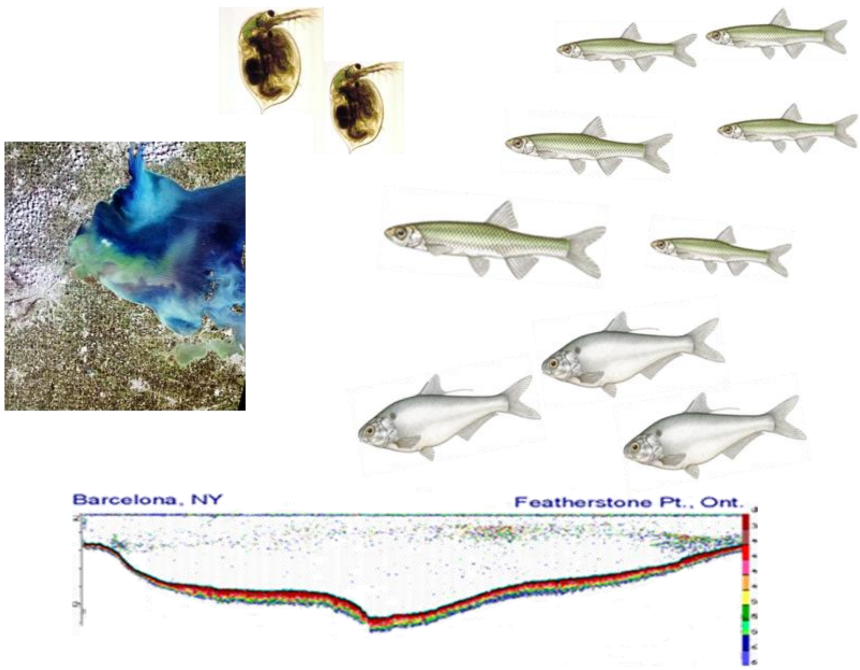
Report of the Lake Erie Forage Task Group

March 2023



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Forage Task Group Executive Summary

March 2023

Lake Erie Committee

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

Introduction

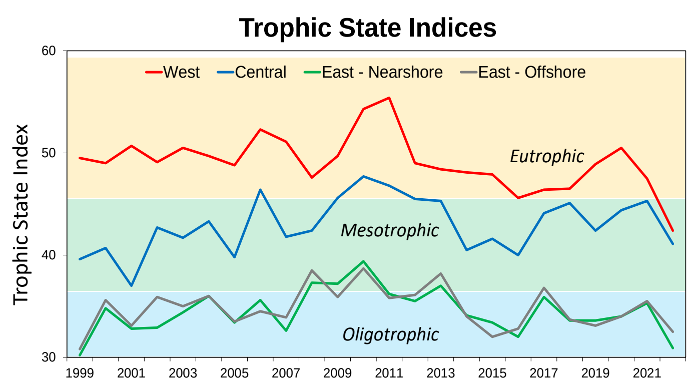
The Lake Erie Committee Forage Task Group (FTG) report addresses progress made on four charges:

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 Fish Community Objectives.
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 new USGS invasive 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.

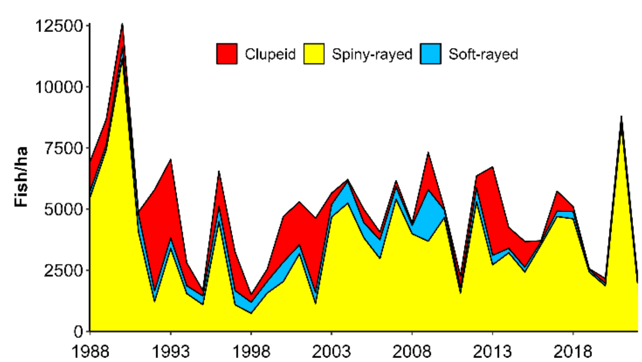
Interagency Lower Trophic Level Monitoring

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 2022, the Trophic State Index, which is a combination of phosphorus levels, water transparency, and chlorophyll *a*, indicated that both the West and Central Basins were within the targeted mesotrophic status (favoring percid production). This is the first year that the West Basin reached target status. The East Basin offshore and nearshore areas were both oligotrophic in 2022. Low hypolimnetic dissolved oxygen continues to be an issue in the Central Basin during the summer months.



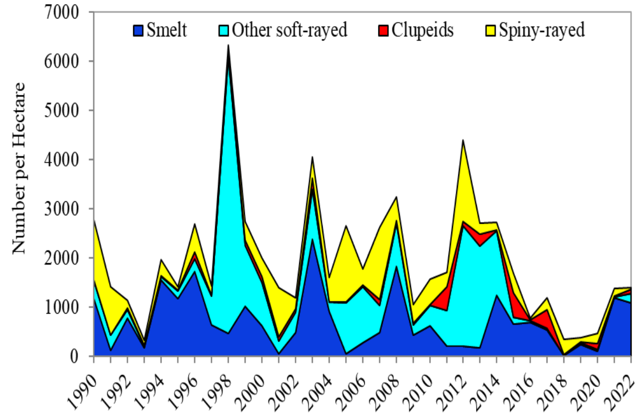
West Basin Status of Forage

In 2022, data from 69 trawl tows were used (up from 68 in 2020). Total forage density averaged 2,278 fish per hectare across the West Basin, returning to low levels similar to 2019–2020. Forage biomass (10.8 kg/ha) also fell from the 2021 high. Age-0 White Perch abundance (1,160/ha) fell from a 30-year high. Age-0 Yellow Perch density (572/ha) was near average. Age-0 Gizzard Shad abundance (124/ha) rose from 2021 but remained below the ten-year mean (714/ha). Age-0 Walleye relative abundance (83/ha) fell from a time-series high. Densities of Emerald Shiners have remained low for seven years. Round Goby abundance (25/ha) fell from a recent high abundance in 2021.



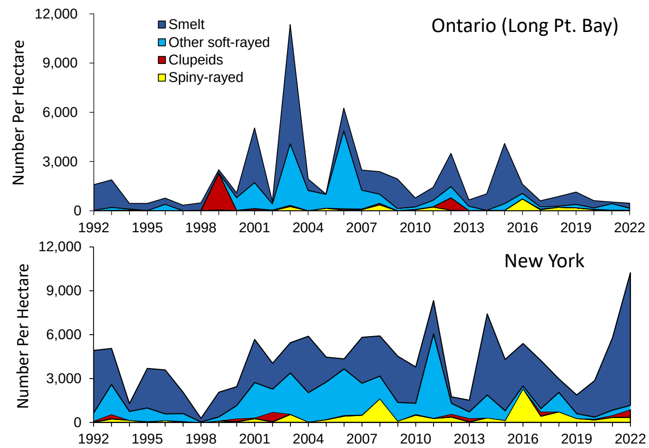
Central Basin Status of Forage

In 2022, 57 trawl tows were completed in the Ohio waters of the Central Basin (up from 33 in 2021). Total forage density averaged 1,401 fish per hectare across the Central Basin, similar to 2021. Total forage biomass was 4.656 kg/ha and well below the long-term mean. Age-0 Rainbow Smelt density increased from 2021 and was near the long-term mean. Age-1+ Rainbow Smelt density decreased from a 2021 and is well below the long-term mean. Round Goby indices decreased across the basin and were below the long-term mean. Age-0 Emerald Shiner density (120/ha) increased from 2021. Yellow Perch density was similar to 2021; 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

Total forage fish density in 2022 decreased in Ontario and remains well below the long-term mean. Forage fish density increased in New York waters and was at the highest level in the time series, mainly due to a high abundance of age-0 Rainbow Smelt (highest in time series). Catches of age-1+ Rainbow Smelt were low in both Ontario and New York. Catches of age-0 and age-1+ Emerald Shiner were low in all jurisdictions. Round Goby densities were below average in both New York and Ontario waters. Abundance of clupeids (Gizzard Shad, Alewife) was the second highest in the time series in New York but below average in Ontario. High numbers of age-0 Walleye were caught in New York and moderate catches of age-0 and age-1 Yellow Perch. 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 2022, a total of 455 km of transects were sampled, 60 water column profiles were measured, and 34 companion mid-water trawls were towed (the latter in the Central Basin only). Densities of fish (number per hectare) were highest in the East Basin, followed by the Central Basin, and lowest in the West Basin. In the East Basin, age-1+ Rainbow Smelt density increased slightly in 2022 relative to 2021, and was well above the time series low observed in 2019. In the Central Basin, fish species other than Rainbow Smelt and Emerald Shiner were the most abundant in the epilimnion, whereas age 1+ Rainbow Smelt were the most abundant in the hypolimnion. In the West Basin, prey fish density was much lower in 2022 than observed in 2021 and was the third lowest value for the time series.

Aquatic Invasive Species

In 2022, the U.S. Fish and Wildlife Early Detection and Monitoring program did not capture any novel aquatic invasive species. Across all agencies, the only notable catch was one Striped Bass (*Morone saxatilus*) captured in Dunkirk, NY. 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 2022–2023

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.
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 new USGS invasive species database.

Acknowledgements

The Forage Task Group would like to thank Andy Cook (MNRF) for contributing to this report.

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)

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 24 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 2022, 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 = 23.5 °C), becoming progressively cooler in the Central (mean = 21.9 °C) and East Basins (mean = 20.5 °C; Figure 1.0.2). In 2022, the mean summer surface water temperature was nearly the same in both the West (23.0 °C) and Central (22.5 °C) basins but slightly below average in the West and slightly above average in the Central Basin. In the East Basin, mean summer surface water temperatures were 21.6 °C, which was above average. An increasing trend in summer surface water temperature is evident in all three basins for this time series.

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 2022, 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 2022, bottom DO was below the 2.0 mg/L threshold in the Central Basin on two occasions (Station 8: 7/26/22 – 1.38 mg/L; Station 10: 8/25/22 – 1.11 mg/L) and slightly above the 2.0 mg/L threshold on two other occasions (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 2022, East Basin bottom DO measurements ranged between 5.6–10.8 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 2022, the mean chlorophyll *a* concentration was 5.8 µg/L in the West Basin, which is 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 2022 (3.6 µg/L; Figure 1.0.4). An increasing trend in chlorophyll *a* had been evident in the Central Basin over the previous eight years. In the East Basin, chlorophyll *a* concentrations in the nearshore waters have been below the targeted mesotrophic level for the entire time series, including 2022 (2.3 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 (2022: 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, and in some years they have been in the hyper-eutrophic range (Figure 1.0.5). In 2022, mean total phosphorus concentrations in the West Basin decreased for the third consecutive year to 16.6 µg/L, the lowest value in the time series and within the targeted mesotrophic range for the first time. 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 decreased in 2022 to 15.5 µg/L and were within the targeted mesotrophic range for the first time in the last seven years. 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 2022, mean total phosphorus measures remained stable in nearshore waters (7.7 µg/L) of the East Basin but decreased in offshore waters to the second lowest value in the time series (4.7 µg/L).

Water Transparency

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 (Figure 1.0.6). Mean summer transparency in the West Basin was 2.7 m in 2022, which was an increase compared to 2021 but still 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 2022, water transparency increased to 4.6 m, which was within the mesotrophic range. In the nearshore water of the East Basin, water transparency was in the oligotrophic range, which is above the FCO targets, from 1999 through 2006, sharply declined, and then steadily increased but has generally remained within the FCO targets (Figure 1.0.6). In 2022, water transparency increased to 5.8 m and was within targets but near the cusp of the mesotrophic/oligotrophic range. 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 increased in 2022 (7.2 m) and was within the oligotrophic range.

Trophic State Index (TSI) and Ecosystem Targets

A box and whisker plot was used to describe the trophic state index (TSI) for each of the basins in Lake Erie (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 2015, which was more favorable for a centrarchid (bass, sunfish) fish community. In recent years, overall measures of productivity have declined and are near or within the targeted mesotrophic status, 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 2022 indicate mesotrophic status in the West Basin (42.4) for the first time in the time series. The Central Basin remains in mesotrophic status (41.1), and oligotrophic status in both the nearshore (30.9) and offshore (32.5) waters of the East Basin (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 among basins and years. In the West Basin, the 2022 average biomass was 88.5 mg/m^3, which was a large decline from the time series high in 2021 (493.0 mg/m^3) and below the time series average of 134.9 mg/m^3 (Figure 1.0.8). The decrease in biomass in 2022 was across all groups, and all groups were below their time series averages. In the Central Basin, the 2022 average zooplankton biomass was 85.6 mg/m^3, which was below the average time series biomass (139.5 mg/m^3). This represented a slight decrease over 2021 and the third consecutive year of decline in the Central Basin (Figure 1.0.8). Similar to the West Basin, all groups were below their time series averages. 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). The 2022 zooplankton biomass in the East Basin (31.9 mg/m^3) decreased slightly from 2021 and was below the time series average (57.8 mg/m^3). A declining trend in total zooplankton biomass is evident in the East Basin from the time series high in 2011.

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. 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: Trophic state index and current trophic status, by basin, from Lake Erie in 2022.

Trophic Status	Trophic State Index (TSI)	Harmonic Fish Community
Oligotrophic	<36.5	Salmonids
Mesotrophic	36.5 – 45.5	Percids
Eutrophic	45.5 – 59.2	Centrarchids
Hyper-eutrophic	>59.2	Cyprinids

	2022 TSI	2022 Trophic Status
West	42.4	Mesotrophic
Central	41.1	Mesotrophic
East - Nearshore	30.9	Oligotrophic
East - Offshore	32.5	Oligotrophic

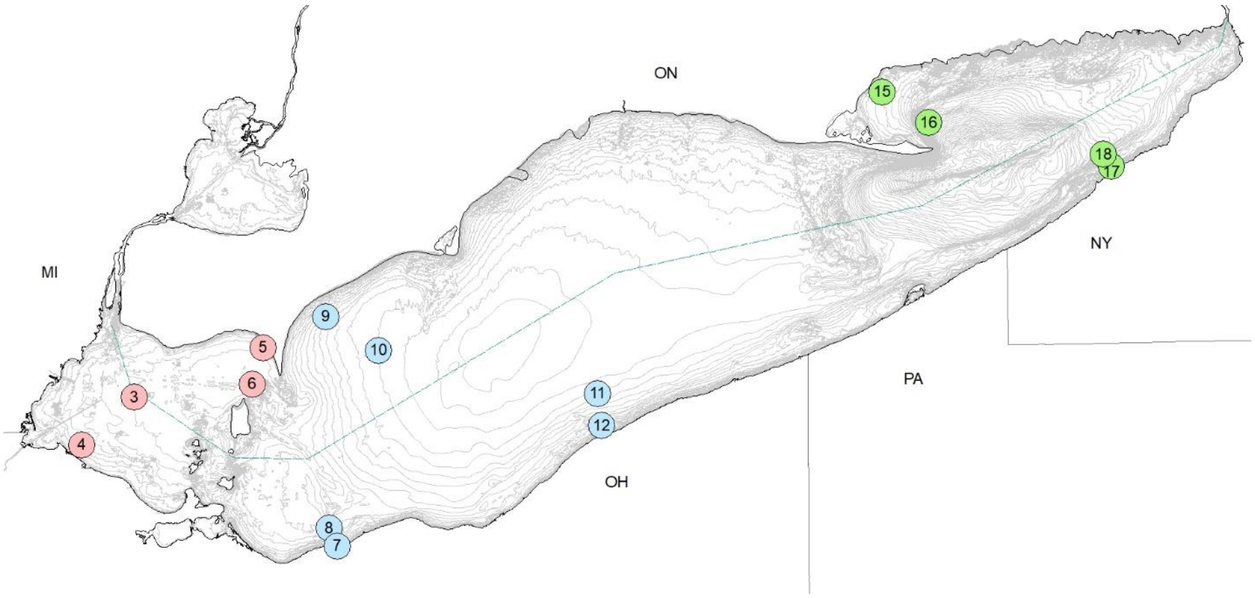


Figure 1.0.1: Lower trophic level sampling stations in Lake Erie (red = West Basin, blue = Central Basin, and green = East Basin).

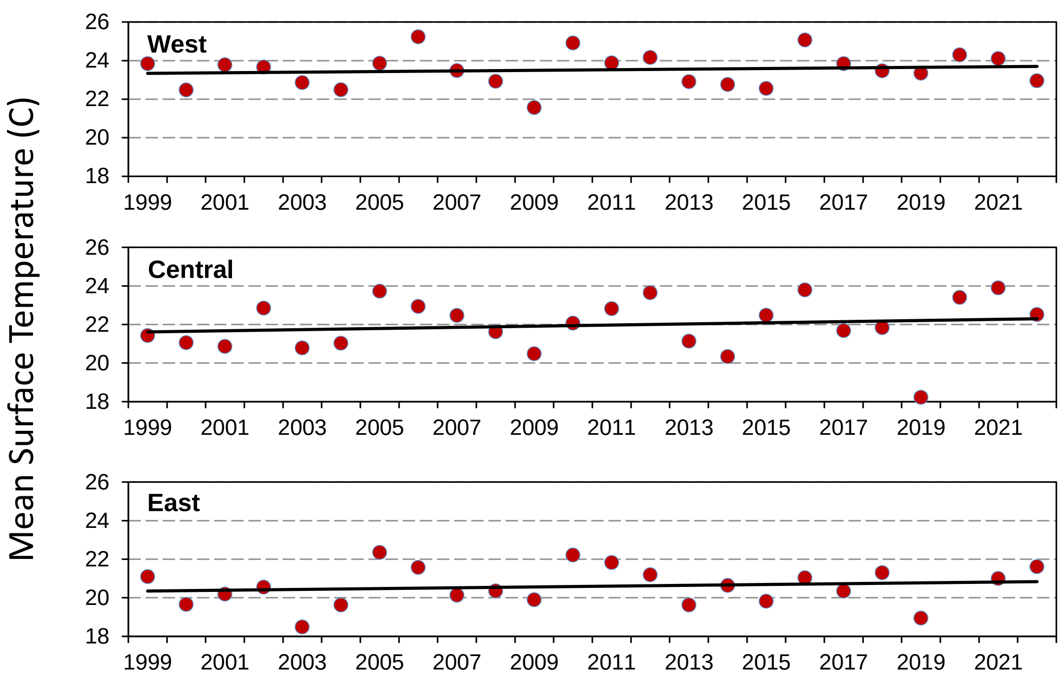


Figure 1.0.2: Mean summer (June-August) surface water temperature (°C) at offshore stations weighted by month for each basin in Lake Erie, 1999 –2022. Solid black lines represent time series trends.

