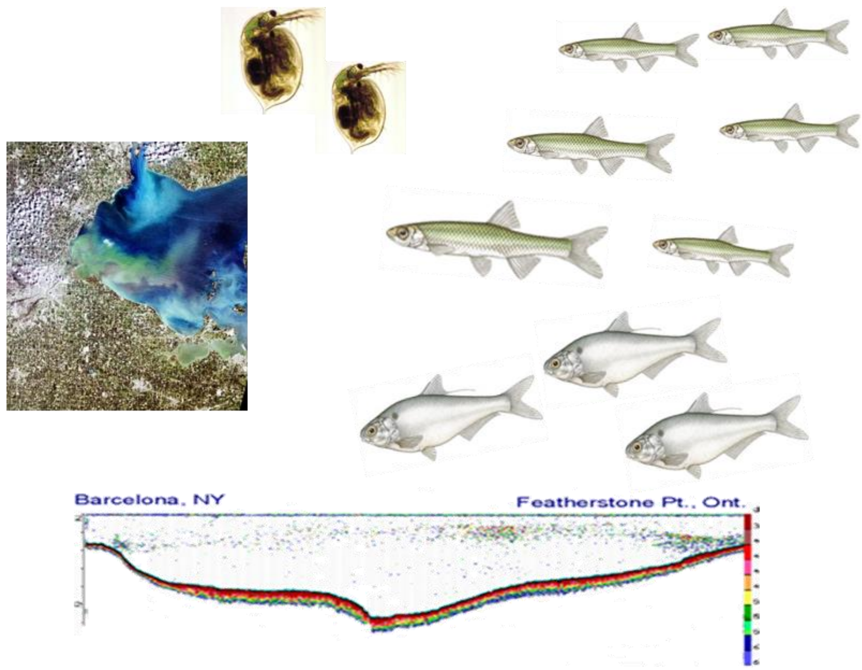
Report of the Lake Erie Forage Task Group

March 2024



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Lake Erie Committee
Great Lakes Fishery Commission

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Forage Task Group Executive Summary

March 2024

Lake Erie Committee

REPRESENTING THE FISHERY MANAGEMENT AGENCIES OF LAKE ERIE AND LAKE ST. CLAIR

Introduction

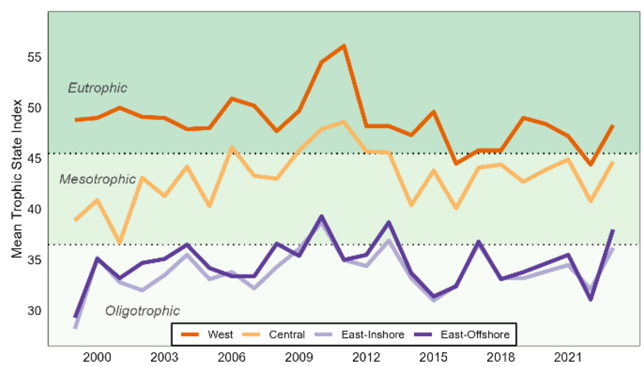
The Lake Erie Committee Forage Task Group (FTG) report addresses progress made on four charges:

1. Report on the results of the interagency lower trophic level monitoring program and status of trophic conditions as they relate to the Lake Erie Environmental Priorities.
2. Describe the status and trends of forage fish in each basin of Lake Erie and evaluate alternate data sources and methods to enhance description of forage fish abundance.
   2.1. Describe forage fish abundance and status using trawl data.
   2.2. Report on the diets of important Lake Erie predator fish where available.
   2.3. Describe growth and condition of Walleye, Lake Trout, and Black Bass.
3. Continue hydroacoustic assessment of the pelagic forage fish community in Lake Erie, while incorporating new methods in survey design and analysis following the GLFC's Great Lakes Hydro Acoustic Standard Operating Procedures where possible/feasible.
4. Act as a point of contact for any new/novel invasive aquatic species and incorporate into the USGS Nonindigenous Aquatic Species database.

The complete report is available from the Great Lakes Fishery Commission's Lake Erie Committee Forage Task Group website (http://www.glfc.org/lake-erie-committee.php) or upon request from a Lake Erie Committee, STC, or FTG representative.

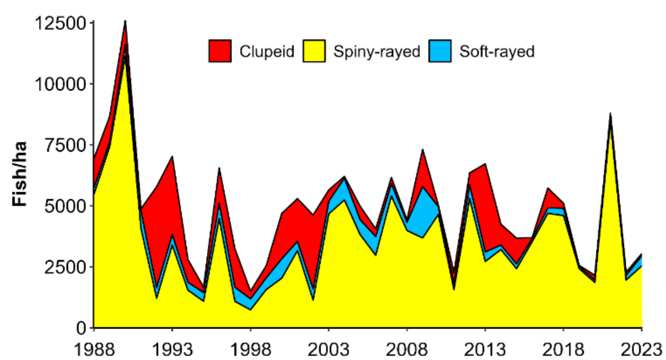
Interagency Lower Trophic Level Monitoring

The Lower Trophic Level Assessment monitoring program has measured nine environmental variables at 18 stations around Lake Erie since 1999 to characterize trends in lake productivity. In 2023, the Trophic State Index, which is a combination of phosphorus levels, water transparency, and chlorophyll *a*, indicated that the Central Basin was within the targeted mesotrophic status. However, the West Basin returned to the above-target Eutrophic classification after one year of mesotrophy. The East Basin offshore and nearshore areas were mesotrophic and oligotrophic, respectively, in 2023. Low hypolimnetic dissolved oxygen continues to be an issue in the Central Basin during the summer months.



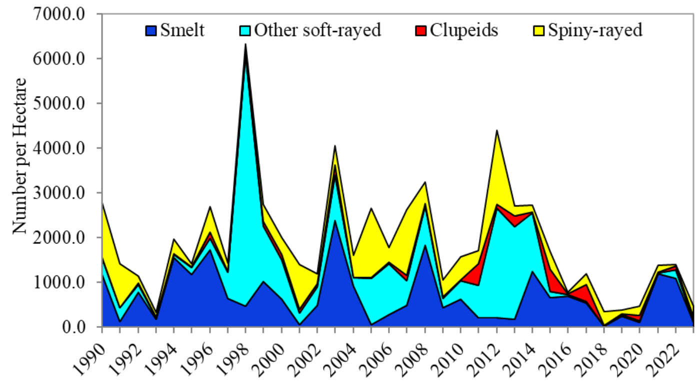
West Basin Status of Forage

In 2023, data from 71 trawl tows were used (up from 69 in 2022). Total forage density averaged 3,043 fish per hectare across the West Basin, similar to moderate levels in 2019–2020 and 2022. Forge biomass (14.9 kg/ha) increased 39% from 2022. Age-0 White Perch abundance (1,912/ha) increased. Age-0 Yellow Perch density (381/ha) was well under recent levels. Age-0 Gizzard Shad abundance (94/ha) remained below the ten-year mean (682/ha). Age-0 Walleye relative abundance (132/ha) remained above average. Densities of Emerald Shiners have remained low for eight years. Round Goby abundance (15/ha) is on a two-year decline.



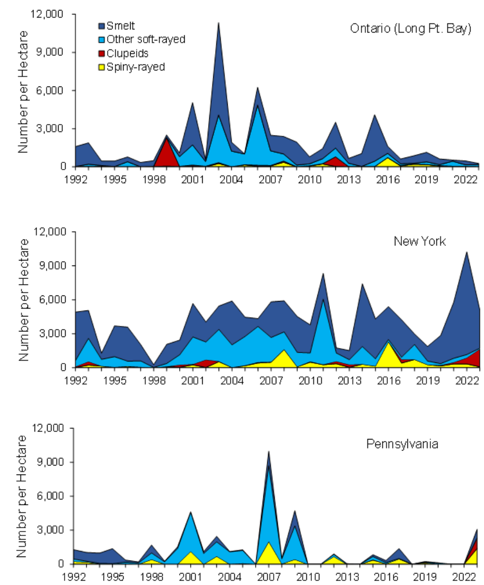
Central Basin Status of Forage

In 2023, 57 trawl tows were completed in the Ohio waters of the Central Basin. Total forage density averaged 470 fish per hectare across the Central Basin, returning to levels similar to 2020. Total forage biomass was 5.093 kg/ha, well below the long-term mean. Age-0 Rainbow Smelt density decreased from 2022 and was well below the long-term average. Age-1+ Rainbow Smelt density decreased from 2022 and was well below the long-term mean. Round Goby indices decreased across the basin and were below the long-term mean. Spiny-rayed forage density (195/ha) increased from 2022. Yellow Perch density was similar to 2022; however, these continue to be some of the lowest densities in the time series. Walleye densities were well above the long-term mean.



East Basin Status of Forage

In 2023, overall forage fish densities were the ninth highest in the time series in New York waters, remained below time series averages in offshore Ontario waters, and were the third highest in the time series in Pennsylvania waters. Total forage biomass was 25.0 kg/ha in New York waters and was the fourth highest level in the time series. Catches of age-1+ Rainbow Smelt were low in Ontario and Pennsylvania and moderate in New York. Catches of age-0 Emerald Shiner (400/ha) increased in 2023 in New York waters; however, catches of age-1+ Emerald Shiner were low. Catches of Emerald Shiner in Ontario were the highest observed since 2015, but still considered low. No Emerald Shiner were sampled in Pennsylvania waters. Round Goby densities were below average in all jurisdictions. Abundance of clupeids (Gizzard Shad, Alewife) was the highest in the time-series in New York and Pennsylvania but below average in Ontario. Moderate numbers of age-0 Walleye were caught in New York and above-average catches age-1 Yellow Perch. Catch of Age-0 Lake Whitefish was at the second highest level in the time series in New York waters. Catches of most other species were low.



Hydroacoustic Assessments

The primary purpose of Lake Erie hydroacoustic surveys is to estimate densities of important forage fishes in each basin of Lake Erie in July during the new moon. After completing several years of comparison studies, the hydroacoustic surveys in Lake Erie adopted a common stratified, random transect design. The standardization of the survey design allows for results to be generated lake wide and by basin. In 2023, a total of 460 km of transects were sampled, 76 water column profiles were measured, and 37 companion mid-water trawls were towed (the latter in the Central Basin only). Densities of fish (number per hectare) were highest in the West Basin, followed by the East Basin, and lowest in the Central Basin. In the East Basin, age-1+ Rainbow Smelt density increased in 2023 relative to 2022 and was well above the time series low observed in 2019. In the Central Basin, total density of fish remained low in 2023, with Rainbow Smelt being the most abundant species in both the epilimnion and hypolimnion. In the West Basin, prey fish density increased significantly in 2023 to the second highest value in the time series.

Aquatic Invasive Species

In 2023, the U.S. Fish and Wildlife Early Detection and Monitoring program did not capture any novel aquatic invasive species. No other Lake Erie agency encountered a novel aquatic invasive species, either. The FTG is continuing work towards incorporating the FTG Aquatic Invasive Species (AIS) database as well as other agency data into the USGS Nonindigenous Aquatic Species database so that the data can be archived and help track AIS on greater geographic scale.

Charges to the Forage Task Group 2023–2024

1. Report on the results of the interagency lower trophic level monitoring program and status of trophic conditions as they relate to the Lake Erie Environmental Priorities.

2. Describe the status and trends of forage fish in each basin of Lake Erie and evaluate alternate data sources and methods to enhance description of forage fish abundance.
   2.1. Describe forage fish abundance and status using trawl data.
   2.2. Report on the diets of important Lake Erie predator fish where available.
   2.3. Describe growth and condition of walleye, lake trout, and black bass.

3. Continue hydro acoustic assessment of the pelagic forage fish community in Lake Erie, while incorporating new methods in survey design and analysis following the GLFC's Great Lakes Hydro Acoustic Standard Operating Procedures where possible/feasible.

4. Act as a point of contact for any new/novel invasive aquatic species and incorporate into the USGS Nonindigenous Aquatic Species database.

Acknowledgements

The Forage Task Group would like to thank Andy Cook (Ontario Ministry of Natural Resources and Forestry), Carey Knight (Ohio Division of Wildlife), and Jim Markham (New York State Department of Environmental Conservation).

Charge 1: Report on the results of the interagency lower trophic level monitoring program and status of trophic conditions as they relate to the Lake Erie Fish Community Objectives.

(J. Markham, Z. Slagle)

Background

In 1999, the Forage Task Group (FTG) initiated a Lower Trophic Level Assessment program (LTLA) within Lake Erie and Lake St. Clair (Figure 1.0.1). Nine key variables, as identified by a panel of lower trophic level experts, were measured to characterize ecosystem change. These variables included temperature and dissolved oxygen profiles, water transparency (Secchi disc depth), nutrients (total phosphorus), chlorophyll *a*, phytoplankton, and zooplankton. The protocol called for each station to be visited every two weeks from May through September, totaling 12 sampling periods. For this report, we will summarize the last 25 years of data for summer surface temperature, summer bottom dissolved oxygen, chlorophyll *a* concentrations, water transparency, total phosphorus, and zooplankton. Data from all sampled stations were included in the analysis unless noted. In 2023, stations 3–6 in the West Basin, 7–12 in the Central Basin, and 15-18 in the East basin were sampled (Figure 1.0.1).

Lake Erie's Environmental Priorities (EP; LEC, 2019), in prescribing actions that are critical for achievement of its Fish Community Objectives (Francis et al. 2020), describe desirable trophic conditions in Lake Erie. The EPs designate mesotrophic conditions in the West Basin, Central Basin, and nearshore waters of the East Basin and embayments as desirable. Conversely, an oligotrophic environment would most benefit the coldwater fish community that utilizes the deep, offshore waters of the East Basin (Ryan et al. 2003). Associated with these trophic classes are target ranges for total phosphorus, water transparency, and chlorophyll *a* (Table 1.0.1). For mesotrophic conditions, the total phosphorus range is 9-18 µg/L, summer (June-August) water transparency is 3-6 meters, and chlorophyll *a* concentrations between 2.5-5.0 µg/L (Leach et al. 1977). For the offshore waters of the East Basin, the target for total phosphorus is < 9 µg/L, summer water transparency > 6 m, and chlorophyll *a* concentrations < 2.5 µg/L.

A trophic state index (TSI; Carlson 1977) was used to produce a metric which merges three independent variables to report a single broader measure of trophic conditions. This index uses algal biomass as the basis for trophic state classification, which is independently estimated using measures of chlorophyll *a*, water transparency, and total phosphorus. Each independent measure is combined and the average of the three indices reflects a trophic state value for that site and sampling event. The median value of the combined daily indices is used to determine an annual index for each basin. Because the number generated is only a relative measure of the trophic conditions and does not define trophic status, this index was calibrated to accept Lake Erie ranges for values of total phosphorus, chlorophyll *a*, and transparency (from Leach et al. 1977) that have long been used to assess trophic conditions. In these terms, oligotrophic was determined to have a TSI < 36.5, mesotrophic between 36.5 and 45.5, eutrophic between 45.5 and 59.2, and hyper-eutrophic >59.2.

Mean Summer Surface Water Temperature

Summer surface water temperature represents the temperature of the water at 0-1 meters depth for offshore stations only. This index should provide a good measure of relative system production and growth rate potential for fishes, assuming prey resources are not limiting. Mean summer surface temperatures across all years are warmest in the West Basin (mean = 22.8°C), becoming progressively cooler in the Central (mean = 21.9 °C) and East Basins (mean = 20.6 °C; Figure 1.0.2). In 2023, the mean summer surface water temperature was close to long-term averages in both the West (22.6 °C) and Central (21.8 °C) basins. In the East Basin, mean summer surface water temperatures were 20.3 °C, slightly below average. An increasing trend in summer surface water temperature is evident in all three basins for this time series (Figure 1.0.2).

Hypolimnetic Dissolved Oxygen

Dissolved oxygen (DO) levels less than 2.0 mg/L are deemed stressful to fish and other aquatic biota (Craig 2012; Eby and Crowder 2002). Low DO can occur when the water column becomes stratified, which can begin in early June and continue through September in the Central and East Basins. In the West Basin, shallow depths allow wind mixing to penetrate to the bottom, generally preventing thermal stratification. Consequently, there are only a few summer observations that detect low bottom DO concentrations in the time series (Figure 1.0.3). In 2023, there were no observed measurements from the West Basin stations of DO below the 2.0 mg/L threshold.

Low DO is more of an issue in the Central Basin, where it happens almost annually at the offshore stations (8, 10, 11 and 13) and occasionally at inshore stations. Dissolved oxygen of less than 2.0 mg/L has been observed as early as mid-June and can persist until late September when fall turnover remixes the water column. In 2023, bottom DO was below the 2.0 mg/L threshold in the Central Basin on three occasions (Station 7: 7/12/23 – 0.53 mg/L and 7/27/23 – 0.11 mg/L; Station 8: 8/25/23 – 1.41 mg/L; Figure 1.0.3).

DO is rarely limiting in the East Basin due to greater water depths, a large hypolimnion and cooler water temperatures. The only occasion when DO was below the 2.0 mg/L threshold was on 14 July and 13 August, 2010 (Figure 1.0.3). In 2023, East Basin bottom DO measurements ranged between 6.5–11.1 mg/L and were never below the 2.0 mg/L threshold.

Chlorophyll a

Chlorophyll *a* concentrations indicate biomass of the phytoplankton resource, ultimately representing production at the lowest trophic level. In the West Basin, mean chlorophyll *a* concentrations have mainly been above targeted levels in the 24-year time series, fitting into eutrophic status rather than targeted mesotrophic status (Figure 1.0.4). Annual variability is also the highest in the West Basin. In 2023, the mean chlorophyll *a* concentration was 5.4 μg/L in the West Basin, which is classified as eutrophic, above the targeted mesotrophic range. In the Central Basin, chlorophyll *a* concentrations have been less variable and within the targeted mesotrophic range for the entire time series; that trend continued in 2023 (4.6 μg/L; Figure 1.0.4). In the East Basin, chlorophyll *a* concentrations in the nearshore waters have been below the targeted mesotrophic level for the entire time series, including 2023 (1.4 μg/L; Figure 1.0.4). This may be due to high levels of grazing by dreissenids (Nicholls and Hopkins 1993) in the nearshore East Basin waters where biomass of quagga mussels (*Dreissena bugensis*) remains high (Patterson et al. 2005). Conversely, chlorophyll *a* levels in the offshore waters of the East Basin remain in, or slightly above, the targeted oligotrophic range (2023: 2.1 μg/L). Chlorophyll *a* concentrations remain the most stable in the East Basin.

Total Phosphorus

Total phosphorus levels in the West Basin have exceeded EP targets since the beginning of the LTLA monitoring program; in some years, they have been in the hyper-eutrophic range (Figure 1.0.5). In 2023, mean total phosphorus concentrations in the West Basin increased to 23.5 μg/L, rising from the lowest value in the time series and returning to eutrophic status. In the Central Basin, mean total phosphorus levels had exceeded FCO targets from 2006 through 2013, were borderline mesotrophic/eutrophic in 2014 and 2015, and then began to increase again in 2016 (Figure 1.0.5). Total phosphorus measures in the Central Basin sharply increased in 2023 to 26.6 μg/L and also returned to eutrophic status. In the nearshore waters of the East Basin, total phosphorus levels have remained stable and within or near the targeted mesotrophic range for the entire time series (Figure 1.0.5). Total phosphorus levels in the offshore waters of the East Basin show a similar trend to nearshore waters and had risen above the targeted oligotrophic range from 2008 through 2013 but have declined in more recent years. In 2023, mean total phosphorus measures increased in both nearshore (10.3 μg/L) and offshore (11.8 μg/L) waters of the East Basin, both in the mesotrophic range (within target for inshore waters but above target for offshore).

Water Transparency

In 2023, Secchi depths decreased (i.e., became more eutrophic) across all basins of Lake Erie (Figure 1.0.6). Similar to other fish community ecosystem targets (i.e., chlorophyll *a*, total phosphorus), water transparency in the West Basin has been in the eutrophic range, which is below the FCO target, for the entire time series. Mean summer transparency in the West Basin was 1.8 m in 2023, a decline compared to 2022 and within the eutrophic range. In contrast, water transparency in the Central Basin has remained within the targeted mesotrophic range for most of the entire series (Figure 1.0.6). In 2023, water transparency decreased to 3.1 m and is within the mesotrophic range. In the nearshore water of the East Basin in 2023, water transparency (5.1 m) was in the mesotrophic range within the FCO target (Figure 1.0.6). In the offshore waters of the East Basin, water transparency was within the oligotrophic target from 1999 through 2007, decreased into the mesotrophic range in five of the next six years, then increased thereafter. Similar to the nearshore waters, water transparency in the offshore waters decreased in 2023 (6.8 m) and was within the oligotrophic range.

Trophic State Index (TSI) and Ecosystem Targets

The trophic state index for each of the basins in Lake Erie has fluctuated over time (Figure 1.0.7). Median TSI values indicate that the West Basin remained in a eutrophic status from the beginning of the entire time series until 2016, which was more favorable for a centrarchid (black bass and sunfish) fish community. In some years, overall measures of productivity have declined and are near or within the targeted mesotrophic status (2016 and 2022), which is more favorable for percid (Walleye and Yellow Perch) production. In the Central Basin, median TSI values have generally remained within the targeted mesotrophic range for the entire time series. Trends in the nearshore waters of the East Basin indicate median TSI values and ranges mostly below the targeted mesotrophic range in the early years of the time series, increasing into the targeted mesotrophic zone in the late-2000s, then decreasing back into oligotrophic status since 2014. Similar trends are apparent in the offshore waters of the East Basin. The TSI values for 2023 indicate eutrophic status in the West Basin (48.3), returning from one year of mesotrophy. The Central Basin (44.7) remained in mesotrophic status in 2023. In the East Basin, offshore waters (38.0) were classified as mesotrophic while nearshore waters (36.2) were oligotrophic (Table 1.0.2). Trends in trophic status measures indicate that Lake Erie continues to decrease in overall productivity but generally remains in a favorable condition for percid production.

Zooplankton Biomass

Average zooplankton biomass varies across basins and years. In the West Basin, the 2023 average biomass was 104.0 mg/m^3, a slight increase from 2022 (94.8 mg/m^3) and below the time series average of 143 mg/m^3 (Figure 1.0.8). Biomass increased most for calanoid copepods (from 5.4 mg/m^3 in 2022 to 8.5 mg/m^3 in 2023). In the Central Basin, the 2023 average zooplankton biomass was 120.9 mg/m^3, which was below the average time series biomass (141.0 mg/m^3). This represented a slight increase from 2022 (100.5 mg/m^3) in the Central Basin (Figure 1.0.8). Many groups increased from 2022. In the East Basin, overall zooplankton biomass is traditionally lower compared to the Central and West Basins with cladocerans and calanoid copepods equally important (Figure 1.0.8). Zooplankton data for the East Basin are not yet available and will be reported next year.

Looking at larger trends, there appeared to be a gradient of high zooplankton biomass in the West and lower biomass in the east from 2000 to 2007. From 2009 through 2013, zooplankton biomass increased in the Central and East basins, but shifted back to the West basin in 2015 with declines observed in the Central and East basins. High zooplankton biomass in the Central Basin coincides with years of high Yellow Perch production there, while recent high zooplankton biomass in the West Basin coincides with high production of both Walleye and Yellow Perch (although this pattern has broken down in recent years). Cladocerans are typically more dominant in the West Basin zooplankton community and decline to the east while calanoid and cyclopoid copepods tend to be higher in biomass in the Central and East basins. Calanoid copepods have typically been higher in biomass in the Central Basin compared to the West Basin with cladocerans less numerous, but copepod biomass has been conspicuously low for the past nine years.

Table 1.0.1: Thresholds for trophic indicators and the trophic state index associated with each trophic state and fish community (Leach et al. 1977; Ryder and Kerr 1978; Carlson 1977).

