Status and Trends in the Lake Superior Fish Community, 2020[1]

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As was the case for all Great Lakes fisheries management and research agencies, the impacts of the COVID-19 pandemic on the U.S. Geological Survey (USGS) Great Lakes Science Center's deepwater science work were significant. The most severe impacts were related to deepwater science cruises scheduled in the spring/early summer, and those requiring extended overnight stays on vessels. In addition, USGS vessels could not get clearance to cross into Canadian waters as a result of the pandemic, which reduced the spatial scope of data normally collected. Because of these limitations, reporting for 2020 deepwater science surveys will be limited in scope, and in some cases, limited in the ability to make meaningful comparisons to data from previous years. All USGS personnel involved in deepwater science cruises are looking forward to the return of a more normal sampling schedule in 2021, pandemic conditions permitting.

[1]The data associated with this report have not received final approval by the U.S. Geological Survey (USGS) and are currently under review. The Great Lakes Science Center is committed to complying with the Office of Management and Budget data release requirements and providing the public with high quality scientific data. We plan to release all USGS research vessel data collected between 1958 and 2020 and make those publicly available. Please direct questions to our Information Technology Specialist, Scott Nelson, at snelson@usgs.gov.

Abstract

The Lake Superior fish community within Management Unit WI-2 was sampled in July 2020 with daytime bottom trawls at 11 nearshore stations. Management Unit WI-2 encompasses the Bayfield Peninsula and the Apostle Islands area which is located in the western side of Lake Superior. The 11 locations sampled were long-term monitoring sites that had been annually sampled since 1974. All comparisons to 2020 results were limited to past collections from Management Unit WI-2. In 2020, the number of species collected at each site ranged from 0 to 13, with a mean of 6.3 and median of 6. Average fish biomass was 10.5 kg/ha, which was similar to the average observed over the past 10 years (10.8 kg/ha), less than averages observed from 2001-10 (18.1 kg/ha), 1991-2000 (28.7 kg/ha), and 1981-1990 (23.6 kg/ha), but higher than the average from 1974-1980 (5.3 kg/ha). Average biomass in 2020 was highest for Bloater (6.2 kg/ha), Lake Whitefish (2.3 kg/ha), and Cisco (0.9 kg/ha). Rainbow Smelt biomass averaged 0.3 kg/ha. Year-class strength, as measured by age-1 densities, was below the 5, 10, and 25-year averages for Bloater, Cisco, Lake Whitefish and Rainbow Smelt. Bloater averaged 1 age-1 fish/ha, Cisco, 0.2 age-1 fish/ha, Lake Whitefish, 15 age-1 fish/ha, and Rainbow Smelt 6 age-1 fish/ha. Cisco survival to age-1 has been near zero since the 2014- and 2015-year classes and the last moderate sized year class was in 2009. This lack of survival has yet to be adequately explained and continues to be a major concern of fishery managers due to Cisco's importance in ecosystem dynamics and value to the commercial fishery.

Introduction

The U.S. Geological Survey Lake Superior Biological Station conducts annual daytime bottom trawl surveys in nearshore (~15-80 m depths) and offshore (~100-300 m depths) waters of Lake Superior. These surveys provide data for assessment of trends in species occurrence, relative abundance, and biomass for principally demersal fish. These data have historically been considered population indices rather than absolute abundance and biomass estimates. The nearshore survey has been conducted annually since 1974 around the Bayfield Peninsula and the Apostle Islands area which is located in the western side of Lake Superior, since 1978 throughout U.S. waters, and since 1989 throughout Lake Superior including Canadian waters. The offshore survey has been conducted annually since 2011. The primary goal of the surveys is to report on population biomass estimates for all sizes of common species and age-1 density estimates (for selected commercial and recreational species (Rainbow Smelt, Cisco, Bloater, Kiyi, Lake Whitefish, scientific names are provided in Table 1) as a measure of age-1 year class strength. Aging structures and stomach contents are collected for selected species. Fish population data in this report are based solely on bottom trawl sampling. Fishing gear bias should be considered when interpreting the results, particularly for species with lower vulnerability to daytime bottom trawls, such as adult Cisco and adult Lake Trout (Yule, et al. 2008). At each fish sampling station zooplankton are sampled by a whole water column (up to 100 m) vertical zooplankton tow, and an electronic water profiler is deployed that collects data on depth, water temperature, specific conductance, pH, dissolved oxygen, chlorophyll a, photosynthetic active radiation (PAR), and beam transmission. Herein we report on fish collected during the 2020 survey and compare them to previous annual collections made since 1974 in Management Unit WI-2.

Due to the COVID-19 pandemic, sampling in 2020 was limited to locations accessible from Ashland, Wisconsin within a single day, which encompasses the area from 90.4-91.2° west longitude and 46.5-47.2° north latitude. This limited our sampling to sites in Management Unit WI-2 which encompasses the Apostle Islands.

Methods

In 2020, 11 sampling sites were sampled from 9-14 July (Figure 1). At each location, a single bottom trawl tow was conducted with a 12-m Yankee bottom trawl with a chain foot rope. The median start and end depths for bottom trawl tows were 15 m (range 10-35 m) and 53 m (range 37-96 m), respectively. The median distance trawled was 1.3 km (range 0.6-2.6 km). The median trawl wingspread was 7.2 m (range 6.4-9.2 m). Fish collected in trawls were sorted by species, counted, and weighed in aggregate to the nearest gram. Total length was measured on a maximum of 50 individuals per species per trawl. Lengths for these individuals were extrapolated to the entire catch when more than 50 individuals were collected. Relative density (fish/ha) and biomass (kg/ha) were estimated by dividing sample counts and aggregate weights by the area of the bottom swept by each trawl tow (ha). Biomass estimates are reported for all species combined and individually for Bloater, Cisco, Lake Whitefish, Rainbow Smelt, Sculpin species (Slimy-, Spoonhead-, and Deepwater-Sculpin), hatchery-, lean-, and siscowet-Lake Trout, Burbot, and for a few less-common species. Scientific names are provided in Table 1. A composite estimate is also reported for all the less-common species (Other species). Age-1 year-class strength was estimated as the mean density of age-1 fish as determined by total length; Cisco ≤140 mm, Bloater ≤130 mm, Lake Whitefish ≤160 mm, and Rainbow Smelt ≤100 mm, across all sites. Young Lake Trout densities are presented for small, < 226 mm (ca. ≤ age-3) fish. These age-size cutoffs were based on past unpublished age estimates and are approximate and are known to vary among years.

