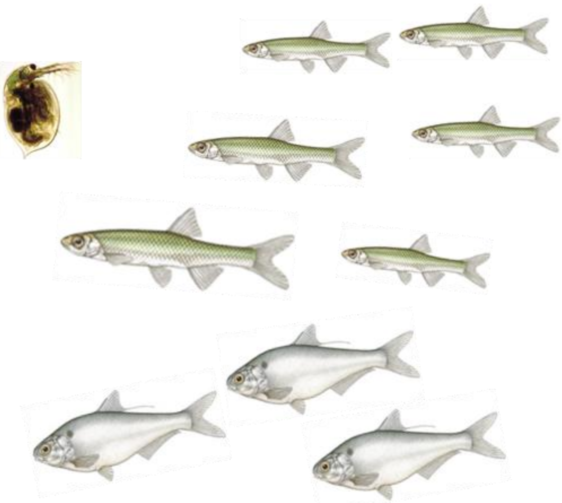
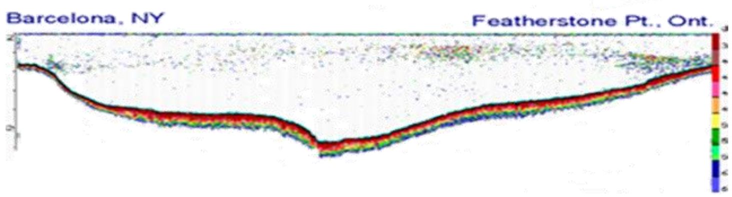
Report of the
Lake Erie
Forage Task Group

March 2017





Members:

Zy Biesinger - United States Fish and Wildlife Service, (USFWS) {Co-Chair}
Geoff Steinhart - Ohio Department of Natural Resources, (ODNR) {Co-Chair}
Mark Clapsadl - The State University of New York, (SUNY- Buffalo State College)
John Deller - Ohio Department of Natural Resources, (ODNR)
Andrew Briggs - United States Fish and Wildlife Service, (USFWS)
Jan-Michael Hessenauer - Michigan Department of Natural Resources, (MDNR)
Mike Hosack - Pennsylvania Fish and Boat Commission, (PFBC)
Patrick Kočovský - United States Geological Survey - Great Lakes Science Center (USGS)
Tom MacDougall - Ontario Ministry of Natural Resources and Forestry, (OMNRF)
Jim Markham - New York Department of Environmental Conservation, (NYSDEC)
David Marson - Fisheries and Oceans Canada, (DFO)
Paulette Penton - Ontario Ministry of Natural Resources and Forestry, (OMNRF)
Eric Weimer - Ohio Department of Natural Resources, (ODNR)

Presented to:

Standing Technical Committee
Lake Erie Committee
Great Lakes Fishery Commission

Charges to the Forage Task Group 2016-2017

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 Goals and Objectives.

2. Describe the status and trends of forage fish in each basin of Lake Erie.

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 Hydroacoustic Standard Operating Procedures where possible/feasible.

4. Report on the use of forage fish and new invasive species in the diets of selected commercially or recreationally important Lake Erie predator fish.

5. Develop and maintain a database to track new or emerging Aquatic Invasive Species in Lake Erie that exhibit the potential to directly impact economically important fisheries.

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

(J. Markham, T. MacDougall, Z. Biesinger)

In 1999, the 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 and 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 two dates, once in the spring and once in the fall. For this report, we will summarize the last 18 years of data for summer surface temperature, summer bottom dissolved oxygen, chlorophyll *a* concentrations, zooplankton, water transparency and total phosphorus. Stations were only included in the analysis if there were at least 3 years each containing 6 or more sampling dates. Stations included in this analysis are stations 3, 4, 5 and 6 from the west basin, stations 7, 8, 9, 10, 11, 12, 13 and 14 from the central basin, and stations 15, 16, 17, 18, 19, 20 and 25 from the east basin (Figure 1.0.1). Station 25 (located off Sturgeon Point in 19.5 meters of water) was added in 2009.

The fish community objectives (FCO) for the lower trophic level ecosystem in Lake Erie are to maintain mesotrophic conditions that favor percids in the west, central and nearshore waters of the east basin, and oligotrophic conditions that favor salmonids in the offshore waters of the east basin (Ryan et al. 2003). Associated with these trophic classes are target ranges for total phosphorus, water transparency, and chlorophyll *a* (Table 1.0.1). For mesotrophic conditions, the total phosphorus range is 9-18 μg/L, summer (June-August) water transparency is 3-6 meters, and chlorophyll *a* concentrations between 2.5-5.0 μg/L (Leach et al. 1977). For the offshore waters of the east basin, the target ranges for total phosphorus are < 9 μg/L, summer water transparency of > 6 m, and chlorophyll *a* concentrations of < 2.5 μg/L.

Mean Summer Surface Water Temperature

Summer surface water temperature represents the temperature of the water at 0-1 meters depth for offshore stations only. This index should provide a good measure of relative system production and growth rate potential for fishes, assuming prey resources are not limiting. Mean summer surface temperatures across all years are warmest in the west basin (mean=23.4 °C), becoming progressively cooler in the central (mean = 21.9 °C) and east basins (mean = 20.5 °C) (Figure 1.0.2). Annual means range from 21.6 °C (2009) to 25.2 °C (2006) in the west basin, 20.5 °C (2009) to 24.1°C (2012) in the central basin, and 18.5 °C (2003) to 22.4 °C (2005) in the east basin. Above series-mean temperatures were evident across all basins in 2005, 2006, 2010, 2011 and 2012; below mean temperatures occurred in 2000, 2003, 2004, 2008, and 2009. A slightly increasing trend in summer surface water temperature is evident for all basins in this 18 year time series (Figure 1.0.2). In 2016, the mean summer surface water temperature was above the series-mean in all three basins (west: 25.1 °C; central: 23.8°C; east: 21.0 °C). This was the second highest mean in the time series in the west basin, the highest in the central basin, and seventh highest in the east basin

Hypolimnetic Dissolved Oxygen

Dissolved oxygen (DO) levels less than 2.0 mg/L are deemed stressful to fish and other aquatic biota (Craig 2012; Eby and Crowder 2002). Low DO can occur when the water column becomes stratified, which can begin in early June and continue through September in the central and east basins. In the west basin, shallow depths allow wind mixing to penetrate to the bottom, generally preventing thermal stratification. Consequently, there are only a few summer observations that detect low bottom DO concentrations in the time series (Figure 1.0.3). In 2016, there were no observations from the west basin stations of DO below the 2.0 mg/L threshold.

Low DO is more of an issue in the central basin, where it happens almost annually at the offshore stations (8, 10, 11 and 13) and occasionally at inshore stations. Dissolved oxygen of less than 2.0 mg/L has been observed as early as mid-June and can persist until late September when fall turnover remixes the water column. In 2016, bottom DO was below the 2.0 mg/L threshold in the central basin on five occasions (Station 10 on 7/27/16 (0.12 mg/L) and 8/25/2016 (0.94 mg/L); Station 8 on 7/28/16 (0.77 mg/L), 8/7/16 (0.96 mg/L) and 8/23/16 (0.10 mg/L)) (Figure 1.0.3). There were also three other occasions where bottom DO was just above the 2.0 mg/L threshold.

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 at Station 25 (Figure 1.0.3). No DO concentrations of less than 6.0 mg/L were recorded in the east basin in 2016.

Chlorophyll *a*

Chlorophyll *a* concentrations indicate biomass of the phytoplankton resource, ultimately representing production at the lowest level. In the west basin, mean chlorophyll *a* concentrations have mainly been above targeted levels in the 18 year time series, fitting into eutrophic status rather than mesotrophic status (Figure 1.0.4). Annual variability is also the highest in the west basin. In 2016, the mean chlorophyll *a* concentration was 5.5 µg/L in the west basin, which was slightly 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, and that trend continued in 2016 (3.6 µg/L) (Figure 1.0.4). In the east basin, chlorophyll *a* concentrations in the nearshore waters have been below the targeted mesotrophic level for the entire time series (Figure 1.0.4). Conversely, chlorophyll *a* levels in the offshore waters of the east basin remain in, or slightly above, the targeted oligotrophic range. In 2016, the mean chlorophyll *a* concentrations were 1.8 µg/L in the nearshore waters of the east basin and 1.9 µg/L in the offshore waters. Chlorophyll *a* concentrations are 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 (Figure 1.0.5). In 2016, total phosphorus concentrations in the west basin decreased to 22.9 µg/L but remained above targets and in the eutrophic range. In the central basin, total phosphorus levels had exceeded FCO targets from 2006 through 2013, but have been declining in recent years (Figure 1.0.5). Total phosphorus measures in the central basin in 2016 were 26.7 µg/L, which was an increase compared to both 2014 and 2015 values and above the desired mesotrophic range. The value was heavily influenced by one exceptionally high value (671 µg/L) recorded on 28 July at Station 7 off the mouth of the Vermillion River. Total phosphorus readings without this value are lower (18.2 µg/L) and near readings for the previous two years. In the nearshore waters of the east basin, total phosphorus levels have remained stable and within the targeted mesotrophic range for nearly the entire time series (Figure 1.0.5). A gradual increasing trend was evident from 2006 through 2010, but a declining trend has been evident since 2010. 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 2016, mean total phosphorus concentrations in the east basin decreased slightly again in the nearshore waters to 6.7 µg/L, which was below the targeted mesotrophic range for the third consecutive year. Phosphorus measures in the offshore waters of the east basin decreased in 2016 to 6.3 µg/L and remained in the targeted oligotrophic range for the third consecutive year.

Water Transparency

Similar to other fish community ecosystem targets (i.e. chlorophyll *a*, total phosphorus), water transparency has been in the eutrophic range, which is below the FCO target in the west basin, for the entire time series (Figure 1.0.6). Mean summer Secchi depth in the west basin was 2.6 m in 2016, which was the highest transparency since 2008. In contrast, water transparency in the central basin has remained within the targeted mesotrophic range for the entire series with the exception of 2015 (2.9 m), which was slightly below the mesotrophic target range (Figure 1.0.6). In 2016, water transparency increased to 5.4 m, which was once again the mesotrophic target range and was the highest mean Secchi depth in 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, but was stable and within the FCO targets for the next nine years (Figure 1.0.6). However, water transparency increased in 2016 to 6.4 m, which was once again in the oligotrophic range. In the offshore waters of the east basin, water transparency was within the oligotrophic target from 1999 through 2007, decreased into the mesotrophic range in five of the next six years, then increased thereafter. In 2016, mean summer Secchi depth was 7.5 m in the offshore waters, which was within the targeted oligotrophic range. Mean summer Secchi depths have been steadily increasing in both areas since 2008.

Zooplanktivory Biomass

Zooplankton biomass varies among basins and years. In the west basin, the 2016 mean biomass was 191.9 mg/m^3, which was the second highest value in the time series and well above the long term average of 98.9 mg/m^3 (Figure 1.0.7). Cladocerans provide the bulk of the biomass of zooplankton in the west basin. However, increases in both calanoid and cyclopoid copepods were also observed in both 2015 and 2016. In the central basin, mean zooplankton biomass was 91.7 mg/m^3, which was equal to values from 2014 and 2015 but slightly less than average time-series biomass (132.6 mg/m^3). Copepods have typically been higher in biomass in the central basin compared to the west basin with cladocerans less numerous, but copepod biomass has been conspicuously low for the past three years. East basin zooplankton results are not yet available for 2015 and 2016, but overall zooplankton biomass is traditionally lower in the east basin compared to the central and west basins (Figure 1.0.7). Looking at larger trends, there appeared to be a gradient of high zooplankton biomass in the west and lower biomass in the east from 2000 to 2007. From 2009 through 2013, zooplankton biomass increased in the central and east basins. Since 2014, zooplankton biomass has increased in the west basin and decreased in the central basin. Cladocerans are typically more dominant in the west basin and decline to the east, while calanoid and cyclopoid copepods tend to be higher in biomass in the central and east basins.

Distribution of New Zooplankters

For this review, data from stations 3, 4, 5, 6, 9, 10, 11, 12, 15, 16, 17, 18, 19 and 20 were included. *Bythotrephes longimanus* was first collected in Lake Erie in October 1985 (Bur *et al.* 1986). It is consistently present at central and east basin stations, but is very rare at west basin stations. Densities ranged from 0.001 to 6,370 individuals/m^3 and were generally higher from July through September.

Cercopagis pengoi was first collected in Lake Ontario in 1998, and by 2001 was also collected in the west basin of Lake Erie (Therriault et al. 2002). It first appeared in this sampling effort at station 5 in July 2001 and station 9 in September 2001. In subsequent years it has also been found at stations 5, 6, 9, 10, 15, 16, 17, 18 and 19. Except for the year 2002, when it was collected at 8 stations, *Cercopagis* is seen less frequently around the lake than *Bythotrephes*. Densities ranged from 0.03 to 876 individuals/m^3.

The first record of *Daphnia lumholtzi* in the Great Lakes was in the west basin of Lake Erie in August 1999 (Muzinic 2000). It was first identified in our seasonal sampling effort in August 2001 at stations 5 and 6, and at station 9 by September 2001. *D. lumholtzi* was collected at stations 5 and 6 in 2002, and at stations 5, 6, 8 and 9 in 2004. Data are not available for these stations from 2005 through 2010, but in 2011 *D. lumholtzi* was found at station 5 and 6 with densities of 91 and 83 individuals/m^3, respectively. In 2007, it was found at station 18, the first and only year observed in the east basin; densities ranged from 0.002 to 91 individuals/m^3.

Fish Community Ecosystem Targets

Measures of lower trophic indicators (total phosphorus, transparency, chlorophyll *a*) in 2016 indicate that the west basin is in a eutrophic state. Current conditions favor a centrarchid (bass, sunfish) fish community instead of the targeted percid (Walleye, Yellow Perch) fish community (Table 1.0.2). In the central basin, the lower trophic measures in 2016 continue to mainly fall within the targeted mesotrophic range preferred by percids. Central basin phosphorus readings were higher than the mesotrophic target range in 2016, but this was mainly due to one extremely high value at the Vermillion River sampling site. In the east basin, 2016 measures of total phosphorus, chlorophyll *a*, and transparency indicate an oligotrophic state for both the nearshore and offshore waters. The nearshore waters are less productive than the targeted mesotrophic range, but the offshore waters are within the targeted oligotrophic range favored by salmonids. In general, recent trophic measure trends across Lake Erie indicate that productivity appears to be slowly declining.

Table 1.0.1. Ranges of selected lower trophic indicators for each trophic class and associated fish community (Leach et al. 1977; Ryder and Kerr 1978).

Trophic Class	Phosphorus (µg/L)	Chlorophyll a (µg/L)	Transparency (m)	Harmonic Fish Community
Oligotrophic	<9	<2.5	>6	Salmonids
Mesotrophic	9 - 18	2.5 - 5.0	3 - 6	Percids
Eutrophic	18 - 50	5.0 - 15	1 - 3	Centrarchids
Hyper-eutrophic	>50	>15	<1	Cyprinids

Table 1.0.2. Measures of key lower trophic indicators and current trophic class, by basin, from Lake Erie, 2016. The east basin is separated into nearshore and offshore.

Basin	Phosphorus (µg/L)	Chlorophyll a (µg/L)	Transparency (m)	2016 Status	Target Status
West	22.9	5.5	2.6	Eutrophic	Mesotrophic
Central	26.7	3.6	5.4	Mesotrophic	Mesotrophic
East - Nearshore	6.7	1.8	6.4	Oligotrophic	Mesotrophic
East - Offshore	6.3	1.9	7.5	Oligotrophic	Oligotrophic

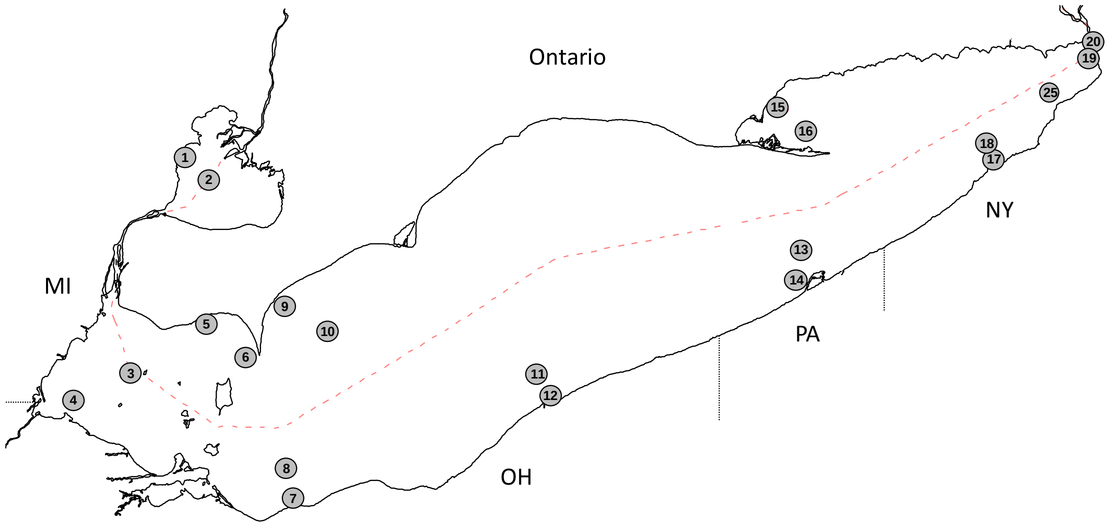


Figure 1.0.1. Lower trophic level sampling stations in Lake Erie and Lake St. Clair. Station 25 was added in 2009. Lake St. Clair stations were last sampled in 2005.

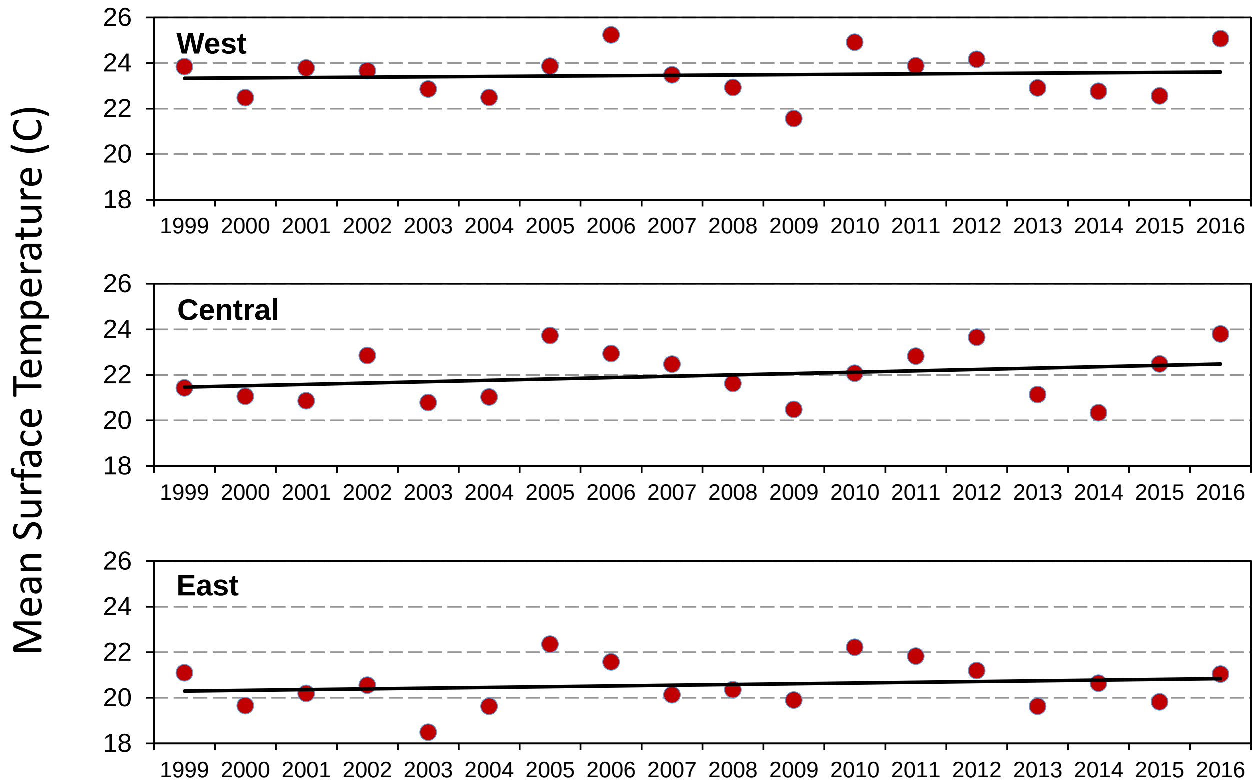


Figure 1.0.2. Mean summer (June-August) surface water temperature (°C) at offshore stations, weighted by month, by basin in Lake Erie, 1999-2016. Solid black lines represent time series trends. Data included in this analysis by basin and station: West – 3, 6; Central – 8, 10, 11, 13; East – 16, 18, 19, 25.

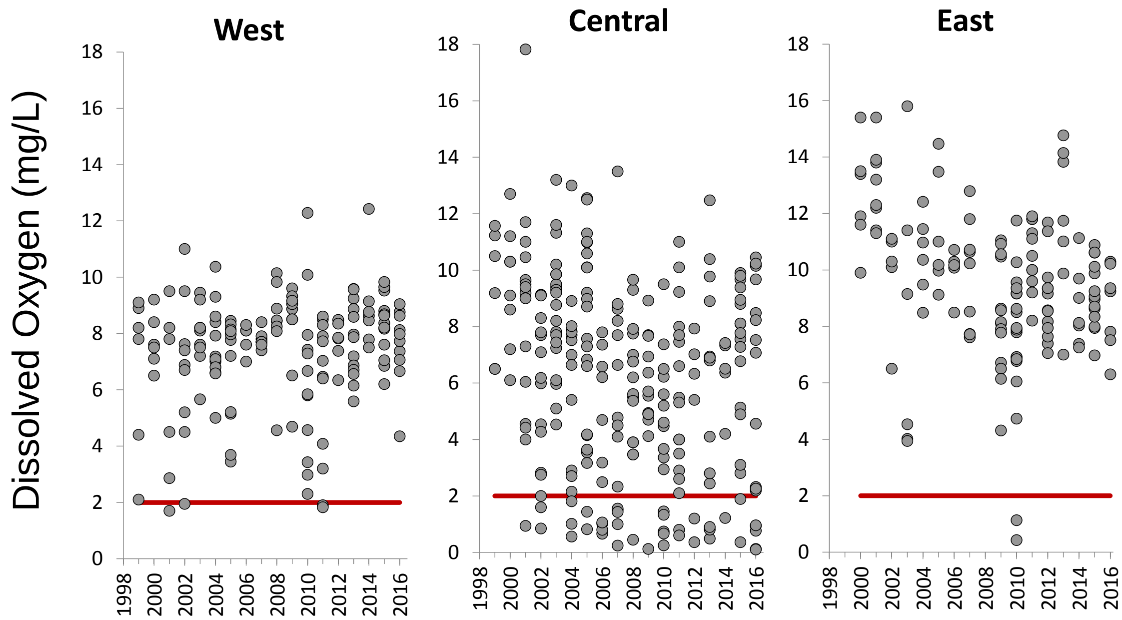


Figure 1.0.3. Summer (June-August) bottom dissolved oxygen (mg/L) concentrations for offshore sites by basin in Lake Erie, 1999-2016. The red horizontal line represents 2 mg/L, a level below which oxygen becomes limiting to the distribution of many temperate freshwater fishes. Data included in this analysis by basin and station: West – 3, 6; Central – 8, 10, 11, 13; East – 16, 18, 19, 25.