Trophic Status	Phosphorus (µg/L)	Chlorophyll a (µg/L)	Transparency (m)	Trophic State Index (TSI)	Harmonic Fish Community
Oligotrophic	<9	<2.5	>6	<36.5	Salmonids
Mesotrophic	9 - 18	2.5 - 5.0	3 - 6	36.5 – 45.5	Percids
Eutrophic	18 - 50	5.0 - 15	1 - 3	45.5 – 59.2	Centrarchids
Hyper-eutrophic	>50	>15	<1	>59.2	Cyprinids

Table 1.0.2: Current trophic status, by basin, from Lake Erie in 2023.

Basin	2023 TSI	2023 Trophic Status
West	48.3	Eutrophic
Central	44.7	Mesotrophic
East-Inshore	36.2	Oligotrophic
East-Offshore	38.0	Mesotrophic

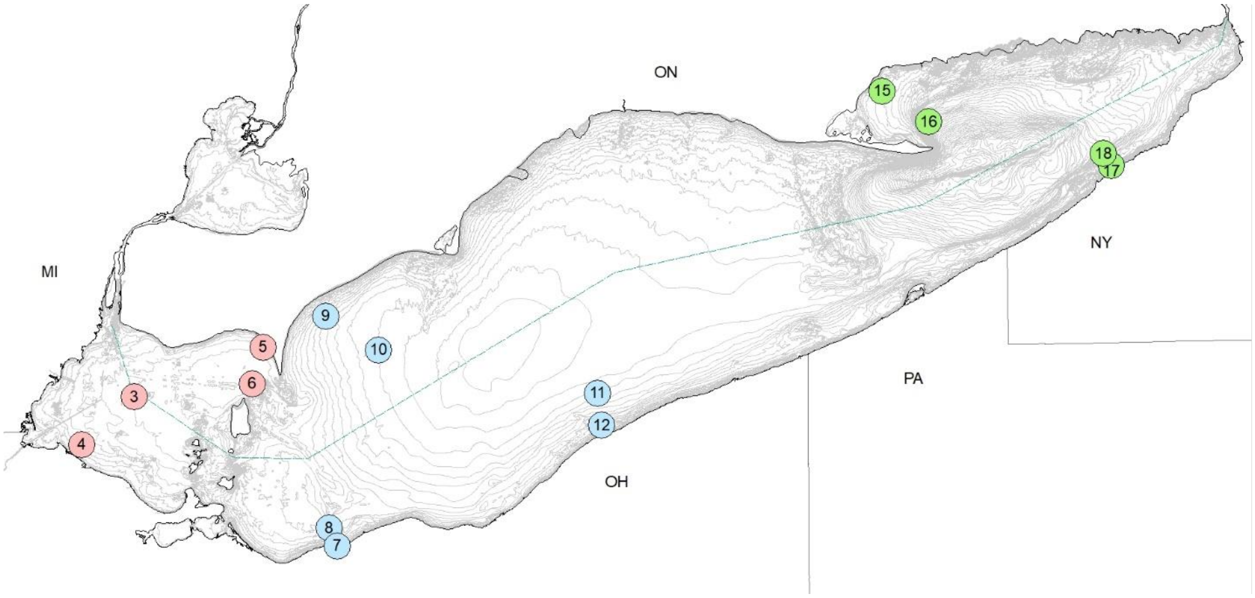


Figure 1.0.1: Lower trophic level sampling stations in Lake Erie (red = West Basin, blue = Central Basin, and green = East Basin).

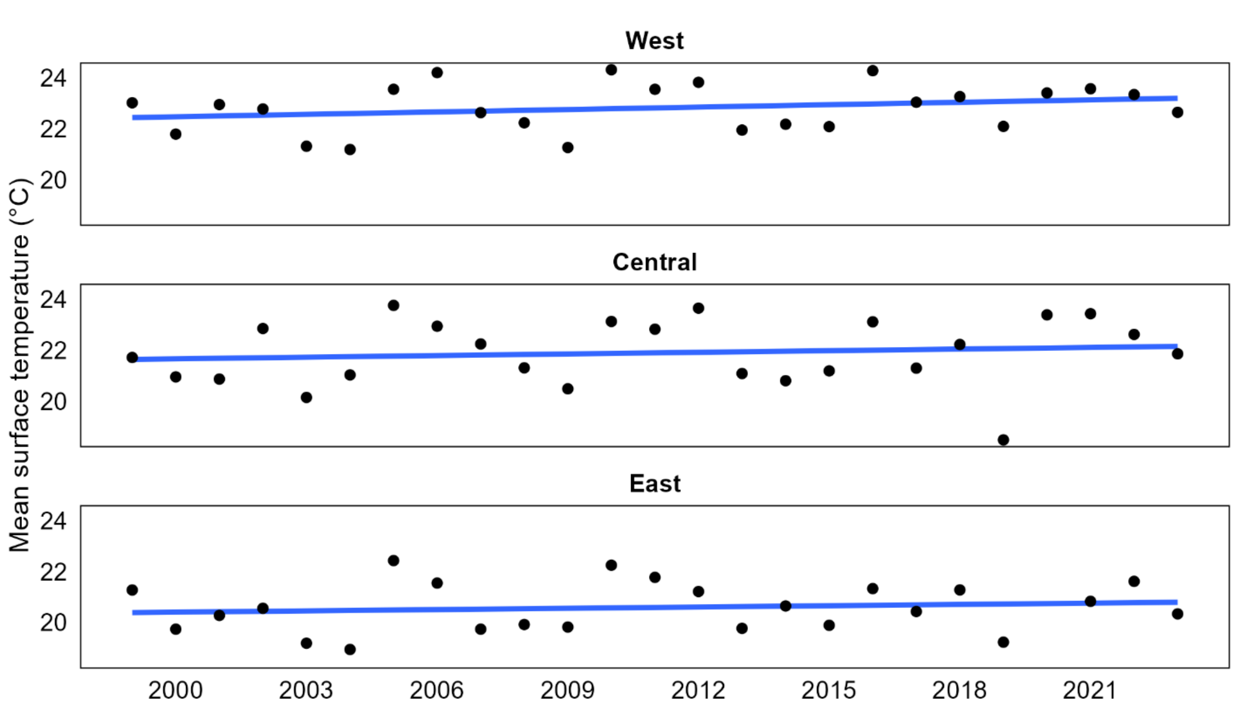


Figure 1.0.2: Mean summer (June-August) surface water temperature (°C) at offshore stations weighted by month for each basin in Lake Erie, 1999 –2023. Solid blue lines represent time series trends.

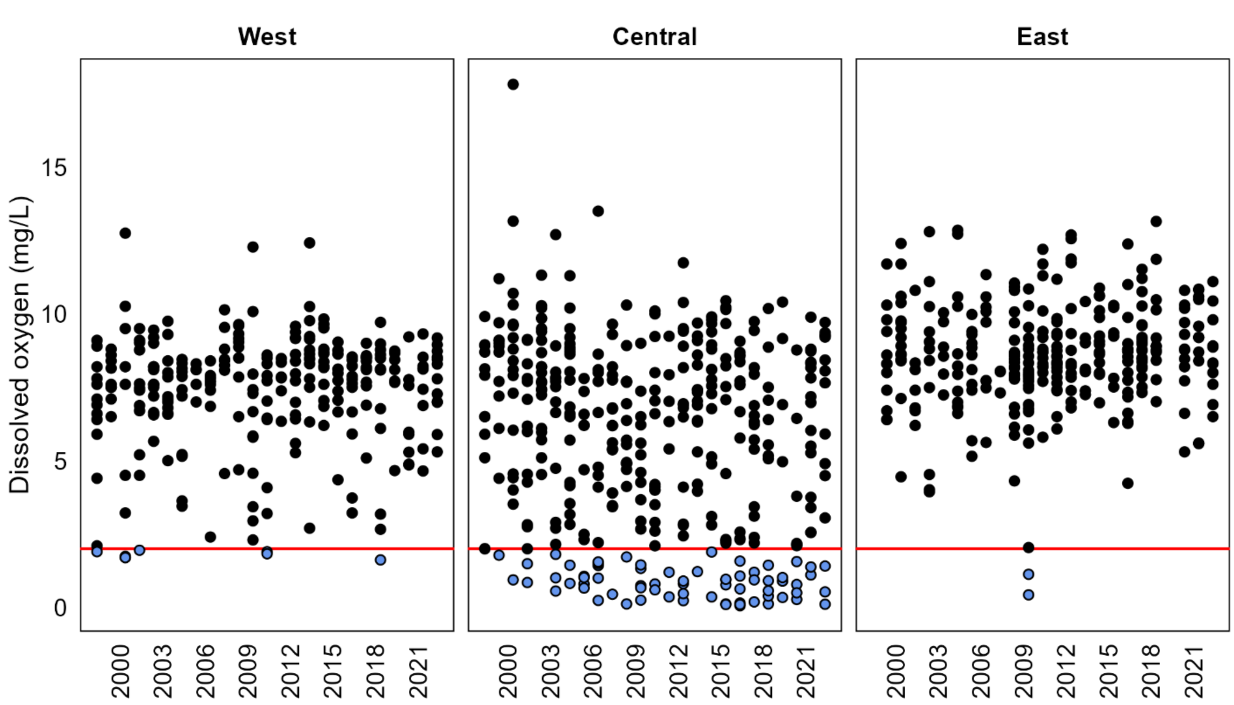


Figure 1.0.3: Summer (June-August) bottom dissolved oxygen (mg/L) concentrations for offshore sites by basin in Lake Erie, 1999–2023. The red horizontal line represents 2 mg/L, a typical threshold for hypoxia. Values below this are denoted by blue points.

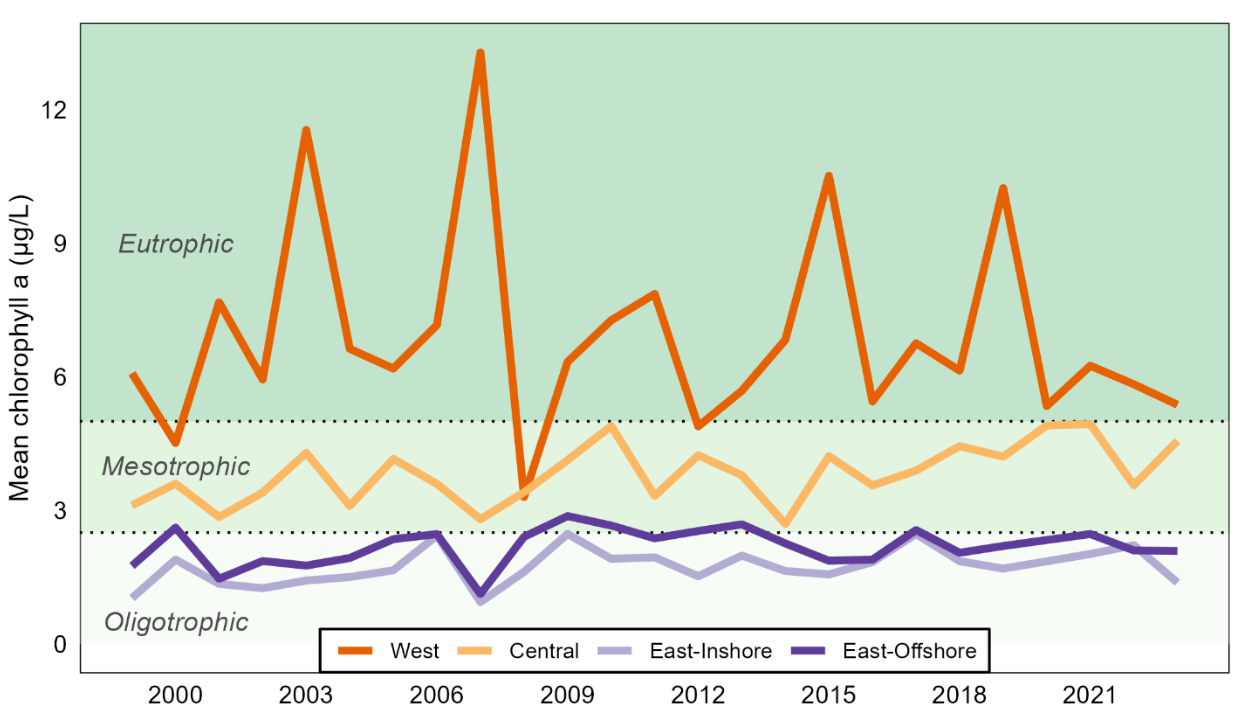


Figure 1.0.4: Mean chlorophyll *a* concentration (µg/L), weighted by month, for each basin in Lake Erie, 1999–2023. The East Basin is separated into nearshore and offshore. Shaded areas represent trophic class ranges.

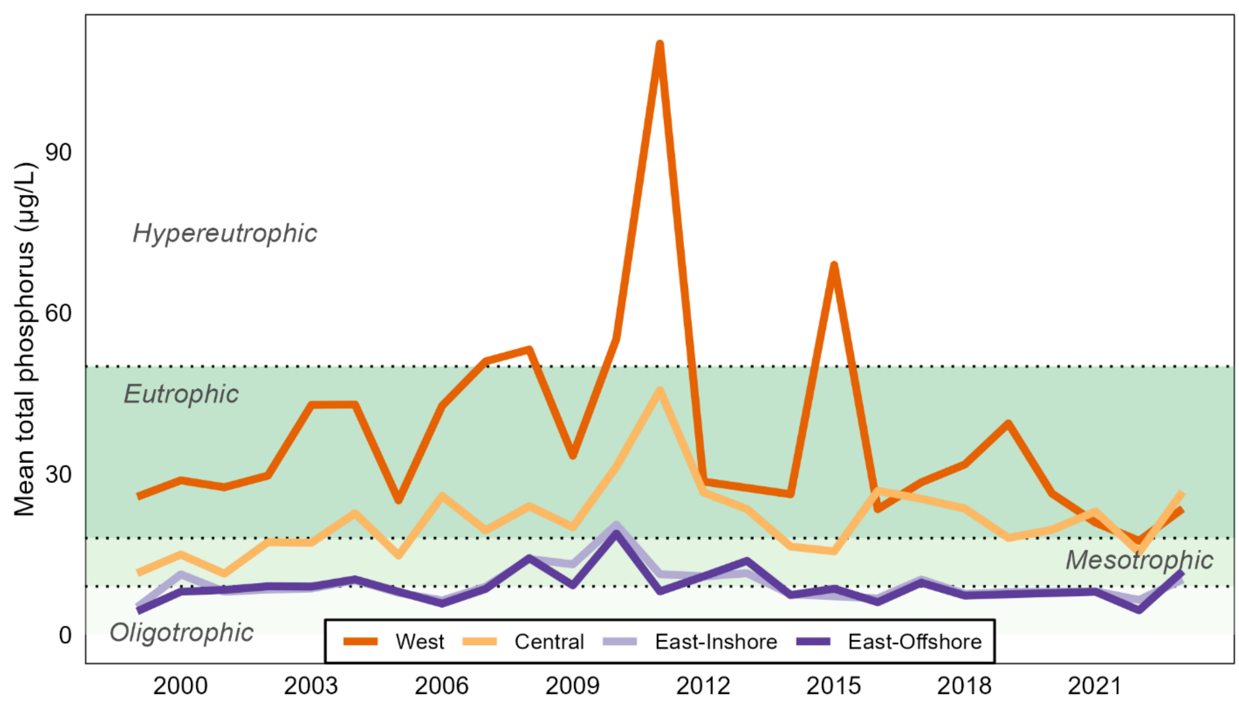


Figure 1.0.5: Mean total phosphorus (µg/L), weighted by month, for offshore sites in each basin of Lake Erie, 1999–2023. The East Basin is separated into nearshore and offshore. Shaded areas represent the trophic class ranges.

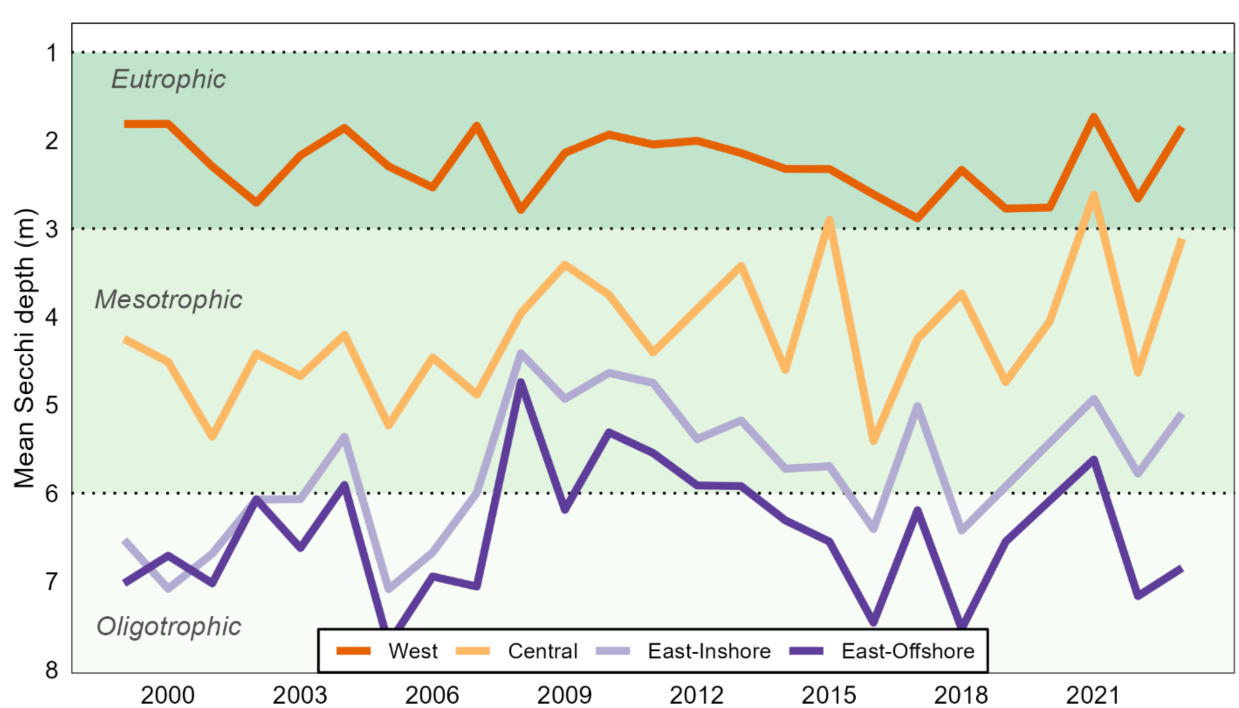


Figure 1.0.6: Mean summer (June–August) Secchi depth (m), weighted by month in each basin of Lake Erie, 1999–2023. The East Basin is separated into inshore and offshore. Shaded areas represent the trophic class ranges.

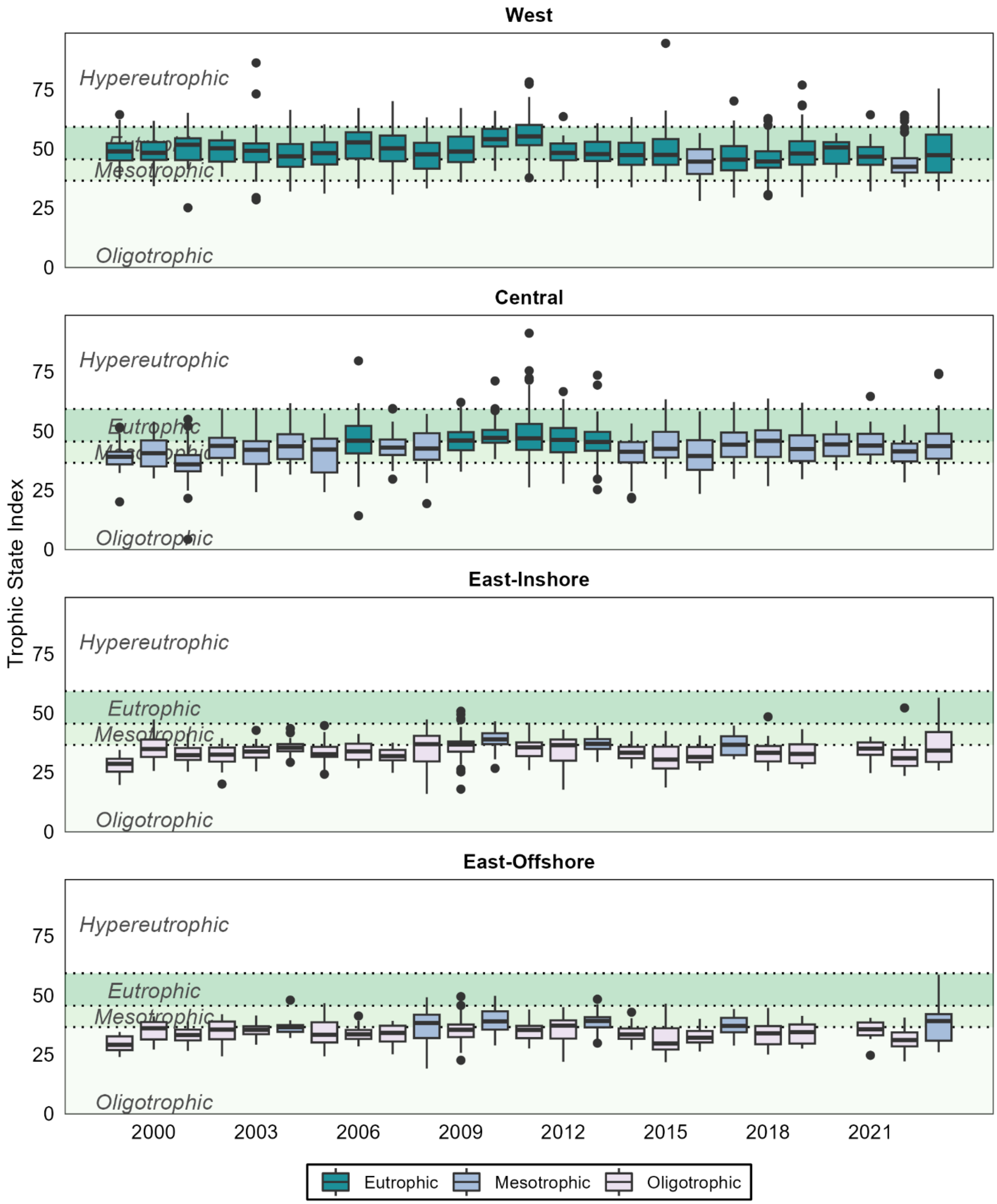


Figure 1.0.7: Box and whisker plot of trophic state indices by basin in Lake Erie, 1999–2023. Shaded areas represent trophic class ranges. Boxes indicate 25th and 75th quartiles of the values with the median (dark line). Vertical lines show the range of values with individual points representing outliers.