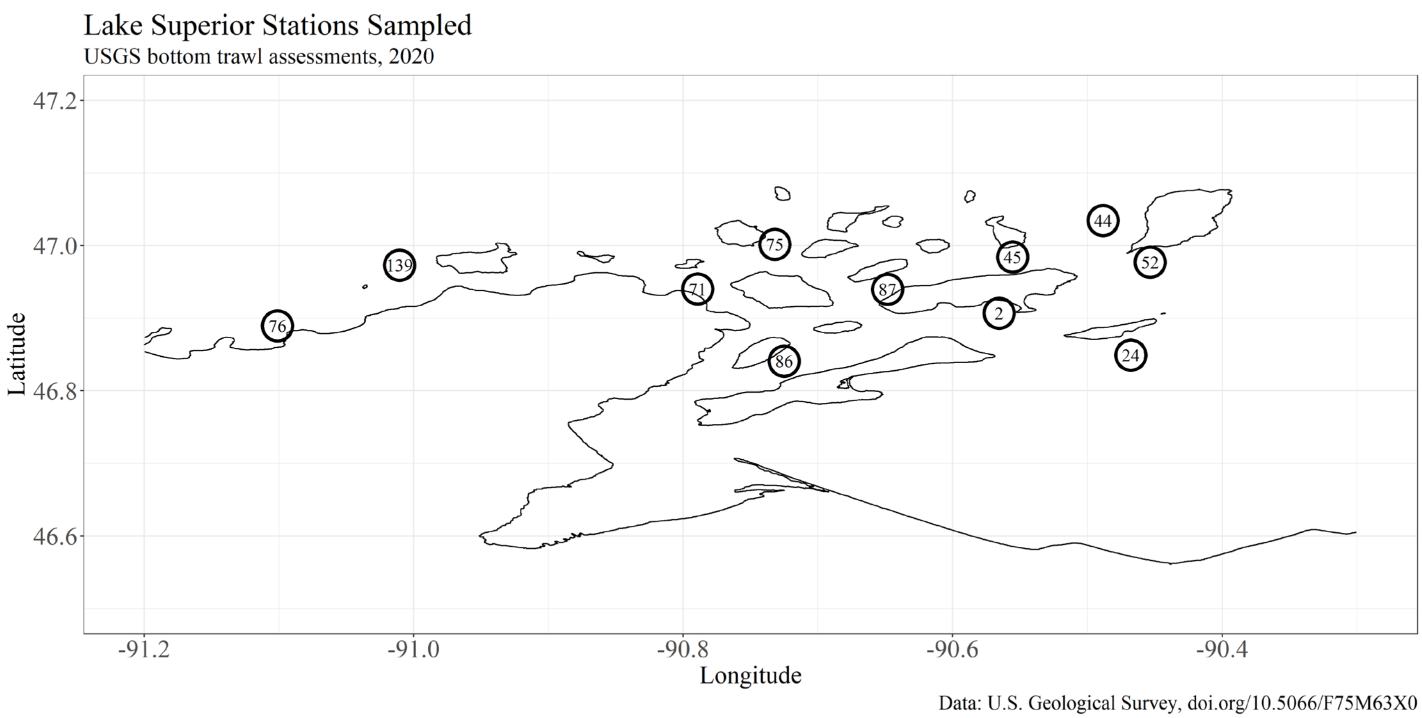

Figure 1. Location of 11 stations sampled from 9-14 July 2020. Samples collected at each location included bottom trawl tows for demersal fish, whole water column zooplankton collections, and a water profile that electronically collected data on depth, temperature, specific conductance, pH, dissolved oxygen, chlorophyll a, photosynthetic active radiation, and beam transmission.

Results

During our July 2020 sampling of 11 sites a total of 2,058 individual fish from 17 species or morphotypes were collected (Table 1). The number of species collected at each station ranged from zero to 13, with a mean of 6.3 and median of 6. Estimated fish biomass at individual stations ranged from zero to 51.9 kg/ha (Figure 2). Individual stations with the highest biomass were 86-Basswood Island and 139-Sand Island (Figure 2). Average fish biomass was 10.5 kg/ha, which was similar to the average observed over the past 10 years

(10.8 kg/ha), less than averages observed from 2001-10 (18.1 kg/ha), 1991-2000 (28.7 kg/ha), and 1981-1990 (23.6 kg/ha), but higher than the average from 1974-1980 (5.3 kg/ha, Figure 3). Mean biomass was highest for Bloater (6.2 kg/ha), Lake Whitefish (2.3 kg/ha), and Cisco (0.9 kg/ha) and low for Rainbow Smelt (0.3 kg/ha) and other small prey fish.

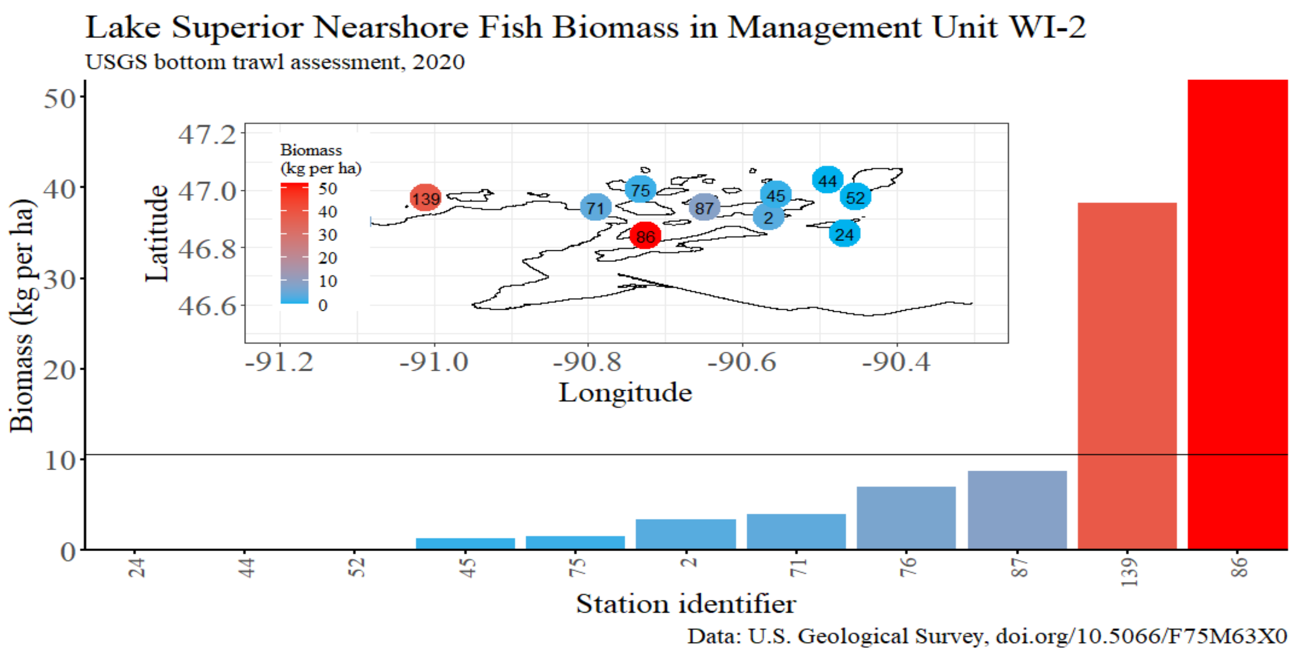

Figure 2. Estimated total fish biomass (kg/ha) at 11 nearshore sampling stations in 2020. The horizontal line is the 2020 average biomass across all stations (10.5 kg/ha). The inset figure shows station locations and biomass (kg/ha) in 2020.

