Bottom trawl assessment of Lake Ontario's benthic preyfish community, 2023

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Abstract
Since 1978, bottom trawl surveys in Lake Ontario have provided information on the status and trends of the benthic preyfish community related to Fish Community Objectives that includes understanding preyfish population dynamics and community diversity. Beginning in 2015, the benthic preyfish survey expanded from only U.S.-based sites to incorporate Canadian sites, increasing the survey's spatial coverage to a lake-wide scale. Additionally, sampling in eastern U.S. embayments (Black River, Chaumont, Guffin, and Henderson Bays), that were historically sampled during a September bottom trawl survey to index yellow perch (*Perca flavescens*; 1978–2007), resumed in 2015. The current survey provides abundance indices for sculpins, round goby (*Neogobius melanostomus*) and bloater (*Coregonus hoyi*) using techniques, gear and timing comparable to surveys on Lake Michigan. This alignment provides a necessary biological reference point for measuring the success of Lake Ontario Bloater reintroduction. In 2023, the collaborative benthic preyfish survey completed 188 bottom trawl sites across main lake and embayment sites at depths from 6 to 249 m. In total, the 2023 survey sampled 85,801 fish from 38 species. Round goby was the most common species comprising 43% of the total catch, followed by deepwater sculpin (*Myoxocephalus thompsonii*) and alewife (*Alosa pseudoharengus*) at 22% and 13%, respectively. Slimy sculpin (*Cottus cognatus*) lake-wide biomass density (0.06 kg/ha) remained low relative to historical observations from U.S. waters during the 1980-1990s and was orders of magnitude lower than in Canadian waters. Lake-wide deepwater sculpin biomass density remains high since the population recovery (4.1 kg/ha). Embayment catches continue to have unique species assemblages compared to main lake habitat. Historically common native benthic preyfish species like trout-perch (*Percopsis omiscomaycus*), spottail shiner (*Notropis hudsonius*), and darters (*Etheostoma* spp.), still occur in some embayment trawl sites, however these species are now rare at trawl sites throughout the main lake.

Introduction
Lake Ontario Fish Community Objectives (herein FCOs) established by the Great Lakes Fishery Commission's Lake Ontario Committee call for maintaining predator-prey balance and for maintaining and restoring pelagic and benthic (bottom–oriented, demersal) preyfish diversity (Stewart et al., 2017). Collaborative bottom trawl surveys conducted by the U.S. Geological Survey (USGS), the New York State Department of Environmental Conservation (NYSDEC), and the Ontario Ministry of Natural Resources and Forestry (OMNRF) have annually assessed Lake Ontario preyfish community status and trends since 1978 to provide information for decision-making relative to those objectives.

During 1978–1980s, Lake Ontario's benthic preyfish community was dominated by slimy sculpin (*Cottus cognatus*), with fewer trout-perch (*Percopsis omiscomaycus*), johnny darter (*Etheostoma nigrum*), and spottail shiner (*Notropis hudsonius*). Recent bottom trawl surveys have documented a decline in slimy sculpin abundance and an increase in non-native round goby (*Neogobius melanostomus*) beginning in 2005, as well as a resurgence in native deepwater sculpin (*Myoxocephalus thompsonii*), once considered extirpated (O'Malley et al. 2021; Weidel et al. 2017). These considerable changes in benthic preyfish composition exemplify the importance of monitoring populations and improving survey design to provide the best information possible to track population changes through time. Moreover, Lake Ontario preyfish surveys have routinely sampled the same lake areas across different seasons from April to October over multiple years, which allows for quantifying seasonal migrations of fish populations to better understand ecosystem structure and function and how habitats are coupled by different species (Ives et al. 2019; Pennuto et al. 2021).

Bottom trawl surveys also measure the progress of native species restoration. In Lake Ontario, bloater (*Coregonus hoyi*), a native coregonine that inhabits deep, offshore habitats, was considered extirpated from the lake by the 1980s (Weidel et al. 2022). Since 2012, bloater have been reintroduced through stocking, and bottom trawl recaptures allow for tracking the progress of the restoration program (Holey et al. 2021; Weidel et al. 2022). In 2015, bloater were caught in Lake Ontario bottom trawl surveys for the first time since their last capture in 1983 (Weidel et al. 2022). Additionally, using similar gear types and trawling at similar times of year to other surveys conducted throughout the Laurentian Great Lakes has allowed managers to interpret Lake Ontario preyfish dynamics at a basin-wide scale, as well as across different habitats (e.g., main lake vs. embayments) and depth strata. This provides a relevant biological reference point to evaluate progress toward restoration within a contemporary Lake Ontario ecosystem.

This report describes the status and long term trends of the Lake Ontario benthic preyfish community, with an emphasis on information addressing the binational (OMNRF and NYSDEC) FCOs (Stewart et al. 2017). This research is also guided by USGS Ecosystems Mission Area science strategy that seeks to understand how ecosystems function and provide services, as well as what drives them, and to develop science and tools that inform decision making related to ecosystem management, conservation and restoration (Williams et al. 2013). Here, we summarize recent findings from the fall (September-October) 2023 Lake Ontario benthic preyfish survey, in context with long term trends 1978-2023. In addition to presenting long term results from the benthic preyfish survey, we also leverage bottom trawl data from a survey that sampled northeastern Lake Ontario embayments from 1978 to 2007 to describe community changes in these habitats that were added to the benthic preyfish survey in 2015.