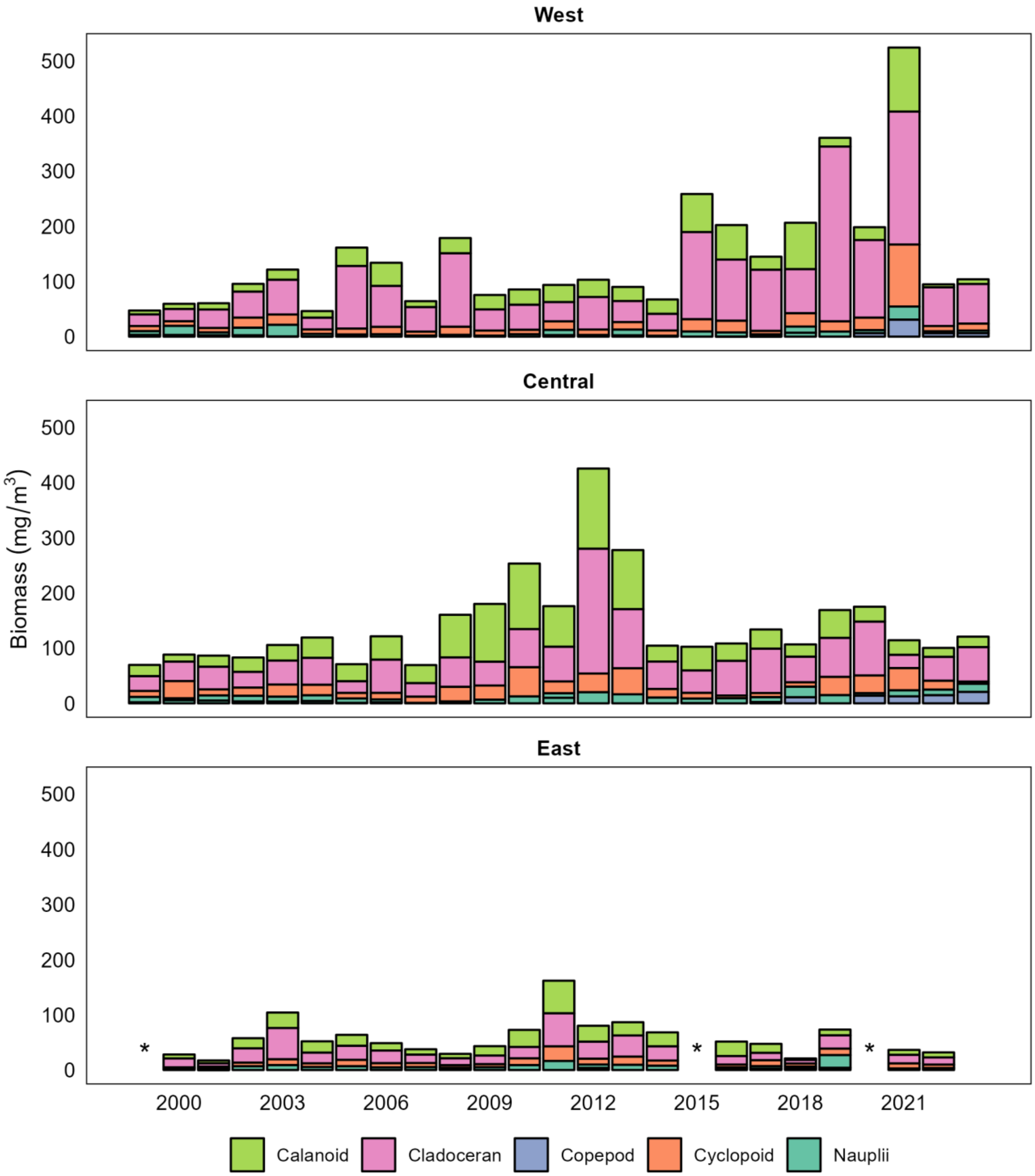


Figure 1.0.8: Average zooplankton biomass (mg/m^3) by major taxonomic group by basin, 1999-2023. Years of missing data are denoted with asterisks (*; East Basin data were not available in time for this report). Data excludes rotifers and veligers. Harpacticoid zooplankton comprise a miniscule biomass for most years and are not included in the graph.

Charge 2: Describe the status and trends of forage fish in each basin of Lake Erie and evaluate alternate data sources and methods to enhance description of forage fish abundance.

Note: A full species list and their scientific names can be found in Appendix 1.

2.1: Describe forage fish abundance and status using trawl data.

2.1.1 East Basin Status of Forage (P. Wilkins, A. Bonsall, and M. Hosack)

Forage fish abundance and distribution is determined primarily from long-term bottom trawl assessments conducted by the basin agencies (also see East Basin Hydroacoustic Survey, Section 3.1). In 2023, a total of 4 trawl tows were completed in Pennsylvania waters, 34 trawl tows were sampled across New York waters, and 110 trawl tows in the nearshore (n = 70) and offshore (n = 40) waters of Long Point Bay in Ontario (Figure 2.1.1.1). Pennsylvania trawled in East Basin waters for the first time since 2020, using the research vessel United States Geological Survey (USGS) R/V *Muskie*.

In 2023, overall forage fish densities were the ninth highest in the time-series in New York waters, remained below time series averages in the offshore waters of Long Point Bay, and were the third highest in the time series in Pennsylvania waters (Figure 2.1.1.2). Rainbow Smelt is typically the most abundant forage species in most years and jurisdictions. In 2023, Rainbow Smelt catches were primarily composed of age-0 individuals in New York with moderate densities of age-1+ Rainbow Smelt, while the age-class composition was distributed more evenly in Ontario waters with only slightly higher abundance of age-0 fish. In Pennsylvania waters, age-0 densities were the highest observed since 1990, whereas age-1 densities were well-below average. The age-0 index in New York was the sixth highest abundance in the time-series. Age-1+ Emerald Shiner catches were again low in 2023 in all surveys; however, age-0 Emerald Shiner abundance was the fifth highest in New York. Emerald Shiner catches were the highest in the Ontario time series since 2015, but still considered low. No Emerald Shiner were sampled in Pennsylvania waters. Round Goby, an important species in the East Basin forage fish community since it appeared in the late 1990s, peaked in the mid-2000s and have since generally remained at a lower but stable abundance in all jurisdictions. The abundance of Round Goby remained below average in all jurisdictions in 2023. Clupeid (Gizzard Shad, Alewife) abundance was the highest in the time-series in New York and Pennsylvania waters and accounted for most of the increase in overall fish densities, but remained below average in Ontario waters. New York also recorded its second highest abundance of age-0 Lake Whitefish in their time-series in 2023 along with moderate catches of age-1 yellow perch. Catches of age-0 and age-1 Yellow Perch in offshore Ontario waters were below average and lower than in 2022. Catches of most other species were low in 2023.

2.1.2 **Central Basin Status of Forage** (P. Jenkins, M. Hosack)

Central basin bottom trawl surveys to assess age-0 percid and forage fish abundance and distributions began in Pennsylvania in 1982 and in Ohio in 1990. Trawl locations in Pennsylvania range from 13 to 24 m in depth and Ohio trawl locations range from 5 to >20 m in depth (Figure 2.1.2.1). Ohio West covers the area from Lorain to Fairport Harbor. Ohio East covers the area from Fairport Harbor to the Pennsylvania state line. The Pennsylvania survey covers the area from the Pennsylvania state line to Erie. In 2023, 57 trawl tows were completed in Ohio and 9 trawl tows were done in Pennsylvania waters. Pennsylvania trawled in Central Basin waters for the first time since 2020, using the USGS R/V *Muskie*. Ontario began bottom trawling the Central Basin in 2016 and data from this program will be included in future Forage Task Group reports.

Overall, Central Basin forage abundance was low in Ohio waters. Rainbow Smelt densities decreased in 2023 (Figure 2.1.2.2). The density of spiny-rayed fishes increased by 1100% relative to the 2022 density. Clupeid density stayed very similar to 2022. Other soft-rayed fish density decreased 61% relative to 2022 densities. Age-0 Yellow Perch densities increased slightly while age-1 fish decreased in 2023 relative to 2022. Yellow Perch densities continue to be some of the lowest in the time series. Walleye densities increased from 2022 continuing to be high relative to the long-term mean. Central Basin forage abundance was well-above average in Pennsylvania waters. High forage abundance in Pennsylvania waters was driven by exceptionally high catches of age-0 White Perch, Alewife, and Trout Perch. Catches of age-0 Yellow Perch were well above average in Pennsylvania waters.

2.1.3 **West Basin Status of Forage - Interagency** (Z. Slagle)

Background

Annual interagency bottom trawling has been conducted in August within the Ontario and Ohio waters of the West Basin, Lake Erie since 1987, though missing effort data from 1987 has resulted in the use of data since 1988. In 2003, an interagency trawl comparison exercise was conducted that allows catches to be standardized across vessels using Fishing Power Correction (FPC) factors and basin-wide estimates to be calculated (Tyson et al. 2006; FTG 2001, 2017). To estimate forage abundance, species are first enumerated by age class in each trawl based on total length. Trawls are then filtered to remove catches where the trawl net was damaged or hung on the bottom. Since 2009, trawls beginning with bottom dissolved oxygen <2.0 mg/L have also been removed as an "interim policy" to deal with hypoxia (FTG 2012). Catches are then divided by area fished (square metres of bottom, calculated by multiplying vessel-specific wing widths from SCANMAR estimates and GPS-measured distance travelled while trawling with the net assumed to be on bottom) to yield catch/m2 (catch per effort, CPE). Arithmetic mean CPE is then converted to hectares and averaged by depth (0-6 m and >6m) and country (US/CAN) strata. CPE by strata are multiplied by strata areas and summed to yield a basin-wide total abundance and is then divided by total basin area to yield basin-wide catch per hectare.

To estimate species biomass, a similar process to abundance calculation is conducted. On deck, a minimum of 30 fish by species and age class are measured for total length. In summary calculations, a length for each unmeasured fish is randomly drawn from a normal distribution with mean and standard deviation calculated from the measured fish within the specific trawl-species-age class combination. Biomass (in grams) is then estimated for each fish (measured and unmeasured) by applying a species-age-class specific length-weight regression generated from historical data.

For reporting purposes, species are pooled into three functional groups, following Knight et al. (1984): clupeids (age-0 age classes of Gizzard Shad and Alewife), soft-rayed fish (all age classes of Rainbow Smelt, Emerald Shiner, Spottail Shiner, other leucicids, Silver Chub, Trout-Perch, and Round Goby), and spiny-rayed fish (age-0 age classes of White Perch, White Bass, Yellow Perch, Walleye and Freshwater Drum). Total forage is calculated by summing these functional groups.

2023 Results

In 2023, hypolimnetic dissolved oxygen levels were not below the 2.0 mg/L threshold (i.e., hypoxic) at any sites during the August trawling survey. Two sites were excluded due to net snags. In total, data from 71 sites were used in 2023, which is up from 69 in 2022 (Figure 2.1.3.1).

Total forage density in 2023 increased 33% from last year but remained below the ten-year mean, similar to the low to moderate abundances observed in 2019, 2020, and 2022 (Figure 2.1.3.2; Table 2.1.3.1; note that the 2021 high abundance was likely influenced by a hypoxia-induced outlier catch of forage fishes). Spiny-rayed density increased 30% from 2022. Soft-rayed species abundance doubled from 2022. Clupeid density declined from 2022, 24% lower than the previous year. Total forage density averaged 3,043 fish/ha across the West Basin, which is 35% below the ten-year mean (4,666 fish/ha). Clupeid density was 95 fish/ha (ten-year mean 683 fish/ha), soft-rayed fish density was 408 fish/ha (mean 242 fish/ha), and spiny-rayed fish density was 2,541 fish/ha (mean 3,742 fish/ha). Age-0 White Perch (63%), Yellow Perch (13%), Trout perch (5%), and Walleye (4%) made up the majority of forage fish abundance.

Total forage biomass (14.9 kg/ha; Figure 2.1.3.3) greatly increased from a low point in 2022 (10.7 kg/ha). Spiny-rayed prey biomass (13.0 kg/ha) increased 41% from the previous year. Soft-rayed forage increased slightly (1.2 kg/ha), while clupeid biomass was similar (0.8 kg/ha) but well below the ten-year mean of 4.3 kg/ha. Biomass of Age-0 White Perch (9.1 kg/ha) was near the ten-year mean (9.9 kg/ha), while Yellow Perch biomass (1.1 kg/ha) was about half the ten-year mean (1.9 kg/ha). Age-0 Gizzard Shad biomass was similar (0.8 kg/ha) to recent years.

Recruitment of individual species remains highly variable in the West Basin (Table 2.1.3.2). Age-0 Walleye density in 2023 (132/ha) was again above the ten-year mean (106/ha; Figure 2.1.3.4). Age-0 Yellow Perch density (381/ha; Figure 2.1.3.4) was well below recent densities and was well under the ten-year mean (601/ha). Age-0 White Perch density (1,912/ha) was well below the ten-year mean (2,844/ha) in 2023 (Figure 2.1.3.5). Age-0 Gizzard Shad density (94/ha) remained well below the ten-year mean (682/ha), continuing a trend of low abundance (Figure 2.1.3.5). Densities of age-0 (0.2/ha) and age-1+ Emerald Shiners (0/ha) were again nearly non-existent, with minimal densities for eight straight years (Figure 2.1.3.6). Round Goby (all ages) continued a two-year decline in density (15/ha). Age-0 Mimic Shiner density was again unusually high at 61/ha (ten-year mean = 8/ha). Age-0 Silver Chub (35/ha), Age-0 Trout perch (156/ha), and age-1+ Trout perch (53/ha) were all notably above regular densities.

2.1.4 West Basin Status of Forage – Michigan (J.-M. Hessenauer)

Michigan initiated a trawling program to assess the forage and age-0 sportfish community in Michigan waters of Lake Erie in August of 2014. This assessment samples eight two-minute index grids for one five- or ten-minute tow, typically sampling an area of approximately 0.2–0.4 ha depending on tow time. Our otter trawl has a 10-meter head rope and 9.5-mm terminal mesh and is deployed with a single warp and 45.7-meter bridle. In 2023 all eight sites were sampled on August 7th, 8th, and 9th, 2023. Additionally, information on the consumption of forage species is obtained by sampling the diets of adult Walleye captured as part of the trawl survey as well as our annual gill net survey. Our gill net survey occurred during October 2nd–5th, 2023.

The 2023 trawl survey captured 2,440 forage sized fish per ha trawled, the fourth highest catch in the ten-year time series and a 68% increase in total catch compared year over year to 2022 (Figure2.1.4.1; Table 2.1.4.1). Age-0 White Perch (1547 per ha trawled) and age-0 Yellow Perch (365 per ha trawled) were the two most abundant species in the catch (Table 2.1.4.1 & 2.1.4.2). White Perch were up nearly 83% year over year from 2022, though Yellow Perch were only up about 5% compared with 2022. We captured 17 Emarald Shiners per ha trawled, up 114% from 2022 and 81% when compared to the 2014-2022 average. Spottail Shiner increased 50.4% from 2022 to their highest catch in our time series. Gizzard Shad were up 77% from their catch in 2022, though still 27% below the 2014-2022 series average. Silver Chub were caught in 2023 at a rate of 34.6 per ha trawled, the highest rate we have observed during the ten-year time series. Silver Chub were up 606% from last year and 81% from the 2014-2022 mean. Age-0 Walleye catch was 25.5 fish per hectare down about 16% from 2022 and 1% below the 2014-2022 mean (Table 2.1.4.2).

Other interesting observations included the first ever detection of Alewife during our time series at 2 per ha trawled, and the largest observed capture of Channel Darter at 3.7 per ha trawled.

2.2: Report on the use of forage fish in the diets of selected commercially or recreationally important Lake Erie predator fish.

2.2.1 Black Bass

West and Central Basin – Ohio (Z. Slagle)

Smallmouth bass diet percent occurrence (n = 54) in 2023 was dominated by Round Goby (74%), which is typical for the species (Figure 2.2.1.1). Gizzard Shad (15%) and White Bass (7%) made up the remainder of gut contents. These data come from the ODNR Smallmouth Bass gill-net survey (September of each year in West and Central basins).

Largemouth Bass diets (n = 67) are more varied than Smallmouth Bass, with 13 distinct prey species identified in 2023 (Figure 2.2.1.2). Round Goby (39%) made up the majority of stomach contents by percent occurrence, but Emerald Shiner (13%) and *Lepomis* spp. (13%) also made significant contributions. Largemouth Bass diet data come from the ODNR nearshore electrofishing survey (June–August of each year in West and Central basins). Methods for both surveys can be found in the Appendix of the ODNR Lake Erie Data Report (Ohio Division of Wildlife 2022).

2.2.2 Lake Trout

East Basin – New York (P. Wilkins)

Lake Trout diet information was collected from fish caught during August 2023 (n = 201) in the interagency coldwater gill net assessment surveys in the East Basin of Lake Erie. Rainbow Smelt have traditionally been the main prey item for Lake Trout, typically comprising over 90% of Lake Trout diet items. However, Round Goby have become a common prey item since they invaded the East Basin of Lake Erie in the early 2000s. In years of lower adult Rainbow Smelt abundance, Lake Trout prey more on Round Goby. In 2023, Rainbow Smelt were again the prominent prey fish for Lake Trout, occurring in 63.8% of the non-empty stomachs, followed by Round Goby (44.2%; Figure 2.2.2.1). Yellow Perch (1.8%), Gizzard Shad (1.8%), Alewife (1.8%) and White Sucker (2.5%) were the only other identifiable fish species found in Lake Trout stomachs in 2023.

2.2.3 Walleye

West Basin – Michigan (J.-M. Hessenauer)

During August trawls 64% of Walleye sampled had stomach contents (Table 2.2.3.1). Unidentified fish remains (46%) were the most abundant diet items followed by White Perch (15%) and Gizzard Shad (12%). During the October gillnet survey, 48% of sampled Walleye contained food items (Table 2.2.3.2). Unidentified fish were again the most abundant prey item (42%), followed by Gizzard Shad (14%).

West and Central Basin – Ohio (Z. Slagle)

Walleye diets in the fall of 2023 were comprised mostly of Gizzard Shad (80%), typical for the time of year (Figure 2.2.3.1). Unidentified fish (16.7%) made up much of the remainder. A total of 210 Walleye stomachs were examined and empty stomachs were excluded from the analysis. These data come from the ODNR fall gill-net survey (September–October of each year in West and Central basins). Methods can be found in the Appendix of the ODNR Lake Erie Data Report (Ohio Division of Wildlife 2022).

East Basin – New York (P. Wilkins)

Beginning in 1993, annual summertime (June–August) visits were made to fish cleaning stations by the NYSDEC to gather stomach content information from angler-caught Walleye in the New York waters of Lake Erie. In 2023, 322 Walleye stomachs were examined of which only 92 (28.6%) contained food remains (Wilkins 2024a). Rainbow Smelt was the dominant (74%) walleye diet item by volume for angler-caught adult Walleye followed by Yellow Perch (14%) and Round Goby (6%; Figure 2.2.3.2). 2023 was the 3rd time in the last 10 years that smelt comprised the majority (>50% by volume) of the diet. Also of note was the presence of zooplankton in walleye stomachs (4% by volume) which was a rare occurrence but has been present for the past seven years.

2.2.4 Yellow Perch

Central Basin – Ohio (Z. Slagle)

Yellow Perch stomach contents were collected in the Central Basin from fish captured in the ODNR bottom trawl survey (June-October in the Central basin). Yellow Perch diets shifted seasonally, although spiny water flea were important throughout the season. In June, spiny water flea (35%) and midges (35%) made up most of Yellow Perch diet frequency of occurrence (n = 46; Figure 2.2.4.1), while zooplankton made up 8%. During July and August, spiny water flea dominated diets (69%), although sample size was relatively small (n = 12). In October, spiny water flea were again prevalent (56%), with midges (20%), zooplankton (9%), and benthic invertebrates (9%) also important (n = 27).

2.3: Describe growth and condition of selected commercially or recreationally important Lake Erie predator fish

2.3.1 East Basin Predator Growth (P. Wilkins)

Walleye and Yellow Perch

Walleye length at age-1 and age-2 from netting surveys targeting juveniles in New York has declined for the past seven years. Growth for both age-1 and age-2 walleye decreased in 2023 and remain 45 and 40 mm below the long-term average length, respectively, and ranked the lowest in the 43-year time series (Wilkins 2024b). Age-0 and age-1 Yellow Perch sampled in fall trawl surveys in New York have exhibited stable growth rates since 2006. In 2023, age-0 Yellow Perch equaled the time series average of 80 mm while age-1 Yellow perch (150 mm) also equaled the time series average (Markham and Wilkins 2024).

Adult Walleye condition in the New York waters of Lake Erie had generally been trending down over the last decade. In 2023 the relative weight of the average 18–24 inch walleye was 82, slightly below the time series average of 85 (Murphy et al. 1990; Figure 2.3.1.1). Decreasing weight at length may indicate a lack of suitable forage in recent years, especially Smelt, and increasing predator demand.

Lake Trout

Adult Lake Trout condition in the East Basin of Lake Erie has generally remained stable over the past 10 years (Figure 2.3.1.2). A decline in both length and weight at age-5 was evident in 2023 and consistent with changes in the forage community.

2.3.2 West and Central Basin Predator Growth (Z. Slagle)

Age-0 Sportfishes

Overall, mean length of age-0 sport fish in 2023 from the West Basin interagency trawl were similar to 2022 (Figure 2.3.2.1). Lengths of select age-0 species in 2023 include Walleye (115 mm), Yellow Perch (67 mm), White Bass (71 mm), and White Perch (66 mm). Walleye average length has increased four straight years from the time series low. Other sportfish lengths were above time series averages.

Walleye

Walleye total length at age-2 through age-4 declined in 2023, returning to a declining trend since ~2019 (Figure 2.3.2.2). Length at age-2 (386 mm) and age-3 (444 mm) remain below the ten-year means (410 mm and 467 mm, respectively), while length at age-4 (485 mm) was near the ten-year mean (498 mm). Length-at-age data come from the ODNR fall gill-net survey (September–October of each year in West and Central basins). Methods can be found in the Appendix of the ODNR Lake Erie Data Report (Ohio Division of Wildlife 2022).

Black Bass

Black bass (*Micropterus* spp.) total length at age-3 exhibit different patterns depending on the species (Figure 2.3.2.3). Smallmouth Bass length at age-3 has been relatively stable for over ten years; in 2023, mean total length at age-3 was 364 mm (n = 17). Largemouth Bass length at age-3 has varied widely for the eight years of data collection, with a 2023 mean total length at age-3 of 340 mm (n = 29). Length-at-age data come from two sources: the ODNR Smallmouth Bass gill-net survey (September of each year in West and Central basins) and the ODNR nearshore electrofishing survey (June–August of each year in West and Central basins). Methods can be found in the Appendix of the ODNR Lake Erie Data Report (Ohio Division of Wildlife 2022).

Table 2.1.3.1: Ten-year mean density (arithmetic mean number per hectare), 2023 density, and the percent difference between 2023 and the ten-year average for forage fish functional groups from fall trawl surveys in the West Basin Lake Erie. Data are collected by MNRF and ODNR and combined using FPC factors.

Functional Group	Mean: 2012–2022	2023	+/-
All forage species	4666	3042.9	-34.8%
Clupeid	682.7	94.8	-86.1%
Soft-rayed	241.5	407.6	+68.8%
Spiny-rayed	3741.8	2540.6	-32.1%

Table 2.1.3.2: Ten-year mean density (arithmetic mean number per hectare), 2023 density, and the percent difference between 2023 and the ten-year average for selected forage species from fall trawl surveys in West Basin Lake Erie. Data are collected by MNRF and ODNR and combined using FPC factors.

Species	Age class	Mean: 2012–2022	2023	+/-
Emerald shiner	Age-0	33.8	0.2	-99.4%
Emerald shiner	Ages-1+	36.5	0	-100%
Freshwater drum	Age-0	104.4	61	-41.6%
Gizzard shad	Age-0	682.3	94.2	-86.2%
Rainbow smelt	Age-0	36.4	63.5	74.5%
Rainbow smelt	Ages-1+	0.3	0.7	133.3%
Round goby	All ages	28.3	15.3	-45.9%
Walleye	Age-0	106.3	132.5	24.6%
White bass	Age-0	86.6	53.5	-38.2%
White perch	Age-0	2843.6	1912.3	-32.8%
Yellow perch	Age-0	600.9	381.4	-36.5%

Table 2.1.4.1: Average density (number of fish per ha) of select forage sized fish captured during the Michigan trawl survey. Age group for each species presented in first row. Yr/Yr% is the percent change from 2022 to 2023. Yr/2014-2022% is the percent change from 2023 to the 2014-2022 average.

	White Perch	Mimic Shiner	Gizzard Shad	Trout-Perch	Round Goby	Spottail Shiner	Silver Chub	Emerald Shiner	Dreissenid Mussels
Age Group/Year	YOY	All	YOY	All	All	All	All	All	All
2014	715.5	5.3	55.4	25.6	43.4	54.2	0	2.1	0.41
2015	783.2	617.9	2.7	16.8	135.8	18.8	11.3	0	0.55
2016	448.5	170.6	11.4	68.8	19.2	26.6	0.6	0	0.81
2017	1,896.4	120.2	730.9	62.1	41.4	2.2	3.4	0	0.45
2018	8,100	40.1	259.4	290.4	58.6	6.3	5.9	7.2	0.6
2019	389.1	141.5	0.5	19	24.7	10.6	5.2	11.4	0.66
2020	1,193.8	53	15.2	25.4	125.7	24.2	21.6	0	0.68
2021	1,633.3	6	40.9	75.3	84.1	57.7	5.8	0	0.53
2022	846.5	6.3	58.2	60.7	9	73.8	4.9	7.9	0.47
2023	1,546.9	33.2	102.9	117.9	13.2	111	34.6	16.9	1.02
Yr/Yr %	82.7	427.0	76.8	94.2	46.7	50.4	606.1	113.9	117.0
Yr/ 2014-2022 %	-15.0	-288.5	-26.8	39.3	-356.1	72.5	81.1	81.2	43.8

*Dreissenid mussels reported as kilograms captured per ha trawled and are not included in the Grand Total catch per ha values.