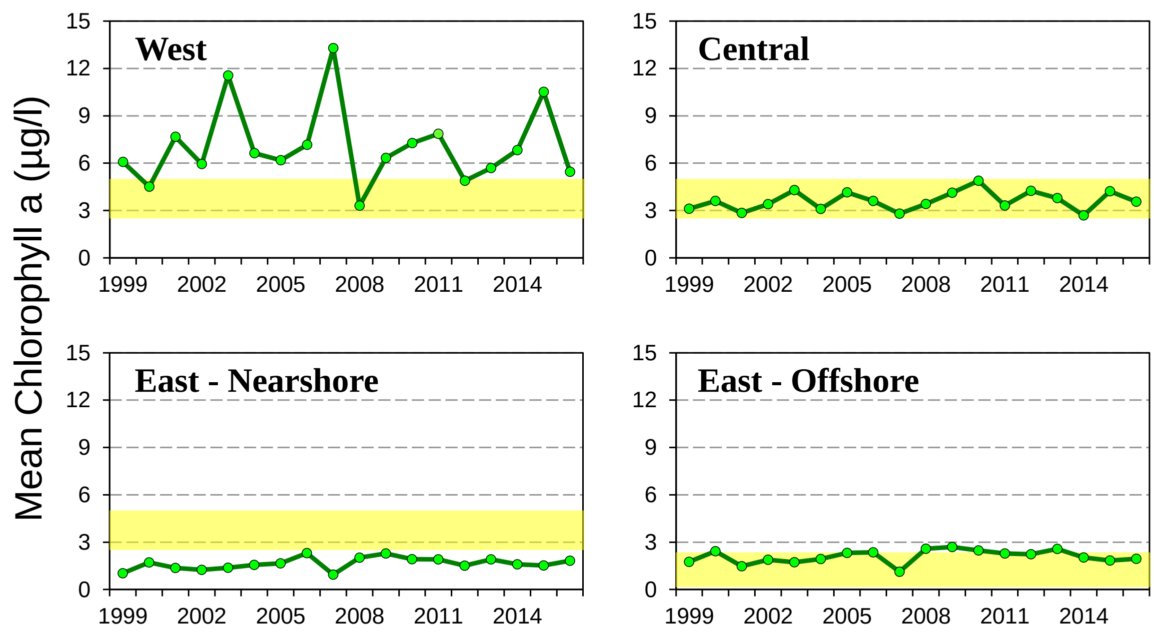


Figure 1.0.4. Mean chlorophyll *a* concentration (µg/L), weighted by month and basin in Lake Erie, 1999-2016. The east basin is separated into nearshore and offshore. Yellow shaded areas represent targeted trophic class range. For this analysis data from stations 3 through 20, and 25 were included.

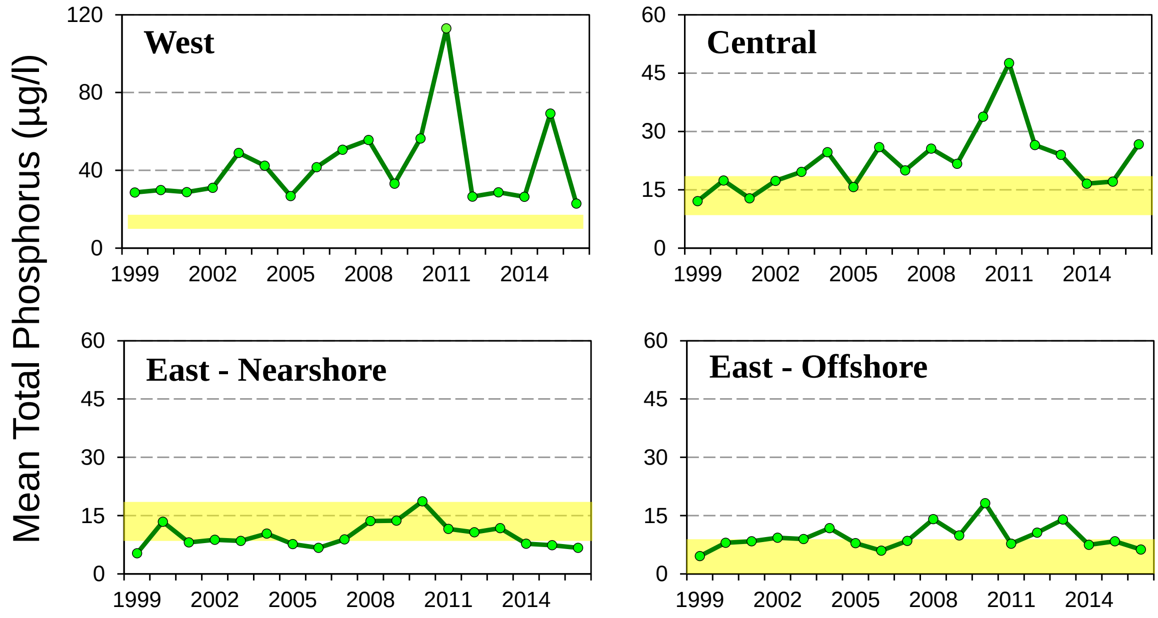


Figure 1.0.5. Mean total phosphorus (µg/L), weighted by month, for offshore sites by basin in Lake Erie, 1999-2016. The east basin is separated into nearshore and offshore. Yellow shaded areas represent the targeted trophic class range. For this analysis data from stations 3 through 20, and 25 were included.

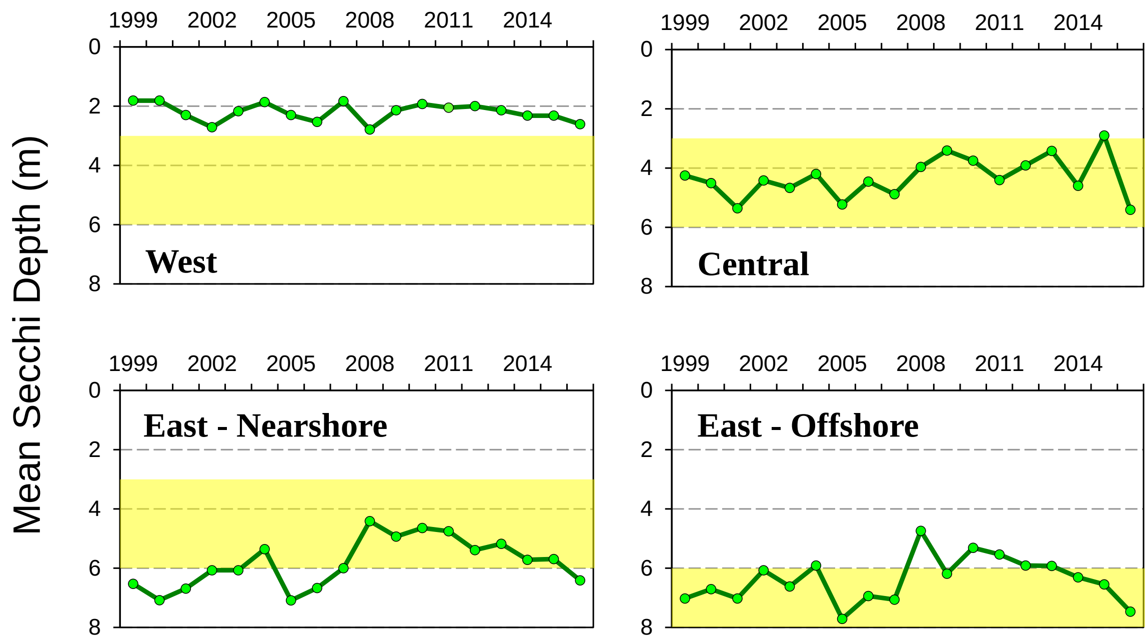


Figure 1.0.6. Mean summer (June-August) Secchi depth (m), weighted by month, by basin in Lake Erie, 1999-2016. The east basin is separated into inshore and offshore. Yellow shaded areas represent the targeted trophic class range. For this analysis data from stations 3 through 20, and 25 were included.

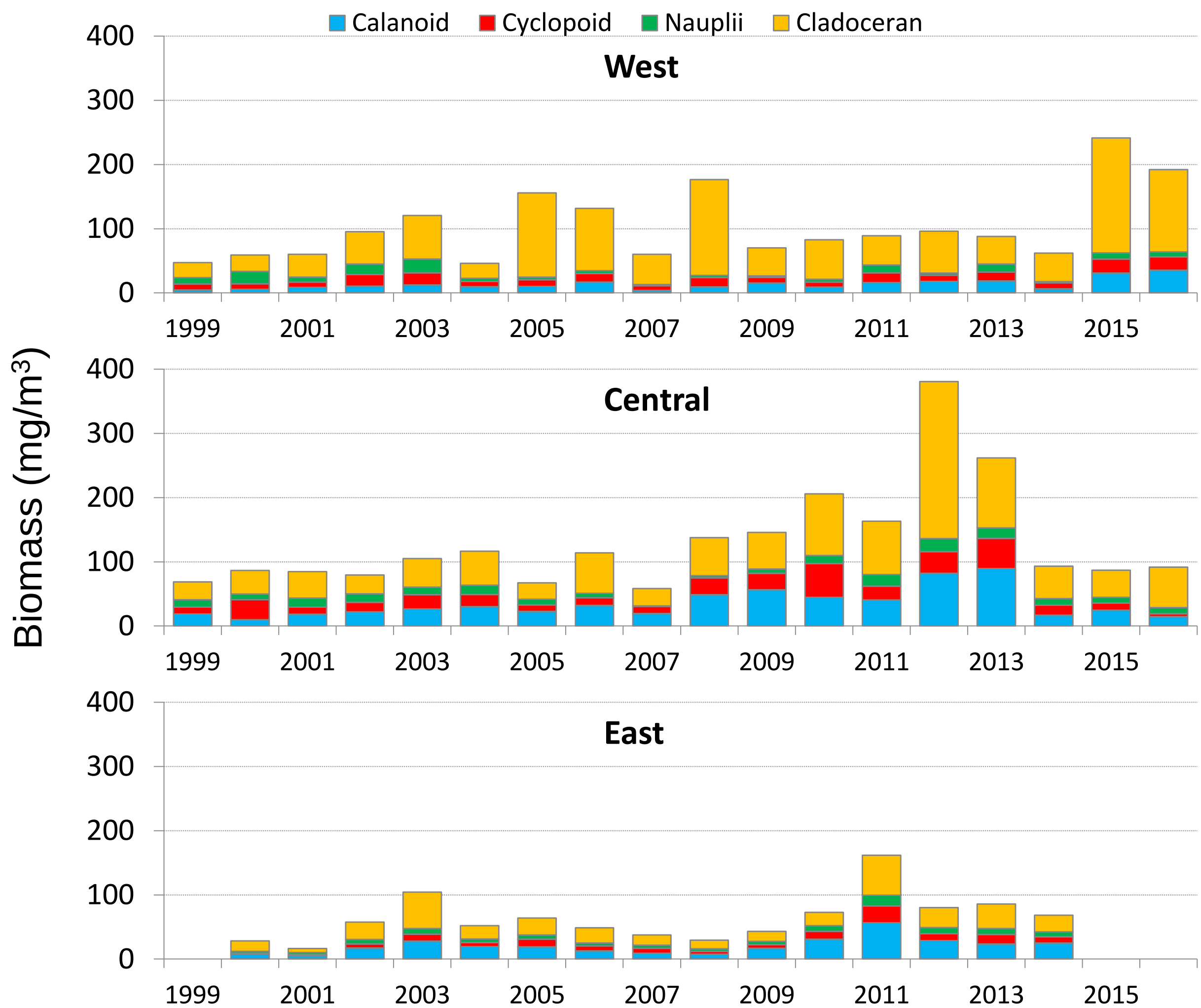


Figure 1.0.7. Mean zooplankton biomass (mg/m^3) by major taxonomic group by basin, 1999 through 2016. There is no data for 1999, 2015, and 2016 in the east basin. West basin includes stations 3 through 6, central basin stations 7 through 14, and east basin stations 15 through 20. Data excludes rotifers and veligers. Harpacticoid zooplankton comprise a miniscule biomass for most years and are not included in the graph.

Charge 2: Describe the status and trends of forage fish in each basin of Lake Erie.

2.1 Synopsis of 2016 Forage Status and Trends

Eastern Basin

- Total forage fish abundance in 2016 decreased in Ontario and Pennsylvania, and increased in New York
- Young-of-the-year (age-0) Rainbow Smelt density was above the long-term mean (10-year) in New York, and below long-term means in Ontario and Pennsylvania
- Yearling-and-older (age-1+) Rainbow Smelt density was below long-term means in all three east basin jurisdictions
- Spiny-rayed fish were a dominant component of the catches in Ontario and New York
- Young-of-the-year Emerald Shiner density decreased and were below long-term means basin wide
- Gizzard Shad indices generally declined and were below long-term means
- Round Goby densities decreased in New York, increased in Pennsylvania and remained the same in Ontario

Central Basin

- In Pennsylvania, overall forage abundance increased from 2015 due to a large age-0 Rainbow Smelt cohort
- In 2016, overall forage abundance in Ohio waters declined from 2015 and has been declining since 2012
- Young-of-the-year Yellow Perch abundance in Pennsylvania is above the long-term mean
- Young-of-the-year Rainbow Smelt abundance increased in Pennsylvania and eastern Ohio
- Yearling-and-older Rainbow Smelt densities decreased in Pennsylvania and Ohio and were some of the lowest indices in the time series
- Young-of-the-year and Age-1+ Emerald Shiner densities were almost absent from central basin trawl surveys
- Young-of-the-year and age-1+ Round Goby abundance decreased and was below long-term means in Ohio and Pennsylvania
- Gizzard Shad indices declined from 2015 and were some of the lowest indices in the time series

West Basin

- Forage abundance below average levels
- Young-of-the-year Spottail Shiners well above long-term mean
- Young-of-the-year Gizzard Shad density lowest in the 29 year period
- Young-of-the-year Rainbow Smelt density extremely low
- Young-of-the-year and age-1+ Emerald Shiner indices lowest in the 29 year period
- Young-of-the-year White Perch density increased from 2015 levels; near long-term mean
- Round Goby abundance declined relative to 2015; well below long-term mean
- Young-of-the-year Walleye recruitment declined relative to 2015; below long-term means
- Young-of-the-year Yellow Perch recruitment declined from 2015; remains above long-term mean but below the mean for the time series
- White Bass recruitment increased near long-term mean
- Size of age-0 Yellow Perch, White Perch, White Bass and Smallmouth Bass were larger than average; age-0 Walleye were below long term means

2.2 Eastern Basin (P. Penton, J. Markham and M. Hosack)

Forage fish abundance and distribution is determined primarily from long-term bottom trawl assessments conducted by the basin agencies (also see East Basin Hydroacoustic Survey, Section 4.1). In 2016, a total of 34 trawl tows were sampled across New York waters (NYSDEC; n=25 years), 102 trawl tows in nearshore and offshore Long Point Bay of Ontario (OMNRF; n=36 and 33 years) and 9 trawls in Pennsylvania waters of the East Basin (PFBC; n=27 years) (Figure 2.2.1).

In 2016, forage fish densities decreased in Ontario and Pennsylvania, and increased in New York waters. Rainbow Smelt are the most abundant forage species in most years and jurisdictions and 2016 was no exception (Figure 2.2.2). However, this is primarily age-0 Rainbow Smelt in 2016. Yearling-and-older Rainbow Smelt declined in 2016, with no age-1+ Rainbow Smelt caught in Pennsylvania, and very low densities caught in Ontario and New York. Spiny-rayed fish were a dominant component of the catches in Ontario and New York in 2016, with higher than average densities of White Bass (Ontario only), White Perch and Yellow Perch (Table 2.2.1). For other soft-rayed fishes, age-0 Emerald Shiner densities decreased across all jurisdictions. There were no major changes observed in densities of Spottail Shiners or Trout Perch, both of which remained low in all jurisdictions (Table 2.2.1). Round Goby, an important species in the eastern basin forage fish community since it appeared in the late 1990s, decreased in New York, increased in Pennsylvania and remained the same in Ontario (Table 2.2.1)

2.3 Central Basin (J. Deller and M. Hosack)

Routine bottom trawl surveys in the central basin began in Pennsylvania in 1982 and in Ohio in 1990 to assess age-0 percid and forage fish abundance and distributions. There are no annual trawl surveys in Ontario waters of the central basin. Trawl locations in Pennsylvania range from 13 to 24 m depth and Ohio trawl locations range from 5 to >20 m depth (Figure 2.3.1). 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, PA. In 2016, a total of 60 trawl tows were completed in the central basin, 24 in Ohio East, 24 in Ohio West, and 12 in Pennsylvania.

In 2016, overall forage abundance in Ohio waters declined from 2015 and has been declining since 2012 (Figure 2.3.2). The largest declines were in the clupeid and spiny-rayed forage groups (primarily age-0 White Perch). The Rainbow Smelt forage group increased slightly from 2015, but the increase was not enough to offset the sharp declines in the other forage groups. In Pennsylvania, overall forage abundance increased from 2015 due to a large age-0 Rainbow Smelt cohort. In 2015 and again in 2016, Rainbow Smelt and spiny-rayed groups were the most abundant forage in Pennsylvania (Figure 2.3.3). All forage group density estimates were below the 25-year average in Pennsylvania and Ohio.

Trends in age-0 Rainbow Smelt abundance were not consistent across central basin surveys. Young-of-the-year Rainbow Smelt indices decreased in Ohio waters from 2015, and were below the long-term mean in the west, but increased from 2015 and were above long-term means in eastern Ohio and Pennsylvania (Table 2.3.1). The Pennsylvania index is the second highest in the time series. Yearling-and-older Rainbow Smelt indices decreased from 2015 in Ohio and Pennsylvania, and were some of the lowest indices in the time series (Table 2.3.2).

Emerald Shiners were almost absent from central basin trawl surveys in 2016. Pennsylvania's age-0 index was only 2.2 fish/ha, and no Emerald Shiners were caught in Ohio age-0 surveys (Table 2.3.1). Yearling-and-older indices declined basin wide, and were some of the lowest in the time series (Table 2.3.2).

Round Goby first appeared in central basin trawl surveys in Ohio in 1994 and in Pennsylvania by 1997. Generally, densities of this exotic species have tended to be higher in eastern relative to western areas of the basin (Table 2.3.1; 2.3.2). In 2016, age-0 and age-1+ Round Goby abundance decreased and was below long-term means in Ohio and Pennsylvania.

Young-of-the-year Gizzard Shad patterns were typical of historic patterns in 2016 with higher densities occurring in western areas of the basin compared to the East (Table 2.3.1). Gizzard Shad indices declined from 2015 and were some of the lowest indices in the time series. Trends in Alewife indices were the opposite of Gizzard Shad with the highest indices in Pennsylvania and Ohio east relative to the west. The only index that was above the long-term mean was Pennsylvania.

Since 2005, Yellow Perch cohorts in the central basin have tended to be strongest in the east relative to the west. In 2016, Yellow Perch age-0 indices in Ohio declined from 2015 and were some of the lowest in the time series. In contrast, the age-0 Pennsylvania index was the third highest in the time series and was above the long-term mean (Table 2.3.1). Yearling-and-older indices in both Ohio surveys decreased from 2015 and were below long-term means. The Pennsylvania age-1+ index increased from 2015, but was slightly below the long-term mean (Table 2.3.2).

Indices for age-0 White Perch declined across the basin and were below the long-term mean. Ohio indices were the lowest estimates in the time series (Table 2.3.1). Trends in White Perch age-1+ indices across the central basin were mixed. Ohio indices increased from 2015, but both indices were below the long-term mean. Pennsylvania's age 1+ index declined from 2015 and was below the long-term mean (Table 2.3.2).

2.4 West Basin (E. Weimer)

History

Interagency trawling has been conducted in Ontario and Ohio waters of the western basin of Lake Erie in August of each year since 1987, though missing effort data from 1987 has resulted in the use of only data since 1988. This interagency trawling program was developed to measure basin-wide recruitment of percids, but has been expanded to provide basin-wide community abundance indices. In 1992, the Interagency Index Trawl Group (ITG) recommended that the Forage Task Group (FTG) review its interagency trawling program and develop standardized methods for measuring and reporting basin-wide community indices. Historically, indices from bottom trawls had been reported as relative abundances, precluding the pooling of data among agencies. In 1992, in response to the ITG recommendation, the FTG began the standardization and calibration of trawling procedures among agencies so that the indices could be combined and quantitatively analyzed across jurisdictional boundaries. SCANMAR was employed by most Lake Erie agencies in 1992, by OMNR and ODNR in 1995, and by ODNR alone in 1997 to calculate actual fishing dimensions of the bottom trawls. In the western basin, net dimensions from the 1995 SCANMAR exercise are used for the OMNR vessel, while the 1997 results are applied to the ODNR vessel. In 2002, ODNR began interagency trawling with the new vessel R/V Explorer II, and SCANMAR was again employed to estimate the net dimensions in 2003. In 2003, a trawl comparison exercise among all western basin research vessels was conducted, and fishing power correction factors (Table 2.4.1) have been applied to the vessels administering the western basin

Interagency Trawling Program (Tyson et al. 2006). Presently, the FTG estimates basin-wide abundance of forage fish in the western basin using information from SCANMAR trials, trawling effort distance, and catches from the August interagency trawling program. Species-specific abundance estimates (number per hectare or number per m3) are combined with length-weight data to generate a species-specific biomass estimate for each tow. Arithmetic mean volumetric estimates of abundance and biomass are extrapolated by depth strata (0-6m, >6m) to the entire western basin to obtain a fishing power correction adjusted, absolute estimate of forage fish abundance and biomass for each species. For reporting purposes, species have been pooled into three functional groups: clupeids (age-0 Gizzard Shad and Alewife), soft-rayed fish (Rainbow Smelt, Emerald and Spottail Shiners, other cyprinids, Silver Chub, Trout-Perch, and Round Gobies), and spiny-rayed fish (age-0 for each of White Perch, White Bass, Yellow Perch, Walleye and Freshwater Drum).

Hypoxic conditions have been observed during previous years of interagency bottom trawl assessment in the west basin. Due to concerns about the potential effects of hypoxia on the distribution of juvenile percids and other species, representatives from task groups, the Standing Technical Committee, researchers from the Quantitative Fisheries Center at Michigan State University and Ohio State University (OSU) developed an interim policy for the assignment of bottom trawl status. Informed by literature (Eby and Crowder 2002; Craig and Crowder 2005) and field study (ODNR /OSU/USGS) concerning fish avoidance of hypoxic waters, an interim policy was agreed upon whereby bottom trawls that occurred in waters with dissolved oxygen less than or equal to 2 mg per liter would be excluded from analyses. The policy has been applied retroactively from 2009. Currently, there is no consensus among task groups on the best way to handle this sort of variability in the estimation of year-class strength in Lake Erie. In part, this situation is hampered by a lack of understanding of how fish distribution changes in response to low dissolved oxygen. This interim policy will be revisited in the future following an improved understanding of the relationship between dissolved oxygen and the distribution of fish species and life stages in Lake Erie (Kraus et al. 2015).

2016 Results

In 2016, hypolimnetic dissolved oxygen levels were below the 2 mg per liter threshold at one site during the August trawling survey (located offshore in the Sandusky sub-basin). In total, data from 69 sites were used in 2016 (Figure 2.4.1).