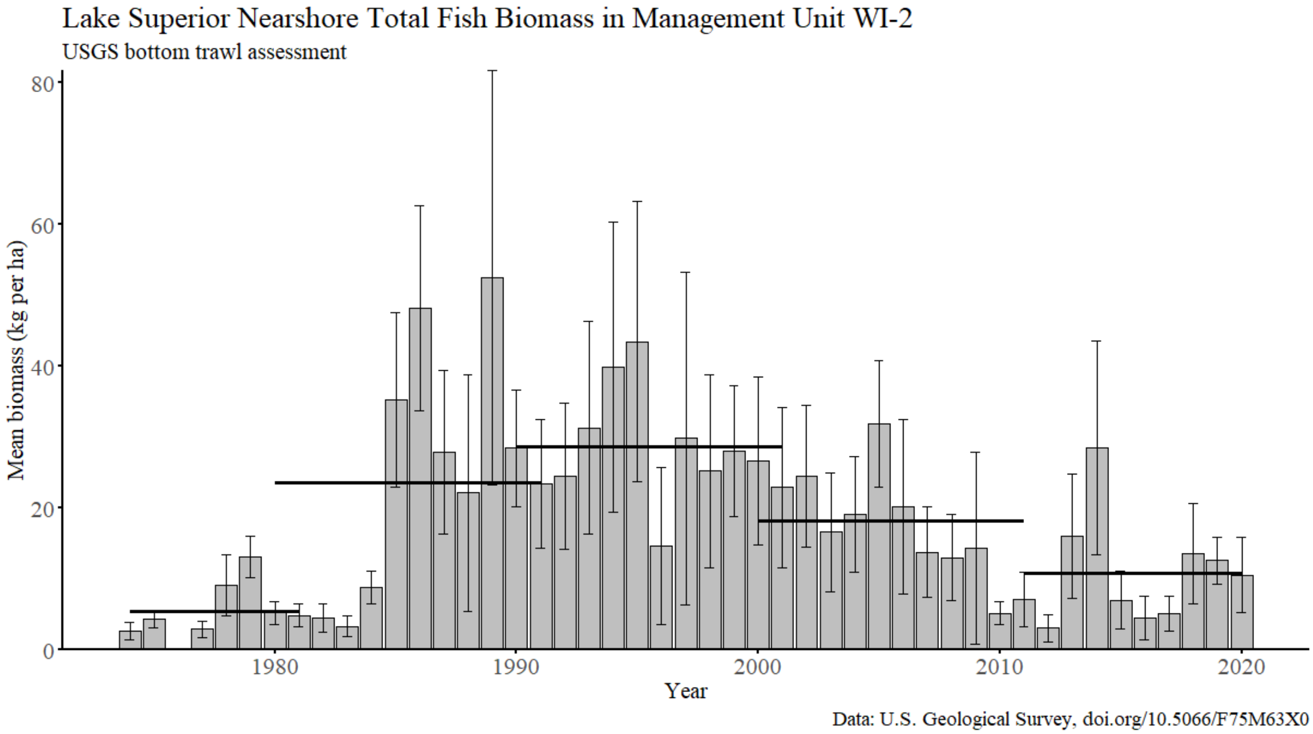

Figure 3. Annual (mean ± standard error) total fish biomass estimates for all fish species collected in bottom trawls from 1974-2020 in Lake Superior Management Unit WI-2. Horizontal lines are 10-year averages across different periods. The number of sites sampled in each year is presented in Table 2.

Cisco biomass averaged 0.9 kg/ha in 2020. This was greater than that observed in the three previous years, similar to the prior ten-year average of 0.9 kg/ha, and much less than that observed from 1985-1995 (Figure 4, Table 2).

Bloater biomass averaged 6.2 kg/ha in 2020. This was greater than that observed since 2009 and well above the previous 47-year average of 2.3 kg/ha (Figure 4, Table 2). Lake

Whitefish biomass averaged 2.3 kg/ha in 2020. This was less than the previous 10-year average of 6.7 kg/ha and the previous 47-year average of 8.5 kg/ha (Figure 4, Table 2).

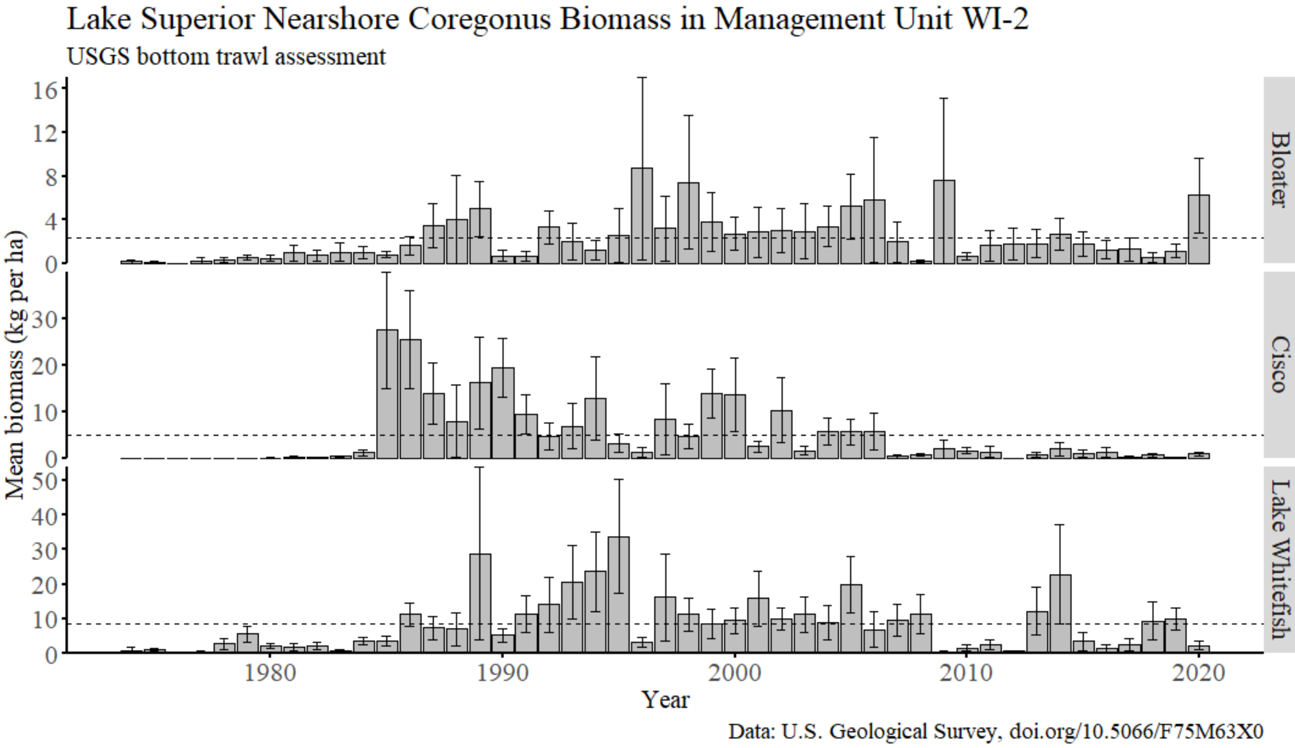

Figure 4. Mean annual biomass estimates (kg/ha ± standard error) for all fish species collected in bottom trawls from 1974-2020 in the Lake Superior Management Unit WI-2. The horizontal line is the 47-year period-of-record mean. The number of sites sampled in each year is presented in Table 2.