Table 2.1.4.2: Average density (number of fish per ha) of select age-0 sportfish captured during the Michigan trawl survey. Yr/Yr% is the percent change from 2022 to 2023. Yr/2014-2022% is the percent change from 2023 to the 2014-2022 average.

	Yellow Perch	Walleye	White Bass	Smallmouth Bass
2014	129.5	0.6	1.2	5.4
2015	335.8	4.8	7	0.3
2016	424.4	3	8.4	1.9
2017	331.6	16.6	101.8	0
2018	1683	50.3	48.2	3.2
2019	1291	68.5	15.5	0
2020	675.2	31.9	11.4	59.9
2021	2723.5	25.6	9.3	14
2022	348.7	30.3	5.3	0.5
2023	365.2	25.5	40.9	2.1
Yr/Yr %	4.7	-15.8	671.7	320.0
Yr/ 2014-2021 %	-58.6	-0.9	76.9	-77.8

Table 2.2.3.1: Diet composition of Walleye sampled by year during the Michigan August trawl survey. Table represents the number of fish sampled, the percent with stomach contents (% With contents), and of fish with stomach contents the percent of prey items that were Gizzard Shad (% G. Shad), White Perch (% White Perch), Mimic Shiner (%Mimic Shiner) Yellow Perch (%Yellow Perch), unidentifiable fish remains (%Unid Fish) and digested liquid (%Digested Liquid).

Year	Fish Sampled	% With Contents	% G. Shad	% White Perch	%Mimic Shiner	%Yellow Perch	%Unid Fish	%Digested Liquid
2014	15	73	62	0	0	0	33	5
2015	19	42	7	60	7	13	7	7
2016	86	64	17	9	0	7	53	14
2017	55	53	34	22	0	14	22	9
2018	18	67	23	31	0	8	38	0
2019	19	16	0	0	0	67	33	0
2020	54	43	8	4	0	0	79	8
2021	51	35	14	10	0	19	57	0
2022	26	38	5	50	0	9	32	9
2023	64	64	12	15	0	0	46	24

Table 2.2.3.2: Diet composition of Walleye sampled by year during the Michigan October gill net survey. Table represents the number of fish sampled, the percent with stomach contents (%With contents), and of fish with stomach contents the percent of prey items that were Gizzard Shad (%G. Shad), White Perch (%White Perch), Emerald Shiner (%Emerald Shiner), Yellow Perch (%Yellow Perch), Round Goby (%Round Goby), unidentifiable fish remains (%Unid. Fish) and digested liquid (%Digested Liquid). Survey not completed in 2020 due to COVID-19 restrictions.

Year	Fish Sampled	%With contents	%G. Shad	%White Perch	%Emerald Shiner	%Yellow Perch	%Round Goby	%Unid. Fish	%Digested Liquid
2007	44	66	49	11	0	0	0	40	0
2008	322	83	24	0	17	0	0	25	34
2009	136	82	10	11	0	1	0	79	0
2010	137	91	28	0	5	0	0	54	13
2011	166	88	28	1	0	0	0	24	46
2012	223	96	19	1	1	0	0	78	0
2013	160	38	33	6	6	0	0	37	17
2014	283	74	25	11	14	1	0	43	6
2015	198	61	39	1	0	0	0	37	23
2016	482	63	38	17	1	1	0	35	9
2017	319	55	33	1	0	0	0	40	25
2018	652	73	43	1	1	0	0	17	38
2019	334	57	32	19	1	0	0	14	33
2020									
2021	295	60	42	9	0	7	0	17	24
2022	404	79	66	2	0	0	0	14	17
2023	182	48	14	0	3	0	0	42	40

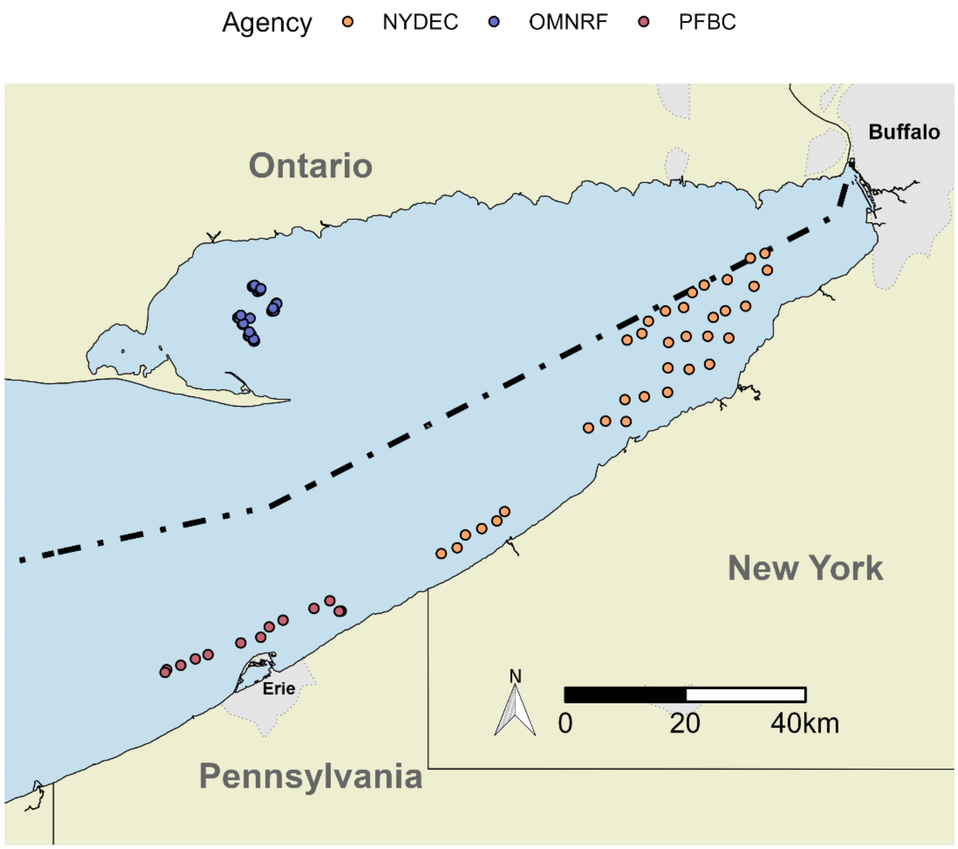


Figure 2.1.1.1. Locations of standard index bottom trawls by Pennsylvania (red), Ontario (blue), and New York (orange) to assess forage fish abundance in the East Basin of Lake Erie in 2023.

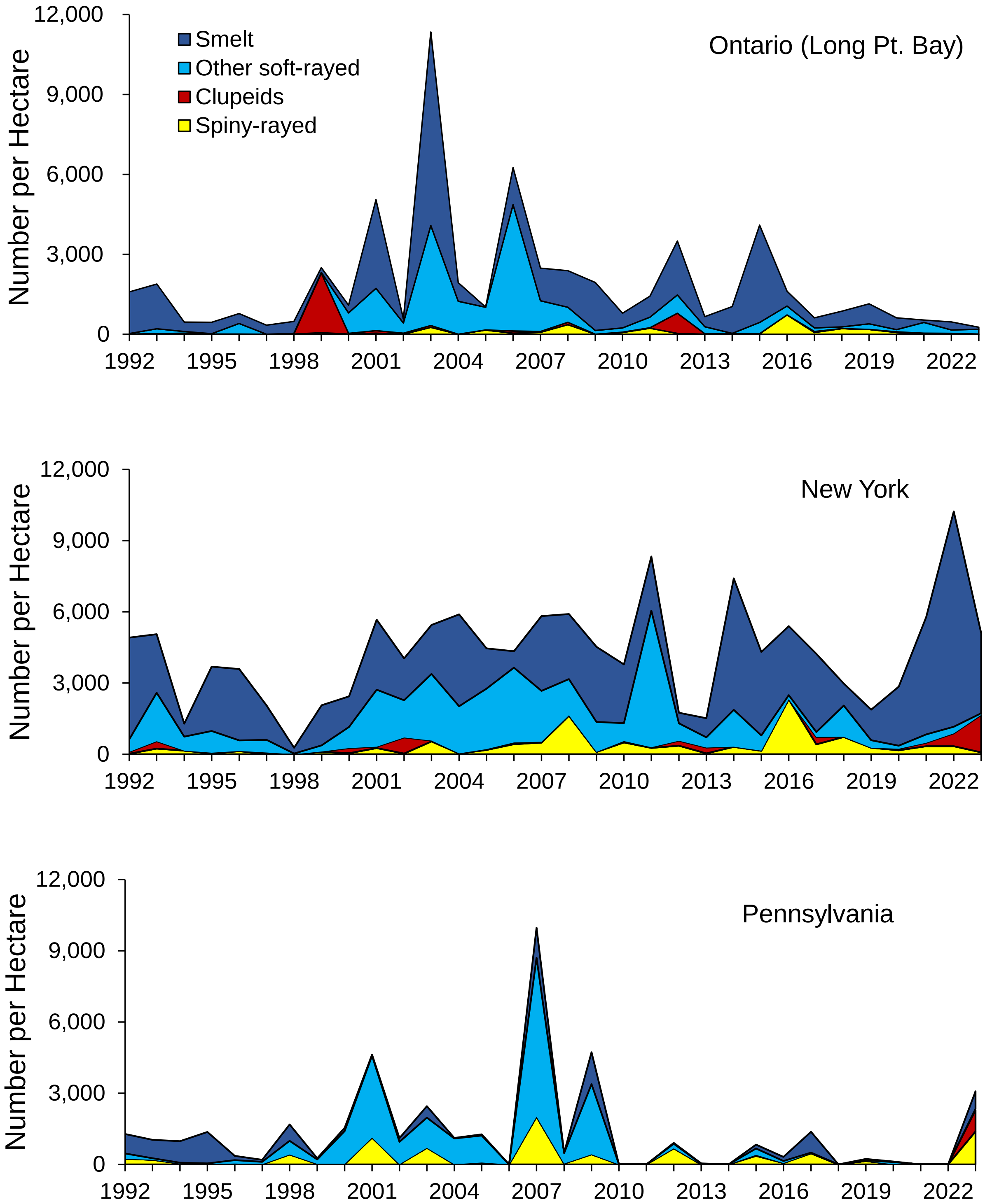


Figure 2.1.1.2: Mean density of prey fish (number per hectare) by functional group in the Ontario, New York, and Pennsylvania waters of the East Basin, Lake Erie, 1992-2023. Pennsylvania did not sample in 2006, 2010, 2011, 2013, 2014, 2018, 2021 or 2022.

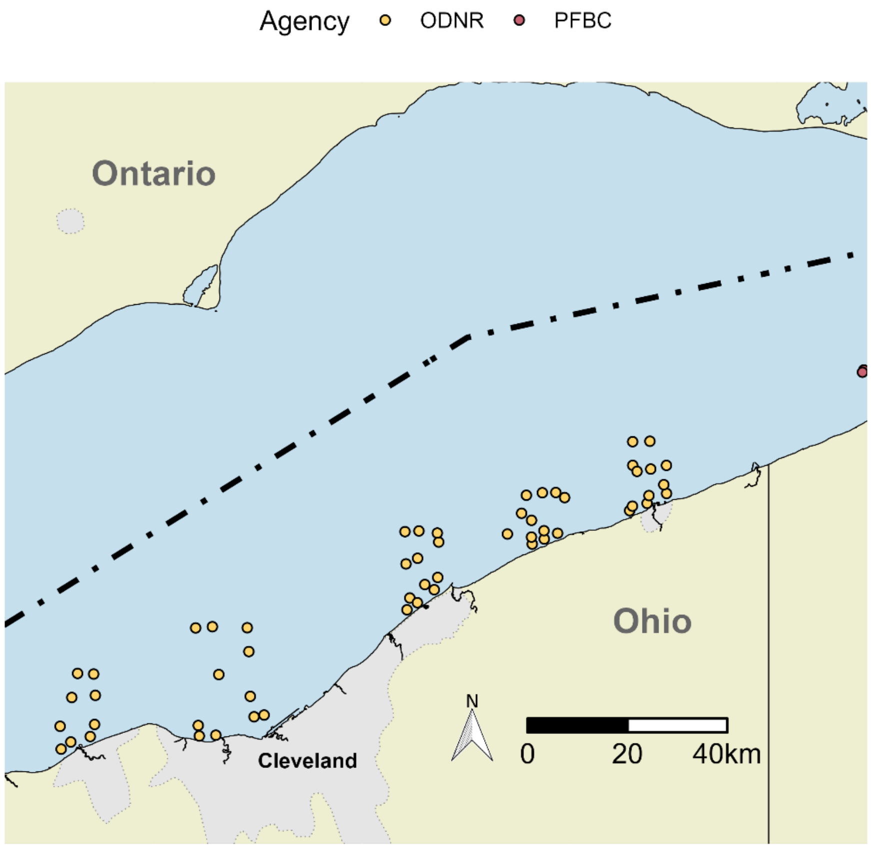


Figure 2.1.2.1. Locations sampled by Ohio (yellow) and Pennsylvania (red) with index bottom trawls to assess forage fish abundance in the Central Basin, Lake Erie during 2023.

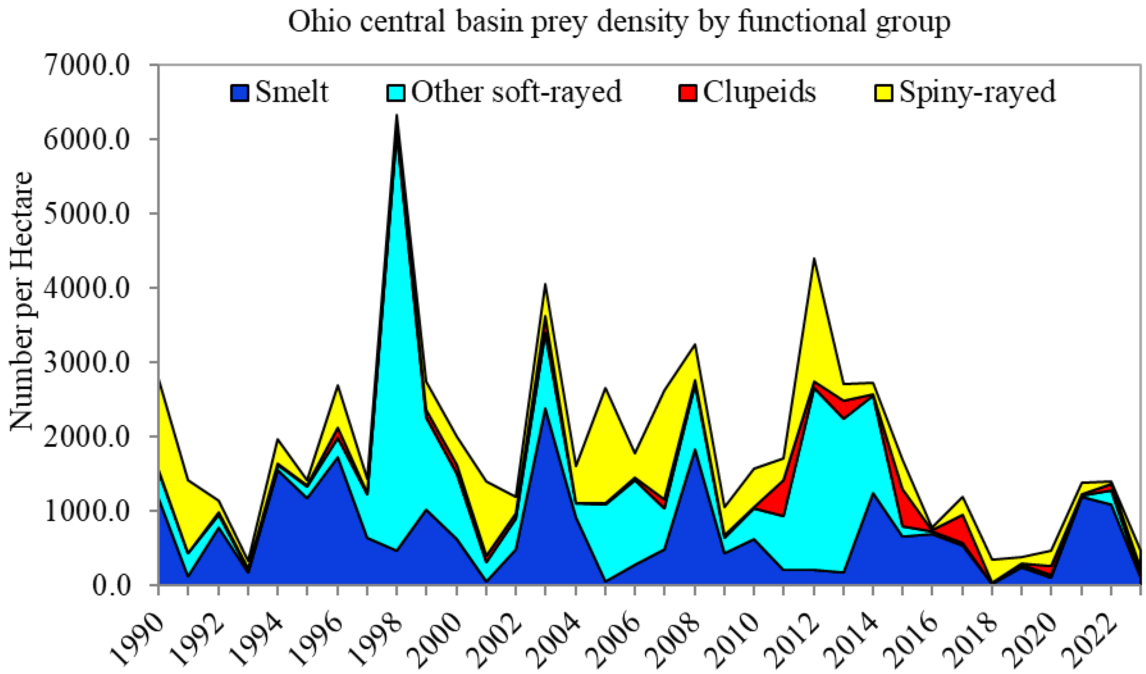


Figure 2.1.2.2: Mean density of prey fish (number per hectare) by functional group in Ohio waters of the Central Basin, Lake Erie, 1990–2023.

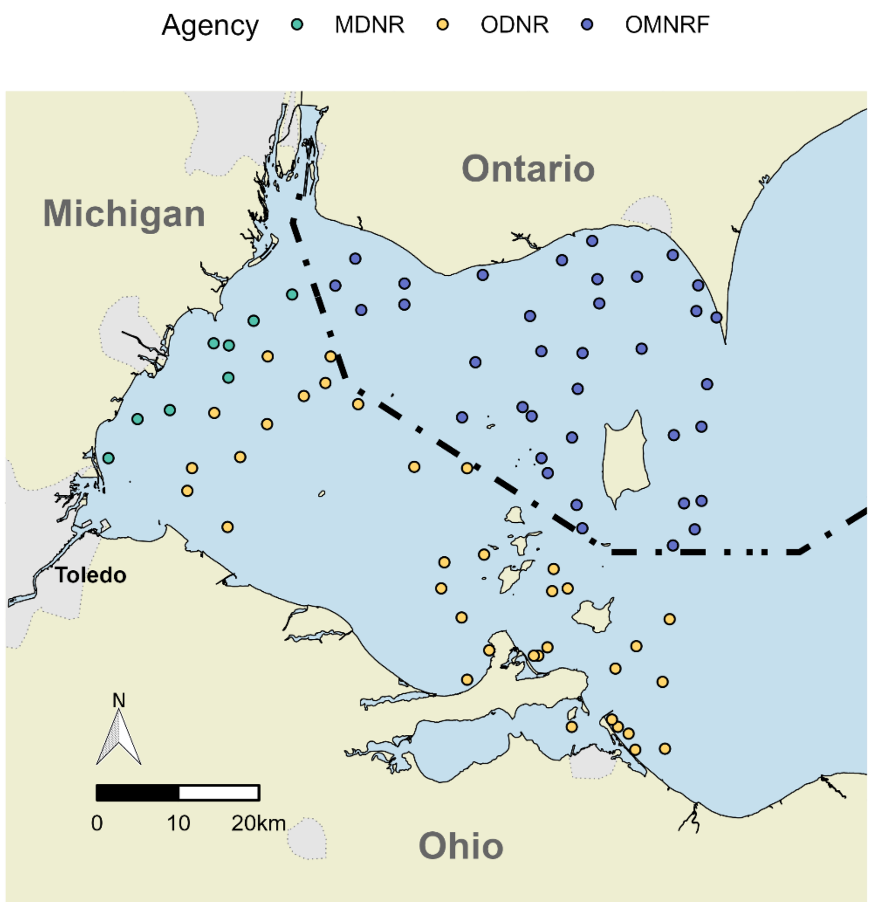


Figure 2.1.3.1: Trawl locations for West Basin bottom trawl surveys in 2023. Ohio (yellow) and Ontario (blue) surveys are combined to summarize the interagency indices, while Michigan (green) cannot yet be included due to lacking trawl comparison data.

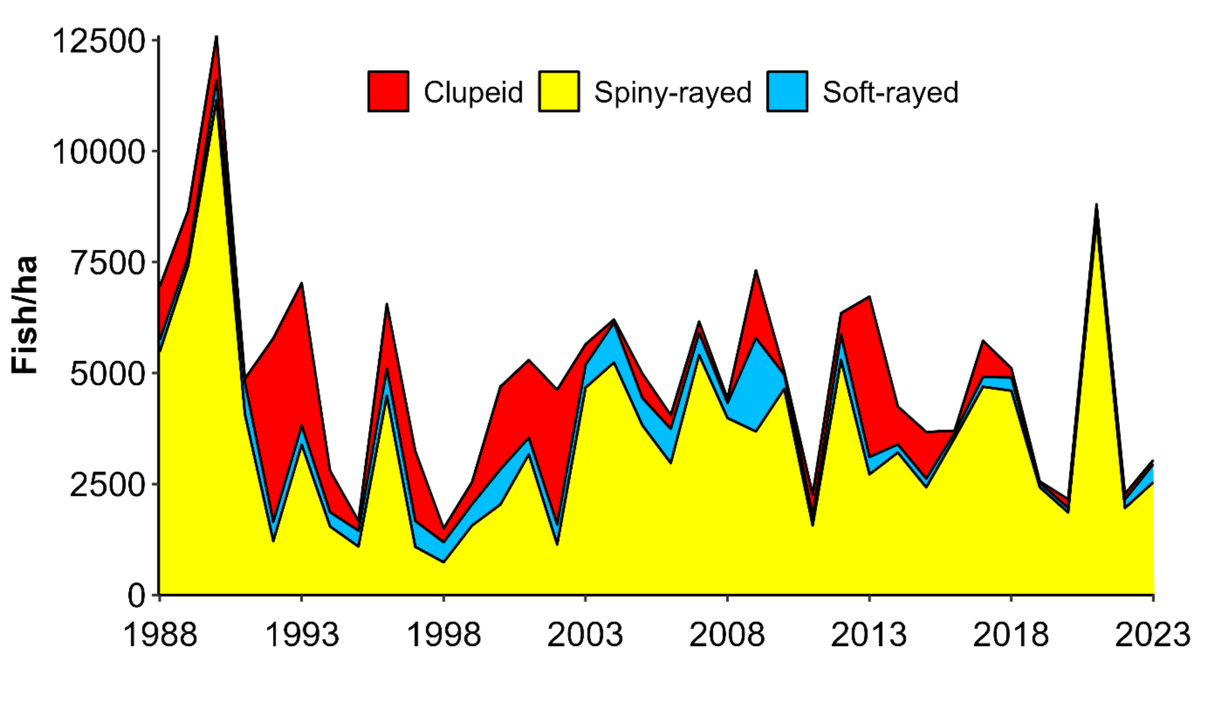


Figure 2.1.3.2: Mean density (number per hectare) of prey fish by functional group in the West Basin of Lake Erie, August 1988–2023.

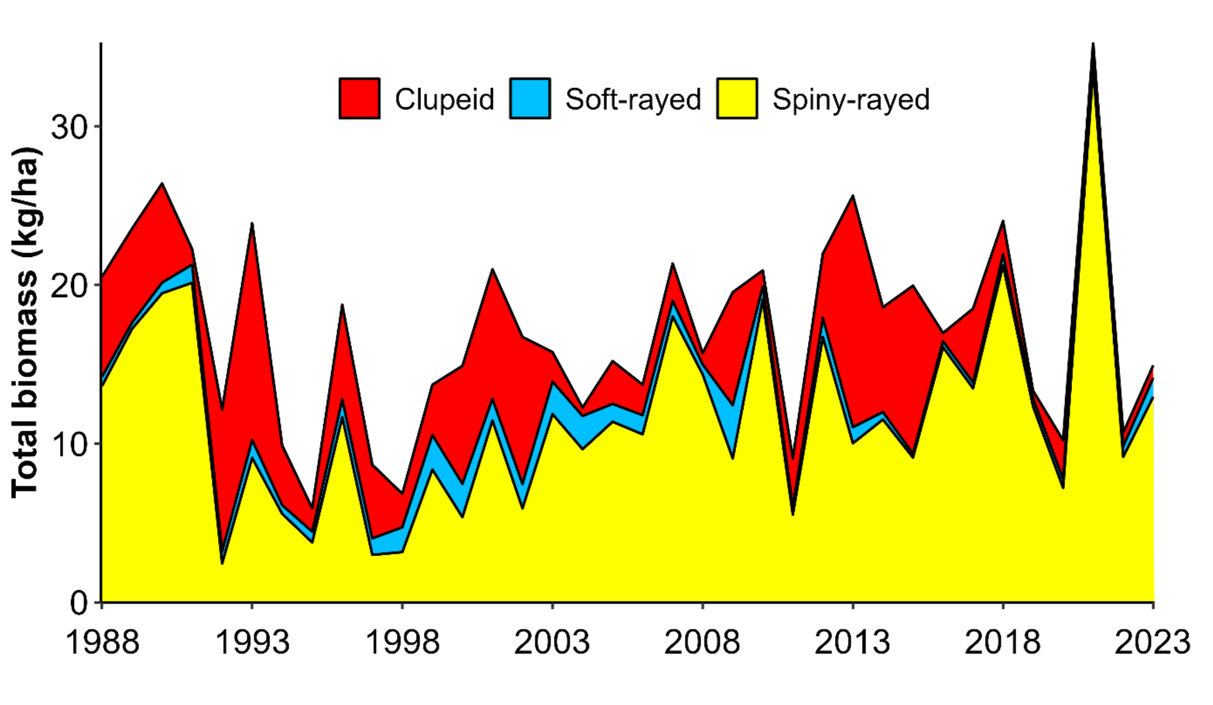


Figure 2.1.3.3: Mean biomass (kilograms per hectare) of prey fish by functional group in the West Basin of Lake Erie, August 1988–2023.

