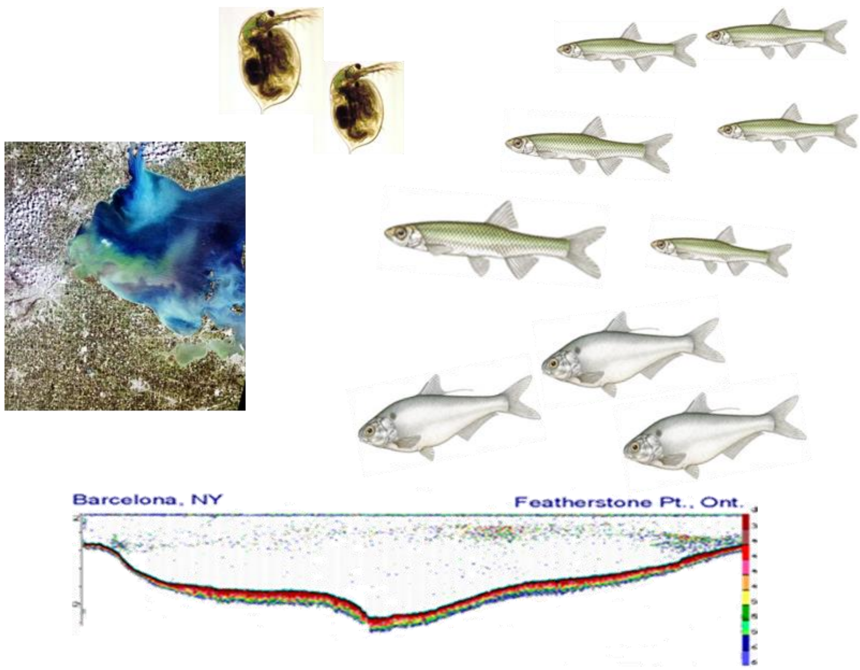
Report of the Lake Erie Forage Task Group

March 2022



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Presented to:

Standing Technical Committee
Lake Erie Committee
Great Lakes Fishery Commission

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Forage Task Group Executive Summary

March 2022

Lake Erie Committee

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

Introduction

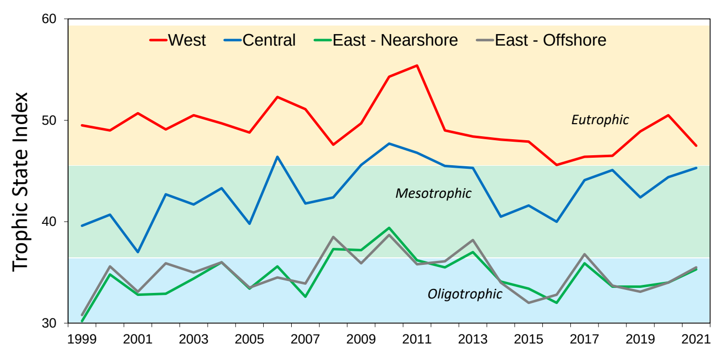
The Lake Erie Committee Forage Task Group (FTG) report addresses progress made on four charges:

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 use of forage fish in the diets of selected commercially or recreationally important Lake Erie predator fish.
   2.3. Describe growth and condition of selected commercially or recreationally important Lake Erie predator fish
3. Continue hydroacoustic assessment of the pelagic forage fish community in Lake Erie, incorporating new methods in survey design and analysis while following the GLFC's Great Lakes Hydro Acoustic Standard Operating Procedures where possible/feasible. Support STC review of hydroacoustics.
4. Act as a point of contact for any new/novel invasive aquatic species.

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.

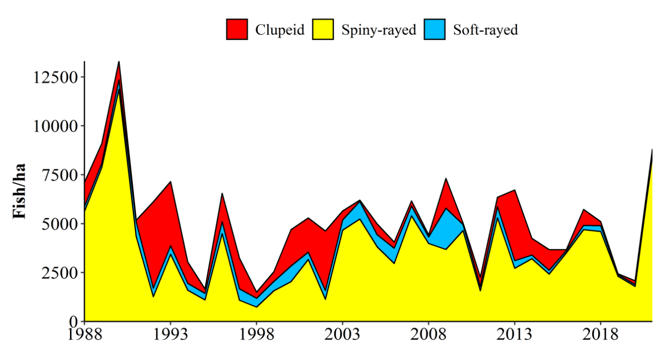
Interagency Lower Trophic Level Monitoring

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 2021, the Trophic State Index, which is a combination of phosphorus levels, water transparency, and chlorophyll *a*, indicated that the West Basin was above the targeted mesotrophic status, while the Central Basin was barely within mesotrophic status (favoring percid production). The East Basin offshore and nearshore areas were both oligotrophic in 2021. Low hypolimnetic dissolved oxygen continues to be an issue in the Central Basin during the summer months.

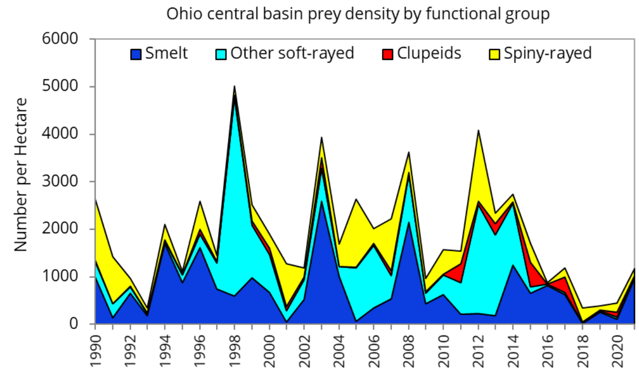


West Basin Status of Forage

In 2021, data from 68 trawl tows were used (up from 66 in 2020). Total forage density averaged 8,800 fish per hectare across the West Basin - the largest forage density since 1990. A large outlier catch of White Perch did upwardly bias the total density estimate. Age-0 Walleye relative abundance (346/ha) was a record high for the time series. Age-0 Yellow Perch density (1,358/ha) was well above average. Age-0 White Perch (6,438/ha) was the greatest since 1990. Age-0 Gizzard Shad abundance (81/ha) was below the ten-year mean (713/ha). Densities of Emerald Shiners have remained low for seven years. Round Goby abundance (81/ha) was the highest since 2009.

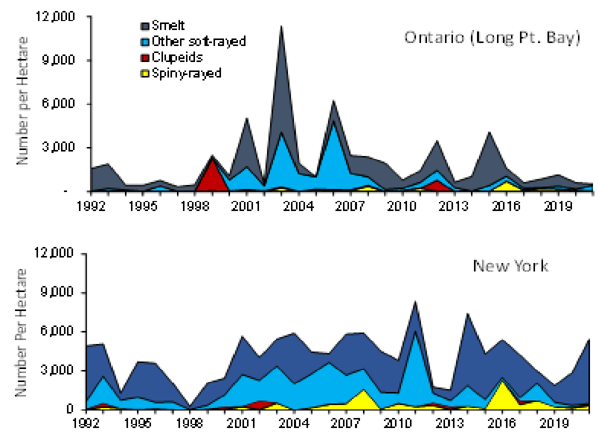


Central Basin Status of Forage



In 2021, 32 trawl tows were completed in the Ohio waters of the Central Basin. Forage abundance increased in 2021 relative to 2020, with most of the catch comprised of Rainbow Smelt and spiny-rayed species (e.g., yellow perch). However, total forage density remained well below the long-term mean. Age-0 Rainbow Smelt density increased from 2020 and were above the long-term mean. Age-1+ Rainbow Smelt abundance decreased from a recent high abundance in 2020 and is now one of the lowest densities in the time series. Round Goby age-0 indices decreased across the basin and were below the long-term mean. Emerald Shiner remain at very low densities in the basin. Yellow Perch density increased slightly from 2020; however, these continue to be some of the lowest densities in the time series. Age-0 Walleye abundance was the highest ever recorded in the time series. The age-0 Walleye index was almost five times the long-term mean.

East Basin Status of Forage



Total forage fish density in 2021 decreased in Ontario and has been below the long-term mean for the last 5 years. Forage fish density increased in New York and is at the highest level since 2016. Catches of age-0 Rainbow Smelt were very high in New York waters (2nd highest in time series), whereas they were low in Ontario. 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 increased in Ontario and were above the long-term mean. Round Goby remained below average in New York waters. Gizzard Shad and Alewife densities were above average in New York and below average in Ontario. Age-0 Walleye density in 2021 was the highest ever observed 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. In the East Basin, age-1+ Rainbow Smelt density (# fish/hectare) decreased in 2021 relative to 2020, but remained higher than the low seen in 2019. In the Central Basin, age-0 Rainbow Smelt densities were the highest on record, while Emerald Shiner and age-1+ Rainbow Smelt remained at low levels. In the West Basin, prey fish density was greater in 2021 than the last five years, whereas prey biomass (kg/hectare) was low suggesting that the forage fish community was composed of small, young fish. Across all basins, work continued on the Lake Erie hydroacoustic survey redesign, and another year of comparison data (new vs. old design) was collected in the Central and East Basins. Further analyses will take place in 2022 with the results informing the path forward for the Lake Erie hydroacoustic survey design.

Aquatic Invasive Species

In 2021, the U.S. Fish and Wildlife Early Detection and Monitoring program captured a Nile Tilapia near Cleveland, Ohio; however, additional sampling efforts in the same area did not yield any more Nile Tilapia. No other nonindigenous aquatic species were captured in Lake Erie. The FTG is working towards incorporating the FTG Aquatic Invasive Species (AIS) database with 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 2021–2022

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.

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

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

Acknowledgements

The Forage Task Group would like to thank Mark DuFour (USGS), Andy Cook (NDMNRF), and Arthur Bonsall (NDMNRF) for contributions to multiple sections of 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 profiles of temperature, dissolved oxygen, light (PAR), water transparency (Secchi disc depth), nutrients (total phosphorus), chlorophyll *a*, phytoplankton, zooplankton, and benthos. The protocol called for each station to be visited every two weeks from May through September, totaling 12 sampling periods, with benthos collected on only two occasions (once in the spring and once in the fall). For this report, we will summarize the last 23 years of data for summer surface temperature, summer bottom dissolved oxygen, chlorophyll *a* concentration, water transparency, total phosphorus, and zooplankton. Data from all sampled stations were included in the analysis unless noted. In 2021, 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 (EPs; 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 seek to achieve mesotrophic conditions in the western, central, and nearshore waters of the eastern basin and embayments. Conversely, an oligotrophic environment would most benefit the coldwater fish community that utilizes the deep, offshore waters of the eastern basin (Ryan et al. 2003). These trophic classes are associated with 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 metres, and chlorophyll *a* concentration 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* concentration < 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 condition. This index uses algal biomass as the basis for trophic state classification, which is 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 conditions have a TSI < 36.5, mesotrophic conditions have a TSI between 36.5 and 45.5, eutrophic conditions have a TSI between 45.5 and 59.2, and hyper-eutrophic conditions have a TSI >59.2.

Mean Summer Surface Water Temperature

Summer surface water temperature represents the temperature of the water at < 1 metre of 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 (time series mean = 23.5 °C), while becoming progressively cooler in the Central (time series mean = 21.8 °C) and East Basins (time series mean = 20.5 °C; Figure 1.0.2). In 2021, the mean summer surface water temperature was above average in the West (24.1 °C) and Central (23.9 °C) Basins. In the East Basin, mean summer surface water temperature was 21.0 °C, which was slightly above average. A slight 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 and prevents thermal stratification across much of the basin. Consequently, there are only a few summer observations that detect low bottom DO concentrations in the time series (Figure 1.0.3). In 2021, there were no observations from the West Basin stations with a 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. In 2021, bottom DO was below the 2.0 mg/L threshold in the Central Basin on four occasions (Station 11: 7/26/21 – 1.56 mg/L, 8/26/21 – 0.27 mg/L; Station 8: 8/25/21 – 0.5 mg/L; Station 10: 8/26/21 – 0.78 mg/L) and slightly above the 2.0 mg/L threshold on three 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 2021, East Basin bottom DO measurements ranged between 5.3–10.8 mg/L and were never below the 2.0 mg/L threshold.

Chlorophyll *a*

Chlorophyll *a* concentration is an indicator of phytoplankton biomass and represents production at the lowest trophic level. In the West Basin, mean chlorophyll *a* concentrations have mostly been above targeted levels in the 23-year time series, which is consistent with eutrophic status rather than the targeted mesotrophic status (Figure 1.0.4). Annual variability is highest in the West Basin. In 2021, the mean chlorophyll *a* concentration in the West Basin (6.3 μg/L) was 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 – a trend that continued in 2021 (4.9 μg/L; Figure 1.0.4). An increasing trend in chlorophyll *a* is evident in the Central Basin over the past 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 2021 (2.0 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 (2021: 2.5 μg/L). Chlorophyll *a* concentrations remain the most stable in the East Basin.

Total Phosphorus

Total phosphorus levels in the West Basin have exceeded FCO targets since the beginning of the LTLA monitoring program and, in some years, have been in the hyper-eutrophic range (Figure 1.0.5). In 2021, mean total phosphorus concentrations in the West Basin decreased to 20.9 μg/L, which is the lowest value in the time series but still above the mesotrophic target. 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 increased slightly in 2021 to 31.5 μg/L and have been above the targeted mesotrophic target for six consecutive 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 2021, mean total phosphorus measures were nearly equal in the nearshore (8.1 μg/L) and offshore (8.0 μg/L) waters of the East Basin.

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 and below the FCO target for the entire time series (Figure 1.0.6). Mean summer transparency in the West Basin was 1.7 m in 2021 and was the lowest value in the time series. In contrast, water transparency in the Central Basin has remained within the targeted mesotrophic range for most of the time series (Figure 1.0.6). However, water transparency in the Central Basin was 2.6 m in 2021 and is a new low for the time series. 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 and generally remaining within the FCO targets for the next ten years (Figure 1.0.6). Water transparency has generally hovered around the cusp of the mesotrophic/oligotrophic range since 2016 but decreased in 2021 (4.9 m) and was within the targeted mesotrophic 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 following six years, then increased thereafter. Similar to the nearshore waters, water transparency decreased in 2021 in the offshore waters (5.6 m) and was in the mesotrophic range.

Trophic State Index (TSI) and Ecosystem Targets

A box and whisker plots were used to describe the trophic state index (TSI) for each basin in Lake Erie (Figure 1.0.7). Median TSI values indicate that the West Basin was in a eutrophic status from 1999-2015, which is most 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 most favorable for percid (Walleye (*Sander vitreus*) and Yellow Perch (*Perca flavescens*)) 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 2021 indicate eutrophic status in the West Basin (46.9), mesotrophic status in the Central Basin (44.4), and oligotrophic status in both the nearshore (35.3) and offshore (35.7) waters of the East Basin (Table 1.0.2). Trends in trophic status measures indicate that Lake Erie has decreased in productivity over the past decade but generally remains in a favorable condition for percid production.

Zooplankton Biomass

Zooplankton samples were collected at most stations in 2021. However, analysis of this data is not complete and therefore updated zooplankton biomass will not be presented in this report.

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 2021.

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

	2021 TSI	2021 Trophic Status
West	46.9	Eutrophic
Central	44.4	Mesotrophic
East - Nearshore	35.3	Oligotrophic
East - Offshore	35.7	Oligotrophic

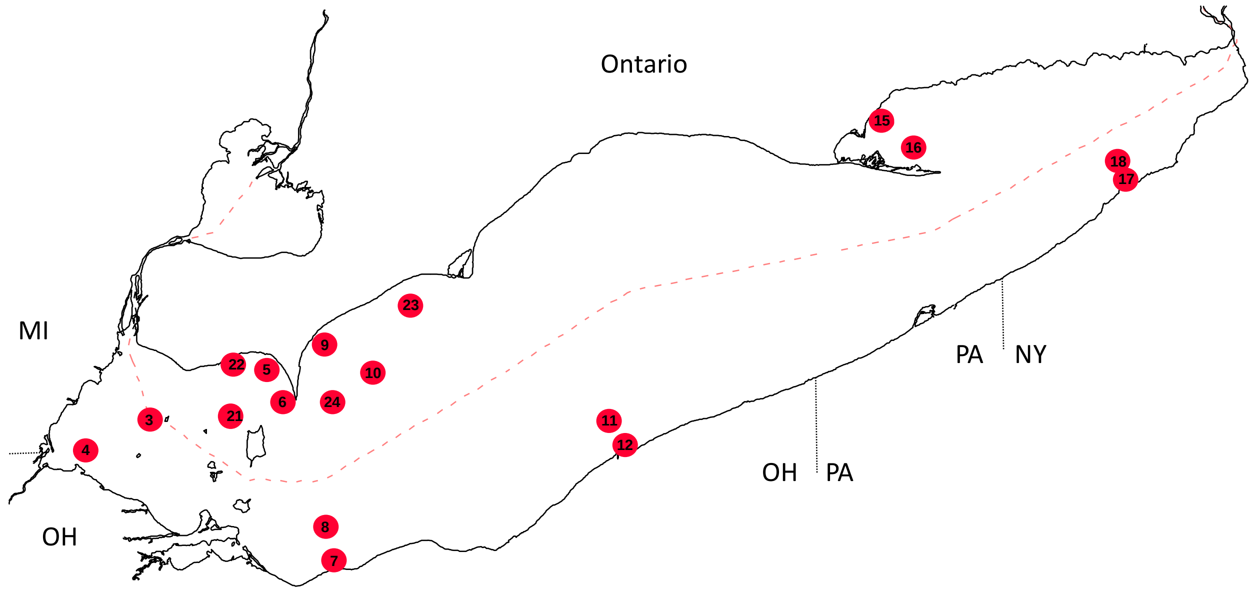


Figure 1.0.1: Lower trophic level sampling stations in Lake Erie. Stations 3–12 and 15–18 were sampled in 2021.

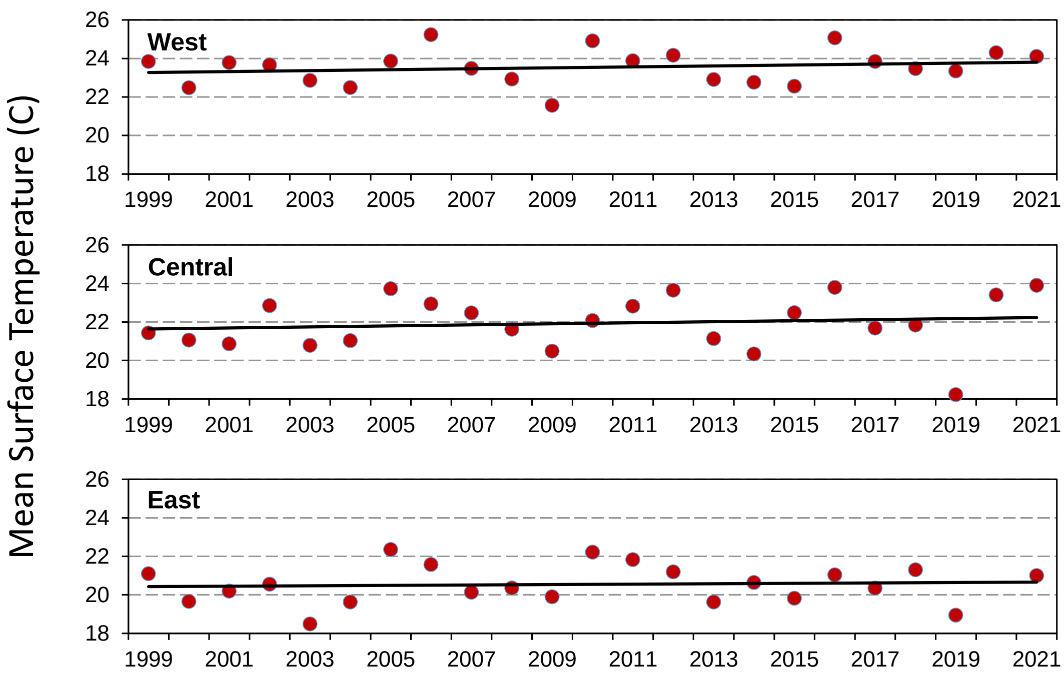


Figure 1.0.2: Mean summer (June-August) surface water temperature (°C) at offshore stations weighted by month for each basin in Lake Erie, 1999 –2021. Solid black lines represent time series trends.