Methods

Benthic preyfish survey

From 1978 to 2011, the benthic preyfish survey sampled six to ten transects along the southern shore of Lake Ontario from Olcott to Oswego, NY. 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 with an 11.8-m (39 ft) headrope and was spread with flat, rectangular, wooden trawl doors (2.1 m x 1 m). The survey typically occurred during October but also included sampling from September to November (Figure 1). Abundant dreissenid (*Dreissena* spp.) mussel catches in the early 2000s 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 that alternate trawls caught fewer demersal fishes and the alternative trawl doors influenced net morphometry (Weidel and Walsh, 2013). Since 2011, the survey has used the historically standard Yankee trawl and doors, but has reduced tow times to reduce mussel catches. Typical trawl tows in recent years have been 5 minutes, and in nearshore areas or those where mussel catches are high as indicated by the preceding trawl site, tow times have been reduced to 2.5-4 minutes. Experimental sampling at new transects and in deeper habitats began in 2012. More notably, in 2015, the spatial extent of the survey was doubled to include Canadian waters and embayment sites in the eastern basin. At that time, the NYSDEC and OMNRF research vessels joined the survey, which greatly expanded the spatial extent and diversity of habitats assessed. We used results from the benthic preyfish survey from 1978 to develop time series plots for trend inference. No adjustments are available for data when the alternative trawls were used.

In 2023, the benthic preyfish survey consisted of 188 trawl sites completed between three research vessels from September 18 to October 20 (Figure 2). Trawl catches were sorted by species, counted, and weighed. Subsamples of species in each trawl catch were measured for individual length and weight. Additional samples for growth, diet, reproduction, and genetic analysis were collected for some species. Dreissenid mussels were weighed but not counted or identified to species.

Trawl effort was historically based on tow time, and abundance indices were reported as number or weight per 10-minute trawl. Area-swept estimates calculated using trawl mensuration sensors and video cameras indicated that trawl effort expressed as area swept differed substantially from tow-time based effort. Trawl results are expressed as biomass densities (kg/ha, kilograms of fish per hectare) and account for depth-based differences in the lake area swept by the trawl (Weidel and Walsh, 2013). Time series are still regarded as biomass indices, rather than absolute densities, because we lack estimates of trawl catchability (proportion of the true density within a surveyed area captured by the trawl). Trawl sites were assigned to a country based on the mid-point of start-end trawl coordinates. Historical trawl sites without coordinates were assigned to a country based on the nearest port (only U.S. waters). Annual area-weighted biomass indices expressed as kg/ha were calculated for U.S waters (1978–2022) and lake-wide (2015–2023) using thirteen 20 m strata (66 ft) within U.S. and Canadian waters (O'Malley et al. 2021). The lake-wide index was calculated assuming 52% and 48% area for Canadian and US waters, respectively. Mean and standard error calculations are from Cochrane (1977).

Perch Survey

From 1978 to 2007, fish communities in northeastern embayments of Lake Ontario (Chaumont, Guffin, Black River, and Henderson Bays) were sampled during late September through early October (Figure 1) to assess yellow perch (*Perca flavescens*) and white perch (*Morone americana*) populations and document long term trends in the fish community of these habitats (O'Gorman and Burnett, 2001). We refer to this dataset as the perch survey for convenience. In our analysis, we pooled observations from Guffin and Chaumont Bays, and simply refer to these as Chaumont Bay given their proximity to each other in Lake Ontario. Catch protocols were similar to those described above where species were sorted, counted, weighed, and subsamples were measured for length frequency. From 1978 to 1997, sampling was conducted by the USGS R/V Kaho with a 7.9-m headrope bottom trawl, with a 13-mm stretch nylon mesh cod end. Trawling occurred during the day and typically lasted for 5 minutes at each location. Site depths were between 6 to 20 m, and approximately 15 sites were sampled each year. In 1996, problems with fouling from large catches of dreissenid mussels led to the adoption of mud rollers in 1997 to reduce fouling. From 1998-2007, the NYSDEC R/V Seth Green continued the sampling using an 18-m, 3N1 bottom trawl at the same locations. For detailed descriptions of trawl gear used in Lake Ontario surveys, see Lantry et al. (2007). In 2015, the R/V Seth Green resumed sampling these sites annually in early October as part of the benthic preyfish survey using a Yankee bottom trawl. The recent expansion of our annual benthic preyfish survey into these historically sampled habitats has created an opportunity to assess long term trends for benthic preyfish communities from these embayments.