We developed length-frequency distributions for Cisco, Bloater and Lake Whitefish from 1974-2020 for Management Unit WI-2 to understand how recruitment events have shaped these populations over time (Appendix A). The Cisco population in this region has been characterized by high recruitment variation, with clear evidence that sporadic catches of age-1 Cisco persist and can be seen growing larger in subsequent years. That same general pattern is evident for Bloater, but with strong year-classes occurring at a lower frequency. Recruitment of Lake Whitefish has shown far less variation compared to Cisco and Bloater. It is interesting to note that large Lake Whitefish (> 300 mm) are not always caught (e.g., 2019 and 2020) when prior-year catches would suggest those fish should have been present in the area. This may point to interannual variation in large Lake Whitefish spatial distributions such that large individuals may not be present at our fixed stations each year and these larger fish may be less susceptible to our bottom trawl gear.

Rainbow Smelt was the only exotic species collected in the July 2020 sampling and their biomass averaged 0.3 kg/ha ~~in 2020~~ which was less than observed over the past three years and similar to that observed over the previous 10 years (0.5 kg/ha). Average biomass of Rainbow Smelt in WI-2 over the entire 47-year series is 1 kg/ha.

Other species sampled in bottom trawls in the July 2020 sampling (number collected) included Slimy Sculpin (46), Kiyi (31), Spoonhead Sculpin (26), lean Lake Trout (16), Unidentified Coregonid (15),
Ninespine Stickleback (13), Shortjaw Cisco (11), Pygmy Whitefish (10), Deepwater Sculpin (6), Burbot (3), Blackfin Cisco (2), siscowet Lake Trout (1), and hatchery Lake Trout (1). Scientific names are provided in Table 1. The combined average biomass of these other species was 0.8 kg/ha (Table 2).

Density of age-1 prey fish (fish/ha) was used as a measure of year-class strength. Average age-1 Cisco density was near zero (0.2 fish/ha) in 2020 in Management Unit WI-2. Age-1 Cisco were collected at one (Sand Island) of the 11 nearshore stations sampled (Figure 5). The last Cisco age-1 year-classes that exceeded 10 fish/ha in Management Unit WI-2 were the 2014 (11 fish/ha) and 2015 (36 fish/ha) year-classes (Figure 6). Over the past 20-years, six Cisco age-1 year-classes have exceeded 10 fish/ha in Management Unit WI-2. Preliminary analysis of the effect of age-1 Cisco year-class strength (Table 3) on adult Cisco population size (D. Carl, Wisconsin Department of Natural Resources, unpublished data) suggests 10 age-1 fish/ha may be the threshold for meaningful contribution of that year-class to future commercial fishery catch.

Age-1 Bloater density averaged 1.1 fish/ha in 2020 in Management Unit WI-2. Age-1 Bloater were collected at five of the 11 nearshore stations sampled (Figure 5). Over the past 20-years, five Bloater age-1 year-classes have exceeded 10 fish/ha in Management Unit WI-2 (Figure 6).

In comparison to Bloater and Cisco, Lake Whitefish have exhibited more consistent recruitment and lower overall population biomass fluctuations over the past 42 years (Appendix A). In 2020, age-1 Lake Whitefish density averaged 15.2 fish/ha in Management Unit WI-2, which was less than the period-of-record average of 39.5 fish/ha (Table 3, Figure 6), but greater than that observed for the 2014-2018 year-classes.

Rainbow Smelt age-1 density averaged 6.3 fish/ha in 2020 in Management Unit WI-2. This was much less than the period of record mean (248 fish/ha) and median (124 fish/ha) and was the lowest value observed since the 2011 year-class (Table 3).

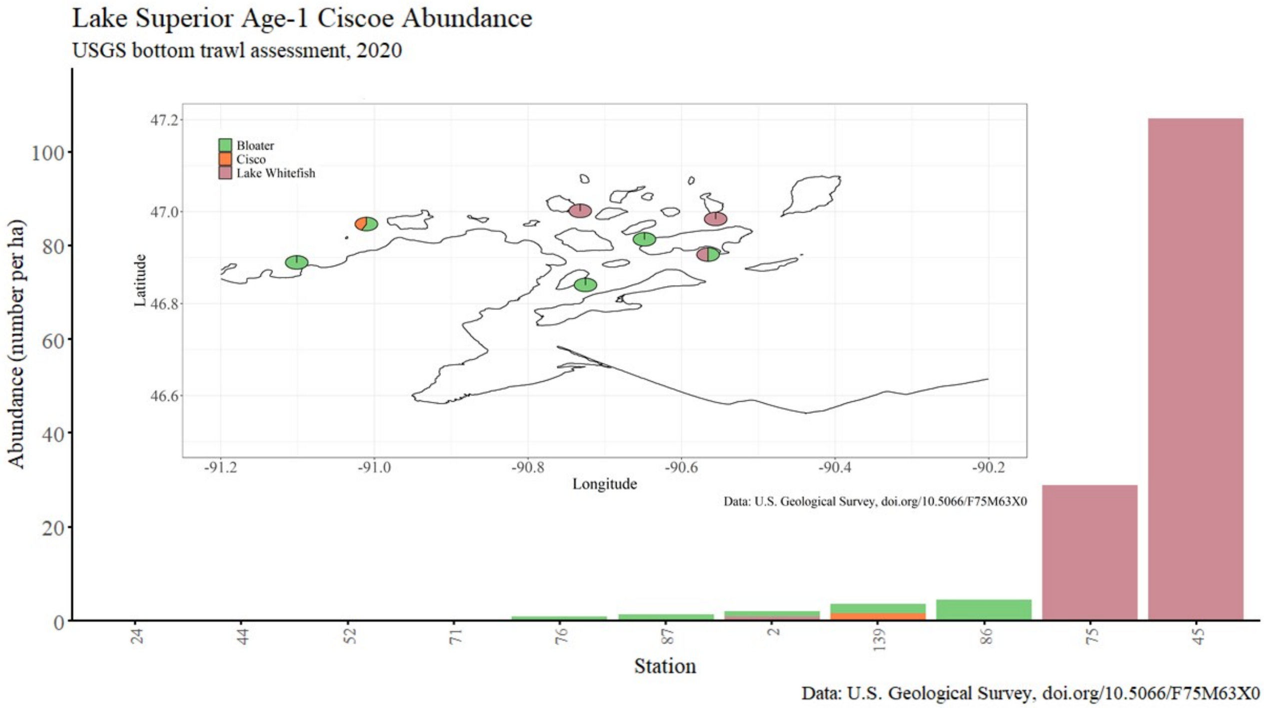

Figure 5. Estimated abundance (number/ha) of age-1 Bloater, Cisco, and Lake Whitefish at individual nearshore sampling stations in 2020. The inset map shows sampling station locations.