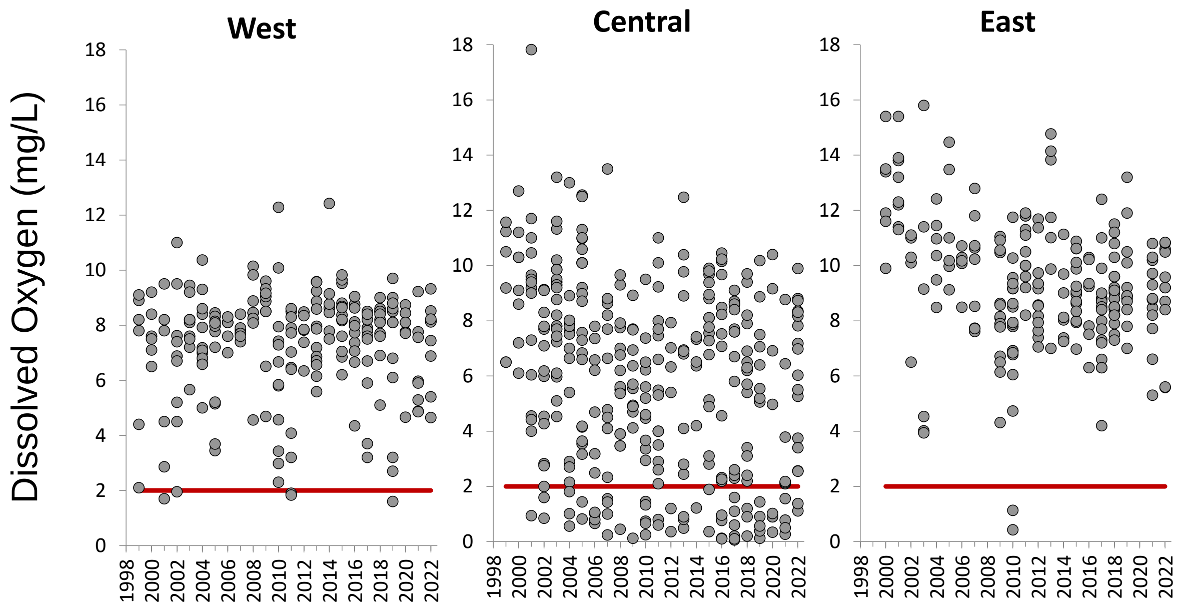


Figure 1.0.3: Summer (June-August) bottom dissolved oxygen (mg/L) concentrations for offshore sites by basin in Lake Erie, 1999–2022. The red horizontal line represents 2 mg/L, a level below which oxygen becomes limiting to the distribution of many temperate freshwater fishes.

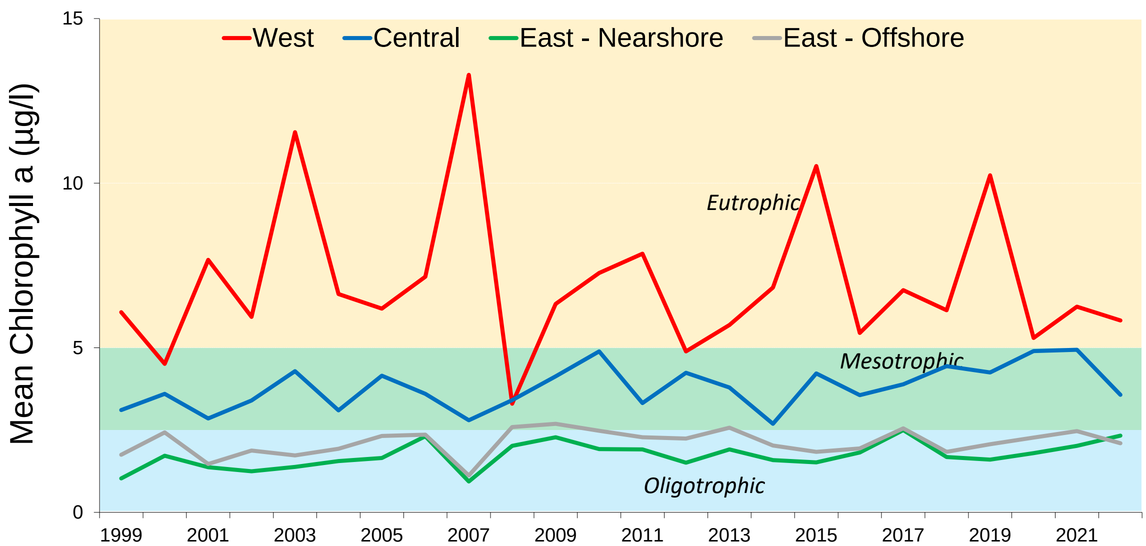


Figure 1.0.4: Mean chlorophyll *a* concentration (µg/L), weighted by month, for each basin in Lake Erie, 1999–2022. The East Basin is separated into nearshore and offshore. Shaded areas represent trophic class ranges.

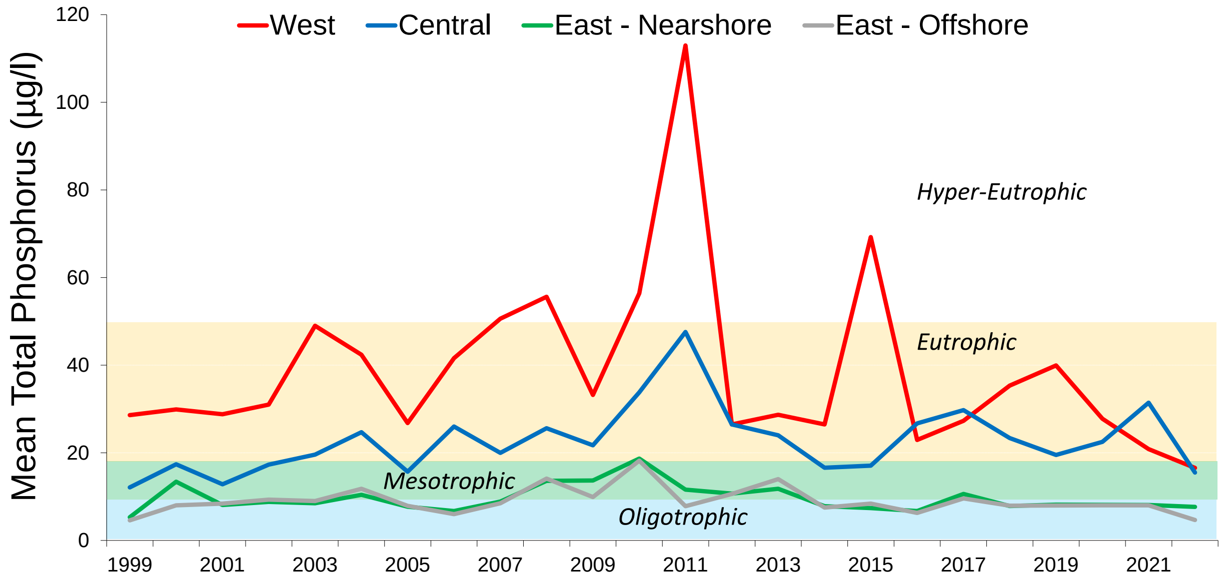


Figure 1.0.5: Mean total phosphorus (µg/L), weighted by month, for offshore sites in each basin of Lake Erie, 1999–2022. The East Basin is separated into nearshore and offshore. Shaded areas represent the trophic class ranges.

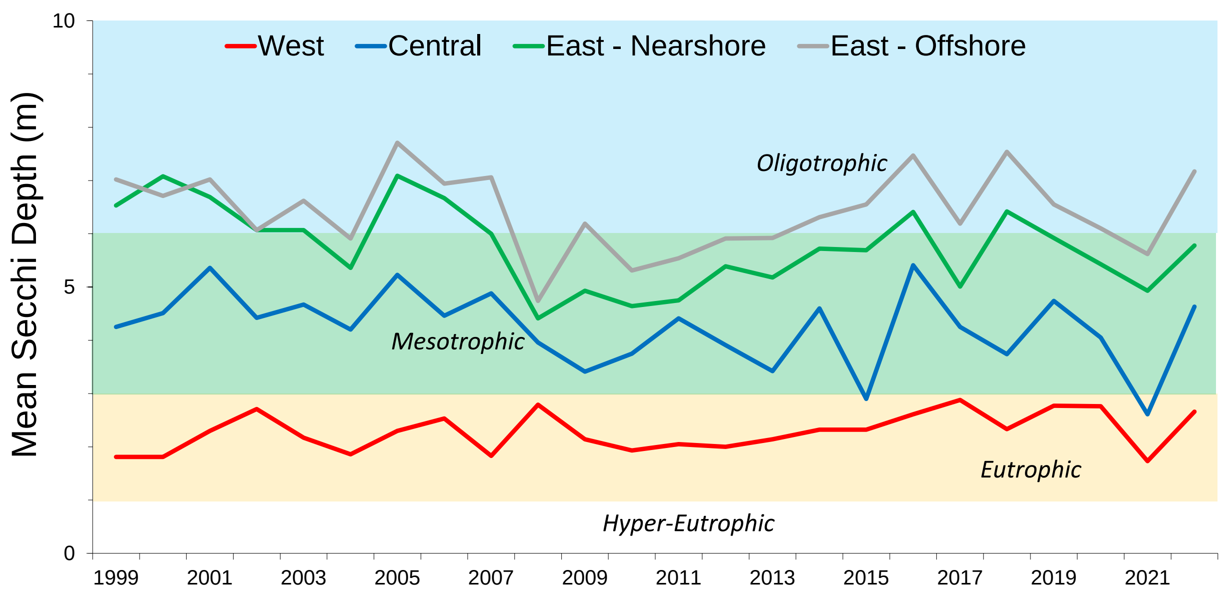
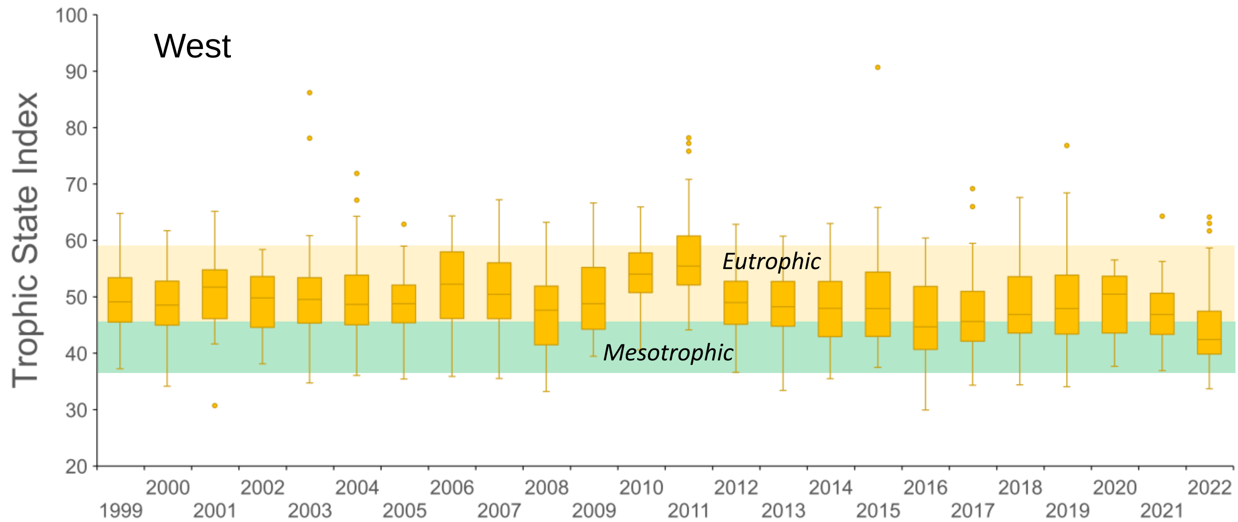


Figure 1.0.6: Mean summer (June–August) Secchi depth (m), weighted by month in each basin of Lake Erie, 1999–2022. The East Basin is separated into inshore and offshore. Shaded areas represent the trophic class ranges.



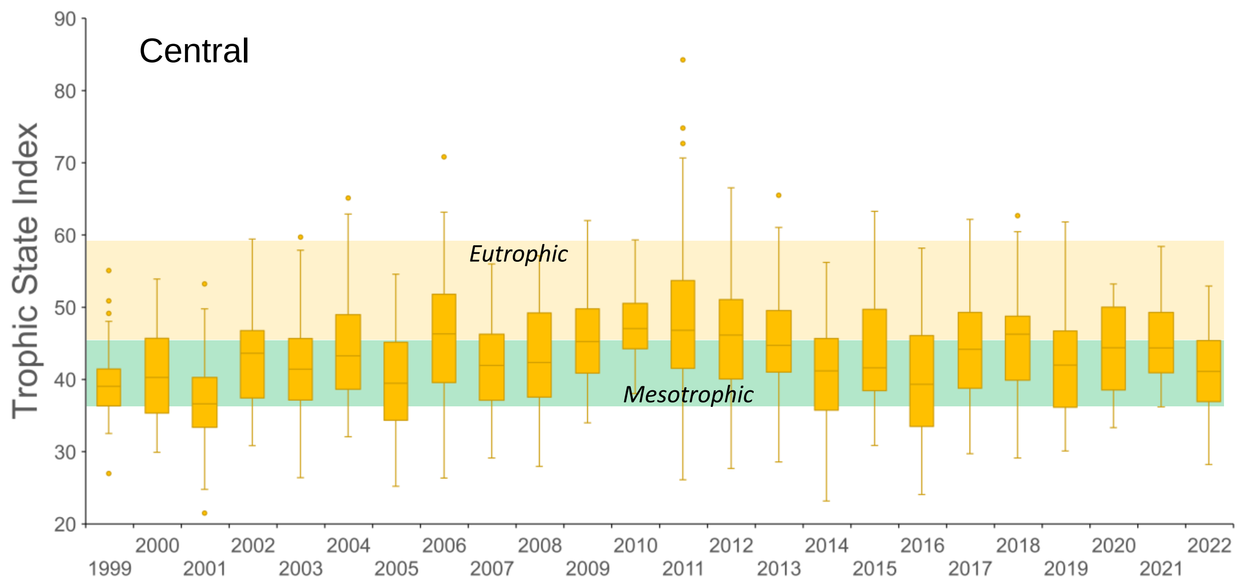


Figure 1.0.7: Box and whisker plot of trophic state indices (TSI) by basin in Lake Erie, 1999–2022. The East Basin is separated into nearshore and offshore. Shaded areas represent trophic class ranges. Boxes indicate 25th and 75th quartiles of the values with the median value as the horizontal line. Vertical lines show the range of values with individual points representing outliers.

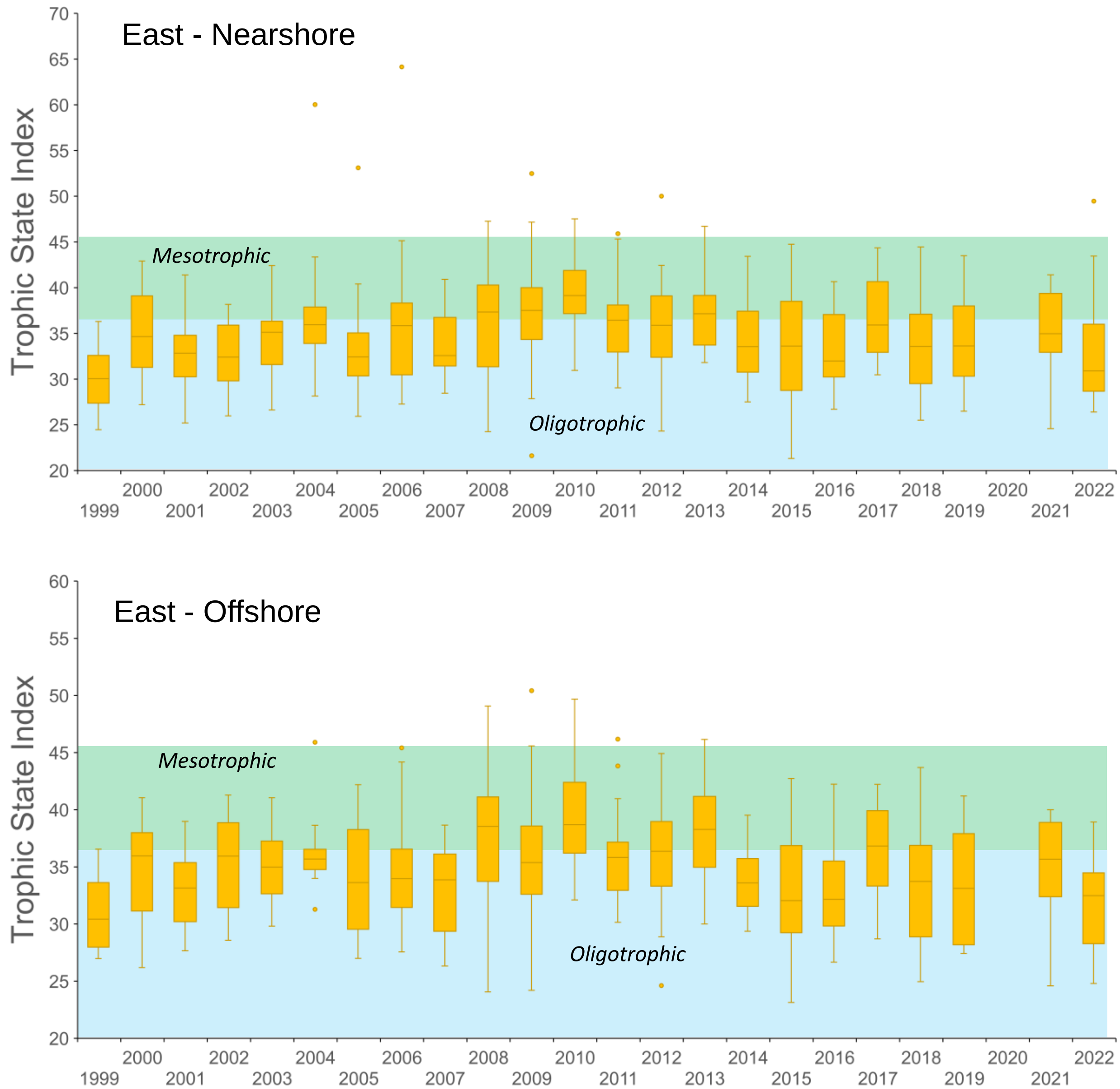


Figure 1.0.7: (Continued) Box and whisker plot of trophic state indices (TSI) by basin in Lake Erie, 1999–2022. The East Basin is separated into nearshore and offshore. Shaded areas represent trophic class ranges. Boxes indicate 25th and 75th quartiles of the values with the median value as the horizontal line. Vertical lines show the range of values with individual points representing outliers.