In addition to the benthic preyfish survey data, we used data from the perch survey to illustrate long term trends in the benthic fish populations of embayments by combining both datasets. In contrast to lake-wide trends which use an area weighted mean, we report mean biomass density for yellow and white perch for the embayments (1978–2023) without weighting by depth strata. We calculated the biomass proportion of benthic preyfish species for each year using the total weight across all trawl sites per embayment. Additionally, we compared 2023 catches among the eastern embayments to trawl sites that were added to the benthic preyfish survey in 2021 at Little Sodus and Sodus Bays. Bay of Quinte was added to the survey in 2021 (using a different trawl type (3N1) to avoid fouling from sediments, O'Malley et al. 2021), however, Upper Bay sites that are most comparable to other perch survey sites, were not sampled in 2022-2023. These additional embayment sites have generally been sampled in the spring preyfish bottom trawl survey that uses a 3N1 trawl (Weidel et al. 2023).

Results and Discussion

The 2023 benthic preyfish survey conducted 188 trawls in main lake and embayment sites (Figure 2), at depths from 6 to 249 m. The survey captured 85,801 fish from 38 species with a total weight of 1,477 kg, and 4,860 kg of dreissenid mussels (Table 1). Numerically, round goby was the most common species comprising 43% of the total catch, followed by deepwater sculpin (*Myoxocephalus thompsonii*) and alewife (*Alosa pseudoharengus*) at 22% and 13%, respectively.

Bloater – Bloater are a benthopelagic species native to Lake Ontario that historically inhabited deep, offshore habitats. While records are sparse, commercial fishery catches suggest bloater were historically abundant in Lake Ontario but rare by the 1970s (Christie, 1973). Catches have been sporadically low since restoration stocking began in 2012 but are reasonable based on our power to detect species at low abundance (Weidel et al., 2022). In 2023, two coregonines from the benthic preyfish survey were identified using molecular techniques at the USGS Great Lakes Science Center in Ann Arbor, MI. Preliminary results identified one as a cisco (*Coregonus artedi*) and the other as a putative hybrid (*C. artedi* x *C. hoyi*; A.S. Ackiss, unpublished data, USGS Great Lakes Science Center, March 2024).

Slimy Sculpin – Slimy sculpin biomass density (lake-wide = 0.06 kg/ha) in 2023 continued to be lower than when lake-wide sampling began in 2015 (0.15 kg/ha). Slimy sculpin biomass density in U.S. waters in 2023 (0.0007 kg/ha) was orders of magnitude lower than in Canadian waters (0.12 kg/ha), and both were considerably lower compared to observations in the early part of the time series (Figure 4). Once the dominant demersal preyfish 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 further declines of slimy sculpin that occurred in the mid-2000s appear to be related to negative interactions associated with round goby expansion. Recent increases in deepwater sculpin may also have negative impacts on slimy sculpin at the deep edge of their depth distribution where the two species overlap (Volkel et al. 2021). Slimy sculpin distribution appears to vary spatially across suitable Lake Ontario depth strata. Trawl sites in Canadian waters, notably at sites south of Pickering and Oshawa, had the highest biomass density among all trawl catches (Figure 5).

Deepwater Sculpin **–** Deepwater sculpin were the second most abundant fish in trawl catches during the benthic preyfish survey in 2023 (Table 1). Deepwater sculpin biomass has generally increased since 2010. In 2023, lake-wide deepwater sculpin biomass density (4.1 kg/ha) remained high relative to early points of their population recovery, and biomass density in Canadian waters (3.8 kg/ha) was similar that observed in US waters (4.4 kg/ha; Figure 4). In contrast to spatial patterns of slimy sculpin occurrence, deepwater sculpin were present at each of the trawl transects in the main lake where suitable depths (>50m) were sampled (Figure 5).

Round Goby **–** Round goby was the most abundant fish in trawl catches during the 2023 survey (Table 1). Round goby biomass density in 2023 (1.6 kg/ha) was similar to the lake-wide average during 2018-2022 (2.4 kg/ha, Figure 4). 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; Pennuto et al., 2021). Round goby are typically concentrated at shallower depths during the survey (Figure 5).

Embayment Catches **–** Trawl catches at embayment sites sampled in 2023 (Chaumont Bay, Black River Bay, Henderson Bay, Sodus and Little Sodus Bays) continued to represent species that are not common in main lake catches. Since 2015, these habitats, especially Black River Bay, are the only sites where trawls routinely capture trout-perch, darters, and spottail shiner, native species that were once common in main lake portion of Lake Ontario in the 1970–1990s (Figure 6, Figure 7). Yellow perch accounted for most of the benthic preyfish biomass across the embayments surveyed in 2023 (Figure 8), except for in Black

River Bay where white perch constituted a greater proportion of the catch. Time series constructed from combining the perch survey and benthic preyfish survey indicate increases in white perch biomass density in Black River Bay (Figure 8).

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Data Release
The data associated with this report are currently under review and will be publicly available in 2024. Previous versions of the data may be accessed at U.S. Geological Survey, Great Lakes Science Center, 2019, Great Lakes Research Vessel Operations 1958-2018. (ver. 3.0, April 2019): U.S. Geological Survey data release, https://doi.org/10.5066/F75M63X0. Please direct questions to our Data Management Librarian, Sofia Dabrowski, at sdabrowski@usgs.gov.