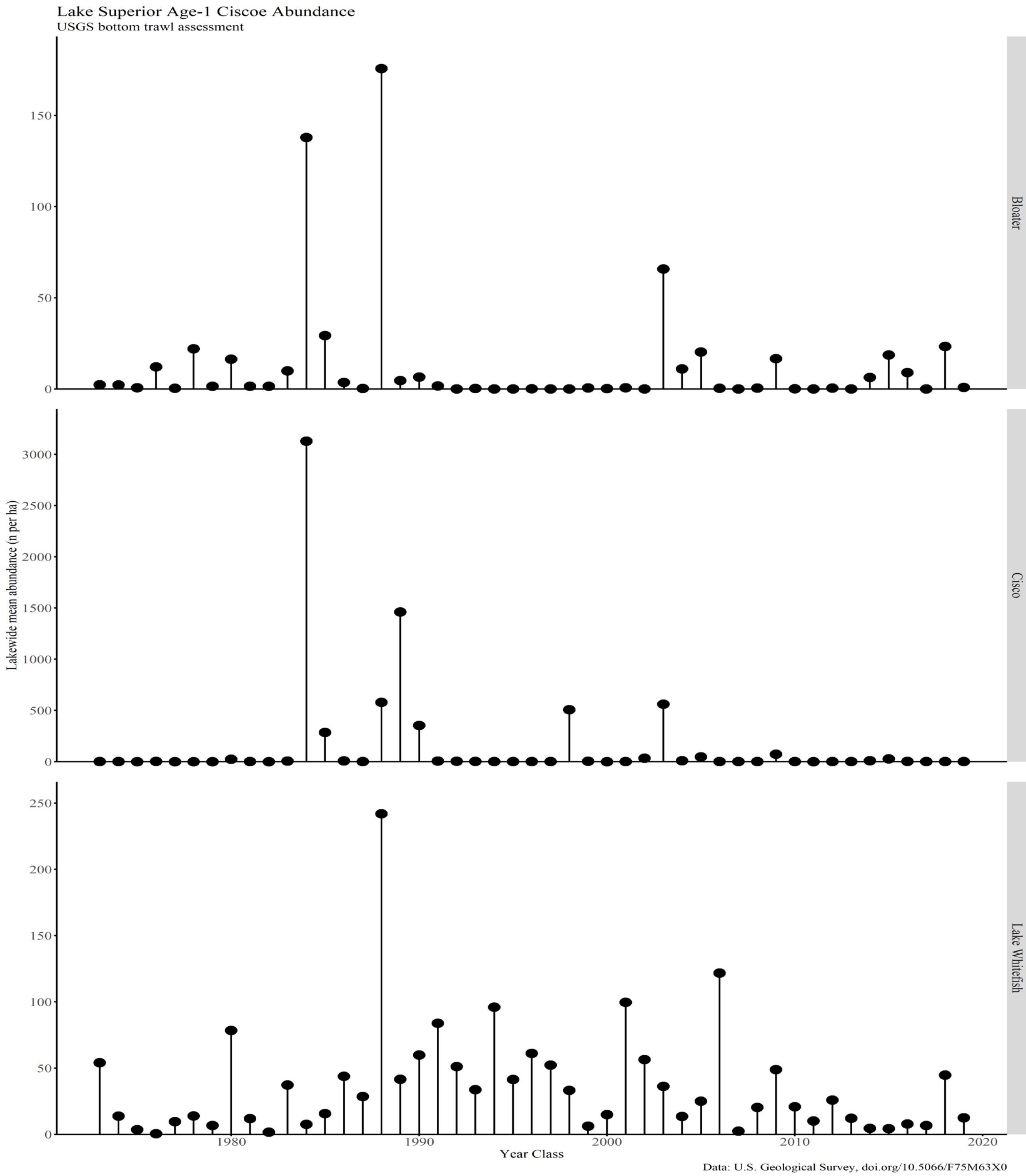

Figure 6. Estimated annual average abundance (number/ha) of age-1 Bloater, Cisco, and Lake Whitefish from 1974-2020 in Management Unit WI-2. Y-axis scales differ among species.

Summary

Over the 47-year history of the U.S. Geological Survey's Lake Superior nearshore fish community surveys in Management Unit WI-2, total estimated biomass of demersal fish has been a reflection of the survival of Bloater, Cisco, and Lake Whitefish populations to age-1+ as well as survival of Rainbow Smelt to age-3 or older. The lack of significant survival of Bloater and Cisco to age-1 over the past twenty years has resulted in lower adult prey fish biomass estimates than were observed during 1985-2000, when several large year-classes of Bloater and Cisco were present. Conversely, fish biomass estimates over the past two decades in Management Unit WI-2 are larger than observed during the first 10 years of this survey prior to the large 1984 Cisco year-class. Coregonine populations worldwide have experienced declines due to highly variable and low survival to age-1 (Lepak et al., 2017; Nyberg et al., 2001; Parks and Rypel, 2018) which have been associated with climate-induced changes in early-life stage environments (Nyberg et al., 2001). However, an underlying mechanism between changing lake environments and coregonine year-class strength has yet to be established. This is disconcerting to fishery managers as coregonine fishes support valuable commercial fisheries, are native prey for a rehabilitated Lake Trout population, and play an important role in energy transfer throughout the lake (Stockwell et al. 2009, 2014; Gorman et al. 2012).

Note: All GLSC sampling and handling of fish during research are carried out in accordance with guidelines for the care and use of fishes by the American Fisheries Society (http://fisheries.org/docs/wp/Guidelines-for-Use-of-Fishes.pdf).