Total forage abundance was below average in 2016, the third year of decline (Figure 2.4.2). Spiny-rayed species increased 43% compared to 2015, while clupeids and soft-rayed species decreased 96% and 37%, respectively. Total forage abundance averaged 3,651 fish/ha across the western basin, decreasing 1% from 2015, and residing below the long-term mean (5,174 fish/ha). Clupeid density was 45 fish/ha (average 1,110 fish/ha), soft-rayed fish density was 136 fish/ha (mean 527 fish/ha), and spiny-rayed fish density was 3,470 fish/ha (mean 3,538 fish/ha). Relative abundance of the dominant species includes: age-0 White Perch (80%), age-0 Yellow Perch (10%), and age-2+ Yellow Perch (5%). Total forage biomass in 2016 increased relative to 2015, increasing 33% (Figure 2.4.3). Relative biomass of clupeid, soft-rayed, and spiny-rayed species was 2%, 2%, and 96%, respectively, and differed from their respective historic averages of 28%, 7%, and 65%. Spatial maps of forage distribution were constructed using FPC-corrected site-specific catches (number per hectare) of the functional forage groups (Figure 2.4.4). Abundance contours were generated using kriging techniques to interpolate abundance among trawl locations. Clupeid catches were highest in Sandusky Bay and west of Pelee Island. Soft-rayed fish were most abundant near the Detroit River mouth in Ontario waters. Spiny-rayed abundance was densest at the mouth of Sandusky Bay and in the center of the basin west of Pelee Island.

Recruitment of individual species is highly variable in the western basin. Young-of-the-year Yellow Perch (372/ha) decreased relative to 2015, but was above the long-term mean; age-0 Walleye abundance (9/ha; Figure 2.4.5) also decreased and was below the long-term mean. Young-of-the-year White Perch (2,925/ha) climbed above the 2015 abundance, near the long-term mean. Young-of-the-year White Bass (101.5/ha) increased to near the long-term mean. Young-of-the-year Rainbow Smelt (0.1/ha) disappeared in 2016. Young-of-the-year Gizzard Shad (45.3/ha) decreased relative to 2015, well below the time series mean, while age-0 Alewife were almost non-existent (Figure 2.4.6). Densities of age-0 and age-1+ shiners (all species) were similar to 2015 (Figure 2.4.7); however, age-0 (0.7/ha) and age-1+ Emerald Shiners (0.2/ha) were the lowest in the time series. Young-of-the-year Spottail Shiners were the second highest density of the last 10 years (21.9/ha). Density of Round Goby (29.6/ha) was one of the lowest abundances since their appearance in 1997.

Table 2.2.1 Indices of relative abundance of selected forage fish species in Eastern Lake Erie from bottom trawl surveys conducted by Ontario, New York, and Pennsylvania for the most recent 10-year period. Indicies are reported as arithmetic mean number caught per hectare (NPH) for the age groups young-of-the-year (YOY), yearling-and-older (YAO), and all ages (ALL). Long-term averages are reported as the mean of the annual trawl indices for the most recent 10-year period (2007-2016) and for the two most recent completed decades. Agency trawl surveys are described below. Pennsylvania FBC (PA-Fa) did not conduct a fall index trawl survey in 2006, 2010, 2011, 2013, and 2014 and the 2008 survey was a reduced effort of four tows sampled in a single day.

Species	Age Group	Trawl Survey	Year 2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	10-Yr & Long-term Avg. by decade 10-Yr	2000's	1990's
Rainbow Smelt	YOY	ON-DW	538.3	3245.2	1001.6	217.9	1657.7	509.2	326.9	148.2	1293.0	991.3	992.9	1391.5	431.7
	YOY	NY-Fa	2901.3	2930.7	5520.2	755.2	424.4	1621.7	1453.6	73.4	2184.5	2963.6	2082.9	1566.1	1468.0
	YOY	PA-Fa	166.9	129.1	NA	NA	560.2	NA	NA	47.7	15.1	260.2	196.6	112.5	421.1
	YAO	ON-DW	20.2	411.0	4.6	165.3	367.8	277.1	222.7	1654.3	77.3	232.8	343.3	360.7	358.6
	YAO	NY-Fa	5.8	590.1	24.8	45.8	22.7	656.8	1023.8	3088.6	560.8	183.0	620.2	772.6	583.3
	YAO	PA-Fa	0.0	39.6	NA	NA	22.3	NA	NA	407.2	1.8	1006.3	246.2	179.5	1108.8
Emerald Shiner	YOY	ON-DW	2.0	346.7	2.9	58.7	438.3	70.3	117.6	54.8	16.0	29.3	113.6	463.2	52.3
	YOY	NY-Fa	6.1	137.6	526.3	130.9	96.8	3006.7	64.6	49.7	3.8	154.9	417.7	188.3	115.1
	YOY	PA-Fa	0.0	68.2	NA	NA	14.8	NA	NA	1063.0	0.0	81.7	204.6	203.4	39.9
	YAO	ON-DW	28.2	6.5	2.5	188.6	119.2	201.1	30.7	40.1	95.2	149.8	86.2	819.0	37.7
	YAO	NY-Fa	22.2	24.8	822.8	67.1	96.2	1874.0	21.1	160.4	18.6	87.1	319.4	309.3	108.1
	YAO	PA-Fa	0.0	146.9	NA	NA	86.9	NA	NA	1360.3	0.0	4713.1	1051.2	694.7	10.3
Spottail Shiner	YOY	ON-OB	4.1	5.8	5.0	8.1	19.1	2.5	3.0	3.7	37.8	35.2	12.5	119.3	815.9
	YOY	ON-IB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.5	113.9
	YOY	NY-Fa	0.1	0.0	0.1	0.0	1.8	0.7	6.7	0.1	0.3	0.1	1.0	6.3	20.4
	YOY	PA-Fa	0.0	0.0	NA	NA	0.0	NA	NA	1.1	0.0	0.0	0.2	0.1	3.6
	YAO	ON-OB	0.0	1.5	0.2	3.0	1.6	0.5	2.1	3.3	7.5	4.1	2.4	10.8	74.6
	YAO	ON-IB	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0
	YAO	NY-Fa	9.3	0.0	0.2	0.3	2.1	29.7	10.7	5.2	1.5	0.0	5.9	6.8	4.0
	YAO	PA-Fa	0.0	0.0	NA	NA	0.1	NA	NA	0.0	0.0	0.0	0.0	0.0	5.7
Alewife	YOY	ON-DW	0.8	0.7	0.0	17.7	707.3	2.1	0.9	0.1	2.3	1.0	73.3	22.5	231.2
	YOY	ON-OB	0.0	3.4	0.0	26.1	6.0	6.8	0.0	1.9	11.9	44.6	10.1	82.1	88.5
	YOY	NY-Fa	0.8	5.6	0.0	223.9	188.6	12.7	15.8	0.0	5.7	22.7	47.6	96.7	53.4
	YOY	PA-Fa	0.0	0.0	NA	NA	4.6	NA	NA	0.0	0.0	8.0	2.1	1.1	2.2
Gizzard Shad	YOY	ON-DW	1.9	0.4	0.0	0.0	47.6	18.9	13.3	0.4	86.5	34.6	20.4	21.3	7.5
	YOY	ON-OB	0.0	10.1	0.4	0.3	20.0	3.4	3.8	0.0	4.0	22.0	6.4	7.6	13.4
	YOY	NY-Fa	1.9	3.3	0.6	3.9	4.9	15.4	42.0	5.4	11.1	12.0	10.0	12.2	4.4
	YOY	PA-Fa	0.0	41.5	NA	NA	1.0	NA	NA	0.0	0.0	0.0	7.1	0.0	0.3
White Perch	YOY	ON-DW	96.1	0.5	0.0	0.0	0.8	0.0	1.6	0.6	5.4	0.1	10.5	2.9	1.8
	YOY	ON-OB	0.0	0.2	0.0	0.0	0.9	0.0	0.0	0.0	2.1	0.7	0.4	2.8	17.6
	YOY	NY-Fa	79.3	17.3	36.1	4.5	18.7	37.5	161.3	20.7	442.8	35.5	85.4	76.2	30.1
	YOY	PA-Fa	2.3	287.9	NA	NA	380.0	NA	NA	598.5	0.7	444.6	285.7	231.0	71.5
Trout Perch	All	ON-DW	0.2	0.1	0.0	0.0	0.0	0.0	0.3	0.8	0.8	0.8	0.3	0.9	0.6
	All	NY-Fa	26.1	33.1	64.9	152.7	347.8	671.4	473.7	530.1	1022.4	576.9	389.9	846.7	417.5
	All	PA-Fa	0.2	2.1	NA	NA	52.2	NA	NA	558.8	0.6	156.9	128.5	137.3	64.6
Round Goby	All	ON-DW	300.9	67.2	0.5	14.5	129.0	125.4	9.7	43.6	452.6	973.2	211.7	235.9	0.0
	All	ON-OB	54.0	359.1	98.5	76.3	68.0	103.3	67.6	91.2	63.4	73.9	105.5	86.9	0.1
	All	ON-IB	160.8	151.6	95.4	49.6	80.2	114.6	135.1	280.5	211.8	263.0	154.3	120.0	0.1
	All	NY-Fa	104.9	441.58	140.33	86.06	184.89	170.15	177.81	515.73	478.96	1326.96	362.7	671.5	1.0
	All	PA-Fa	85.6	47.2	NA	NA	32.1	NA	NA	350.1	441.6	1740.7	449.6	1074.9	42.0

"NA" denotes that reporting of indices was Not Applicable or that data were Not Available.
Indices are reported as NPH; Unless otherwise noted, 90's Avg. is for the period 1990 to 1999; 00's Avg. is for the period 2000 to 2009.

Ontario Ministry of Natural Resources Trawl Surveys

ON-DW Trawling is conducted weekly during October at 4 fixed stations in the offshore waters of Outer Long Point Bay using a 10-m trawl with 13-mm mesh cod end liner.

ON-OB Trawling is conducted weekly during September and October at 3 fixed stations in the nearshore waters of Outer Long Point Bay using a 6.1-m trawl with a 13-mm mesh cod end liner.

ON-IB Trawling is conducted weekly during September and October at 4 fixed stations in Inner Long Point Bay using a 6.1-m trawl with a 13-mm mesh cod end liner.

New York State Department of Environment Conservation Trawl Survey

NY-Fa Trawling is conducted at approximately 30 nearshore (15-30 m) stations during October using a 10-m trawl with a 9.5-mm mesh cod end liner.
90's Avg. is for the period 1992 to 1999.

Pennsylvania Fish and Boat Commission Trawl Survey

PA-Fa Trawling is conducted at nearshore (<22 m) and offshore (>22 m) stations during October using a 10-m trawl with a 6.4-mm mesh cod end liner.

Table 2.3.1 Relative abundance (arithmetic mean number per hectare) of selected age-0 species from fall trawl surveys in the central basin, Ohio and Pennsylvania, Lake Erie, from 2006-2016. Ohio West (OH West) is the area from Huron, OH, to Fairport Harbor, OH. Ohio East (OH East) is the area from Fairport Harbor, OH to the Ohio-Pennsylvania state line. PA is the area from the Ohio-Pennsylvania state line to Presque Isle, PA.

		Year											
Species	Survey	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
Yellow	OH West	11.3	155.7	32.1	1.6	41.1	10.3	69.2	8.9	37.7	19.6	0.5	38.8
Perch	OH East	20.1	160.1	52.8	0.5	96.3	15.1	134.4	8.9	49.1	18.6	1.6	55.6
	PA	-	10.0	863.4	14.2	-	-	481.6	28.0	-	107.0	332.9	250.7
White	OH West	430.4	1273.4	470.6	379.0	254.8	346.6	1709.6	174.7	135.0	371.0	15.3	554.5
Perch	OH East	38.9	427.6	91.6	34.6	190.3	72.1	661.9	200.1	99.4	338.8	5.4	215.5
	PA	-	17.4	199.0	146.3	-	-	380.1	2.2	-	758.6	165.5	250.6
Rainbow	OH West	97.4	88.3	765.8	267.8	776.2	29.8	84.4	126.0	747.8	447.0	219.4	343.1
Smelt	OH East	640.4	741.5	3997.7	0.3	421.6	247.3	319.1	12.8	1709.5	236.4	1383.4	832.7
	PA	-	34.8	552.2	23.1	-	-	10.4	132.8	-	148.1	506.4	150.2
Round	OH West	15.0	28.9	19.1	24.5	28.4	100.8	18.2	17.5	6.3	56.8	14.5	31.6
Goby	OH East	51.8	296.7	26.3	1.0	41.8	256.0	53.9	45.8	86.2	66.8	28.0	92.6
	PA	-	224.0	227.1	72.0	-	-	3.3	11.7	-	124.1	47.2	110.4
Emerald	OH West	707.4	37.2	25.1	7.5	8.8	361.7	951.3	2218.5	1369.3	3.5	0.0	569.0
Shiner	OH East	1254.5	67.8	20.2	1.7	234.9	103.7	2188.5	306.2	650.1	13.2	0.0	484.1
	PA	-	0.8	0.0	304.6	-	-	0.0	31.6	-	57.7	2.2	65.8
Spottail	OH West	0.0	2.1	3.4	0.4	0.0	0.6	0.0	0.0	2.5	0.0	0.0	0.9
Shiner	OH East	0.3	0.6	0.2	0.0	0.0	0.3	0.0	0.0	0.0	0.4	0.0	0.2
	PA	-	0.0	0.0	0.0	-	-	0.0	0.0	-	0.0	0.0	0.0
Alewife	OH West	3.1	0.0	0.0	0.0	0.0	0.0	0.0	52.1	0.0	0.0	0.0	5.5
	OH East	4.0	0.0	0.0	0.0	0.0	0.0	0.1	36.1	0.0	0.0	0.0	4.0
	PA	-	0.0	0.0	0.0	-	-	2.8	5.0	-	0.0	4.0	1.3
Gizzard	OH West	41.3	178.9	34.3	52.6	2.6	675.8	98.7	304.2	33.8	568.0	14.2	199.0
Shad	OH East	31.0	7.8	63.1	3.9	8.5	4.2	28.7	39.5	7.3	455.6	1.2	65.0
	PA	-	0.0	0.0	0.0	-	-	0.0	0.0	-	8.7	0.0	1.4
Trout-	OH West	0.2	1.3	0.3	0.5	0.7	1.3	0.0	0.1	0.3	0.4	0.0	0.5
perch	OH East	0.1	3.9	0.1	0.2	1.4	2.2	0.2	0.0	0.6	1.2	0.0	1.0
	PA	-	10.8	126.1	28.2	-	-	0.0	0.0	-	2.2	4.6	27.9

- The Pennsylvania Fish and Boat Commission was unable to sample in 2006, 2010, 2011 and 2014.

Table 2.3.2 Relative abundance (arithmetic mean number per hectare) of selected age-1+ species from fall trawl surveys in the central basin, Ohio and Pennsylvania, Lake Erie, from 2006-2016. Ohio West (OH West) is the area from Huron, OH, to Fairport Harbor, OH. Ohio East (OH East) is the area from Fairport Harbor, OH to the Pennsylvania state line. PA is the area from the Ohio-Pennsylvania state line to Presque Isle, PA.

		Year											
Species	Survey	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
Yellow	OH West	4.1	21.7	55.0	20.2	11.9	6.3	7.4	34.9	15.4	41.3	5.0	21.8
Perch	OH East	14.1	33.1	26.4	139.4	12.4	55.5	23.3	109.5	24.2	30.2	8.7	46.8
	PA	-	27.4	76.4	121.8	-	-	117.7	73.7	-	59.0	61.2	79.3
White	OH West	35.3	24.5	81.7	45.8	32.6	26.4	45.8	195.9	5.8	1.7	47.5	49.6
Perch	OH East	25.2	14.8	36.6	282.3	44.8	49.8	7.7	546.9	4.4	1.4	55.4	101.4
	PA	-	0.8	4.2	62.6	-	-	7.8	18.4	-	78.9	4.0	28.8
Rainbow	OH West	4.9	66.1	7.4	368.8	9.0	15.6	9.1	8.1	34.9	340.8	0.5	86.5
Smelt	OH East	17.2	304.1	48.7	98.2	49.8	186.0	95.4	200.7	6.2	295.4	17.1	130.2
	PA	-	10.8	3.5	406.5	-	-	20.5	25.1	-	69.7	5.0	89.4
Round	OH West	17.9	25.9	64.8	60.4	44.0	68.6	11.8	24.3	6.9	35.8	3.7	36.0
Goby	OH East	88.5	208.6	167.8	19.3	36.0	118.1	27.0	46.3	89.1	72.4	18.1	87.3
	PA	-	356.8	326.6	76.0	-	-	72.9	8.6	-	50.3	12.7	148.5
Emerald	OH West	159.2	298.6	601.2	127.7	51.5	138.2	998.8	298.0	55.8	0.9	1.3	273.0
Shiner	OH East	506.4	27.4	1159.4	167.8	375.1	149.7	433.2	8.4	333.5	1.8	0.0	316.3
	PA	-	793.2	28.0	172.5	-	-	8.9	17.2	-	179.5	6.4	199.9
Spottail	OH West	0.8	1.6	2.4	1.9	0.0	20.7	0.0	0.5	1.7	0.0	0.0	3.0
Shiner	OH East	0.7	0.6	2.9	0.0	0.0	3.1	3.0	2.9	0.0	0.0	0.0	1.3
	PA	-	0.0	0.0	0.0	-	-	0.0	0.0	-	0.0	0.0	0.0
Trout-	OH West	4.1	4.6	3.3	0.9	0.7	3.3	1.6	3.3	0.6	0.7	0.0	2.3
perch	OH East	4.6	5.6	8.4	1.5	5.0	7.9	11.7	1.0	0.4	3.0	0.1	4.9
	PA	-	15.8	61.7	127.5	-	-	30.4	9.3	-	8.3	2.4	42.2

\- The Pennsylvania Fish and Boat Commission was unable to sample in 2006, 2010, 2011 and 2014.

Table 2.4.1. Mean catch-per-unit-effort (CPUE) and fishing power correction factors (FPC) by vessel-species-age group combinations. All FPCs are calculated relative to the R.V. Keenosay.

Vessel	Species	Age group	Trawl Hauls	Mean CPUE (#/ha)	FPC	95% CI	Apply rule [a]
R.V. Explorer	Gizzard shad	Age 0	22	11.8	2.362	-1.26-5.99	Y
	Emerald shiner	Age 0+	50	67.8	1.494	0.23-2.76	Y
	Troutperch	Age 0+	51	113.2	0.704	0.49-0.91 z	Y
	White perch	Age 0	51	477.2	1.121	1.01-1.23 z	Y
	White bass	Age 0	50	11.7	3.203	0.81-5.60	Y
	Yellow perch	Age 0	51	1012.2	0.933	0.62-1.24	N
	Yellow perch	Age 1+	51	119.6	1.008	0.72-1.30	N
	Walleye	Age 0	51	113.7	1.561	1.25-1.87 z	Y
	Round goby	Age 0+	51	200.3	0.423	0.22-0.63 z	Y
	Freshwater drum	Age 1+	51	249.1	0.598	0.43-0.76 z	Y
R.V. Gibraltar	Gizzard shad	Age 0	29	14.2	1.216	-0.40-2.83	Y
	Emerald shiner	Age 0+	43	51.3	2.170	0.48-3.85	Y
	Troutperch	Age 0+	45	82.1	1.000	0.65-1.34	N
	White perch	Age 0	45	513.5	0.959	0.62-1.30	N
	White bass	Age 0	45	21.9	1.644	0.00-3.28	Y
	Yellow perch	Age 0	45	739.2	1.321	0.99-1.65	Y
	Yellow perch	Age 1+	45	94.6	1.185	0.79-1.58	Y
	Walleye	Age 0	45	119.2	1.520	1.17-1.87 z	Y
	Round goby	Age 0+	45	77.4	0.992	0.41-1.57	N
	Freshwater drum	Age 1+	45	105.2	1.505	1.10-1.91 z	Y
R.V. Grandon	Gizzard shad	Age 0	29	70.9	0.233	-0.06-0.53 z	Y
	Emerald shiner	Age 0+	34	205.4	0.656	-0.04-1.35	Y
	Troutperch	Age 0+	35	135.9	0.620	0.42-0.82 z	Y
	White perch	Age 0	36	771.4	0.699	0.44-0.96 z	Y
	White bass	Age 0	36	34.9	0.679	0.43-0.93 z	Y
	Yellow perch	Age 0	36	1231.6	0.829	0.58-1.08	Y
	Yellow perch	Age 1+	36	123.4	0.907	0.58-1.23	Y
	Walleye	Age 0	36	208.6	0.920	0.72-1.12	Y
	Round goby	Age 0+	36	161.8	0.501	0.08-0.92 z	Y
	Freshwater drum	Age 1+	36	58.8	2.352	1.51-3.19 z	Y
R.V. Musky II	Gizzard shad	Age 0	24	8.8	1.885	-1.50-5.26	Y
	Emerald shiner	Age 0+	47	32.3	3.073	0.36-5.79	Y
	Troutperch	Age 0+	50	62.4	1.277	0.94-1.62	Y
	White perch	Age 0	50	255.7	2.091	1.37-2.81 z	Y
	White bass	Age 0	46	8.4	4.411	0.90-7.92	Y
	Yellow perch	Age 0	50	934.0	1.012	0.77-1.26	N
	Yellow perch	Age 1+	50	34.9	3.452	1.23-5.67 z	Y
	Walleye	Age 0	50	63.7	2.785	2.24-3.33 z	Y
	Round goby	Age 0+	49	66.9	1.266	0.39-2.14	Y
	Freshwater drum	Age 1+	49	1.6	93.326	48.39-138.26 z	Y

z - Indicates statistically significant difference from 1.0 (α=0.05); [a] Y means decision rule indicated FPC application was warranted; , N means decision rule indicated FPC application was not warranted

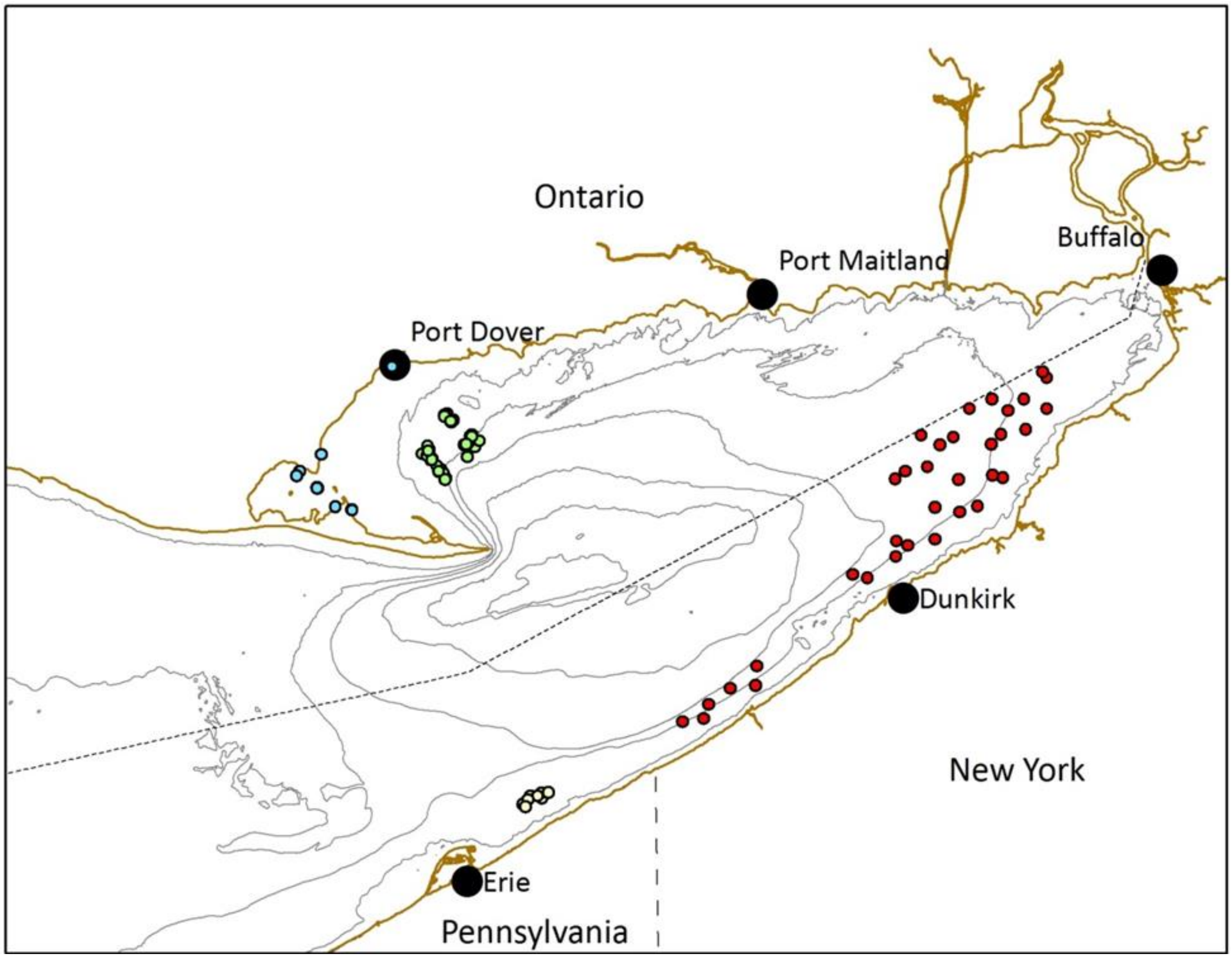


Figure 2.2.1 Locations sampled with standard index bottom trawls by Ontario (OMNRF), New York (NYSDEC) and Pennsylvania (PFBC) to assess forage fish abundance in eastern Lake Erie during 2016.

