Bottom trawl assessment of Lake Ontario prey fishes

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Abstract

Collaborative Lake Ontario bottom trawl surveys, led by the United States Geological Survey (USGS), provide science and management information for evaluating Fish Community Objectives including predator-prey balance and prey fish community diversity. In 2018, the New York State Department of Environmental Conservation (NYSDEC), Ontario Ministry of Natural Resources and Forestry (OMNR), and the (USGS) completed an April bottom trawl survey (n = 208 tows) and an October survey (n = 118 tows), at depths 6-228 m, and captured 384,651 fish from 31 species. Alewife were 80% of the total catch by number and round goby, deepwater sculpin, and rainbow smelt comprised 12, 4, and 3% of the catch, respectively. The adult alewife abundance index for U.S. waters decreased in 2018 relative to 2017, while the index in Canadian waters increased. While lake wide density increased, biomass indices for Age-2 alewife decreased. Alewife condition indices were below the 10-year average for both the April and October indices. The 2018 Age-1 alewife abundance index, which measures reproductive success the previous year, was the third lowest observed in U.S. waters over the past 22 years. The Canadian Age-1 index 2018 value was four-times larger than the U.S. value. Within-year differences between Canadian and U.S. alewife abundance indices, highlight the importance of assessing Lake Ontario fishes at a whole-lake scale. Abundance indices for rainbow smelt, threespine stickleback and emerald shiner were similar to 2017. New experimental trawl sites in embayment habitats generally captured more species, a higher proportion of native species, and higher densities relative to similar depth sites in the main lake and regions adjacent to embayments. Pelagic prey fish diversity continues to be low because a single species, alewife, dominates the catch. Deepwater sculpin and round goby were the most abundant demersal (bottom-oriented) prey fishes in 2018. Slimy sculpin and native nearshore demersal prey fishes, which were historically more abundant in trawl catches, are rare and restricted to specific habitats, since round goby proliferation. Despite declines in some species, demersal prey fish community diversity continues to increase as deepwater sculpin and round goby comprise more even portions of the community in contrast to when a single species, slimy sculpin, dominated the community. Five bloater were captured in the 2018 surveys which is the largest number captured in Lake Ontario since restoration stocking began in 2012.

Introduction

Lake Ontario Fish Community Objectives (FCOs) call for maintaining predator-prey balance and for maintaining and restoring pelagic and benthic or demersal (bottom–oriented) prey fish diversity (Stewart et al. 2017). Collaboratively-conducted bottom trawl surveys have continually measured Lake Ontario prey fish community status and trends since 1978 to provide information for management decisions relative to these objectives.

Alewife are the most abundant fish in Lake Ontario and, as prey, support most of the lake's piscivores (Mills et al. 2003; Stewart and Sprules 2011; Weidel et al. 2018). Accordingly, their abundance and population abundance trajectories are critical to maintaining FCOs and sport fishing quality. Recent bottom trawl prey fish surveys have documented lower-than-average alewife reproduction in 2013 and 2014 resulting in reduced adult abundances (Weidel et al. 2018). Concerns over maintaining alewife in balance with the lake's predators has resulted in management agencies reducing the number of sport fish stocked in 2016 - 2018 (Lake Ontario Committee 2016; New York State Department of Environmental Conservation 2018; OMNRF 2018).

In addition to providing information for managing sport fisheries, prey fish surveys also quantify the status of native species and prey fish communities, providing information for other FCOs and basin-wide prey fish status assessments (Environment and Climate Change Canada and U.S. Environmental Protection Agency 2017). Recently, surveys documented the natural recovery of native deepwater sculpin, a bottom-oriented prey fish once thought to be extirpated from the lake (Weidel et al. 2017). Bottom trawl surveys also measure the progress of bloater restoration. Bloater, a native, species that inhabits deep, offshore habitats was last caught by trawl surveys in 1983, indicating this species was also likely extirpated from the lake (Owens et al. 2003). Lake Ontario bloater restoration began in 2012 by stocking fish collected from Lake Michigan (Connerton 2018). Surveys also provide extensive, lake-wide surveillance for nonnative species and their effects such as round goby and its apparent negative effect on other demersal fishes (Weidel et al. 2018). In addition to sampling standardized annual trawl sites, surveys also conduct targeted research to better interpret historic bottom trawl data and design more-efficient sampling strategies. For instance, video cameras attached to the bottom trawls determined how long trawls were in contact with the lake bottom and found the area swept by deep trawls was three times what had been previously estimated based on recorded tow times (Weidel and Walsh 2013). Identifying where different surveys produced generally-duplicative results has allowed effort to be reallocated, expanding the spatial extent of the April and October surveys (Weidel et al. 2015). Expanding surveys to a whole-lake scale has provided new and critical insights, such as demonstrating the highest April alewife densities annually vary between the U.S. and Canadian waters of Lake Ontario (Weidel et al. 2018). Within this report we also document these value-added research projects to improve our interpretations of long-term survey data.

This report describes the status of Lake Ontario prey fishes with emphasis on information addressing the bi-national (OMNRF, NYSDEC) Lake Ontario Committee's FCOs (Stewart et al. 2017). This research is also guided by the U.S. Geological Survey (USGS) Ecosystems Mission Area science strategy whose goals seek to understand how ecosystems function and provide services, what drives ecosystems, and to develop science and tools that inform decision making related to ecosystem management, conservation and restoration (Williams et al. 2013).

Methods

April survey

The Lake Ontario April bottom trawl survey has been collaboratively conducted by NYSDEC and USGS during April and early-May since 1978. The survey collects many species but targets alewife at a time when their winter behaviors place them near the lake bottom which maximizes their susceptibility to bottom trawls (Wells 1968). Daytime trawling is conducted at fixed sites located along transects extending from shallow (~6m) to deep (228m) habitats. Although random sampling is preferable for trawl-based abundance estimates, it is not practical because of varied substrates that can prohibitively damage trawls at randomly selected sites (MacNeill et al. 2005). A team of fish sampling experts reviewed the Lake Ontario prey fish trawl program and found the fixed-station sampling design generated a suitable estimate of relative abundance (ICES 2004; MacNeill et al. 2005). The original survey sampled from 8-150m (26-495 ft) in U.S. waters at 12 transects. Changes in fish depth distribution and the need for lake-wide information have resulted in survey expansion. For instance, nutrient reductions and dreissenid mussel filtration increased water clarity in the mid 1990s (O'Gorman et al. 2000). Subsequently, the depth distributions of alewife and other prey fish shifted deeper and in 2004, trawling was expanded to 170m (557 ft) in U.S. waters (O'Gorman et al. 2000). In 2016, the survey was further expanded to a whole-lake extent and the OMNRF research vessel joined the survey. Since 2016, trawls have been collected from 6-225m (20-743 ft), with sites organized in 20-23 transects or regions distributed around the lake (Figure 1).

The original survey used a nylon Yankee bottom trawl with an 11.8-m (39 ft) headrope and flat, rectangular, wooden trawl doors. Prohibitive large catches of dreissenid mussels in the 1990s required changing to a "3N1" trawl, with an 18-m (59 ft) headrope and slotted, metal, cambered V-doors. This trawl was configured such that the trawls footrope was not in contact with the lake bottom to reduce mussel catches. The survey adopted this trawl design in 1997 and for consistency, the time series statistics for the April bottom trawl survey are illustrated in this report's figures, from 1997 to present.

Bottom trawl catches are separated to species, counted, and weighed in aggregate. Subsamples of all species are also measured for individual length and weight, and stomachs, muscle tissue, and various aging structures are removed for age interpretation and archives. Abundance indices are based on the mean, lake area-weighted catch per 10-minute bottom trawl. Stratification is based on 20 m (66 ft) depth intervals and the proportional area of those depth intervals within the U.S. and Canadian portions of the lake (Table 1). The maximum depth sampled has increased as alewife distribution has increased. This survey expansion complicates analyses because the proportions of lake area within each 20m-strata change as more strata are included (Table 1). To estimate abundance based on a consistent area of the lake, stratified means for all years are calculated using all depth strata, assuming alewife catch was zero in those years when deep strata were not sampled. Separate abundance indices are calculated for U.S. and Canadian trawl catches. Mean and standard error calculations are from Cochrane (1977). Statistics reported for trawl catches in Canadian waters follow a similar analysis, however the area within 20m strata in Canadian waters differ from U.S. waters (Table 1). We also report a lake-wide alewife biomass index expressed in kilograms per hectare combining biomass estimates from U.S. and Canadian portions of the lake (48% lake area in U.S., 52% in Canada). Area-weighted biomass means based on 20 m strata are calculated similarly to number per 10 minute tow indices describe above; however, these calculations account for the area swept by the trawl, which changes with fishing depth (Weidel and Walsh 2013). Reporting in these units provides data in a more readily useable form to address ecosystem-scale management questions and facilitates comparisons across lakes. Condition indices are estimated using a linear model that predicts fish weight based on fish length, and are displayed as the average weight of a 165-mm (6.5 inch) alewife in the April and October surveys. Statistics for community diversity calculations were based on the most commonly captured pelagic species and those species identified FCOs (Table 2). The Shannon index was used to describe pelagic and demersal community diversity based on the overall trawl catch (Shannon and Weaver 1949).