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Table 1. *Fish species collected, the number of individuals collected, and the average estimated biomass (kg/ha) from a nearshore bottom trawl survey at 11 locations in Lake Superior Management Unit WI-2 in 2020. Sampling locations shown in Figure 1.*

Common name	Scientific name	Native or exotic	Individuals collected	Mean biomass kg/ha	Mean abundance fish/ha
Bloater	*Coregonus hoyi*	native	1210	6.2	77.2
Rainbow Smelt	*Osmerus mordax*	exotic	389	0.3	31.6
Lake Whitefish	*Coregonus clupeaformis*	native	191	2.3	21.6
Cisco	*Coregonus artedii*	native	87	0.9	5.9
Slimy Sculpin	*Cottus cognatus*	native	46	0.006	3.4
Kiyi	*Coregonus kiyi*	native	31	0.1	1.5
Spoonhead Sculpin	*Cottus ricei*	native	26	0.003	1.2
lean Lake Trout	*Salvelinus namaycush*	native	16	0.3	1.1
Unidentified Coregonid	*Coregonus*	native	15	0.1	1.3
Ninespine Stickleback	*Pungitius pungitius*	native	13	0.001	1.3
Shortjaw Cisco	*Coregonus zenithicus*	native	11	0.09	0.8
Pygmy Whitefish	*Prosopium coulteri*	native	10	0.006	0.8
Deepwater Sculpin	*Myoxocephalus thompsoni*	native	6	0.0004	0.3
Burbot	*Lota lota*	native	3	0.06	0.1
Blackfin Cisco	*Coregonus nigripinnis*	native	2	0.02	0.2
siscowet Lake Trout	*Salvelinus namaycush siscowet*	native	1	0.01	0.04
hatchery Lake Trout	*Salvelinus namaycush*	native	1	0.003	0.04

Table 2. *Average bottom trawl biomass (kg/ha) estimates for common prey fishes collected in an annually conducted nearshore bottom trawl survey in Lake Superior Management Unit WI-2. Sculpin includes Slimy, Spoonhead, and Deepwater Sculpin. Mean and median total biomass includes all species. Other species includes Ninespine Stickleback, Trout-perch, Kiyi, Shortjaw Cisco, Pygmy Whitefish, Round Whitefish, Longnose Sucker, and lean, siscowet, and hatchery Lake Trout. No fish sites are the number of sites where no fish were collected.*

Year	Sites	No fish sites	Mean fish species	Total fish species	Mean Biomass all fishes	Median biomass all fishes	Bloater	Cisco	Lake Whitefish	Rainbow Smelt	Burbot	Sculpin	Other species
1974	6	0	10.0	17	2.6	0.9	0.2	0.0	0.9	0.1	0.7	0.11	1.5
1975	9	0	9.9	15	4.3	3.0	0.1	0.0	1.2	1.0	0.3	0.18	2.0
1976	9	0	7.2	14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0
1977	11	0	8.0	15	2.9	1.9	0.3	0.0	0.4	1.5	0.1	0.06	0.6
1978	11	0	7.2	15	9.1	1.7	0.3	0.0	2.7	4.3	0.2	0.03	1.7
1979	11	0	9.8	13	13.2	9.9	0.6	0.0	5.6	2.9	0.4	0.06	4.0
1980	11	0	8.6	15	5.2	3.9	0.5	0.1	2.0	0.8	0.3	0.05	1.8
1981	10	0	8.1	15	4.8	2.8	0.9	0.3	1.9	0.2	0.3	0.04	1.5
1982	11	0	8.0	14	4.4	1.0	0.7	0.2	2.1	0.5	0.0	0.04	0.9
1983	11	0	7.0	14	3.3	1.7	1.0	0.4	0.6	0.7	0.0	0.03	0.6
1984	11	0	10.3	17	8.8	5.7	1.0	1.2	3.6	0.7	0.3	0.06	2.4
1985	11	0	9.4	15	35.3	23.3	0.8	27.5	3.6	1.3	0.0	0.08	2.1
1986	11	0	10.9	15	48.2	34.8	1.6	25.6	11.2	7.8	0.3	0.08	1.9
1987	11	0	8.8	15	27.9	2.8	3.5	13.9	7.3	1.6	0.3	0.04	1.6
1988	11	0	8.9	15	22.2	3.2	4.0	8.0	7.1	1.8	0.0	0.05	1.3
1989	11	0	9.3	16	52.5	10.4	5.0	16.2	28.8	1.4	0.1	0.03	0.9
1990	11	0	10.3	15	28.5	26.3	0.7	19.4	5.2	1.4	0.2	0.05	1.5
1991	11	0	9.6	14	23.4	11.4	0.7	9.4	11.2	0.7	0.4	0.04	1.0
1992	11	0	9.4	15	24.5	5.8	3.3	4.7	14.1	0.4	0.2	0.04	1.8
1993	11	0	9.8	16	31.3	10.8	2.0	6.9	20.5	0.5	0.0	0.04	1.4
1994	11	0	9.7	16	39.8	15.8	1.2	12.9	23.6	0.5	0.1	0.02	1.5
1995	11	0	9.3	17	43.5	15.1	2.6	3.2	33.8	1.3	0.2	0.04	2.3
1996	11	0	7.9	16	14.6	2.4	8.7	1.3	3.2	0.4	0.1	0.01	1.0
1997	11	0	8.5	16	29.8	5.4	3.2	8.3	16.1	0.4	0.0	0.01	1.7
1998	11	0	9.0	17	25.2	9.6	7.4	4.8	11.3	0.5	0.4	0.02	0.9
1999	10	0	6.8	16	28.1	20.4	3.8	13.8	8.5	1.2	0.2	0.01	0.5
2000	10	0	6.4	14	26.6	8.7	2.7	13.7	9.5	0.3	0.0	0.00	0.4
2001	11	0	8.2	19	22.9	17.3	2.9	2.5	15.9	0.7	0.1	0.01	0.8
2002	11	0	7.1	18	24.5	16.1	3.0	10.3	10.0	0.5	0.0	0.00	0.7
2003	11	0	6.5	17	16.6	3.2	2.9	1.6	11.2	0.4	0.0	0.00	0.4
2004	11	0	9.2	17	19.1	4.0	3.4	5.8	8.9	0.3	0.4	0.02	0.4
2005	9	0	7.9	17	31.8	25.1	5.2	5.7	20.0	0.2	0.2	0.00	0.6
2006	9	0	5.7	14	20.2	1.2	5.8	5.8	6.8	1.2	0.0	0.00	0.4
2007	9	0	7.7	19	13.8	1.7	2.0	0.4	9.6	1.0	0.2	0.01	0.6