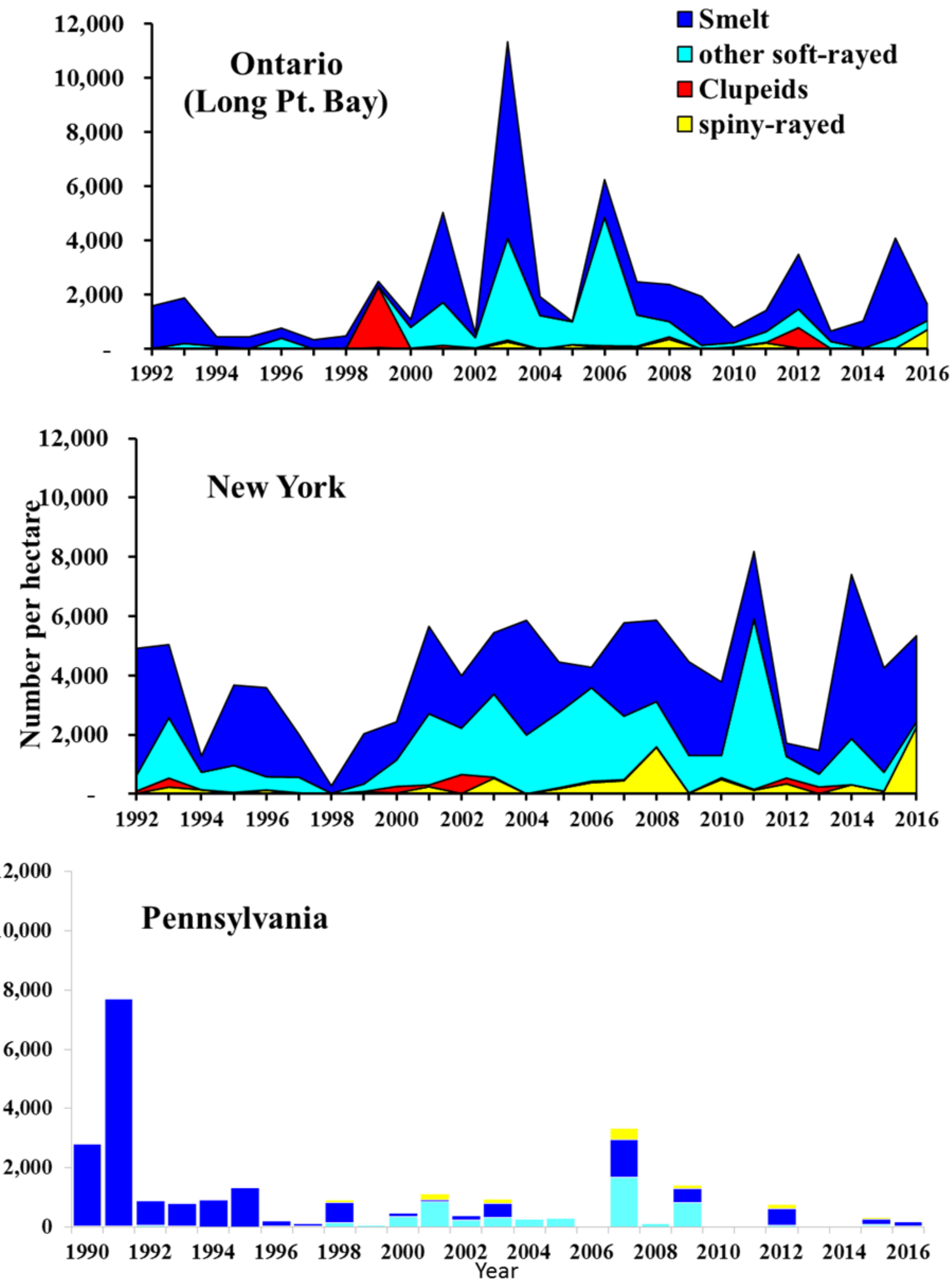


Figure 2.2.2 Mean density of prey fish (number per hectare) by functional group in the Ontario, New York and Pennsylvania waters of the eastern basin, Lake Erie, 1990/92-2016.

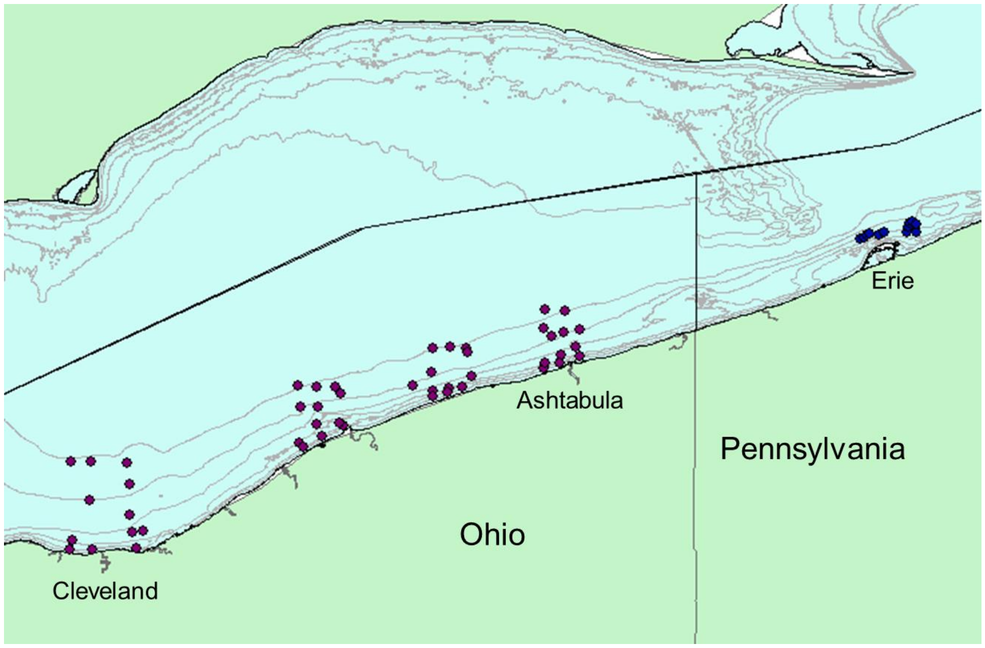


Figure 2.3.1 Locations sampled with index bottom trawls by Ohio (ODNR) and Pennsylvania (PFBC) to assess forage fish abundance in central Lake Erie during 2016.

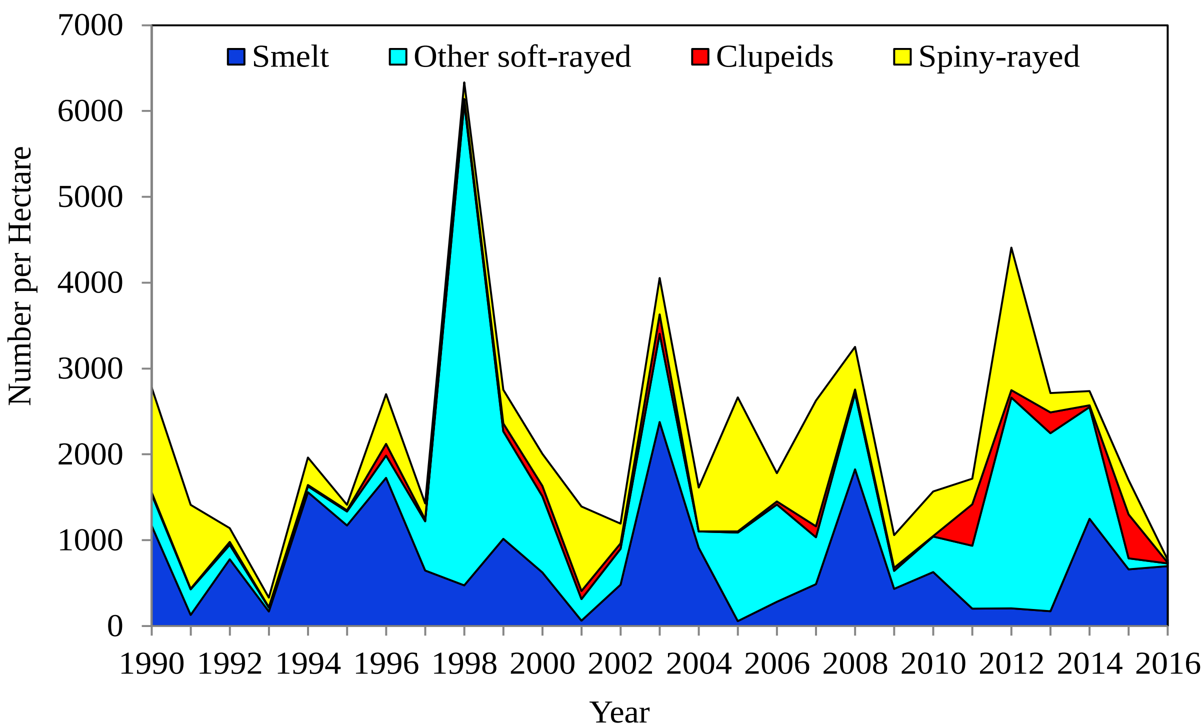


Figure 2.3.2 Mean density of prey fish (number per hectare) by functional group in the Ohio waters of the central basin, Lake Erie, 1990-2016.

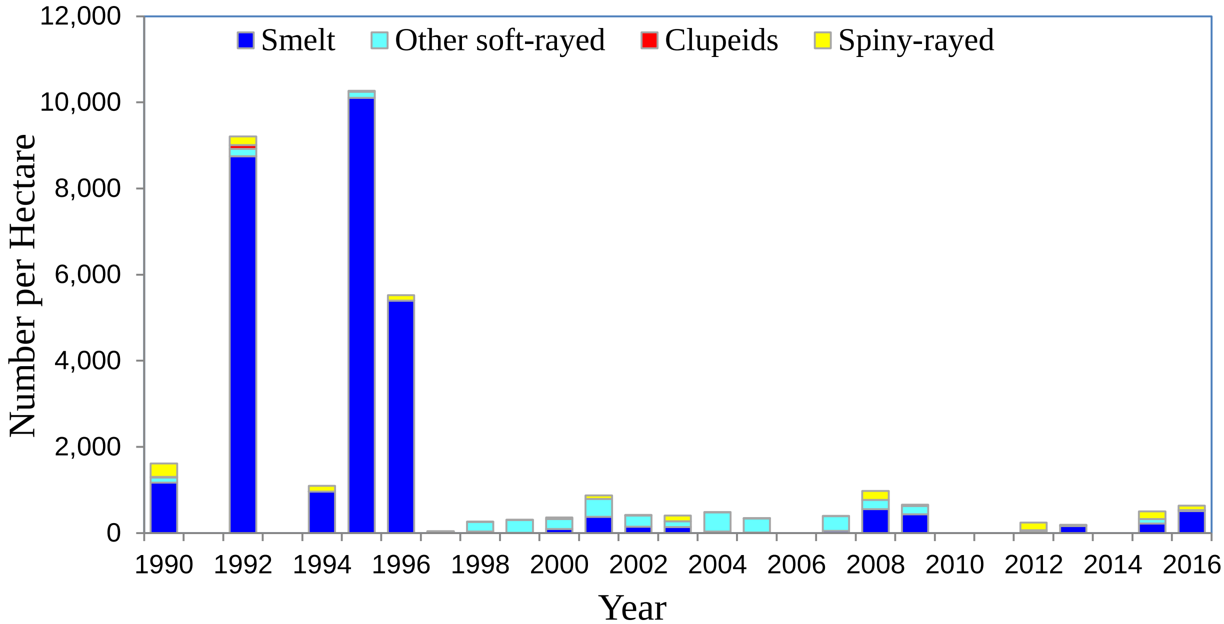


Figure 2.3.3 Mean density of prey fish (number per hectare) by functional group in the Pennsylvania waters of the central basin, Lake Erie, 1990-2016.

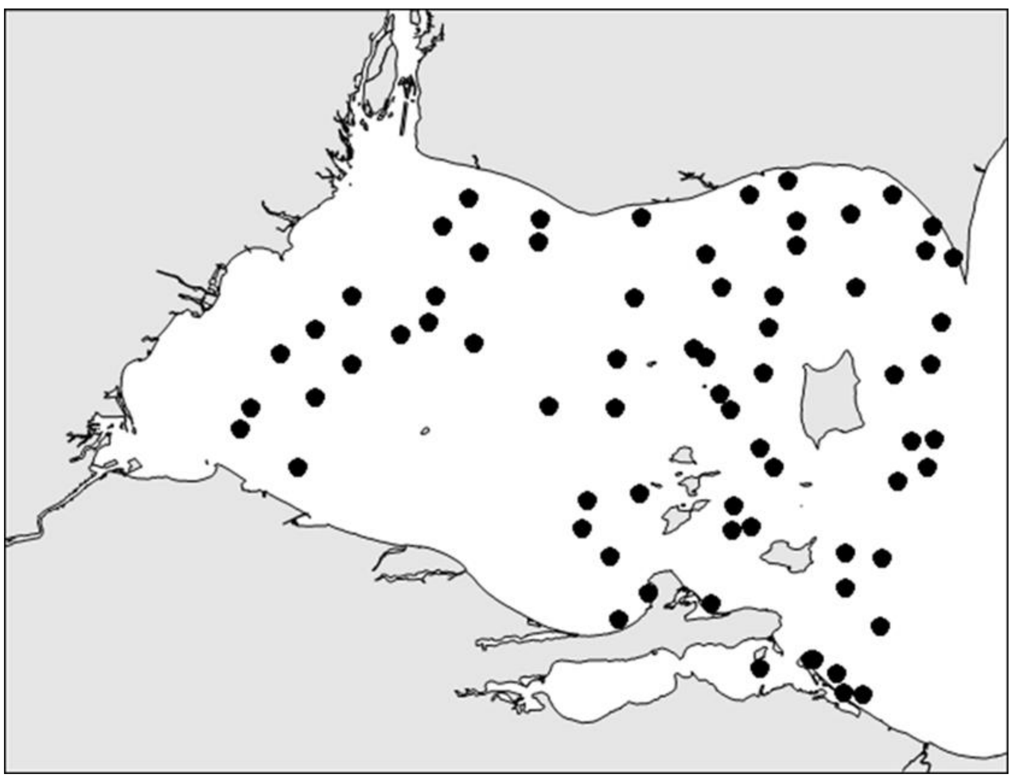


Figure 2.4.1. Trawl locations for the western basin interagency bottom trawl survey, August 2016

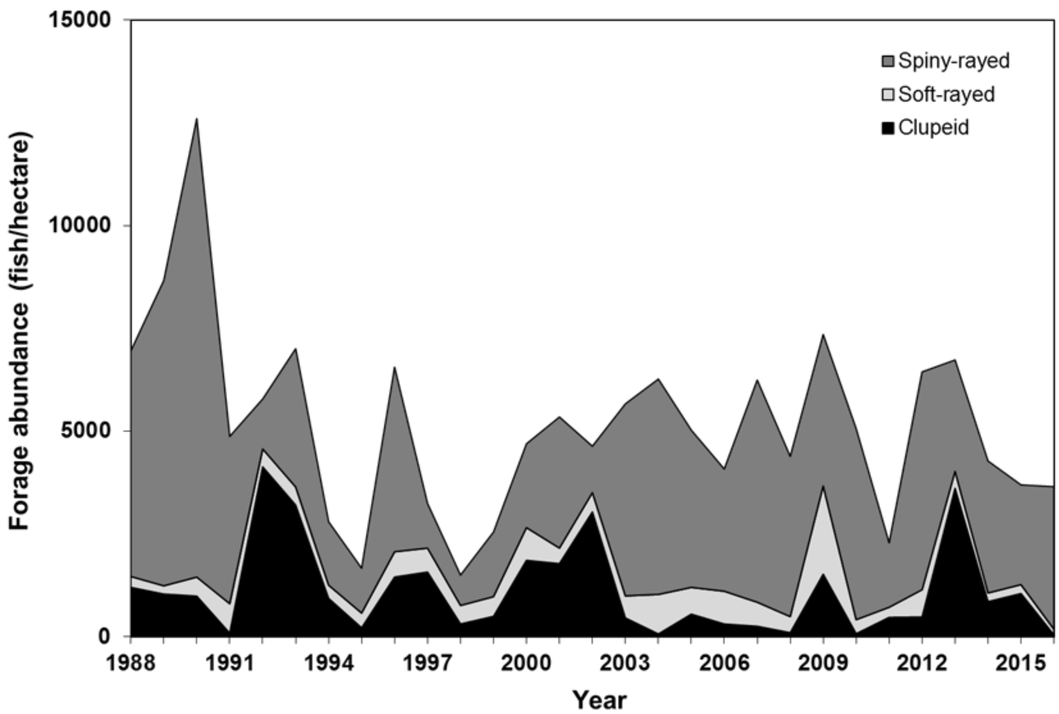


Figure 2.4.2. Mean density (number per hectare) of prey fish by functional group in western Lake Erie, August 1988-2016.

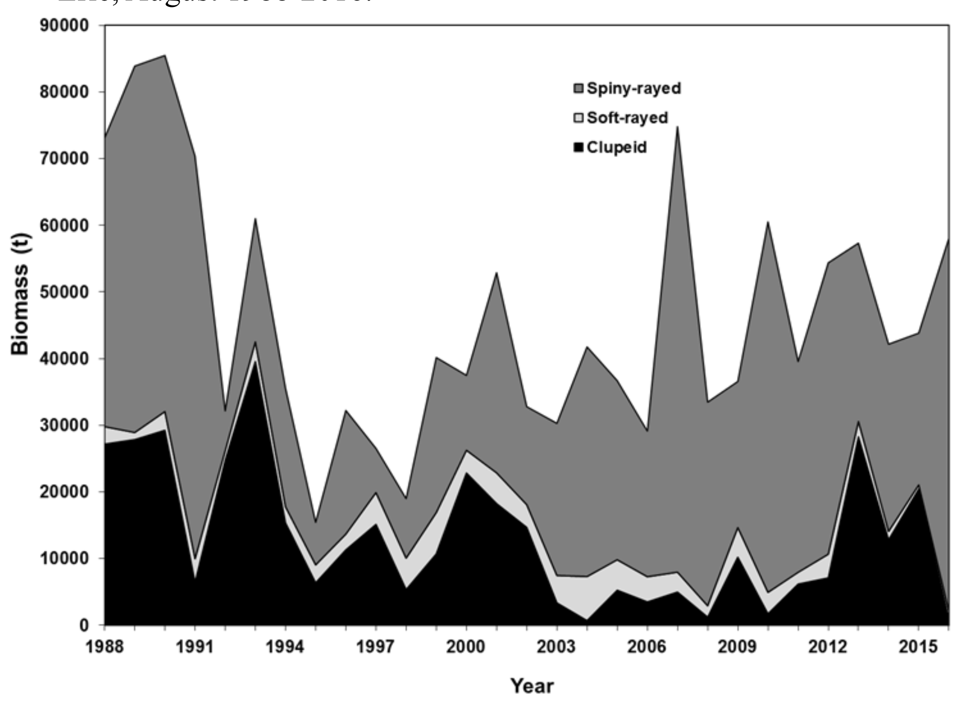


Figure 2.4.3. Mean biomass (tonnes) of prey fish by functional group in western Lake Erie, August 1988-2016.

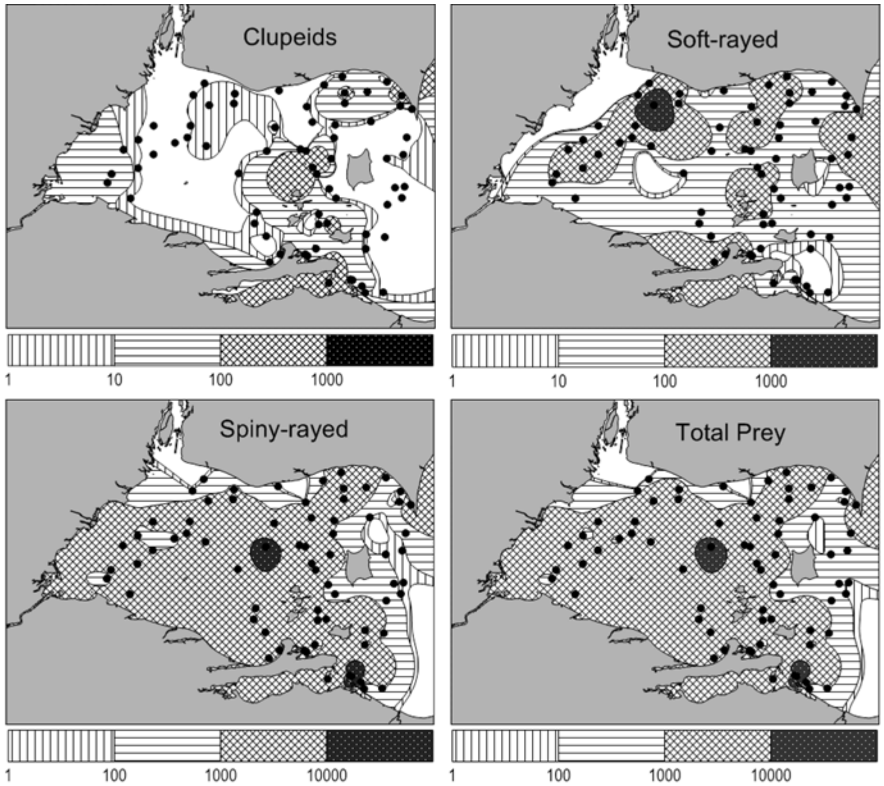


Figure 2.4.4. Spatial distribution of clupeids, soft-rayed, spiny-rayed, and total forage abundance (individuals per hectare) in western Lake Erie, 2016. Black dots are trawl sites, white areas are estimates of zero abundance, and contour levels vary with each functional fish group.