In 2018, additional experimental trawling was conducted during the April survey to determine how embayment habitats differed from main lake habitats and understand how trawling effort influenced the chances of catching recently stocked bloater. Relative to the main lake, Lake Ontario embayments provide unique habitats and often contain different fish species, however these habitats have not historically been included in the April bottom trawl survey, except for sporadic sampling within Chaumont and Black River bays. For this study, trawls were conducted in the Bay of Quinte and northeastern embayments and catches were compared to trawls in habitat immediately adjacent to embayments and main lake trawl catches. Additional trawls were also collected near the bloater stocking site in U.S. waters (~100 m depth, near Oswego, NY) to determine if increased sampling effort was needed to capture bloater stocked the previous fall.

October survey

From 1978-2011, the October bottom trawl survey sampled six transects along the southern shore of Lake Ontario from Olcott to Oswego, NY, and targeted demersal prey fish. Daytime trawls were typically 10 minutes and sampled depths from 8–150 m (26-495 ft). The original survey gear was a Yankee bottom trawl using doors described above. Abundant dreissenid mussel catches led to the survey abandoning the standard trawl and experimenting with a variety of alternate polypropylene bottom trawls and metal trawl doors (2004-2010). Comparison towing indicated alternate trawls caught few demersal fishes and the alternative trawl doors influenced net morphometry (Weidel and Walsh 2013). Since 2011, the survey has used the historical-standard Yankee trawl and doors but has reduced tow times to reduce mussel catches. Experimental sampling at new transects and in deeper habitats began in 2012. More notably, in 2015, the survey spatial extent was doubled to include Canadian waters. At that time the NYSDEC and OMNRF research vessels joined the survey, which greatly expanded the spatial extent and diversity of habitats surveyed. Demersal prey fish time series are illustrated in this report from 1978 to present and no adjustments are available for data when the alternative trawls were used. Trawl catch processing is as described for the April survey. Trawl results are expressed as biomass (kilograms of fish per hectare) and account for depth-based differences in the lake area swept by the trawl (Weidel and Walsh 2013). Reporting in these units provides data in a more readily useable form to address ecosystem-scale management questions and facilitates comparisons across lakes. Time series are still regarded as biomass indices because we lack estimates of trawl catchability (proportion of the true density within a surveyed area captured by the trawl).

The total number of tows and spatial extent of the 2018 fall prey fish survey was reduced relative to the past three years. The USGS RV Kaho was delayed in starting the survey by approximately three weeks due to scheduling complications during routine maintenance. Additional weather-related delays reduced the transects sampled by the RV Kaho, especially in Canadian waters. In addition, scheduling conflicts and mechanical issues reduced the number of tows conducted by the OMNRF RV Ontario Explorer during the 2018 October survey.

Results and Discussion

Alewife – The adult alewife (Age-2 and older) abundance index (number per 10-minute tow) for U.S. waters decreased in 2018 (993) relative to 2017 (2,519) and was below the 10-year average (10-yr average =1,712; Figure 2). In contrast to the U.S. index, Figure 2 illustrates the adult alewife index for trawls in Canadian waters increased in 2018 (2,922) relative to 2017 (754). Figure 4 illustrates the spatial variability in alewife density. The U.S. and Canadian indices have trended in opposite directions in each of three years since the April survey was expanded into Canadian waters (Figure 2). Given the alternating trend in alewife distributions between the U.S. and Canadian waters, it is important to consider both when interpreting the Lake Ontario alewife population trends. The whole lake alewife density increased because the 2016 alewife year class was age-2 and counted towards the adult index, however the whole lake biomass declined (Table 3). Because density or number per 10-minute tow indices can not account for changes in alewife size we recommend using biomass indices to describe future changes in the Lake Ontario alewife population

In 2018, the adult alewife population was primarily Age-2, Age-3, and Age-6 fish (Figure 5) with relatively few fish from the 2013 and 2014 year-classes (Figure 5). As predicted, the large 2016 alewife year class (which was Age-2 in 2018 and counted towards the adult index) increased the overall adult alewife biomass, however at the time of sampling in April 2018, much of the adult population was in Canadian waters (Table 3; Figure 4). This apparent strong spatial variability in alewife habitat use in April further supports the need for whole-lake approaches to Lake Ontario fish sampling. The mechanisms contributing to the different spatial distribution across years are currently unknown.

The 2018, Age-1 alewife abundance index (number of fish per 10 minute trawl) for U.S. waters (102) was substantially smaller than 2017 (2945) which was among the highest values observed in U.S. waters since in 1997 (Figure 3). The 2018 U.S. waters Age-1 index value was the third lowest observed since 1997 with only 2015 (14) and 1997 (42) having lower values (Figure 3). The index value in Canadian waters was also lower in 2018 (911) relative to 2017 (1,012) but was higher than the U.S. index (Figure 3). The relatively cool 2017 spring and cold winter likely contributed to the lower than average 2017 year class since both spring and winter temperature has been shown to influence alewife reproduction success (O'Gorman et al. 2004; Madenjian et al. 2005). Adult alewife condition, assessed by the predicted weight of a 165 mm fish (6.5 inches) declined in April of 2018 relative to 2017, and followed a declining trend since 2016, however the October 2018 value indicated alewife condition increased during the 2018 year (Figure 6).

Other Pelagic Fishes – Bottom trawl abundance indices for other pelagic species noted in the FCOs (threespined stickleback, rainbow smelt, emerald shiner) either declined or remained at low levels in 2018 (Figure 7). Cisco catch per unit effort (CPUE) appeared to increase in 2018, however that value was driven predominantly by catches in experimental trawl sites within the Bay of Quinte that had not been sampled in previous years. Of the 21 cisco captured in the April survey, 20 were caught in the Bay of Quinte. If cisco predominantly inhabit embayments habitats in April, future survey efforts may consider additional sampling in these regions to better survey this native species. Alewife dominance relative to other pelagic fishes in Lake Ontario trawl catches is likely related to alewife predation on larval stages of other pelagic species (Crowder 1980; Brandt et al. 1987). The habitat distribution of pelagic larvae, such as rainbow smelt, overlaps with adult alewife during the summer (Simonin et al. 2016) and in the spring for species like yellow perch (Brandt et al. 1987).

Bloater – Bloater are a pelagic species native to Lake Ontario that historically inhabited deep, offshore habitats. While records are sparse, commercial fishery catches suggest the species was historically abundant in Lake Ontario, but by the 1970s, was rare (Christie 1973). Restoration in Lake Ontario began in 2012 by stocking bloater raised from eggs collected from Lake Michigan. From 2012 – 2017, two bloater were captured in the April bottom trawl survey, one in U.S. waters and one in Canadian waters (Table 4). In 2018, three bloater were captured in the April survey and two bloater were captured in the October survey (Table 4). Bloater stocked in U.S. waters are batch marked with calcein, a nonantibiotic compound that produces a visible mark on fish scales and bones (Chalupnicki et al. 2016). Initial examinations suggest that most of the bloater captured in U.S. waters (2015:1; 2018: 3 April survey) were raised at the USGS Tunison Laboratory (personal communication, Marc Chalupnicki, USGS, July 2018) and stocked near Oswego, NY. The three Bloater captured in the 2018 April survey were 4 - 6 g and of similar size to the 5 g fish stocked in the fall of 2017 (Connerton 2018). The calcein mark and size of these fish suggest they were from the 2017 stocking near Oswego, NY. This means these fish moved at least 114 and 203 kilometers (71 and 126 miles) from the stocking site in fall of 2017 to their capture locations in April 2018 (Table 4; Figure 8). In 2018 additional trawling effort was conducted near the stocking location off Oswego NY, but none of the 72 trawls captured bloater, suggesting stocked fish move from the stocking site (Figure 8). The bloater captured in the October 2018 survey was a female (gonad weight 1.49g). Interestingly, the capture location of this female fish was on the same transect and similar depth as the only bloater captured in historic surveys (Table 4). Multiple catches in this same region may identify an important lake habitat for this native species.

Given the relatively large number of bloaters captured in 2018 relative to previous years we wondered if it these catches were unusual given the size of Lake Ontario and the number of if fish stocked. We used our understanding of how many rainbow smelt and alewife we caught relative to their population estimates to better understand our bloater catches. Since 1997, bottom trawls in U.S. waters captured on average 0.016 % of the alewife and rainbow smelt estimated in the U.S. portion of the lake (Figure 9). If we conservatively assume 10% of bloater survived from the fall when they are stocked to the following spring, and 58% survive each year thereafter (Brown et al. 1985), we can estimate the number of bloater in U.S. waters in April (Table 5). Using the trawl catch proportion from alewife and rainbow smelt (mean = 0.016%) and the estimated number of bloater in the lake we can estimated expected bloater trawl catches. Our observed April trawl catches were similar to the predicted catch (Table 5). This suggests the current trawl surveys may be able to track restoration success at the current bloater stocking levels. This analysis is simple and requires a number of assumptions, but it serves as a starting point from which to improve our understanding of Lake Ontario bloater restoration and assessment.