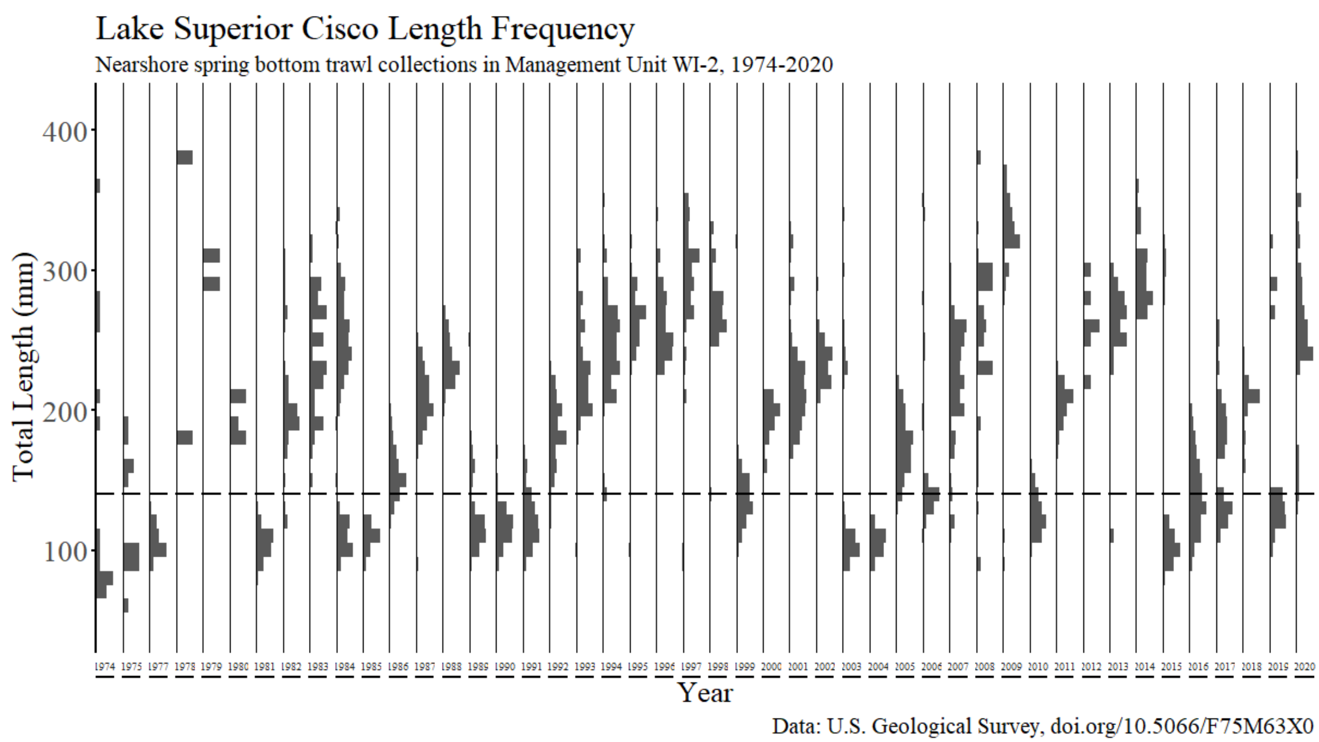
2008	9	0	7.1	18	13.0	3.2	0.2	0.7	11.4	0.4	0.0	0.00	0.5
2009	9	1	4.4	14	14.4	0.3	7.6	2.0	0.4	0.4	0.3	0.00	3.8
2010	10	1	6.9	15	5.2	3.9	0.7	1.7	1.6	0.8	0.1	0.00	0.3
2011	10	0	6.6	12	7.1	0.3	1.6	1.3	2.5	0.6	0.0	0.00	1.0
2012	11	0	7.2	18	3.0	1.0	1.8	0.0	0.6	0.0	0.0	0.02	0.5
2013	11	0	7.5	18	16.0	2.0	1.8	0.8	12.2	0.3	0.0	0.01	0.9
2014	11	0	7.0	17	28.5	2.8	2.7	2.0	22.8	0.3	0.2	0.00	0.5
2015	11	2	5.9	16	7.0	0.0	1.8	0.9	3.5	0.1	0.0	0.01	0.7
2016	11	2	4.3	16	4.5	0.0	1.3	1.2	1.4	0.2	0.2	0.00	0.3
2017	11	0	5.8	15	5.1	0.3	1.3	0.3	2.5	0.8	0.0	0.00	0.3
2018	11	1	5.9	15	13.6	0.2	0.5	0.7	9.4	1.9	0.4	0.00	0.7
2019	11	1	7.2	19	12.6	15.5	1.1	0.2	10.0	0.7	0.1	0.01	0.4
2020	11	1	6.4	17	10.5	3.3	6.2	0.9	2.3	0.3	0.1	0.01	0.8
Mean	10.5	0.2	7.9	15.8	18.1	7.2	2.3	5.0	8.5	1.0	0.2	0.03	1.0
Median	11	0	7.9	16.0	14.6	3.2	1.8	1.6	7.1	0.6	0.1	0.02	3.5

Table 3. *Mean annual Lake Superior bottom trawl age-1 density (number/ha) estimates for Bloater, Cisco, Lake Whitefish, and Rainbow Smelt and for small lean Lake Trout (<age-3) collected in an annually conducted nearshore bottom trawl survey in Lake Superior Management Unit WI-2. Age-1 fish were defined by species-specific lengths: Cisco <140 mm, Bloater <130 mm, Lake Whitefish <160 mm, Rainbow Smelt <100 mm, and Kiyi <130 mm. Small lean Lake Trout data are for fish <226 mm (~< age 3).*

Year	Year-class	Bloater	Cisco	Lake Whitefish	Rainbow Smelt	lean Lake Trout
1974	1973	7.1	4.1	161.9	4508.2	1.2
1975	1974	2.3	0.8	13.7	188.7	5.6
1976	1975	0.7	0	3.5	26.6	0.4
1977	1976	12.2	2.4	0.4	140.3	0.2
1978	1977	0.5	0	10.5	21	0.7
1979	1978	22.1	0	13.8	189	0.8
1980	1979	1.5	0	6.7	57.9	0.2
1981	1980	16.4	23.1	78.4	110.8	0.7
1982	1981	1.5	0.2	11.8	105.4	1
1983	1982	1.5	0	1.6	56.2	1.2
1984	1983	10	5.4	37.2	268.1	2
1985	1984	138	3129.9	7.5	208.7	1.6
1986	1985	29.3	284.6	15.7	142.9	2.2
1987	1986	3.6	7.2	43.7	196.6	1.6
1988	1987	0.3	0.2	28.5	360.3	0.6
1989	1988	175.7	579.3	241.9	457.7	0.9
1990	1989	4.6	1460.8	41.5	371.6	1.1
1991	1990	6.6	353.9	59.8	136.2	0.7
1992	1991	1.7	5.8	83.8	95.6	1.6
1993	1992	0	4.4	51.1	280.4	1.6
1994	1993	0.3	2	33.7	101.3	1.7
1995	1994	0	1.4	95.9	532.9	1.2
1996	1995	0	0.7	41.3	104	0.7
1997	1996	0.2	1.6	61.1	218.9	1.7
1998	1997	0	0.9	52.2	124.3	1.6
1999	1998	0	506.9	33.2	314.8	0.2
2000	1999	0.6	4.6	6.8	11.1	0.4
2001	2000	0.2	0	14.9	40.4	0.8
2002	2001	0.7	1.6	99.6	159.9	0.3
2003	2002	0	37.6	62.1	70	0