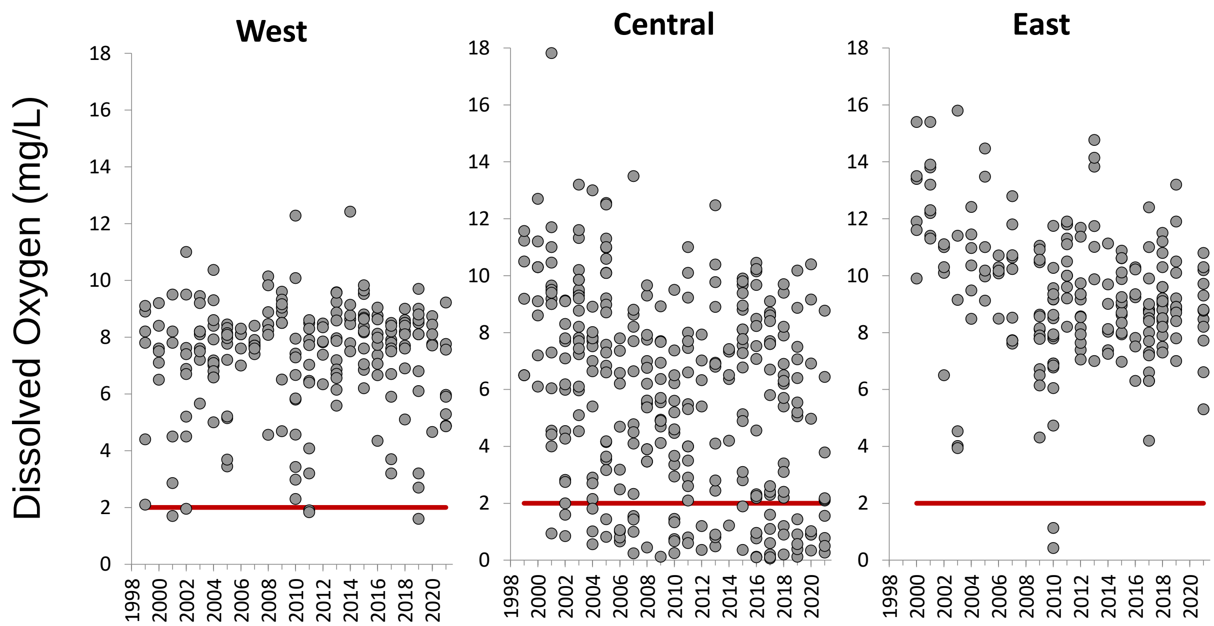


Figure 1.0.3: Summer (June-August) bottom dissolved oxygen (mg/L) concentrations for offshore sites by basin in Lake Erie, 1999–2021. The red horizontal line represents 2 mg/L, a level below which oxygen becomes limiting to the distribution of many temperate freshwater fishes.

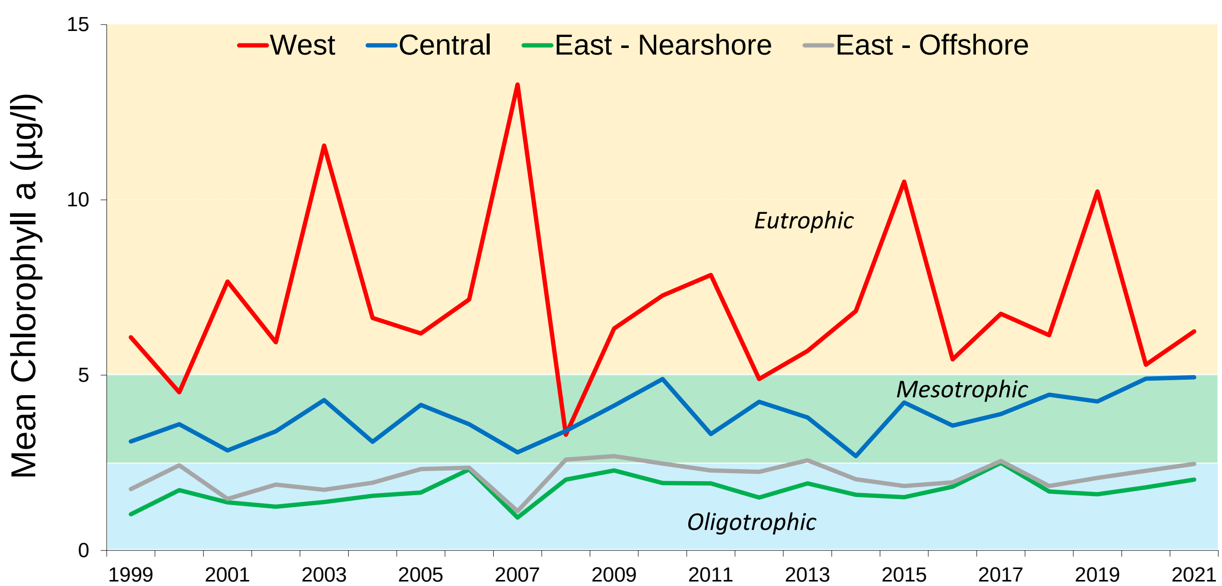


Figure 1.0.4: Mean chlorophyll *a* concentration (µg/L), weighted by month, for each basin in Lake Erie, 1999–2021. The East Basin is separated into nearshore and offshore. Shaded areas represent trophic class ranges.

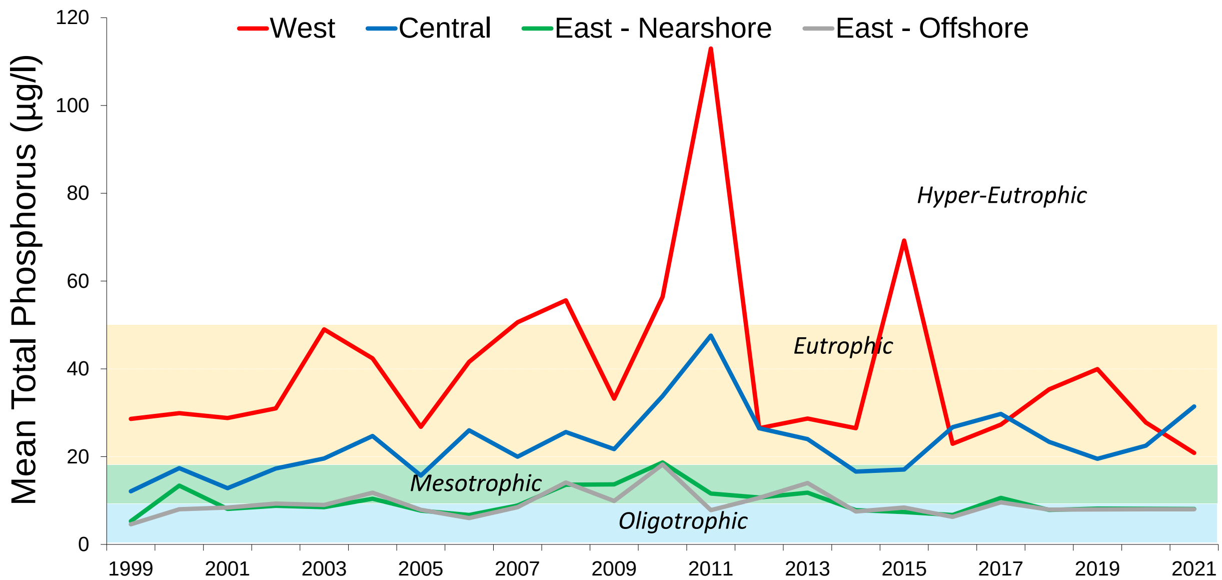


Figure 1.0.5: Mean total phosphorus (µg/L), weighted by month, for offshore sites in each basin of Lake Erie, 1999–2021. The East Basin is separated into nearshore and offshore. Shaded areas represent the trophic class ranges.

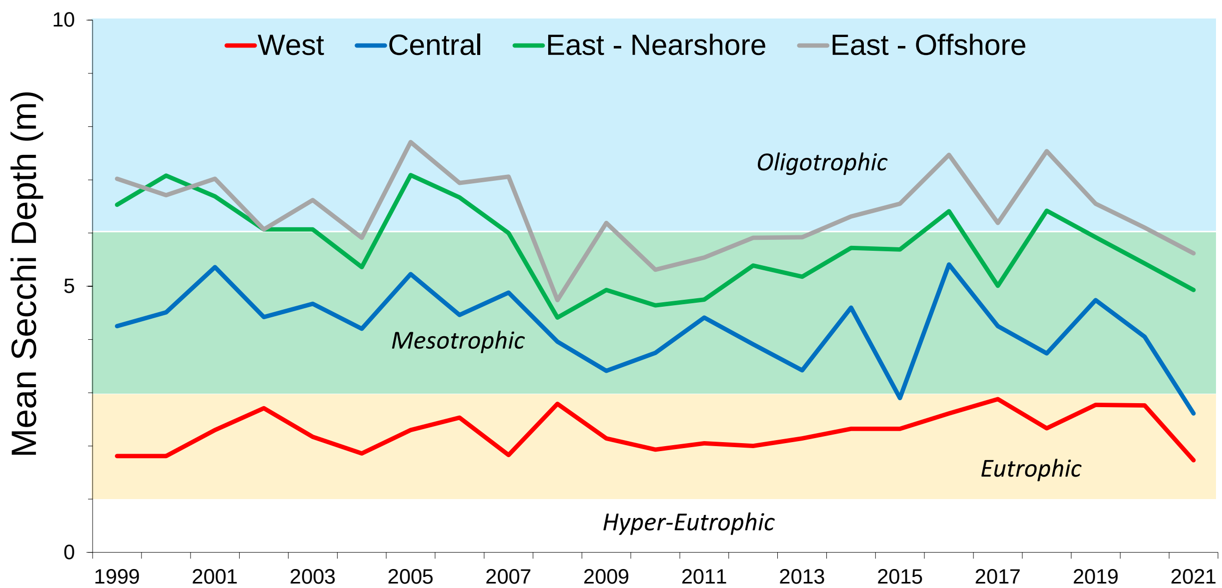


Figure 1.0.6: Mean summer (June–August) Secchi depth (m), weighted by month in each basin of Lake Erie, 1999–2021. The East Basin is separated into inshore and offshore. Shaded areas represent the trophic class ranges.

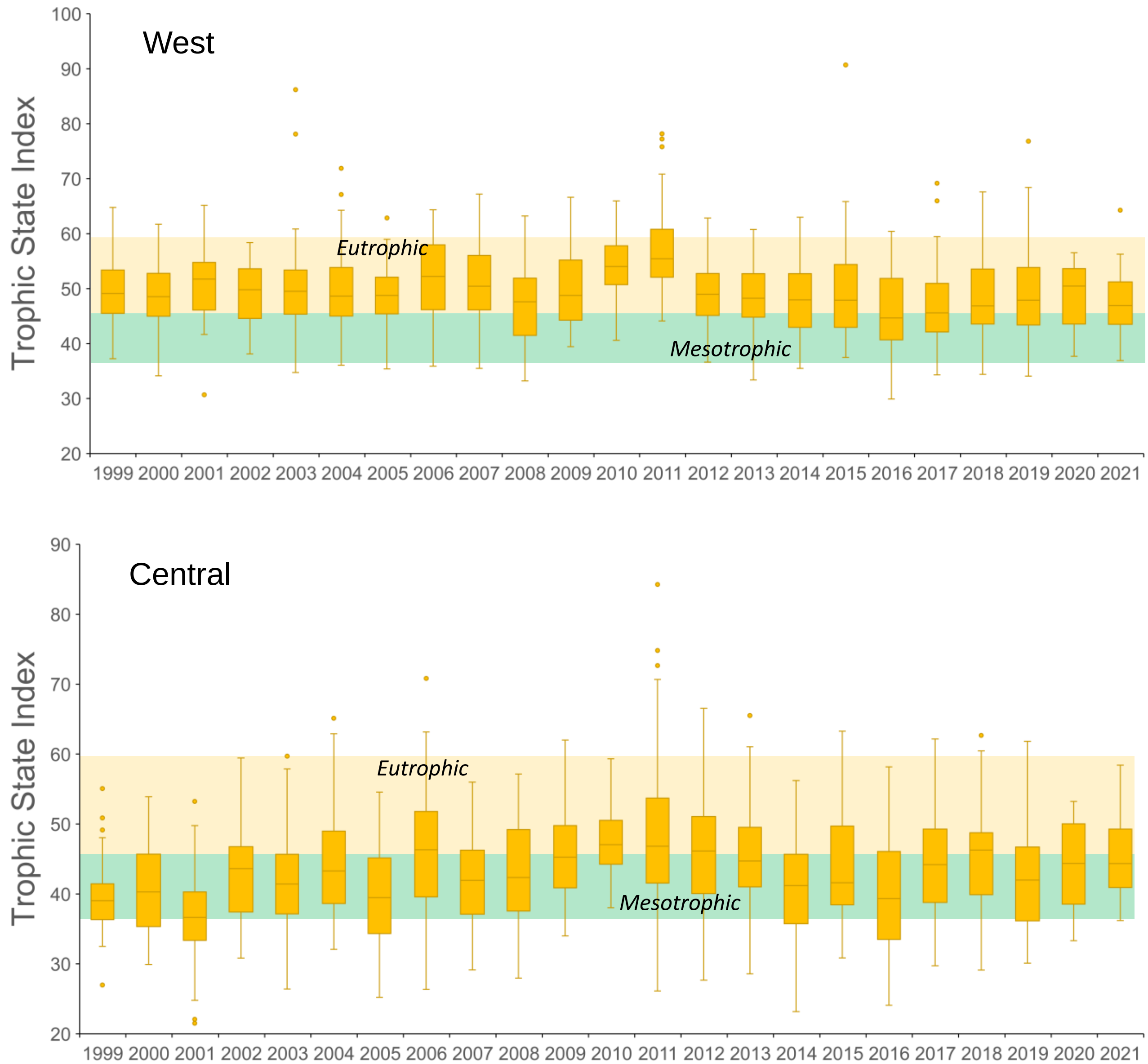
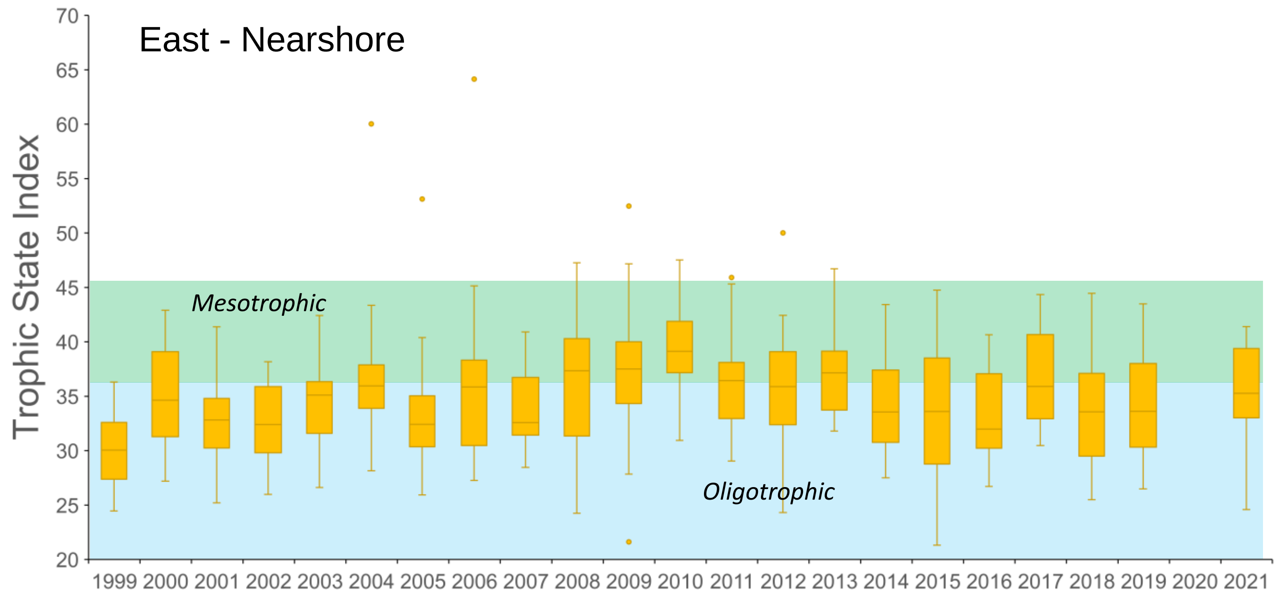


Figure 1.0.7: Box and whisker plot of trophic state indices (TSI) by basin in Lake Erie, 1999–2021. The East Basin is separated into nearshore and offshore. Shaded areas represent trophic class ranges. Boxes indicate 25th and 75th quartiles of the values with the median value as the horizontal line. Vertical lines show the range of values with individual points representing outliers.



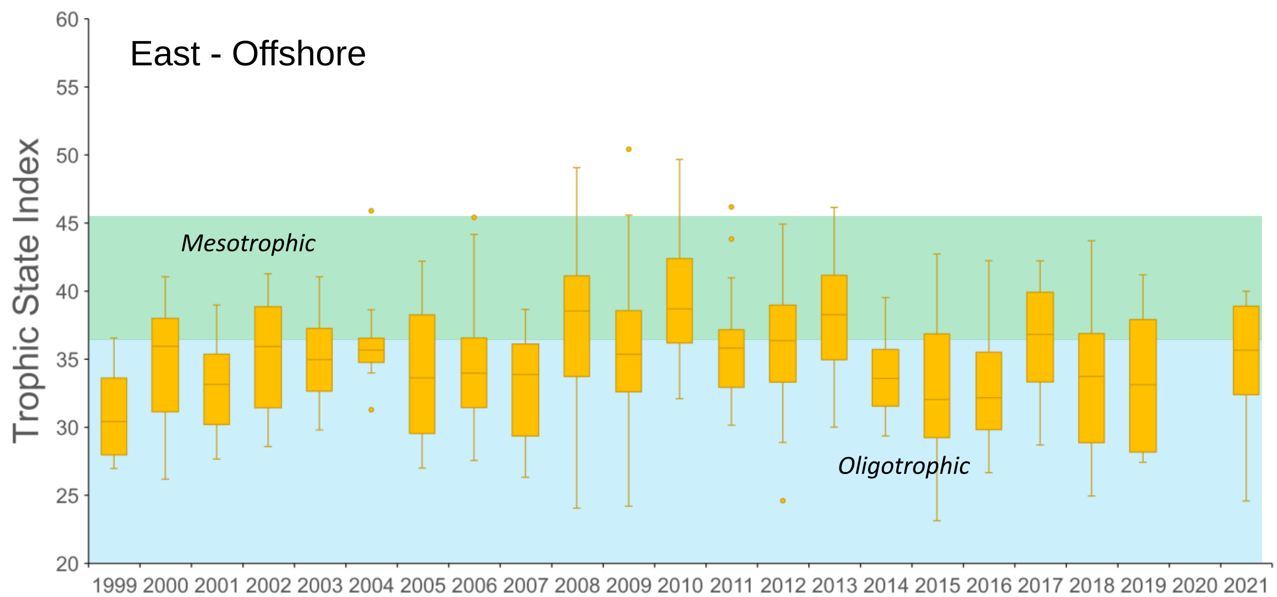


Figure 1.0.7: (Continued) Box and whisker plot of trophic state indices (TSI) by basin in Lake Erie, 1999–2021. The East Basin is separated into nearshore and offshore. Shaded areas represent trophic class ranges. Boxes indicate 25th and 75th quartiles of the values with the median value as the horizontal line. Vertical lines show the range of values with individual points representing outliers.

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 Eastern Basin Status of Forage (J. Markham, M. Thorn, and M. Hosack)

Long-term bottom trawl surveys conducted by New York, Ontario, and Pennsylvania are used to assess forage fish abundance and distribution in the East Basin (also see East Basin Hydroacoustic Survey, Section 3.1). In 2021, a total of 34 trawl tows were conducted in New York waters and 32 trawl tows in the offshore waters of Long Point Bay, Ontario (Figure 2.1.1.1). No trawling was conducted in the Pennsylvania waters of the eastern basin in 2021 due to boat issues.

In 2021, overall forage fish densities increased in New York waters, while forage fish densities remained low and well below the time series average in Long Point Bay (Figure 2.1.1.2). Rainbow Smelt is typically the most abundant forage species in most years and jurisdictions. In 2021, Rainbow Smelt catches were primarily composed of age-0 individuals in both New York and Ontario waters; low densities of age-1+ Rainbow Smelt were caught in both jurisdictions. The age-0 Rainbow Smelt density in New York was the second highest density in the time series and accounted for most of the increase in overall forage density. Age-0 Rainbow Smelt density was low in 2021 for Ontario waters. Emerald Shiner catches remained low in all surveys for 2021. Round Goby, an important species in the eastern basin forage fish community since it appeared in the late 1990s, peaked in the mid-2000s and has since generally remained at a lower but stable abundance in all jurisdictions (Table 2.1.1.2). The abundance of Round Goby increased in Ontario surveys in 2021 and was above average, whereas it remained below average in New York. Clupeid (Gizzard Shad, Alewife) abundance was above average in New York waters but below average in Ontario waters. New York also recorded its highest abundance of age-0 walleye in their time series in 2021 along with moderate catches of both age-0 and age-1 yellow perch. Catches of most other species were low in 2021.

2.1.2 Central Basin Status of Forage (J. Deller and 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 2021, 32 trawl tows were completed in Ohio. Pennsylvania was not able to trawl in 2021. Ontario began bottom trawling the Central Basin in 2016 and data from this program will be included in future Forage Task Group reports.

Overall, forage density in Ohio increased from 2020 and was primarily composed of Rainbow Smelt. Rainbow Smelt was the only functional group that increased from 2020 and were above long-term means (Figure 2.1.2.2). The remaining functional groups continue to be well below long-term means in Ohio.

The density of Rainbow Smelt, Emerald Shiner, Round Goby, and Gizzard Shad, which are the primary forage species in the Central Basin, showed mixed results in 2021. Age-0 Rainbow Smelt density in 2021 was the highest since 2014 and was the 7th highest density in the 31-year time series. Age-1+ Rainbow Smelt abundance decreased from a recent high abundance in 2020 to one of the lowest densities in the time series. There are no apparent long-term trends in the density of either Rainbow Smelt age group. Age-0 and age-1+ Emerald Shiner densities remained low in 2021 and have been at the lowest levels in the time series since 2015. Round Goby density for both age-0 and age-1+ fish declined from 2020 and were well below long-term means. Densities for both age groups were the third lowest since Round Goby became established in the Central Basin. Age-0 Gizzard Shad density decreased from 2020 and was well below the long-term mean. Densities for spiny-rayed species also showed mixed results in 2021. Yellow Perch densities for age-0 and age-1+ fish increased slightly from 2020; however, these continue to be some of the lowest indices in the time series. White Perch densities for both age groups declined from 2020 and were well below long-term means. Age-0 Walleye abundance was the highest ever recorded in the 31-year time series of the Ohio Central Basin trawl program; the age-0 Walleye index was almost five times 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 2017). 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 cyprinids, 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.