Slimy Sculpin – Slimy sculpin abundance indices in 2018 were among the lowest observed for the entire time series (Figure 10). Once the dominant demersal prey fish in Lake Ontario, slimy sculpin declines in the 1990s were attributed to the collapse of their preferred prey, the amphipod *Diporeia* (Owens and Dittman 2003). The declines of slimy sculpin that occurred in the mid-2000s appear to be related to round goby. Since round goby numbers have increased, the proportion of juvenile slimy sculpin in the total catch of slimy sculpins dropped from ~10% to less than 0.5% (Weidel et al. 2018). These data suggest round goby are limiting slimy sculpin reproduction or possibly recruitment of juvenile slimy sculpin to adult stages.

Deepwater Sculpin - In 2018, deepwater sculpin were among the most abundant demersal prey fishes in Lake Ontario, however, their biomass estimates declined slightly from 2017 (Figure 10). Interestingly, 9 of the 37 (24%) trawls that captured deepwater sculpin in the October survey also contained dead deepwater sculpin. The 54 dead individuals ranged in length from 100 to 170 mm. Deepwater sculpin condition has been declining as their abundance has increased over time (Figure 11), suggesting that the deepwater sculpin population may be nearing its carrying capacity in Lake Ontario and we might expect density and biomass to stabilize or decline slightly.

Round Goby – Round goby density increased in 2018 relative to 2017 for both the U.S. abundance index and the whole lake index based on data from the October survey (Figure 10). Estimating round goby abundance using bottom trawls can be complicated by the fish's preference for rocky substrate and seasonal changes in depth distribution (Ray and Corkum 2001; Walsh et al. 2007). Round goby were captured during the April trawl survey as early as 2002, however that survey's trawl is likely less effective at capturing round goby since the foot rope is elevated off the lake bottom.

Prey fish diversity - Lake Ontario FCOs call for increased prey fish diversity (Stewart et al. 2017). Based on bottom trawl catches, the pelagic prey fish community diversity remains low because a single species, alewife, dominates the catch (Figure 12). Actions to improve pelagic community diversity are currently underway in Lake Ontario, including bloater restoration and cisco rehabilitation (Connerton 2018). Despite slimy sculpin declines, demersal prey fish community diversity has generally increased during recent decades. In the 1970s – 1990s, a single species, slimy sculpin, dominated the catch, resulting in lower diversity values. More recently, deepwater sculpin and round goby comprise similar proportions of the trawl catch, increasing diversity relative to when only slimy sculpin dominated the catches (Figure 12).

Embayment Catches – Trawl catches at embayment sites (Bay of Quinte, Chaumont Bay and Black River Bay) differed from trawl catches at similar depths in the main lake and at Eastern Basin sites immediately adjacent to the embayments (Figure 13, Table 6). Trawls in 2018 suggested embayment sites generally had more species, a higher proportion of native species, and higher fish densities relative to adjacent and similar main lake habitats (Figure 13). Historically, the April trawl survey focused solely on estimating alewife abundance; therefore, areas where alewife were rare or in low abundance, such as embayments, received little sampling effort. More recently, the April survey has provided more information on species other than alewife. For instance, cisco and lake whitefish are species mentioned in FCOs that may be more readily sampled with trawls in embayments as 100% of the cisco and 82% of the lake whitefish were caught in these habitats. The addition of embayment trawl sites in future surveys could more thoroughly address Lake Ontario FCOs by providing consistent sampling methods across different lake habitats.

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Table 1. Lake Ontario area in square kilometers within different depth strata in U.S. and Canadian (CA) waters. The proportional area columns illustrate how the area-weighting of stratified abundance mean indices changes as additional depths have been added to the survey over time.

Range (m)	Area U.S. (km^2)	Area CA (km^2)	Proportional Area U.S. 0-160m	Proportional Area U.S. 0-180m	Proportional Area U.S. 0-244m	Proportional Area CA 0-160m
0-20	1155	1749	0.19	0.15	0.12	0.18
20-40	905	1616	0.15	0.12	0.10	0.16
40-60	680	1248	0.11	0.09	0.08	0.13
60-80	514	1426	0.08	0.07	0.06	0.14
80-100	441	1198	0.07	0.06	0.05	0.12
100-120	527	1293	0.09	0.07	0.06	0.13
120-140	822	964	0.13	0.11	0.09	0.10
140-160	1112	353	0.18	0.14	0.12	0.04
160-180	1598	0		0.21	0.18	NA
180-200	737	0			0.09	NA
200-220	448	0			0.05	NA
220-240	79	0			0.01	NA
240-260	<1	0			>.01	NA

Table 2. Number of fish captured in all of Lake Ontario during the 2018 April and October prey fish bottom trawl surveys. Figures represent total numbers caught in each survey except for Dreissena sp. mussels, which represent a total weight in kilograms. The classification column denotes which species are used in pelagic and demersal prey fish community diversity calculations.

Species	April	October	total	percent	classification
Alewife	289706	16258	305964	80	pelagic
Round goby	5465	39603	45068	12	demersal
Deepwater sculpin	10245	5886	16131	4	demersal
Rainbow smelt	8418	1763	10181	3	pelagic
Yellow perch	1573	1107	2680	1	demersal
Trout-perch	1184	841	2025	1	demersal
White perch	319	279	598	< 1	pelagic
Slimy sculpin	238	352	590	< 1	demersal
Spottail shiner	262	201	463	< 1	demersal
Gizzard shad	0	308	308	< 1	
Lake trout	89	97	186	< 1	
White sucker	28	67	95	< 1	
Emerald shiner	79	8	87	< 1	pelagic
Brown bullhead	1	47	48	< 1	
White bass	5	35	40	< 1	
Threespine stickleback	26	2	28	< 1	pelagic
Walleye	25	2	27	< 1	
Cisco	21	1	22	< 1	pelagic
Logperch	0	20	20	< 1	demersal
Pumpkinseed	19	1	20	< 1	
Freshwater drum	4	15	19	< 1	
Lake whitefish	17	0	17	< 1	
Rockbass	12	1	13	< 1	
Johnny darter	0	8	8	< 1	demersal
Bloater	3	1	4	< 1	pelagic
Carp	0	3	3	< 1	
Chinook salmon	0	2	2	< 1	
American eel	1	0	1	< 1	
Bluntnose minnow	0	1	1	< 1	
Lake sturgeon	1	0	1	< 1	
Northern pike	1	0	1	< 1	
		total=	384651		
Dreissena mussel weight(kg)	79	3947	4026		

Table 3. Lake Ontario area-weighted stratified mean alewife density (numbers per hectare) and biomass (kilograms per hectare) based on the April bottom trawl survey (2016-2018). Whole lake figures are based on 52% of the lake area in Canada and 48% in U.S. waters.

Year	Density			Biomass		
	U.S. (n/ha)	Canada (n/ha)	Whole Lake (n/ha)	U.S. (kg/ha)	Canada (kg/ha)	Whole Lake (kg/ha)
2016	708	1649	1197	26	58	43
2017	2503	848	1642	75	27	50
2018	907	2929	1958	22	57	40

Table 4. Sampling and fish data for all bloater captured in Lake Ontario bottom trawls. The capture from Rocky Point in 2017 was from the OMNRF Community Index program (OMNRF 2018). Bloater can be difficult to distinguish from other coregonines such that additional meristic and genetic evaluations are ongoing to confirm the species identification.

Date	Transect	Fishing Depth (m)	Fishing Temp. (°C)	Length (mm)	Weight (g)	Distance from stock (km)
28-Apr-1983	Smoky Pt.	110	3.6	272	182	
8-May-2015	Oswego	95	3.5	125	10.2	3
5-Jul-2017	Rocky Point	90		130	14	39
22-Apr-2018	Youngstown	60	2.7	108	6	203
22-Apr-2018	Youngstown	75	2.7	102	4	203
25-Apr-2018	Hamlin	95	2.6	96	5	114
14-Oct-2018	30-Mile Pt	75	4.1	117		unknown
23-Oct-2018	Smoky Pt.	78	9.8	240	122	unknown

Table 5. Expected and observed number of bloater caught in U.S. waters of Lake Ontario during the April bottom trawl survey. Estimated abundance assumes bloater survival of 10% from when they are stocked in the fall to the following spring and 58% annual survival for all years after that (Brown et al. 1985). Expected catch is based on the mean percentage of alewife and rainbow smelt caught in trawls relative to their estimated abundance since 1997 in U.S. waters of Lake Ontario (Figure 9; 0.016 %).