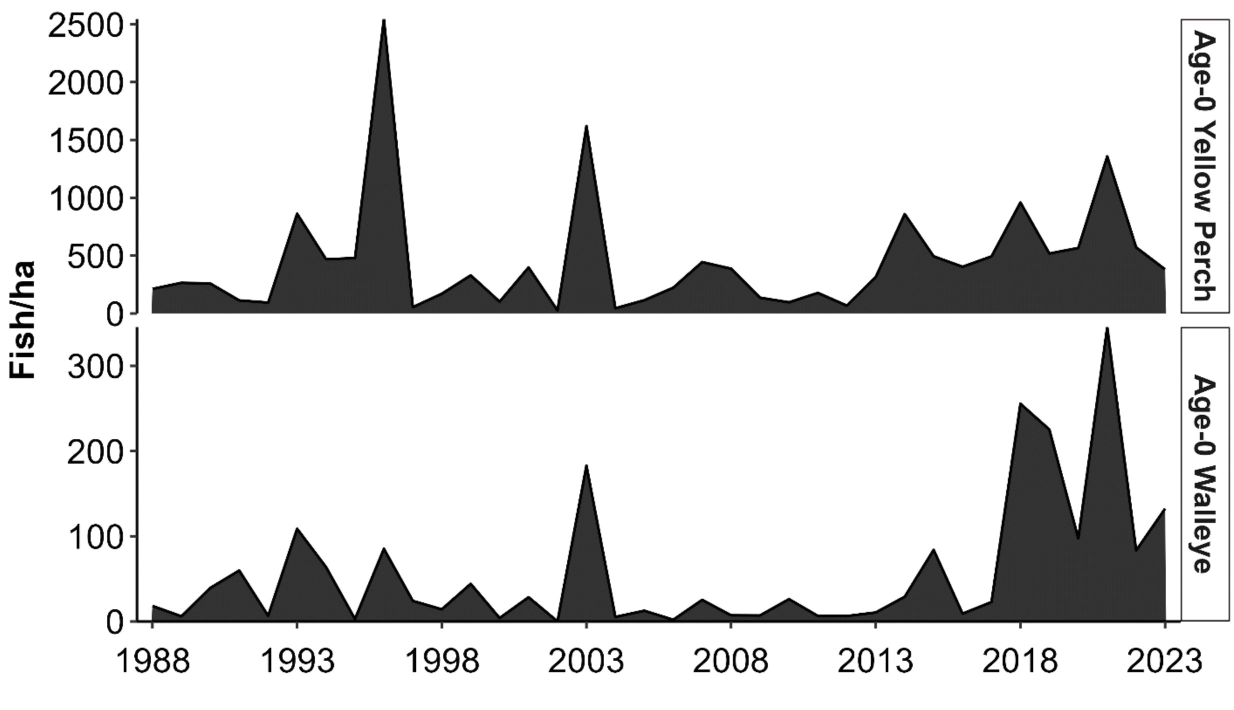


Figure 2.1.3.4: Densities of age-0 Yellow Perch (top) and age-0 Walleye (bottom) in the West Basin of Lake Erie, August 1988–2023. Note that the Y-axis scales differ.

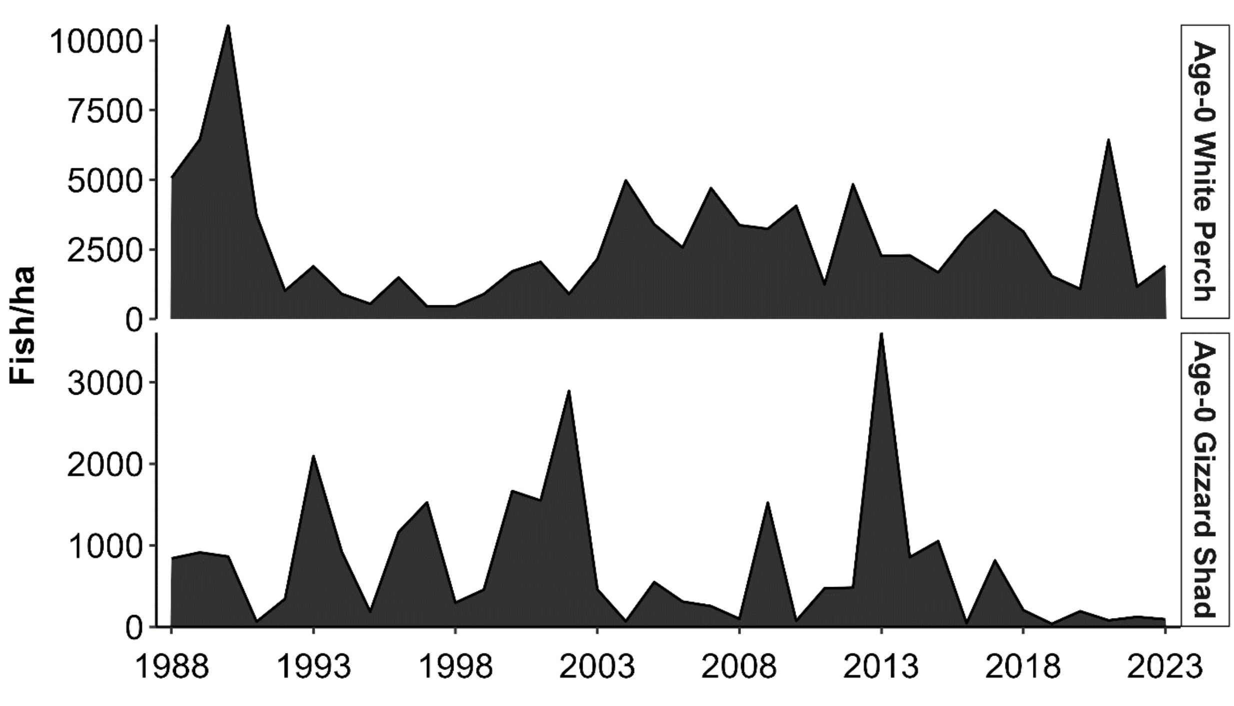


Figure 2.1.3.5: Densities of age-0 White Perch (top) and age-0 Gizzard Shad (bottom) in the West Basin of Lake Erie, August 1988–2023. Note that the Y-axis scales differ.

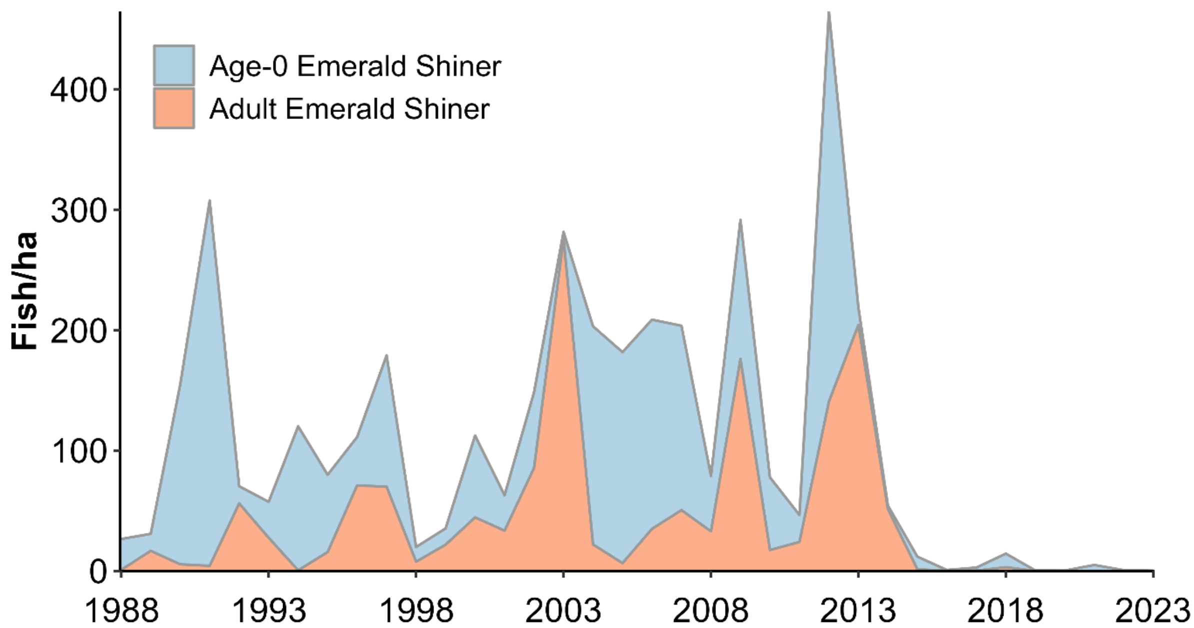


Figure 2.1.3.6: Densities of age-0 (blue) and age-1+ (red) Emerald Shiner in the West Basin of Lake Erie, August 1988–2023. Densities for both groups have remained minimal for eight years.

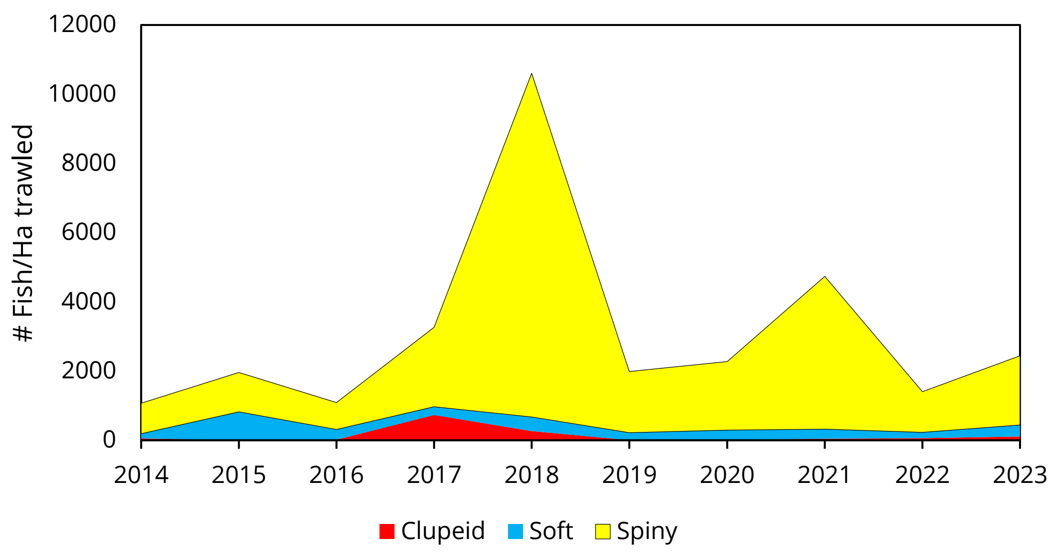


Figure 2.1.4.1: Mean density (number per hectare) of prey fish by functional group in Michigan waters of Lake Erie, August 2014–2023.

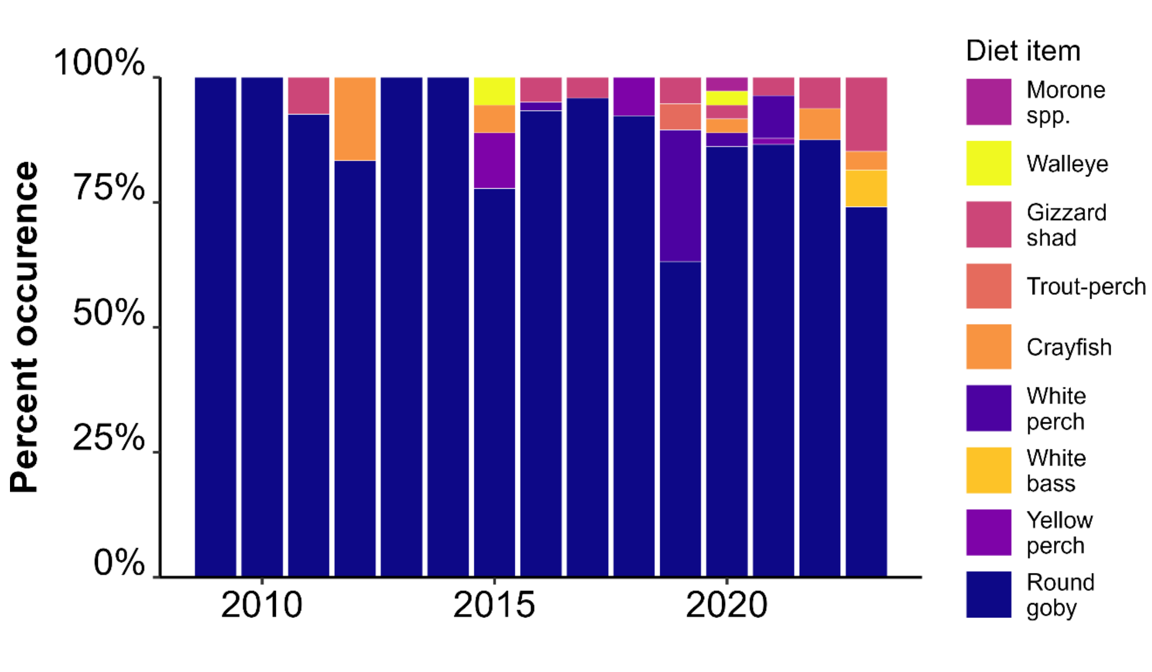


Figure 2.2.1.1: Percent occurrence of diet items from non-empty stomachs of Smallmouth Bass collected in West and Central Basin gill-net assessments in September 1998–2023.

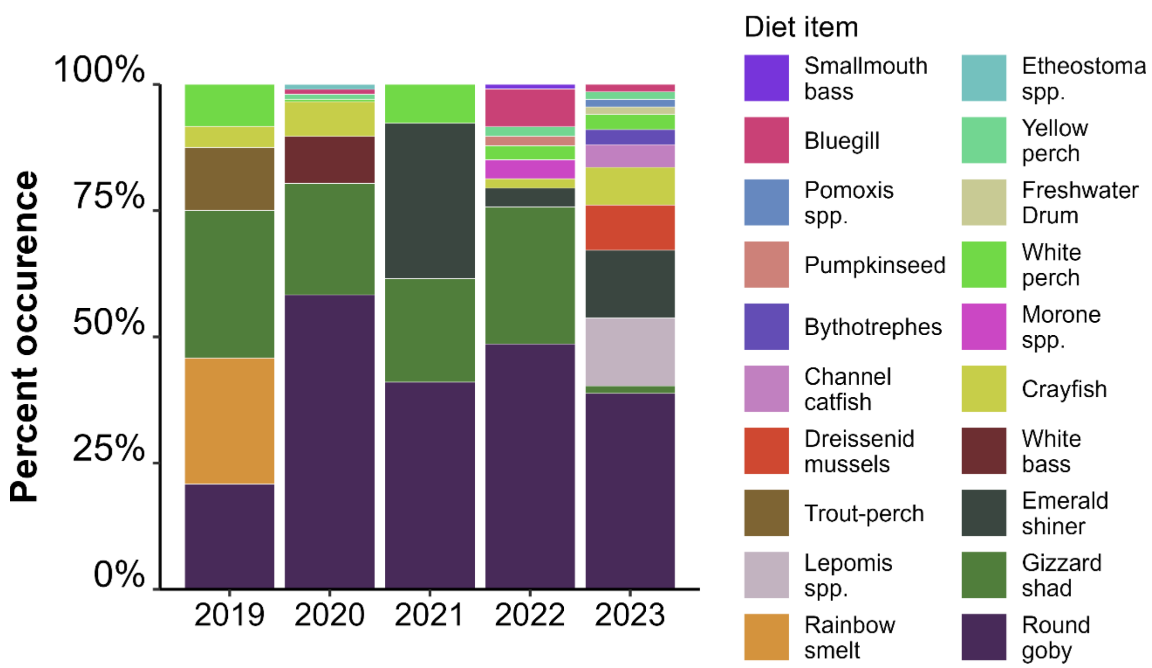


Figure 2.2.1.2: Percent occurrence of diet items from non-empty stomachs of Largemouth Bass collected in West and Central Basin electrofishing assessments, June–August 2019–2023.

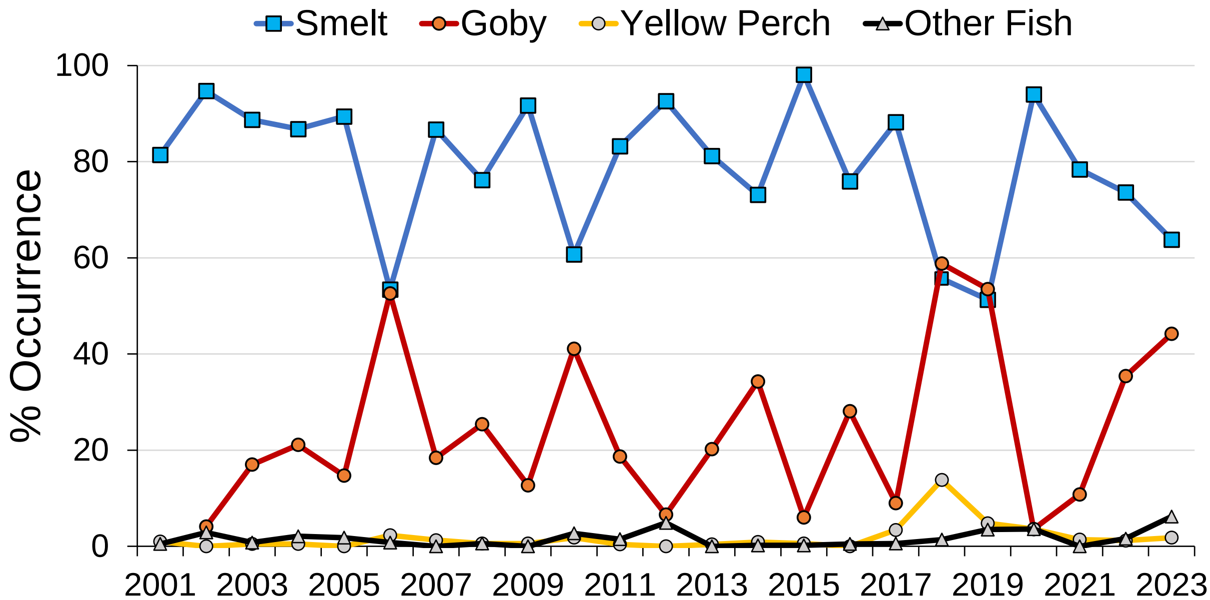


Figure 2.2.2.1: Percent occurrence of diet items from non-empty stomachs of lean strain Lake Trout collected from gill net assessment surveys in the East Basin of Lake Erie, August 2001-2023.

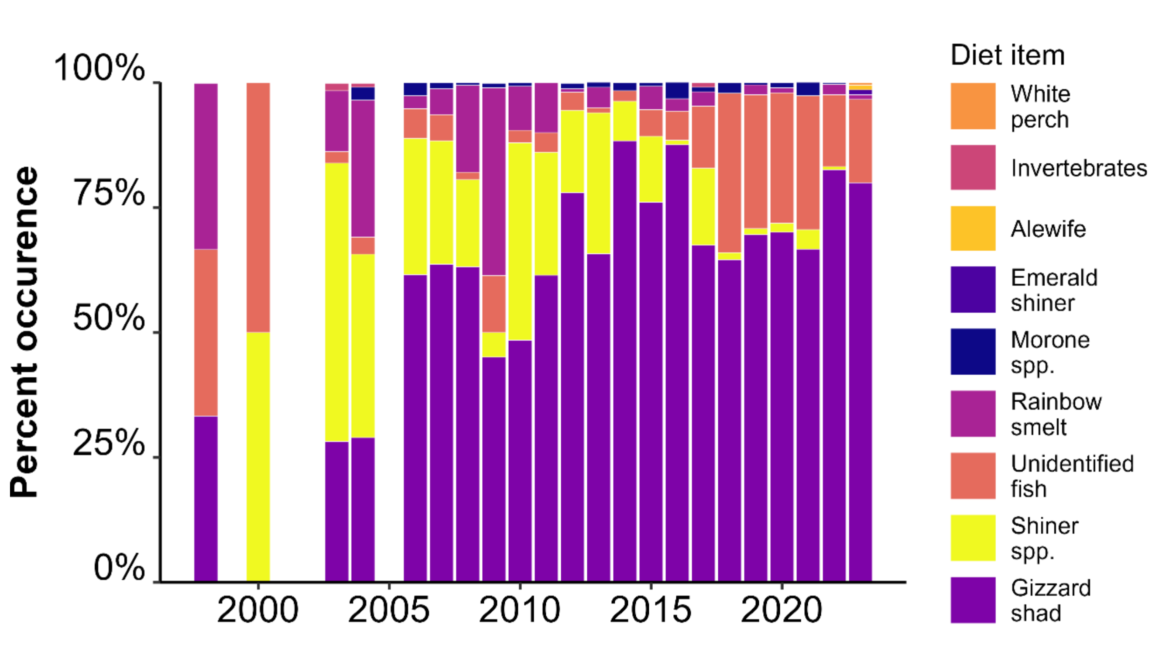


Figure 2.2.3.1: Percent occurrence of diet items from non-empty stomachs of Walleye collected in West and Central Basin gill-net assessments, September–November, 1998–2023.

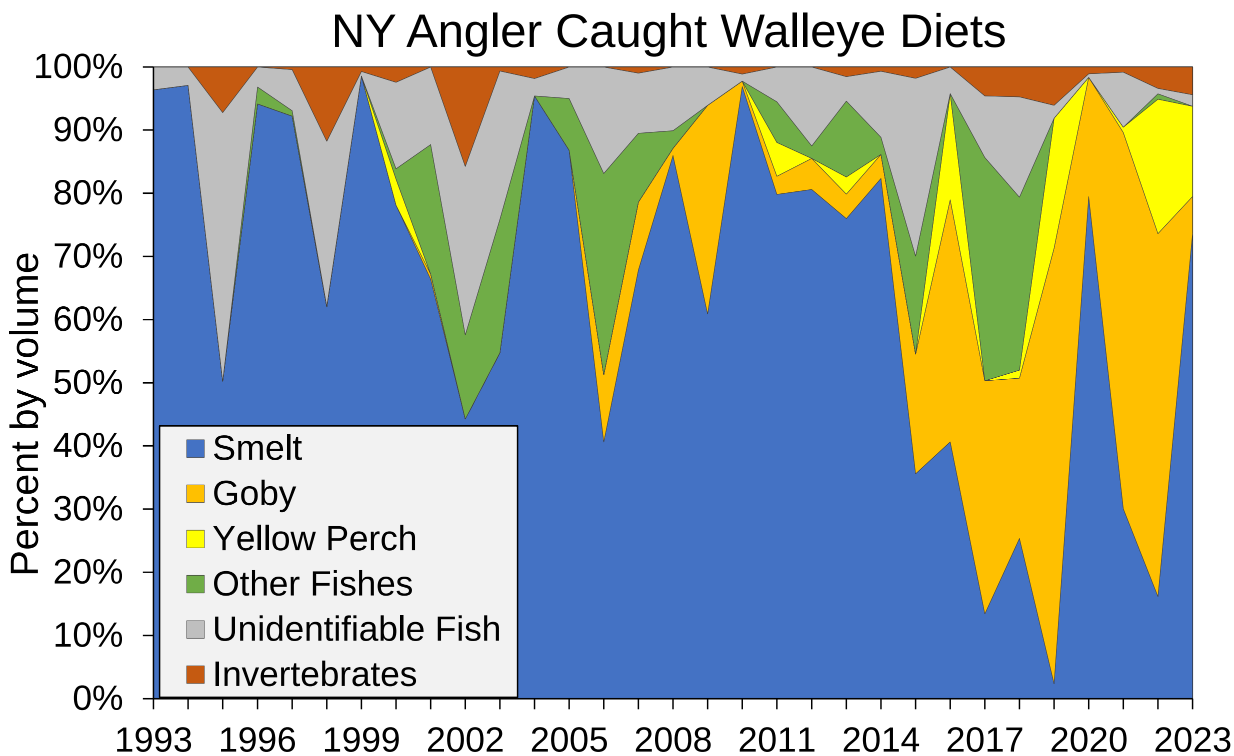


Figure 2.2.3.2: The percent contribution (by volume) of identifiable prey in non-empty stomachs of adult Walleye caught by anglers in New York's portion of Lake Erie, June–August 1993–2023.