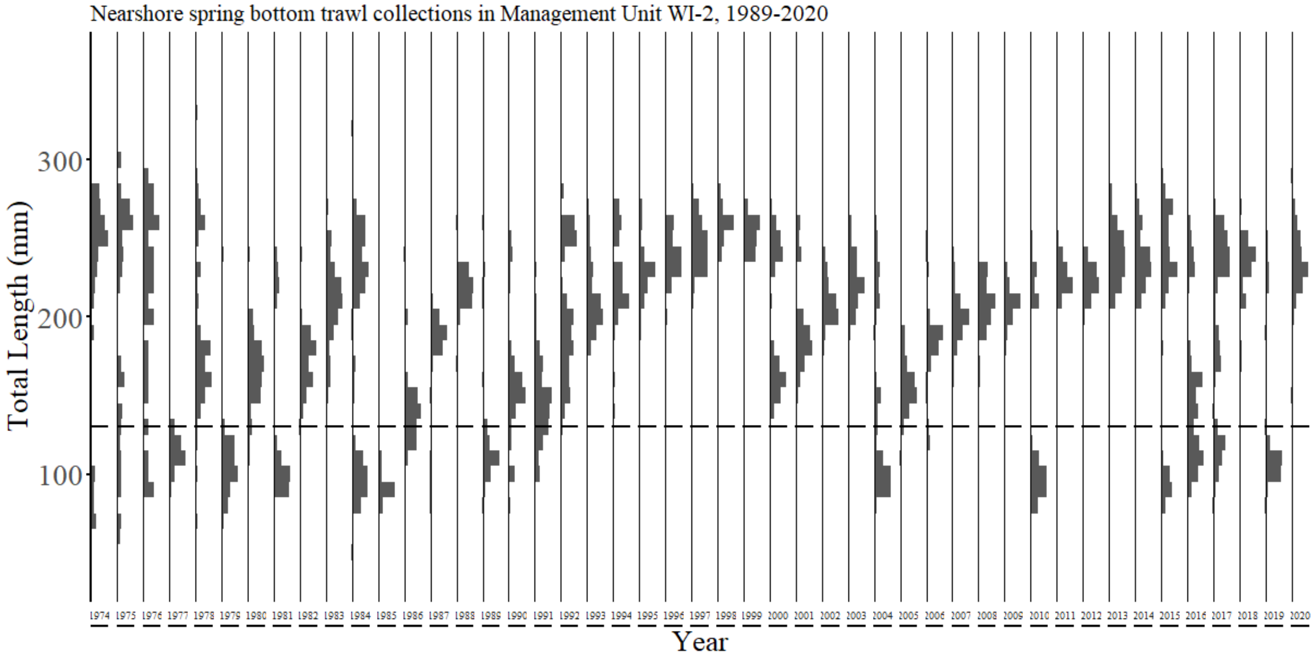
2004	2003	65.9	560.9	36.3	83.7	0.7
2005	2004	11	8.3	13.5	42.9	1.2
2006	2005	22.9	52.8	28	530.9	0.1
2007	2006	0.4	0.3	121.7	167.6	0.1
2008	2007	0	0.4	2.7	44	0.1
2009	2008	0.6	1.2	26.1	314.9	0.5
2010	2009	18.5	80.7	54.3	155	0.2
2011	2010	0.1	0	20.8	26.4	0.5
2012	2011	0	0	11.1	3.5	1.4
2013	2012	0.5	0.7	25.8	58.1	0.3
2014	2013	0	0	12.1	44	0.5
2015	2014	7.7	10.6	5.5	36.7	0.5
2016	2015	25.7	36.4	5.8	103.1	0.3
2017	2016	9	2.4	7.8	138.8	0.4
2018	2017	0	0	7.4	237	0.1
2019	2018	25.7	1.5	49.1	84.2	0.2
2020	2019	1.1	0.2	15.2	6.3	0.4
Mean		13.3	152.6	39.5	248.4	0.9
Median		1.5	1.6	26.1	124.3	0.7

Appendix A. Length-frequency distributions of Cisco, Bloater and Lake Whitefish in spring bottom trawl collections in Management Unit WI-2, 1974-2020. Note that Lake Whitefish data are for fish <500 mm, as Lake Whitefish >500 mm are known to be less vulnerable to our bottom trawl. The horizontal dotted line is the estimated total length for age-1 fish in May-July; Cisco ≤140 mm, Bloater ≤130 mm, and Lake Whitefish ≤160 mm.



Lake Superior Bloater Length Frequency

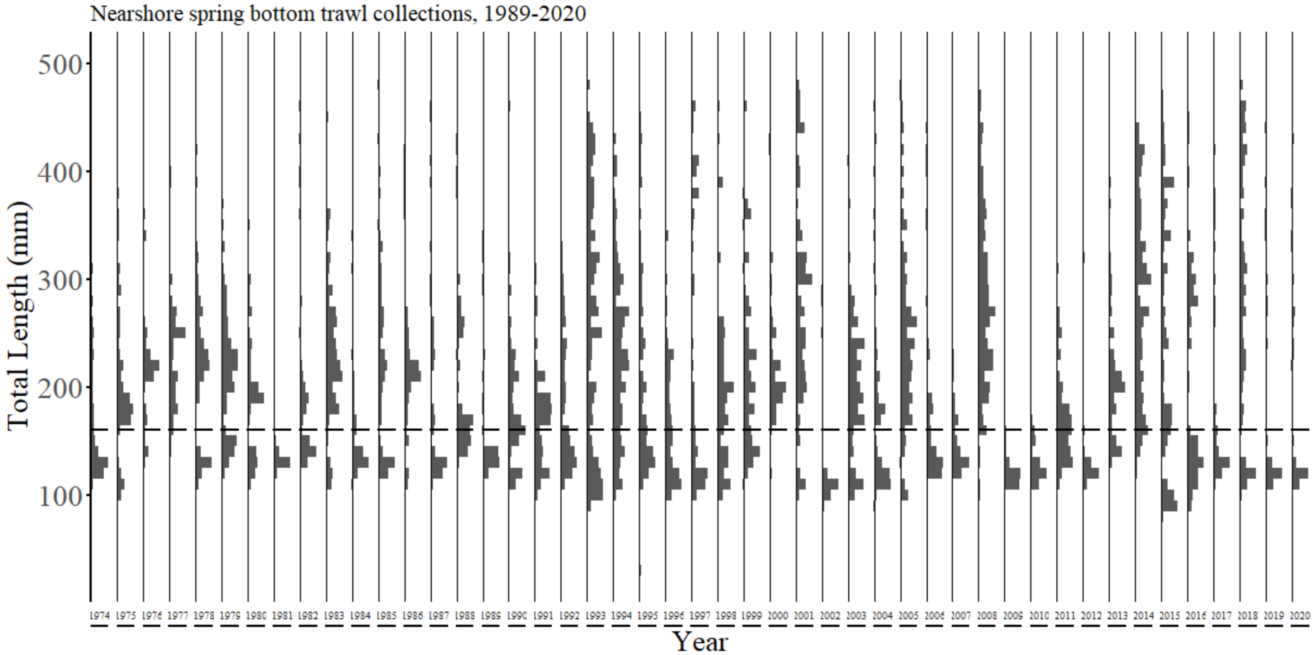
Nearshore spring bottom trawl collections in Management Unit WI-2, 1989-2020



Data: U.S. Geological Survey, doi.org/10.5066/F75M63X0

Lake Superior Lake Whitefish (<500 mm) Length Frequency

Nearshore spring bottom trawl collections, 1989-2020



Data: U.S. Geological Survey, doi.org/10.5066/F75M63X0