Year Stocked (fall)	Number Stocked	Survey Year (spring)	Estimated Spring Abundance	Estimated Trawl Catch	Observed Trawl Catch
2012	1000	2013	100	0	0
2013	7000	2014	758	0.1	0
2014	20000	2015	2440	0.4	1
2015	62000	2016	7615	1.2	0
2016	149000	2017	19317	3.1	0
2017	94000	2018	20604	3.3	3

Table 6. Species captured in bottom trawls fished in specific embayment habitats, shallow main lake habitats (trawl depth < = 20m) and the deeper habitats within the Eastern Basin not within an embayment, in the 2018 Lake Ontario April prey fish survey.

Species	Bay of Quinte	Chaumont Bay & Black Riv. bay	Main lake <20m	Eastern Basin
Alewife	0	5	0	1
American Eel	1	0	0	0
Brown Bullhead	1	0	0	0
Cisco	20	1	0	0
Emerald Shiner	0	54	14	0
Freshwater Drum	4	0	0	0
Lake Trout	0	0	4	0
Lake Whitefish	14	0	0	1
Northern Pike	1	0	0	0
Pumpkinseed	18	1	0	0
Rainbow Smelt	65	126	102	345
Rockbass	12	0	0	0
Round Goby	3	1	9	6
Slimy Sculpin	0	0	1	0
Spottail Shiner	24	230	8	0
Threespine Stickleback	0	0	2	0
Trout-perch	210	974	0	0
Walleye	12	13	0	0
White Bass	1	4	0	0
White Perch	77	242	0	0
White Sucker	8	15	5	0
Yellow Perch	1440	103	2	0

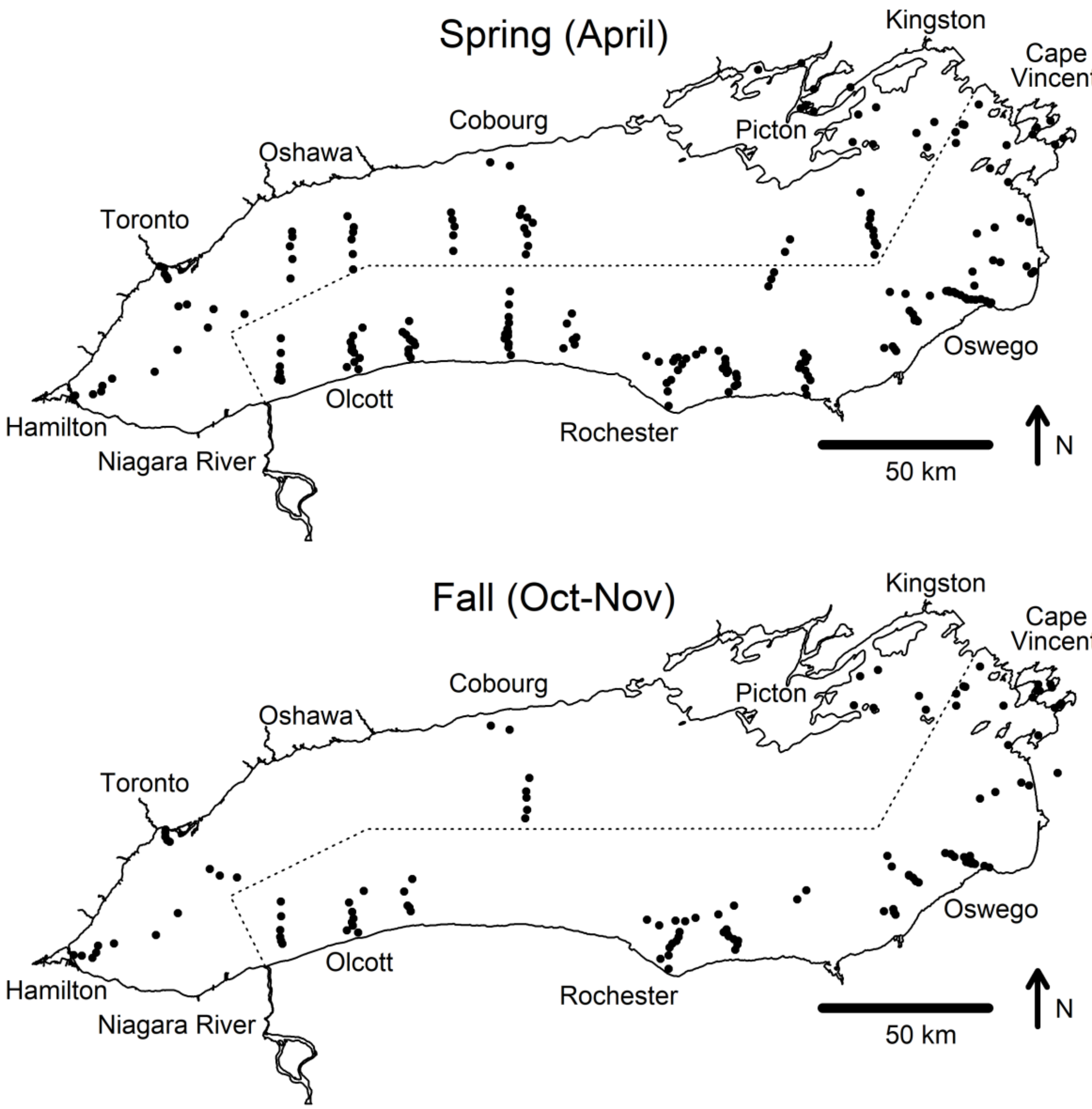

Figure 1. Lake Ontario bottom trawl sites from the 2018 April and October surveys. The April survey targets alewife and other pelagic prey fishes and the October survey targets demersal or benthic prey fishes. A total of 208 trawls were conducted in April and 118 trawls were conducted in the fall. Sample size and spatial sampling extent of the October survey were reduced due to mechanical, scheduling and weather complications.

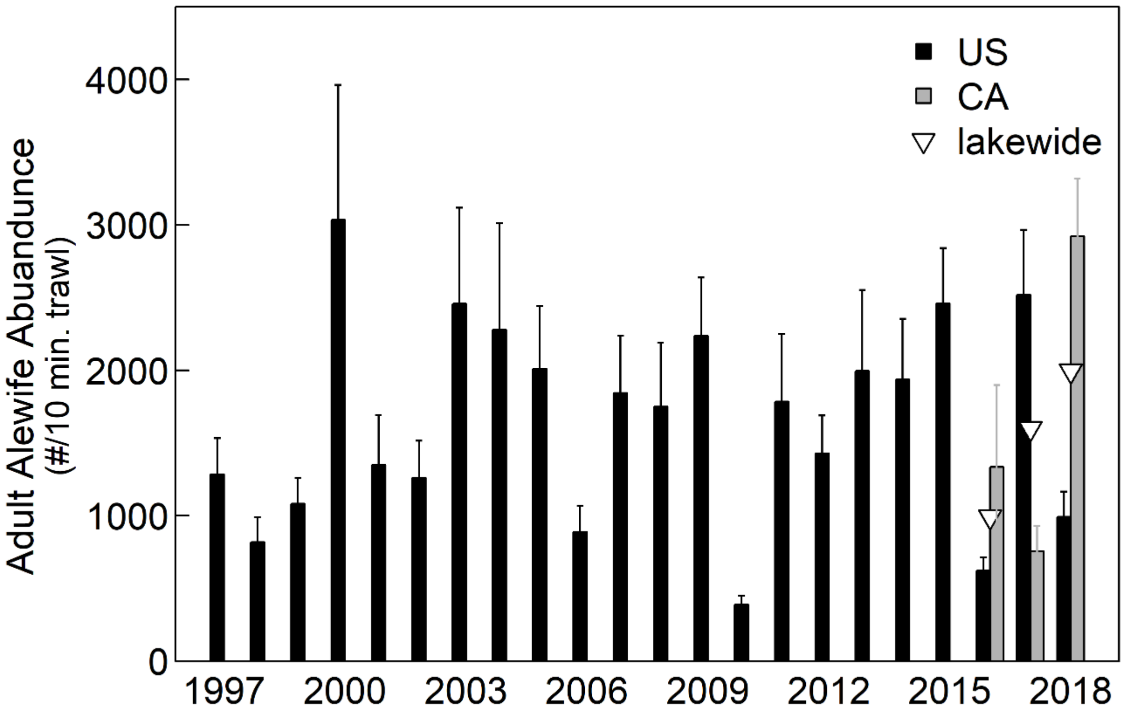

Figure 2. Lake Ontario April bottom trawl-based abundance indices for adult alewife. Values represent a stratified, area-weighted mean number of alewife in a 10-minute bottom trawl. Error bars represent one standard error of the mean. Trawling in Canadian waters began in 2016, but to maintain consistent comparisons through time, separate indices are illustrated for Canadian and U.S. waters. For reference the area of the lake in Canada is approximately 52% and in the U.S. is 48%. The values for 1997-2015 in this figure are slightly lower than reported in previous reports because those historic calculations did not include the portion of U.S. water greater than 180m in the area-stratified calculations. Alewife are rarely captured at depths greater than 180m and for those years when deep strata were not sampled we assumed alewife catch in those strata was zero. The above figure represents the index value calculated using a consistent lake area for all years (U.S. = 0-244m, Canada = 0-175m, Whole lake = 0-244m).