2021 Results

In 2021, hypolimnetic dissolved oxygen levels were below the 2.0 mg/L threshold (i.e., hypoxic) at two sites during the August trawling survey; both hypoxic sites were located west of Point Pelee. In total, data from 68 sites were used in 2021, which is up from 66 in 2020 (Figure 2.1.3.1).

Total forage density in 2021 increased 322% from last year and was over double the ten-year mean – the greatest forage density in the West Basin since 1990 (Figure 2.1.3.2; Table 2.1.3.1). This high density estimate was partially driven by an outlier catch of 27,111 age-0 White Perch that occurred on the west shoreline of Point Pelee, possibly stemming from nearby hypoxia concentrating fish. Spiny-rayed density increased 371% from 2020. Soft-rayed species increased 181% from 2020. Clupeid density was low in 2021, declining 58% from last year. Total forage density averaged 8,800 fish/ha across the West Basin, which is around twice the ten-year mean (4,302 fish/ha). Clupeid density was 81 fish/ha (ten-year mean 714 fish/ha), soft-rayed fish density was 281 fish/ha (mean 246 fish/ha), and spiny-rayed fish density was 8,438 fish/ha (mean 3,342 fish/ha).

Recruitment of individual species remains highly variable in the West Basin (Table 2.1.3.2). Age-0 Walleye density in 2021 was the greatest in the time series (97/ha), with three out of the last four years hitting new highs (including 2018 and 2019; Figure 2.1.3.3). Age-0 Yellow Perch density (1,358/ha; Figure 2.1.3.3) was the third greatest in the time series and remained above the ten-year mean (445/ha) for the fourth consecutive year. Age-0 White Perch density (6,438/ha) was the greatest since 1990, partially due to the outlier catch of 27,111 individuals (Figure 2.1.3.4). Age-0 White Bass density (31/ha) remained well below the ten-year mean (108/ha). Densities of all ages of Rainbow Smelt continue to be minimal in the West Basin. Age-0 Gizzard Shad density (81/ha) fell to well below the ten-year mean (713/ha), continuing a trend of high annual variation (Figure

2.1.3.4). Densities of age-0 (5/ha) and age-1+ Emerald Shiners (0.1/ha) were again very low, with minimal densities for six straight years (Figure 2.1.3.5). Round Goby (all ages) reached their greatest density (81/ha) since 2009. Age-1+ Silver Chub density (9/ha) remained high again in 2021, well above the ten-year mean (2.4/ha); age-0 Silver Chub fell to ~1/ha. Age-0 Mimic Shiner density was unusually high at 33/ha (ten-year mean = 2/ha).

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

Michigan initiated a bottom trawling program to assess the forage and age-0 sportfish community in the Michigan waters of Lake Erie in August of 2014. The 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. The otter trawl has a 10-metre head rope and 9.5-mm terminal mesh and is deployed with a single warp and 45.7-metre bridle. In 2021, all eight sites (Figure 2.1.3.1; green points on West Basin map) were sampled on August 2nd, 3rd and 4th, 2021.

The 2021 trawl survey captured 4,727.9 (forage fish/ha), the second largest catch in the MI time series and a 108% increase in density relative to 2020 (Figure 2.1.4.1; Table 2.1.4.1). Age-0 Yellow Perch (2,723.5 fish/ha) and age-0 White Perch (1633.3 fish/ha) were the two most abundant species in the catch. The densities of Yellow Perch and White Perch in 2021 were up from 2020. No Emerald Shiners were caught in 2021 or 2020. Mimic Shiners continued their decline and were at lower density than 2020; however, Spottail Shiners increased 138% in 2021 relative to 2020 — their highest catch in the time series. Gizzard Shad density was up 169% from 2020 but remains well below the time series mean. Silver Chub and Channel Darters were both observed in the trawl in 2021. Another strong year class of Smallmouth Bass was observed in 2021 (14 fish/ha), which is the second highest catch in the time series. Age-0 Walleye catch was 25.6 fish/ha indicating another strong year class of this sportfish as well.

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 Western 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 Eastern Basin Predator Diet (J. Markham)

Walleye

Beginning in 1993, annual summer (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 2021, 305 Walleye stomachs were examined of which only 60 (20%) contained food remains. Round Goby were the dominant species (60%), by volume, in Walleye diets followed by Rainbow Smelt (30%; Figure 2.2.1.1). Also of note was the presence of zooplankton in Walleye stomachs (1% by volume) which was a rare occurrence but has been present for the past five years.

Lake Trout

Seasonal diet information for Lake Trout is not available based on current sampling protocols. Diet information was limited to fish caught during August 2021 (N=74) 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 tend to prey more on Round Goby. In 2021, Rainbow Smelt were again the prominent prey fish for Lake Trout, occurring in 78.4% of the non-empty stomachs, followed by Round Goby (10.8%; Figure 2.2.1.2). Yellow Perch (1.4%) were the only other identifiable fish species found in Lake Trout stomachs in 2021.

2.2.2 Central Basin Predator Diet

Predator diet data collected from the Ohio waters of the Central Basin are not yet available and will be reported in next year's Forage Task Group Report.

2.2.3 West Basin Predator Diet

Yellow Perch (R. Oldham [USGS], K. Keretz [USGS], and Z. Slagle)

Yellow Perch diet samples were collected by the USGS Lake Erie Biological Station (Sandusky, OH) in 2021. However, at the time of publication, samples were not yet processed due to an ongoing physical location change for the office. Yellow Perch diet summaries for 2021 will be reported in next year's FTG Report.

Walleye (J-M. Hessenauer)

Diets of adult Walleye are sampled as part of the Michigan trawl and gill net surveys. Fifty-one adult Walleye diets were sampled from August trawls and 295 adult Walleye diets were sampled from October gill nets in 2021.

Of the 54 walleye stomachs sampled in August, 35% contained prey items (Table 2.2.3.1). Of those with gut contents, the majority (57%) were unidentifiable fish. Species identified in gut contents included Gizzard Shad (14%), White Perch (10%), and Yellow Perch (19%). In October, 60% of diets sampled were not empty. Gizzard Shad were the most abundant prey item (42%), followed by White Perch (9%) and Yellow Perch (7%), while 17% of the diet comprised unidentifiable fish (Table 2.2.3.2).

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

2.3.1 Eastern Basin Predator Growth (J. Markham)

Walleye length at age-1 and age-2 from netting surveys targeting juveniles in the New York waters of the East Basin has declined for the past five years. In 2021, age-1 and age-2 walleye were 1.4 and 1.5 inches below the long-term average length, respectively; both metrics ranked at or near the lowest observed lengths in the 40-year time series (Wilkins 2022). In general, age-0 and age-1 Yellow Perch have exhibited stable growth rates over the past decade. In 2021, growth of both age-0 and age-1 Yellow perch was above their time series averages (2.5 and 7.6 mm, respectively; Markham and Wilkins 2022).

Adult Walleye condition in the New York waters of Lake Erie has increased for the past three years. In 2021, the estimated weight of a 20-, 24- and 28-inch harvested Walleye was 2.6, 4.6 and 7.4 lbs., respectively – consistent with their long-term averages of 2.7, 4.7 and 7.6 lbs. (Figure 2.3.1.1).

Adult Lake Trout condition in the New York waters 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 increased in 2020 and 2021 to values more typically observed in the past decade.

2.3.2 Central Basin Predator Growth (J. Deller)

Growth rates of age-0 Walleye increased slightly from 2020 but remain below the long-term mean. Age-0 Walleye growth rates have been below long-term means since 2015, most likely due to density dependent effects; Walleye densities have been above the long-term mean since 2017 in the Central Basin. Growth rates of most other age-0 fish species increased from 2020 and were above long-term means. The increase in size is likely biased because of the Ohio bottom trawl survey was not completed until mid November, the latest calendar date in the time series, due to poor weather.

2.3.3 West Basin Predator Growth (Z. Slagle)

Overall, mean length of age-0 sport fish in 2021 was similar to 2020 (Figure 2.3.3.1). Lengths of select age-0 species in 2021 include Walleye (103 mm), Yellow Perch (71 mm), White Bass (69 mm), and White Perch (65 mm). Walleye average length has increased two straight years from the time series low. Other sportfish lengths were near time series averages.

Table 2.1.3.1: Ten-year mean density (arithmetic mean number per hectare), 2021 density, and the percent difference between 2021 and the ten-year average for forage fish functional groups from fall trawl surveys in the West Basin Lake Erie. Data are collected by NDMNRF and ODNR and combined using FPC factors.

Functional Group	**Mean: 2010–2020**	**2021**	**+/-**
All forage species	4301.9	8800.1	105%
Clupeid	713.8	81.4	-89%
Soft-rayed	246.1	280.6	14%
Spiny-rayed	3342.1	8438.1	152%

Table 2.1.3.2: Ten-year mean density (arithmetic mean number per hectare), 2021 density, and the percent difference between 2021 and the ten-year average for selected forage species from fall trawl surveys in West Basin Lake Erie. Data are collected by NDMNRF and ODNR and combined using FPC factors.

Species	**Age class**	**Mean: 2010–2020**	**2021**	**+/-**
Emerald Shiner	Age-0	40.9	4.9	-88%
Emerald Shiner	Age-1+	40.3	0.1	-100%
Freshwater Drum	Age-0	96.9	264.9	173%
Gizzard Shad	Age-0	713.4	81.4	-89%
Rainbow Smelt	Age-0	32.2	21.5	-33%
Rainbow Smelt	Age-1+	0.4	0.0	-91%
Round Goby	All ages	23.0	80.6	251%
Walleye	Age-0	68.8	345.6	402%
White Bass	Age-0	107.8	31.4	-71%
White Perch	Age-0	2623.6	6438.2	145%
Yellow Perch	Age-0	444.9	1358.0	205%

Table 2.1.4.1: Average density (number of fish per ha) of forage sized and age-0 sportfish captured during the Michigan trawl survey. Yr/Yr% is the percent change from 2020 to 2021. Yr/2014-2020% is the percent change from 2021 to the 2014-2020 average. Blanks indicate no catch in either 2021, 2020, or both.

Common Name	Age Group	2014	2015	2016	2017	2018	2019	2020	2021	Yr/Yr %	Yr/ 2014–2020 %
Emerald Shiner	All	2.1	0	0	0	7.2	11.4	0	0		
Channel Catfish	YOY	0	0	0	0	0	1.6	0	0		
Freshwater Drum	YOY	29.4	6.9	6.3	0	45.6	7.9	5.4	5.7	5.6	-60.7
Gizzard Shad	YOY	55.4	2.7	11.4	730.9	259.4	0.5	15.2	40.9	169.1	-73.4
Johnny Darter	All	0	0	0	0	0.3	0	1.4	0		
Logperch	All	1.9	14.8	3.1	4.4	2.3	2.2	29.1	46.1	58.4	458.3
Mimic Shiner	All	5.3	617.9	170.6	120.2	40.1	141.5	53	6.0	-88.7	-96.3
Rainbow Smelt	YOY	0.3	2.7	0	2.2	0	0	0	0.3		-59.6
Round Goby	All	43.4	135.8	19.2	41.4	58.6	24.7	125.7	84.1	-33.1	31.2
Silver Chub	All	0	11.3	0.6	3.4	5.9	5.2	21.6	5.8	-73.1	-15.4
Smallmouth Bass	YOY	5.4	0.3	1.9	0	3.2	0	59.9	14.0	-76.6	38.6
Spottail Shiner	All	54.2	18.8	26.6	2.2	6.3	10.6	24.2	57.7	138.4	182.6
Trout-Perch	All	25.6	16.8	68.8	62.1	290.4	19	25.4	75.3	196.5	3.7
Tubenose Goby	All	0	0	1.9	2.2	1.7	0	0	0.3		-63.8
Walleye	YOY	0.6	4.8	3	16.6	50.3	68.5	31.9	25.6	-19.7	1.8
White Bass	YOY	1.2	7	8.4	101.8	48.2	15.5	11.4	9.3	-18.4	-66.4
White Perch	YOY	715.5	783.2	448.5	1896.4	8100	389.1	1193.8	1633.3	36.8	-15.5
Yellow Perch	YOY	129.5	335.8	424.4	331.6	1683	1291	675.2	2723.5	303.4	305.4
Grand Total	-	1070.1	1958.8	1203	3315.4	10603	1988.5	2273.8	4727.9	108.0	48.8
Dreissenid Mussels*	ALL	0.41	0.55	0.81	0.45	0.6	0.66	0.68	0.53	-22.1	-10.2

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

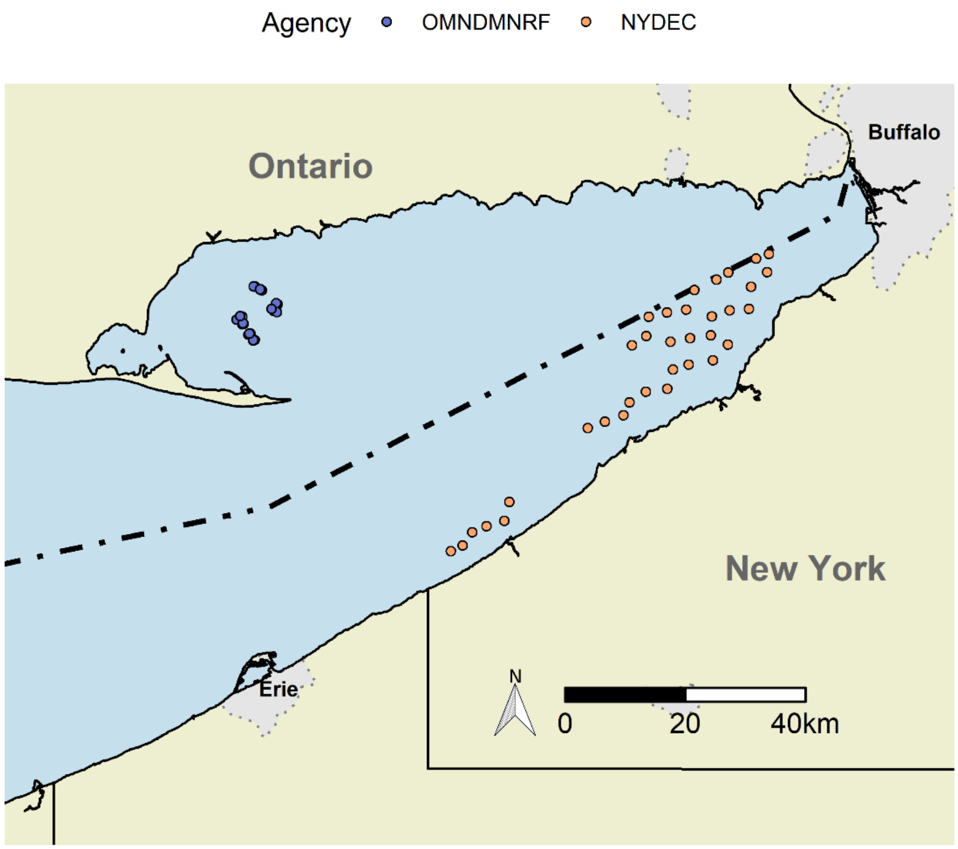


Figure 2.1.1.1. Locations of standard index bottom trawls by Ontario (blue) and New York (orange) to assess forage fish abundance in the East Basin of Lake Erie in 2021. Pennsylvania did not trawl in 2021 due to vessel issues.

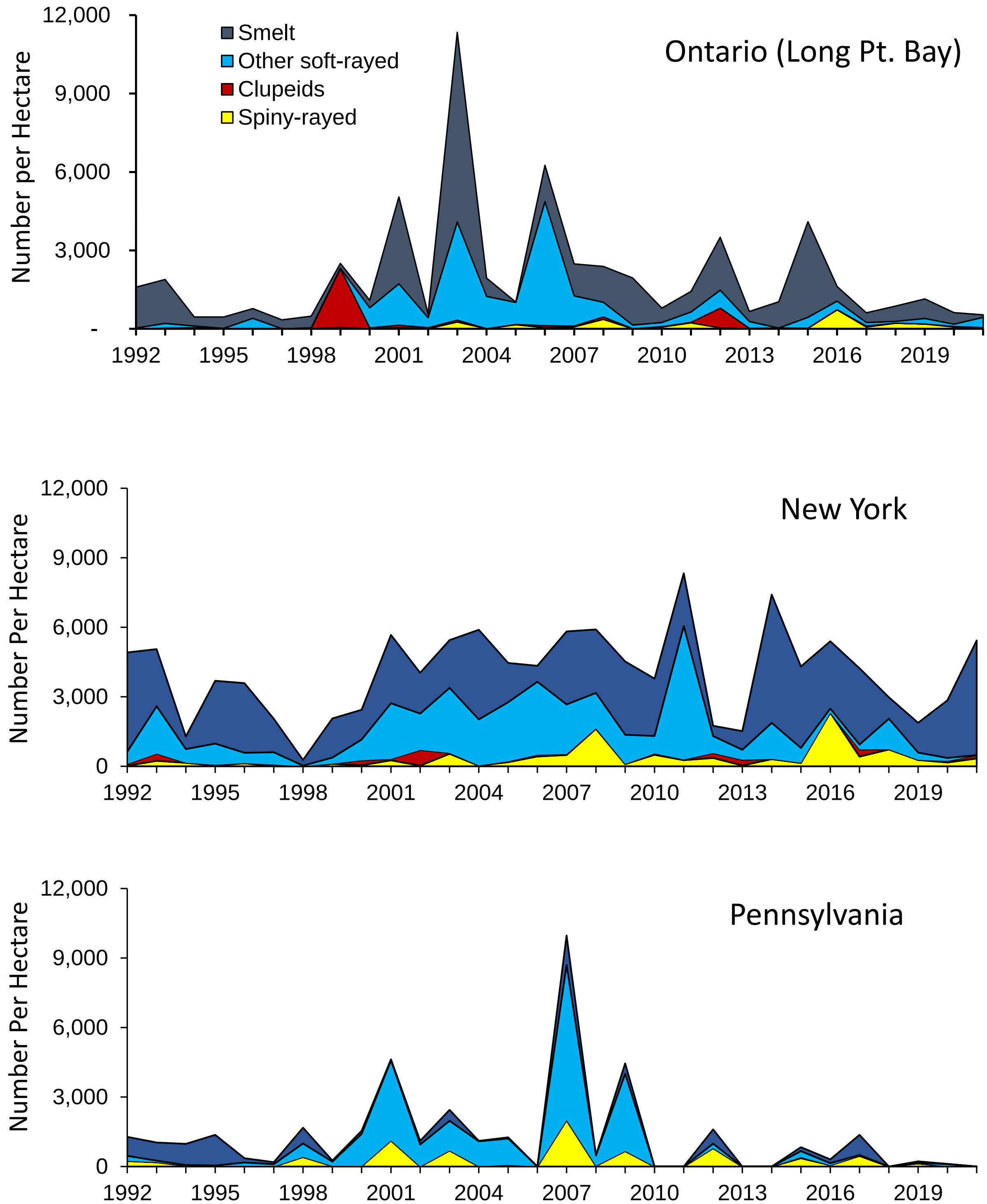


Figure 2.1.1.2: Mean density of prey fish (number per hectare) by functional group in the Ontario, New York and Pennsylvania waters of the eastern basin, Lake Erie, 1992-2021. Pennsylvania did not sample in 2010, 2011, 2013, 2014, 2018, or 2021.

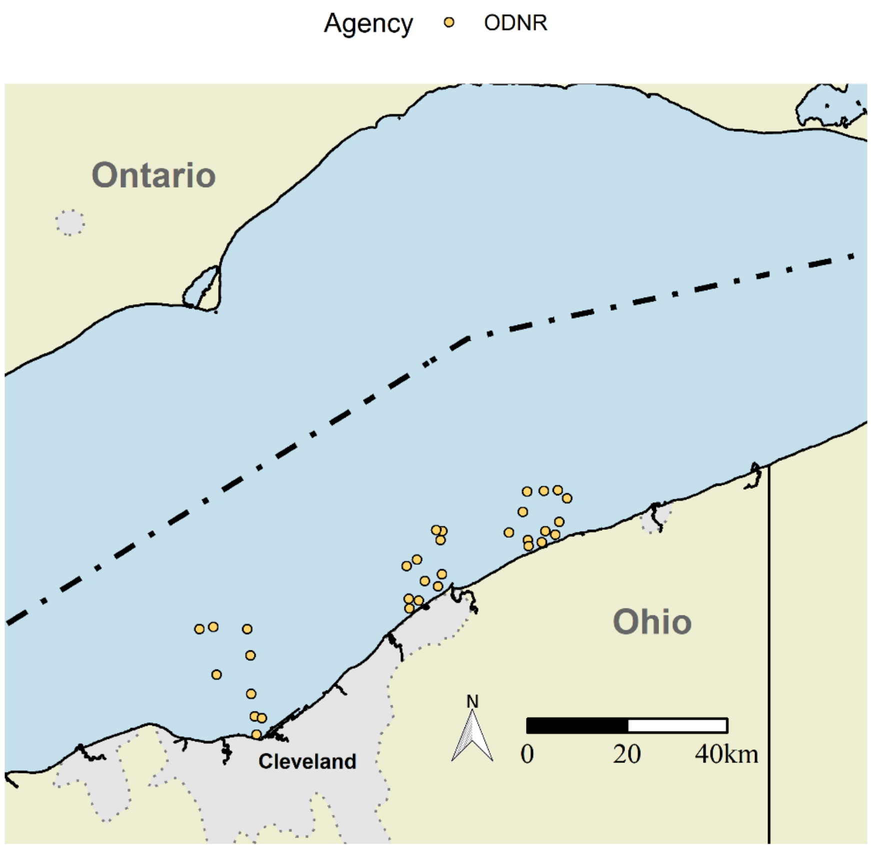


Figure 2.1.2.1. Locations sampled by Ohio (yellow) with index bottom trawls to assess forage fish abundance in the Central Basin, Lake Erie during 2021. Pennsylvania did not trawl in 2021 due to vessel issues.