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Table 1. Number and weight (kilograms) of fish caught in the 2023 benthic preyfish survey. Dreissenid (*Dreissena* spp.) mussel catch is weighed but individuals are not counted. Lake sturgeon were released; only 2 out of 3 where weighed, therefore an accurate total weight cannot be given. Values include all Lake Ontario trawl sites sampled, including Canadian waters.

Common name	Scientific name	Number caught	Weight caught (kg)
round goby	*Neogobius melanostomus*	36,843	171.93
deepwater sculpin	*Myoxocephalus thompsonii*	18,671	473.32
alewife	*Alosa pseudoharengus*	11,329	279.64
rainbow smelt	*Osmerus mordax*	6,384	39.48
eastern silvery minnow	*Hybognathus regius*	4,666	21.34
yellow perch	*Perca flavescens*	4,141	112.37
white perch	*Morone americana*	1,564	137.89
gizzard shad	*Dorosoma cepedianum*	550	9.12
trout-perch	*Percopsis omiscomaycus*	515	6.65
slimy sculpin	*Cottus cognatus*	278	2.28
pumpkinseed	*Lepomis gibbosus*	205	7.85
brown bullhead	*Ameiurus nebulosus*	167	38.01
spottail shiner	*Notropis hudsonius*	138	1.34
lake trout	*Salvelinus namaycush*	96	38.75
white sucker	*Catostomus commersonii*	94	29.63
bullheads	*Ameiurus* spp.	32	12.67
freshwater drum	*Aplodinotus grunniens*	31	8.58
walleye	*Sander vitreus*	14	10.27
white bass	*Morone chrysops*	11	0.54
lake whitefish	*Coregonus clupeaformis*	11	3.91
channel catfish	*Ictalurus punctatus*	10	0.85
common carp	*Cyprinus carpio*	8	57.07
tessellated darter	*Etheostoma olmstedi*	7	0.02
emerald shiner	*Notropis atherinoides*	5	0.03
rock bass	*Ambloplites rupestris*	5	0.24
sea lamprey	*Petromyzon marinus*	3	0.37
lake sturgeon	*Acipenser fulvescens*	3	
northern pike	*Esox lucius*	3	6.57
threespine stickleback	*Gasterosteus aculeatus*	3	< 0.01
brook silverside	*Labidesthes sicculus*	3	0.01
quillback	*Carpiodes cyprinus*	2	1.33
largemouth bass	*Micropterus salmoides*	2	0.62
burbot	*Lota lota*	1	4.92
cisco	*Coregonus artedi*	2	0.03
putative cisco x bloater hybrid	*Coregonus artedi* x *Coregonus hoyi*	1	0.06
smallmouth bass	*Micropterus dolomieu*	1	0.01
black crappie	*Pomoxis nigromaculatus*	1	0.01
sunfish spp.	*Lepomis* spp.	1	< 0.01
dreissenid mussel (weight only)	*Dreissena* spp.		4,860