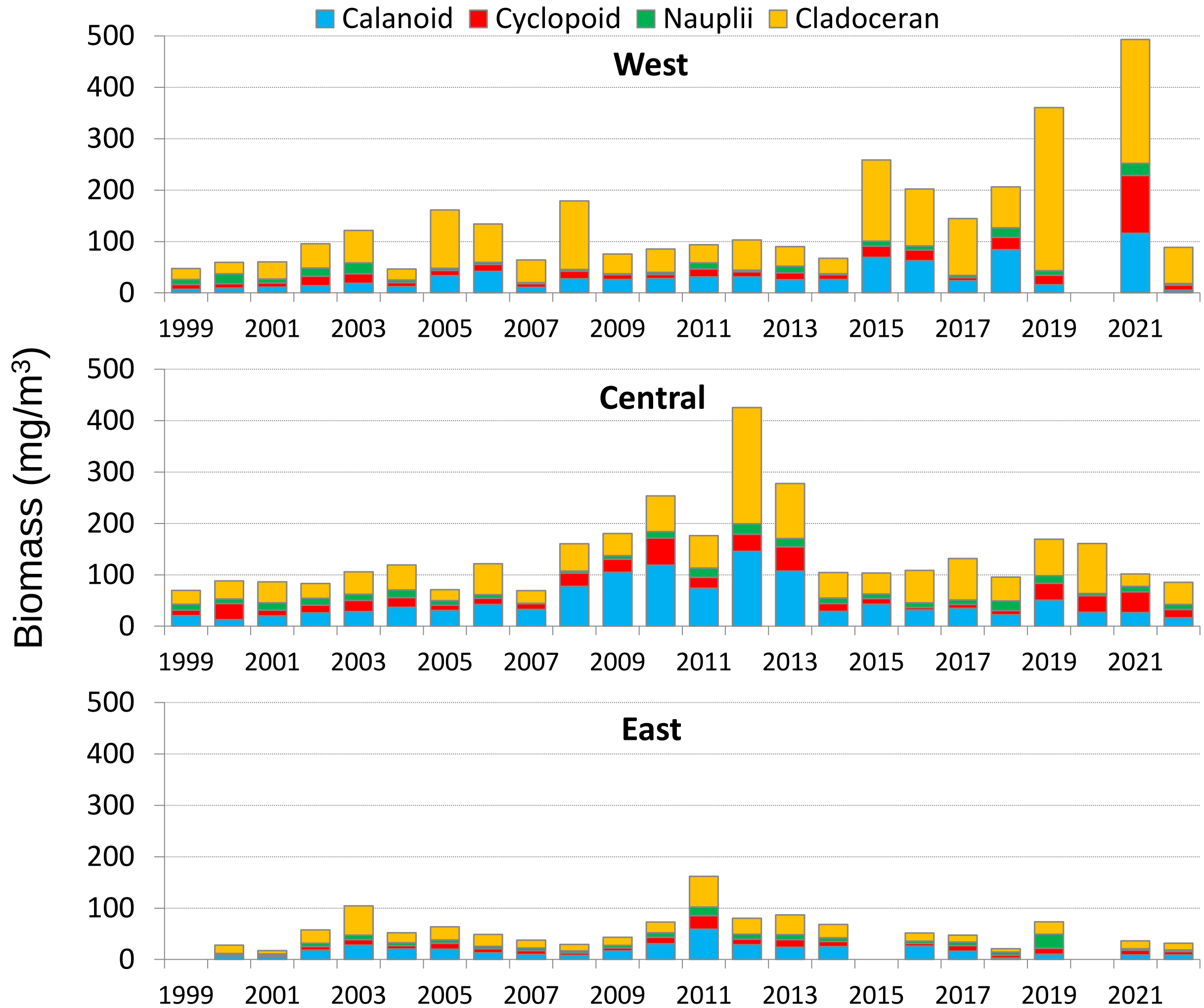


Figure 1.0.8: Average zooplankton biomass (mg/m^3) by major taxonomic group by basin, 1999-2022. There is no data for 1999 and 2015 in the East Basin, and samples were not taken in 2020 in the West or East basins. Data excludes rotifers and veligers. Harpacticoid zooplankton comprise a miniscule biomass 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 (J. Markham, 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 2022, a total of 34 trawl tows were sampled across New York waters and 109 trawl tows in the nearshore and offshore waters of Long Point Bay in Ontario (Figure 2.1.1.1). No trawling was conducted in the Pennsylvania waters of the East Basin in 2022 due to personnel issues.

In 2022, overall forage fish densities were the highest in the time-series in New York waters but remained low and well below the time series averages in the offshore waters of Long Point Bay (Figure 2.1.1.2). Rainbow Smelt is typically the most abundant forage species in most years and jurisdictions. In 2022, Rainbow Smelt catches were primarily composed of age-0 individuals in New York with low densities of age-1+ Rainbow Smelt; densities in Ontario waters were low with a more even distribution between size-class. The age-0 index in New York was the highest abundance in the time-series and accounted for most of the increase in overall fish densities. Emerald Shiner catches were again low in 2022 in all surveys. 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 both New York and Ontario. Clupeid (Gizzard Shad, Alewife) abundance was the second highest in the time-series in New York waters but below average in Ontario waters. New York also recorded its second highest abundance of age-0 walleye in their time-series in 2022 along with moderate catches of both age-0 and age-1 yellow perch. Catches of most other species were low in 2022.

2.1.2 Central Basin Status of Forage (P. Jenkins)

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 2022, 57 trawl tows were completed in Ohio. Pennsylvania was not able to trawl in 2022. 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 moderate. Rainbow smelt densities continue to be high in 2022 (Figure 2.1.2.2). The density of spiny-rayed fishes was the lowest in the time series with a 75 % decrease from 2021. Clupeid density increased 250% in 2022 compared to 2021 densities ranking 21st highest in the timeseries. Other soft-rayed fish density increased 860% relative to 2021 densities. The density of soft-rayed fishes was comprised mainly of Emerald Shiners, with the highest densities observed in 2022 since 2014. Yellow Perch densities for age-0 and age-1+ fish decreased in 2022 relative to 2021. Yellow Perch densities continue to be some of the lowest in the time series. Walleye densities decreased from 2021 but is still high relative to the long-term mean.

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, trawl catches 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 on bottom while trawling) to yield catch/m^2 (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: clupeids (age-0 age classes of Gizzard Shad and Alewife), soft-rayed fish (all age classes of Rainbow Smelt, Emerald Shiner, Spottail Shiner, other leucicds, 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.

2022 Results

In 2022, hypolimnetic dissolved oxygen levels were below the 2.0 mg/L threshold (i.e., hypoxic) at four sites during the August trawling survey; these sites were located west and south of Point Pelee in Ontario waters. In total, data from 69 sites were used in 2022, which is up from 67 in 2021 (Figure 2.1.3.1).

Total forage density in 2022 decreased 74% from last year and was half of the ten-year mean, returning to the low abundances documented in 2019 and 2020 (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 declined 76% from 2021. Soft-rayed species declined 30% from 2021. Clupeid density rebounded somewhat from 2021, increasing by 52% compared to the previous year. Total forage density averaged 2,278 fish/ha across the West Basin, which is around half of the ten-year mean (4,665 fish/ha). Clupeid density was 124 fish/ha (ten-year mean 714 fish/ha), soft-rayed fish density was 196 fish/ha (mean 244 fish/ha), and spiny-rayed fish density was 1,958 fish/ha (mean 3,706 fish/ha). Age-0 White Perch (51%), Yellow Perch (25%), Freshwater Drum (5%), and Gizzard Shad (5%) made up the majority of forage fish abundance.

Total forage biomass (10.8 kg/ha; Figure 2.1.3.3) greatly decreased compared to 2021 (35.2 kg/ha; again, likely due to one outlier catch). Likewise, spiny-rayed prey biomass declined 73% from the previous year (9.2 kg/ha). Soft-rayed forage also declined (0.7 kg/ha), while clupeid biomass was similar (0.9 kg/ha) but well below the ten-year mean of 4.5 kg/ha. Biomass of Age-0 White Perch (5.1 kg/ha) and Yellow Perch (2.0 kg/ha) were low compared to 2021, while age-0 Gizzard Shad biomass was similar (0.9 kg/ha).

Recruitment of individual species remains highly variable in the West Basin (Table 2.1.3.2). Age-0 Walleye density in 2022 (83/ha) dropped from a time-series high (346/ha; Figure 2.1.3.4). Age-0 Yellow Perch density (572/ha; Figure 2.1.3.4) also fell from 2021 and was near the ten-year mean (565/ha). Age-0 White Perch density (1,160/ha) fell from a 30 year high in 2021 (Figure 2.1.3.5). Density of age-0 Rainbow Smelt (27/ha) were similar to the ten-year mean (34/ha), while age-1+ smelt abundance was not measurable. Age-0 Gizzard Shad density (124/ha) remained well below the ten-year mean (714/ha), continuing a trend of high annual variation (Figure 2.1.3.5). Densities of age-0 (0.5/ha) and age-1+ Emerald Shiners (0.1/ha) were again very low, with minimal densities for seven straight years (Figure 2.1.3.6). Round Goby (all ages) fell from a high 2021 density (25/ha). Age-0 Mimic Shiner density was again unusually high at 39/ha (ten-year mean = 5/ha).

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 (Figure 2.1.3.1). 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 2022, all eight sites were sampled on August 8th, 9th, and 15th, 2022.

The 2022 trawl survey captured 1,453 foraged sized individual per ha trawled, the third lowest catch in the time series and a 69% decrease in total catch compared year over year from 2021 (Figure 2.1.4.1; Table 2.1.4.1). Age-0 White Perch (846.5 per hectare) and age-0 Yellow Perch (348.7 per hectare) were the two most abundant species in the catch (Table 2.1.4.1, 2.1.4.2), though both were down substantially from 2021. We captured 7.9 Emarald Shiners per hectare, which is the first time the species was measurable since 2019. Spottail Shiners increased nearly 28% from 2021, to their highest catch in the time series. Gizzard Shad were up 42% from their catch in 2021, however, remain well below their mean. Silver Chub were observed in 2022 at a rate of 4.9 per hectare, down 15.5% from last year and 27.1 from the 2014-2021 mean. Age-0 Walleye catch was 30.3 per hectare up 18% from 2021 and 30% above the 2014-2021 mean, though catches of other age-0 sportfishes were down (Table 2.1.4.2).

The development of this dataset will allow for the evaluation of trends in forage abundance and the recruitment of sportfishes in Michigan's Lake Erie waters in future years, while contributing to a greater understanding of forage dynamics in Lake Erie's West Basin.

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 = 32) in 2022 was dominated by Round Goby (87%), which is typical for the species (Figure 2.2.1.1). Gizzard Shad (6%) and Crayfish (6%) 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 = 107) are more varied than Smallmouth Bass, with ten distinct prey species identified in 2022 (Figure 2.2.1.2). Round Goby (49%) and Gizzard Shad (27%) made up the majority of stomach contents by percent occurrence, but Bluegill (7%), Emerald Shiner (4%), and *Morone* spp. 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 (J. Markham)

Lake Trout diet information was collected from fish caught during August 2022 (n = 254) in the interagency coldwater gill net assessment (CWA) 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 2022, Rainbow Smelt were again the prominent prey fish for Lake Trout, occurring in 73.6% of the non-empty stomachs, followed by Round Goby (35.4%; Figure 2.2.2.1). Yellow Perch (1.2%), Gizzard Shad (1.2%), and Freshwater Drum (0.4%) were the only other identifiable fish species found in Lake Trout stomachs in 2022.

2.2.3 Walleye

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

During August trawls in the Michigan waters of the west basin, 38% of Walleye sampled had stomach contents (Table 2.2.3.1). White Perch (50%) were the most common diet item followed by unidentified fish (32%), Yellow Perch (9%) and Gizzard Shad (5%). During the October gillnet survey 79% of sampled Walleye contained food items (Table 2.2.3.2). Gizzard Shad were the most abundant prey item (66%), followed by unidentified fish (14%), and White Perch (2%).

West and Central Basin – Ohio (Z. Slagle)

Walleye diets in the fall of 2022 were comprised mostly of Gizzard Shad (82.6%), somewhat greater than recent years (Figure 2.2.3.1). Unidentified fish (14.4%) and Rainbow Smelt (2.1%) made up much of the remainder. A total of 300 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 (J. Markham)

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 2022, 336 Walleye stomachs were examined of which only 49 (15%) contained food remains (Wilkins 2023a). Round goby was the dominant (57%) walleye diet item by volume for angler-caught adult Walleye followed by Yellow Perch (21%) and Rainbow Smelt (16%; Figure 2.2.3.2). 2022 was the 7th time in the last 8 years that smelt did not comprise the majority (>50% by volume) of the diet. Also of note was the presence of zooplankton in walleye stomachs (3% by volume) which was a rare occurrence but has been present for the past six years.

2.2.4 Yellow Perch

Central Basin – Ohio (P. Jenkins)

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 with the highest percent occurrence of spiny water flea, zooplankton, and midges in June (Figure 2.2.4.1). Spiny water flea percent occurrence increases in July and August to over 50 %. October yellow perch diets become more diverse with a higher percent occurrence of unidentified fish.

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

2.3.1 East Basin Predator Growth (J. Markham)

Walleye

Walleye length at age-1 and age-2 from netting surveys targeting juveniles in New York has declined for the past six years. While growth for both age-1 and age-2 walleye increased slightly in 2022, they remained 20 and 13 mm below the long-term average length, respectively, and ranked in the lower quartile in the 42-year time series (Wilkins 2023b). Age-0 and age-1 Yellow Perch sampled in fall trawl surveys in New York have exhibited stable growth rates since 2006. In 2022, age-0 Yellow Perch equaled the time series average of 81 mm while age-1 Yellow perch (150 mm) was above the time series average (Markham and Wilkins 2023).

Adult Walleye condition in the New York waters of Lake Erie had generally been trending down over the last decade. In 2022 the estimated weight of a 20-, 24- and 28-inch harvested Walleye was 2.6, 4.6 and 7.4 lbs., respectively, compared to long-term averages of 2.7, 4.7 and 7.6 lbs. (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 2019 and consistent with changes in the forage community. However, both metrics have steadily increased since 2020 to values more typically observed in the past decade.

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

Age-0 Sportfishes

Overall, mean length of age-0 sport fish in 2022 from the West Basin interagency trawl increased somewhat compared to 2021 (Figure 2.3.2.1). Lengths of select age-0 species in 2022 include Walleye (107 mm), Yellow Perch (70 mm), White Bass (82 mm), and White Perch (70 mm). Walleye average length has increased three 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 rebounded somewhat in 2022 after several years of decline (Figure 2.3.2.2). Length at age-2 (387 mm) and age-3 (458 mm) remain below the ten-year means, while length at age-4 (503 mm) was near the ten-year mean (500 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 ten years; in 2022, mean total length at age-3 was 363 mm. Largemouth Bass length at age-3 has varied widely for seven years, with a 2022 mean total length at age-3 of 321 mm. 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), 2022 density, and the percent difference between 2022 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: 2011–2021	2022	+/-
All forage species	4664.6	2278.2	-51.2%
Clupeid	714.4	124.2	-82.6%
Soft-rayed	243.7	196	-19.6%
Spiny-rayed	3706.4	1958	-47.2%

Table 2.1.3.2: Ten-year mean density (arithmetic mean number per hectare), 2022 density, and the percent difference between 2022 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: 2011–2021	2022	+/-
Emerald Shiner	Age-0	35.8	0.5	-98.6%
Emerald Shiner	Age-1+	38.7	0.1	-99.7%
Freshwater Drum	Age-0	99.5	124.3	24.9%
Gizzard Shad	Age-0	714	124.1	-82.6%
Rainbow Smelt	Age-0	34.1	27.3	-19.9%
Rainbow Smelt	Age-1+	0.4	0	-100%
Round Goby	All ages	28.8	25.2	-12.5%
Walleye	Age-0	99.3	83.4	-16%
White Bass	Age-0	91.2	19.1	-79.1%
White Perch	Age-0	2851.3	1159.6	-59.3%
Yellow Perch	Age-0	565.1	571.5	1.1%

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 2021 to 2022. Yr/2014-2021% is the percent change from 2022 to the 2014-2021 average. Blanks indicate no catch in either 2022, 2021, or both.

Year	YOY White Perch	All Mimic Shiner	YOY Gizzard Shad	All Trout-Perch	All Round Goby	All Spottail Shiner	All Silver Chub	All Emerald Shiner	All Dreissenid Mussels
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	1896.4	120.2	730.9	62.1	41.4	2.2	3.4	0	0.45
2018	8100	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	1193.8	53	15.2	25.4	125.7	24.2	21.6	0	0.68
2021	1633.3	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
Yr/Yr%	-69.3	-48.2	5.0	42.3	-19.4	-89.3	27.9	-15.5	
Yr/2014-2021 %	-57.2	-55.3	-95.6	-58.3	-16.8	-86.5	194.3	-27.1	205.3

*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 2021 to 2022. Yr/2014-2021% is the percent change from 2022 to the 2014-2021 average. Blanks indicate no catch in either 2022, 2021, or both.

Year	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
Yr/Yr %	-87.2	18.4	-43.0	-96.4
Yr/ 2014-2021 %	-63.3	20.4	-79.1	-95.3

Table 2.2.3.1: Number of fish sampled (N), the percent with stomach contents (% With contents), and 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) from Walleye captured during the August Michigan trawl survey.

Year	N	% 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

Table 2.2.3.2: Number of fish sampled (N), the percent of fish with stomach contents (%With Contents), and 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) from Walleye captured in October during the Michigan gill netting survey. The survey was not completed in 2020 due to COVID-19 restrictions.

Year	N	%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

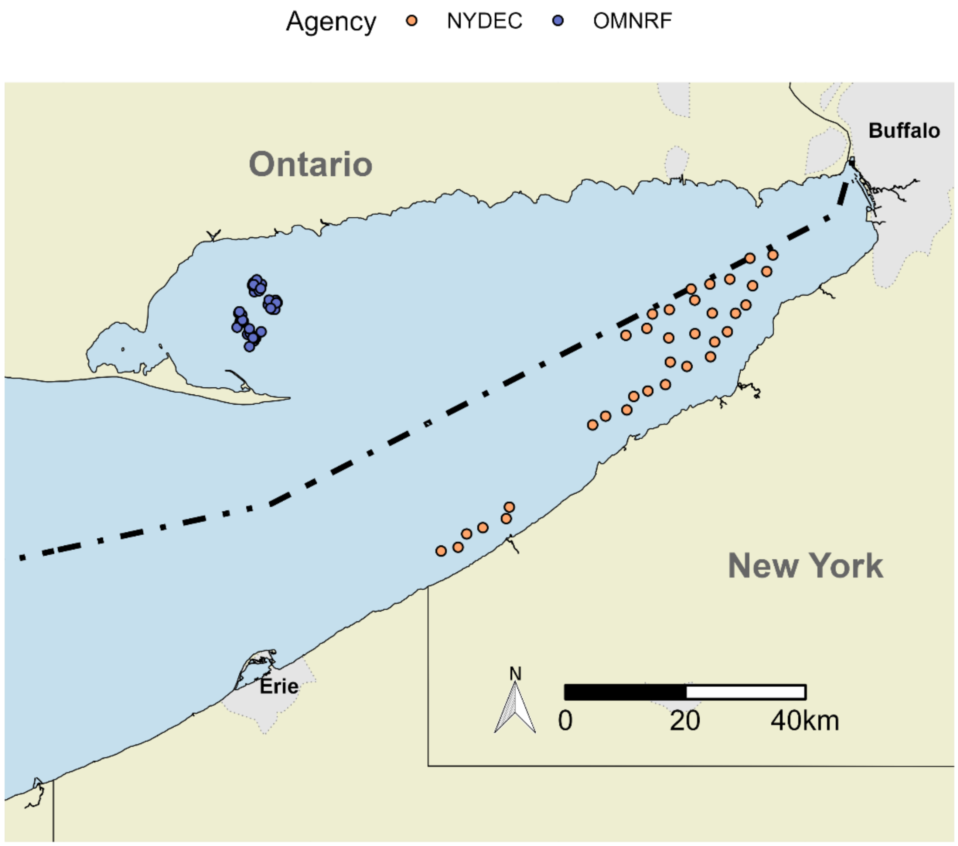


Figure 2.1.1.1. Locations of standard index bottom trawls by Ontario (blue) and New York (orange) to assess forage fish abundance in the East Basin of Lake Erie in 2022. Pennsylvania did not trawl in 2022 due to vessel issues.