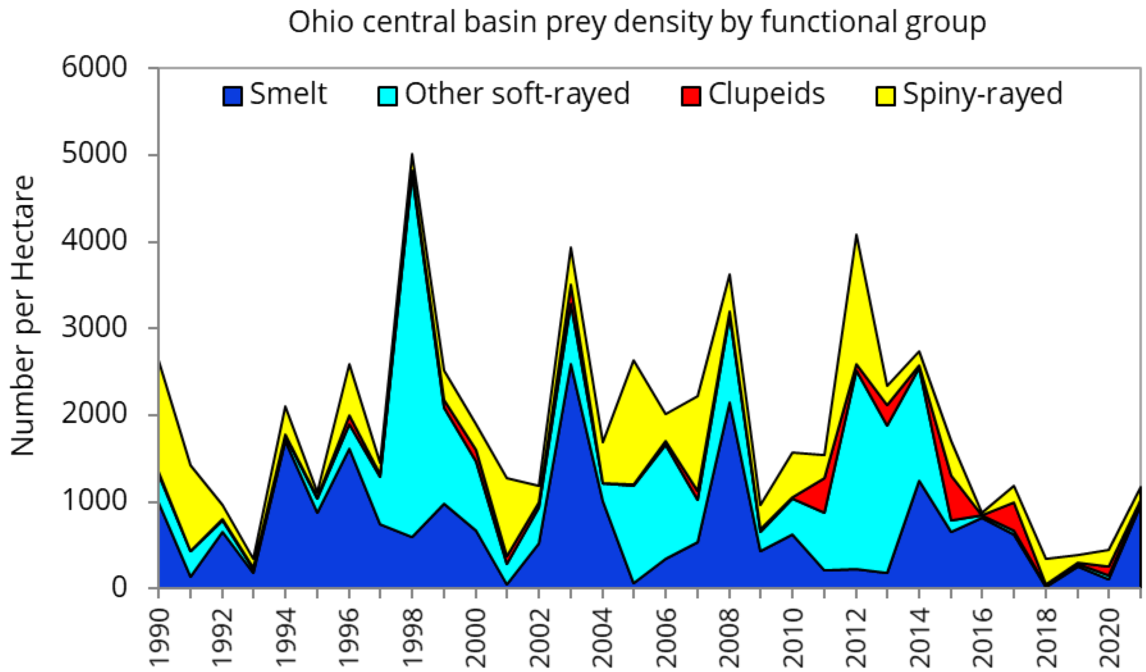


Figure 2.1.2.2: Mean density of prey fish (number per hectare) by functional group in Ohio waters of the Central Basin, Lake Erie, 1990–2021.

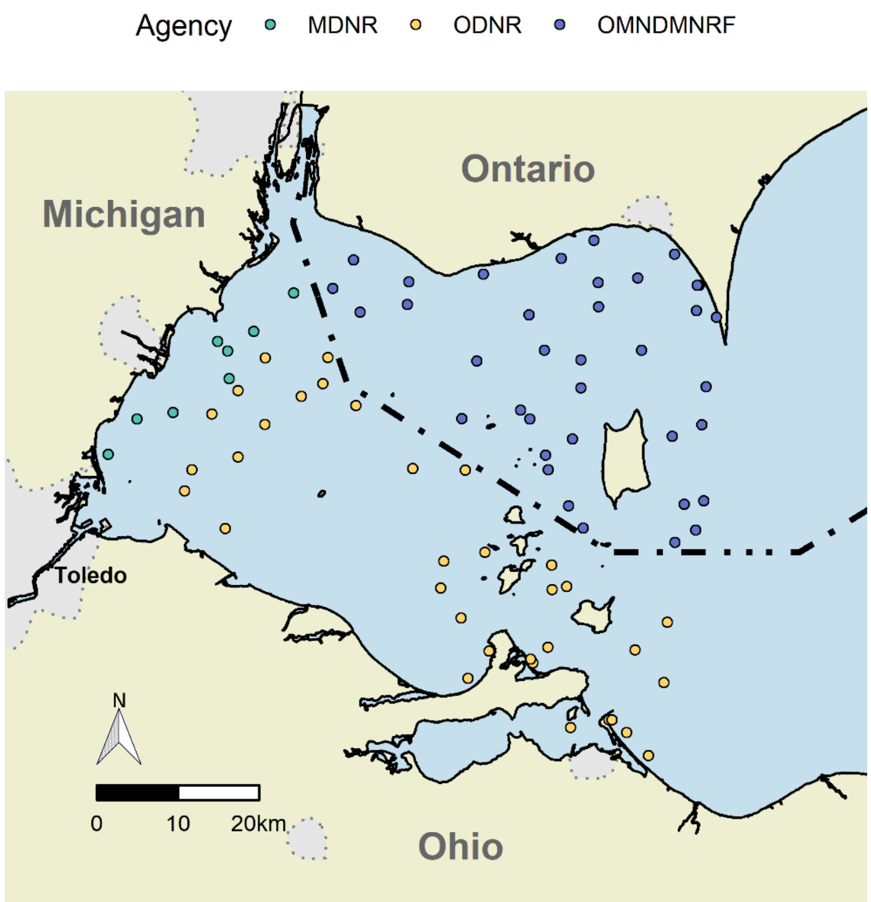


Figure 2.1.3.1: Trawl locations for West Basin bottom trawl surveys in 2021. Ohio (yellow) and Ontario (blue) surveys are combined to summarize the interagency indices, while Michigan (green) cannot yet be included due to lacking trawl comparison data.

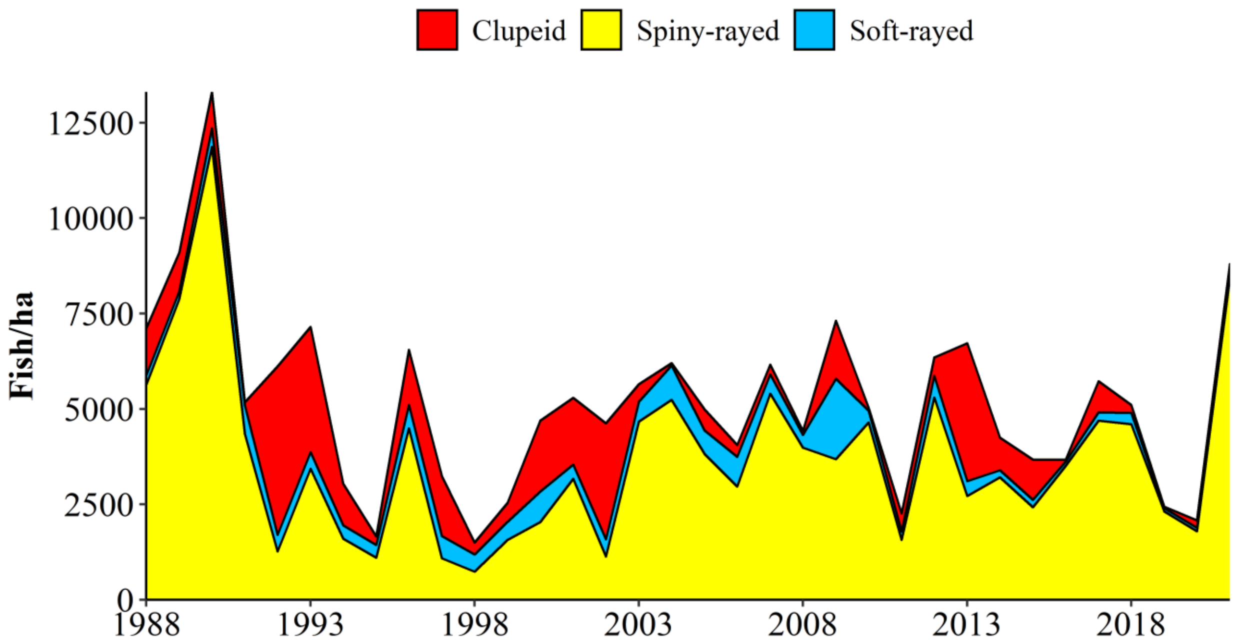


Figure 2.1.3.2: Mean density (number per hectare) of prey fish by functional group in western Lake Erie, August 1988–2021.

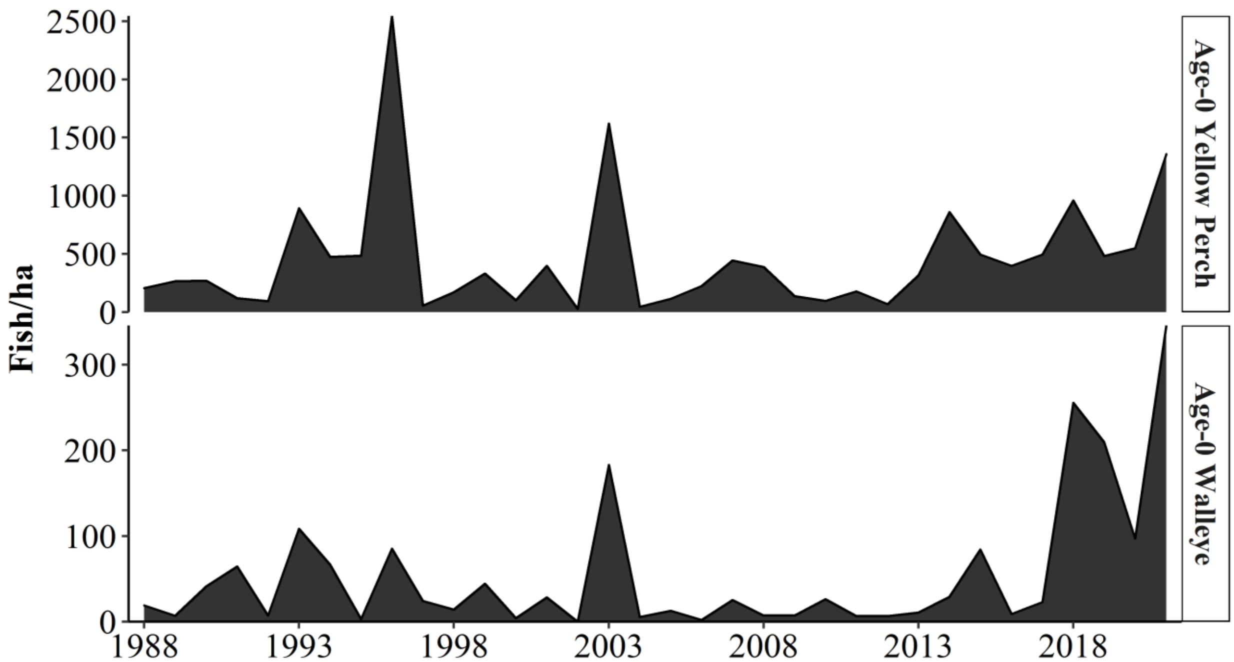


Figure 2.1.3.3: Densities of age-0 Yellow Perch (top) and age-0 Walleye (bottom) in the West Basin of Lake Erie, August 1988–2021. The 2021 Walleye year class was the largest on record.

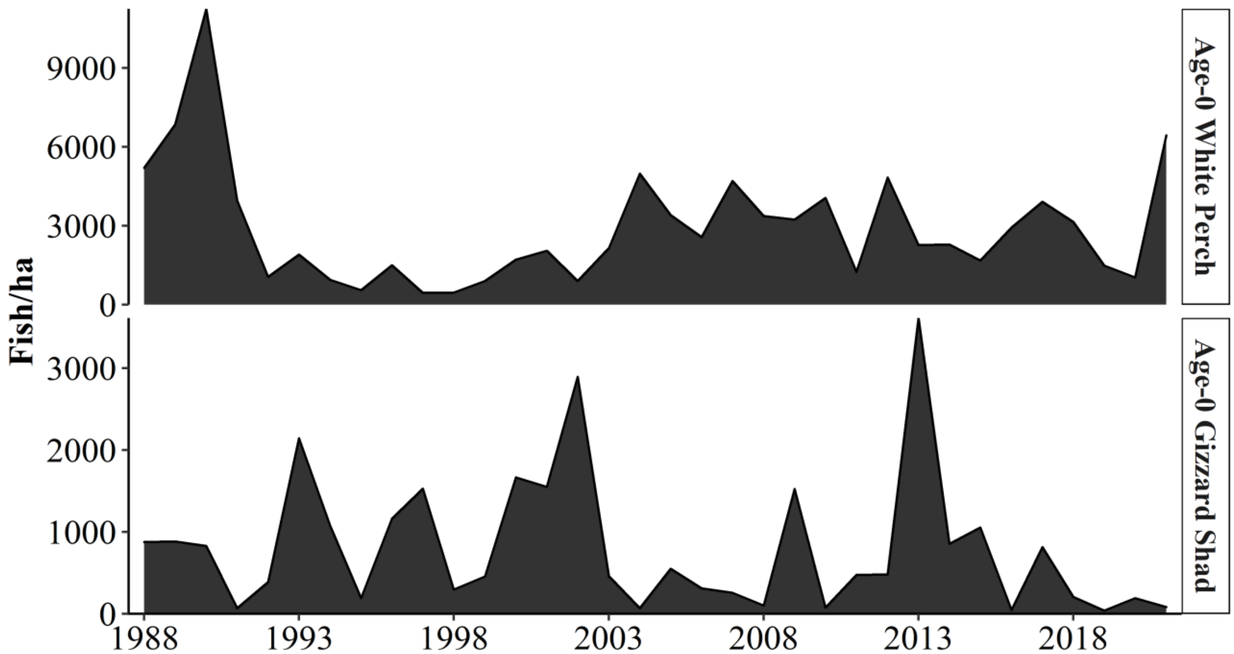


Figure 2.1.3.4: Density of age-0 Gizzard Shad (top) and age-0 White Perch (bottom) in the West Basin of Lake Erie, August 1988–2021. An outlier catch of White Perch inflated the abundance to twice the ten-year mean in 2021.

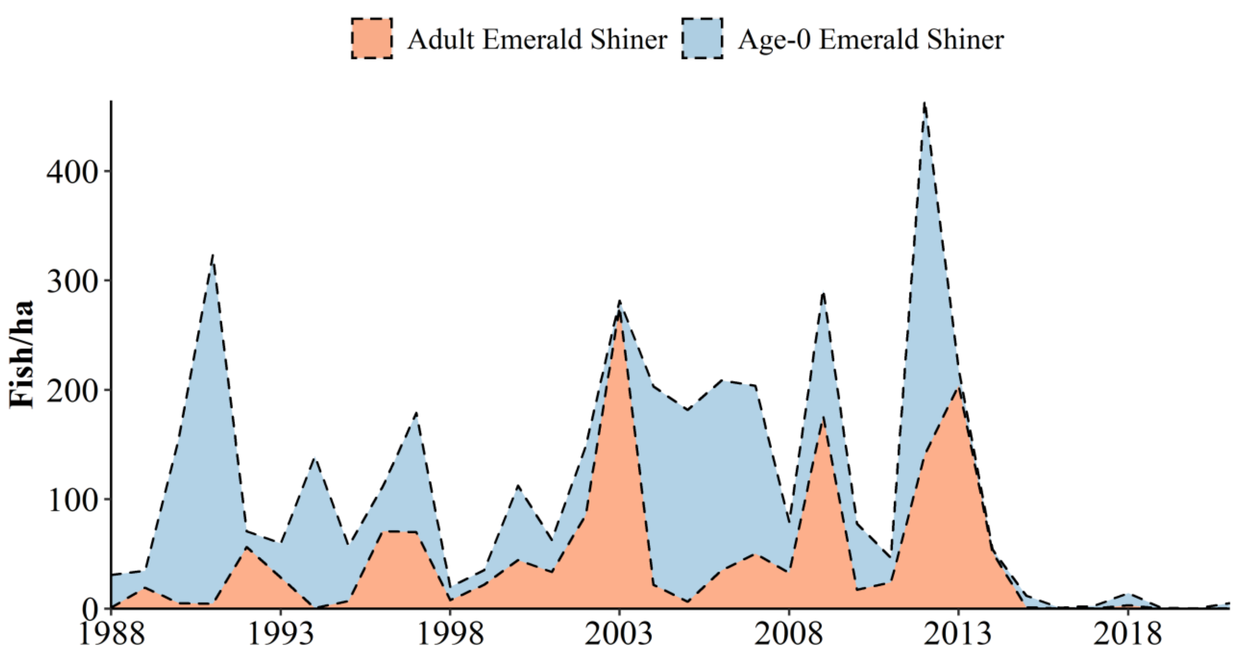


Figure 2.1.3.5: Densities of age-0 (blue) and age-1+ (red) Emerald Shiner in the West Basin of Lake Erie, August 1988–2021. Densities for both groups have remained minimal for seven years.

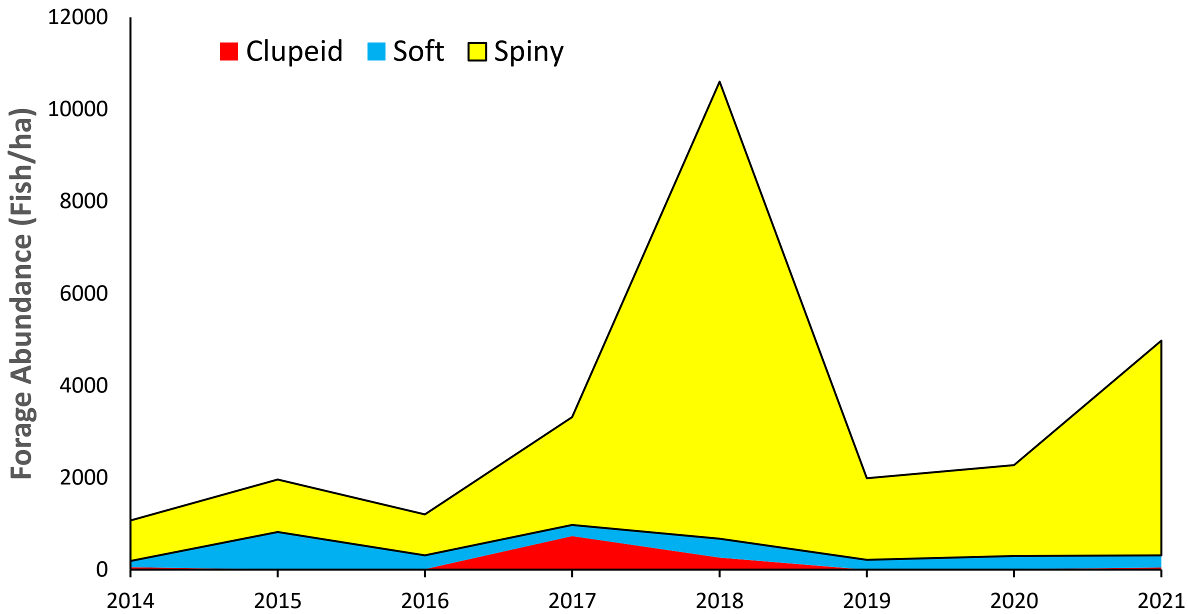


Figure 2.1.4.1: Mean density (number per hectare) of prey fish by functional group in Michigan waters of Lake Erie, August 2014–2021.