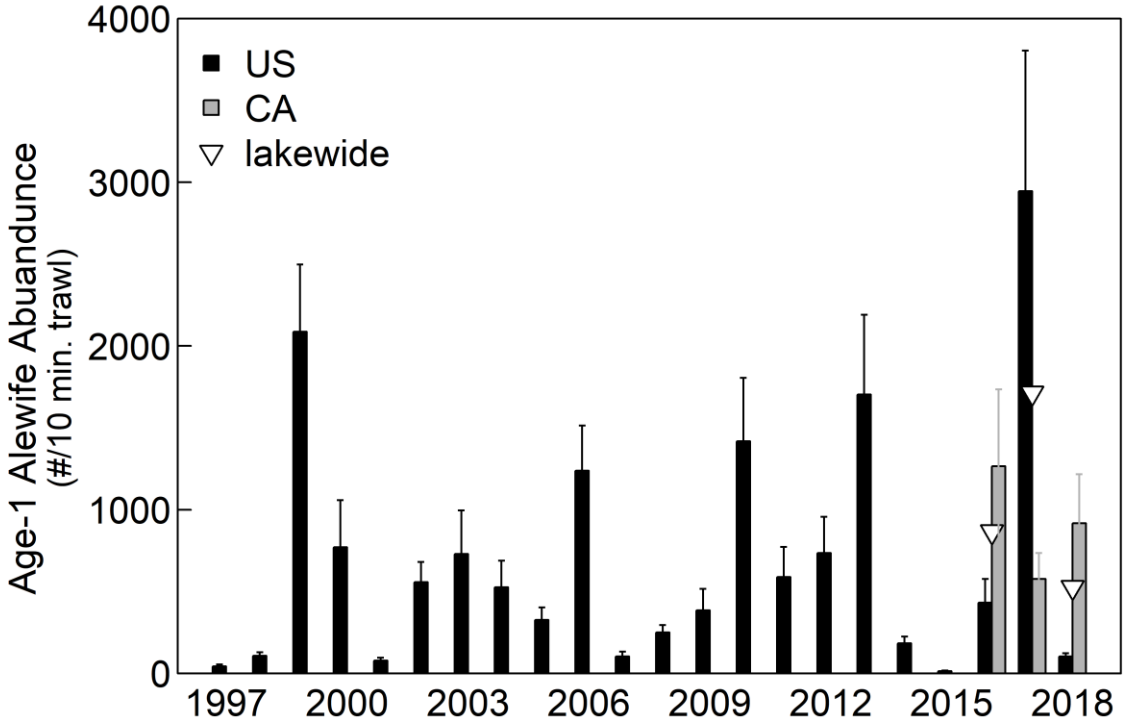

Figure 3. Lake Ontario April bottom trawl-based abundance indices for yearling or Age-1 alewife . Values represent a stratified, area-weighted mean number of alewife in a 10-minute bottom trawl. Error bars represent one standard error of the mean. Trawling in Canadian waters began in 2016, but to maintain consistent comparisons through time, separate indices are illustrated for Canadian and U.S. waters. For reference the area of the lake in Canada is approximately 52% and in the U.S. is 48%. The values for 1997-2015 in this figure are slightly lower than reported in previous reports because those historic calculations did not include the portion of U.S. water greater than 180m in the area-stratified calculations. Alewife are rarely captured at depths greater than 180m and for those years when deep strata were not sampled we assumed alewife catch in those strata was zero. The above figure represents the index value calculated using a consistent lake area for all years (U.S. = 0-244m, Canada = 0-175m, Whole lake = 0-244m).

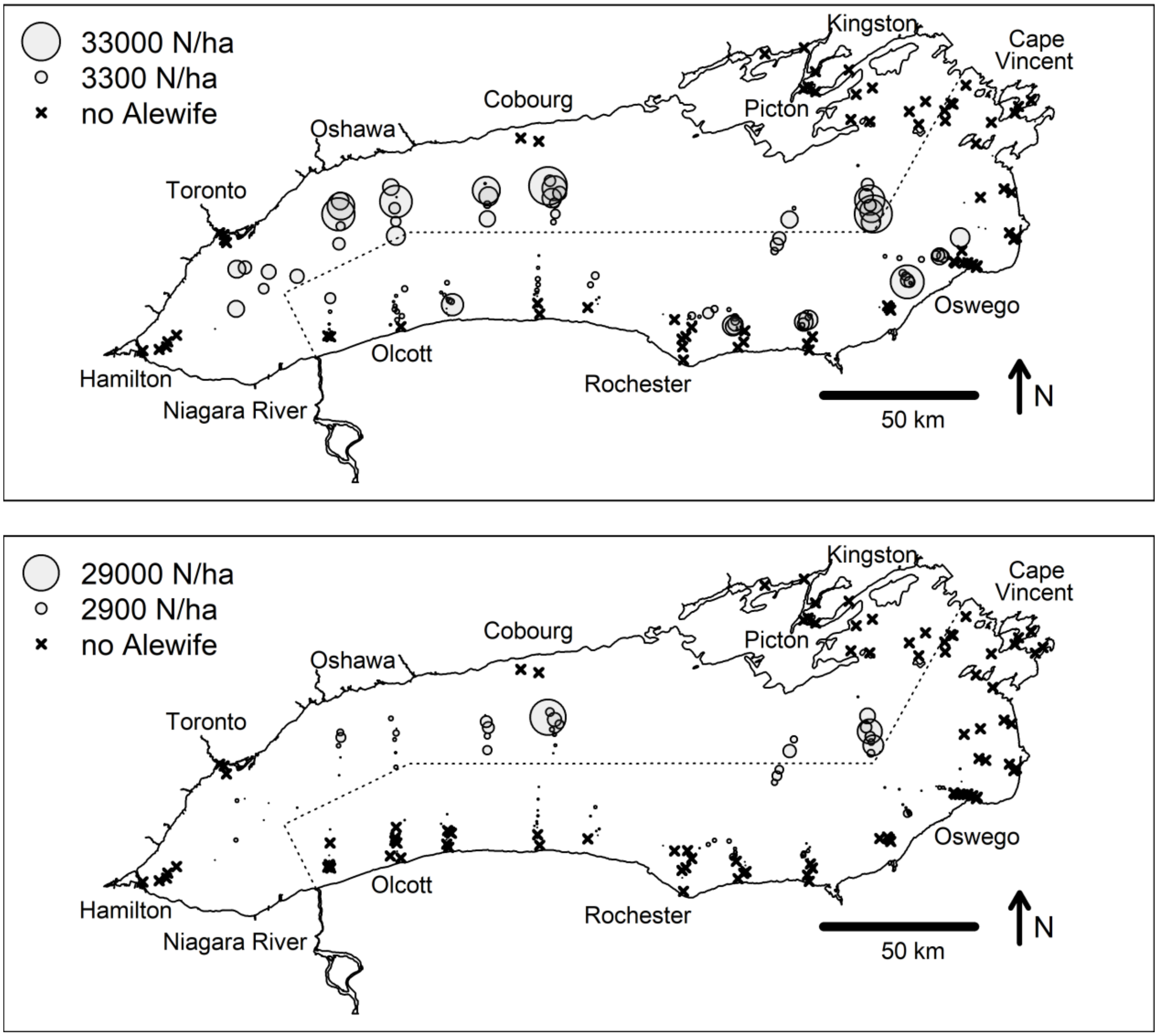

Figure 4. Density of adult (top panel) and Age-1 alewife (bottom panel) caught in the 2018 Lake Ontario April bottom trawl survey conducted collaboratively by USGS, NYSDEC, and OMNRF. The size of the gray circles represents the relative density in number per hectare of alewife captured while an "x" signifies a location where no alewife were captured.