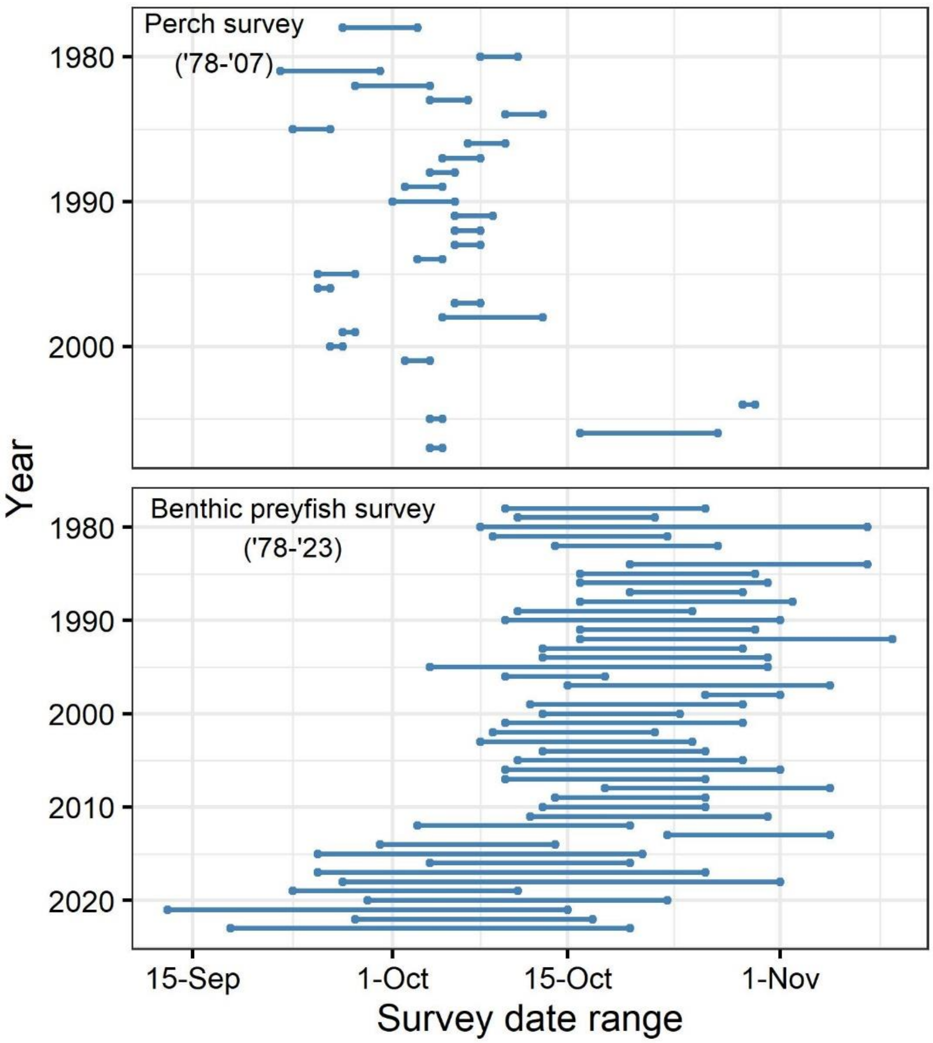

Figure 1. Calendar date range for Lake Ontario bottom trawl tows conducted during the yellow perch survey (top panel; 1978–2007) and the benthic preyfish survey (1978–2023).

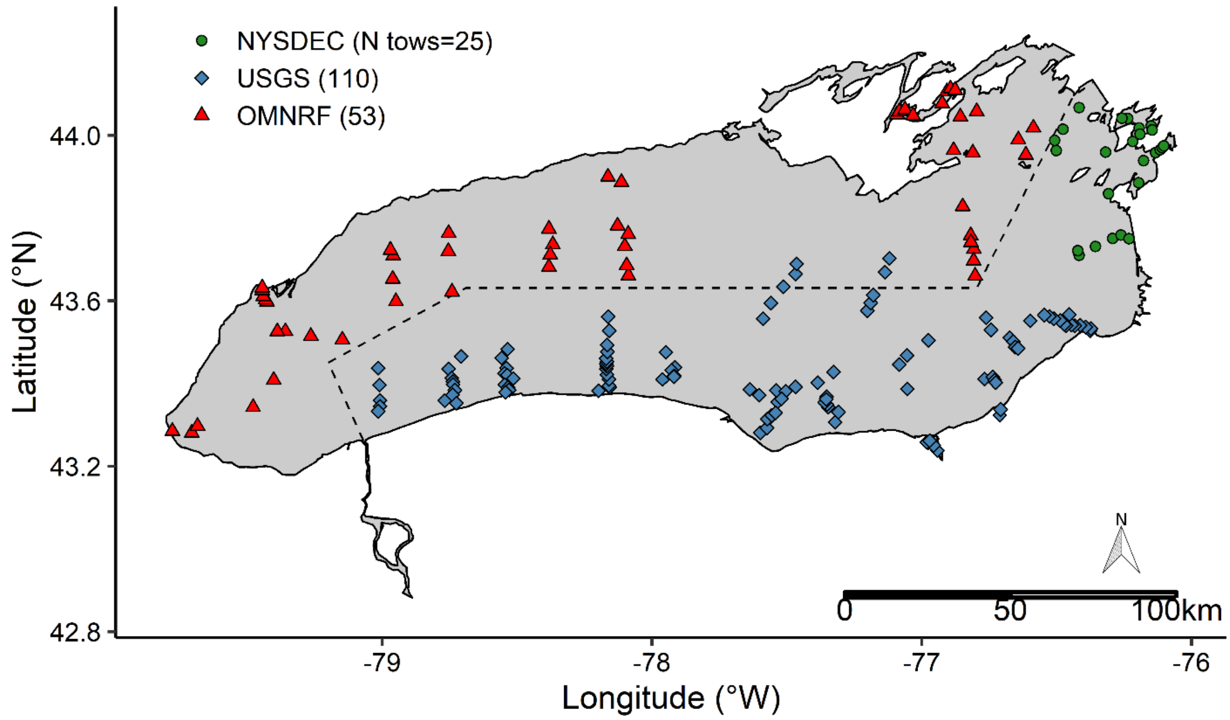

Figure 2. Lake Ontario bottom trawl sites visited during the 2023 benthic preyfish survey (N=188 bottom trawl sites) collectively sampled by the New York State Department of Environmental Conservation (NYSDEC) R/V Seth Green, U.S. Geological Survey (USGS) R/V Kaho, and Ontario Ministry of Natural Resources and Forestry (OMNRF) R/V Ontario Explorer during September 18 – October 20, 2023. Dashed line represents the U.S.-Canada international boundary.