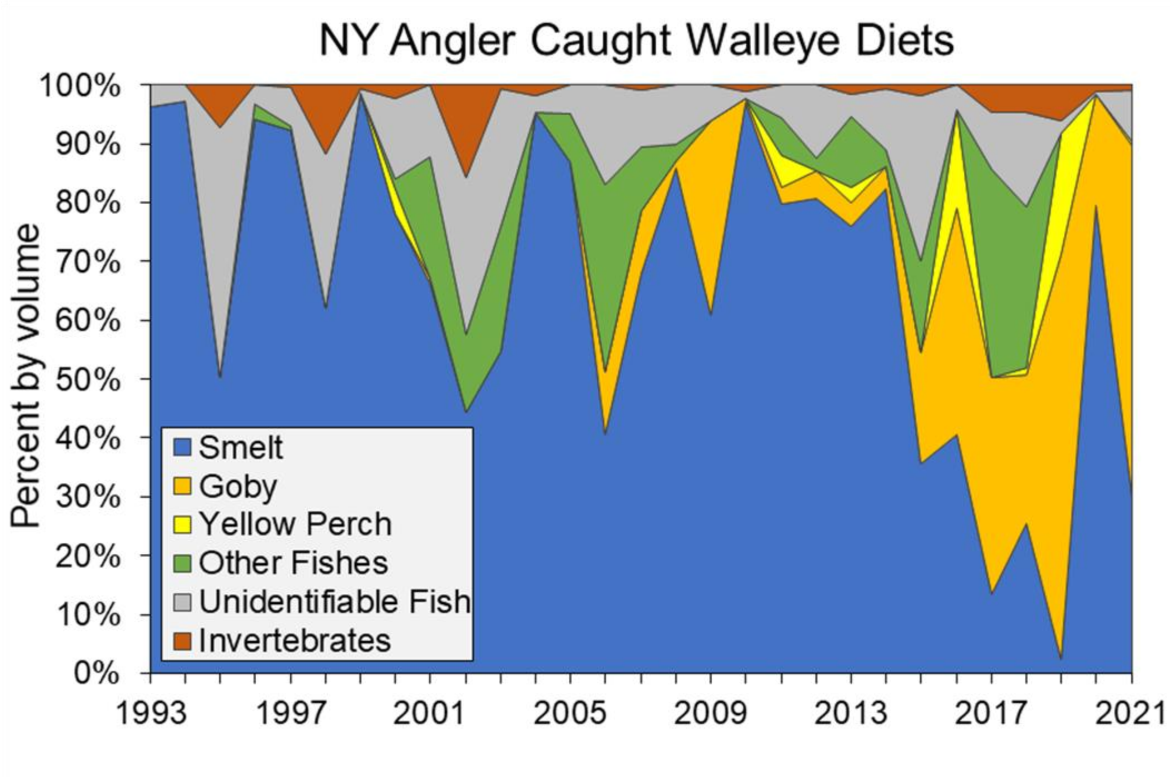


Figure 2.2.1.1: The percent contribution (by volume) of identifiable prey in non-empty stomachs of adult Walleye caught by anglers in New York's portion of Lake Erie, June–August 1993-2021.

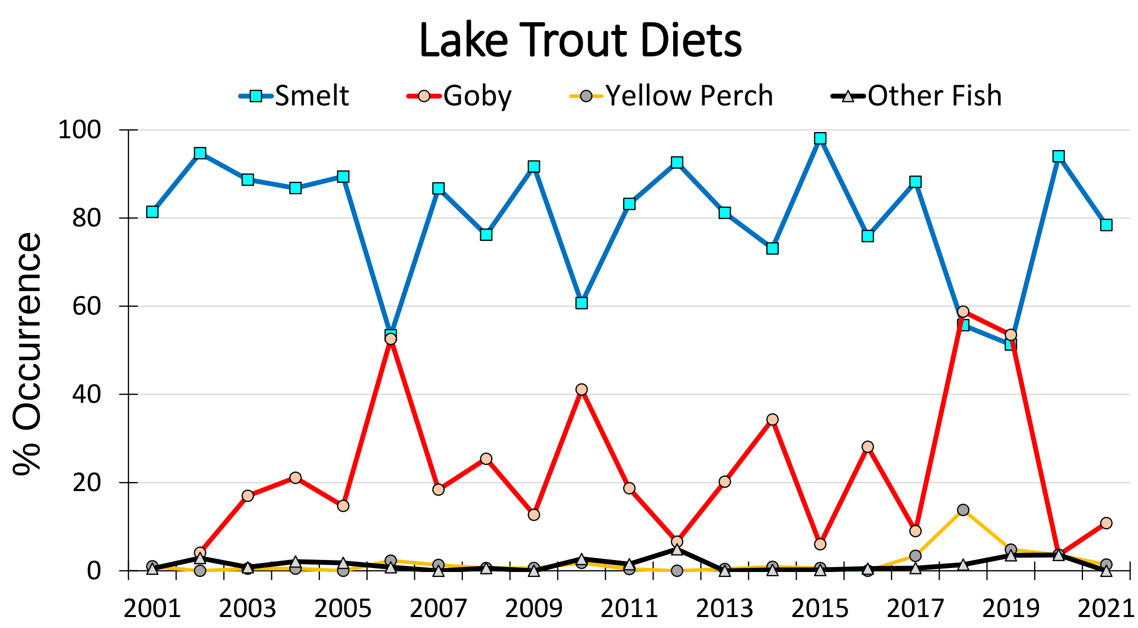


Figure 2.2.1.2: Percent occurrence of diet items from non-empty stomachs of lean strain Lake Trout collected in eastern basin gill net assessments, August, 2001–2021.

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

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

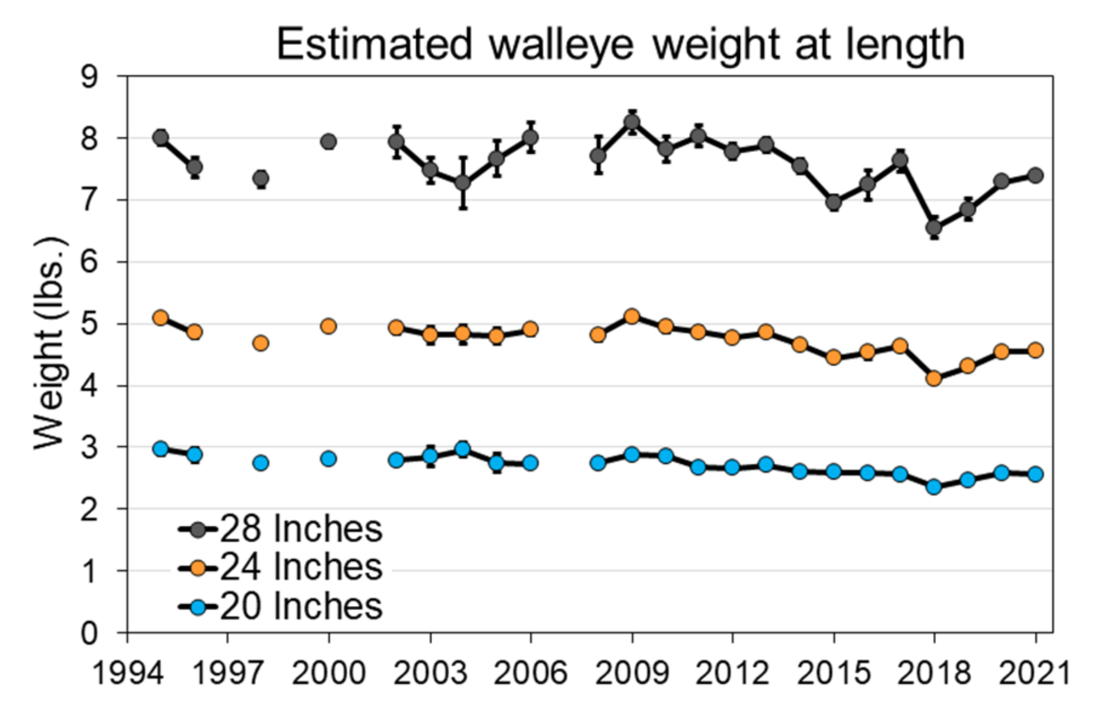


Figure 2.3.1.1: Estimated body weight (lbs.) of angler-caught Walleye in the New York waters of Lake Erie at 20, 24, and 28 inches from 1995–2021. Error bars represent 95% confidence intervals.

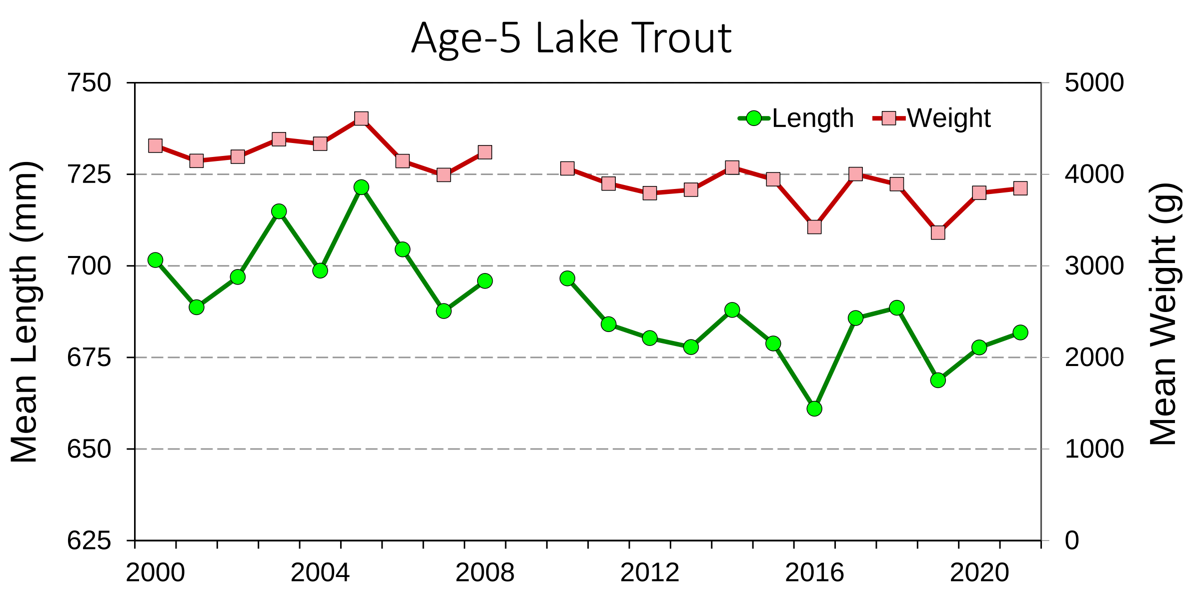


Figure 2.3.1.2: Mean length (mm) and weight (g) of age-5 lean strain Lake Trout caught in the New York coldwater assessment gill net survey in Lake Erie, 2000–2021.

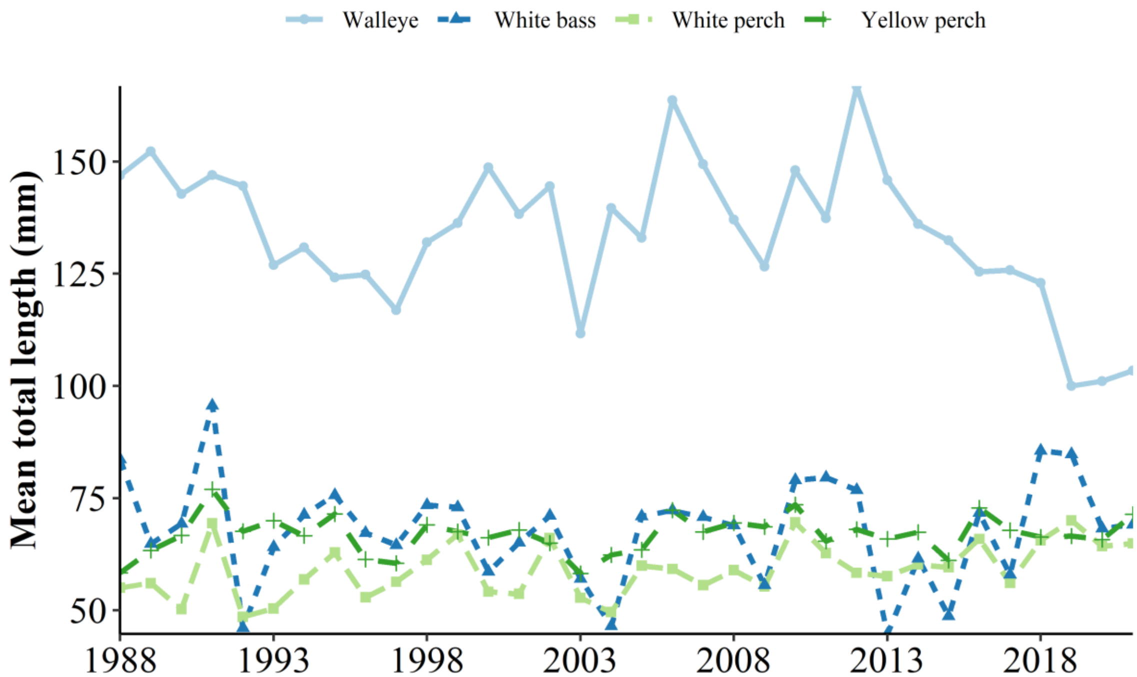


Figure 2.3.3.1: Mean total length of select age-0 fishes in western Lake Erie, August 1988–2021. Age-0 Walleye total length has rebounded somewhat from a time series low in 2019.

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

3.0 Hydroacoustics Surveys in 2021 (Z. Slagle)

In 2021, the hydroacoustic survey redesign for the three basin-wide surveys continued (FTG 2021). As with the 2020 survey, a hybrid survey design was implemented that used both cross-basin transects (old design) and randomly chosen grid transects (new design). Comparison work between these two surveys is ongoing (Appendix 2).

3.1 East Basin Hydroacoustic Survey (J. Holden)

Methods

A fisheries hydroacoustic survey has been conducted in the East Basin since 1993 to provide estimates of the distribution and abundance of age-1+ Rainbow Smelt. The original design was based off a fixed transect design that provided spatial coverage throughout the basin. In 1998, the survey was redesigned to include a random transect approach within defined strata. The strata are defined by 150 Loran-C lines providing equal distribution of transects across the basin. Two of the central strata were combined and divided north/south to allow separation of the 25-40m depth zone that previous surveys have shown are typically higher in age-1+ Rainbow Smelt abundance (Figure 3.1.1). From 1993 to 1996, a 70kHz single beam Simrad EY-M system was used. Since 1997, the hydroacoustic data acquisition system consists of a Simrad EY60 surface unit with a 120 kHz 7-degree split-beam general purpose transducer mounted on a fixed pole in a down facing orientation approximately 1 m below the water surface on the NDMNRF research vessel, R/V *Erie Explorer.* Early surveys were conducted multiple times throughout the year (2 seasons from 1993–1997, 3 seasons 1998–1999, July only since 2000). The July survey window maximizes the separation between age-0 and age-1+ Rainbow Smelt in the water column. The 2014 edition of this report details the history, design and analytical methods of the hydroacoustic survey (Forage Task Group 2014). Up to 2007, companion midwater trawls were completed by NYSDEC and found that age-1+ Rainbow Smelt made up greater than 95% of catches of fish of their acoustic target strength in meta-hypolimnion trawls. In the absence of companion trawls post 2007, the acoustic data were analyzed with the assumption that all meta-hypolimnion targets above the minimum target strength threshold were age-1+ Rainbow Smelt. In 2019, NDMNRF extended the survey window to incorporate mid-water trawling (N = 24) to test the assumption that the meta-hypolimnion targets were still likely to be age-1+ Rainbow Smelt. A midwater trawl 13.6 m long with a 7.1 m headline, spread with 0.5 m^2 aluminum doors was fished throughout the water column in areas where high densities of acoustic targets were identified. Midwater trawl catches confirmed the assumption that the majority of targets meeting the minimum target strength threshold in the hypo-metalimnion layer are age-1+ Rainbow Smelt.

Results

Survey transects were completed in all but Strata 4 during the 2021 survey (Figure 3.1.2). Additional random-grid segments were conducted within the surveyed strata to support the evaluation of the acoustic program (Appendix 2). Only data from the cross-stratum transects were used to generate the annual index of abundance. Transects are segmented in to 800 m sampling units for analytical purposes. Strata density are the mean density of all the 800 m segments within the strata (two transects combined). The basin estimate is a mean of the combined strata. Hydroacoustic analyses in 2021 indicated that age-1+ Rainbow Smelt densities (1436 fish/ha) decreased from 2020 (1,854 fish/ha; Figure 3.1.3) but density remains higher than the previous low years. The highest mean density was observed within Stratum 2.3 (2376 fish/ha), whereas Stratum 2.2 had the lowest density (187 fish/ha; Figure 3.1.4).

3.2 **Central Basin Hydroacoustic Survey** (M. DuFour [USGS], J. Deller)

Since 2004, NDMNRF, ODNR, and USGS have collaborated to conduct joint hydroacoustic and midwater trawl surveys in the Central Basin of Lake Erie. The primary purpose of the survey is to estimate densities of Rainbow Smelt and Emerald Shiner, the primary pelagic forage species in the Central Basin. Beginning in 2008, all hydroacoustic data were collected and analyzed following recommendations in the Standard Operating Procedures for Fisheries Acoustics Surveys in the Great Lakes (Parker-Stetter et al. 2009). The survey consists of eight cross-basin transects; however, unsuitable sampling conditions (i.e., high wind and waves) routinely prohibited survey completion. In 2020, researchers began evaluating a new sampling design, in which 5 km transects are randomly distributed within sampling stratum in proportion to stratum area (Appendix 2).

Methods

In 2021, all hydroacoustic data were collected from the USGS R/V *Muskie* using a downward-facing BioSonics DTX® 120 kHz split-beam echosounder (7.4 degrees) mounted inside a through-hull transducer tube at a depth of 1.5 m below the water surface. Data were collected with BioSonics Visual Acquisition (release 6.2) software from a Dell Precision 7720 laptop and Garmin global positioning system. The acoustic system was calibrated prior to the survey with a tungsten carbide reference sphere of known acoustic size. Data collection began 0.5 h after sunset and completed by 0.5 h prior to sunrise, depending on the length of the transect and vessel speed. Collection settings during the survey were 4 pings/second, a pulse length of 0.4 msec, and a minimum collection threshold of -130 dB. A complete description of Central Basin survey protocols and analysis can be found in the 2017 Forage Task Group Report (FTG 2017). The sampling environment (water temperature) was set to the temperature at 2 m depth in the evening and at the location of sampling. Data were written to file and named by the date and time the file was collected. Files were automatically saved every 15 minutes. Latitude and longitude coordinates were written to the file as the data were collected to identify sample location. A combination of traditional cross lake transects (57850, 58100) and 5 km grid transects

(315, 412, 414,416, 512, 516, 613, 615, 617, 714, 716) were sampled to provide data to continue analysis of the proposed stratified random-grid sample design to the traditional cross-lake transect survey. Transects were navigated with waypoints programmed into the vessel's onboard navigation system.

Mid-water trawl samples were collected within each grid location by the R/V *Keenosay* (NDMNRF) and R/V *Grandon* (ODNR) concurrent with the hydroacoustic data collection. The R/V *Keenosay* operated in Ontario waters and sampled grids 315, 412, 414, 416, and 512. The R/V *Grandon* operated in U.S. waters and sampled grids 516, 613, 615, 617, 714, and 716. Up to four midwater trawls were conducted in each grid, with trawl depths distributed among the epilimnion, metalimnion, and hypolimnion to capture the fish community distribution across depths. Trawl catch was sorted by species and age group, and a subsample of fish were measured (total length). Temperature and dissolved oxygen profiles were collected at each grid.

Hydroacoustic data were analyzed with the Myriax software Echoview 12.1 using a standardized template developed by the NDMNRF, ODNR, and USGS – Lake Erie Biological Station. Analyses produced fish density estimates for each 500 m sampling interval (EDSU; elementary distance sampling unit) and layer along each cross-basin and random-grid transect. Each sampled interval was partitioned vertically into epilimnetic and hypolimnetic layers based on fish distribution and water temperature profiles. Each trawl was associated with a sampled stratum, hydroacoustic transect, and layer. Similar to hydroacoustic data, trawl samples were categorized into epilimnetic and hypolimnetic layers based on trawl depth and thermocline depths identified by hydroacoustic data and temperature profiles. Trawl samples were categorized into five species groups, including all ages of Emerald Shiner, age-0 Rainbow Smelt, age-1+ Rainbow Smelt, age-0 Yellow Perch, and others, while counts were aggregated by sampled stratum, transect, and layer. Species composition (as a proportion of total) was calculated for each unique stratum-transect-layer combination and applied to hydroacoustic density estimates generating species-group density estimates by stratum-transect-interval-layer. Layer density estimates were summed within intervals to produce a whole-water-column density estimate for each stratum-transect-interval combination. Basin wide density estimates were generated by averaging across EDSUs.

Results

Two cross-basin transects (165 km), and ten 5-km random-grid transects (50 km) were sampled in the eastern portion of the Central Basin between 6 July and 10 July 2021, totaling 215 km of sampled transect (Figure 3.2.1). A total of 43 mid-water trawls were collected in conjunction with random-grid and cross-basin transects including 34 samples from the epilimnion and 9 samples from the hypolimnion.

Total forage fish densities exhibited an increasing gradient from north to south in the eastern half of the Central Basin, with highest densities occurring in U.S. waters and lowest densities in nearshore Canadian waters. Total forage fish densities were dominated by age-0 Rainbow Smelt, with small contributions from Emerald Shiner, age-1+ Rainbow Smelt, age-0 Yellow Perch, and other species (Figure 3.2.2). Basin-wide age-0 Rainbow Smelt densities were the highest on record, while Emerald Shiner and age-1+ Rainbow Smelt densities remained at low values compared to the rest of the time series (Figure 3.2.3).

3.3 **West Basin Hydroacoustic Survey** (M. DuFour [USGS])

Since 2005, the Ohio Department of Natural Resources Division of Wildlife (ODNR) has conducted a hydroacoustic forage fish survey in the West Basin of Lake Erie. This survey consisted of three, cross-basin transects through 2019; however, unsuitable sampling conditions (i.e., high wind and waves) routinely prohibited survey completion. In 2020, the sampling strategy was changed to a random stratified design, where 5 km transects are randomly distributed within sampling stratum in proportion to stratum area. No trawling has ever been conducted in conjunction with acoustic data collection.