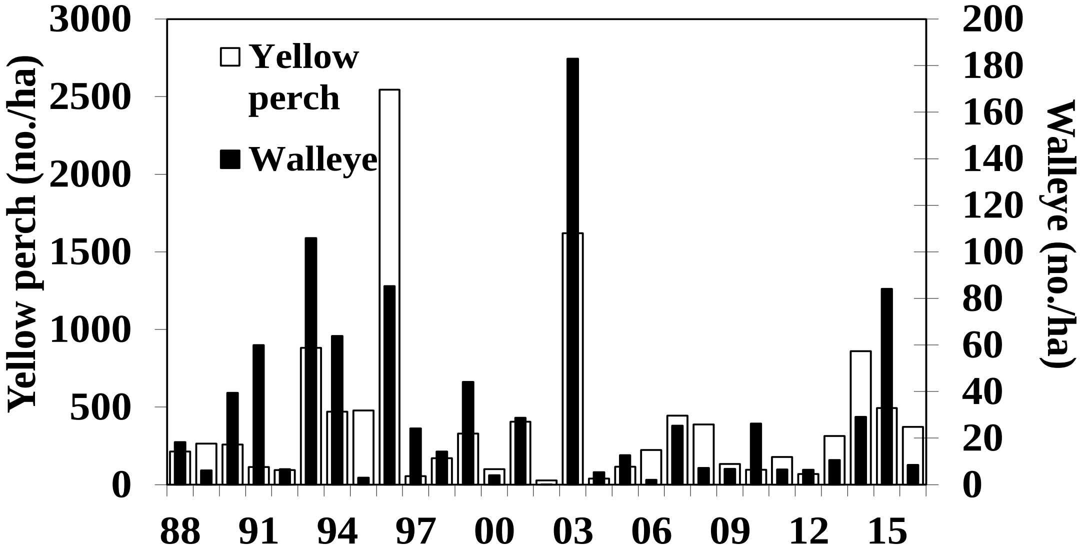


Figure 2.4.5. Density of age-0 Yellow Perch and Walleye in the western basin of Lake Erie, August 1988-2016.

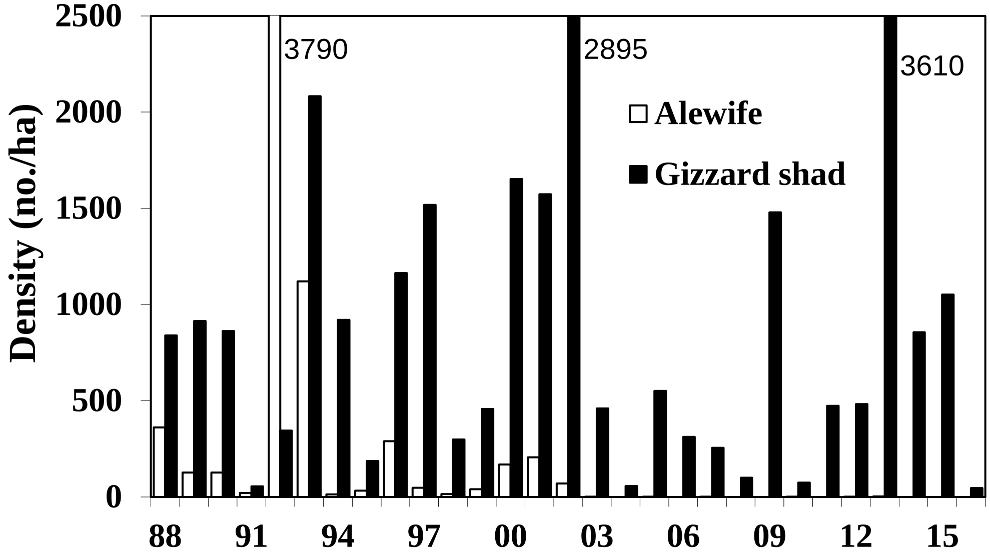


Figure 2.4.6. Density of age-0 Alewife and Gizzard Shad in the western basin of Lake Erie, August 1988-2016.

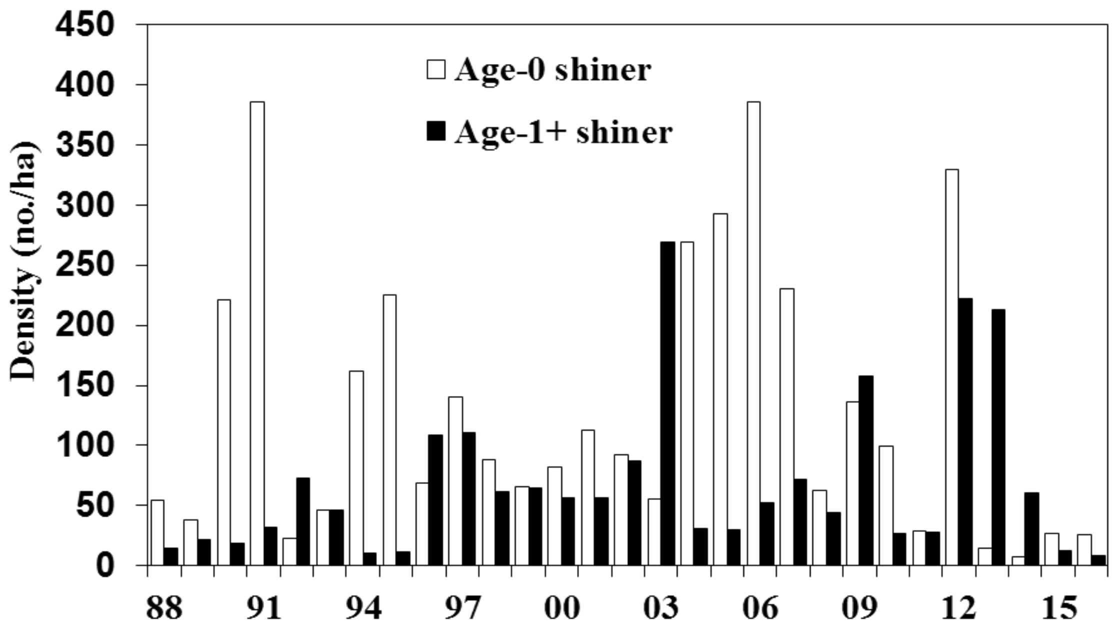


Figure 2.4.7. Density of age-0 and age-1+ shiners (*Notropis* spp.) in the western basin of Lake Erie, August 1988-2016.

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 GLFC's Great Lakes Hydroacoustic Standard Operating Procedures where possible/feasible.

3.1 East Basin Hydroacoustic Survey (J .Trumpickas and P. Penton)

A fisheries hydroacoustic survey has been conducted in the East Basin since 1993 to provide estimates of the distribution and abundance of Rainbow Smelt. The current 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 OMNRF research vessel, R/V *Erie Explorer*. The 2014 edition of this report details the history, design and analytical methods of the hydroacoustic survey, as well as results up to the 2013 survey (Forage Task Group 2014). Hydroacoustic data collected from 2014 to 2016 are presented in this edition. Companion mid-water trawls have been completed by NYSDEC in the past but due to vessel issues, those data have not been collected from 2014 to 2016.

2016

All 12 transects were completed July 4-7, and 10, with a basin-wide average density of 3452 fish per hectare, representing a moderate density of forage fish in the east basin since 2007 (Figure 3.1.1). The largest densities of fish were distributed between Port Dover, ON and Dunkirk, NY (Figure 3.1.2).

2015

Six of the 12 randomly selected transects were completed July 13 and 15, with the smaller number of transects completed due to both boat issues and weather. The transects completed were in the central portion of the east basin (Figure 3.1.3b), with the largest density of forage fish the size of age-1+ Rainbow Smelt located nearest to Port Dover. The average density estimate for the transects that were completed was 615 fish per hectare, the lowest in the time series (Figure 3.1.1).

2014

Eight of the 12 randomly selected transects were completed July 24, and August 1 and 2. The remaining transect were incomplete due to poor weather conditions. The transects completed were in the central portion of the east basin (Figure 3.1.3a), with the largest density of forage fish the size of age-1+ Rainbow Smelt located midway between Port Dover and Port Maitland on the Ontario side. The average density estimate for transects that were completed was 4586 fish per hectare, a moderate density in the time series (Figure 3.1.1).

3.2 Central Basin Hydroacoustic Survey (P. Kočovský and J. Deller)

The Ontario Ministry of Natural Resources (OMNR), Ohio Department of Natural Resources (ODNR), and the U.S. Geological Survey (USGS) have collaborated to conduct joint hydroacoustic and midwater trawl surveys in central Lake Erie since 2004. The 2017 central basin hydroacoustic survey was planned according to the protocol and sample design established at the hydroacoustic workshop held in Port Dover, Ontario in December 2003 (Forage Task Group 2005). That survey design calls for eight cross-basin transects on which both hydroacoustic and trawl data are collected. 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 (GLSOP; Parker-Stetter et al. 2009). The primary purpose of the central basin hydroacoustic survey is to estimate densities of Rainbow Smelt and Emerald Shiner, which are the primary pelagic forage species in the central basin.

Hydroacoustics

Hydroacoustic data were collected from the USGS R/V *Muskie* and the ODNR-DOW R/V *Grandon*. Acoustic transects corresponding to Loran-C TD lines were sampled from one half hour after sunset (approximately 2130) to no later than one half hour before sunrise (approximately 0530), depending on the length of the transect and vessel speed. The prescribed starting and ending points for the survey are the 10 m depth contour lines.

Hydroacoustic data, from both vessels, were collected with BioSonics DTX® echosounders and BioSonics Visual Acquisition (release 6.0) software. Data from the R/V *Muskie* were collected using a 120 kHz, 7.4 degree, split-beam transducer mounted inside a through hull transducer tube at a depth of 1.5 m below the water surface. Data from the R/V *Grandon* were collected with a 122 kHz, 7.6 degree, split-beam transducer mounted to the starboard hull on a movable bracket, roughly equidistant between the bow and stern, with the transducer 1.3 meters below the surface.

Sound was transmitted at four pulses per second with each pulse lasting 0.4 milliseconds. Global Positioning Systems (GPS) coordinates from the R/V *Muskie* were collected using a Garmin ® GPSMAP 76Cx, and from the R/V *Grandon*, with a Garmin 17HVS. Both vessels interfaced GPS coordinates with the echosounders to obtain simultaneous latitude and longitude coordinates. Temperature readings from just above the thermocline were used to calculate speed of sound in water because the largest proportion of fish occurred nearest this depth in the water column. Selecting the temperature nearest the thermocline, where fish were densest, results in the least cumulative error in depth of fish targets. Prior to data collection a standard tungsten-carbide calibration sphere, specific to 120-kHz transducers, was used to calculate a calibration offset for calculating target strengths. Background noise was estimated by integrating beneath the first bottom echo at several locations for each transect, then averaging within a transect. The average noise within a transect was subtracted from total backscatter.

Analysis of hydroacoustic data was conducted following guidelines established in the Standard Operating Procedures for Fisheries Acoustics Surveys in the Great Lakes (Parker-Stetter et al. 2009) using Echoview ® version 7.1 software. Proportionate area backscattering coefficient was scaled by mean target strength calculated from single targets identified using Single Target Detection Method 2 (Parker-Stetter et al. 2009) to generate density estimates for distance intervals. Distance intervals for each transect were 500 m. Two depth strata, epilimnetic and hypolimnetic, were established by examining distributions of single target strength by depth. Settings for pulse length determination level, minimum and maximum normalized pulse length, maximum beam compensation, and maximum standard deviation of major and minor axes followed Parker-Stetter et al. (2009). Minimum target strength threshold was -74 dB. This value permitted inclusion of all targets at least -68 dB within the half-power (6 dB) beam angle. We used -68 dB as the lowest target of interest based on distribution of *in situ* target strength and theoretical values for Rainbow Smelt of the lengths captured in midwater trawls (Horppila et al. 1996, Rudstam et al. 2003). The Nv statistic, a measure of the probability of observing more than one fish within the sampling

volume (Sawada et al. 1993), which will result in overlapping echoes, was calculated for each interval-by-depth stratum cell to monitor the quality of *in situ* single target data. If Nv for an interval-by-depth stratum cell was greater than 0.1, the mean TS of the entire stratum within a transect where Nv values were less than 0.1 was used (Rudstam et al. 2009).
Density estimates for fish species were calculated by multiplying acoustic density estimates within each cell by proportions calculated from trawls. For each cell we used proportions of each species and age group from the trawl sample from the same water stratum and from a similar total depth that was nearest the cell.

Trawling

The R/V *Keenosay* conducted up to nine 20-minute trawls on transects in Ontario waters concurrent with and on the same transect as the R/V *Muskie* acoustic data collection. The R/V *Grandon* conducted up to three 20-minute midwater trawls in Ohio waters concurrent with acoustic data collection on the remaining transects. Whenever possible, trawl effort was distributed above and below the thermocline to adequately assess species composition throughout the water column. The catch was sorted by species and age group, and relative proportions of each species and age group were calculated for each trawl. Age group was determined based on age-length keys and length distributions. Age group classifications consisted of young-of-year (age-0) for all species, yearling-and-older (age-1+) for forage species, and age-2-and-older (age 2+) for predator species. Total lengths were measured from a subsample of individuals from each species and age group. Temperature and dissolved oxygen profiles were recorded at each trawl location.

Results

Seven cross-lake transects were sampled between 5 July and 9 July, 2016 with hydroacoustics and midwater trawls (Figure 3.2.1). Data from one transect, 58100, was compromised due to excessive vessel noise and was not included in the hydroacoustic analysis. The remaining transect was not completed due to weather and vessel commitments to other projects.

A total of 39 midwater trawls were completed during the survey. Rainbow Smelt was the primary species caught in midwater trawls across all transects (Table 3.2.1). Young-of-the-year Rainbow Smelt was the predominant species caught in most midwater trawl samples (n=26). Yearling-and-older Rainbow Smelt was the primary species caught in eight trawl samples. Three trawl samples had greater than 50% Age-0 White Perch. One trawl sample was composed mostly of age-0 Yellow Perch. Young-of-the-year Yellow Perch composed sizable proportions of midwater trawl catches on transects 57225, 57600, 57475, and 57350. Other species caught in midwater trawls included Freshwater Drum, Emerald Shiner, Gizzard Shad, Walleye, White Bass, White Perch Rainbow Trout and Round Goby.

Acoustic TS distributions showed differences in TS across depth strata. Highest acoustic densities occurred in the upper depth layers relative to the lower layer of each transect (Table 3.2.2). Age group composition for Rainbow Smelt in the trawl catch did not separate by depth on most transects. Only on the western transects, 57475 and 57350, were the age groups separated by depth. On the remaining transects, the majority of both Rainbow Smelt age groups were located in the upper layer of the water column. Young-of-the-year Yellow Perch were primarily located in the upper layer of the water column on all transects.

Spatial distribution across transects varied by species and age group. The highest densities of age-0 Yellow Perch were found on the central and western transects (Figure 3.2.2). Young-of-the-year Rainbow Smelt tended to be uniformly distributed across the basin, with slightly higher densities in the eastern relative to the western transects (Figure 3.2.3). Yearling-and-older Rainbow Smelt densities were concentrated off Erieau, Ontario (57600), and transects 57850 and 57975 off Ashtabula, Ohio (Figure 3.2.4).

Hydroacoustic density estimates for Emerald Shiner were the lowest since 2010 and have been generally declining since 2011 (Figure 3.2.5). Young-of-the-year Rainbow Smelt densities increased from 2015 and were the highest in the time series. Yearling-and-older Rainbow Smelt decreased slightly from 2015, but remain one of the highest estimates since 2010.

Temperature and dissolved oxygen profiles collected concurrently with midwater trawls did not find any areas of low oxygen. The lowest oxygen level recorded during the survey was 5.0 mg/L on transect 57475 off Cleveland, Ohio. Based on target distributions from whole-transect echograms, and past experience that highest densities of targets tended to be near the thermocline, the thermocline depth was relatively stable on individual transects run by the R/V *Muskie* (Figure 3.2.6) and R/V *Grandon* (Figure 3.2.7). Temperature and dissolved oxygen profiles collected by the R/V *Keenosay* and R/V *Grandon* during the acoustic survey support the thermocline patterns on the echograms.

Discussion

Temperature and dissolved oxygen profiles did not find any areas of low oxygen that would affect the distribution of species in the water column. In most years, there is a strict pattern of large and small targets separated by the thermocline. The more consistent thermocline pattern encountered in 2016 would suggest that species composition and hydroacoustic target size would separate around the thermocline. However, the partition between large and small targets in acoustic data was not as obvious as in the past as larger targets (age-1+ Rainbow Smelt) were frequently encountered above the thermocline on the central and eastern transects. Large targets at and above the thermocline is most likely a result of the thermocline depth becoming shallower on the ends of each transect. Similar to 2015, age-0 Rainbow Smelt were caught throughout the water column on all four transects, which suggests a large cohort for the second year in a row. Hydroacoustic density estimates of age-0 Rainbow Smelt were the highest since 2010.

Emerald Shiners were noticeably absent from the survey in 2015 and 2016. Only three Emerald Shiners were caught during the 2016 survey on the western most transect. Emerald Shiner densities are at their lowest level since the central basin survey began in 2003.

Young-of-the-year Yellow Perch are commonly encountered in the central basin hydroacoustic survey. Since the objective of the survey is to assess pelagic forage species (primarily Rainbow Smelt and Emerald Shiner) they are not normally included in the analysis. Due to the absence of Emerald Shiners and relatively large catch of age-0 Yellow Perch, they were included in 2016. Similar to previous years, age-0 Yellow Perch distributions tend to be highest on the central and west transects. Density estimates in 2016 were the second highest since 2010. The hydroacoustic survey could be an additional measure to assess age-0 Yellow Perch in the future. A more detailed analysis of midwater trawl data is planned for the spring of 2017. The potential for a midwater trawl survey targeting age-0 Yellow Perch will be part of the analysis.

Hydroacoustics has been used to assess forage fish in central Lake Erie for approximately 13 years. The current design of hydroacoustic data collection in central Lake Erie includes 8 north- to-south-oriented, cross-lake transects between the 10-m depth contours. Ideally two hydroacoustic vessels each collect data along 4 transects, paired with two additional vessels using midwater trawls to collect fish specimens to identify fish species and relative abundances. The stated objective of the survey is to produce a basin-wide snapshot of abundance of pelagic species, primarily Rainbow Smelt and Emerald Shiner. Surveys have been conducted during the new moon phase in July. Sampling is conducted during the new moon because of effects of moonlight on diel vertical migration of Rainbow Smelt, which is in response to movements of prey in response to light level.

Since 2004 we have typically not achieved designed sampling objectives. Given the operational constraint of sampling in July nearest the new moon as possible, we are temporally limited to a 16-day window of opportunity from first to third-quarter moons. Four (if the new moon is on a weekday) or five (if new moon is on a weekend day) days within that window are automatically lost to weekends, and Canadian or US federal holidays have fallen within the window of opportunity in five years. Weather further constrains operations. Cross-lake transects take all night to complete at speeds that result in quality hydroacoustic data (i.e., acceptably low background noise), and it is exceptionally rare to have 4-5 consecutive days of suitable seas (suitable is in terms of quality of data – we are physically capable of sampling in rougher seas, but data are of poor quality). During the past decade we have sampled all 8 prescribed cross-lake transects only once (2005).

In addition to these operational constraints, there has never been a rigorous analysis of sampling strata in central Lake Erie. The original design considered the area between the 10 m contours as a homogenous stratum. That assumption has not been rigorously examined. The design also excludes sampling areas closer to shore, which was done out of consideration for draft of the larger vessels used for hydroacoustics. This is a potentially great liability to assessing abundance and distribution of walleye forage species.

Our chronic operational problems with completing the designed survey and apparent shortcomings with respect to providing relevant data for fisheries management have led us to the conclusion that an evaluation of the design and conduct of the central basin hydroacoustics program is warranted. The principal science/management question is: what are relevant sampling strata? We intend to use the last 10 years' of trawl data from the R/V *Keenosay*, R/V *Musky II*, and R/V *Grandon* to identify sampling strata for key species. Based on past efforts in the Great Lakes we intend to use ordination and clustering methods to discover strata using the following variables: water depth, sampling depth (from surface and bottom), distance from shore, temperature profiles, latitude, and longitude as predictors (at a minimum). A geographic information system will then be used to estimate areas within sampling strata to allocate effort within strata. Results of this evaluation will be merged with results of our evaluation of vessel avoidance (Forage Task Group 2015) to design the next generation hydroacoustic survey. Analysis is expected to be completed by the end of June 2017 with potential implementation of the new survey design in July 2017.

3.3 West Basin Acoustic Survey (G. Steinhart)

Since 2004, the Ohio Department of Natural Resources Division of Wildlife has been conducting a hydroacoustic forage fish survey in the western basin of Lake Erie. This survey consists of three, cross-basin transects surveyed between one-half hour after sunset and one-half hour before sunrise. No companion trawling has been conducted in conjunction with acoustic data collection since 2006.

Methods

Three fixed cross basin transects were planned for the survey in 2016, but only the two western-most transects were completed owing to inclement weather. All transects were surveyed using the Sandusky Fisheries Research Unit's BioSonics DT-X surface unit. This unit still had problems with the primary transducer and cable, but the survey was able to be conducted using the secondary transducer and cable. After the survey was completed, BioSonics replaced all the equipment so there should be no further issues.

Data was collected in 2015 using a single, downward-facing, 9-degree, 201-kHz split-beam transducer, a Garmin GPS, and a Panasonic CF-30 laptop computer. The acoustic system was calibrated after the survey with a tungsten carbide reference sphere of known acoustic size. The mobile survey, conducted aboard the ODNR's *RV Almar*, was initiated 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 kph using the GPS. The transducer was mounted on a BioSonics towfish (on loan from the University of Toledo, Lake Erie Center) deployed off the port side of the boat amidships, one meter below the surface. Data were collected using BioSonics Visual Acquisition 5.0.4 software. Collection settings during the survey were 10 pings per second, a pulse length of 0.2 msec, and a minimum threshold of -70 dB. The sampling environment (water temperature) was set at the temperature 2 m deep on the evening of sampling. Data were written to a file and named by the date and time the file was collected. Files were automatically collected every 30 minutes. Latitude and longitude coordinates were written to the file as the data were collected to identify sample location.

Data were analyzed using the Echoview 4.5 (Myriax Software) using a modified process developed by the Ohio Division of Wildlife Inland Fisheries Research Unit. Target strength range was estimated using Love's dorsal aspect equation (Love 1971):

$$\text{Total length} = 10^{((\text{Target Strength} + 26.1)/19.1)} * 1000$$

Biomass estimates were based on average target length as determined by the above equation.

Results

In 2016, two cross-basin transects (81 km in total) were surveyed July 5 and 12 (Figure 3.3.1). Western basin forage fish were more abundant on the southern end of both transects with the highest overall densities found at the southern end of the western transect. Western basin forage fish density (10,907 fish per hectare) and biomass (6.7 kilograms per hectare) estimates were much lower than in 2015 (54,309 fish per hectare and 22 kilograms per hectare) and the 2005-2015 means (17,739 fish per hectare and 19.9 kilograms per hectare; Figure 3.3.2). Compared to all years back to 2005, mean forage fish density was the fifth lowest and biomass was the fourth lowest. Fish were small in 2016, with nearly all (96%) forage fish in the survey estimated to be between 30-60 mm.