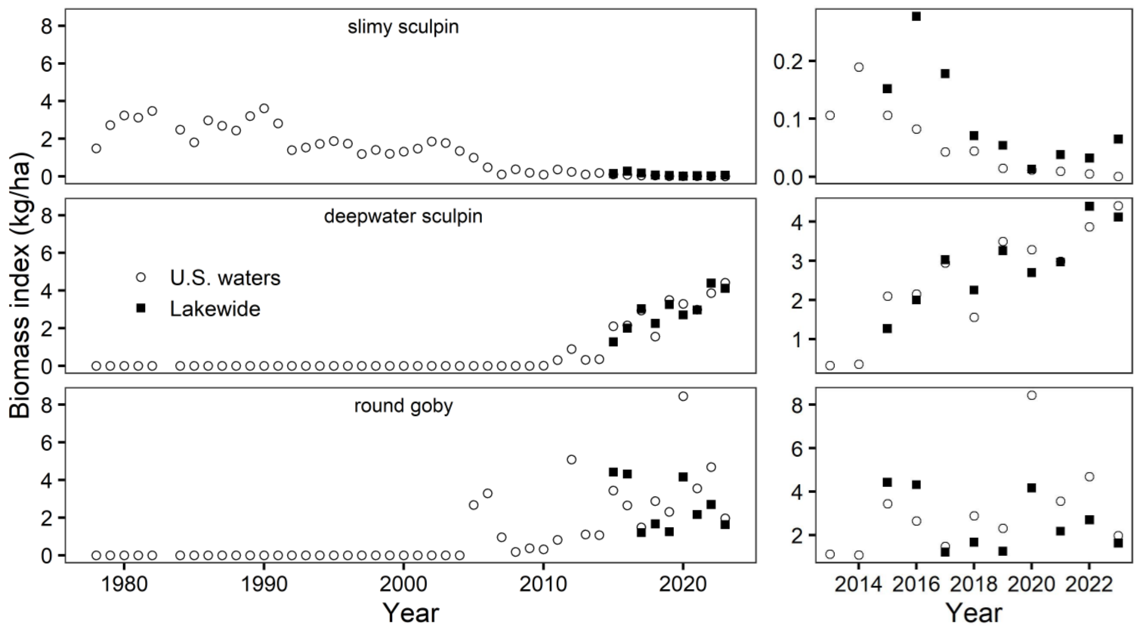

Figure 4. (Left) Area-stratified biomass density (kilograms per hectare) for slimy sculpin (top), deepwater sculpin (middle), and round goby (bottom) in the Lake Ontario benthic preyfish survey, 1978–2023. Open symbols represent the index for US waters only, and closed squares represent lake-wide values that include trawl sites from both US and Canadian waters. (Right) A subset of the time series representing only 2013–2023 to illustrate recent trends over the past decade that may not be apparent when viewing the entire time series. Note the difference in scale between the two time periods.