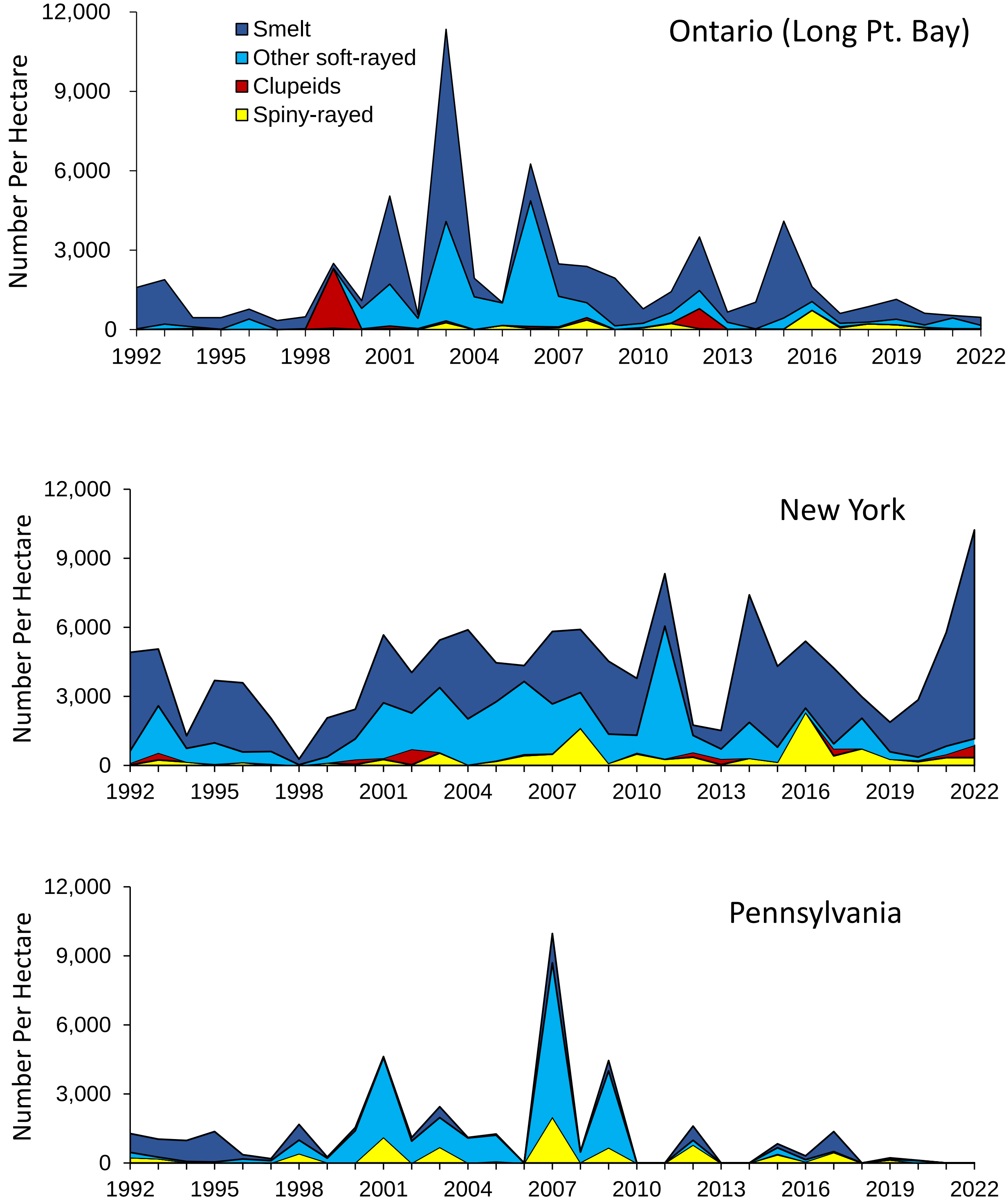


Figure 2.1.1.2: Mean density of prey fish (number per hectare) by functional group in the Ontario, New York and Pennsylvania waters of the East Basin, Lake Erie, 1992-2022. Pennsylvania did not sample in 2010, 2011, 2013, 2014, 2018, 2021 or 2022.

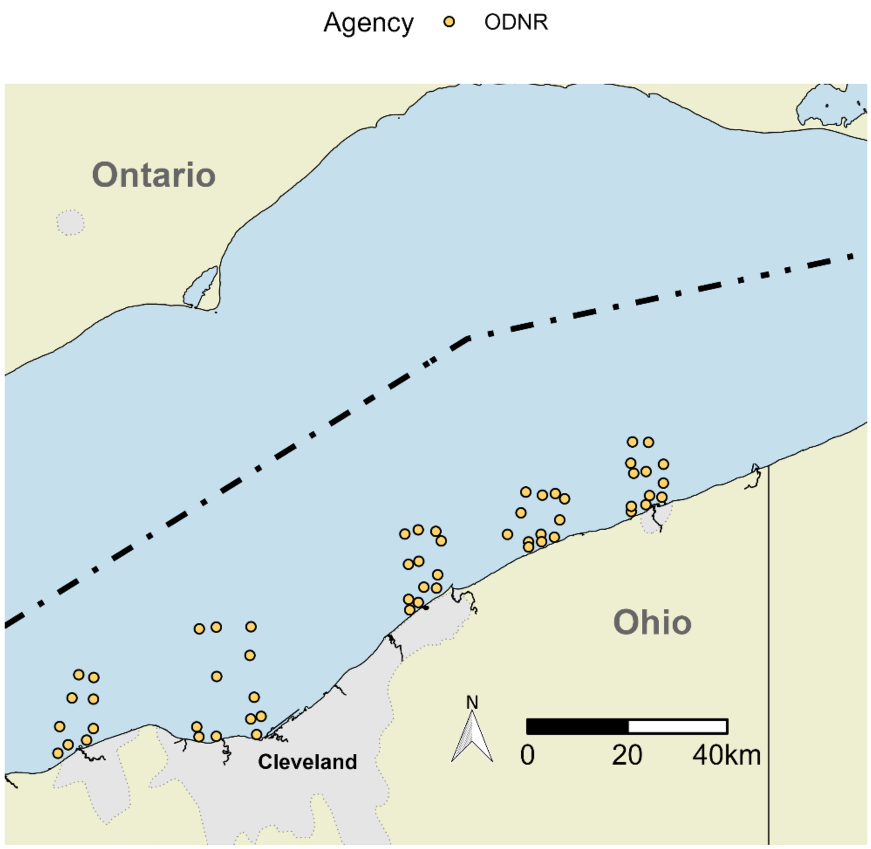


Figure 2.1.2.1. Locations sampled by Ohio (yellow) with index bottom trawls to assess forage fish abundance in the Central Basin, Lake Erie during 2022. Pennsylvania did not trawl in 2022.

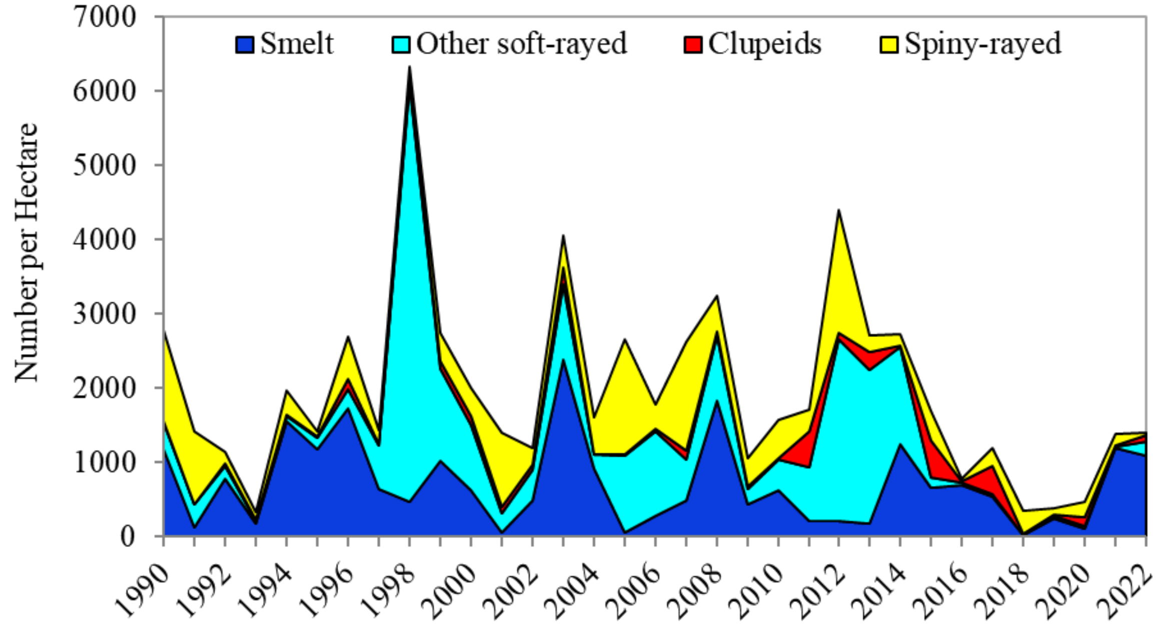


Figure 2.1.2.2: Mean density of prey fish (number per hectare) by functional group in Ohio waters of the Central Basin, Lake Erie, 1990–2022.

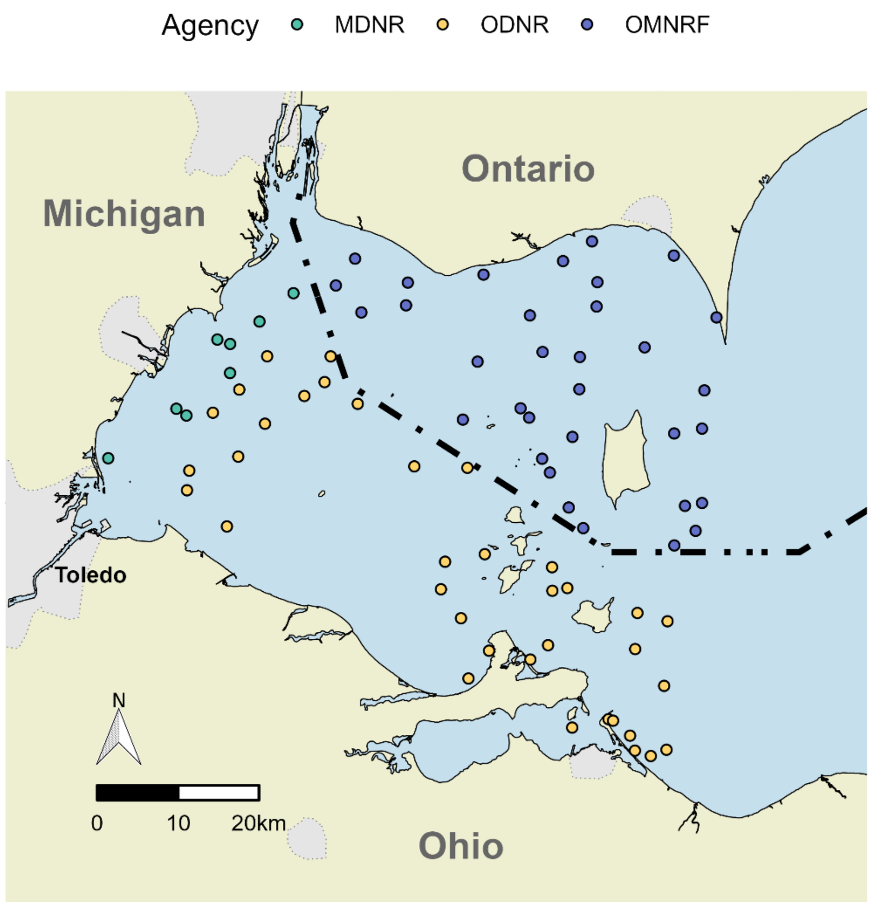


Figure 2.1.3.1: Trawl locations for West Basin bottom trawl surveys in 2022. Ohio (yellow) and Ontario (blue) surveys are combined to summarize the interagency indices, while Michigan (green) cannot yet be included due to lacking trawl comparison data.

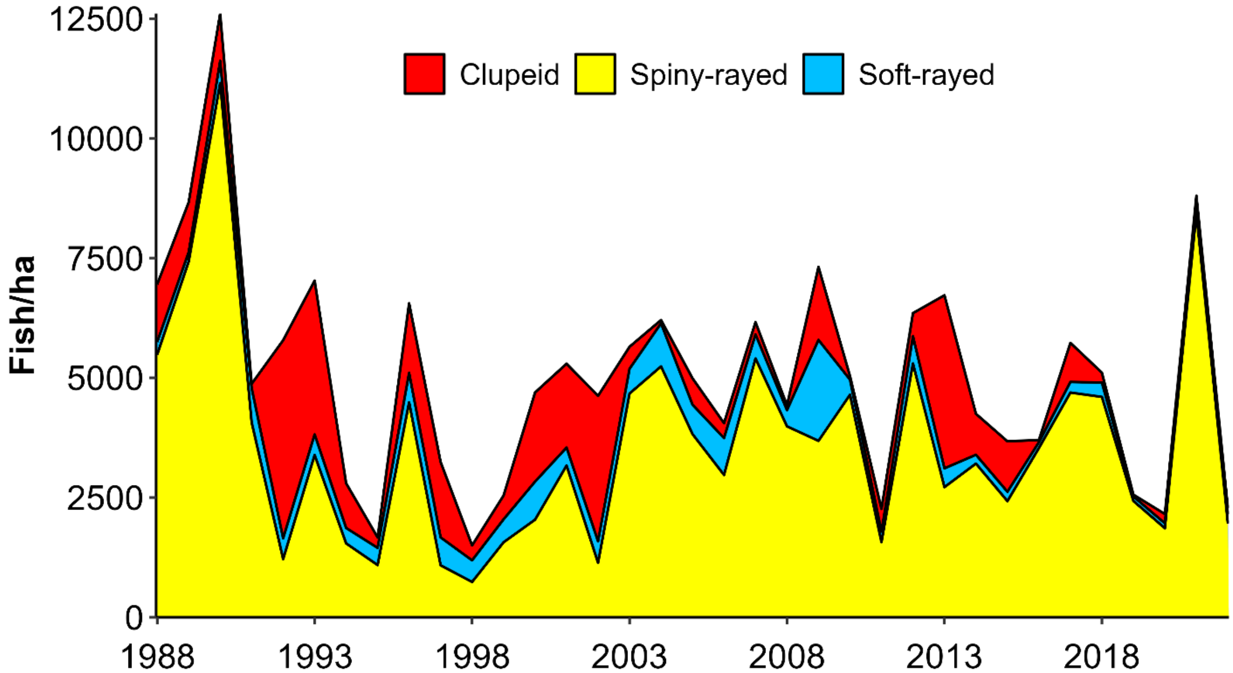


Figure 2.1.3.2: Mean density (number per hectare) of prey fish by functional group in the West Basin of Lake Erie, August 1988–2022.

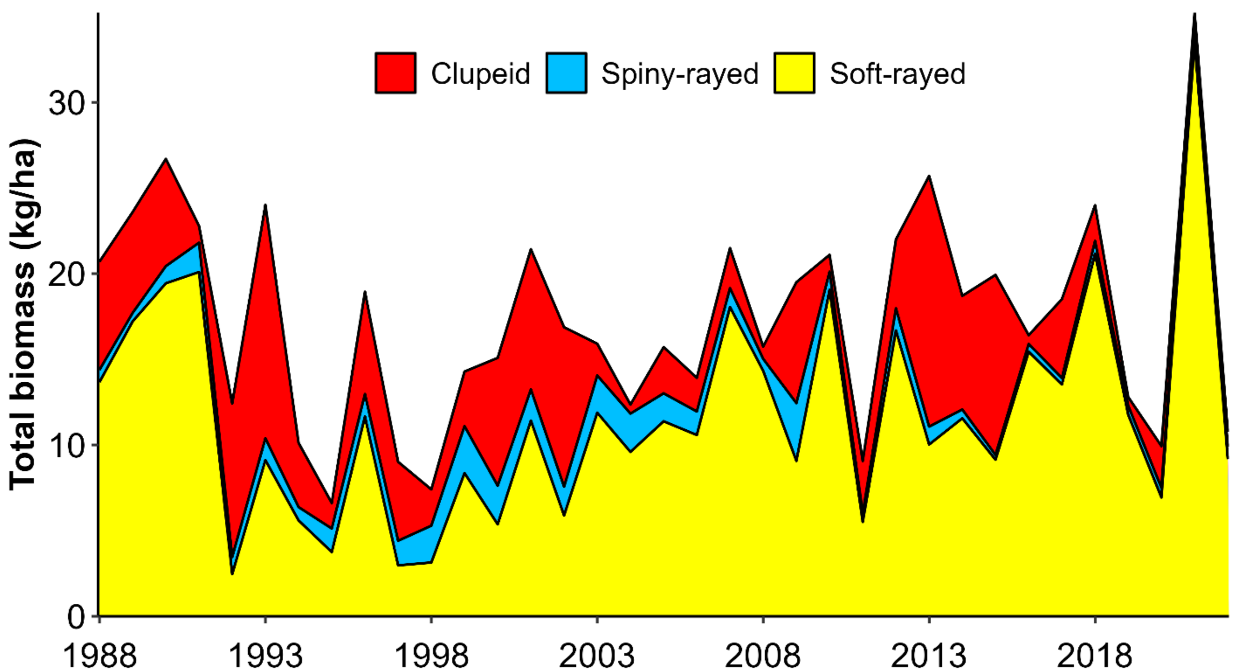


Figure 2.1.3.3: Mean biomass (kilograms per hectare) of prey fish by functional group in the West Basin of Lake Erie, August 1988–2022.