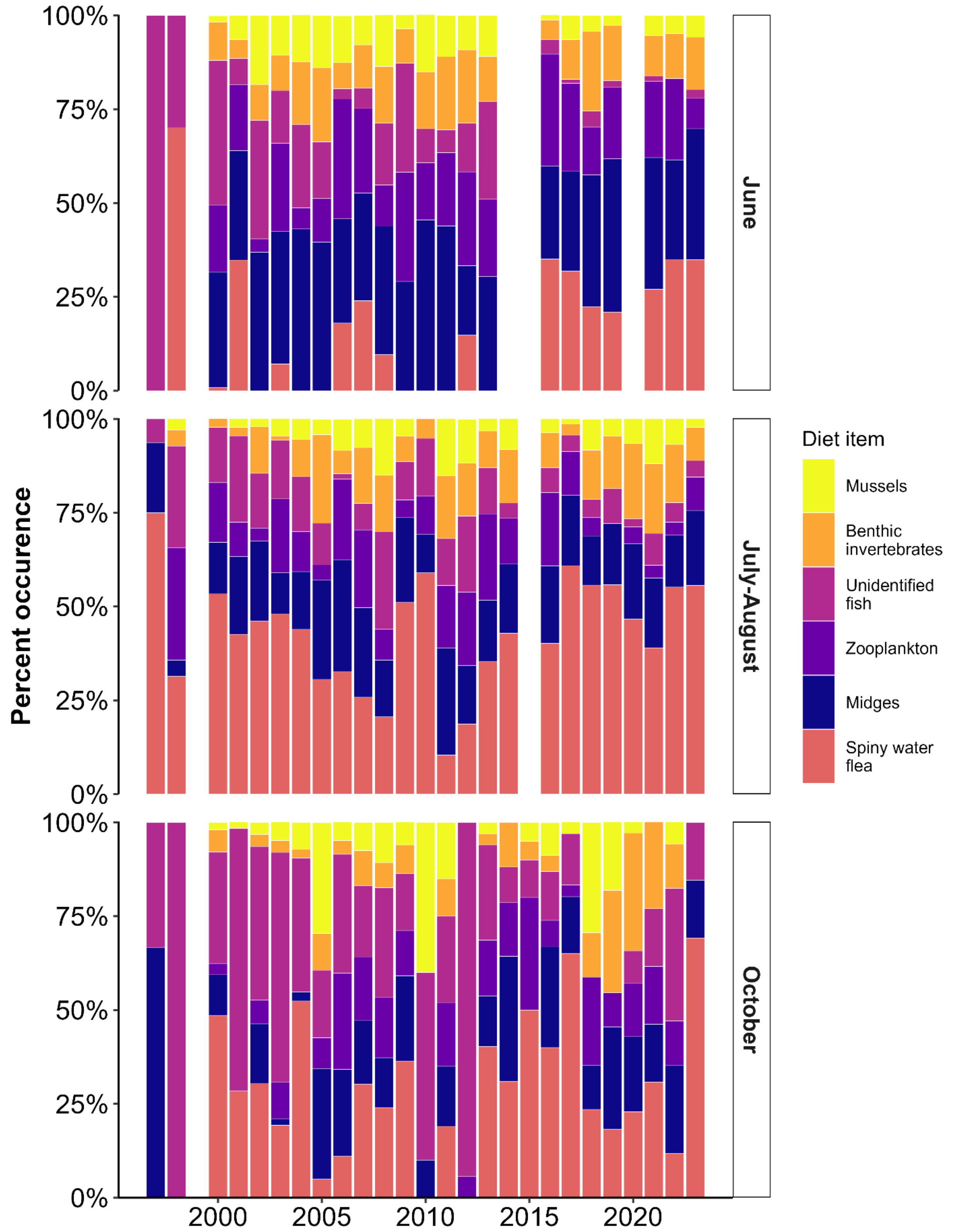


Figure 2.2.4.1: Percent occurrence of diet items from non-empty stomachs of Yellow Perch collected in Central Basin trawl survey, June–October, 1997–2023.

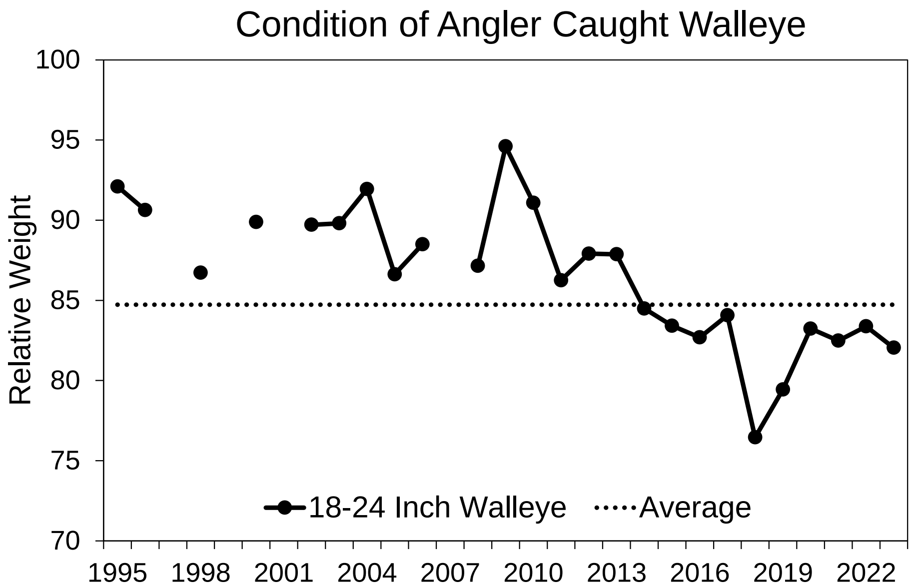


Figure 2.3.1.1: Relative weight of angler-caught walleye in the New York waters of Lake Erie at 18–24 inches from 1995-2023.

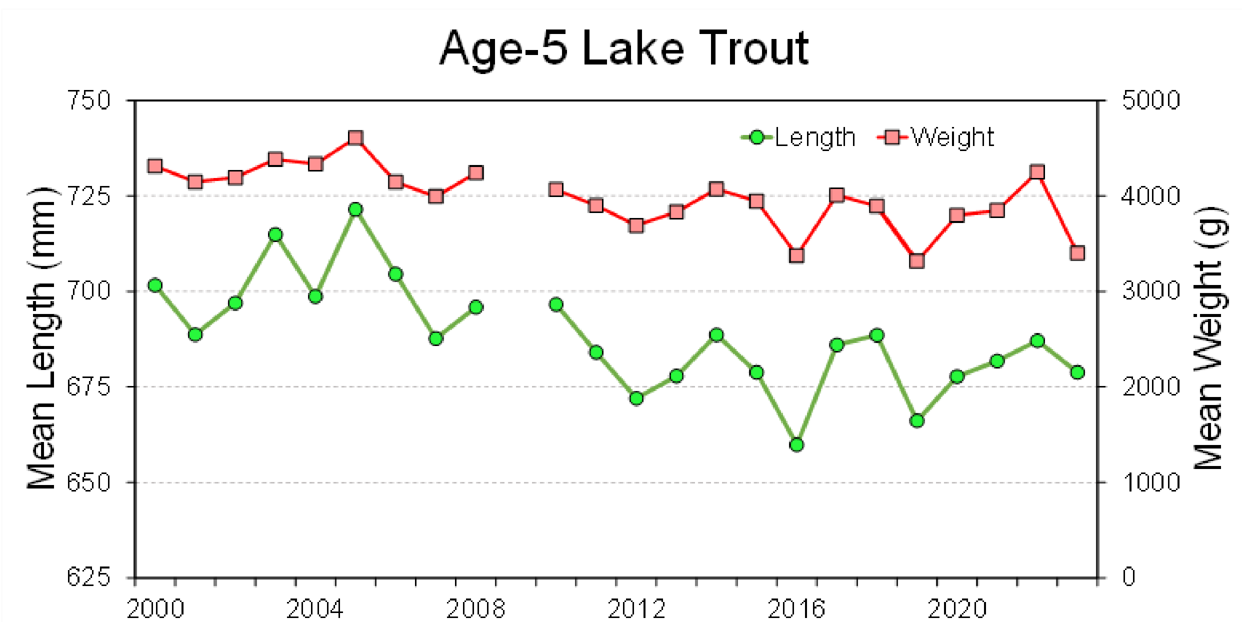


Figure 2.3.1.2: Mean length (mm) and weight (g) of age-5 lean strain Lake Trout caught in gill net assessment surveys from the East Basin of Lake Erie, August 2000–2023.

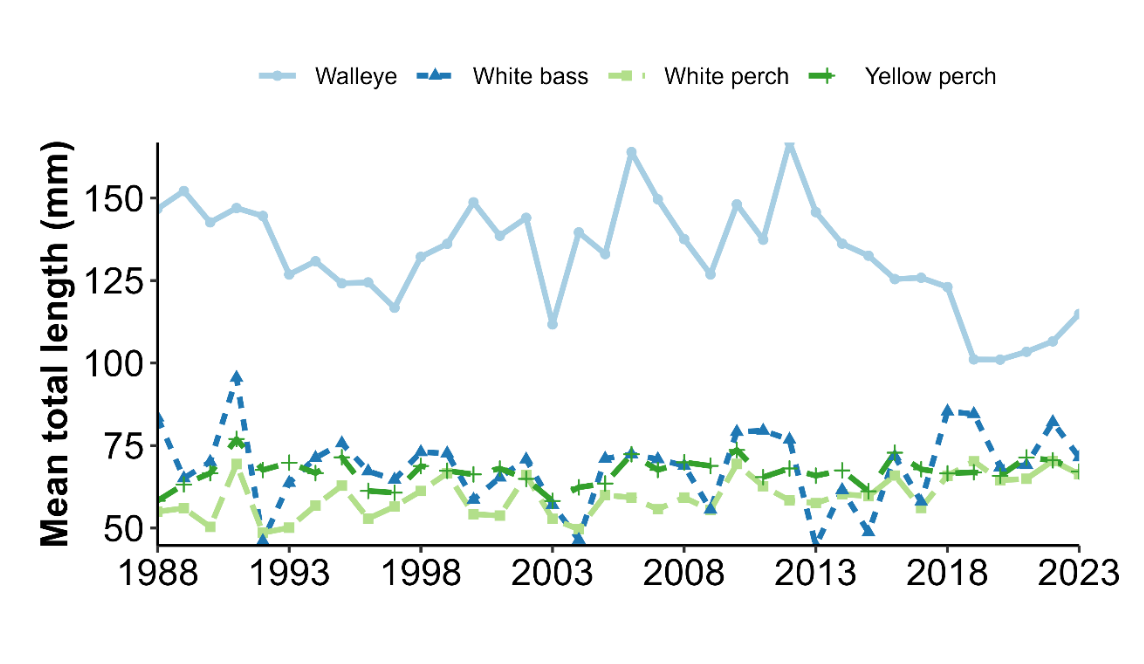


Figure 2.3.2.1: Mean total length of select age-0 fishes in West Basin Lake Erie, August 1988–2023. Data are from the interagency trawl.

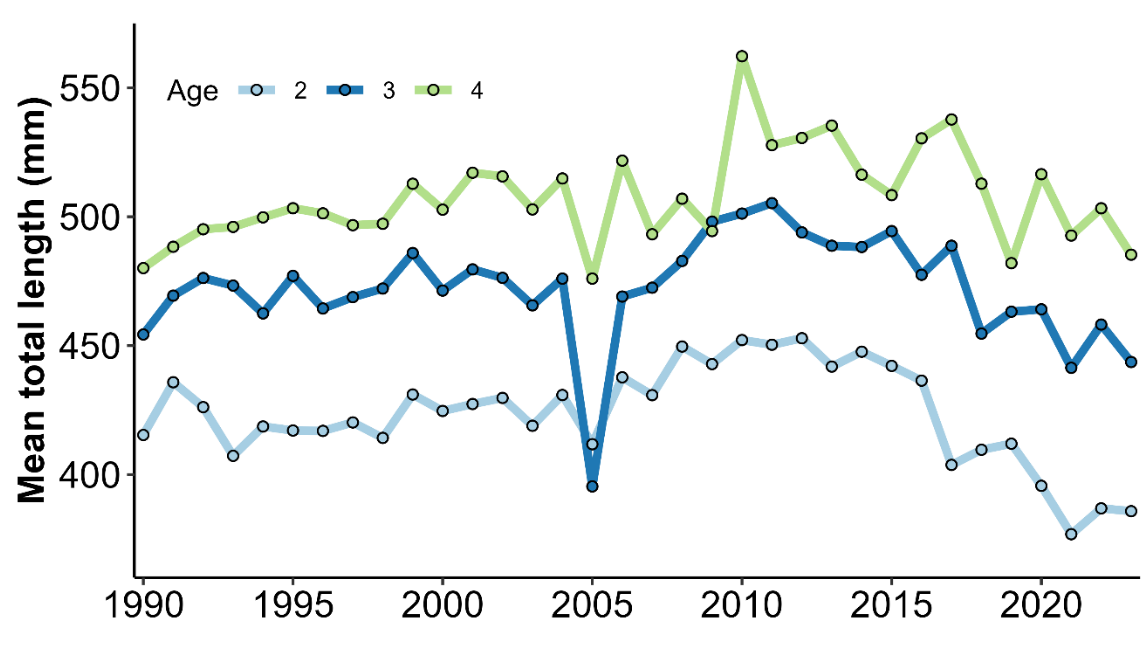


Figure 2.3.2.2: Mean total length of Walleye (ages 2–4) in West and Central basins of Lake Erie, 1988–2023. Data are from the ODNR fall gill net survey (September–November).

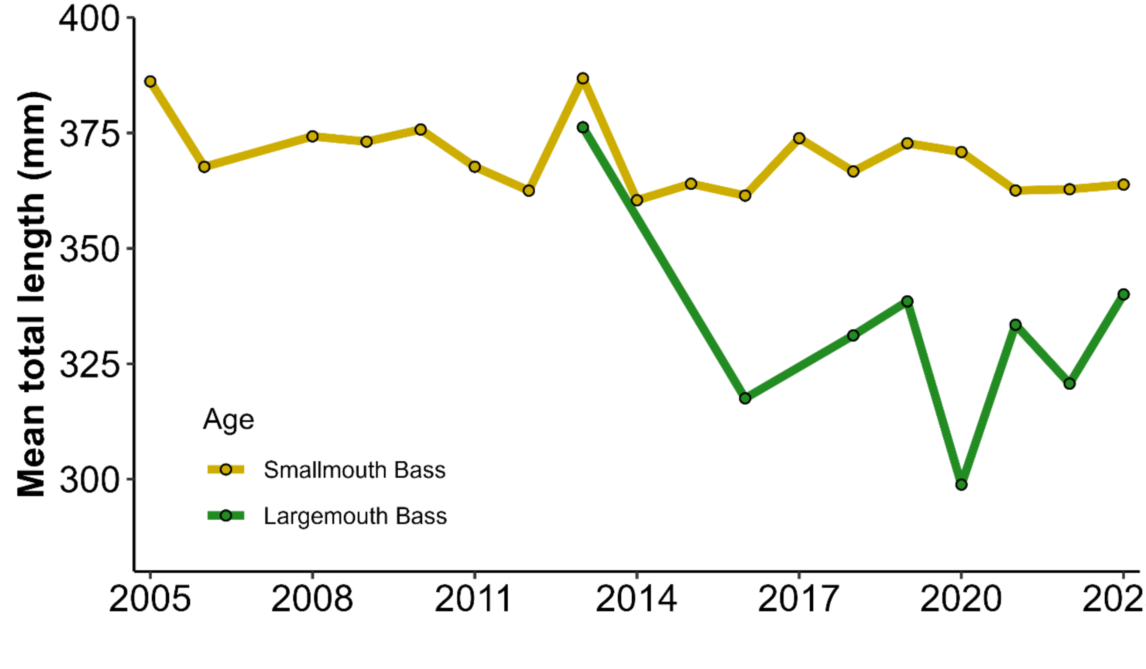


Figure 2.3.2.3: Mean total length of age-3 black basses in West and Central basins of Lake Erie, 2005–2023. Data are from ODNR surveys: gill net (Smallmouth Bass, September) and electrofishing (Largemouth Bass, June–August).

Charge 3: Continue hydroacoustic assessment of the pelagic forage fish community in Lake Erie, while incorporating new methods in survey design and analysis following the GLFC's Great Lakes Hydro Acoustic Standard Operating Procedures where possible/feasible.

3.0 Hydroacoustic Surveys in Lake Erie (M. DuFour, J. Holden, H. Luken)

Introduction

Lake Erie hydroacoustic surveys estimate important forage fish densities including Gizzard Shad and Emerald Shiner in the West Basin (WB), Rainbow Smelt and Emerald Shiner in the Central Basin (CB), and Rainbow Smelt in the East Basin (EB). Historical survey designs were based on cross-lake transects that routinely experienced challenges that inhibited survey completion. In 2022, hydroacoustic surveys across the three basins implemented a new standardized whole-lake approach following a multi-year survey evaluation and redesign process. The new stratified-random grid approach reduces the overall survey effort, emphasizes data collection in strata with the greatest variability, and provides greater operational flexibility. A thorough description of historical surveys and the redesign process can be found in FTG (2022). Implementation and evaluation of the standardized whole-lake survey design continued during 2023.

Methods

The whole-lake survey design uses a stratified approach within each of the three basins (Fig. 3.0.1). Each basin is subdivided into smaller strata based in part on depth, water quality characteristics, forage species compositions, and historical strata. Total sampling effort (i.e., kilometer of transect) in each basin was established through an analysis of historical data to achieve a target precision (Relative Standard Error <15%). Within basins, sampling effort across strata was apportioned based on strata size and historical data variance. Random sites are selected from within each strata using a 5-minute grid. Transects (5 km) must pass through the centroid of the grid but can be surveyed in any direction based on weather or logistical considerations. Hydroacoustic transect data are collected with the ODNR R/V *Almar* in the WB, USGS R/V *Muskie* in the CB, and OMNRF R/V *Erie Explorer* in the EB.

Data collection begins 0.5 h after sunset and is completed by 0.5 h before sunrise. Collection settings during the survey in the Central and East basins include 4 pings per second (pps), a 0.4 milli-second (msec) pulse length, and a -130 dB minimum collection threshold (Table 3.0.1), following recommendations in Parker-Stetter et al. (2009). Collection settings in the West Basin use 10 pps and a 0.2 msec pulse duration to accommodate shallow waters and high fish densities. The sampling environment (water temperature) is set to the temperature at 2 m depth on the evening of sampling. Temperature and dissolved oxygen profiles are collected at each grid. Sampling occurred between July 10 and July 25, 2023.

Currently, midwater trawling only occurs in the CB with the OMNRF R/V *Keenosay* operating in Ontario waters and the ODNR R/V *Grandon* operating in U.S. waters. Midwater trawl samples are collected at grid locations in concordance with the hydroacoustic data collection. Up to four midwater trawls are conducted in each grid, with trawl depths distributed among the epilimnion, metalimnion, and hypolimnion to capture the fish community distribution across depths. Trawl catch is sorted by species and age group, and a subsample of fish are measured (total length). Temperature and dissolved oxygen profiles are collected at each sample grid.

Data Analysis

Hydroacoustic data were analyzed using the 'erieacoustics' R package (Holden and DuFour 2023) which interacts with standardized processing templates developed in Myriax software Echoview 14.0 (Echoview 2023). Each 500-m sample interval (EDSU; elementary distance sampling unit) was partitioned vertically into epilimnetic and hypolimnetic layers based on fish distribution and water temperature profiles. Analyses produced areal fish density (fish per hectare) estimates and size frequency distributions for each EDSU and layer along each 5-km transect.

Trawl catches were associated with the sampled stratum, grid, and layer. Similar to hydroacoustic data, trawl samples were partitioned into epilimnetic and hypolimnetic layers based on trawl depth and thermocline depths identified by hydroacoustic data and temperature profiles. Trawl catches were clustered into five species groups, including all ages of Emerald Shiner, age-0 Rainbow Smelt, age-1+ Rainbow Smelt, age-0 Yellow Perch, and others.

Survey Effort

Lake-wide hydroacoustic effort included 92 sampled grids (WB - 21, CB - 24, and EB - 47), totaling 460 km of sampled transect (Figure 3.0.2). Water column profiles (n = 76) associated with sampled grids were strategically collected to inform portioning of hydroacoustic and trawl data into epilimnetic and hypolimnetic layers. A total of 37 midwater trawls were collected across 15 sample grids in 6 strata of the Central Basin.

Water Column Profiles

Water column profiles demonstrate increasing depth from west to east, with decreasing temperatures and increasing levels of dissolved oxygen (Figure 3.0.3). Much of the WB was isothermal, with only a single site displaying a thermocline. The thermocline was variable in the CB, and consistently deeper in the EB. Low dissolved oxygen (<2 mg/L) was observed at five sites in the CB.

Lake Wide Size Distribution and Fish Density

Hydroacoustic surveys observed two abundant size groups including age-0 fishes between -64 and -55 dB, and age-1+ fishes greater than -55 dB (Figure 3.0.4). Higher frequencies of age-0 fish were observed in epilimnetic waters across the survey, while age-1+ fish dominated the hypolimnion, especially in the EB (Figure 3.0.5 and 3.0.6). The size of age-0 fishes appeared to decline from west to east as cooler waters likely contribute to later hatching dates and slower growth. While no historical midwater trawling data exist in the WB, the CB data suggest epilimnetic catches are a mix of age-0 Rainbow Smelt, Emerald Shiner and other species, and the EB data suggest primarily age-0 Rainbow Smelt and age-0 Yellow Perch based on 2019 midwater trawl data. Hypolimnetic waters in both the CB and EB are dominated by age-1+ Rainbow Smelt.

Lake-wide areal densities (fish/ha), in general, were highest in the WB followed by the EB and CB, respectively (Figure 3.0.6). Epilimnetic densities were consistently higher when compared to hypolimnetic densities, with extremely high observations in the WB. High EB densities in the epilimnion are generated by a high abundance of small age-0 Rainbow Smelt (< -55 dB) and do not contribute proportionally to total biomass. Hypolimnetic habitat was minimal in the WB, but consistently observed in the CB and EB. Some of the highest areal densities observed were in the EB hypolimnion and likely consisted of age-1+ Rainbow Smelt.

West Basin Results

The WB survey consisted of 21 5-km transects with associated water column profiles sampled between July 10-19 (Table 3.0.2; Figure 3.0.2). An alternative grid (G73) was sampled in stratum S06 because commercial trap nets prohibited safe passage through one of the planned grids (G13). Midwater trawl samples were not collected. Results represent prey fish densities in the epilimnion because no stratification was observed. Most single targets were measured at a target strength around -60 dB, likely representing age-0 Percidae and Moronidae species as well as Emerald Shiner and Gizzard Shad (Figure 3.0.4). A low frequency of large targets (>-45 dB) was observed in S05. Prey fish densities were highest in nearshore grids just east of Sandusky Bay (G73 and G15) and Maumee Bay (G245). Mean strata fish density was lowest in S01 (25,598 fish/ha) and highest in S06 (125,984 fish/ha), although only one grid (G73) was sampled in S06. Annual mean prey fish density in the West Basin increased in 2023 to 49,440 fish/ha, the second highest level on record (Figure 3.0.7).