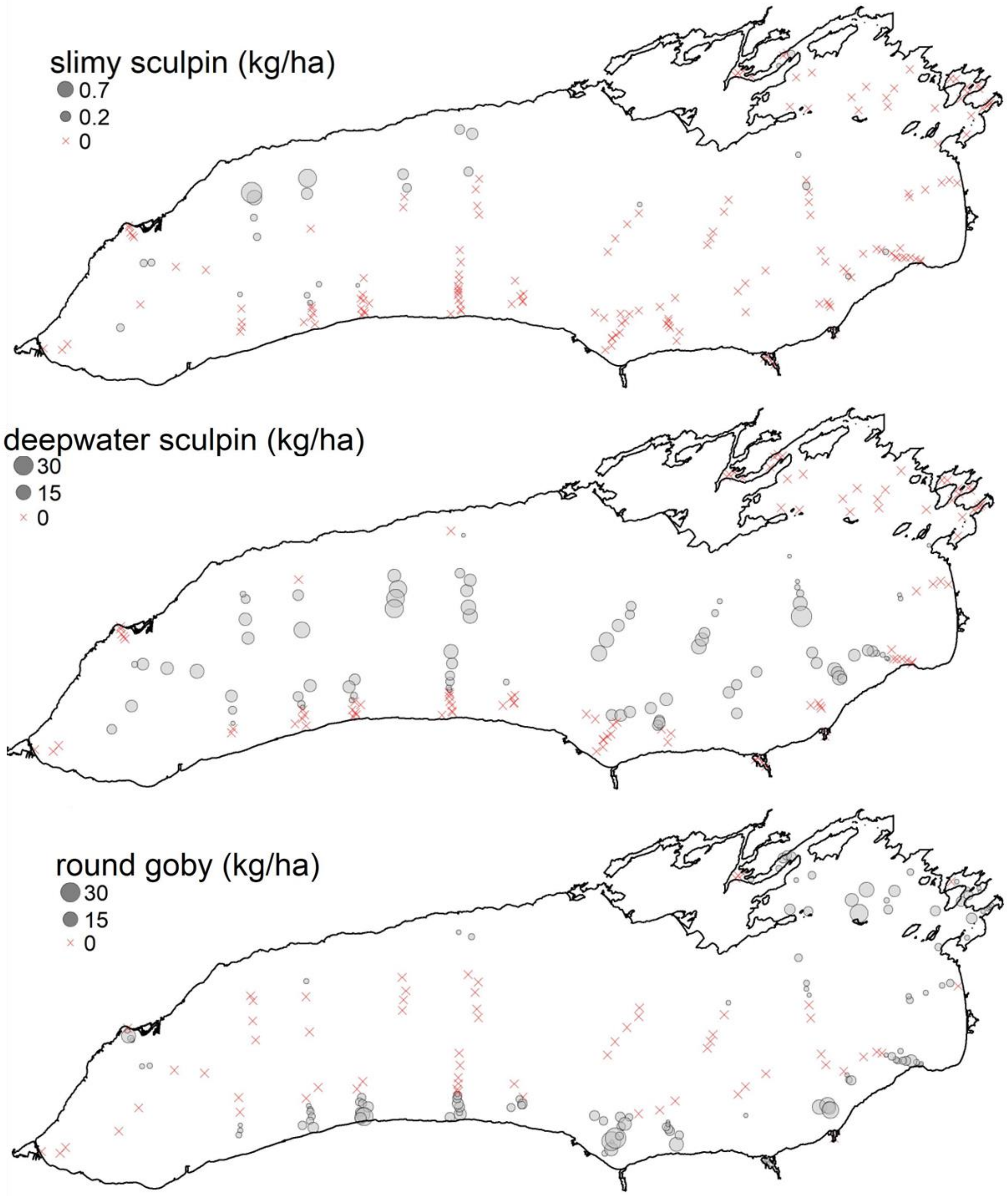

Figure 5. Spatial distribution of biomass density (kg/ha) from individual trawl tows for slimy sculpin (top), deepwater sculpin (middle), and round goby (bottom) in Lake Ontario, 2023. Note the difference in biomass scales among maps.

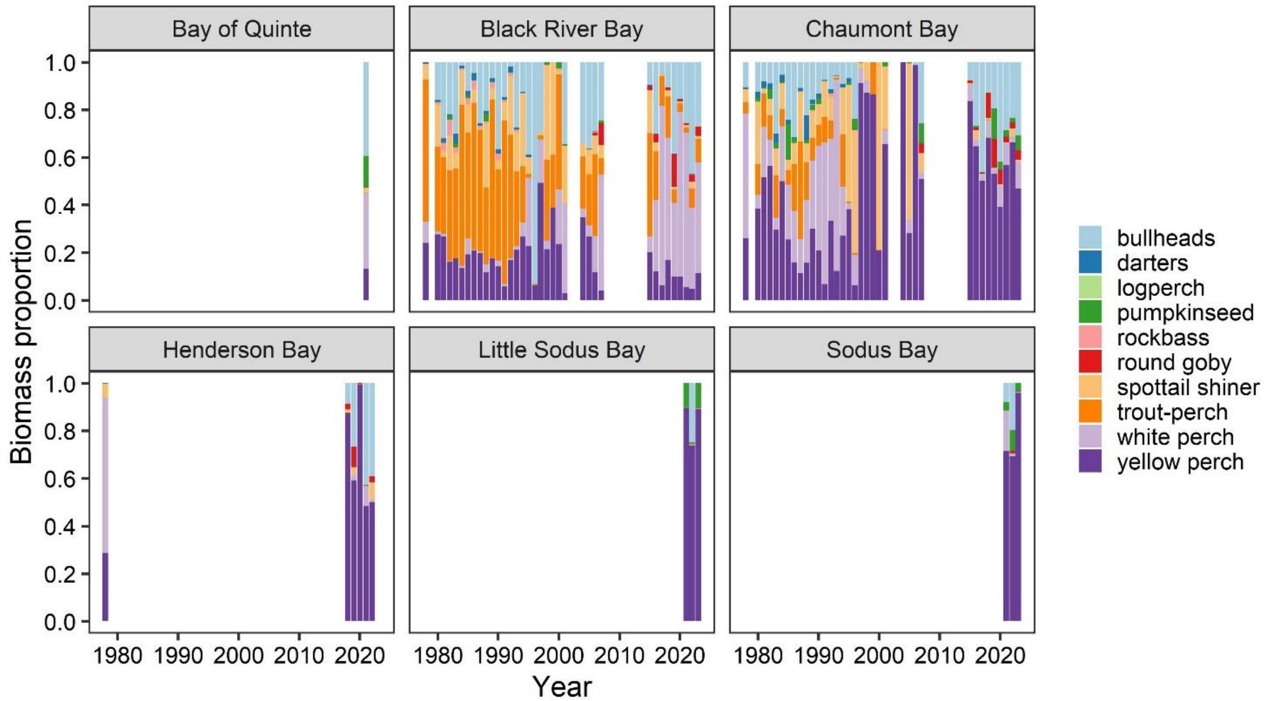

Figure 6. Community composition of benthic preyfish in Lake Ontario embayment catches from the yellow perch survey 1978–2007 (O'Gorman and Burnett 2001), and the benthic preyfish survey 2015–2023. Note that trawl sites in Chaumont, Black River, and Henderson Bays were added to the benthic preyfish survey beginning in 2015, and Bay of Quinte, Sodus, and Little Sodus Bays were added in 2021. Upper Bay of Quinte sites were not sampled during 2022-2023 (see methods).