Methods

In 2021, all transects were surveyed using a single, downward-facing, 6.3-degree, 201-kHz split-beam transducer, a Garmin global positioning system, and a Panasonic CF-30 laptop computer. The acoustic system was calibrated after survey completion with a tungsten carbide reference sphere of known acoustic size. The mobile survey, conducted aboard the ODNR's R/V *Almar*, was initiated approximately 0.5 h after sunset and completed by 0.5 h prior to sunrise. Transects were navigated with waypoints programmed in a Lowrance GPS, and speed was maintained at 8-9 km/h. The transducer was mounted to a BioSonics Towfish at 1 m below the surface at the starboard side of the boat. Data were collected using BioSonics Visual Acquisition 6 software. Collection settings during the survey were 10 pings/second, a pulse length of 0.2 msec, and a minimum collection threshold of -100 dB. The sampling environment (water temperature) was set to the temperature at 2 m depth on the evening of sampling. Data were written to file and named by the date and time the file was collected. Files were automatically collected every 10 minutes. Latitude and longitude coordinates were written to the file as the data were collected to identify sample location.

Data were analyzed with the Myriax software Echoview 12.1 using a standardized template developed by the NDMNRF, ODNR, and USGS Lake Erie Biological Station. Analyses produced fish density and size (mean target strength; TS) estimates for each 1000 m sampling interval (elementary distance sampling unit; EDSU) along each 5-km transect. Fish density estimates were converted to biomass using established TL-TS and Wt-TL relationships.

Average total length (mm) of sampled fish for each EDSU was estimated using Love's dorsal aspect equation (Love 1971):

$$TL = 10 ([TS + 26.1]/19.1) * 1000$$

Biomass (kg/ha) estimates were based on average target length as determined by the above equation and an established length (TL)-weight (Wt) relationship.

$$Wt = (0.0000263*TL^{2.7875})/1000$$

Basin wide density and average biomass estimates, and associated uncertainty, were generated by averaging across EDSU and calculating standard deviation and standard error among EDSU.

Results

In 2021, eighteen 5-km transects were sampled across the western basin between 6-10 July (Figure 3.3.1). One 5-km transect (grid 428) is not displayed due to missing GPS coordinate data. Densities increased in 2021 relative to the previous five years while biomass remained low (Figure 3.3.2), suggesting the forage fish community was made up of primarily small age-0 fishes.

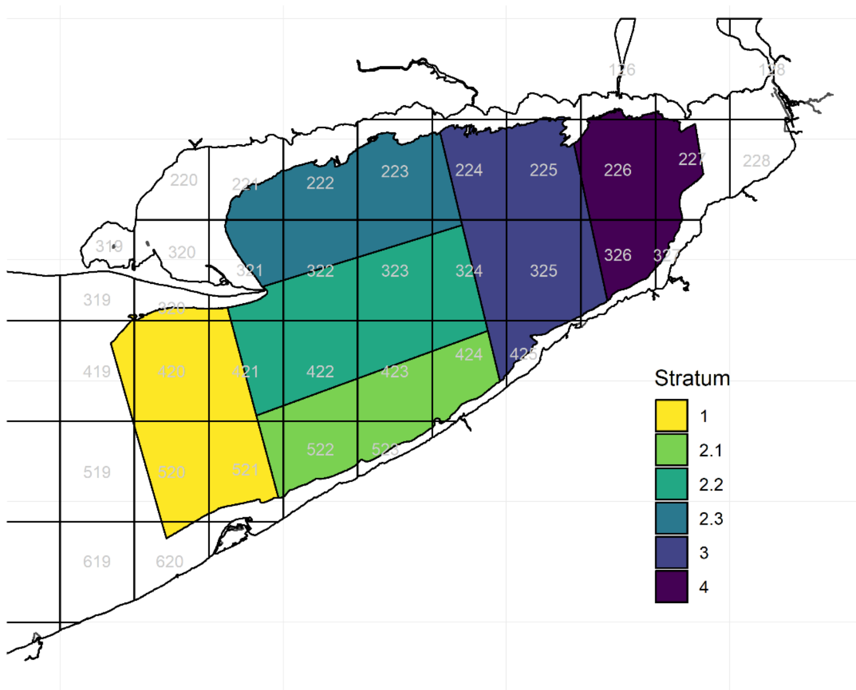


Figure 3.1.1. Strata used in the East Basin survey since 1998. Within each strata, two randomly selected transects (on Loran-C lines, approximately north-south oriented) are selected each year.

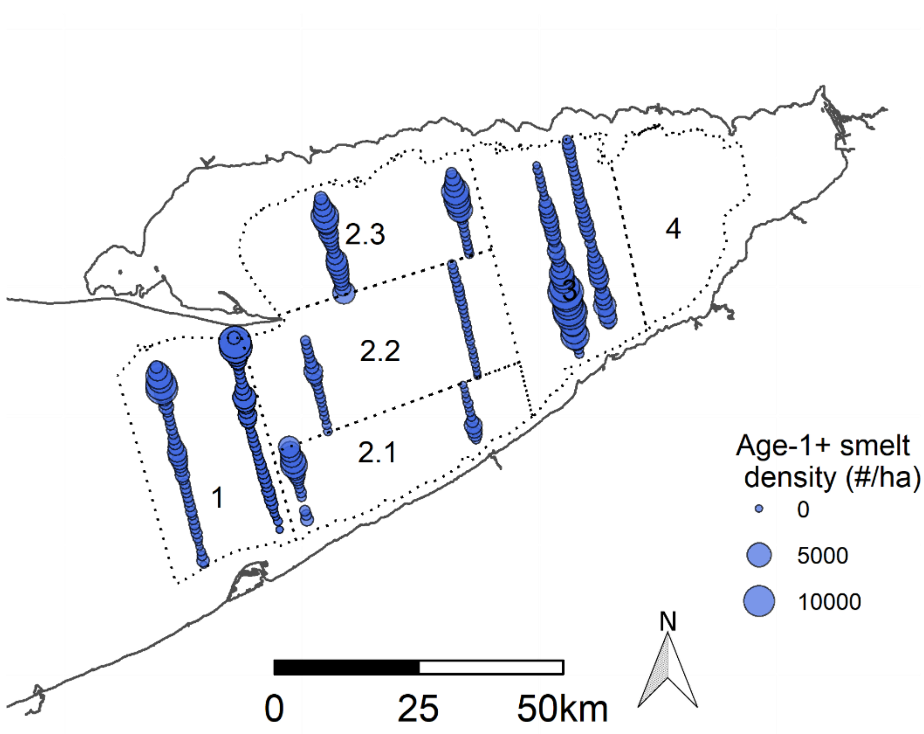


Figure 3.1.2. Age-1+ Rainbow Smelt density (fish per hectare) along hydroacoustic transects in the East Basin, Lake Erie, in 2021.

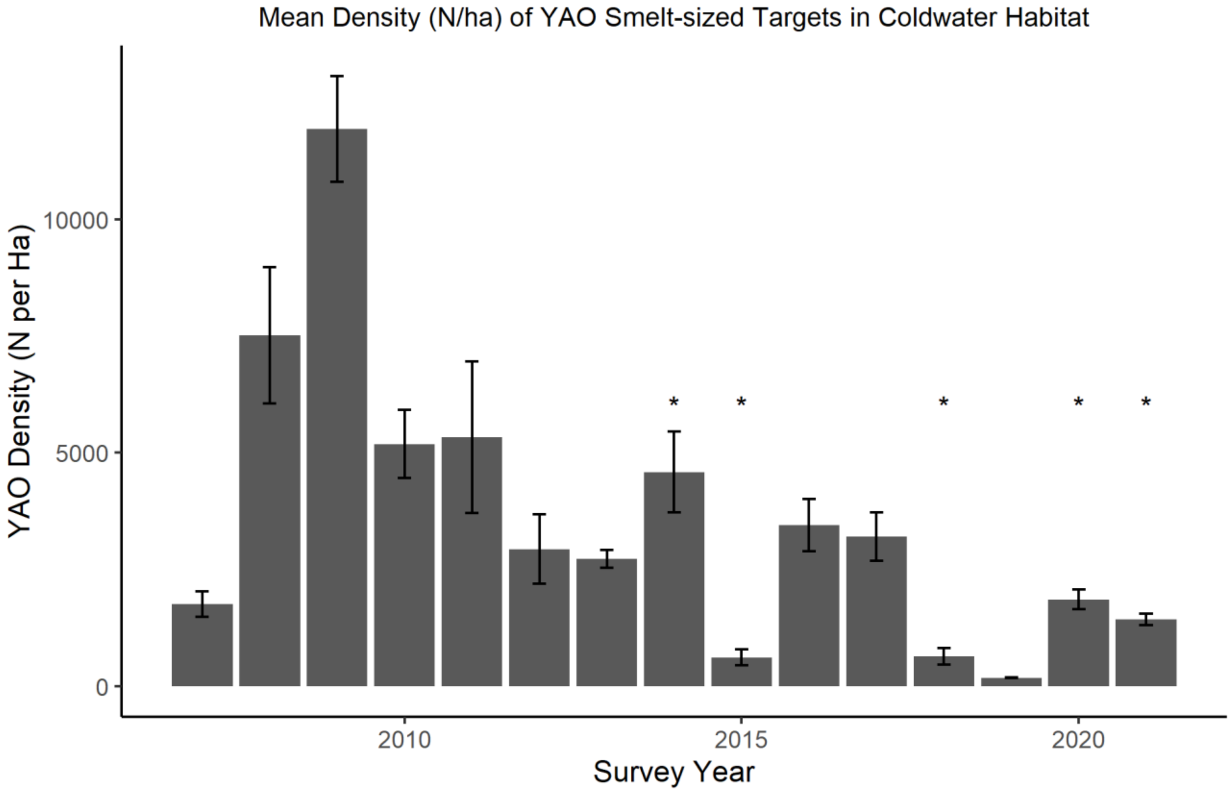


Figure 3.1.3. Annual abundance trend (N/ha) in age-1+ Rainbow Smelt in the East Basin from 2007 to 2021. Since 2007, the survey has relied solely on acoustic data because no companion trawling data was available in most years. Asterisks (*) indicate years where only partial surveys were completed.

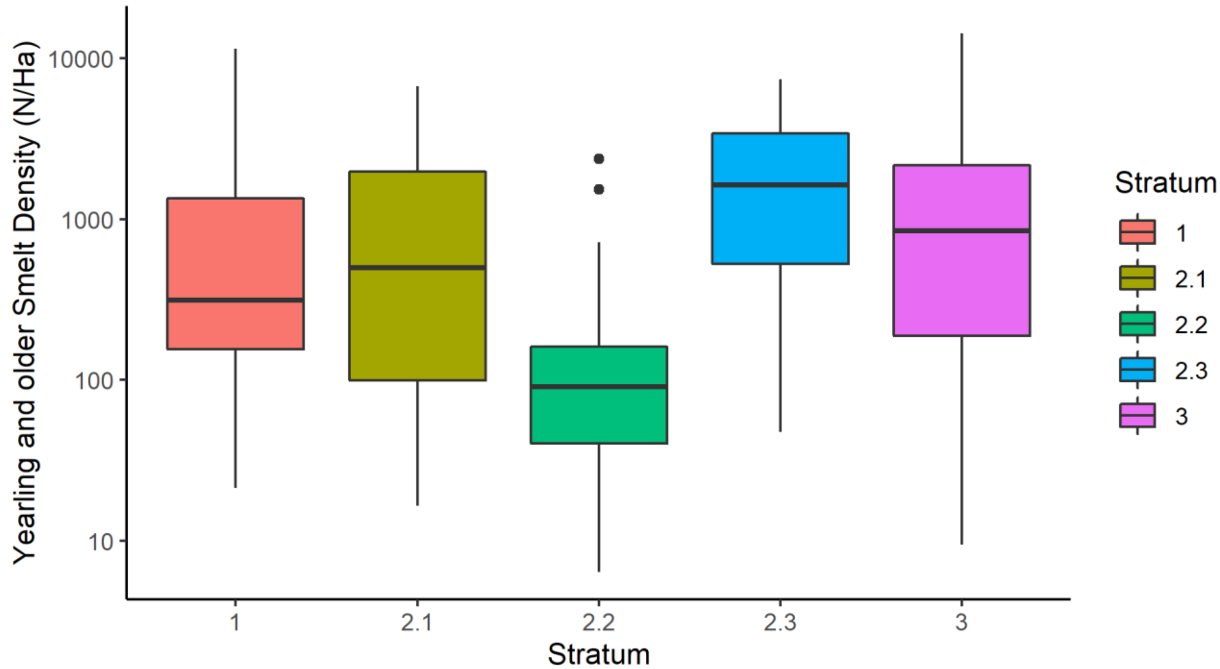


Figure 3.1.4. Abundance (N/ha) of age-1+ Rainbow Smelt in the East Basin on survey transect within each survey Stratum. Solid line indicates the median abundance; the box indicates the 50% of the values (25% and 75% quantile ranges). The vertical lines indicate the largest value no larger than 1.5 times the inter-quartile range (IQR). Values large than 1.5 time the IQR are shown as individual points.

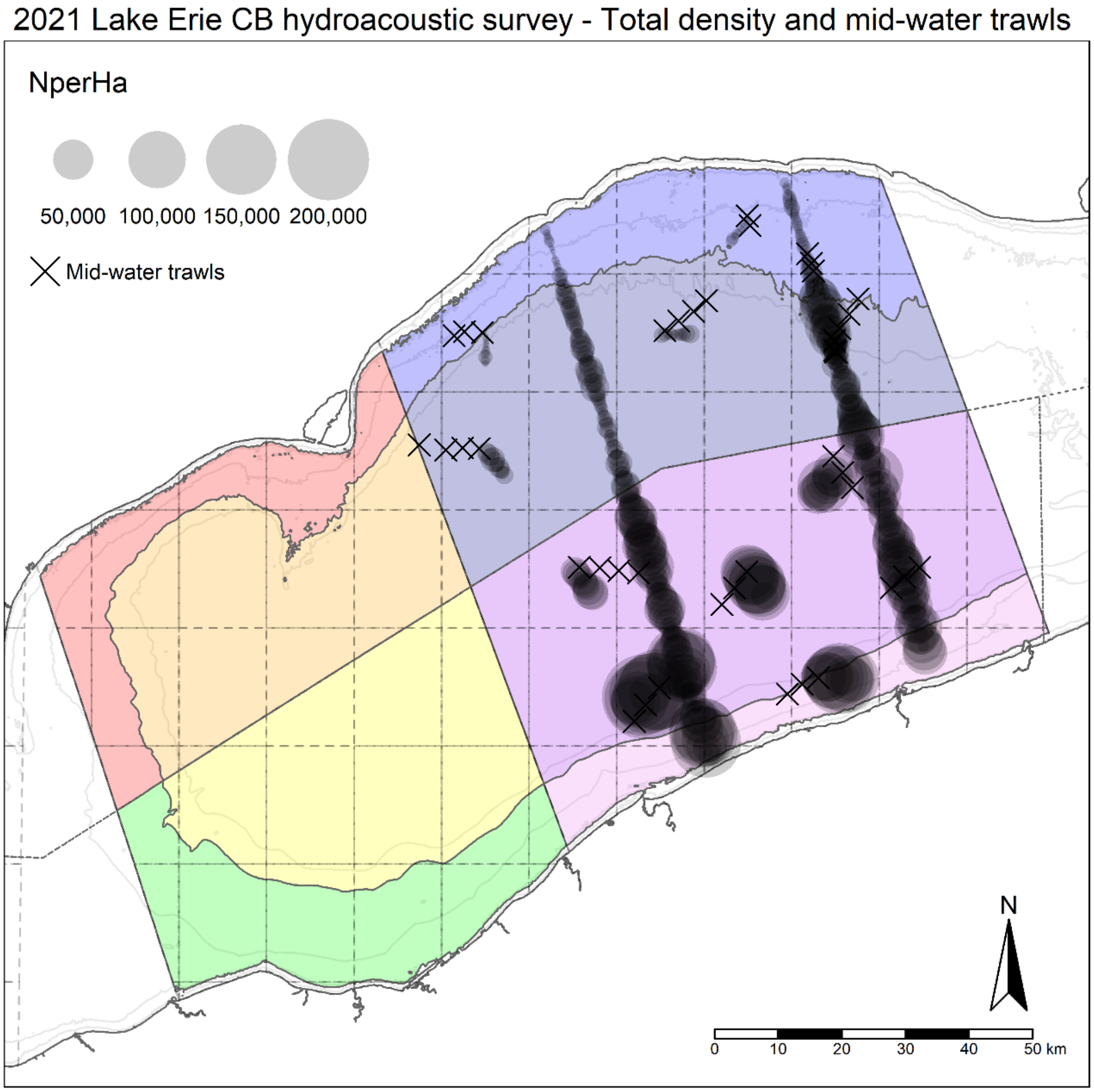


Figure 3.2.1: Total forage fish density estimates (NperHa – gray dots) over cross-basin and random-grid transects and mid-water trawl locations (black X) sampled in the Central Basin, July 2021. Basin strata are distinguished by color.

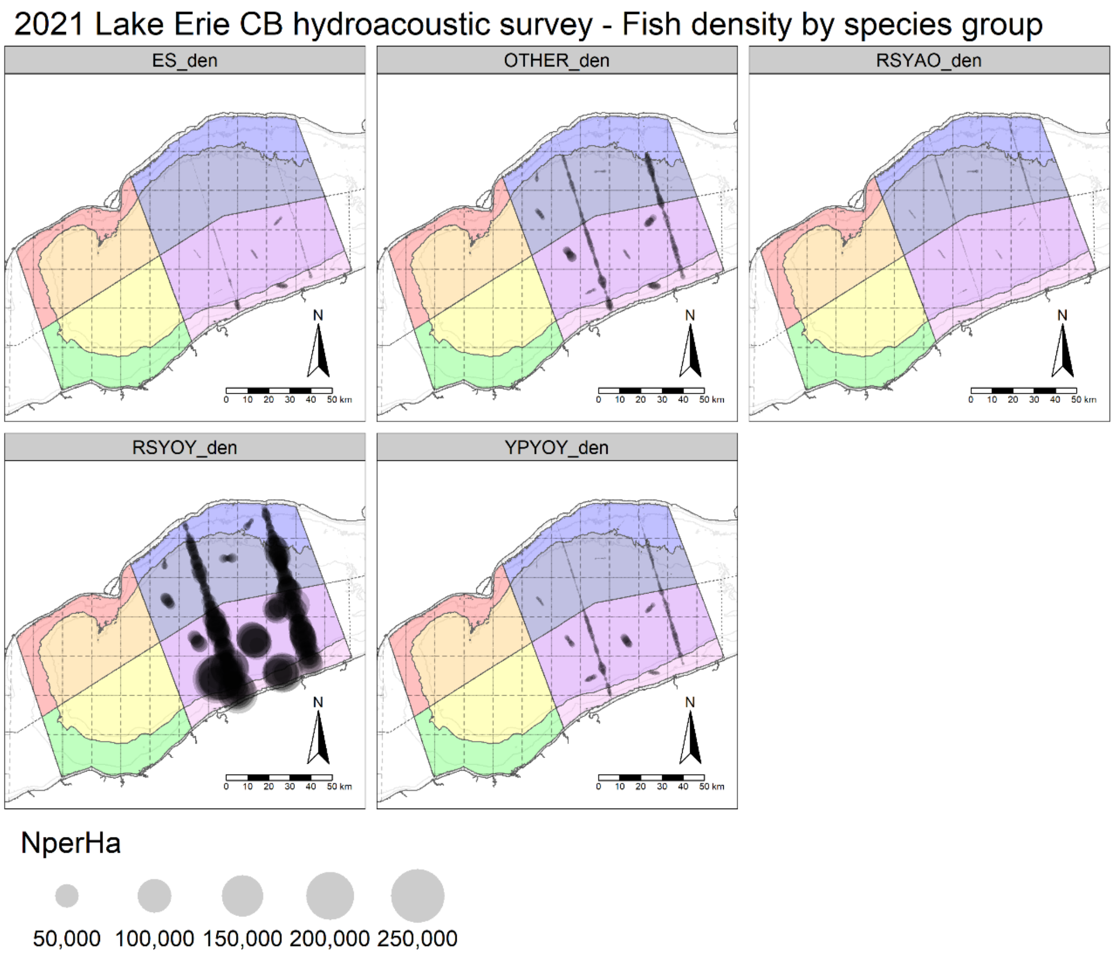


Figure 3.2.2: Fish density estimates (NperHa – gray dots) by species group over cross-basin and random grid transects in the Central Basin, July 2021. Species groups include all Emerald Shiner (ES_den), age-1+ Rainbow Smelt (RSYAO_den), age-0 Rainbow Smelt (RSYOY_den), age-0 Yellow Perch (YPYOY_den), and all other species (OTHER_den). Basin strata are distinguished by color.