Table 3.2.1. Percent composition of fish captured in trawl samples collected by the R/V *Keenosay*, and R/V *Grandon* in the central basin Lake Erie in July, 2016.

Transect	Trawl ID	Depth	Layer	Latitude	Longitude	Yellow Perch Age-0	Rainbow Smelt Age-0	Rainbow Smelt Age-1+	Other species[1] all ages
58100	1006	6	Upper	42.54800	-80.98350	0.3%	99.7%	0.0%	0.0%
58100	1008	6	Upper	42.62333	-81.01300	0.0%	96.8%	3.2%	0.0%
58100	1005	9	Upper	42.54883	-80.98633	0.3%	99.3%	0.4%	0.1%
58100	1007	9	Upper	42.60833	-81.03400	0.0%	1.6%	98.4%	0.0%
58100	1004	12	Upper	42.54767	-80.98483	0.9%	90.7%	8.4%	0.0%
58100	1003	13	Upper	42.38533	-80.91800	0.0%	100.0%	0.0%	0.0%
58100	1002	16	Upper	42.38517	-80.91883	0.0%	95.9%	0.0%	4.1%
58100	1001	18	Lower	42.38700	-80.90000	0.0%	21.1%	63.3%	15.6%
57975	730	9	Upper	41.96379	-80.99040	0.0%	96.2%	0.0%	3.8%
57975	731	11	Upper	42.07589	-81.0429	0.0%	53.2%	40.3%	6.5%
57975	732	17	Lower	42.14174	-81.0748	0.0%	0.0%	99.2%	0.8%
57850	2009	10	Upper	42.35983	-81.38533	0.1%	99.9%	0.0%	0.0%
57850	2004	13	Upper	42.46383	-81.42633	0.0%	94.8%	5.1%	0.1%
57850	2008	13	Upper	42.34450	-81.37733	0.4%	99.6%	0.0%	0.0%
57850	2003	16	Lower	42.47650	-81.43250	0.3%	38.2%	60.7%	0.9%
57850	2007	17	Lower	42.35617	-81.38167	0.0%	90.7%	8.6%	0.7%
57850	2006	20	Lower	42.34117	-81.38033	0.0%	72.6%	27.4%	0.0%
57725	733	7	Upper	41.69528	-81.8366	0.0%	53.8%	0.0%	46.2%
57725	734	13	Upper	41.75906	-81.866	2.6%	76.3%	0.0%	21.1%
57725	735	17	Lower	41.82014	-81.8934	5.5%	55.5%	31.8%	7.3%
57600	3004	7	Upper	42.06950	-81.74050	44.4%	40.7%	0.0%	14.8%
57600	3003	13	Upper	42.07767	-81.74633	5.7%	92.6%	0.0%	1.6%
57600	3005	15	Upper	42.20933	-81.80567	0.0%	0.0%	100.0%	0.0%
57600	3002	17	Lower	42.09683	-81.76483	6.5%	85.5%	3.2%	4.8%
57600	3001	20	Lower	42.08483	-81.75467	0.5%	3.8%	94.3%	1.4%
57475	736	9	Upper	41.88077	-81.4189	8.0%	86.0%	0.0%	6.0%
57475	737	13	Upper	41.93613	-81.4482	0.8%	86.4%	12.9%	0.0%
57475	738	17	Lower	41.99926	-81.4788	0.0%	18.1%	80.1%	1.8%
57350	4002	7	Upper	42.12600	-82.24967	0.0%	15.5%	0.0%	84.5%
57350	4005	8	Upper	42.04217	-82.22433	27.9%	10.8%	0.0%	61.3%
57350	4008	8	Upper	41.92400	-82.16433	5.6%	94.4%	0.0%	0.0%
57350	4001	10	Upper	42.14083	-82.25817	8.2%	30.8%	1.3%	59.7%
57350	4004	15	Upper	42.04050	-82.22433	30.1%	57.6%	7.8%	4.5%
57350	4007	15	Upper	41.92833	-82.17217	10.2%	89.0%	0.3%	0.6%
57350	4003	18	Lower	42.04017	-82.22400	24.8%	62.9%	9.5%	2.8%
57350	4006	18	Lower	41.92467	-82.16333	2.2%	33.7%	63.1%	1.0%

1 Other species (age, N captured): Freshwater Drum (26); Emerald Shiner (3); Gizzard Shad (50); Walleye (15); White Bass (38); White Perch (545); Rainbow Trout (1) Round Goby (1).

Table 3.2.2. Density (number per hectare) of key species by age class and depth layer for hydroacoustic transects in central basin Lake Erie, July 2016. Transect numbers refer to Loran-TD lines. Depth layers were determined by differences in acoustic target strength (TS) across depth strata within each transect. Species were applied from midwater trawl catch by nearest distance within depth layer.

Age Group	Species	57350 Upper	Lower	57475 Upper	Lower	57600 Upper	Lower	57725 Upper	Lower	57850 Upper	Lower	57975 Upper	Lower
Age-0	Rainbow Smelt	12377	1952	15750	400	22414	956	39585	168	40005	2345	54629	230
Age-1+	Rainbow Smelt	212	2140	0	254	6964	2227	3838	744	5137	2764	12191	662
Age-0	Yellow Perch	1866	260	659	39	7284	55	6358	0	87	1	86	0

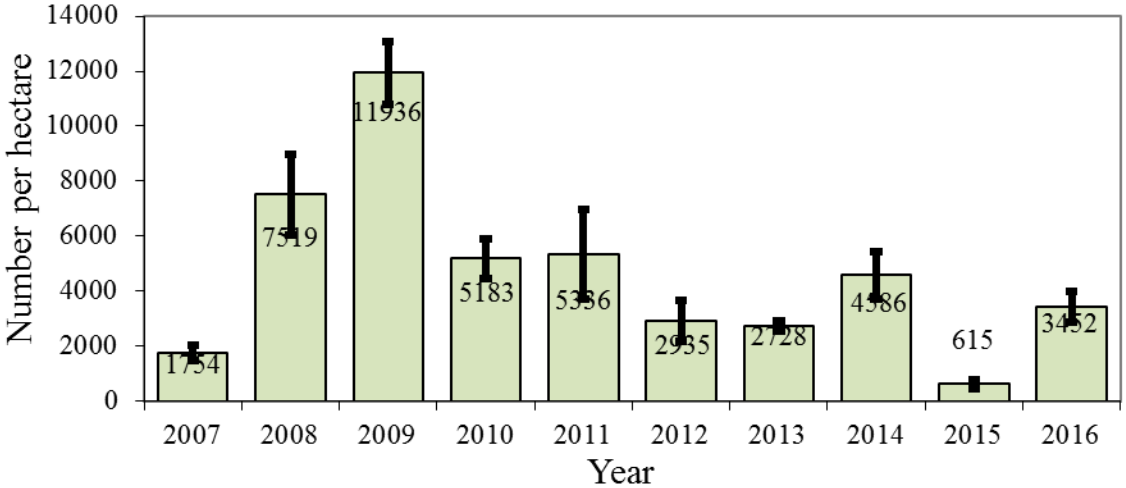


Figure 3.1.1. Mean density (fish per hectare) estimates of pelagic forage fish in cold-water habitat (all species, age-1+ Rainbow Smelt-sized) during the July east basin, Lake Erie hydroacoustic survey, 2007-2016.

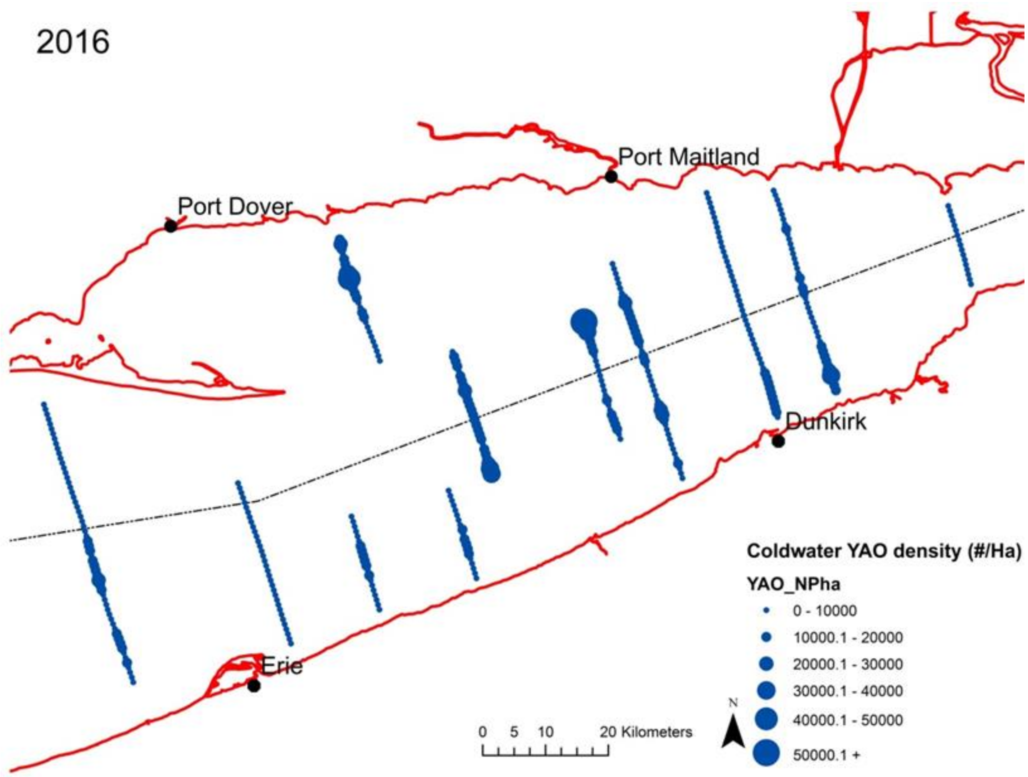


Figure 3.1.2. Density estimates of age-1+ Rainbow Smelt (fish per hectare) per distance interval along hydroacoustic transects in the eastern basin, Lake Erie in 2016.

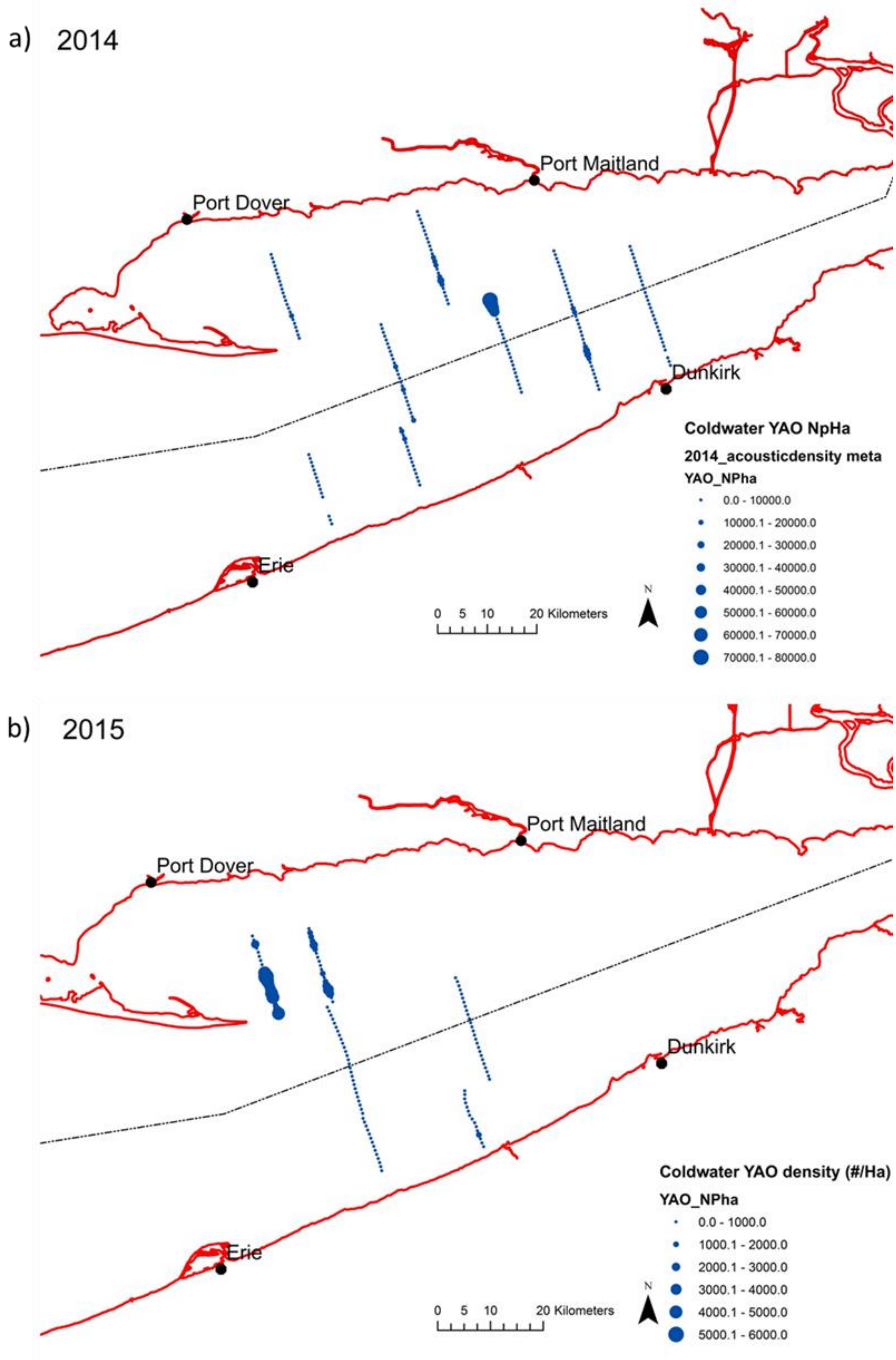


Figure 3.1.3. Density estimates of age-1+ Rainbow Smelt (fish per hectare) per distance interval along hydroacoustic transects in the eastern basin, Lake Erie in (a) 2014 and (b) 2015.

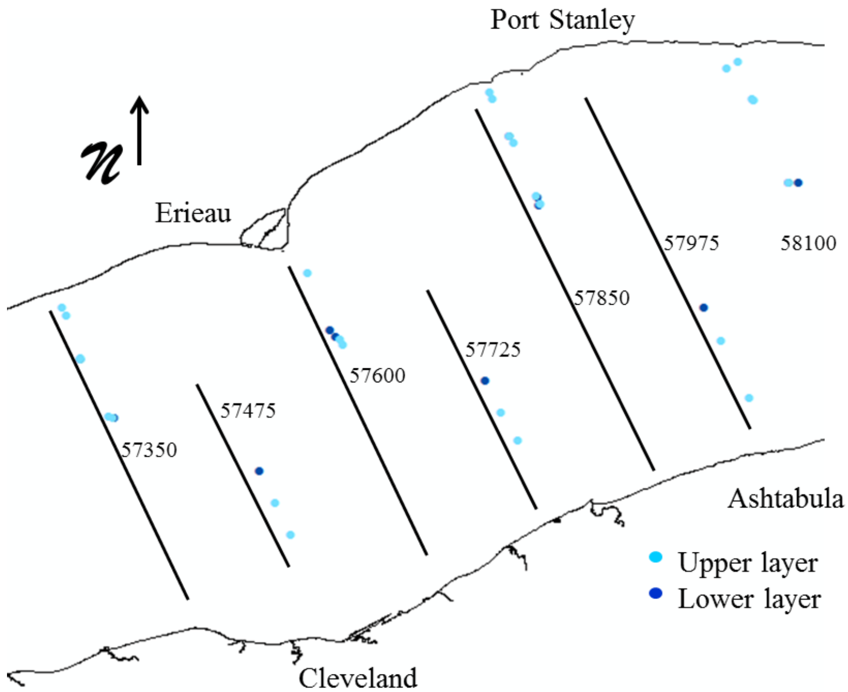


Figure 3.2.1 Hydroacoustic transects (solid lines) and midwater trawling stations (●) in the central basin, Lake Erie, July 5-9, 2016. Transect numbers are Loran-TD lines.

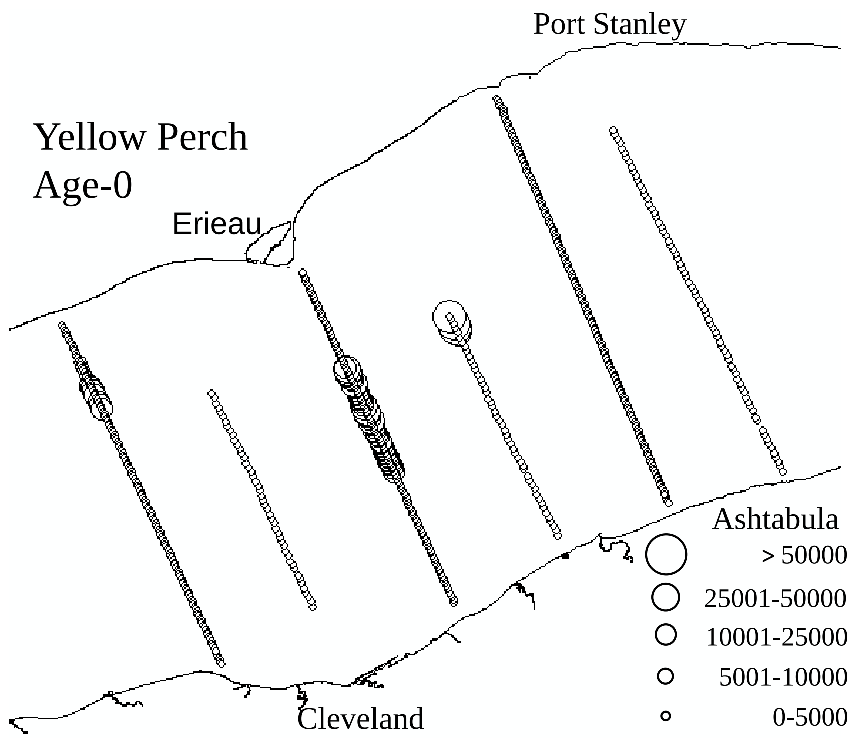


Figure 3.2.2. Density estimates of age-0 Yellow Perch (number per hectare) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 2 km segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2016.

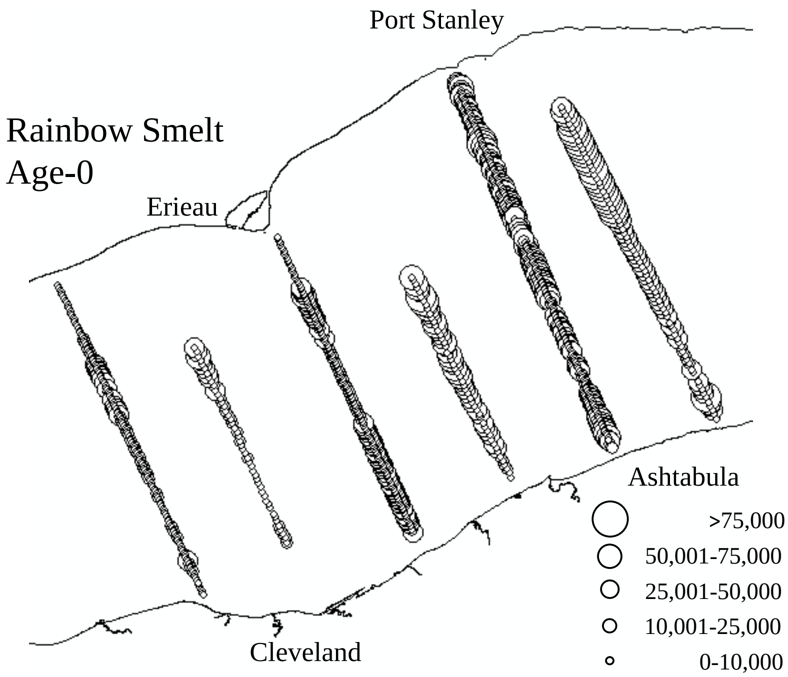


Figure 3.2.3. Density estimates of age-0 Rainbow Smelt (number per hectare) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 2 km segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2016.

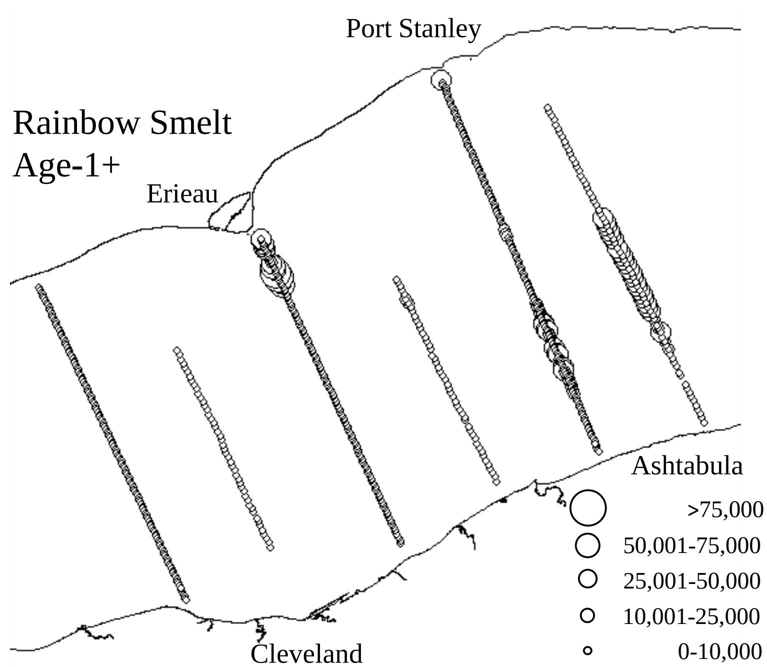


Figure 3.2.4. Density estimates of age-1+ Rainbow Smelt (number per hectare) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 2 km segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2016.