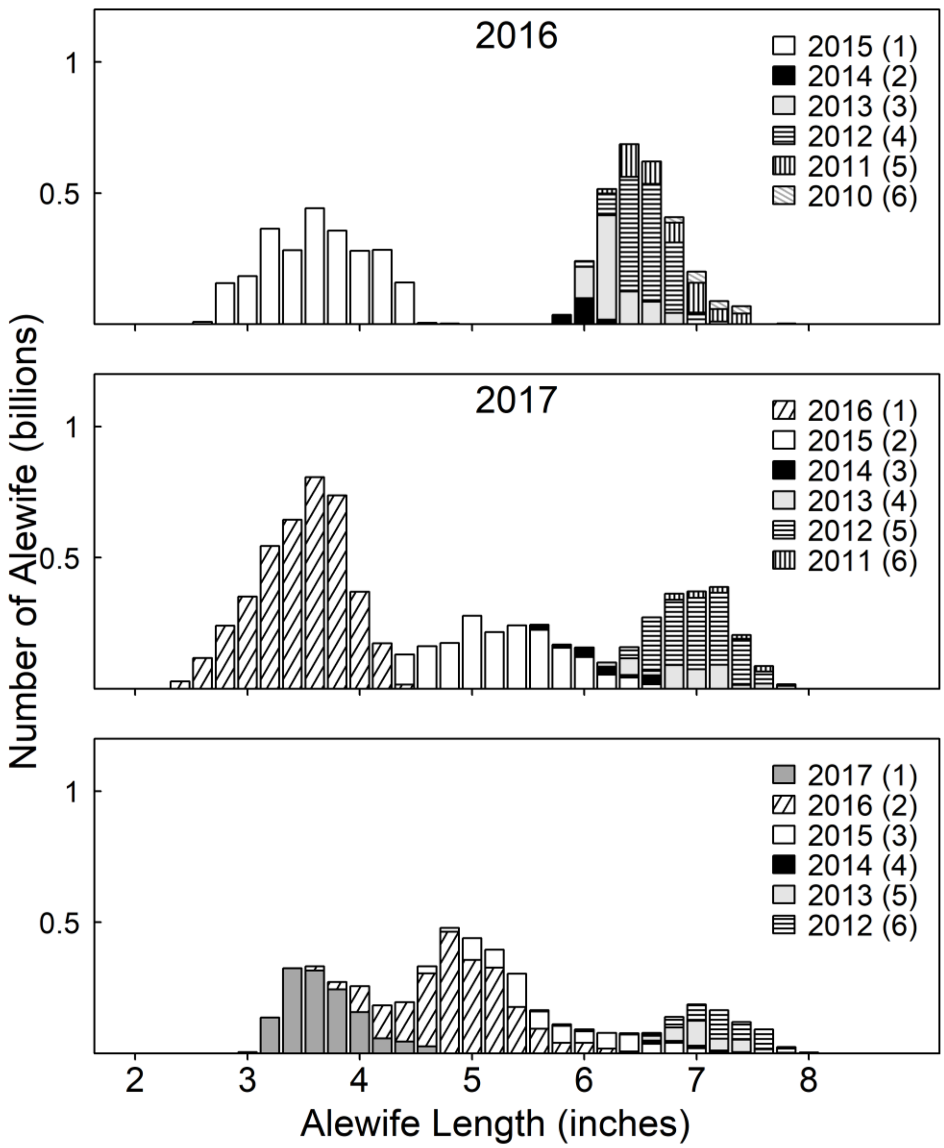

Figure 5. Alewife size and age distributions from April bottom trawl surveys conducted in Lake Ontario, 2016-2018. The height of each bar represents the number of alewife estimated in the lake within that size category (1/5 of inch). Each alewife year class (all the fish born in a given year) are represented by a consistent shading pattern across the different panels. All plots include the combined U.S. and Canadian observations. For instance, the relatively large 2012 alewife year class is illustrated by boxess filled with horizontal lines, whereas the relatively small 2014 year class is illustrated with black filled boxes.

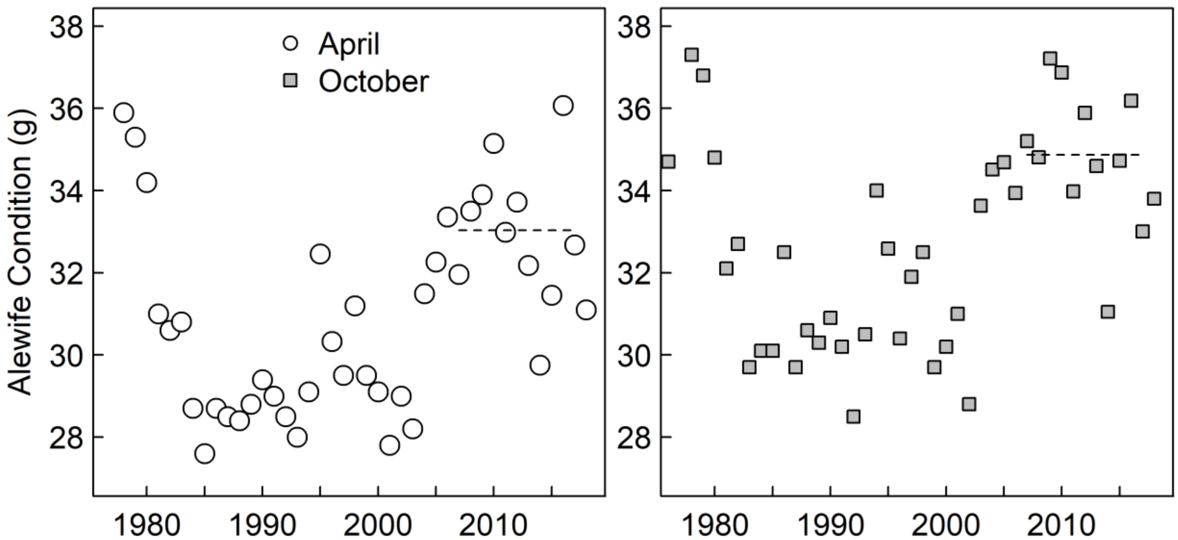

Figure 6. Lake Ontario alewife condition (fatness) represented as the predicted weight of a 165mm (6.5 inch) fish from the April (left panel) and October (right panel) bottom trawl surveys. Dashed lines represent the mean condition over the previous 10 years. Data from 1978-2015 represent trawls in U.S. waters while data from 2016-2019 also include observations from Canadian waters.

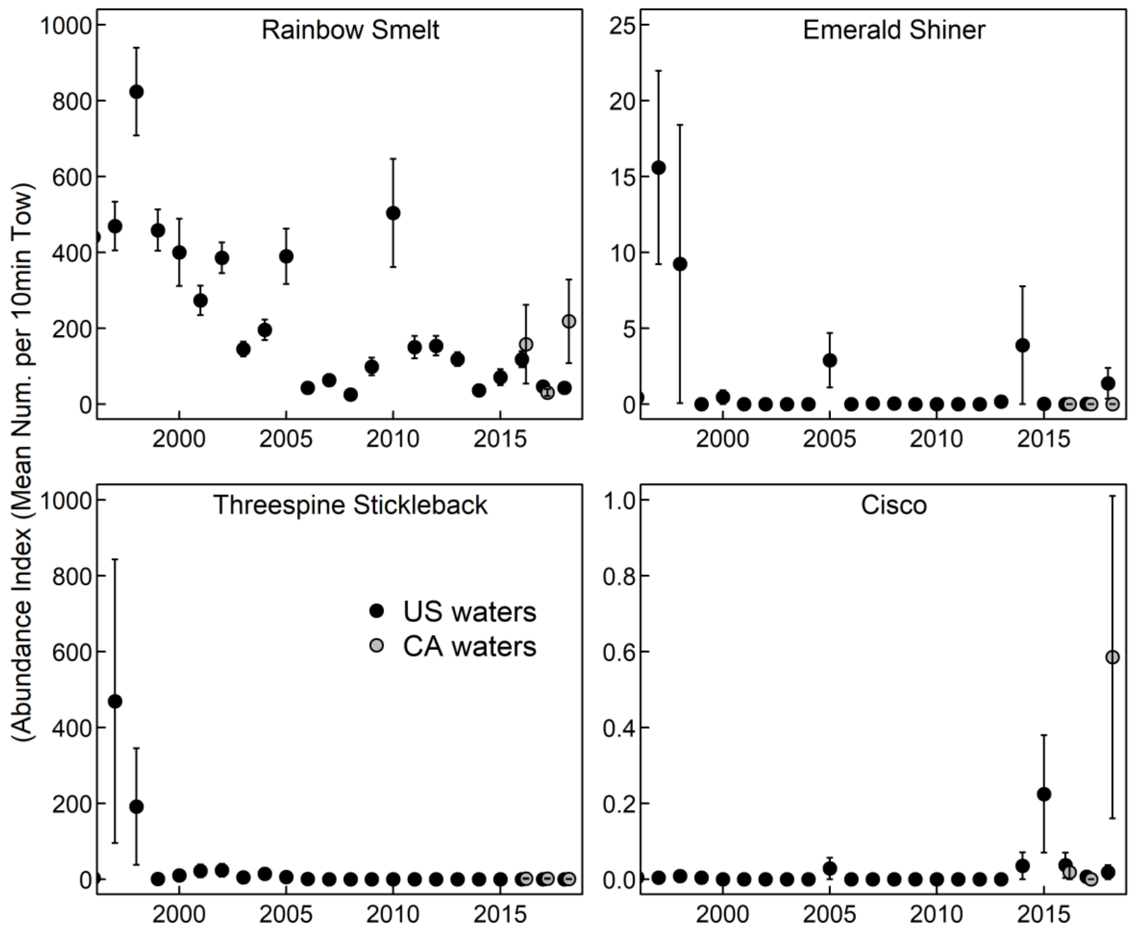

Figure 7. Abundance indices for other Lake Ontario pelagic prey fishes based on bottom trawls in U.S. and Canadian waters, 1997-2018. Error bars represent one standard error of the area-weighted stratified mean. The elevated point for 2018 cisco in Canadian waters was due to the addition of Bay of Quinte trawl sites that were not sampled in other years and where 20 of the 21 total cisco captured during the survey were caught.