Central Basin Results

The CB survey consisted of 24 5-km transects with associated water column profiles sampled between July 17–21. All targeted 5-minute grids were sampled including additional grids in stratum S07, S08, S13, and S14 (Table 3.0.3; Figure 3.0.2). Thirty midwater trawl samples were collected in Canadian waters across four strata (S7, S8, S11, and S12) while 7 midwater trawl samples were collected in U.S. waters between two strata (S09 and S10; Table 3.0.3). Annual mean areal fish density increased but remained low 12,973 fish/ha in 2023 (Figure 3.0.8). In general, the highest midwater trawl catches occurred in the epilimnion and were comprised of age-0 (RSYOY) and age-1+ Rainbow Smelt (RSYAO) while age-1+ Rainbow Smelt (RSYAO) dominated the hypolimnion (Figure 3.0.9). Relative to water column depth (Figure 3.0.10), Emerald Shiner catches were low in both near shore (<20 m) and offshore habits (>20 m). Age-0 Yellow Perch (YPYOY) catches were greater than age-0 Emerald Shiner but showed similar distributional patterns. Age-0 Rainbow Smelt (RSYOY) catches were high in both near shore and offshore waters, while the highest catches of age-1+ Rainbow Smelt (RSYAO) occurred offshore. The highest catches of other species (OTHER) occurred in near shore waters.

East Basin Results

The EB survey consisted of 47 5-km transects with 59 associated water column profiles sampled between July 17-25. Representative water column profiles were taken in each stratum although not for each sampled 5-minute grid. Midwater trawl samples were not collected. The time series of yearling and older (age-1+) Rainbow Smelt is an index of fish abundance in the hypolimnion that have target strengths consistent with yearling and older sized Rainbow Smelt (-60 dB to -40dB). Companion midwater trawls completed by NYSDEC in early years of the survey (up to 2007) found that age-1+ Rainbow Smelt made up greater than 95% of catches of fish of their acoustic target strength in meta-hypolimnion trawls. Midwater trawl catches by OMNRF in 2019 again confirmed the assumption. Grids that did not have hypolimnetic conditions were assumed to not have any yearling and older Rainbow Smelt (0 fish/ha). Strata density is the mean density of all the 500 m EDSU within the strata. The basin estimate is an area weighted mean of the combined strata. The highest density of age-1+ Rainbow Smelt were observed in S17, S21, and S22 (mean N/ha = 12,345, 13,463, and, 7396, respectively). The density of yearling and older Rainbow Smelt increased to 4,204 fish/ha in 2023 from 2,137 fish/ha in 2022 (Figure 3.0.11).

Evaluating Potential Hydroacoustic Biases using Autonomous Vehicles

The U.S. Geological Survey and Cornell University in cooperation with partner agencies (ODNR and OMNRF) deployed three autonomous vehicles in Lake Erie during 2023. An uncrewed sailing vessel (USV) traversed Lake Erie between August 1 and September 26, 2023 (Figure 3.0.12). The USV collected hydroacoustic data as well as other environmental information along its route. The USV is a much quieter platform than a diesel-powered vessel, and its primary objective was to collect hydroacoustic data alongside traditional fisheries research vessels to evaluate the potential for vessel avoidance bias in the existing hydroacoustic surveys. Four agency vessels participated in the comparison including: USGS R/V *Muskie* (n = 14), ODNR R/V *Almar* (n = 17), ODNR R/V *Grandon* (n = 7), and OMNRF R/V *Erie Explorer* (n = 13). In addition, the USV explored Yellow Perch distributions associated with harmful algal blooms in the West Basin, fish distributions related to hypoxia in the Central Basin, and large target (i.e., Lake Trout, Lake Whitefish, Walleye, etc.) distributions in the East Basin. Analyses for these four science objectives are ongoing.

In addition, two long-range autonomous underwater vehicles (LRAUV) were deployed in Lake Erie's Central Basin and operated along prescribed transects near Fairport Harbor, OH between September 9–17, 2023 (Figure 3.0.13). One LRAUV, nicknamed Triton, simultaneously collected upward and downward looking hydroacoustic data to evaluate potential near surface and near bottom sampling bias associated with the existing hydroacoustic surveys. The second

LRAUV, nicknamed Makai, collected environmental DNA samples to remotely characterize species composition. The eDNA samples will be compared with bottom trawl information (24 tows) from the same area and time collected by ODNR (Figure 3.0.13). Analyses for these two science objectives are ongoing.

Table 3.0.1: Lake-wide hydroacoustic data collection summary.

Basin	Sounder	Frequency	Ping Rate	Pulse Length	Collection Threshold	WC Profiles	Companion MTR
WB	Biosonics	201 kHz	10 pps	0.2 msec	-130 dB	yes	no
CB	Biosonics	120 kHz	4 pps	0.4 msec	-130 dB	yes	yes
EB	Simrad EK80	120 kHz	4 pps	0.256 msec	-130 dB	yes	no

Table 3.0.2: Number of targeted and completed 5-minute samples grids for each stratum in the West Basin survey area.

Stratum	Target	N Complete
S01	5	5
S02	4	4
S03	2	2
S04	3	3
S05	6	6
S06	1	1

Table 3.0.3: Number of targeted and completed 5-minute samples grids, and midwater trawl samples collected for each stratum in the Central Basin survey area.

Stratum	Target	N Complete	N Trawls
S07	1	2	4
S08	2	3	9
S09	3	3	6
S10	2	2	1
S11	2	2	5
S12	4	4	12
S13	5	6	NA
S14	1	2	NA

Table 3.0.4: Number of targeted and completed 5-minute samples grids for each stratum in the East Basin survey area.

Stratum	Target	N Complete
S15	2	2
S16	4	4
S17	5	9
S18	6	7
S19	5	5
S20	5	6
S21	4	5
S22	3	4
S23	2	2
S24	3	3

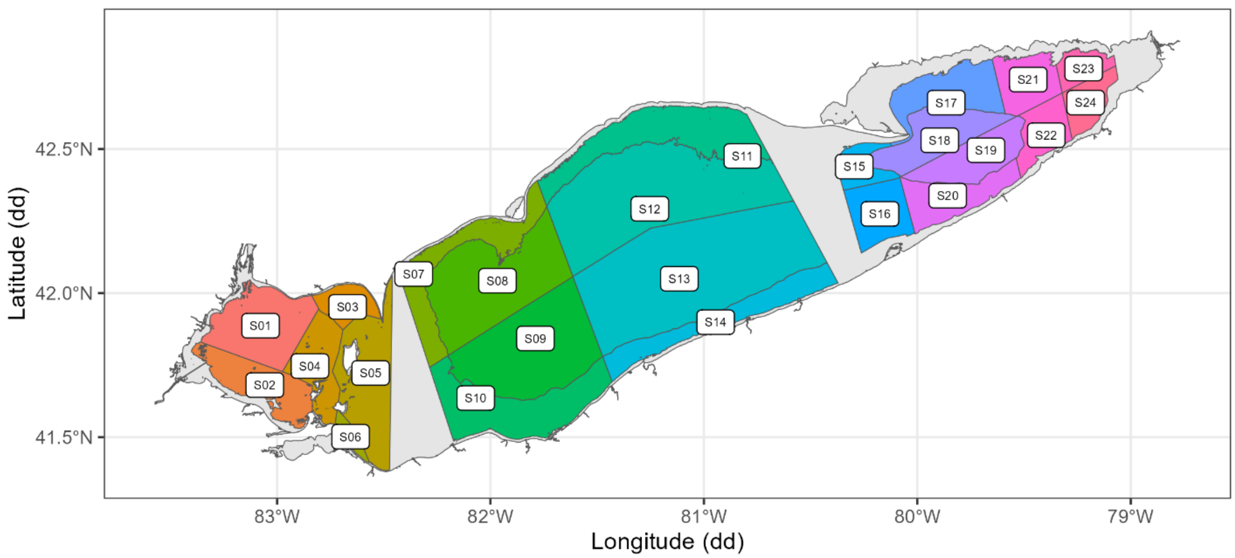


Figure 3.0.1. Lake Erie forage fish acoustic survey strata used following the survey redesign. The Western Basin strata are 1-6; Central Basin are 7-14, and the Eastern Basin are 15-24.

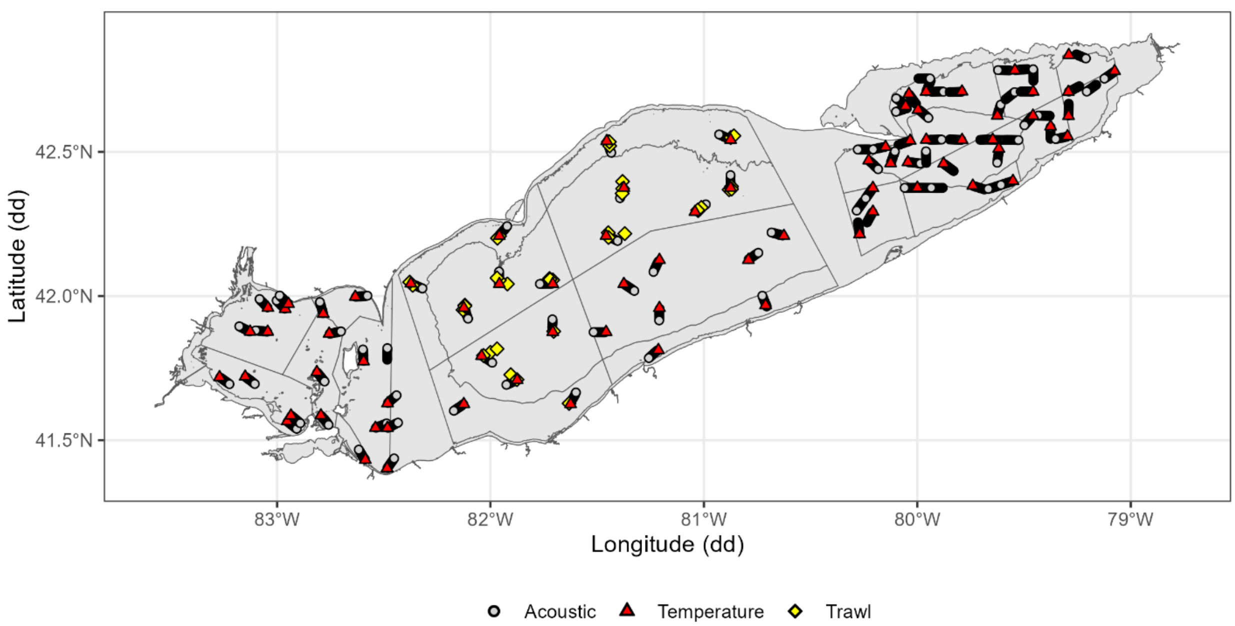


Figure 3.0.2: Lake-wide forage fish survey effort distributed across sample stratum including hydroacoustic transects (open black circles), midwater trawling (yellow diamonds), and water column profiles (red triangles).

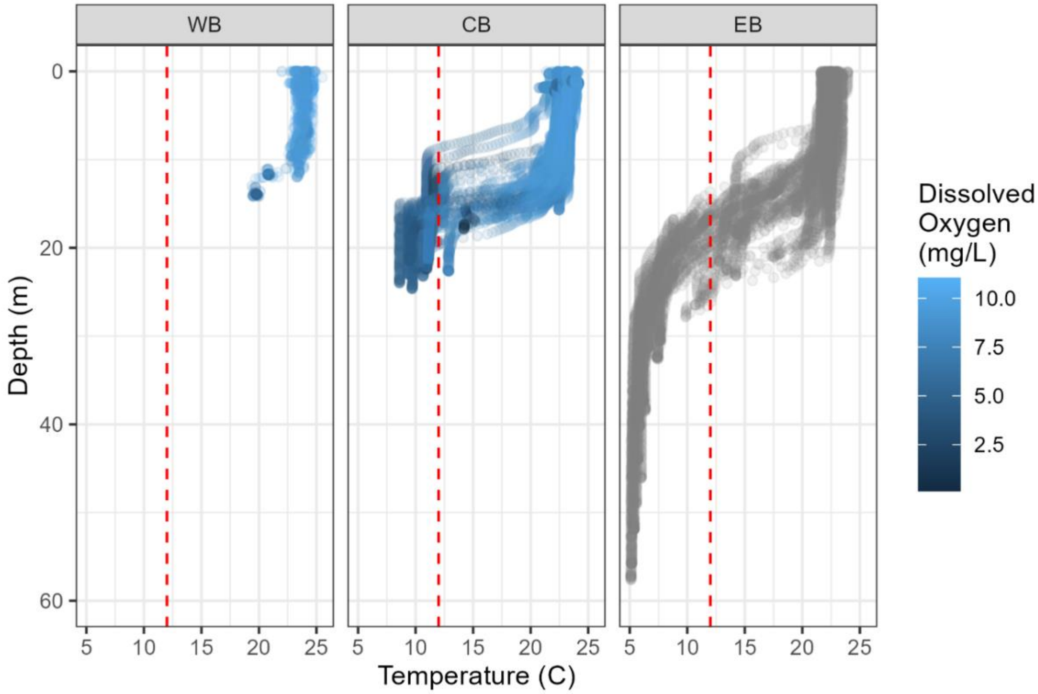


Figure 3.0.3: Water column profiles displayed by basin (West Basin = WB, Central Basin = CB, and East Basin = EB) with depth on the x-axis, temperature (˚C) on the y-axis, and color associated with the level of dissolved oxygen (mg/L). Dissolved oxygen was not measured on EB profiles. The dashed vertical line indicates 12˚C.

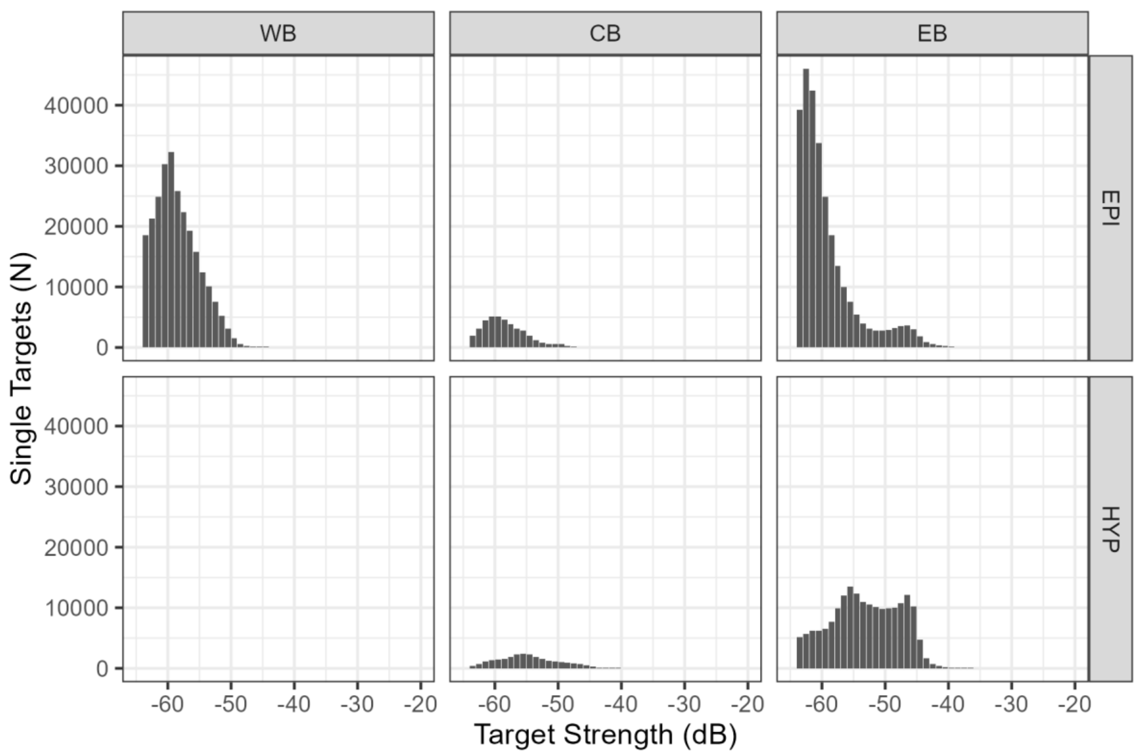


Figure 3.0.4: Target strength distributions of single targets by layer and across basins. Target strength is a measure of echo intensity that is relative to fish size. Single targets are individual echoes produced by fish encountered in the acoustic beam. In general, age-0 fishes are < -55 dB while age-1+ fishes are > -55 dB.

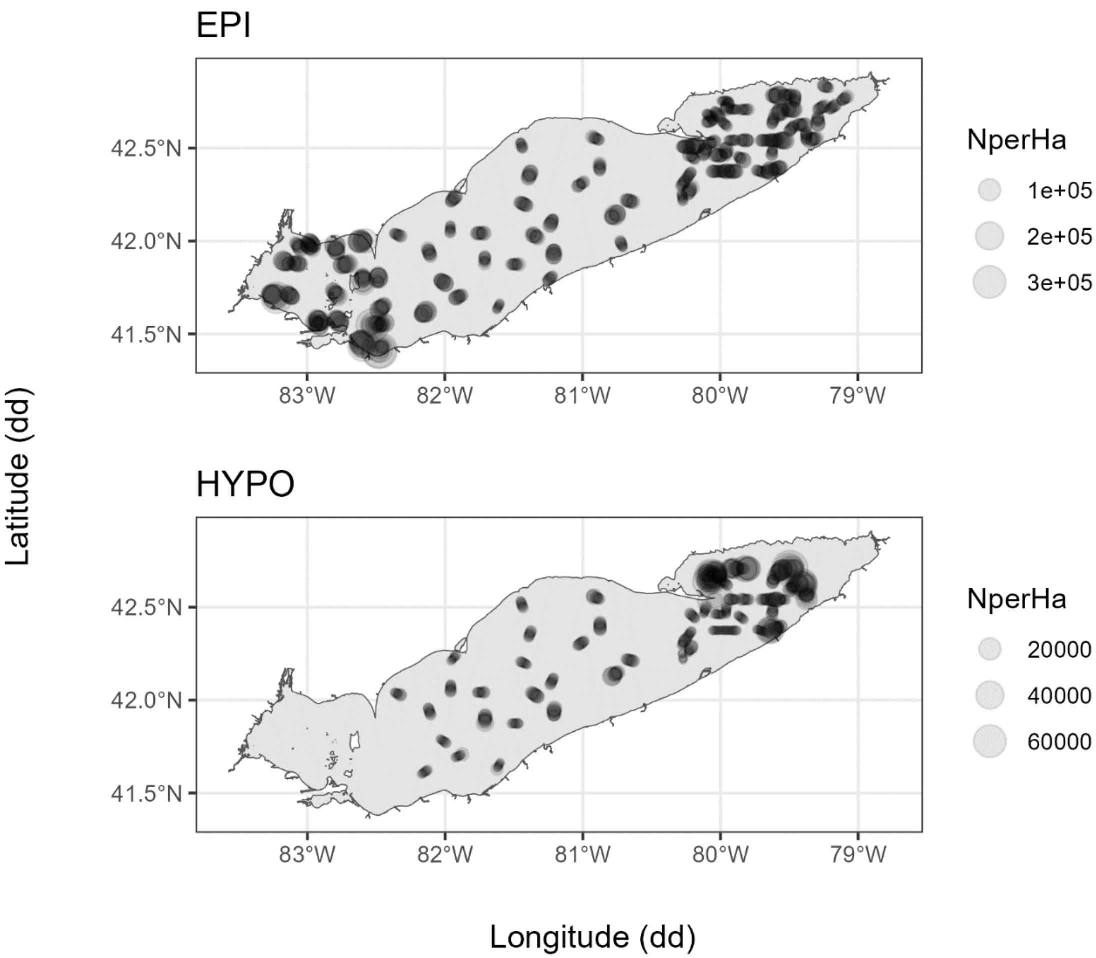


Figure 3.0.5: Lake-wide fish densities (number per hectare; NperHa) by lake layer (epilimnetic [EPI], upper panel, and hypolimnetic [HYP], lower panel). Larger open circles display increased density in epilimnetic waters of the West and East basins, and increased density in the northern hypolimnetic waters of the East Basin.

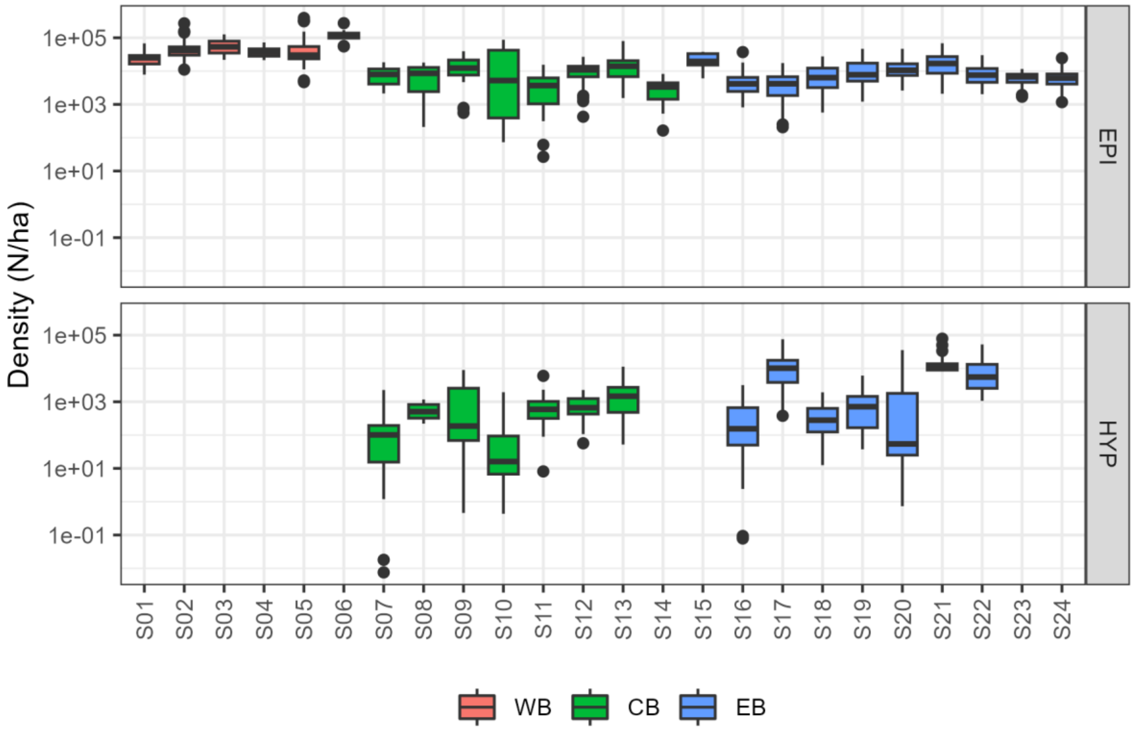


Figure 3.0.6: Density estimates (N/ha) within each stratum in the epilimnetic (upper panel) and hypolimnetic (lower panel) layers. Box captures the 50% quantiles while whiskers capture 95% quantiles of the data and the thick line represents the median value. Points that exceed the 95% quantiles are indicated with individual points Note: y-axis uses a log scale.