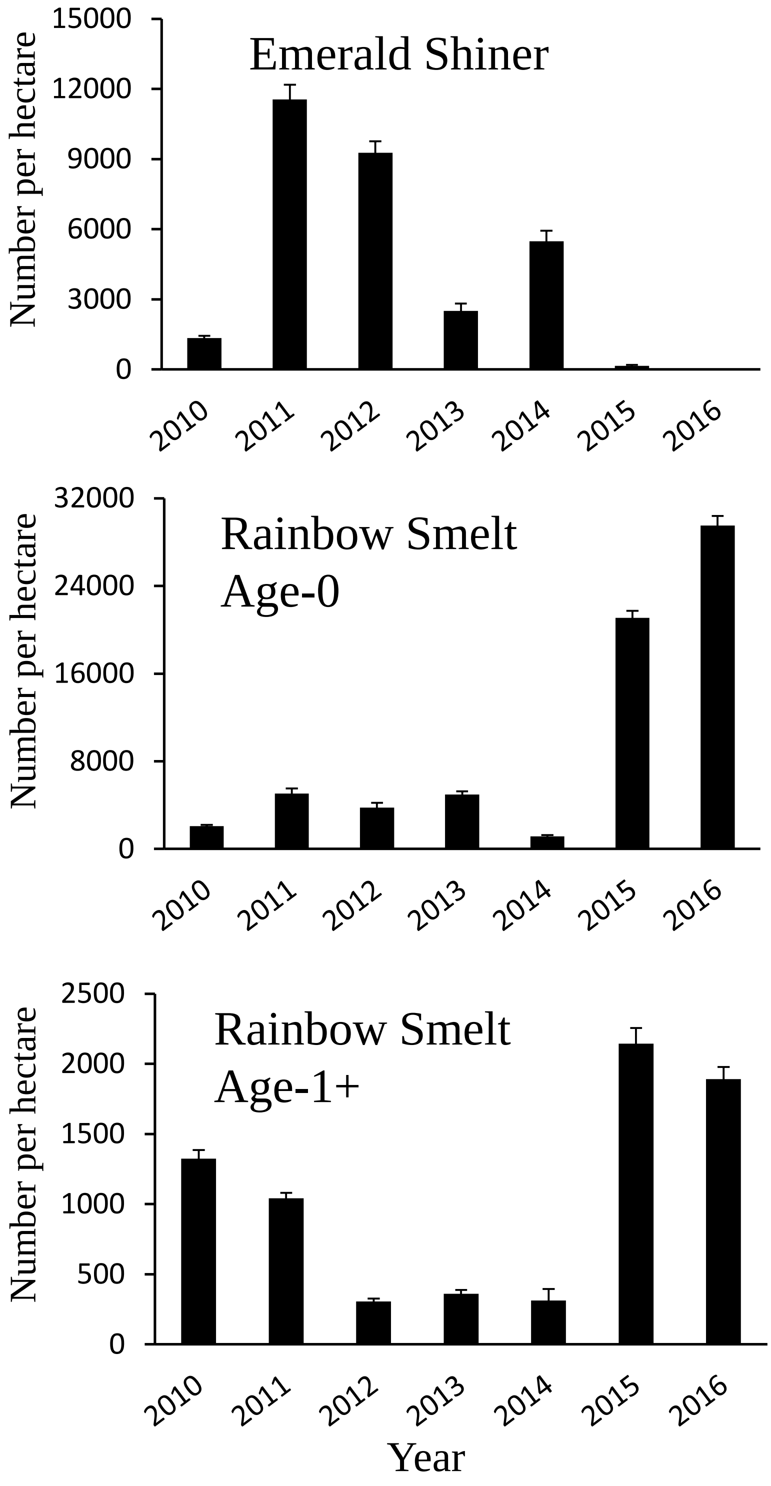


Figure 3.2.5. Mean density (number per hectare) estimates of pelagic forage fish during the July central basin, Lake Erie hydroacoustic survey, 2010-2016.

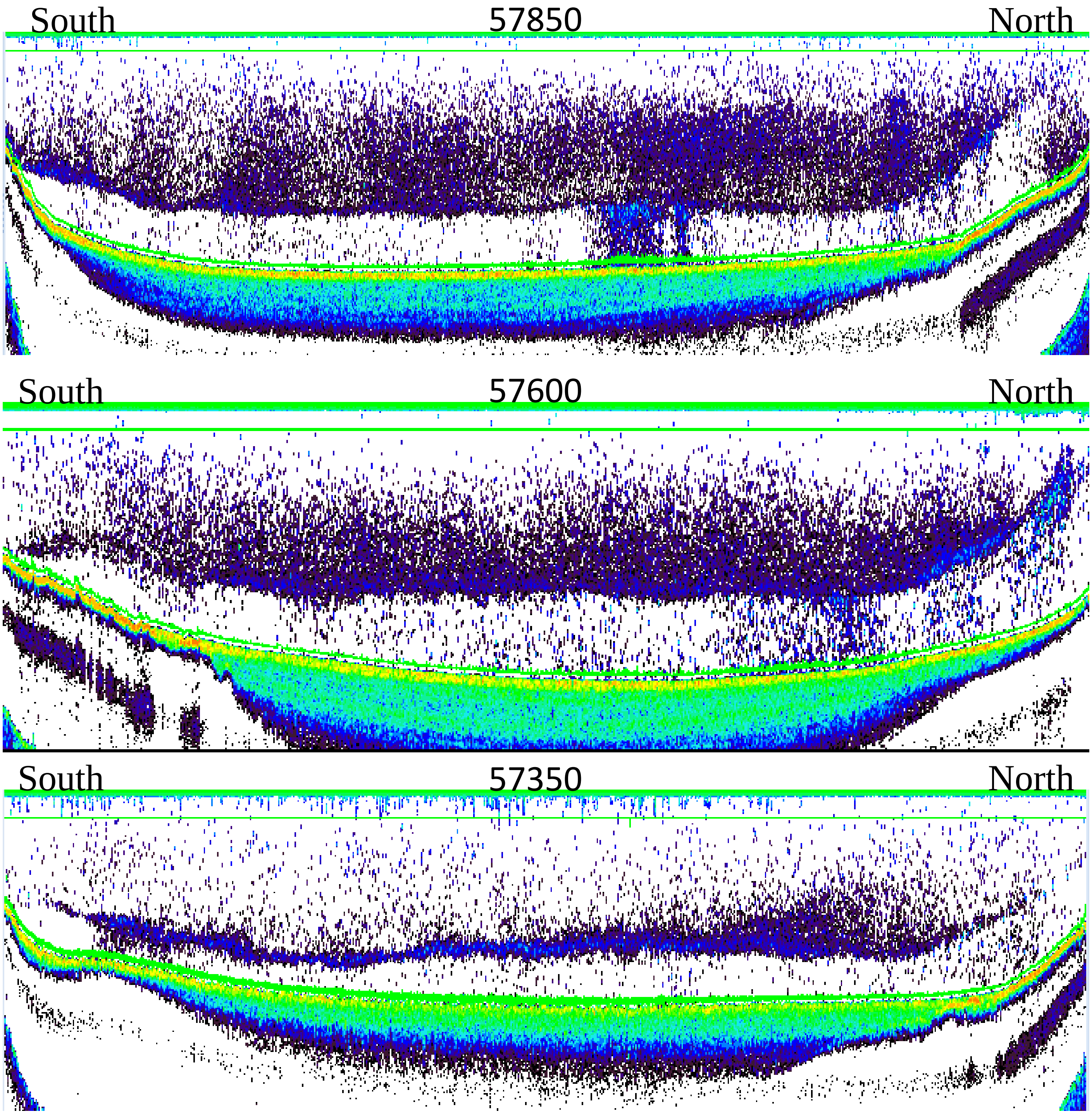


Figure 3.2.6. Echogram files generated from Echoview® software version 6.1 that show total back scattering (Sv) along transects run by the R/V *Muskie* in the central basin, 2016. Top panel is eastern transect, bottom panel is western transect.

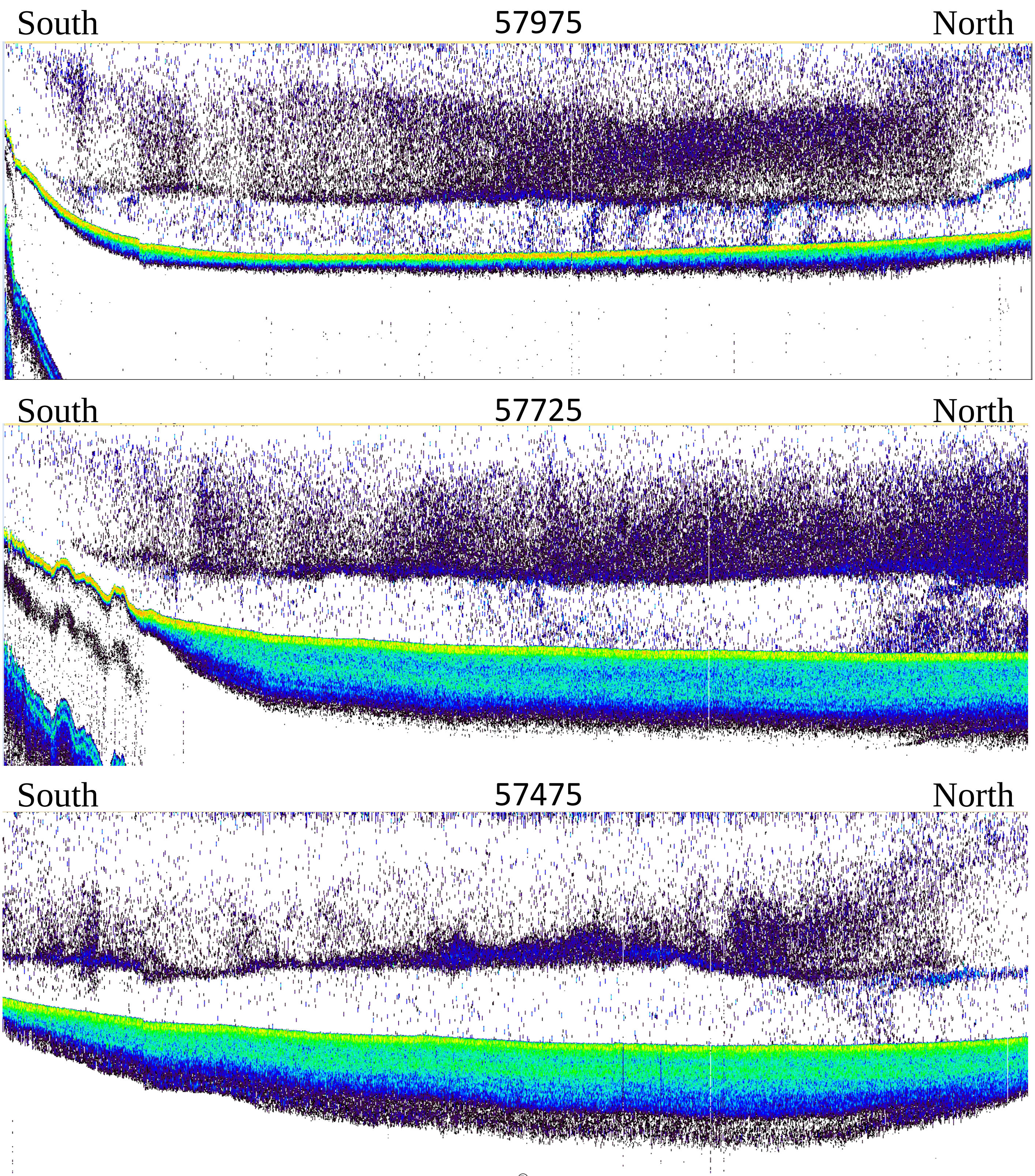


Figure 3.2.7. Echogram files generated from Echoview® software version 6.1 that show total back scattering (Sv) along transects run by the R/V *Grandon* in the central basin, 2016. Top panel is eastern transect, bottom panel is western transect.

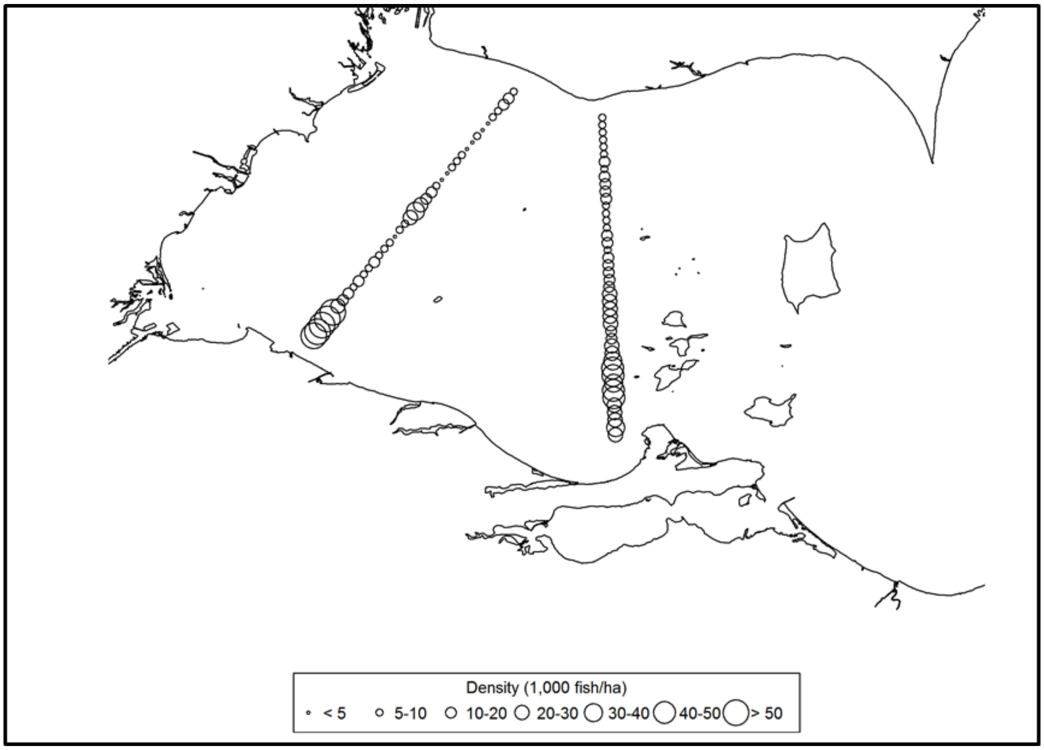


Figure 3.3.1. Acoustic survey transects and associated density (number per hectare) for the western basin of Lake Erie, 2016.

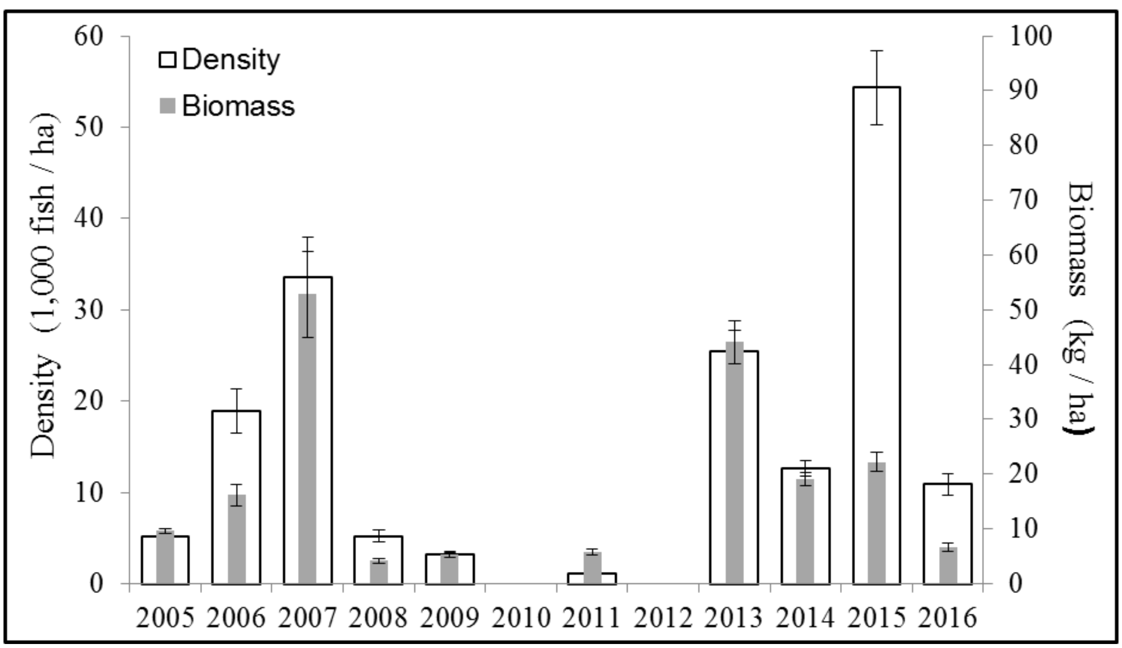


Figure 3.3.2. Mean density (number per hectare) and biomass (kilograms per hectare) estimates from the western basin acoustic survey, 2005-2016. Estimates are for acoustic targets between -60dB and -38dB. Error bars are standard errors.

Charge 4: Report on the use of forage fish and new invasive species in the diets of selected commercially or recreationally important Lake Erie predator fishes.

4.1 Eastern Basin (P. Penton and J. Markham)

Beginning in 1993, annual, summertime (June-August) visits were made to fish cleaning stations by the NYSDEC to gather stomach content information from angler-caught Walleye in the New York waters of Lake Erie. The number of Walleye stomachs examined annually has varied from a high of 409 in 2000 to a low of 34 in 2004. The percent of non-empty stomachs ranged from 58% in 1995 to 17% in 2016. During 2016, 143 Walleye stomachs were examined, of which 24 (17%) contained food remains. Throughout the time series, Rainbow Smelt have been the dominant diet item by volume for angler-caught adult Walleye (Figure 4.1.1). Mayfly nymphs (*Hexagenia* spp.) were occasionally observed in stomach samples during the earlier half of the time series, but they have not been encountered since 2002. In 2016, the contribution by volume of identifiable species included three fish species: Rainbow Smelt (41%), Round Goby (38%), and Yellow Perch (17%). The most commonly occurring prey items found in Walleye diets from summer index gillnets in Long Point Bay (28 non-empty stomachs examined) during 2016 were Rainbow Smelt (occurred in 64% of stomachs) and Round Goby (46%).

Round Goby have been a dominant component in the diets of Yellow Perch and Smallmouth Bass caught in gillnets in Long Point Bay and New York waters since 2000. In Long Point Bay, Round Goby occurred in 78% and 81% of non-empty Yellow Perch (n=163) and Smallmouth Bass (n=130) stomachs, respectively (Figure 4.1.2).

Rainbow Smelt have been the dominant food item in lean strain Lake Trout since coldwater netting surveys began in the early 1980s in Lake Erie, occurring in 85-95% of the stomachs. However, Round Goby have become a more common prey item since they invaded the eastern basin of Lake Erie in the early 2000s, especially during years of low Smelt abundance. Klondike strain Lake Trout have typically shown a higher incidence of Round Goby in stomach contents compared to lean strain Lake Trout. During 2016, 383 Lean strain Lake Trout and 19 Klondike strain Lake Trout stomachs were examined, of which 228 (60%) Lean and 8 (42%) Klondike Lake Trout contained food remains. Rainbow Smelt remained the dominant forage species in lean strain Lake Trout, occurring in 76% of the non-empty stomach samples (Figure 4.1.3). Round Goby were the next most abundant diet item, occurring in 28% of the stomach samples. In Klondike strain Lake Trout, Round Goby (75%) had a higher occurrence than Rainbow Smelt (50%) (Figure 4.1.4). One Freshwater Drum (3%) was the only other identifiable fish species found in 2016, and this was in a Lean strain Lake Trout. Two lean strain fish also contained Dreissenids in their stomachs, possibly consumed while foraging for benthic fish species.

Round Goby have increased in the diet of Burbot since this invasive species first appeared in Lake Erie's eastern basin in 1999, replacing Rainbow Smelt as the main prey item in Burbot diets in 9 of the last 13 years (Figure 4.1.5). In 2016, Round Goby (81%) were the most common fish species found in non-empty Burbot stomachs (n=36) followed by Rainbow Smelt (17%). Yellow Perch (6%) was the only other identifiable fish species found in 2016 samples. In general, Burbot appear to have a more diverse diet than Lake Trout over this time series.

Growth

Mean length of age-2 and age-3 Smallmouth Bass sampled in autumn gill nets (New York) have remained stable over ten years and are among the highest in the 35-year history of this survey. Beginning in the late 1990's, roughly coincident with the arrival of Round Goby, Smallmouth Bass in Long Point Bay, Ontario, exhibited a trend of increasing length-at-age (Figure 4.1.6). However, there has been a moderate decreasing trend in size-at-age of older age classes of Smallmouth Bass since the peak in 2008.

Walleye length at age-1 in 2016 from netting surveys targeting juveniles in New York was less than 2015, and below the long-term average. Length of age-2 Walleye in 2016 was similar to 2015 and the long term average. In general, age-0 and age-1 Yellow Perch have exhibited stable growth rates over the past ten years. Length-at-age of age-1 to age-6 Yellow Perch was above the time-series mean (1986-2016) in Ontario's Long Point Bay gillnet assessments in 2016. Mean size-at-age (length and weight) of Lake Trout in 2016 were consistent with the recent long-term mean (2006 – 2015) and condition coefficients (K) remain high. Klondike strain Lake Trout have significantly lower growth rates compared to Lean strain Lake Trout. Lake Trout growth in Lake Erie continues to be stable and among the highest in the Great Lakes.

There was no major change in fork length of age-0 Rainbow Smelt from 2015 (Figure 4.1.7), as measured in the Ontario survey. Both age-0 and yearlings remained below the long-term average.

4.2 Central Basin (J. Deller)

Diets of adult Walleye are collected from the central basin fall gillnet survey in Ohio waters. In 2016, 111 non-empty stomachs were examined and analyzed for diet composition. Gizzard shad comprised over 86% (by dry weight) of Walleye diets, followed by Rainbow Smelt (8.2%) (Figure 4.2.1). Emerald Shiners normally contribute up to 30% of Walleye diets. Emerald Shiners were not present in Walleye diets examined in 2016. The absence of Emerald Shiners in Walleye diets is most likely due to their extremely low abundance in the central basin.

Round Goby continue to comprise the bulk of Smallmouth Bass Diets in the central basin. In 2016, Round Goby accounted for 89.2% of Smallmouth Bass diets by dry weight (Figure 4.2.2). This was the second highest consumption rate by Smallmouth Bass in a 6 year time series. In 2012, Round Goby comprised over 40% of Adult Yellow Perch diets. Round Goby contributions to Yellow Perch diets has increased to 18% in 2016, reversing a declining trend over the last three years.

Growth

Growth rates of most age-0 predator and forage species in 2016 were below the long-term mean (10 years, 2006-2015). Gizzard Shad was the only species that was above the long-term mean and were some of the largest sizes in the time series. The high summer water temperatures experienced in 2016 most likely contributed to the large size of age-0 Gizzard Shad. Mean length at age for Walleye was below long-term means through age-3. There has been a slight decrease in length at age since 2013 for Walleye through age 5. Mean length of White Bass and Yellow Perch are generally at long-term means through age-6, with no apparent trends in length at age for either species.

4.3 Western Basin (P. Kočovský and E. Weimer)

In 2016, adult Walleye diets (by frequency of occurrence) taken from ODNR fall gillnet catches consisted of Gizzard Shad (65%), White Perch (9%), Emerald Shiners (4%), and Yellow Perch (4%), and unidentifiable fish remains (17%) in the western basin. Yearling Walleye relied on Gizzard Shad (55%), White Perch (6%), Yellow Perch (3%), Round Goby (3%), and unidentifiable fish remains (33%). Only unidentifiable fish remains were found in age-0 Walleye.

Age-2-and-older Yellow Perch were collected for diet content analysis from the western basin during spring (June) and autumn (September) by the U.S. Geological Survey. In spring, benthic macroinvertebrates were present in the highest frequency of diets (74.1%). The occurrence of zooplankton in diets was 51.7% in spring, and increased to 70.5% in the autumn. Fish prey had a 6.9% occurrence in spring diets, and increased in to 10.2% in autumn diets. Ephemeridae (36.2%; exclusively *Hexagenia* spp.), Trichoptera (39.7%), and Chironomidae (32.8%) were the most prominent benthic macroinvertebrates in spring, whereas Ephemeridae (25%) was the most frequently encountered benthic prey taxon in autumn diets. The most commonly found zooplankton prey in spring diets was Daphnidae (50%) and Leptodoridae (29.3%), and Cercopagididae (22.4% exclusively *Bythotrephes* sp.) While in autumn diets, Cercopagididae (68.2%) and Daphnidae (47.7%) were the most common zooplankton. The occurrence of fish prey minimally increased from spring to autumn (6.9% and 10.2% of diets, respectively) with Round Goby (1.7% and 6.8%, respectively) being the most common identifiable fish prey in both seasons. Larval fish (not identified) were observed in 2 Yellow Perch stomachs. There was no observed invasive *Hemimysis* sp. or *Cercopagis* sp. identified in Yellow Perch diets from the western basin in 2016. Comparisons to historical data collected in Michigan and Ontario waters suggest an increasing trend in frequency of occurrence in zooplankton prey for spring and autumn Yellow Perch diets.