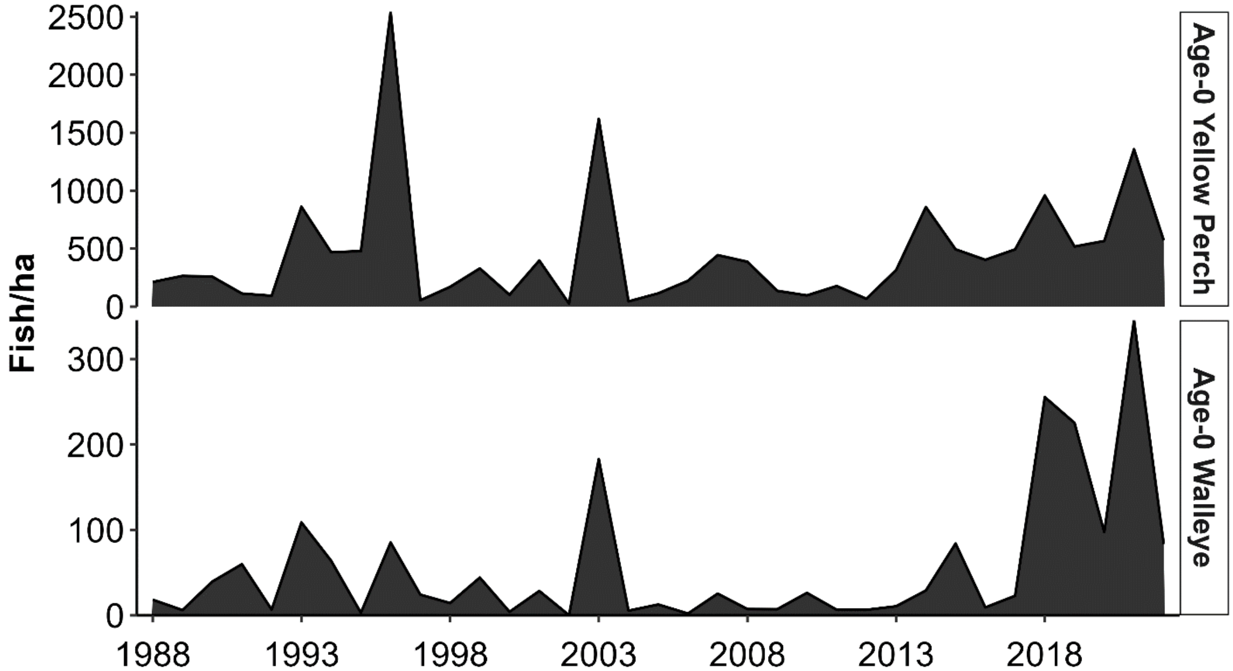


Figure 2.1.3.4: Densities of age-0 Yellow Perch (top) and age-0 Walleye (bottom) in the West Basin of Lake Erie, August 1988–2022.

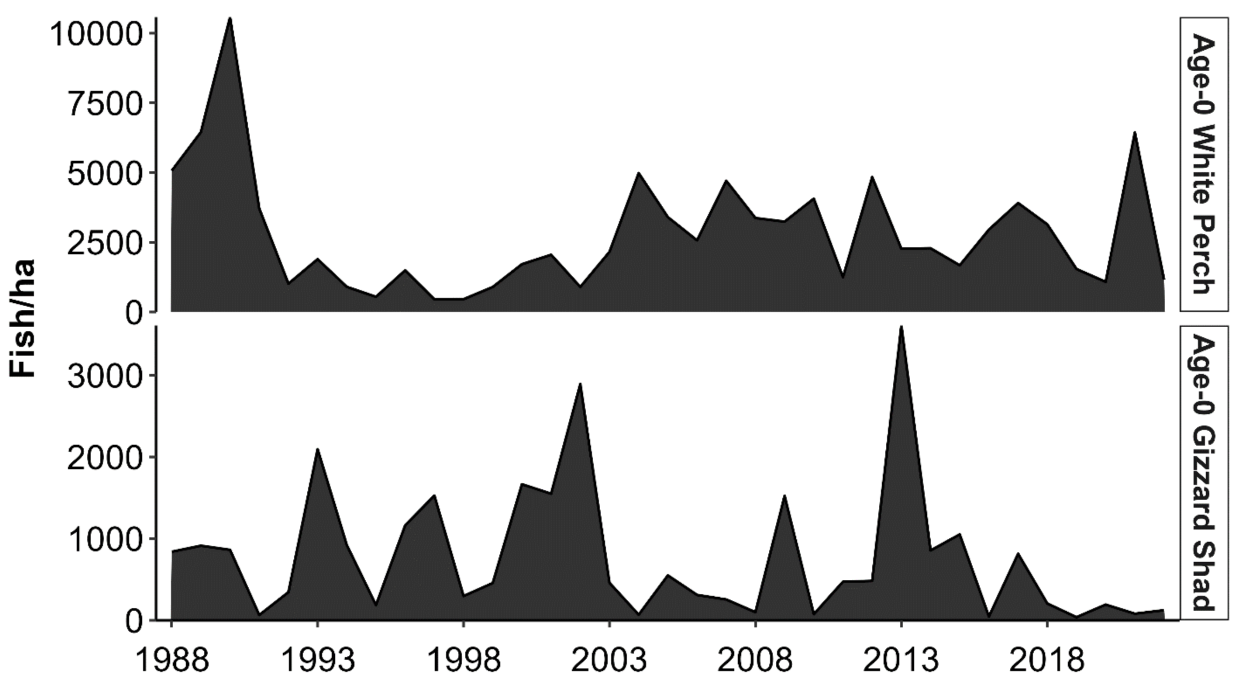


Figure 2.1.3.5: Density of age-0 Gizzard Shad (top) and age-0 White Perch (bottom) in the West Basin of Lake Erie, August 1988–2022.

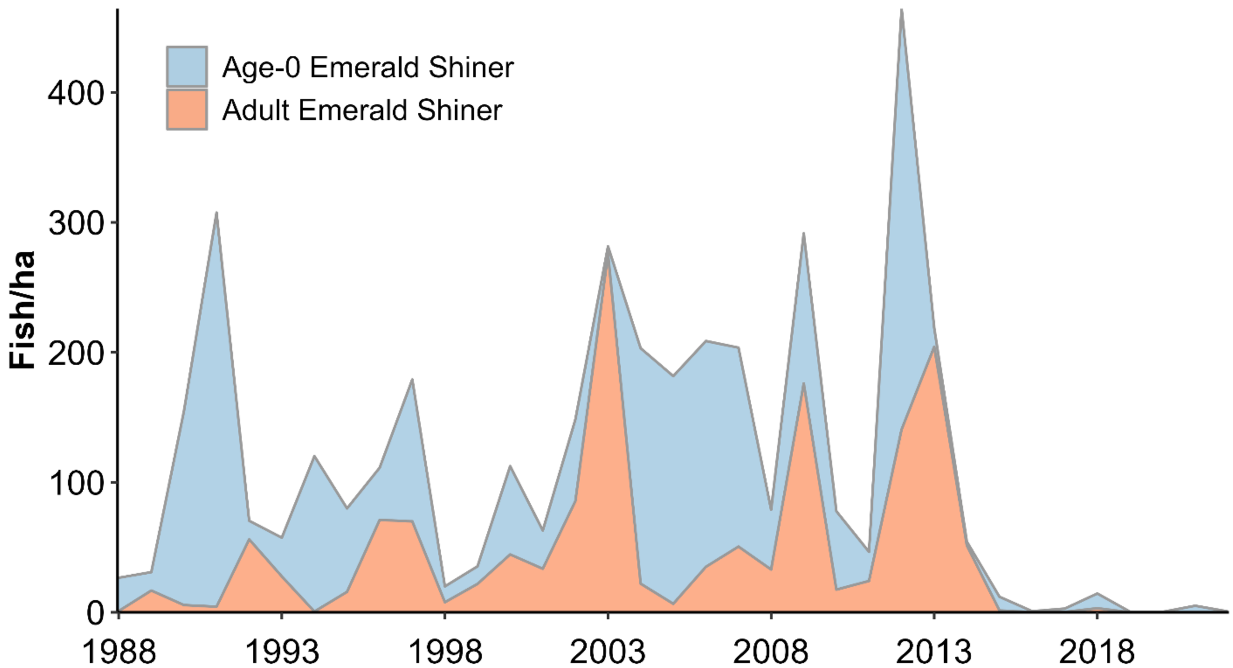


Figure 2.1.3.6: Densities of age-0 (blue) and age-1+ (red) Emerald Shiner in the West Basin of Lake Erie, August 1988–2022. Densities for both groups have remained minimal for seven years.

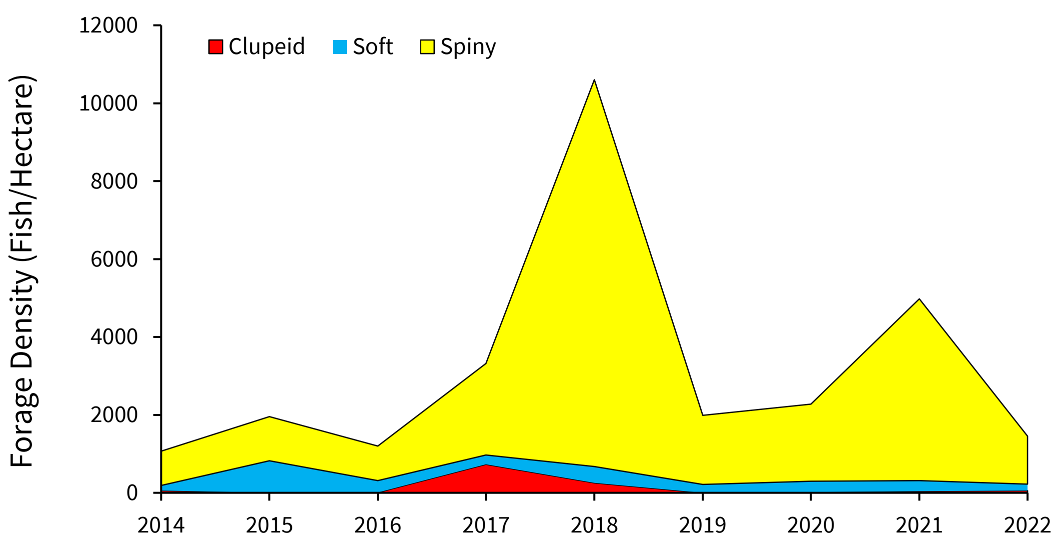


Figure 2.1.4.1: Mean density (number per hectare) of prey fish by functional group in Michigan waters of Lake Erie, August 2014–2022.

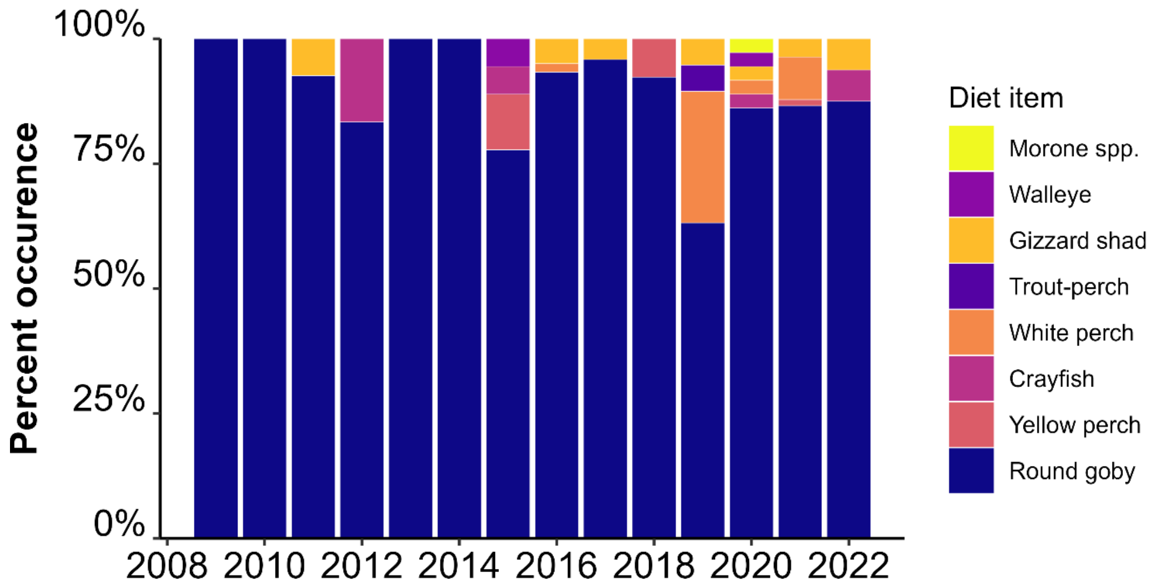


Figure 2.2.1.1: Percent occurrence of diet items from non-empty stomachs of Smallmouth Bass collected in West and Central Basin gill-net assessments in September 1998–2022.

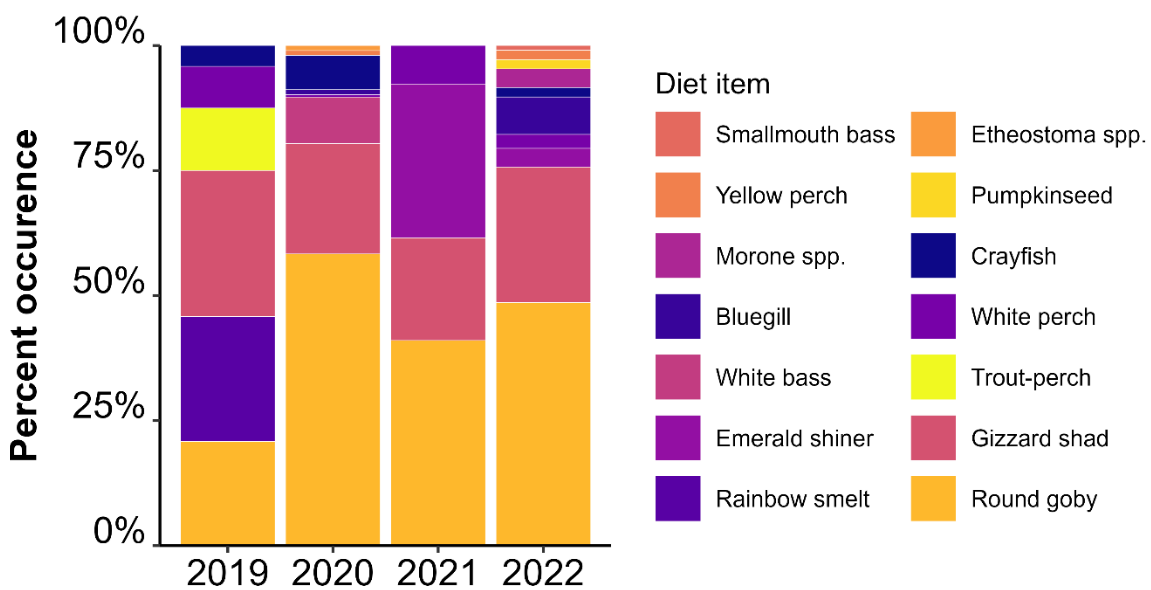


Figure 2.2.1.2: Percent occurrence of diet items from non-empty stomachs of Largemouth Bass collected in West and Central Basin electrofishing assessments, June–August 2019–2022.

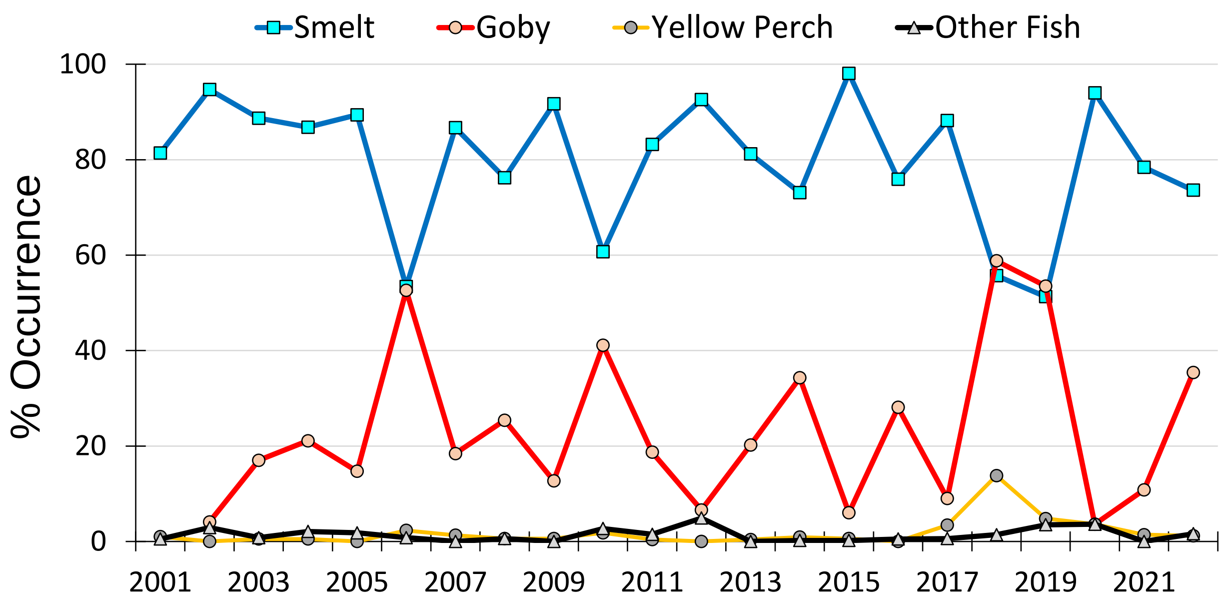


Figure 2.2.2.1: Percent occurrence of diet items from non-empty stomachs of lean strain Lake Trout collected from gill net assessment surveys in the East Basin of Lake Erie, August 2001-2022.

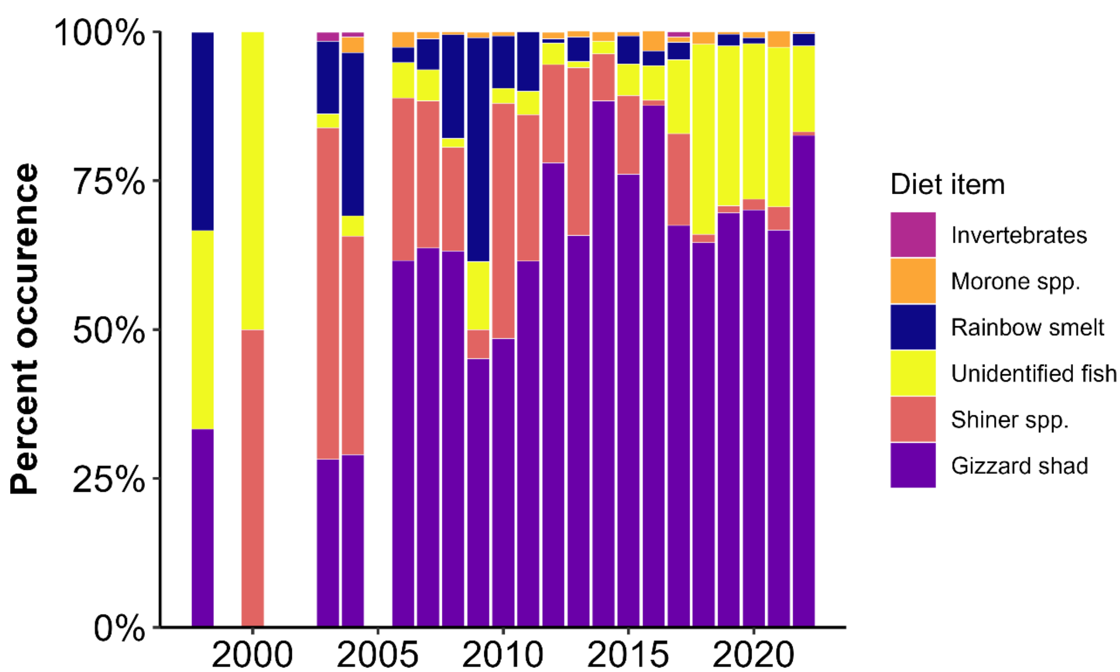


Figure 2.2.3.1: Percent occurrence of diet items from non-empty stomachs of Walleye collected in West and Central Basin gill-net assessments, September–November, 1998–2022.