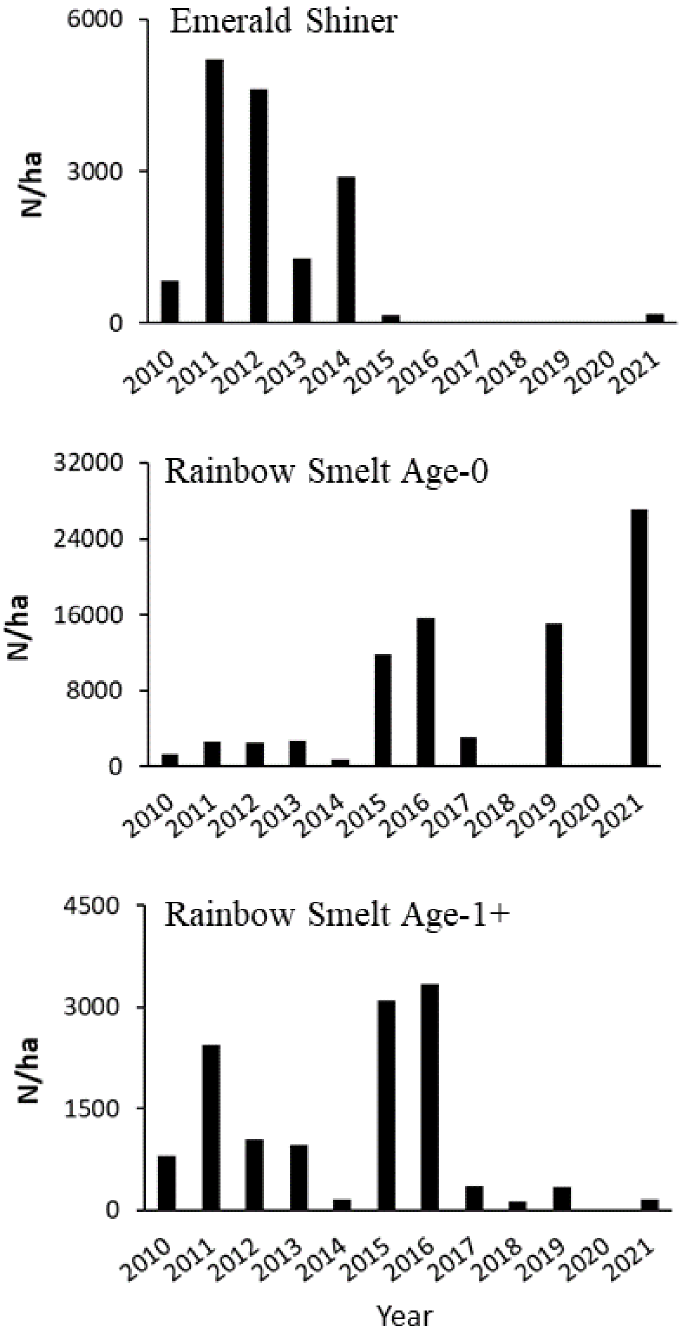


Figure 3.2.3: Annual indices (N/ha) for Emerald Shiner, age-0 Rainbow Smelt, and age-1+ Rainbow Smelt from Central Basin hydroacoustic survey, 2010-2021. Indices are generated by averaging over all sampled EDSU.

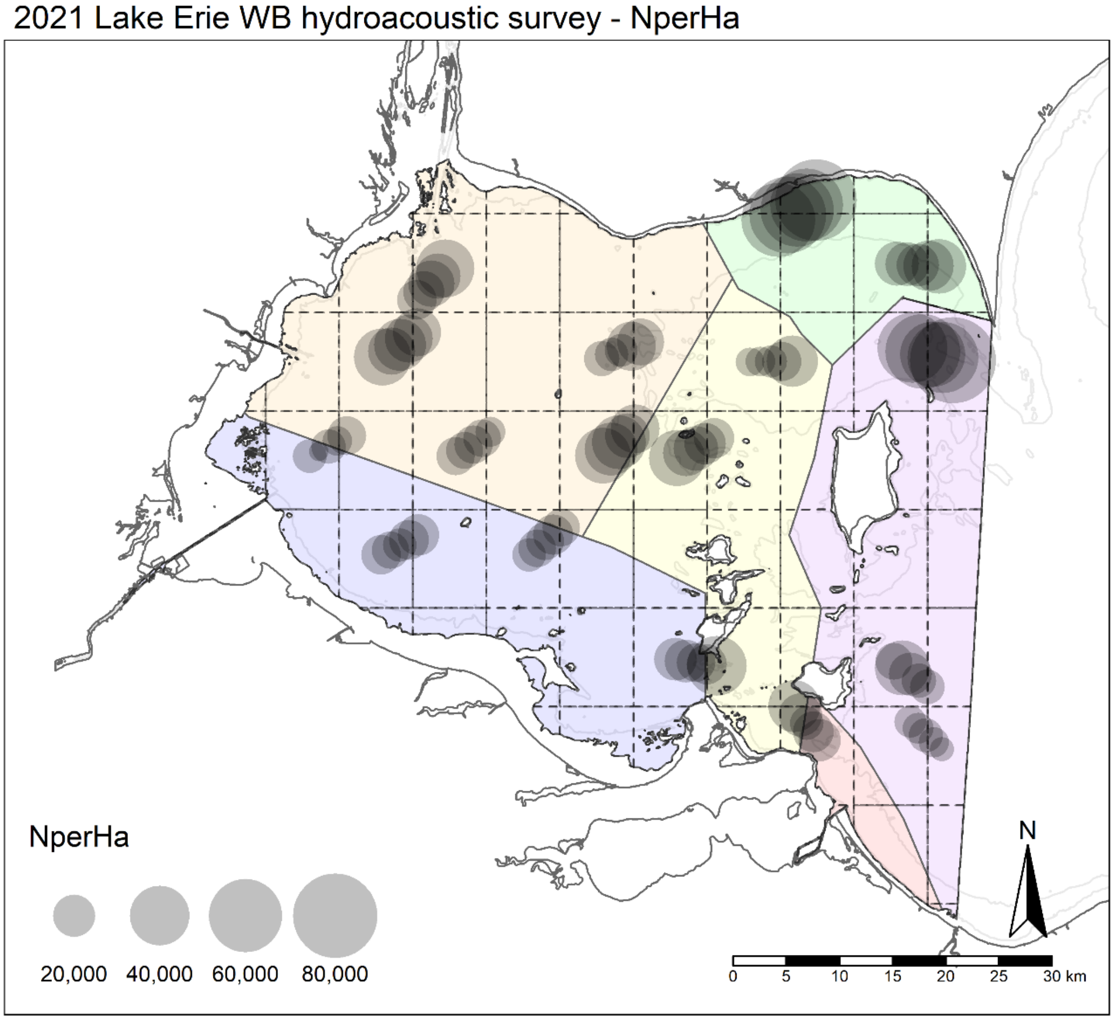


Figure 3.3.1: Forage fish density (fish/ha) estimates over 5-km transects sampled in the West Basin, July 2021. Basin strata are distinguished by color.

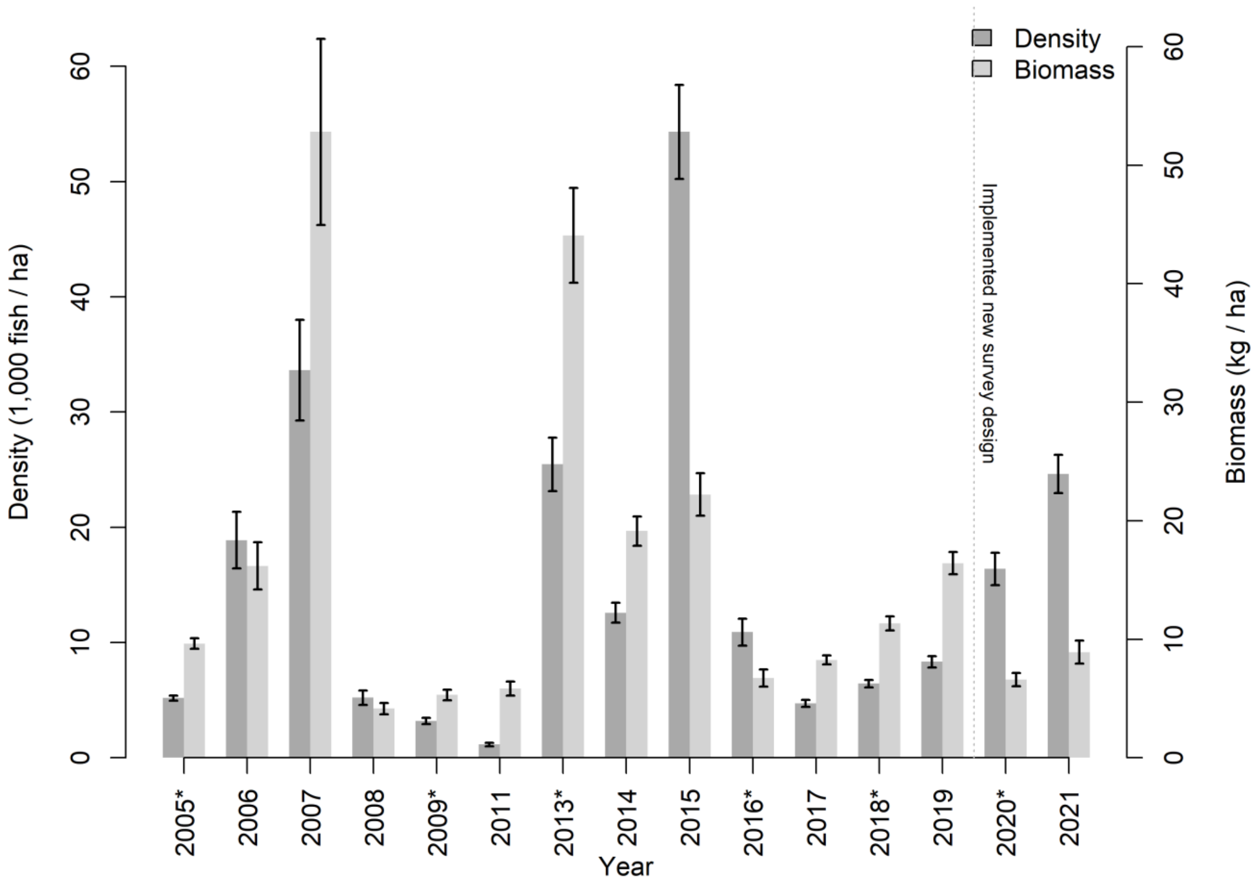


Figure 3.3.2: West Basin density (1,000 fish/ha – dark gray bars) and average biomass (kg/ha – light gray bars) estimates over time. Error bars represent ±1 standard error. Asterisks (*) denote incomplete survey years, and vertical dashed line signifies when the change in sampling design occurred.

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

(K. Towne and G. Wright)

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 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 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.

The U.S. Fish and Wildlife Early Detection and Monitoring program was somewhat reduced in sampling effort and scope due to the COVID-19 pandemic in 2021; however, a single Nile Tilapia (*Oreochromis niloticus*) was detected in Cleveland, Ohio. Additional sampling efforts in the same area did not find any other Nile Tilapia. No Black Carp, Silver Carp, Bighead Carp, or Tench were captured in Lake Erie waters in 2021.

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.

Citation:

Forage Task Group. 2022. 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.

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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
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*	

Appendix 2: Lake Erie Hydroacoustic Survey Redesign – West, Central and East Basins

Andy Cook, Ontario Ministry of Natural Resources and Forestry
John Deller, Ohio Division of Wildlife
Rebecca Dillon, U.S. Geological Survey
Mark DuFour, Ohio Division of Wildlife
Jeremy Holden, Ontario Ministry of Natural Resources and Forestry
Patrick Kočovský, U.S. Geological Survey
James Roberts, U.S. Geological Survey
Joseph Schmitt, U.S. Geological Survey
Zak Slagle, Ohio Division of Wildlife

Existing Survey Background

The primary purpose of Lake Erie hydroacoustic surveys is to estimate densities of important forage fishes including Gizzard Shad and Emerald Shiner in the West Basin, Rainbow Smelt and Emerald Shiner in the Central Basin, and Rainbow Smelt in the East Basin (Figure 1). As of 2019, all surveys were scheduled to take place within five days of the new moon in July to synchronize across the lake; however, each survey routinely experienced challenges that inhibit survey completion. A brief history and description of surveys in each basin follows:

- Lake Erie hydroacoustic surveys have been conducted annually in the East Basin since 1993. Effort is divided among six strata with two randomly chosen north-south transects within each stratum. Companion midwater trawls were initially completed by NYSDEC until 2007. These trawls determined that >95% of the fish caught in cold-water habitat were yearling and older smelt, leading to an analytical approach that vertically splits the echogram based on temperature and target size; all fish in the age-1+ size range (target strength from -59dB to -40dB) are classified as age-1+ Rainbow Smelt. The entire survey is routinely completed; however, only four of six strata were sampled in 2014, only three of the strata in 2015, and only Ontario waters in 2018 and 2020.

- The Central Basin hydroacoustic survey began in 2000. In cooperation, NDMNRF, ODNR, and USGS implemented surveys with consistent methodology since 2004. The survey design targets eight cross-basin transects each year, a total of 643 km. Midwater trawl samples are taken along each transect, usually 6–9 trawls per transect. These trawls allow hydroacoustic targets to be apportioned by species and size/age groups. Thus, the survey estimates relative densities for each species group. Vessel limitations require four to five nights of good weather (waves < 1.0 m). Given the survey length and short temporal window, the full eight-transect survey was completed only once between 2004–2019.

- The West Basin hydroacoustic survey began in 2005 and is conducted solely by ODNR. While midwater trawls were originally planned, none have been accomplished to date; therefore, the West Basin survey cannot apportion by species and only generates a combined estimate of relative forage density and biomass. The survey design calls for three cross-basin transects a year, totaling 143 km. Due to vessel limitations, the full survey requires three nights of good weather (waves < 0.4 m and wind direction parallel to transect direction). Given these strict requirements, the full survey was completed in only 8 of 13 years (2005–2019), with no midwater trawling.

The current survey designs (e.g., spatially intensive, cross-basin transects) and strict operating requirements (e.g., narrow temporal window and optimal weather conditions) have routinely inhibited full survey completion in all basins. Cross-basin transects were initially chosen to provide a basin-wide estimate of forage fish abundance in the absence of prior data on species composition and relative distributions. However, with existing data from hydroacoustic and trawl (coupled and supplemental) surveys, we can now assess efficiency of the current survey designs, and to support the design and evaluation of an alternative survey that limits logistical challenges, promotes survey completion, and produces rigorous forage fish abundance estimates. In this summary report we:

1. Evaluate the hydroacoustic sampling efficiency (West, Central, and East Basins) using historic hydroacoustic density estimates
2. Develop sampling strata (West and Central) using coupled and supplemental trawl and environmental data
3. Propose a survey design that balances logistical constraints and desired survey outcomes (e.g., ability to complete and achieve target accuracy/precision)
    - Initial evaluation of alternative survey

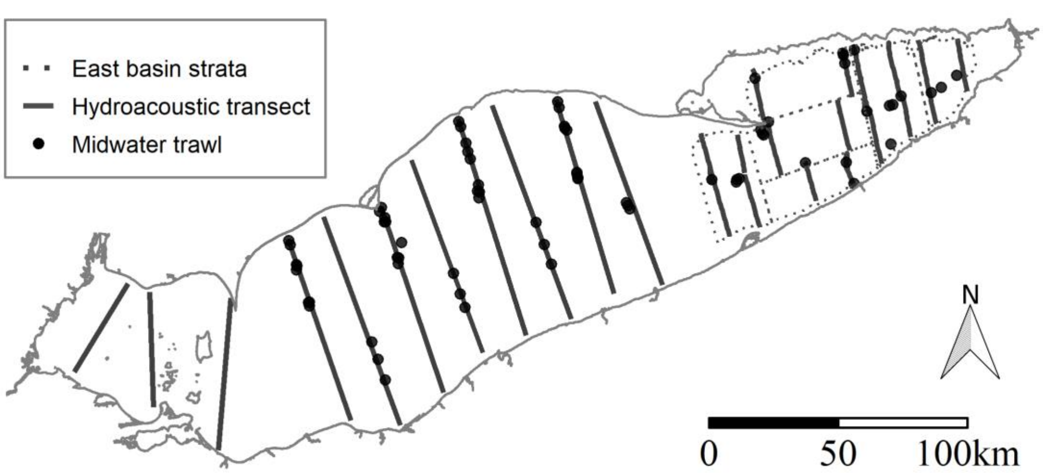

Figure 1: Lake Erie hydroacoustic survey designs (through 2019) including cross basin hydroacoustic transects (West and Central Basins; gray lines) and coupled trawl surveys (Central and East Basins; black dots). The East Basin allocates random transects to six sampling strata and intermittently performs coupled trawling.

Evaluating hydroacoustic sampling efficiency

Guiding question - Can we reduce hydroacoustic sampling effort without compromising density estimate precision?

In each basin, we evaluated the efficiency of current hydroacoustic sampling designs using a resampling analysis (Levine and De Robertis 2019) over a range of years to inform future effort in each basin. Each survey partitions cross-basin hydroacoustic transects into smaller elementary distance sampling units (EDSU) with EDSU lengths varying slightly by basin: 1 km in the West, 0.5 km in the Central, and 0.8 km in the East. Density estimates are calculated by EDSU and depth layer depending on survey location trawl catch composition. Using the historic full-water column density estimates by EDSU in the West and Central basins and the bottom layer density estimates by EDSU in the East basin we calculated the relative standard error (RSE = 100 x SE/mean) in each year with respect to reduced survey effort (i.e., fewer sampled EDSU). We established a precision threshold of <= 15% RSE change for considering reduced sampling effort (Hardin and Conner 1992, Dumont and Schlechte 2004).

West Basin - The historic survey design prescribes 143 km of cross-basin transects which generates 143 1-km EDSU if the full survey is completed. Our efficiency analysis suggested that we were over sampling the West Basin; a mild reduction in effort (143 to 100 km) would produce future density estimates with precision similar (< 15% RSE) to historical estimates (Figure 2). *Central Basin* - The historic survey design prescribes 643 km of cross-basin transects which generates 1286 0.5-km EDSU if the full survey is completed. Our efficiency analysis suggested that we were substantially oversampling the Central Basin, and that a large reduction in effort (643 to 100 km) would conservatively produce future density estimates with precision similar (< 15% RSE) to historic estimates (Figure 2).

East Basin - The current survey prescribes approximately 350 km of cross-basin transects to complete the entire survey with annual variation due to randomized transects. This generates over 430 0.8-km EDSU when the full transects can be completed. Our preliminary analysis suggested that a reduction to 240 km would achieve a survey RSE <15% (Figure 2). At this time, the analysis has not considered how differences across strata may affect future allocation of effort within each stratum.

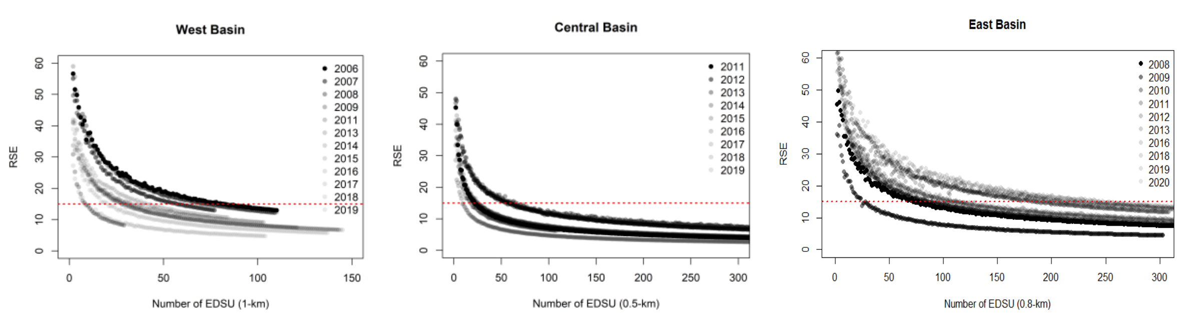

Figure 2: The relationship between reduced sampling effort (number of EDSU) and density estimate precision (RSE) across sampling years (2006-2019 as available) and basins (West, Central, and East). The red dashed lines indicate our precision threshold (15% RSE).

Defining sampling strata

Guiding question - Can we identify homogenous sampling strata within basins, based on physical and biological criteria, to guide future sampling effort allocation?

West Basin – Sample strata, referred to as water masses, were delineated in the late 1990's using abiotic data (e.g., surface and bottom water temperature, bottom dissolved oxygen, Secchi depth, and water depth) from the West Basin Interagency Bottom Trawl Survey and a multivariate statistical analysis (pers. comm., Stuart Ludsin, Ohio State University, Figure 3a). These strata hold consistently unique characteristics influenced by adjacent tributary inputs (e.g., Detroit, Maumee, and Sandusky rivers) or represent dynamic mixing zones as water masses transition to the Central Basin. Moving forward, we used the Interagency Bottom Trawl Survey catch data (2006-2019) and a multinomial regression to explore the uniqueness of species composition associated with these strata. As expected, the western basin trawl catches were dominated by spiny-rayed fishes (e.g., Yellow Perch, Walleye, White Perch, and White Bass); therefore, we removed these species from the analysis. Among forage species, there appeared to be higher proportions of Gizzard Shad along the South shore and higher proportions of Emerald Shiner and other soft-rayed fishes along the North shore, with variation among strata (Figure 3b). As such, further refinement of these strata is warranted to inform hydroacoustic effort allocation. Specifically, collection of midwater trawling, which more adequately samples target species (e.g., Gizzard Shad and Emerald Shiner) compared to bottom trawling, is a critical need to refine the West Basin survey.

