom trawl surveys conducted by U.S. federal and state and Canadian provincial agencies. Metrics from 2020 were not available for Lake Ontario and Superior because precautions associated with COVID-19 pandemic prevented sampling.

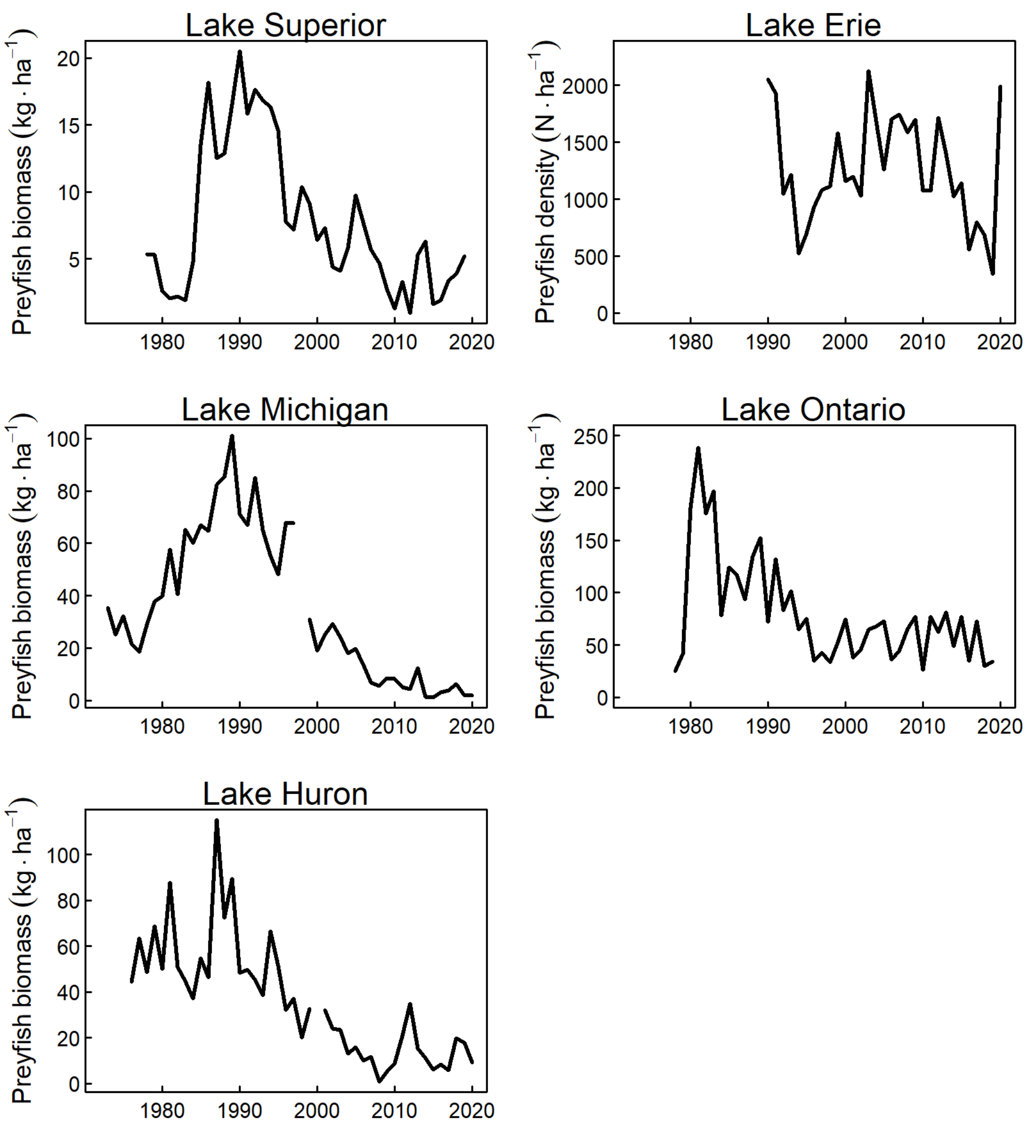

Figure 2. Prey fish biomass or density trends based on annual bottom trawl surveys. Note different scales. Source: Data primarily derive from bottom trawl surveys conducted by U.S. federal and state and Canadian provincial agencies. Metrics from 2020 were not available for Lake Ontario and Superior because precautions associated with COVID-19 pandemic prevented sampling.