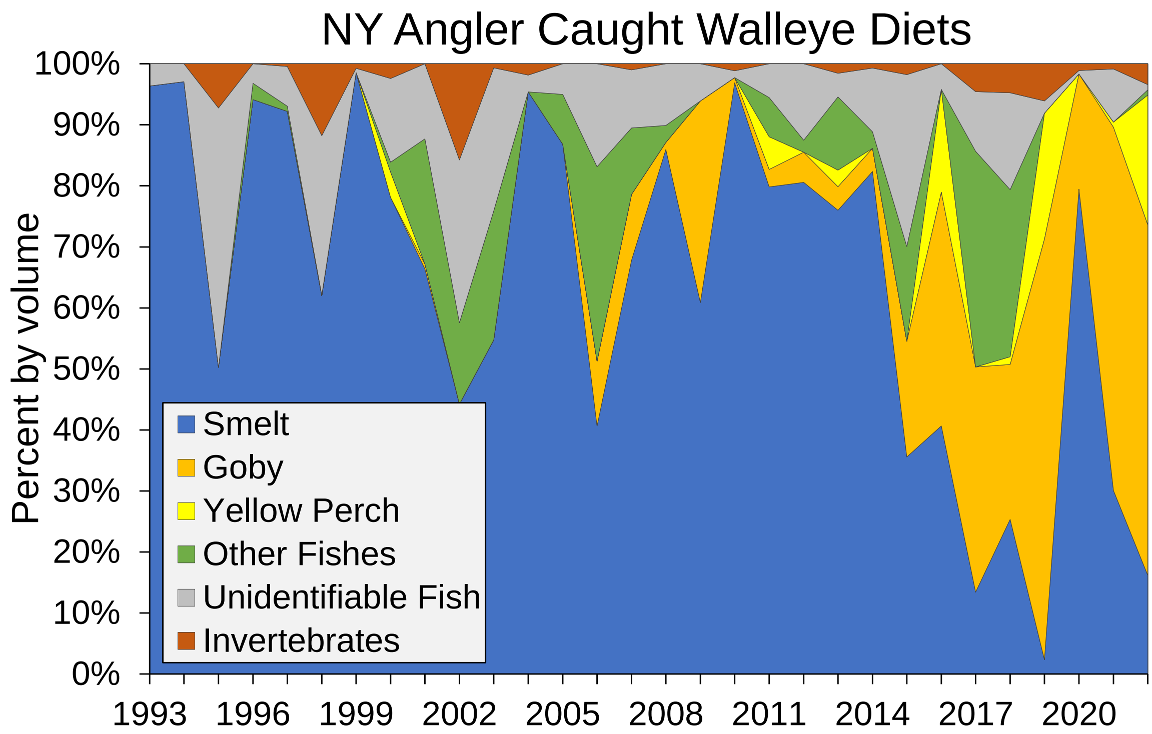


Figure 2.2.3.2: The percent contribution (by volumn) of identifiable prey in non-empty stomachs of adult Walleye caught by summertime anglers in New York's portion of Lake Erie, 1993-2022.

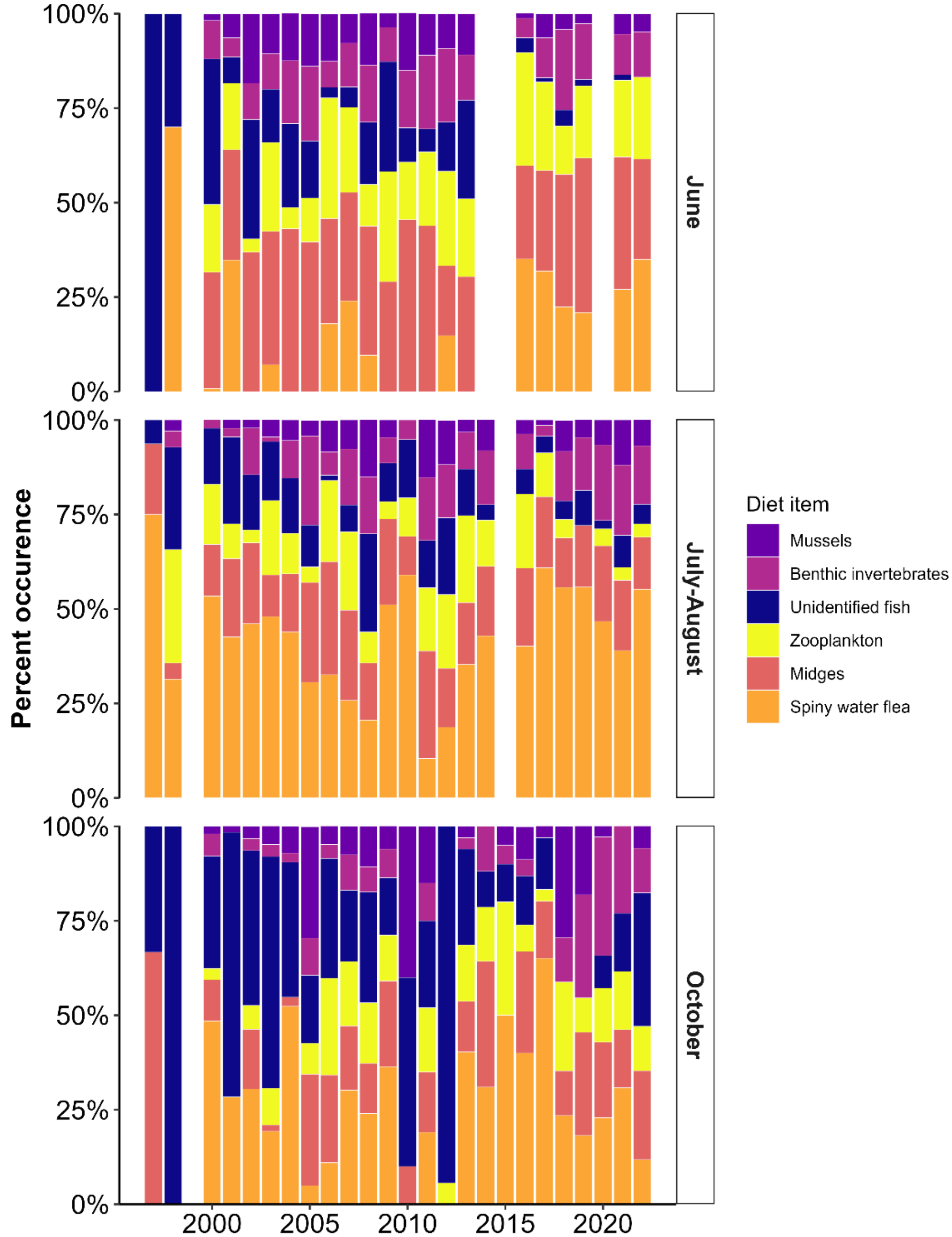


Figure 2.2.4.1: Percent occurrence of diet items from non-empty stomachs of Yellow Perch collected in Central Basin trwal survey, June–Oct.

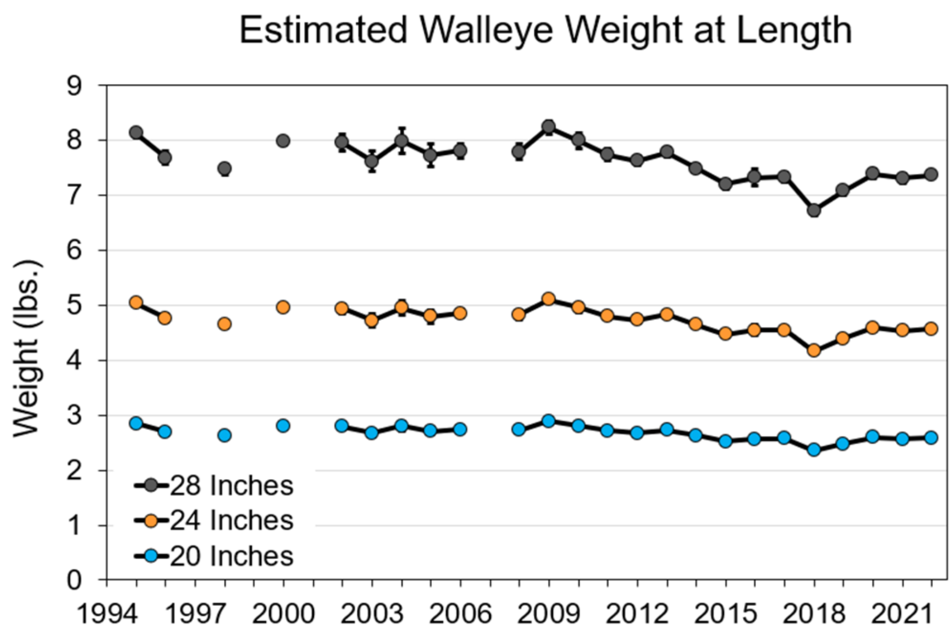


Figure 2.3.1.1: Estimated body weight (lbs.) of angler-caught walleye in the New York waters of Lake Erie at 20, 24, and 28 inches from 1995-2022. Error bars represent 95% confidence intervals.

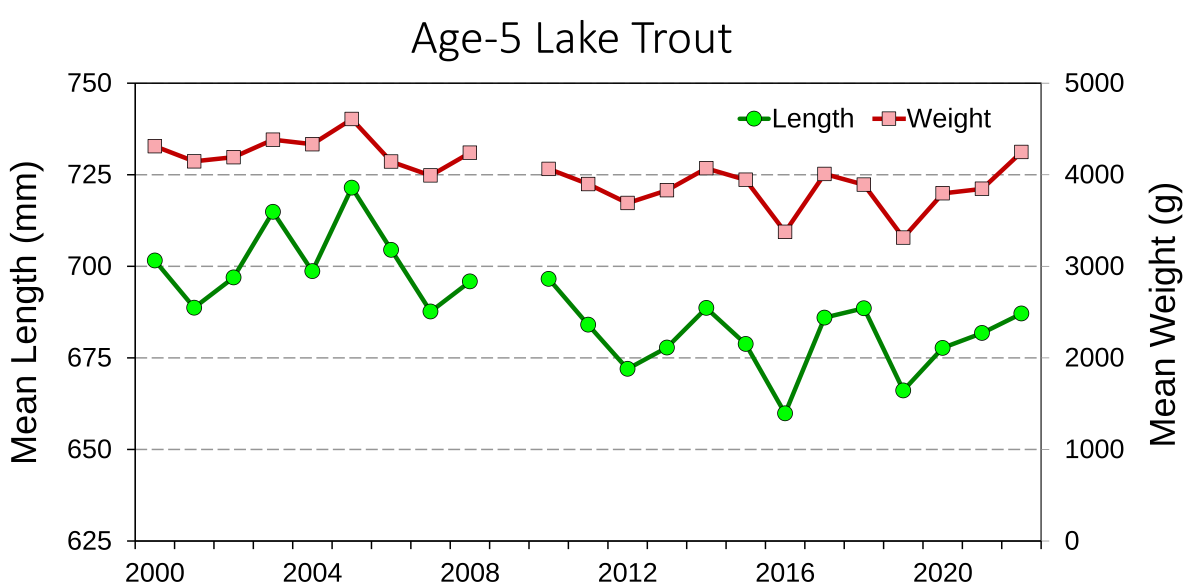


Figure 2.3.1.2: Mean length (mm) and weight (g) of age-5 lean strain Lake Trout caught in gill net assessment surveys from the East Basin of Lake Erie, August 2000-2022.

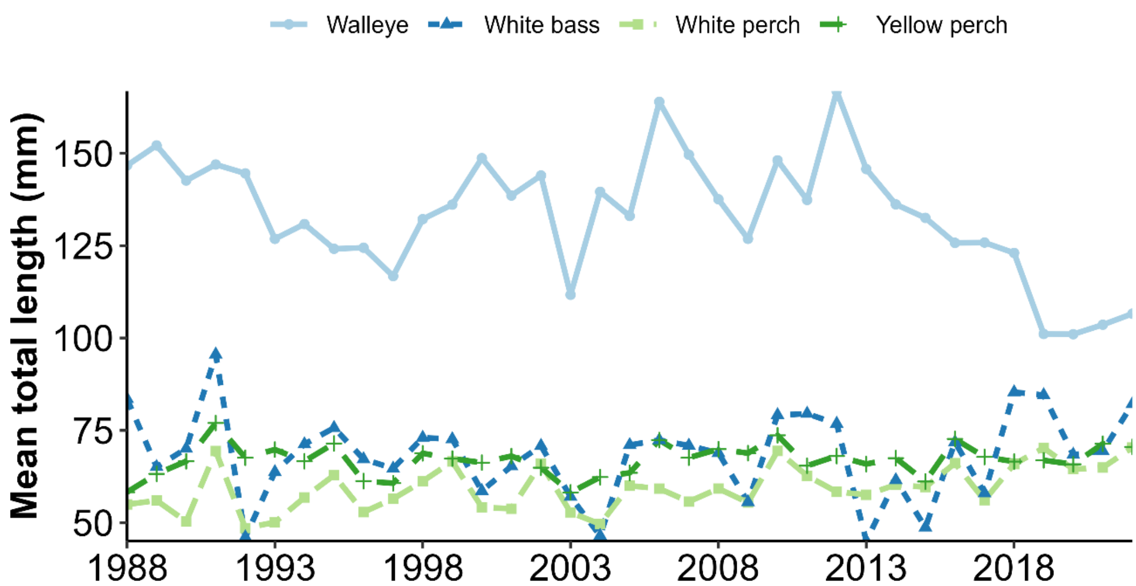


Figure 2.3.2.1: Mean total length of select age-0 fishes in West Basin Lake Erie, August 1988– 2022. Data are from the interagency trawl.

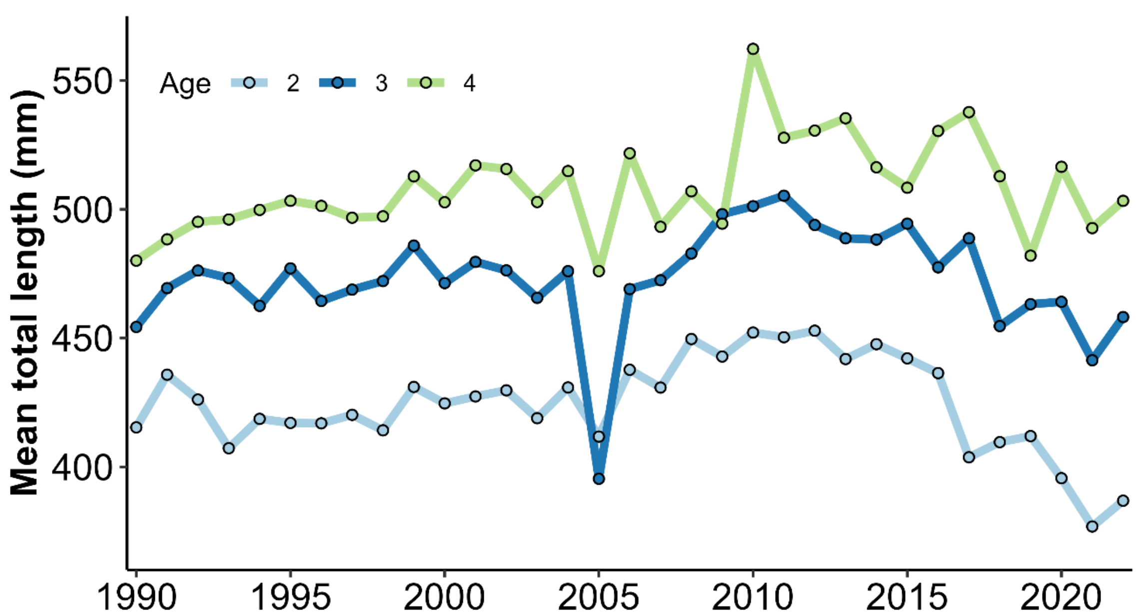


Figure 2.3.2.2: Mean total length of Walleye (ages 2–4) in West and Central basins of Lake Erie, 1988–2022. Data are from the ODNR fall gill net survey.

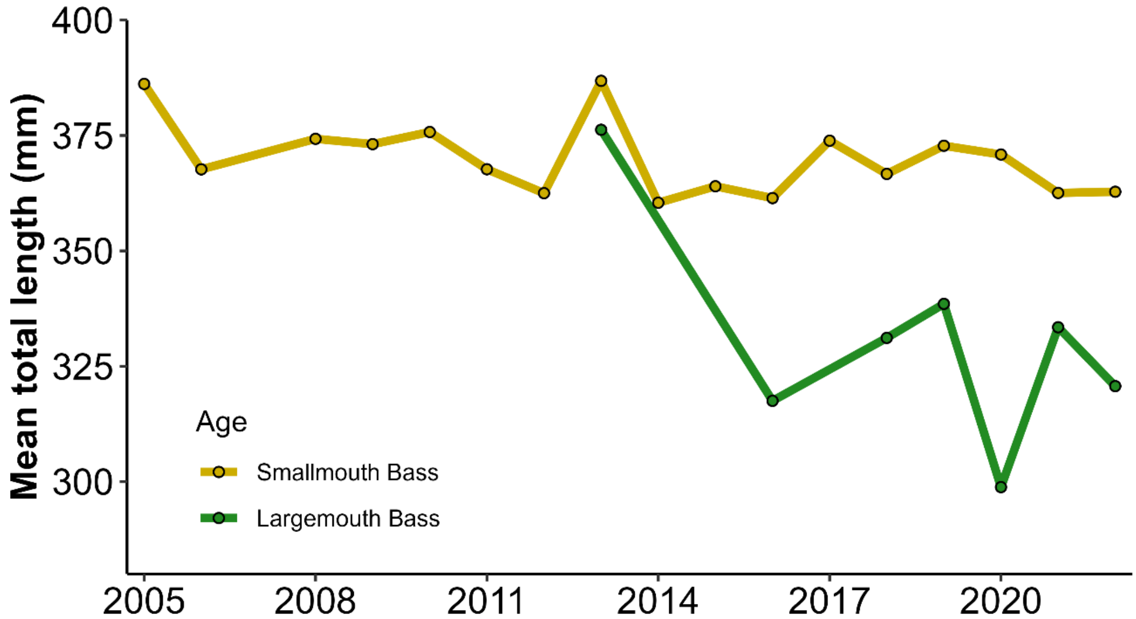


Figure 2.3.2.3: Mean total length of age-3 black basses in West and Central basins of Lake Erie, 2005–2022. Data are from ODNR surveys: gill net (Smallmouth Bass) and electrofishing (Largemouth Bass).