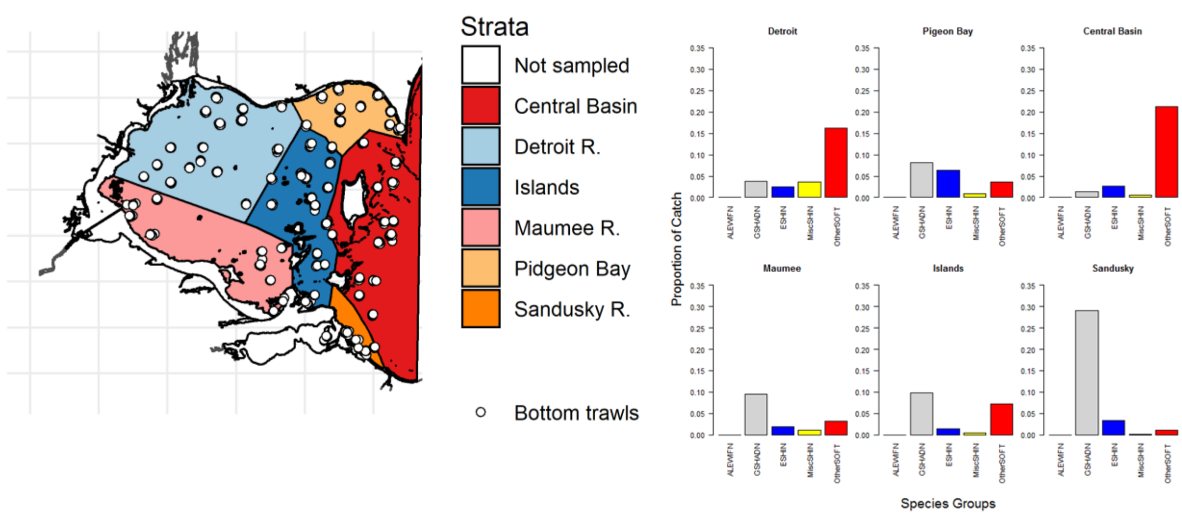

Figure 3: West Basin strata, bottom trawl samples (white dots), and associated community composition of forage fishes (bar graphs).

Central Basin – We used previous studies on environmental gradients and midwater trawl data, those coupled with hydroacoustic transects, to develop Central Basin sampling strata. Beletsky et al. (1999 and 2013) identified circulation and thermal patterns during summer in the Central Basin, where distinct water masses and thermal conditions formed to the West and East of Rondeau Bay, Ontario. Using a multinomial regression and midwater trawl catches we confirmed changes in the fish community associated with these East and West strata, as the proportion of age-0 Rainbow Smelt declined while the proportion of age-1+ Rainbow Smelt increased in the East. Additionally, we explored inshore to offshore gradients in the fish community and found that the proportion of Emerald Shiner was higher inshore; < 20 m in the West and East. To help distribute sampling effort among agency partners, we also partitioned strata using the international boundary. As such, we partitioned the Central Basin into eight sampling strata (Figure 4) including Northwest-shallow (NWS: 7% of the basin), Northwest-deep (NWD: 13%), Southwest-deep (SWD: 14%), Southwest-shallow (SWS: 9%), Northeast-shallow (NES: 9%), Northeast-deep (NED: 20%), Southeast-deep (SED: 24%), and Southeast-shallow (SES: 5%).

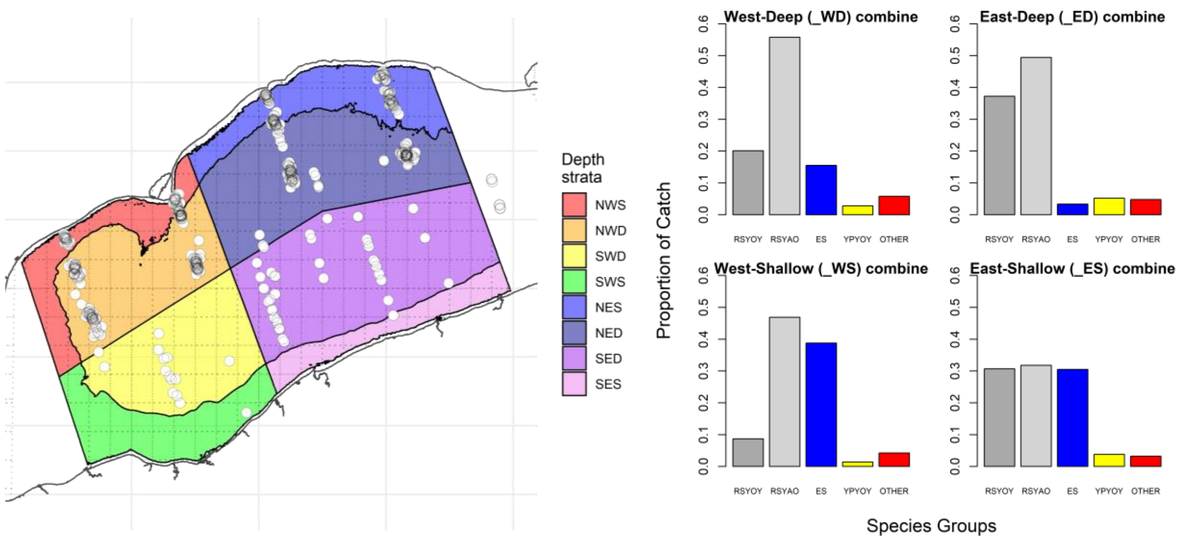

Figure 4: Central Basin strata, midwater trawl samples (white dots)(left), and associated community composition of forage fishes (right). North (N__) and South (S__) components of strata are combined in the community composition plots.

East Basin – East Basin strata were developed based on depth, dividing up the East Basin into approximately equally-sized subunits. The basin was first divided into five approximately equal areas based on north-south lines using Loran-C 9960-Z radio navigation lines (predating modern GPS units). The two middle areas were combined and then split along east-west lines (Strata 2; Figure 5). These strata were defined with a focus on the 25-40 m depth contours where the highest Rainbow Smelt catches had occurred in previous July surveys. This depth-stratified design was recommended by M. Elizabeth Conners (Cornell Biometrics Unit, letter to Don Einhouse, NYDEC, May 29, 1998). Prior to 1998, transects were selected in a “purposeful” design where the lead biologist would select transects to provide a “representative” sample.

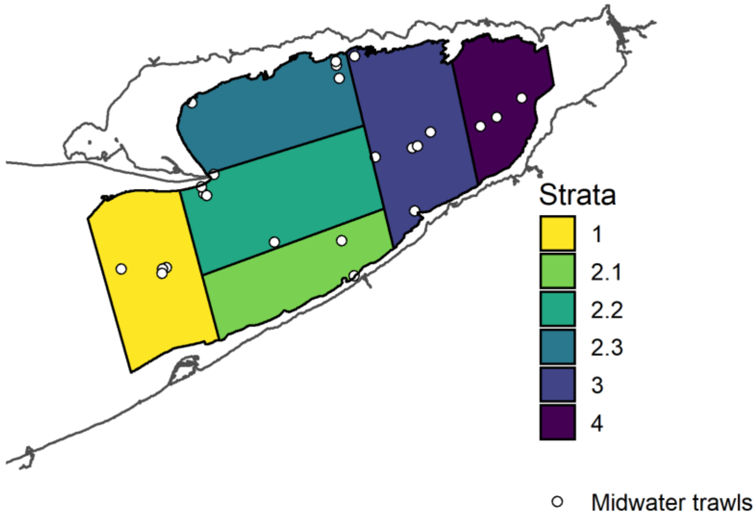

Figure 5: East basin strata and example of midwater trawl locations. Transects are randomly selected each year (two per strata). Midwater trawls in 2019, shown here, were allocated across strata and thermal conditions but chosen based on high densities observed on the sounder during the transects.

Proposed survey design - hydroacoustic portion

The preceding analyses suggest that 1) a reduction in hydroacoustic sampling intensity is warranted and will not compromise the precision of future density estimates, and 2) partitioning effort across sampling strata will likely improve species specific density estimates, as community composition is more consistent within strata. In addition to these findings, a future survey must allow for on-water flexibility to adapt to survey conditions (i.e., wind and wave intensity and direction) which will facilitate annual survey completion.

At present, we propose distributing hydroacoustic effort within each basin (100 km in West Basin, 200 km in Central Basin, and 300 km in East Basin) among sampling strata in proportion to strata area. In addition, we propose distributing within strata effort by randomly selecting grids (5-min grids in West, Central, and East basins) and collecting short transects (5 km) that intersect the grid centroid (Figure 6). The specific grids and transect start location and direction can be predetermined and/or established/adjusted on water, allowing flexibility to adapt to variable wind and wave conditions. All other collection settings and criteria remain the same, as described in the Standard Operating Procedures for Fisheries Acoustic Surveys in the Great Lakes (Parker-Stetter et al. 2009) and survey specific protocols.

This proposed survey design has multiple advantages in that it will reduce the amount of collected hydroacoustic data, improve species specific density estimates, and provide logistical flexibility to aid survey completion. However, survey specifics (e.g., hydroacoustic effort and trawling allocations) will require continued evaluation.

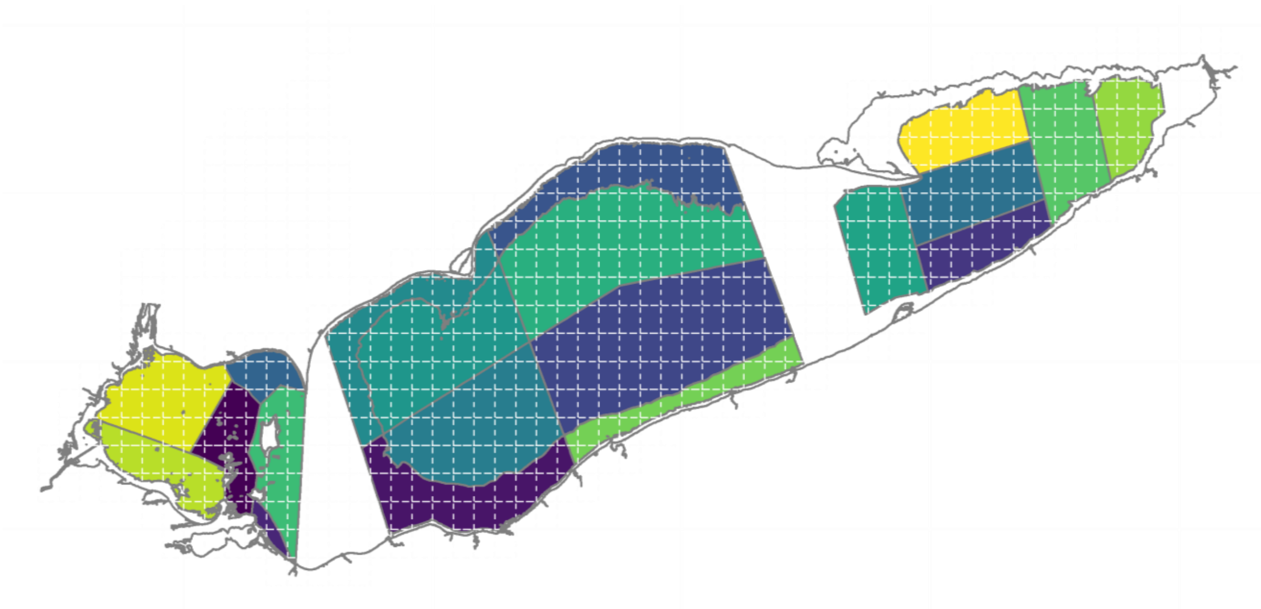

Figure 6: Proposed Lake Erie hydroacoustic survey design using random 5-minute grids proportionally distributed among sampling strata relative to total survey area, by basin.

Initial evaluation of the proposed survey design

The 2020 survey season provided an opportunity to compare the current and proposed survey designs. Due to Covid-19 restrictions, such as reallocation of sampling resources and international border closures, we were unable to complete the surveys as currently designed. As such, we carried out preliminary trials using the proposed survey design.

West Basin – We implemented the proposed, random-grid survey design in U.S. waters July 2020 and U.S. and Canadian waters July 2021 (Figure 7), which allowed us to test out the logistic flexibility. Prior to on-water collection, we randomly determined sample grids distributed in proportion to strata areas. Two nights were required to accomplish 12 5-km transects in 2020 and three nights were required to accomplish 18 5-km transects in 2021 (one transect not displayed). Transect orientation was determined based on the prevailing wind directions throughout the night. In addition, during rougher than expected conditions on the second night of 2020, we changed one sample grid to a less exposed grid (closer to the windward shore) for safety and data quality reasons. One additional benefit to this survey design was that both vessel captain and acoustician were more mentally engaged/aware throughout the night as shorter transects (~40 min) interspersed with running time between transects broke up the monotony of long (4.5–6 hrs) cross-lake transects.

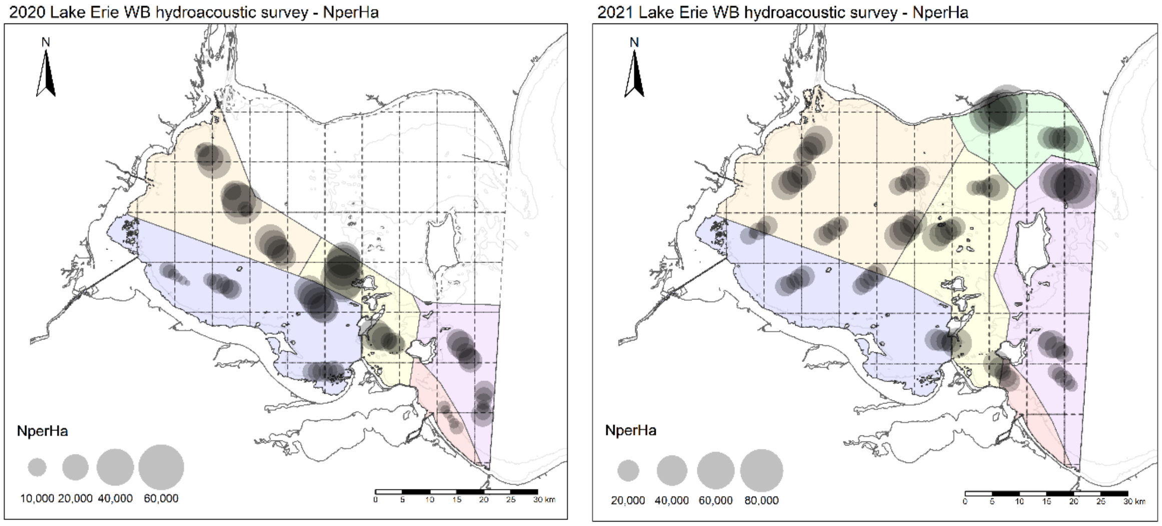

Figure 7: West Basin hydroacoustic density estimates using the proposed survey design in US waters during July 2020 and the basin-wide survey in 2021.

Central Basin - We implemented the alternative survey and collected data from historic cross-basin transects in U.S. waters during 2020 and the eastern part of U.S. and Canadian waters during 2021 (Figure 8). These efforts allowed us to directly compare the two survey types (cross-basin vs. random-grid transects) within strata. Within strata, we compared total water column densities, using EDSU as the sample unit, between survey types. All EDSU-specific densities were log-transformed prior to analysis; means ±1 standard deviation was plotted for visualization. These preliminary analyses indicate that random-grid transect survey design may provide similar density estimates to the cross-basin transect design.

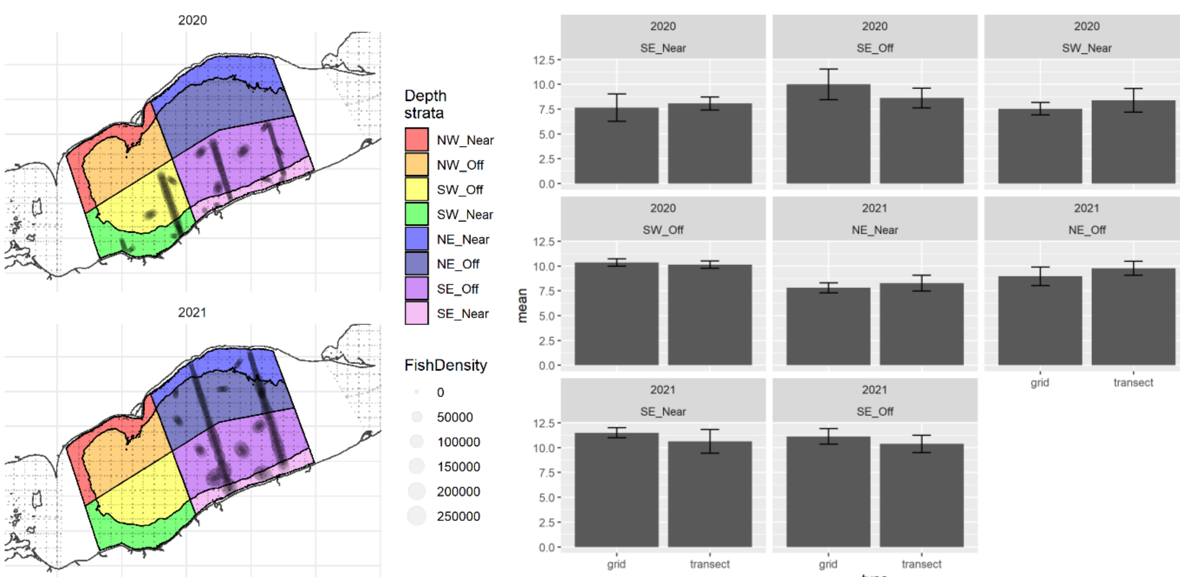

Figure 8: Central Basin hydroacoustic density estimates using random-grid and cross-basin survey designs in July 2020 and July 2021 (maps). Comparison of cross-basin and random-grid mean log-density estimates ±1 standard deviation from both surveys by strata (bar graphs).

East Basin – Survey transects were limited to the Canadian waters of the East Basin in 2020, while the full survey area was sampled in 2021 (Figure 9). In effect, nearly the entire historic cross-strata survey was conducted (sans Stratum 4) and then replicated using the random-grid design in 2021. Cross-strata transects followed the standard north-south orientation along a TD line whereas random transects had variable headings to account for wind and direction of travel to the next transect. Only the cold-water layer was considered in the analysis and fish density was based on the survey thresholds for age-1+ Rainbow Smelt. Data were transformed (natural log) to meet assumptions of linear models. These preliminary analyses indicate that random-grid transect survey design may provide similar density estimates to the cross-strata transect design.

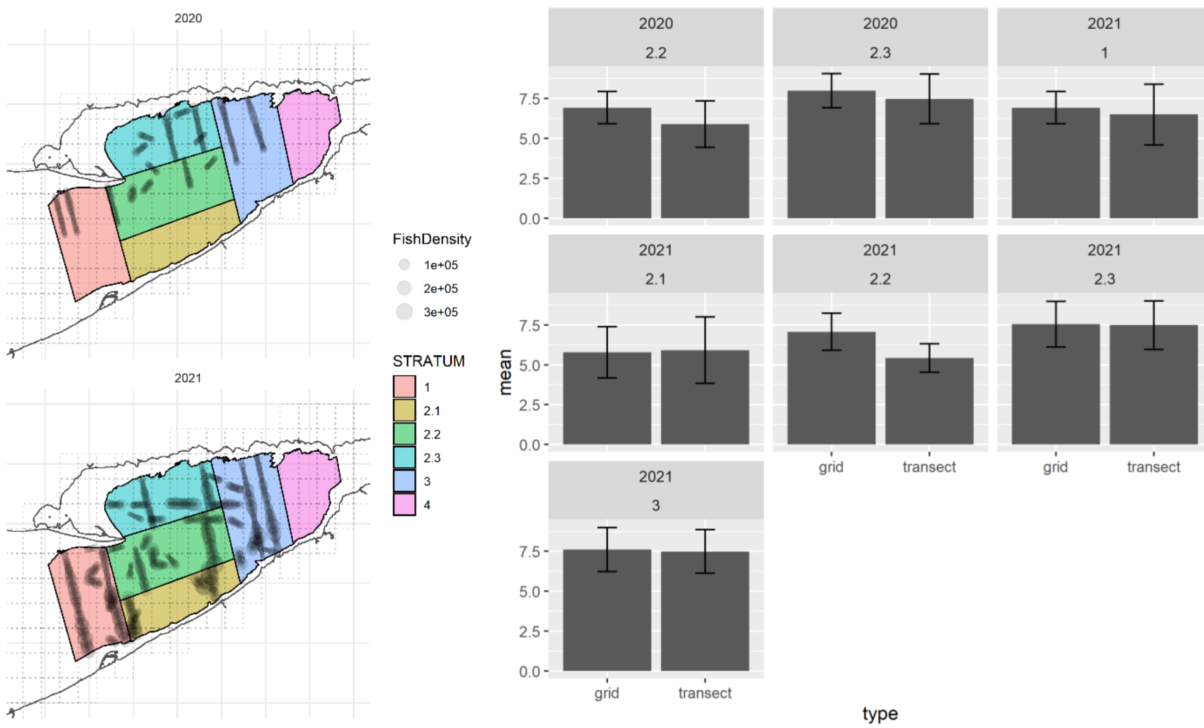

Figure 9: East Basin hydroacoustic density estimates using random-grid and cross-strata survey designs in July 2020 and July 2021 (maps). Comparison of cross-strata and random-grid mean log-density estimates ±1 standard deviation from both surveys by strata (bar graphs).

Next steps

The hydroacoustic survey redesign team will finalize this report after running statistical analyses in Spring 2022. Following that, we will ask for review and feedback from other members of the Great Lakes hydroacoustic community. Upon receiving feedback and discussion among this group, we will implement a final survey design in Summer 2022. The final survey design will balance the cost/benefits of completing the survey (cross-basin transects) and accuracy/precision of pelagic forage fish density estimates.

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