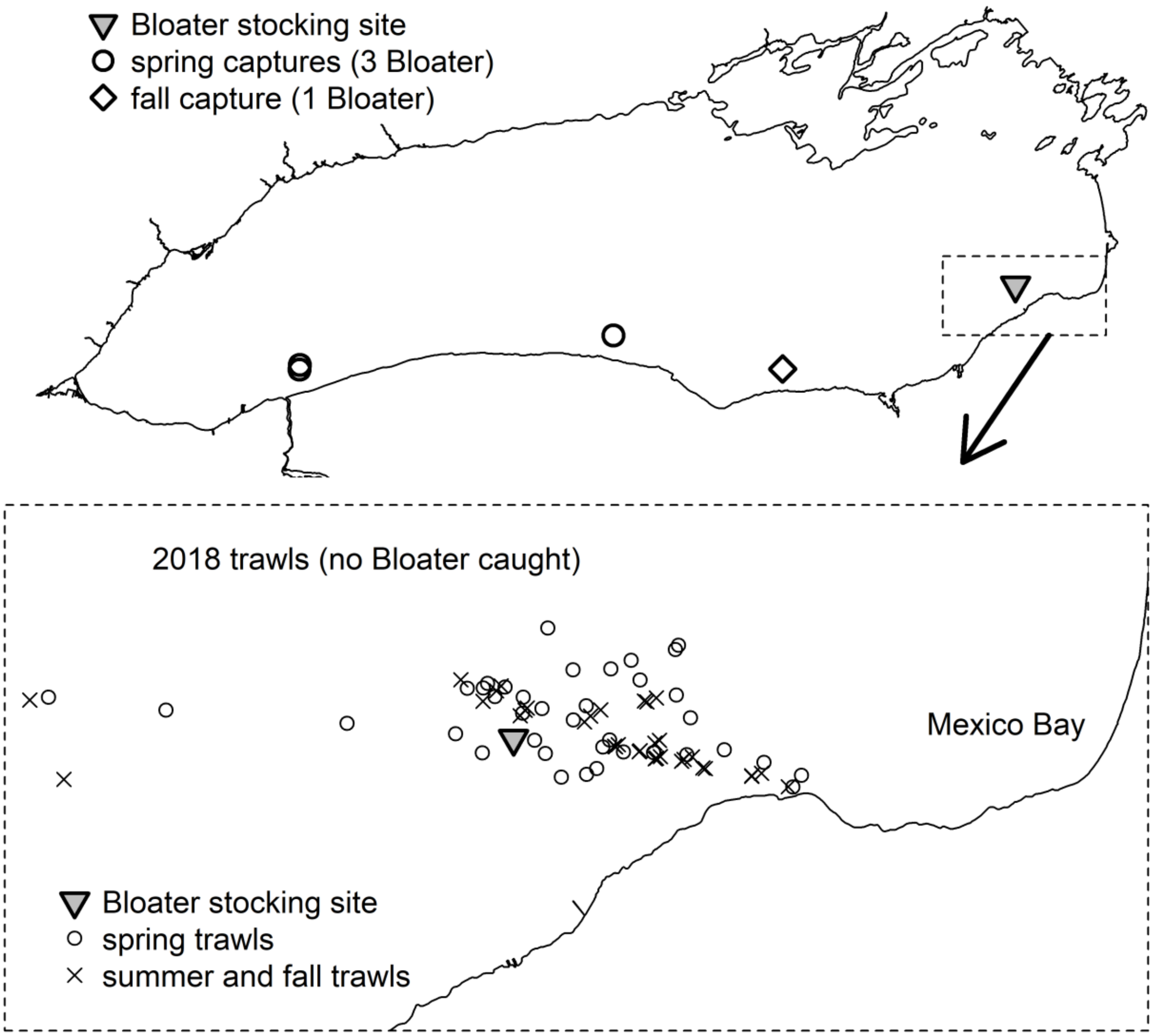

Figure 8. Top panel: bloater stocking location in the U.S. waters and the locations where bloater were captured in April and October bottom trawl surveys. Bottom panel: Additional bottom trawls were conducted near the stocking site but failed to capture any bloater.

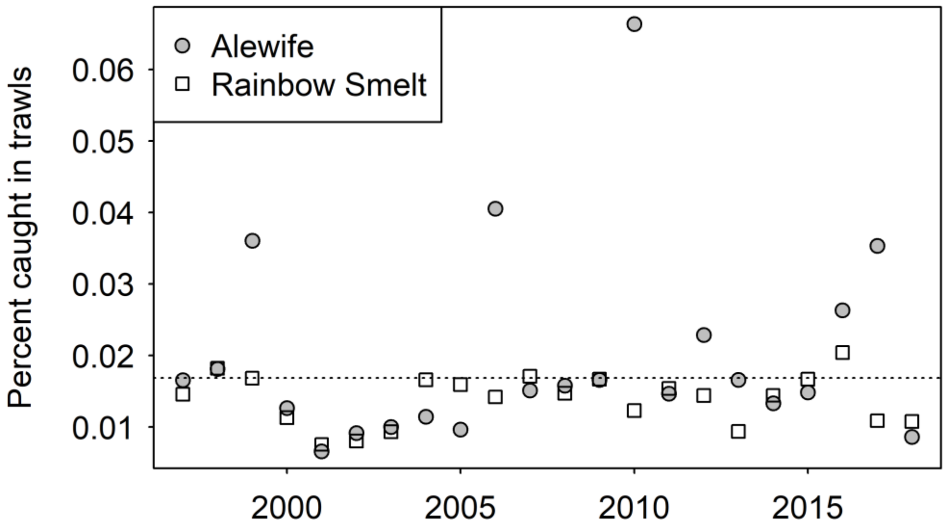

Figure 9. Percent of alewife and rainbow smelt captured in April bottom trawls in U.S. waters each year since 1997. Estimates are based on the total number of that species captured in trawls divided by the total number of that species estimated for all U.S. waters. The dashed line represents the average value of all estimates (0.016%).