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).

Methods

The whole-lake survey design uses a stratified approach within each of the three basins. 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 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). 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.

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 12.1 (Echoview 2022). 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. Species composition (percent occurrence by group) for each stratum, grid, layer was generated and used to apportion total fish density.

Survey Effort

Lake-wide hydroacoustic effort included 91 sampled grids (WB - 19, CB-24, and EB-48), totaling 455 km of sampled transect (Figure 3.0.1). Sixty water column profiles associated with sampled grids were strategically collected to inform portioning of hydroacoustic and trawl data into epilimnetic and hypolimnetic layers. A total of 34 midwater trawls were collected across 12 sample grids in the Canadian waters (strata S07, S08, S11, and S12) of the Central Basin. All but one sampled grid within these strata incorporated hydroacoustic and midwater trawl data.

Water Column Profiles

Water column profiles demonstrate increasing depth from west to east, with decreasing temperatures and increasing levels of dissolved oxygen (Figure 3.0.2). 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. Lower dissolved oxygen (< 5 mg/L) was observed at a single site in CB and two sites in the WB.

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 3.0.3). 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. 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, where highest in the EB followed by the CB and WB, respectively (Figure 3.0.4). Epilimnetic densities were consistently higher when compared to hypolimnetic densities, with extremely high observations in the EB. The 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.

West Basin Results

Nineteen 5-km transects with associated water column profiles were sampled across the WB between 18-21 July (Table 3.0.2; Figure 3.0.1). An alternative grid (190) was sampled in stratum S2 because commercial trap nets prohibited safe passage through one of the planned grids (248). Midwater trawl samples were not collected. 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 3.0.3). Prey fish densities decreased in 2022 to 3,715 fish/ha, the third lowest level on record (Figure 3.0.5).

Central Basin Results

All targeted 5-minute grids were sampled including additional grids in stratum S09, S10, and S14 resulting in 24 5-km transects with associated water column profiles across the CB between 18-22 July (Table 3.0.3; Figure 3.0.1). Thirty-four midwater trawl samples were collected in Canadian waters across stratum S7, S8, S11, and S12 (Table 3.0.3). Annual mean areal fish density reached a survey low of 10,309 fish/ha in 2022 (Figure 3.0.6). Midwater trawl data indicated that the epilimnetic waters included a high proportion of non-target species of all ages such as Alewife, Gizzard Shad, White Perch, White Bass, Yellow Perch, Walleye, and Freshwater Drum (Figure 3.0.7). Hypolimnetic waters were dominated by age-1+ Rainbow Smelt similar to the EB (Figure 3.0.7). When total fish density is apportioned by trawl catches within strata, it appears the abundance of age-0 Rainbow Smelt in the epilimnion and age-1+ Rainbow Smelt in the hypolimnion increase in the eastern portion of the CB (Figure 3.0.8).

East Basin Results

Targeted 5-minute grids were sampled in all but strata S16, S20 and S24 where weather or travel distances resulted in being below target by one grid in each stratum. Additional 5-minute grids were sampled in strata S16, S17, S18, S19, and S21 resulting in collection of 48 5-km transects between July 17th and 27th (Table 3.0.4). 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. Four grids (2 in S17, 1 in S21 and 1 in S23) did not have hypolimnetic conditions and thus were assumed to not have any yearling and older Rainbow Smelt (0 fish/ha). Strata density are 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, S22 and S23 (mean N/ha = 4803, 3917 and 3758 respectively; Figure 3.0.9). The density of yearling and older Rainbow Smelt increased to 2,137 fish/ha in 2022 from 1,432 fish/ha in 2021 (Figure 3.0.10).

Table 3.0.1: Lake-wide hydroacoustic data collection summary.

Basin	Sounder	Transducer Frequency	Ping Rate	Pulse Length	Collection Threshold	WC profiles	Companion MTR
WB	Biosonics	201 kHz	4 pps	0.4 msec	-130 dB	yes	no
CB	Biosonics	120 kHz	4 pps	0.4 msec	-130 dB	yes	yes
EB	Simrad EY60	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	N Target	N Complete
S01	5	5
S02	4	4
S03	1	1
S04	3	3
S05	5	5
S06	1	1
Total	19	19

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	N Target	N Complete	N Trawls
S07	1	1	6
S08	3	3	10
S09	2	3	0
S10	2	3	0
S11	3	3	8
S12	4	4	10
S13	5	5	0
S14	1	2	0
Total	20	24	34

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

Stratum	N Target	N Complete
S15	2	2
S16	4	3
S17	5	12
S18	6	8
S19	5	7
S20	5	4
S21	4	5
S22	3	3
S23	2	2
S24	3	2
Total	39	48

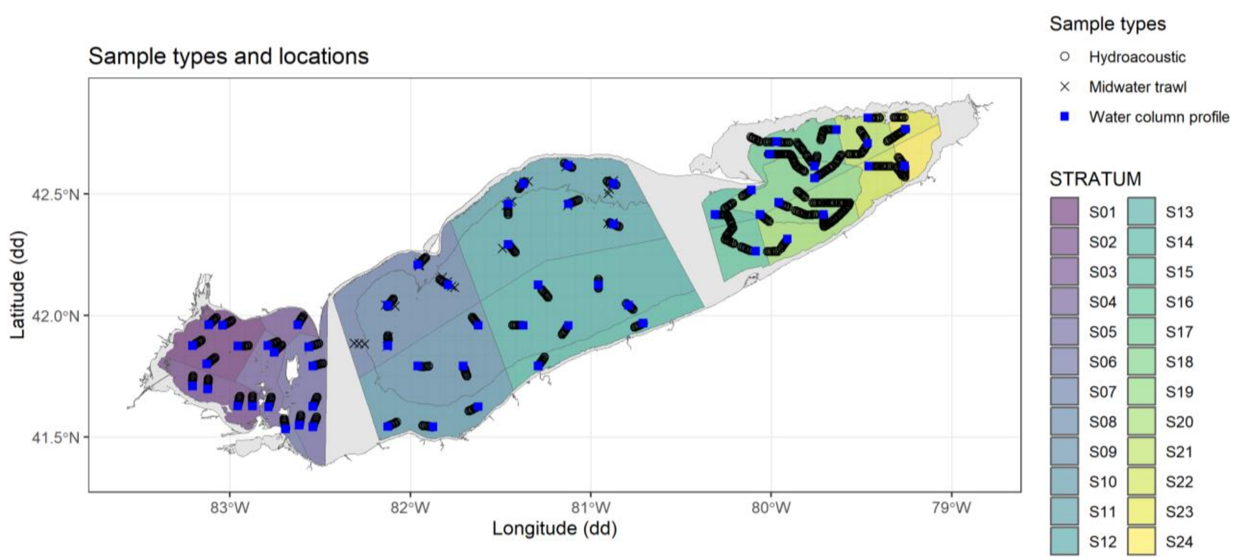


Figure 3.01: Lake-wide forage fish survey effort distributed across sample stratum (by color) including hydroacoustic transects (open black circles), midwater trawling (black x's), and water column profiles (blue squares).

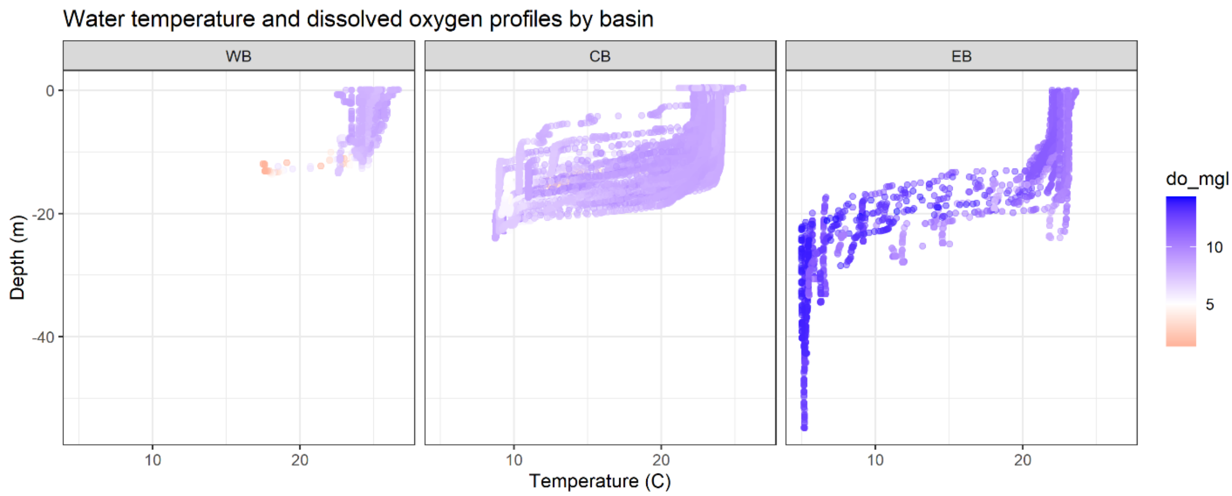


Figure 3.0.2: Water column profiles displayed by basin (West Basin = WB, Central Basin = CB, and East Basin = EB) with depth on the x-axis, temperature (˚C) on the y-axis, and color associated with the level of dissolved oxygen (mg/L).

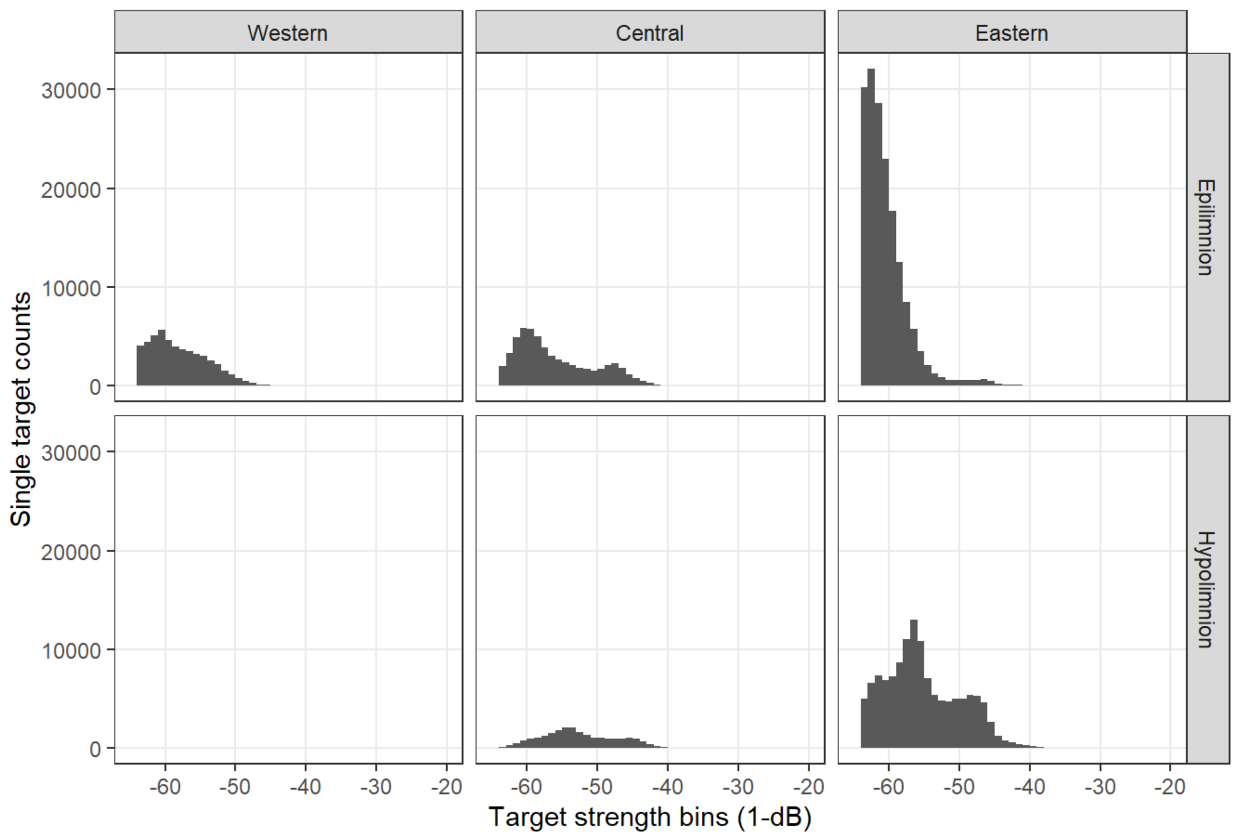


Figure 3.0.3: Target strength distributions of single targets by layer and across basins. Target strength is a measure of echo intensity that is relative to fish size. Single targets are individual echoes produced by fish encountered in the acoustic beam.

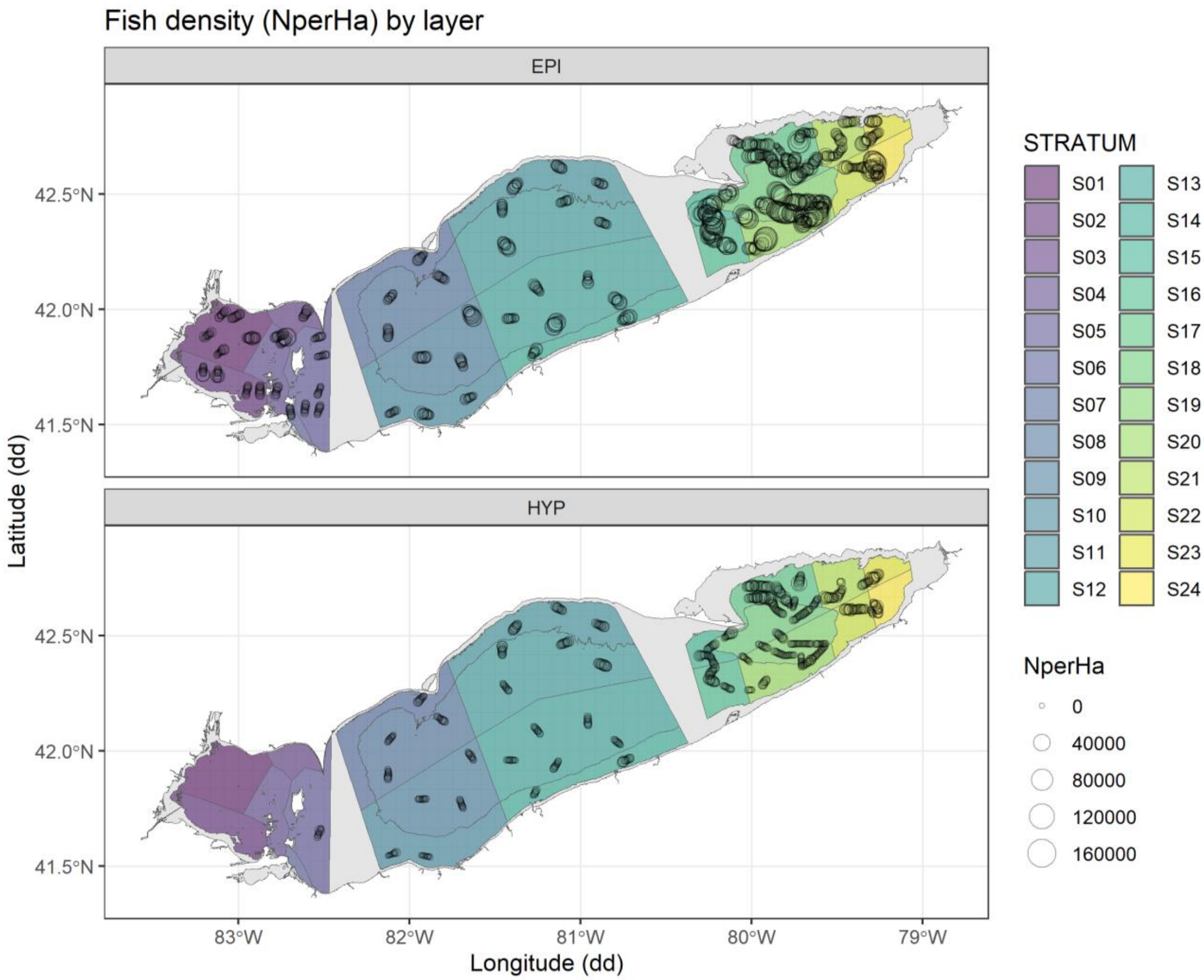


Figure 3.0.4: Lake-wide fish densities (number per hectare; NperHa) by layer (EPI and HYP) and stratum (by color). Larger open circles display increased density in epilimnetic waters of the East Basin.

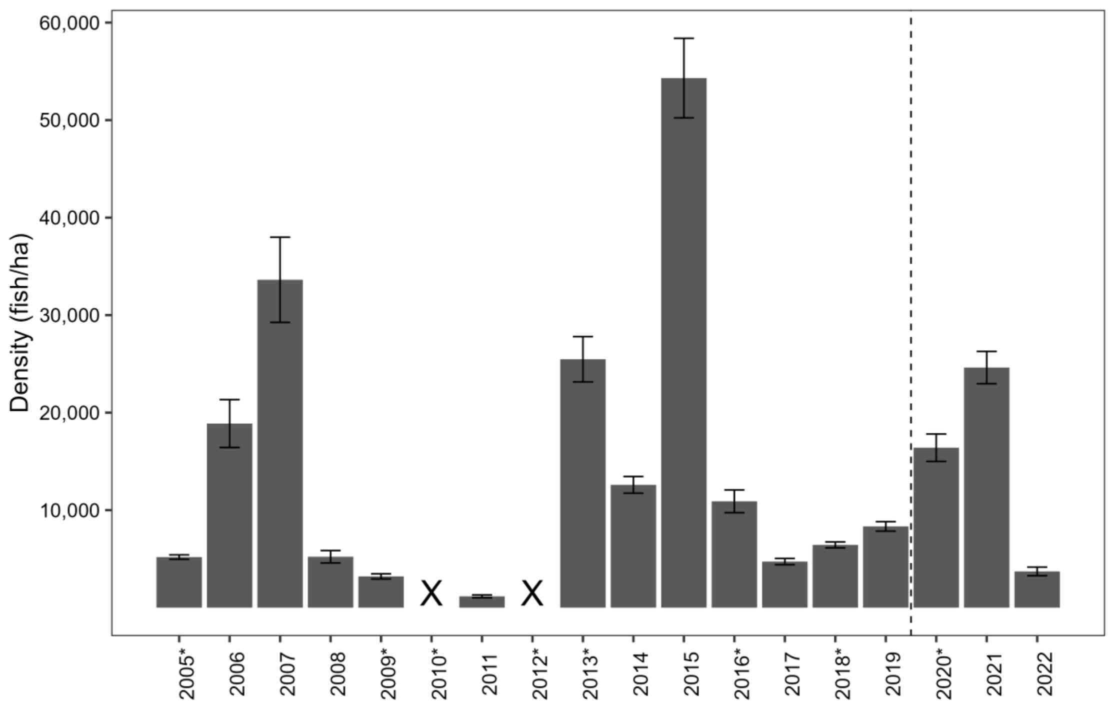


Figure 3.0.5: West Basin mean areal density (fish/ha) estimates over time. Error bars represent ±1 standard error. Asterisks (*) denote survey years with no data (2010 and 2012) or incomplete coverage, and vertical dashed line signifies the change in sampling design.