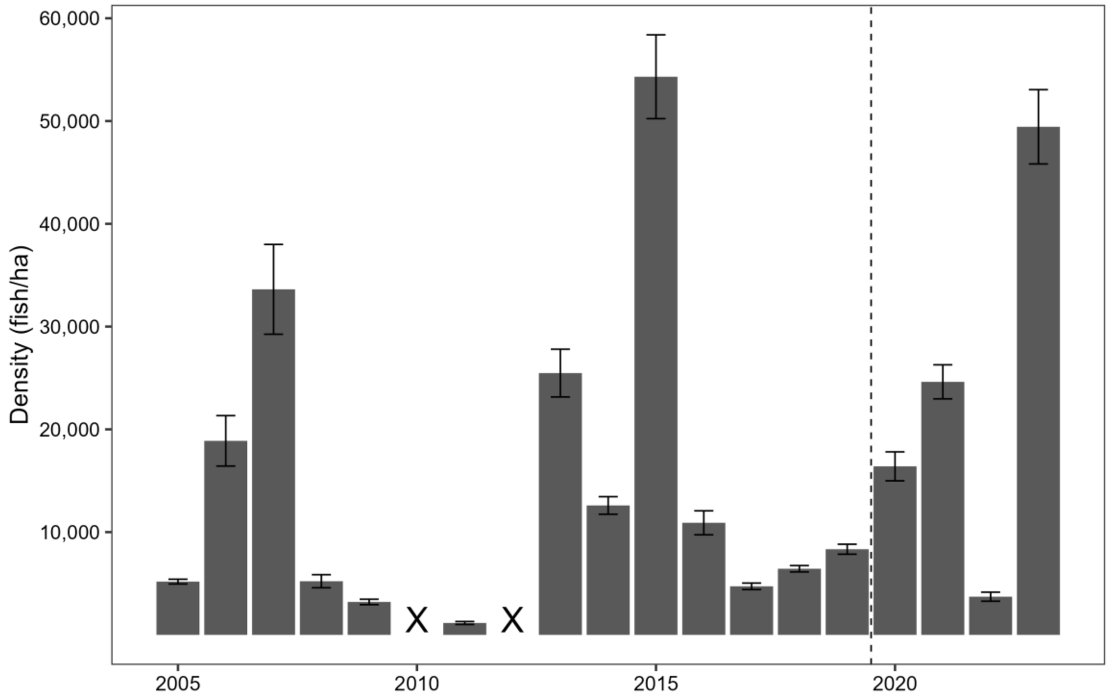


Figure 3.0.7: West Basin mean areal density (fish/ha) estimates over time. Error bars represent ±1 standard error. Survey years with no data (2010 and 2012) are denoted with an “X” and the vertical dashed line signifies the change in sampling design.

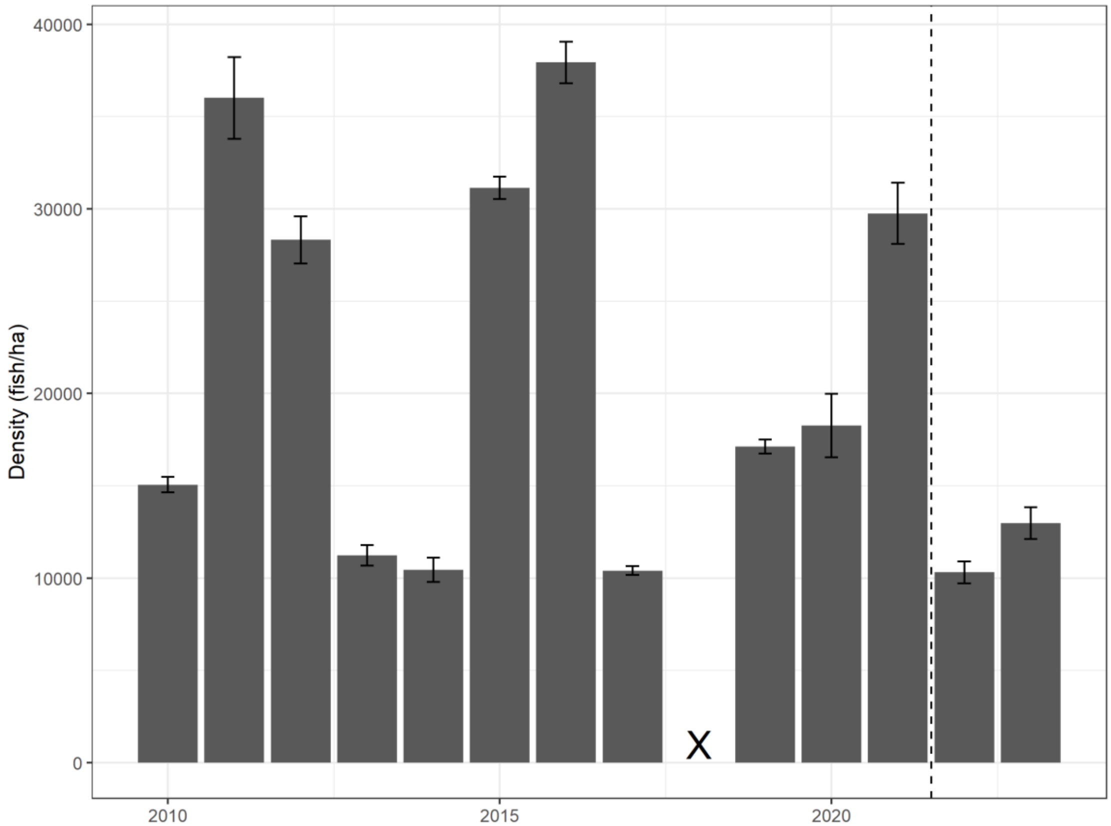


Figure 3.0.8: Central Basin mean areal density (fish/ha) estimates over time. Error bars represent ±1 standard error. Survey years with no data (2018) are denoted with an "X" and the vertical dashed line signifies the change in sampling design.

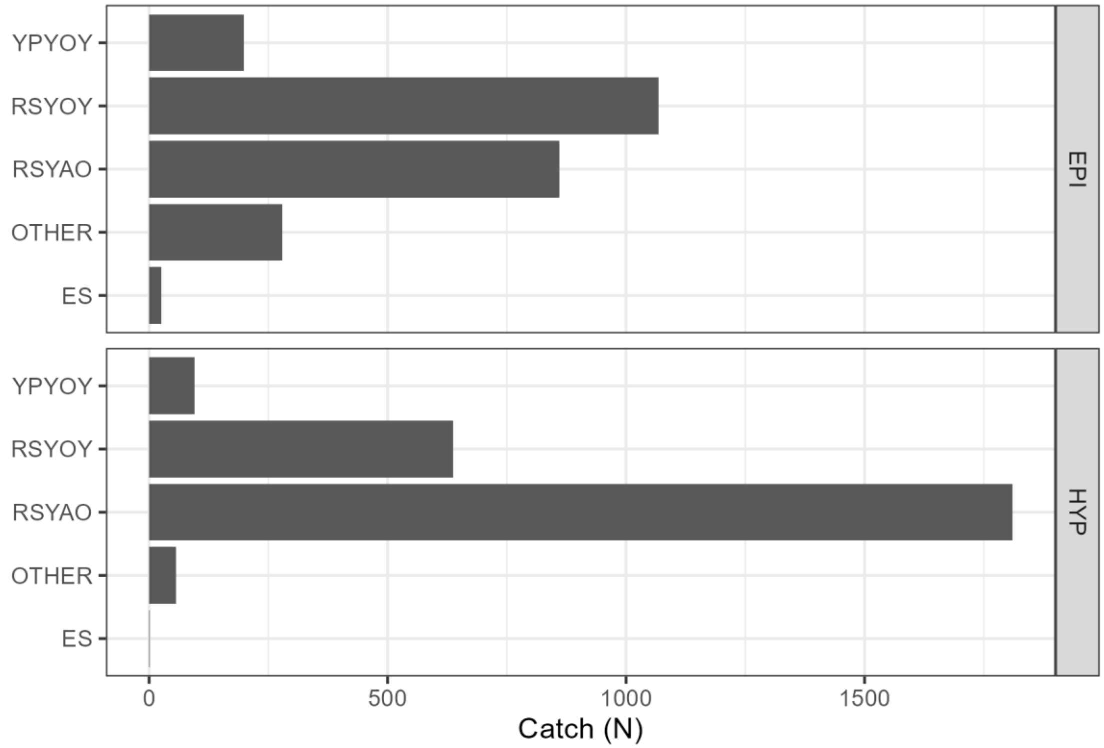


Figure 3.0.9: Total midwater trawl catch from epilimnetic (EPI, upper panel) and hypolimnetic (HYP, lower panel) tows across the Canadian waters and a portion of U.S. waters of the Central Basin, including species groups age-0 Rainbow Smelt (RSYOY), age-1+ Rainbow Smelt (RSYAO), Emerald Shiner (ES), age-0 Yellow Perch, and other species (OTHER).

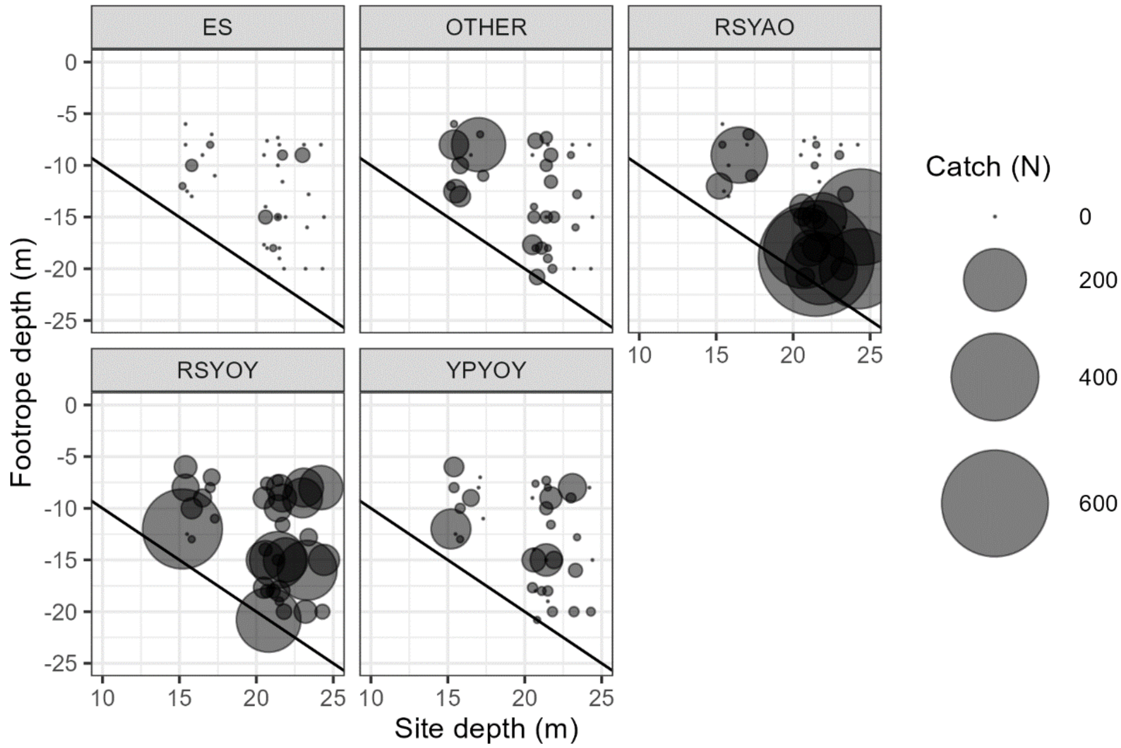
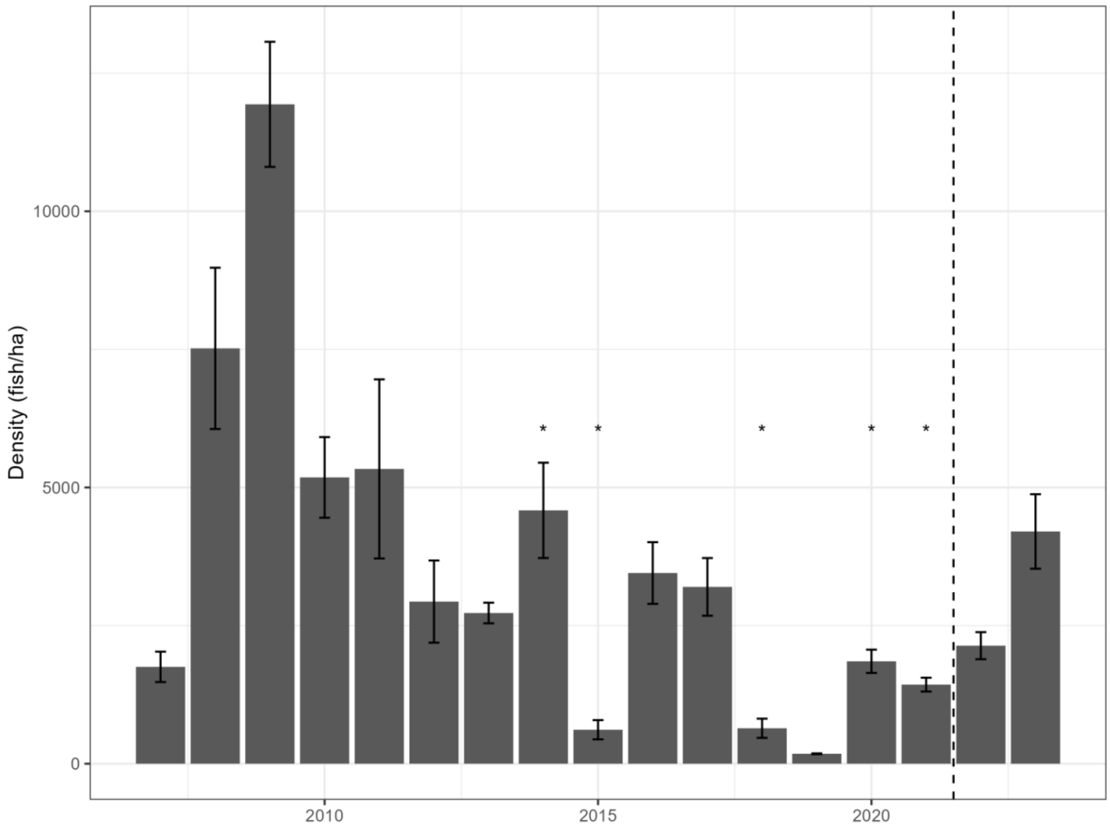


Figure 3.0.10: Species-group catches (N) relative to water column depth (diagonal black line) in Canadian and U.S. waters of the Central Basin including Emerald Shiner (ES), other species (OTHER), age-1+ Rainbow Smelt (RSYAO), age-0 Rainbow Smelt (RSYOY), and age-0 Yellow Perch (YPYOY). Water column depths <20 correspond to near shore strata (S07, S10, S11, and S14) and depths >20 m correspond to offshore strata (S08, S09, S12, and S13).



Figures 3.0.11: East Basin index of age-1+ Rainbow Smelt. Error bars represent ±1 standard error. A single asterisk (*) indicates years where not all transects were completed and vertical dashed line signifies when the change in sampling design occurred.

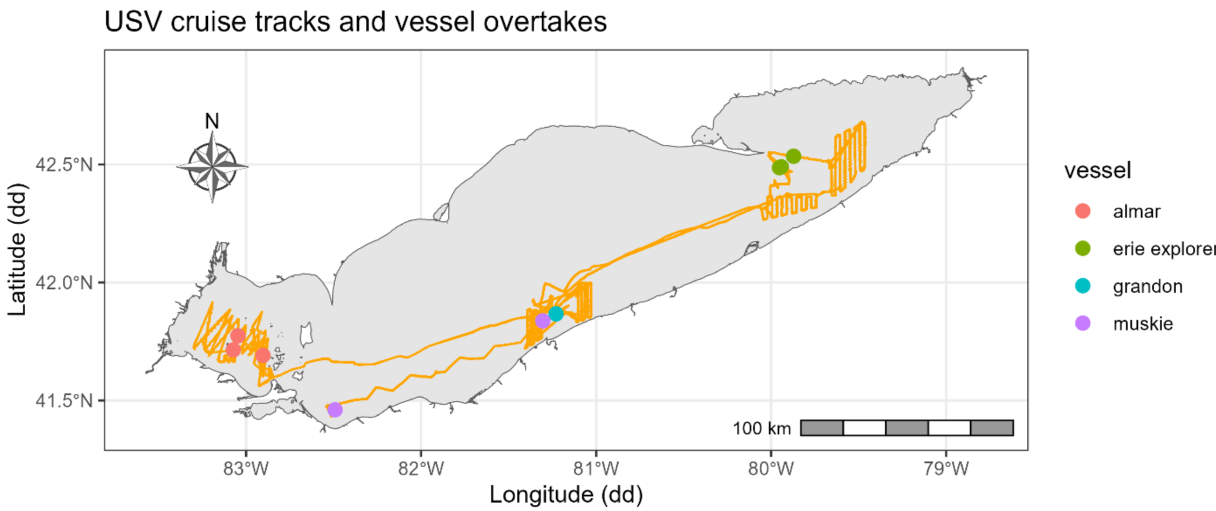


Figure 3.0.12: Uncrewed sailing vessel (USV) cruise tracks (orange lines) in Lake Erie between August 1 and September 26, 2023. Colored points represent the general locations and vessels that participated in the vessel avoidance bias objective.

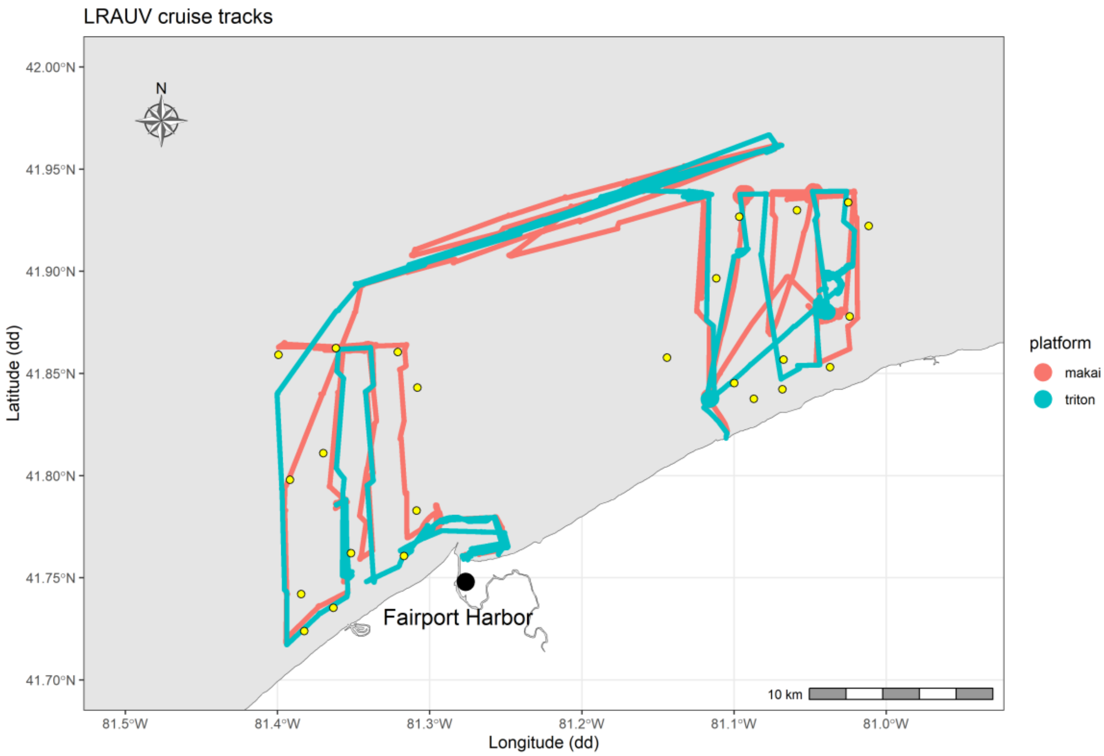


Figure 3.0.13: Long-range autonomous underwater vehicle (LRAUV) cruise tracks near Fairport Harbor, Ohio between September 9–17, 2023. The Triton (blue) collected upward and downward looking hydroacoustic data to evaluate near surface and near bottom biases. The Makai (red) collected eDNA samples with the goal of remotely characterizing fish community compositions. ODNR trawl locations (24) are indicated by yellow points circled in black.

Charge 4: Act as a point of contact for any new/novel invasive aquatic species.

(K. Towne)

Since 2016, the Forage Task Group has maintained a database to track Aquatic Invasive Species (AIS) in Lake Erie. Recently, the FTG has been working with the USGS Nonindigenous Aquatic Species database team to incorporate the FTG database and other agency data into the USGS database so that the Lake Erie data can be better archived and help track AIS on a greater geographic scale.

The FTG is actively monitoring for any new aquatic invasive species that enters the Lake Erie watershed. A few AIS that are not yet in Lake Erie but are of particular concern to the FTG are Black Carp, Silver Carp, Bighead Carp, and Tench. Black, Silver, and Bighead Carps are present throughout the Mississippi Basin and have been found in tributaries close to Lake Michigan. Tench was first detected in a tributary of the St. Lawrence River in 1994 and has since spread into the St. Lawrence River and eastern Lake Ontario (Bay of Quinte; Avlijas et al. 2018). The rapid expansion of Tench suggests there is an elevated risk of Tench entering Lake Erie should their expansion into Lake Ontario continue. No Black Carp, Silver Carp, Bighead Carp, Tench, or any other novel non-native fish species were captured in Lake Erie waters in 2023.

Protocol for Use of Forage Task Group Data and Reports

- The Forage Task Group has standardized methods, equipment, and protocols as much as possible; however, data are not identical across agencies, management units, or basins. The data are based on surveys that have limitations due to gear, depth, time and weather constraints that vary from year to year. Any results, conclusions, or abundance information must be treated with respect to these limitations. Caution should be exercised by outside researchers not familiar with each agency's collection and analysis methods to avoid misinterpretation.

- The FTG strongly encourages outside researchers to contact and involve the FTG in the use of any specific data contained in this report. Coordination with the FTG can only enhance the final output or publication and benefit all parties involved. Raw data and summaries are available upon request; please contact the co-chairs (Michael Thorn [michael.thorn@ontario.ca] and Zak Slagle [zachary.slagle@dnr.ohio.gov]) to initiate a request.

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Appendix 1: List of Species Common and Scientific Names

Common name	Scientific name	Comments
Alewife	*Alosa pseudoharengus*	Invasive species
Bighead Carp	*Hypophthalmichthys nobilis*	Invasive species, not present in Lake Erie
Black Carp	*Mylopharyngodon piceus*	Invasive species, not present in Lake Erie
Bluegill	*Lepomis macrochirus*	
Brook Silverside	*Labidesthes sicculus*	
Channel Catfish	*Ictalurus punctatus*	
Channel Darter	*Percina copelandi*	
Common Carp	*Cyprinus carpio*	Invasive species
Crayfish	*Astacoidea* spp.	
Emerald Shiner	*Notropis atherinoides*	
Freshwater Drum	*Aplodinotus grunniens*	
Gizzard Shad	*Dorosoma cepedianum*	
Grass Carp	*Ctenopharangydon idella*	Invasive species
Johnny Darter	*Etheostoma nigrum*	
Lake Sturgeon	*Acipenser fulvescens*	
Largemouth Bass	*Micropterus nigricans*	Formerly *Micropterus salmoides.*
Logperch	*Percina caprodes*	
Mimic Shiner	*Paranotropis volucellus*	Formerly *Notropis volucellus.*
Mudpuppy	*Necturus maculosus*	Native salamander
Rainbow Smelt	*Osmerus mordax*	Invasive species
Rock Bass	*Ambloplites rupestris*	
Round Goby	*Neogobius melanstomus*	Invasive species
Rudd	*Scardinius erythrophthalmus*	Invasive species
Ruffe	*Gymnocephalus cernuus*	Invasive species
Silver Carp	*Hypophthalmichthys molitrix*	Invasive species, not present in Lake Erie
Silver Chub	*Macrhybopsis storeriana*	
Smallmouth Bass	*Micropterus dolomieu*	
Spottail Shiner	*Hudsonius hudsonius*	Formerly *Notropis hudsonius.*
Tench	*Tinca tinca*	Invasive species, not present in Lake Erie
Troutperch	*Percopsis omiscomaycus*	
Tubenose Goby	*Proterorhinus semilunaris*	Invasive species
Walleye	*Sander vitreus*	
White Bass	*Morone chrysops*	
White Perch	*Morone americana*	Invasive species
White Sucker	*Catostomus commersoni*	
Yellow Perch	*Perca flavescens*	