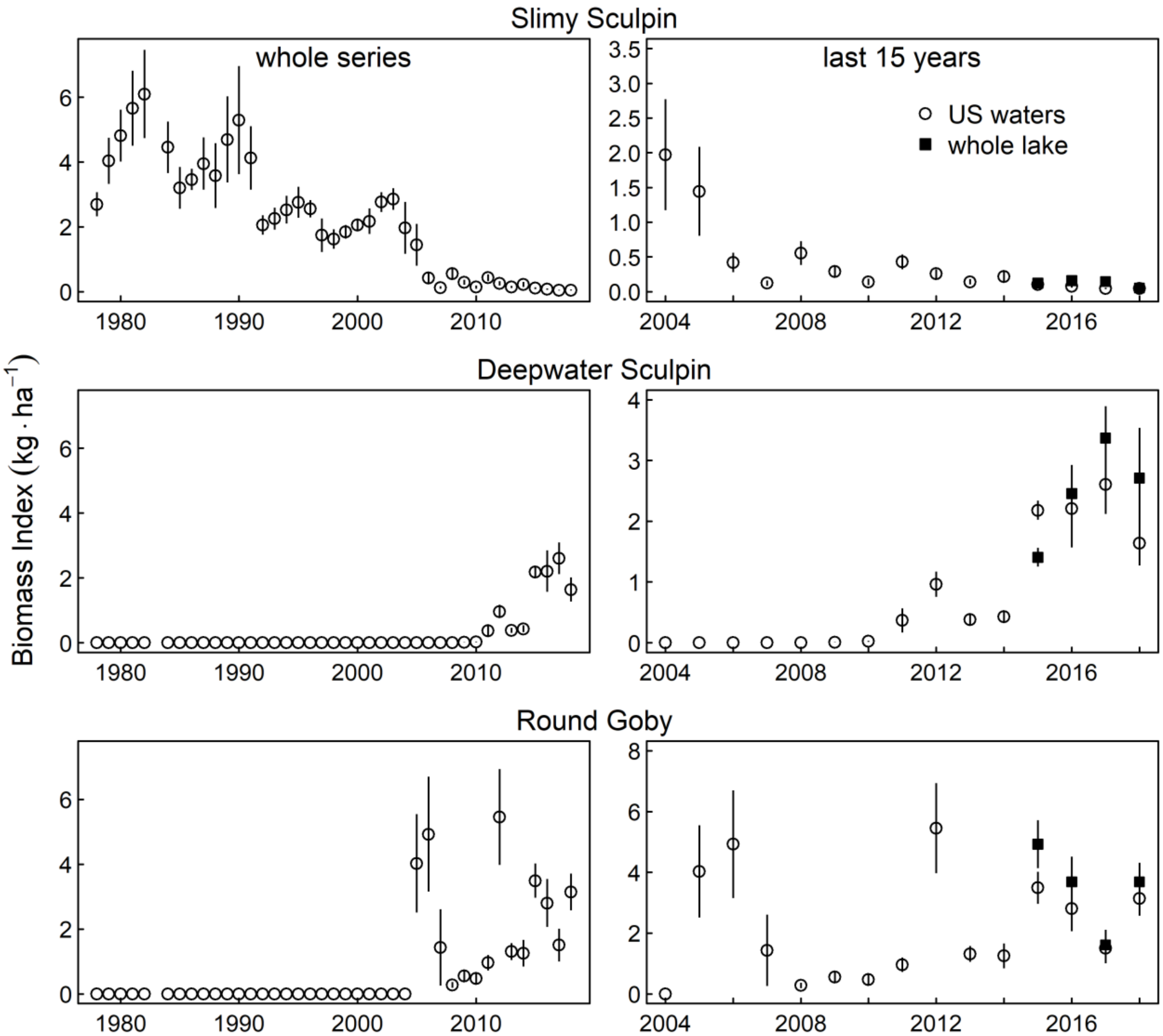

Figure 10. Lake Ontario biomass indices for demersal (bottom-oriented) prey fishes from 1978-2018 (left panels) and 2004-2018 (right panels). Note the different scales in the left and right panels. The survey is conducted in late-September and October. Error bars represent one standard error of the area-weighted stratified mean. Sampling in Canadian waters began in 2015 and values from the whole lake are shown in the right panels as filled squares. Separate means are calculated separately for tows in U.S. waters to maintain comparability across the U.S. time series.

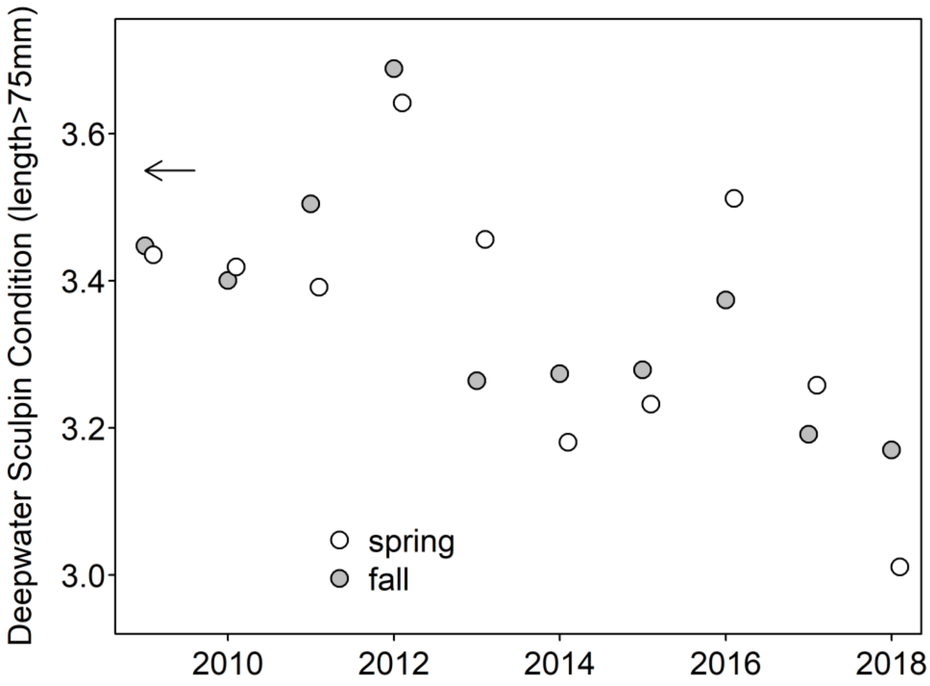

Figure 11. Deepwater sculpin 'condition' as measured by the slope of the relationship between log total length (mm) and log weight (g). When fish are heavier at a given length the y-axis value is higher, when fish are lighter at a given length the value is lower. For reference the arrow represents a value from Lake Superior deepwater sculpin from 1970 (Selgeby 1988).

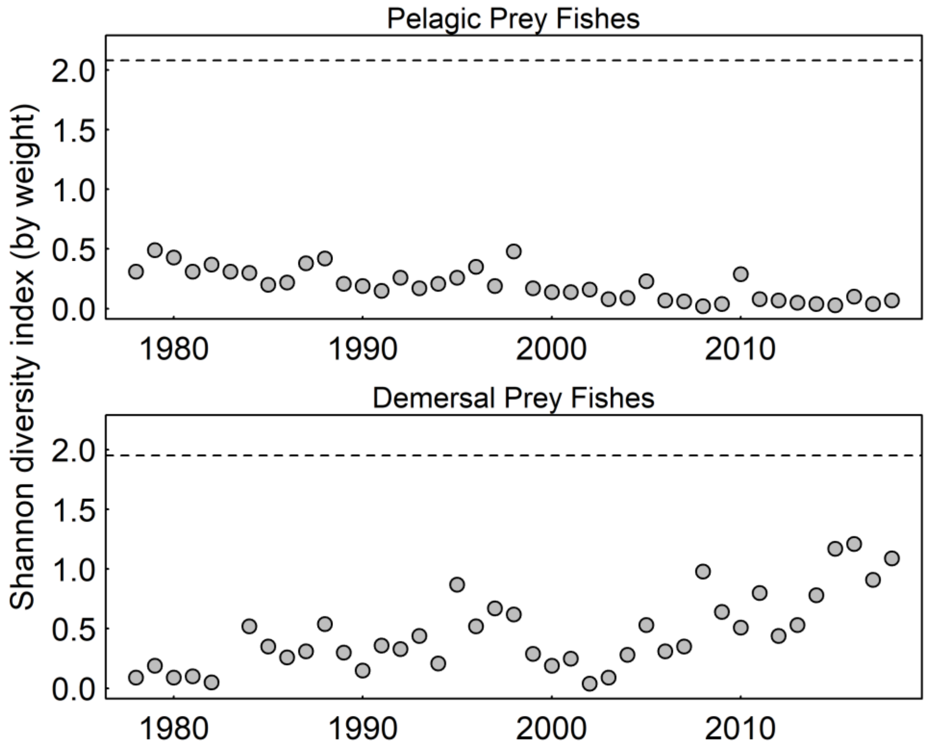

Figure 12. Lake Ontario prey fish diversity indices for pelagic and demersal prey fish communities based on bottom trawl catch weights 1978-2018. Species used for calculations are identified in Table 2. Diversity is represented with the Shannon index (Shannon and Weaver 1949) using commonly encountered species in the April (pelagic) and October (demersal) surveys. The dashed lines represent the maximum diversity index value if all species considered made up equal proportions of the catch by weight. Lake Ontario Fish Community Objectives include improving pelagic and demersal prey fish diversity (Stewart et al. 2017).

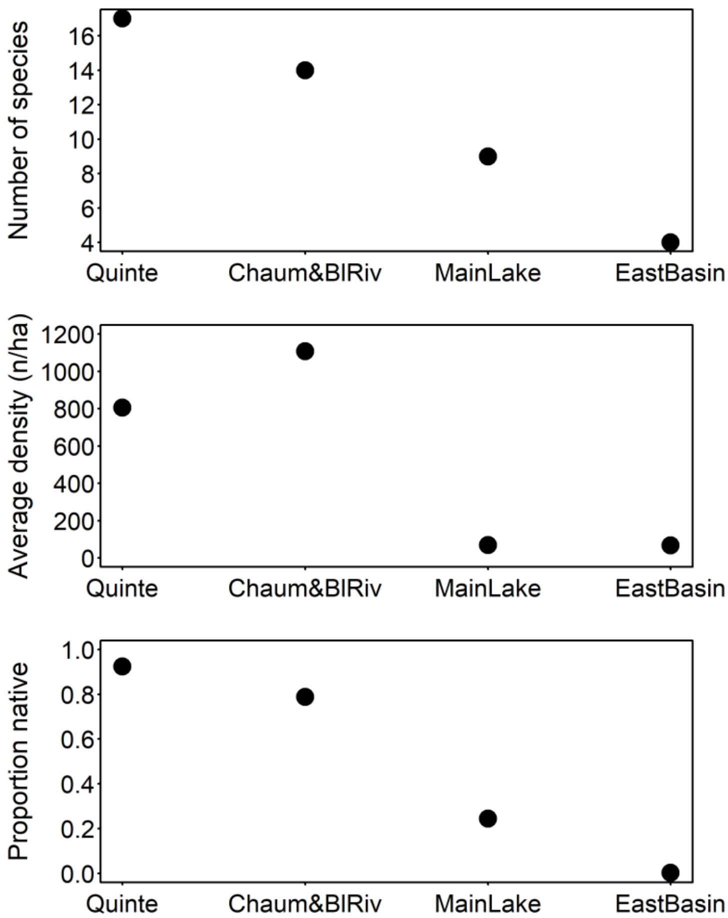

Figure 13. Lake Ontario April prey fish trawl catches differed among embayment (Quinte, Chaumont and Black River bays), shallow Main Lake (< 20m) and deeper East Basin (20 - 55m) habitats.