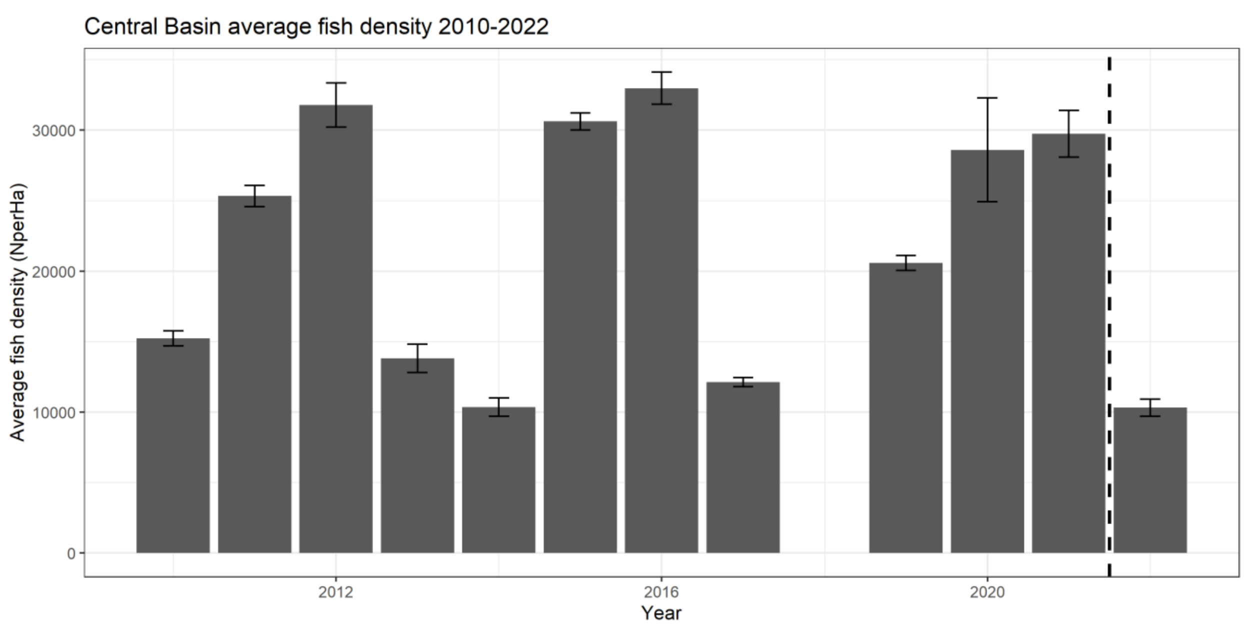


Figure 3.0.6: Central Basin mean areal density (fish/ha) estimates over time. Error bars represent ±1 standard error. Survey data were not collected in 2018, and vertical dashed line signifies the change in sampling design.

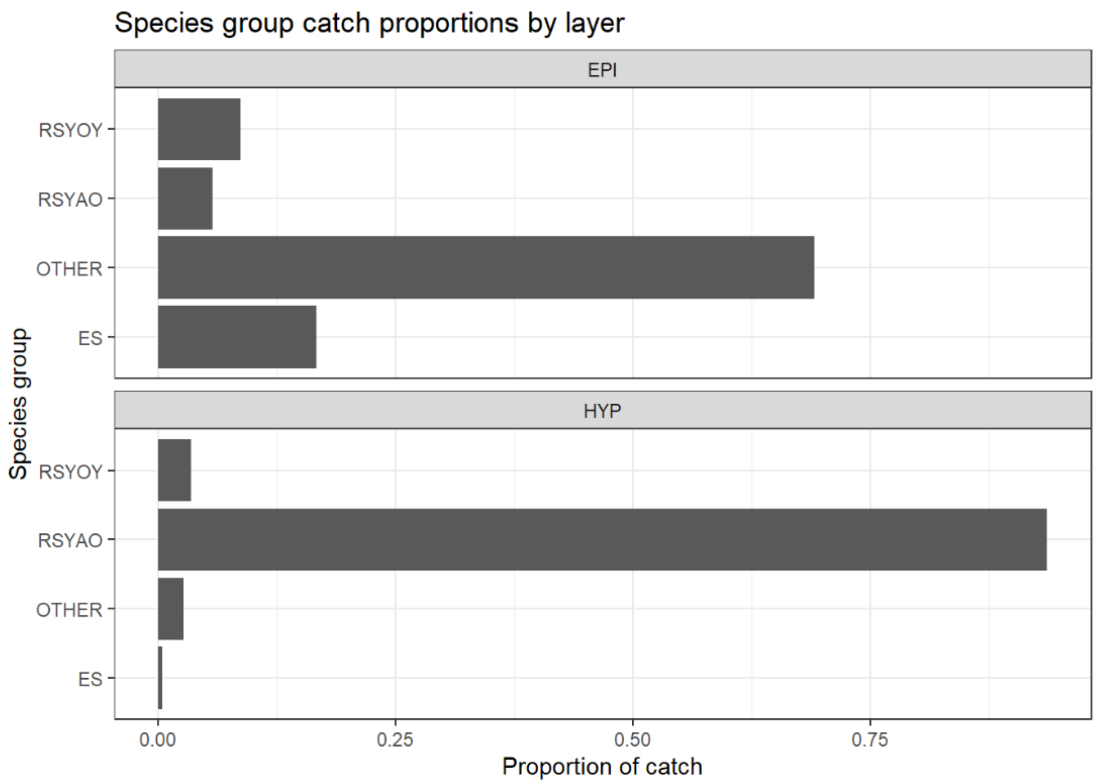


Figure 3.0.7: Mean proportion of midwater trawl catch from epilimnetic (EPI) and hypolimnetic (HYP) tows across the Canadian waters of the Central Basin, including species groups age-0 Rainbow Smelt (RSYOY), age-1+ Rainbow Smelt (RSYAO), Emerald Shiner (ES), and other species (OTHER).

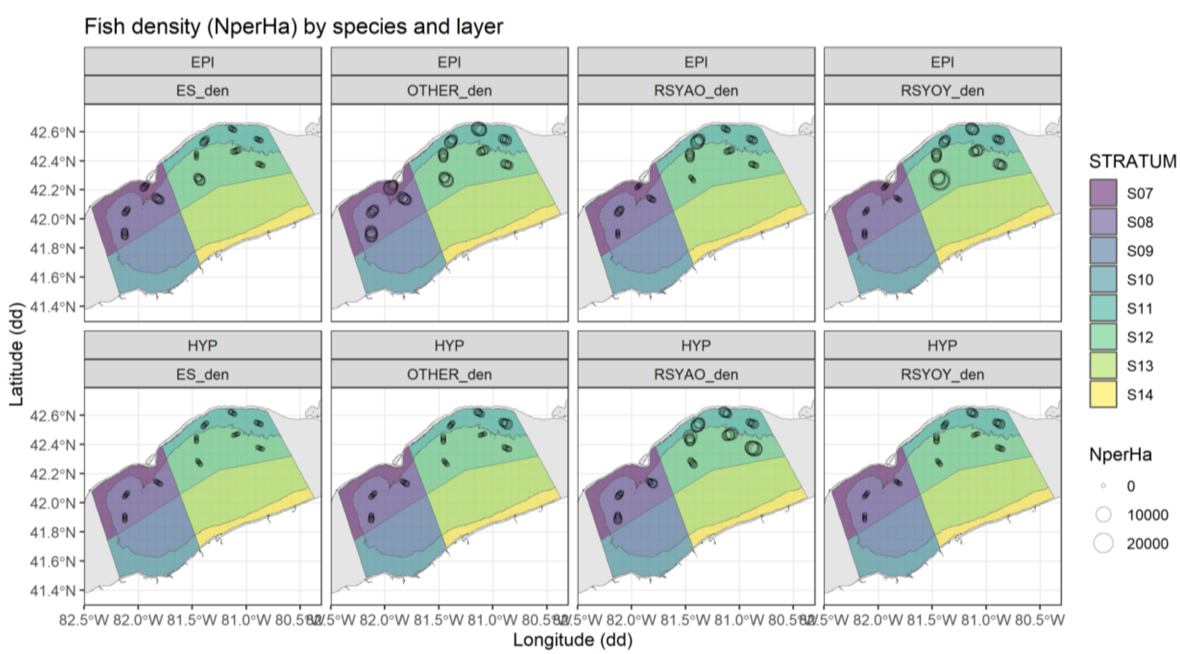


Figure 3.0.8: Species group densities (number per hectare; NperHa) by layer (EPI and HYP) in Canadian waters of the Central Basin including age-0 Rainbow Smelt (RSYOY_den), age-1+ Rainbow Smelt (RSYAO_den), Emerald Shiner (ES_den), and other species (OTHER_den).

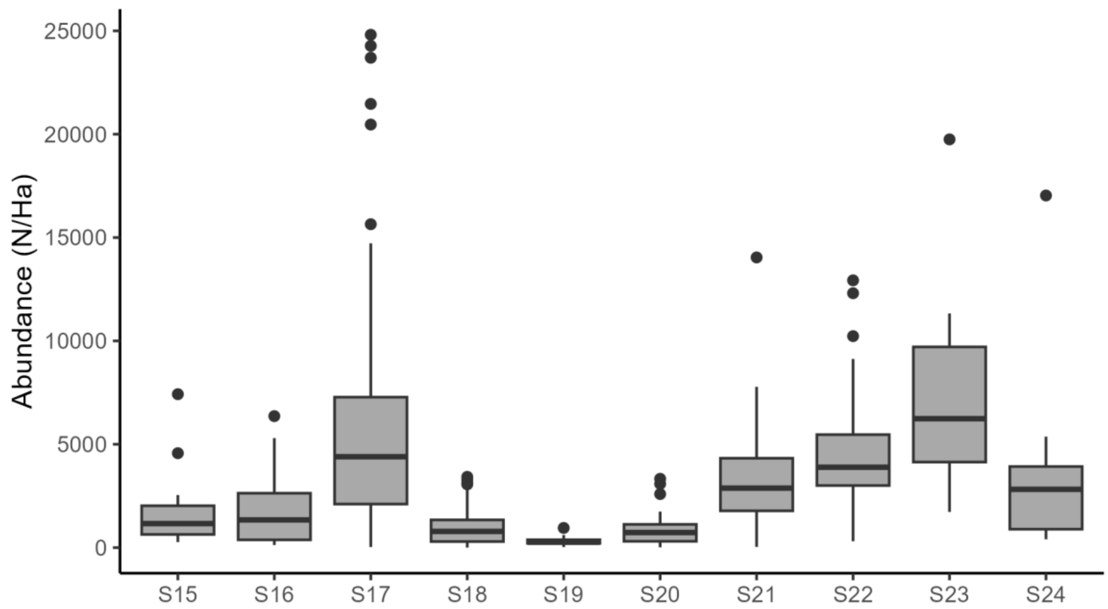
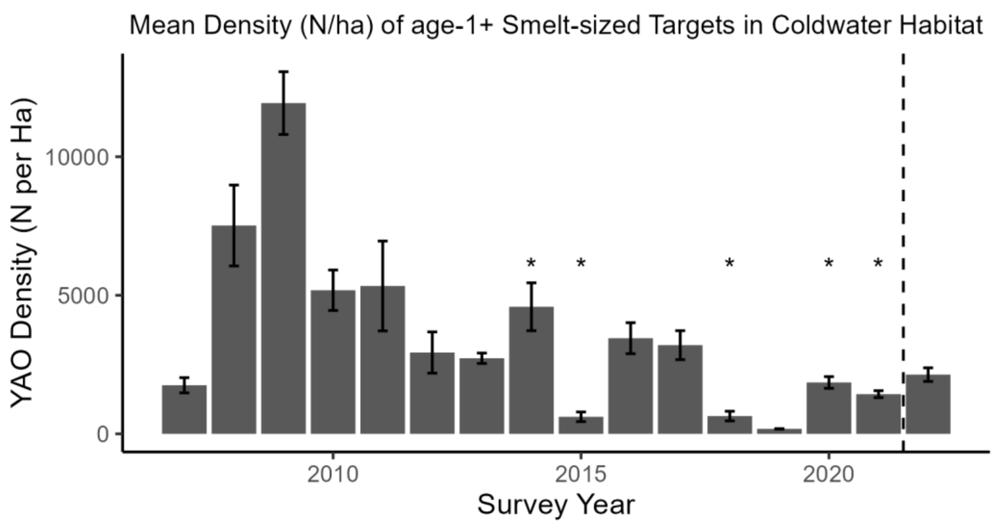


Figure 3.0.9: East Basin density estimates (fish/hectare) of age-1+ Rainbow Smelt by elementary distance sampling unit (EDSU) within each stratum. Solid line represents the median value. Box captures the 50% quantiles while whiskers capture 95% quantiles of the data and points that exceed the 95% quantiles are indicated with individual points.



Figures 3.0.10: 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.

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

(K. Towne and Z. Biesinger)

Since 2016, the Forage Task Group (FTG) 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 U.S. Fish and Wildlife Service AIS Early Detection and Monitoring program was back to operating at full capacity out of Gibraltar, MI and Basom, NY in 2022 following the COVID-19 pandemic.

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 in 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 2022. Only one novel species was captured across all FTG agencies in 2022; one individual Striped Bass (*Morone saxatilus*) was captured in Dunkirk, NY. This individual was archived, and no additional individuals were detected.

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.

- Any data intended for publication should be reviewed by the FTG and written permission obtained from the agency responsible for the data collection.

Literature Cited

Avlijas, S., A. Ricciardi, and N. E. Mandrak. 2018. Eurasian tench (*Tinca tinca*): the next Great Lakes invader. Canadian Journal of Fisheries and Aquatic Sciences 75:169-179.

Carlson, R. E. 1977. A trophic state index for lakes. Limnology and Oceanography 22(2):361-369.

Craig, J. K. 2012. Aggregation on the edge: effects of hypoxia avoidance on the spatial distribution of brown shrimp and demersal fishes in the Northern Gulf of Mexico. Marine Ecology Progress Series 445: 75-95.

Echoview Software Pty Ltd, 2022. Echoview Software, Version 12.1. Echoview Software Pty Ltd, Hobart, Australia.

Forage Task Group. 2012. Report of the Lake Erie Forage Task Group, March 2014. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Forage Task Group. 2014. Report of the Lake Erie Forage Task Group, March 2014. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Forage Task Group. 2017. Report of the Lake Erie Forage Task Group, March 2017. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Forage Task Group. 2021. Report of the Lake Erie Forage Task Group, March 2021. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Forage Task Group. 2022. Report of the Lake Erie Forage Task Group, March 2022. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Holden, J., and DuFour, M. 2023. erieacoustics: Analysis Tools for Erie Acoustic Surveys. R package version 0.3.0.

Leach, J. H., M.G. Johnson, J.R.M. Kelso, J. Hartman, W. Numan, and B. Ents. 1977. Responses of percid fishes and their habitats to eutrophication. Journal of the Fisheries Research Board of Canada 34:1964-1971.

Lake Erie Committee (LEC). 2019. Lake Erie Committee Environmental Priorities. 2pp. Accessed at: http://www.glfc.org/pubs/lake_committees/erie/2019%20Lake%20Erie%20Committee%20Environmental%20Priorities.pdf Accessed March 2022.

Love, R. H. 1971. Dorsal aspect target strength of an individual fish. Journal of the Acoustical Society of America 49: 816-823.

Markham, J. L. and P. D. Wilkins. 2023. Forage and juvenile yellow perch survey. Section C in NYSDEC 2023, Lake Erie 2022 Annual Report. New York State Department of Environmental Conservation, Albany, USA.

Nicholls, K. H. and G. J. Hopkins. 1993. Recent changes in Lake Erie (north shore) phytoplankton: cumulative impacts of phosphorus loading reductions and the zebra mussel introduction. Journal of Great Lakes Research 19: 637-647.

Ohio Division of Wildlife. 2022. Ohio's Lake Erie fisheries, 2021 annual data report. Federal Aid in Sport Fish Restoration Project F-69-P. Page 113. Ohio Department of Natural Resources, Division of Wildlife, Lake Erie Fisheries Units, Fairport and Sandusky. Available: https://ohiodnr.gov/static/documents/wildlife/fish-management/ODW+LE+Angler+Report+2021.pdf

Parker-Stetter, S. L., L. G. Rudstam, P. J. Sullivan and D. M. Warner. 2009. Standard operating procedures for fisheries acoustic surveys in the Great Lakes. Great Lakes Fishery Commission Special Publication 09-01.

Patterson, M. W. R., J.J.H. Ciborowski, and D. R. Barton. 2005. The distribution and abundance of *Dreissena* species (Dreissenidae) in Lake Erie, 2002. Journal of Great Lakes Research 31(Suppl. 2): 223-237.

Ryan, P. A., R. Knight, R. MacGregor, G. Towns, R. Hoopes, and W. Culligan. 2003. Fish-community goals and objectives for Lake Erie. Great Lakes Fisheries Commission Special Publication 03-02. 56 p.

Ryder, R. A., and S. R. Kerr. 1978. Adult Walleye in the percid community - a niche definition based on feeding behavior and food specificity. American Fisheries Society Special Publication 11.

Tyson, J. T., T. B. Johnson, C. T. Knight, M. T. Bur. 2006. Intercalibration of Research Survey Vessels on Lake Erie. North American Journal of Fisheries Management 26:559-570.

Wilkins, P. D. 2023a. Open lake sport fishing survey. Section F in NYSDEC 2023, Lake Erie 2022 Annual Report. New York State Department of Environmental Conservation, Albany.

Wilkins, P. D. 2023b. Warmwater gill net assessment. Section D in NYSDEC 2023, Lake Erie 2022 Annual Report. New York State Department of Environmental Conservation, Albany.

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*	
Logperch	*Percina caprodes*	
Mimic Shiner	*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	*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*	