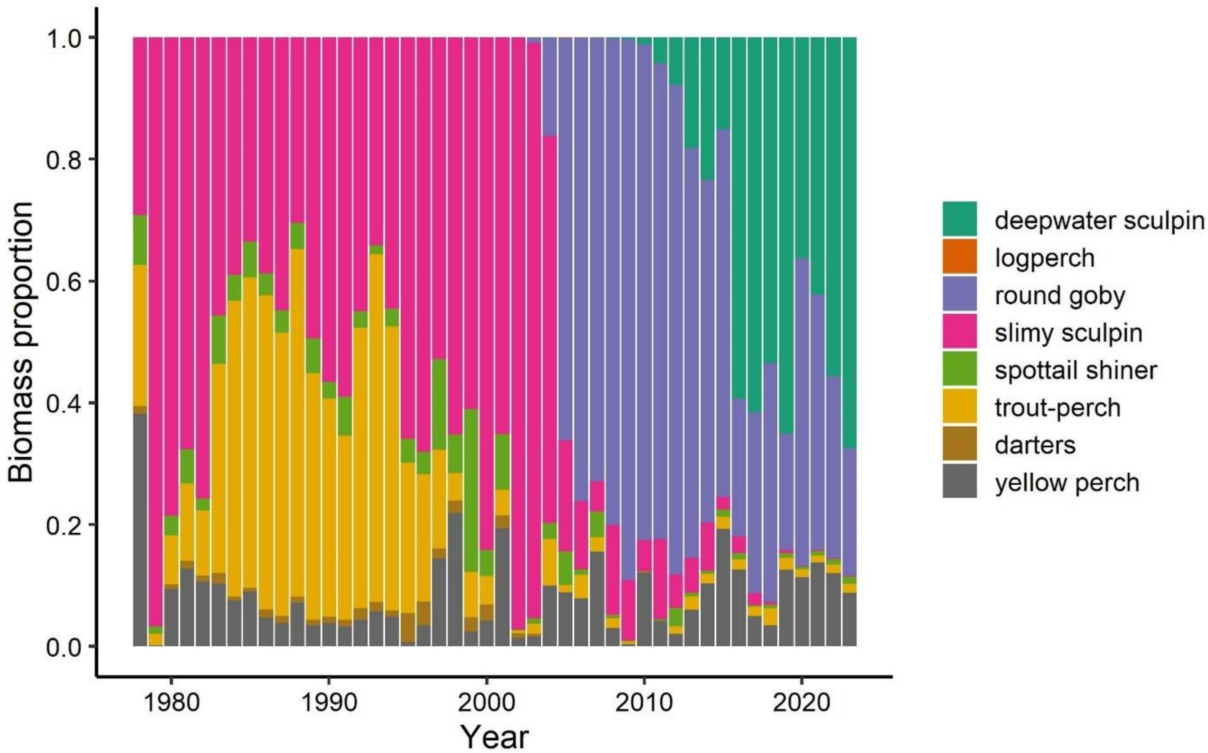

Figure 7. Biomass proportion of benthic preyfish species in bottom trawl catches during the Lake Ontario benthic preyfish survey 1978-2023.

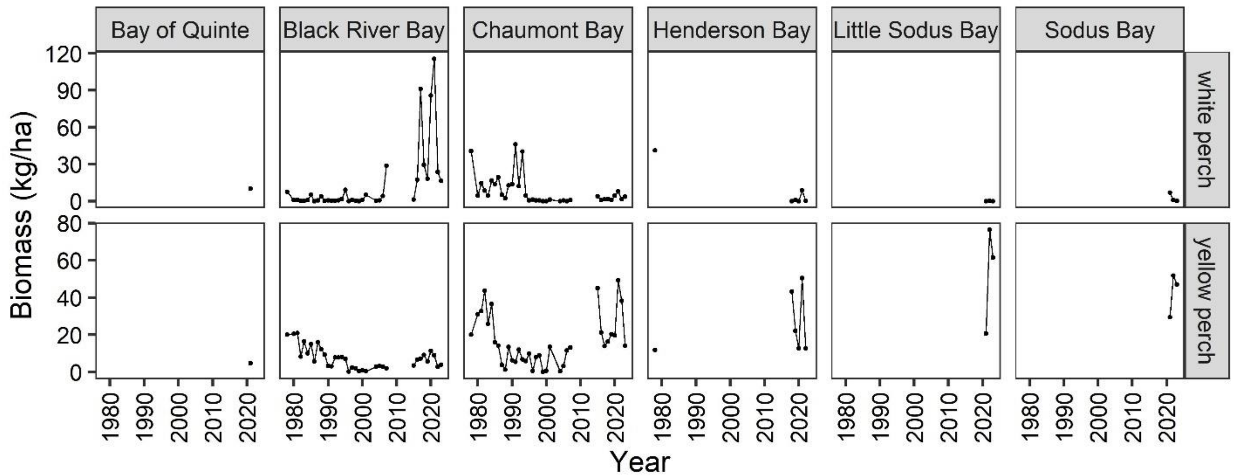

Figure 8. Mean biomass density (kg/ha) of yellow perch and white perch from trawl tows in embayments during the perch survey 1978–2007 (O'Gorman and Burnett 2001), and during the Lake Ontario benthic preyfish survey 2015–2023. Note that y-axis differs in scale between upper and lower panels.