Percent composition by dry weight revealed a pattern similar to the frequency of occurrence data for Yellow Perch diets. Benthic macroinvertebrates contributed most to Yellow Perch diets in spring (55.4%), followed by zooplankton (41%) and fish prey (3.4%). In spring, Ephemeridae (18.3%) were the predominant benthic macroinvertebrate contributors by weight followed by Trichoptera, Dreissenidae, and Gastropoda (8.9%, 8.8%, and 8.5% respectively). In autumn, zooplankton made the highest contribution to diets (63.7%), followed by benthic macroinvertebrates (29.4%) and fish prey (5.9%). The major zooplankton taxa contributor in autumn was Cercopagididae (56.8%). Ephemeridae accounted for 57.4% of total benthic macroinvertebrate weight observed in diets. The major identifiable fish prey contributor in autumn was Round Goby (5.6%). An increasing contribution of fish prey to Yellow Perch diets from spring to autumn is consistent with our historical observations.

Growth

Overall, mean length of age-0 sport fish in 2016 increased compared to 2015 (Figure 4.3.1). Lengths of select age-0 species in 2016 include Walleye (125 mm), Yellow Perch (73 mm), White Bass (72 mm), White Perch (66 mm), and Smallmouth Bass (87 mm). With the exception of Walleye, these lengths are above long-term averages (138 mm, 67 mm, 67 mm, 58 mm, and 79 mm, respectively).

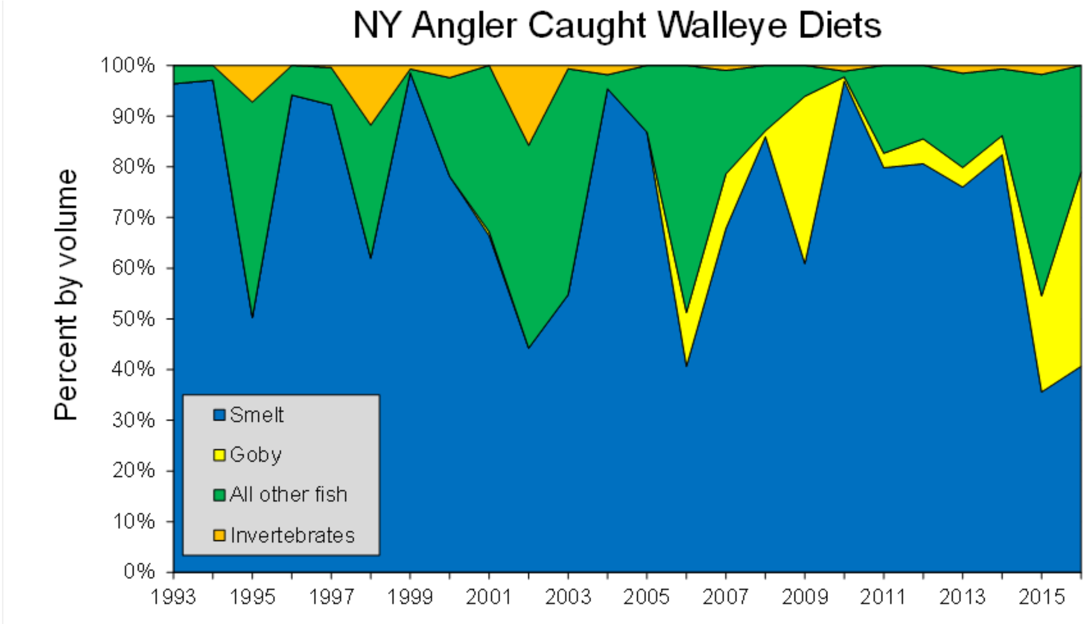


Figure 4.1.1. The percent contribution (by volume) of identifiable prey in stomachs of adult Walleye caught by summertime anglers in New York's portion of Lake Erie, 1993-2016.

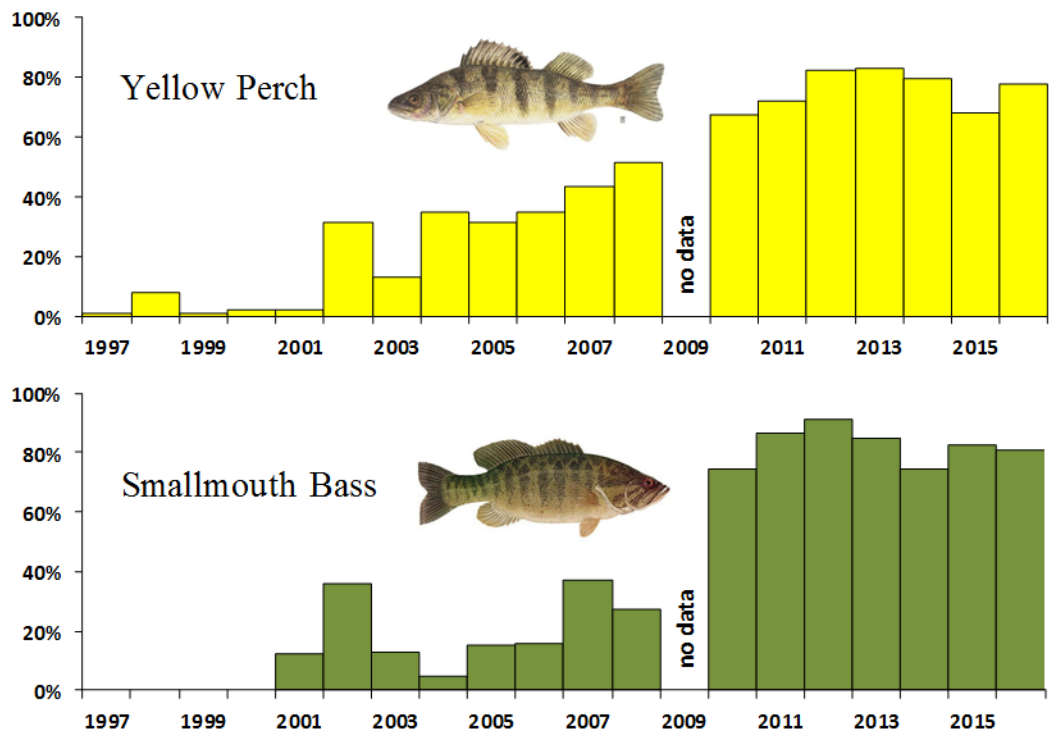


Figure 4.1.2. Percent occurrence of Round Goby in non-empty stomachs of adult Yellow Perch and Smallmouth Bass from OMNRF summer index gillnets, Long Point Bay, Lake Erie 1997-2016.

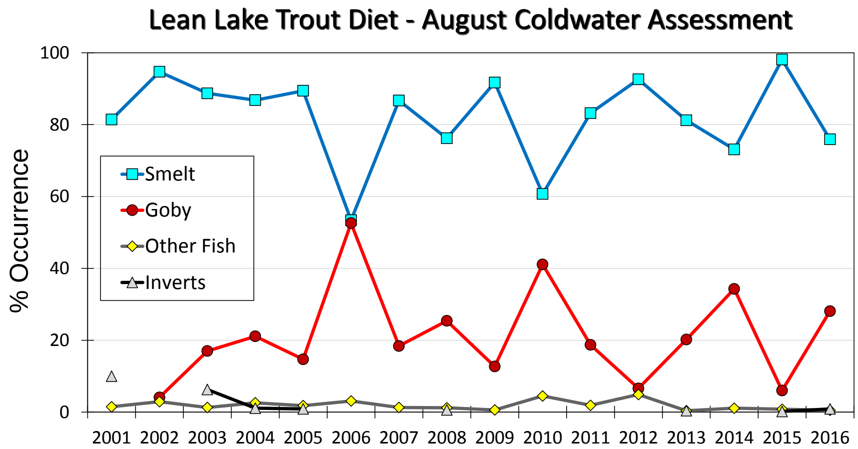


Figure 4.1.3. Percent occurrence of diet items from non-empty stomachs of Lean strain Lake Trout collected in eastern basin gill net assessments, August, 2001-2016.

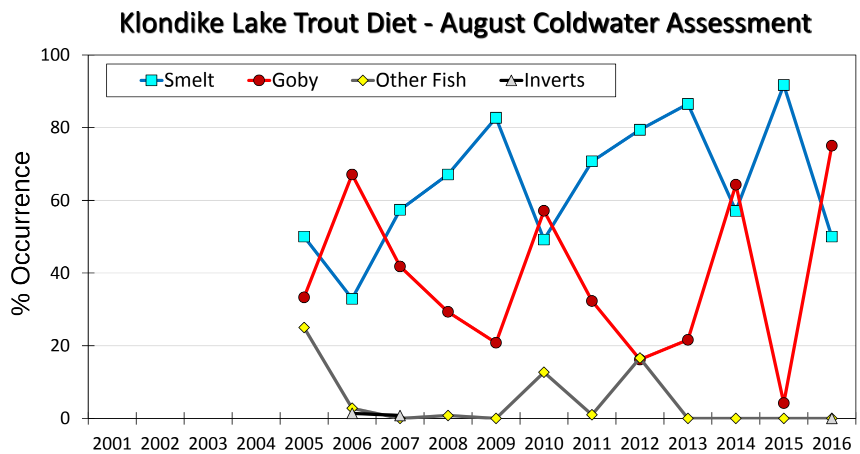


Figure 4.1.4. Percent occurrence of diet items from non-empty stomachs of Klondike strain Lake Trout collected in eastern basin gill net assessments, August, 2001-2016.

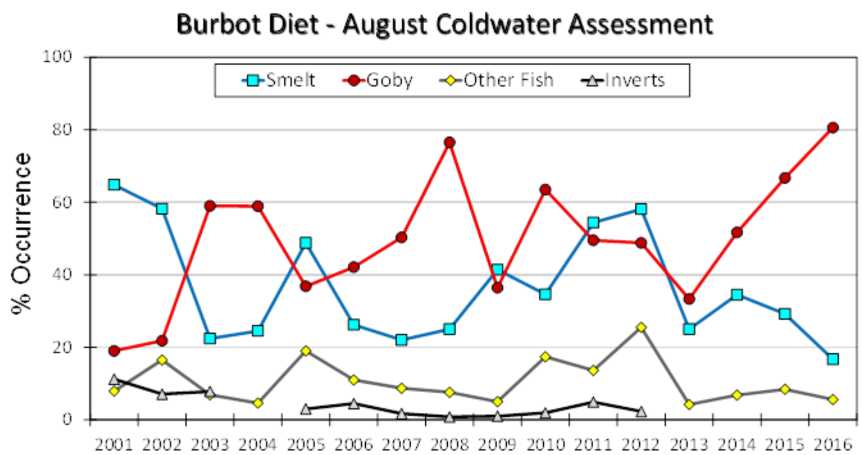


Figure 4.1.5. Percent occurrence of diet items from non-empty stomachs of Burbot collected in eastern basin gill net assessments, August, 2001-2016.

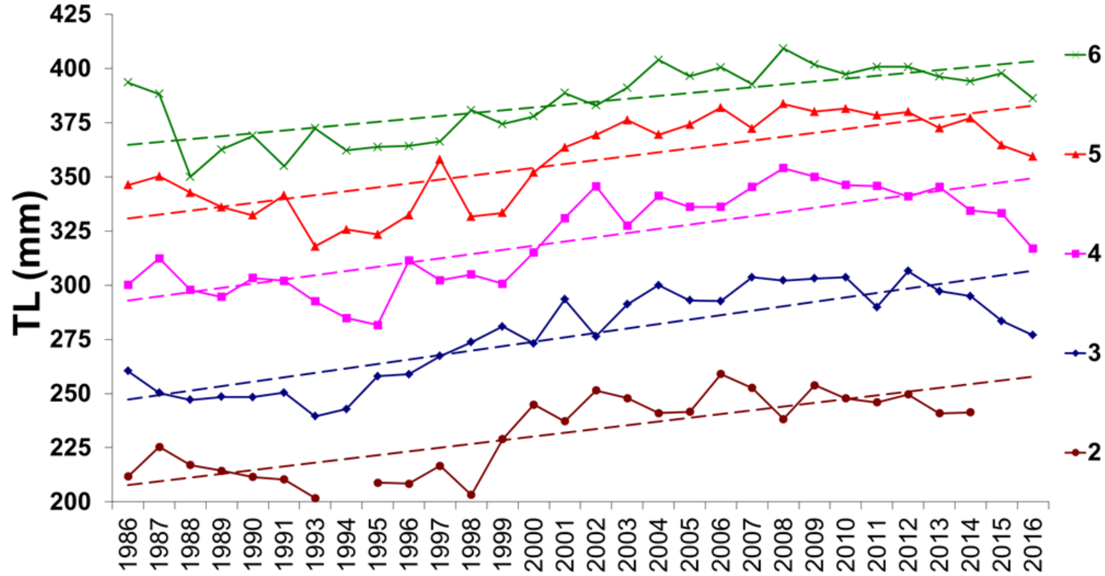


Figure 4.1.6. Smallmouth Bass mean total length (mm) at ages 2 to 6 captured in index gill nets set overnight at 12-30 ft. (3.7-9.1m) depths during summer months in Long Point Bay, Lake Erie, 1986-2016. Males and females combined. Dashed lines represent linear trend across years for each age class. Smallmouth Bass ages were not available for 1992 samples.

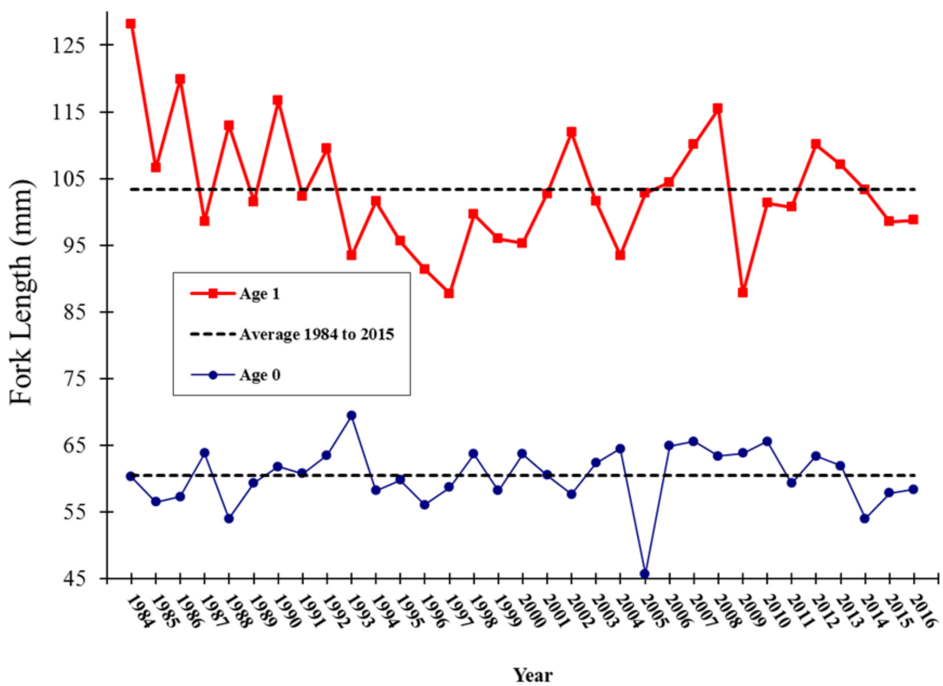


Figure 4.1.7 Mean fork length of age-0 and age-1 Rainbow Smelt from OMNRF index trawl surveys in Long Point Bay, Lake Erie, October 1984 to 2016.

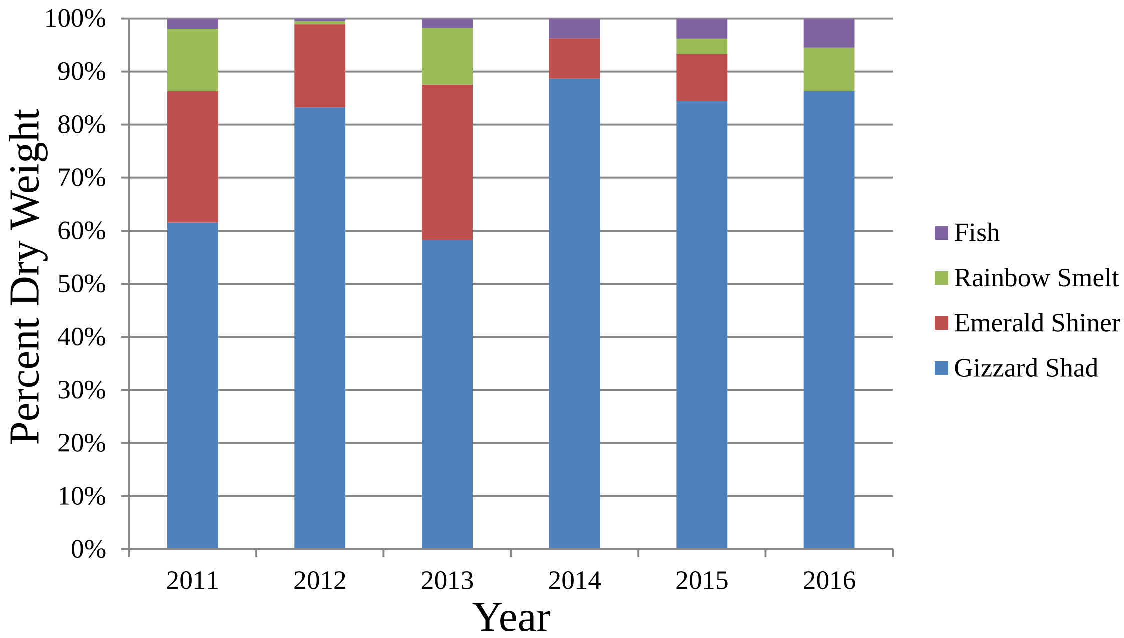


Figure 4.2.1. Adult Walleye diet composition (Percent dry weight) from non-empty stomachs collected in gill nets from central basin, Ohio waters of Lake Erie, 2011 - 2016.

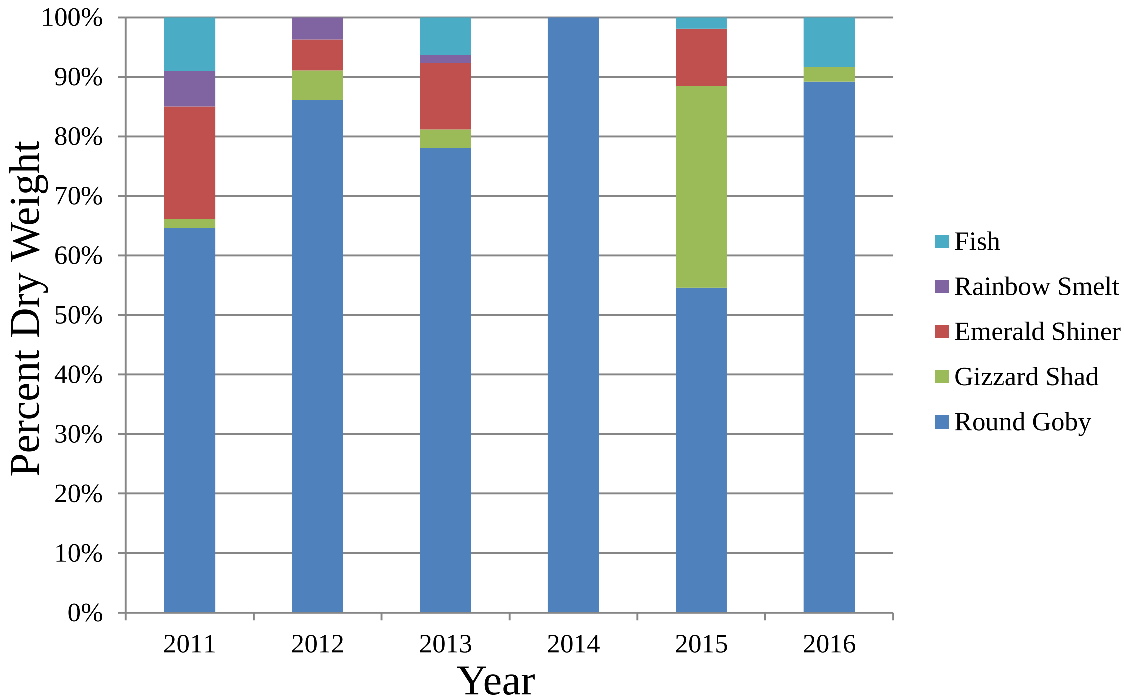


Figure 4.2.2. Adult Smallmouth Bass diet composition (Percent dry weight) from non-empty stomachs collected in gill nets from central basin, Ohio waters of Lake Erie, 2011 - 2016.

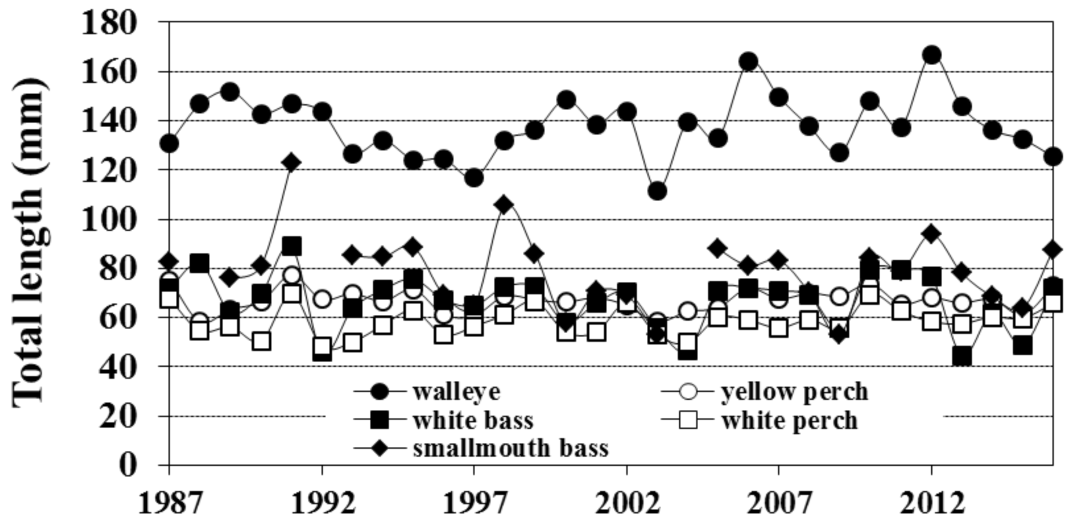


Figure 4.3.1. Mean total length (mm) of select age-0 fishes in western Lake Erie, August 1987- 2016.

Charge 5: Develop and maintain a database to track Aquatic Invasive Species in Lake Erie

(P. Kočovský)

In 2016, the Lake Erie Committee added a new Forage Task Group (FTG) charge to "Develop and maintain a database to track Aquatic Invasive Species (AIS) in Lake Erie." This charge was developed in recognition of the need for a systematic, centralized, lake-wide effort to track records of new, non-native species that might become invasive. The recognized need to better track status of the most recent invaders of management interest, Grass Carp and Hemimysis shrimp, was the impetus for creating this new charge. Placing this charge with the Forage Task Group takes advantage of the FTG's access to sampling data throughout Lake Erie, through which many new invasive species are frequently detected (e.g., Round Goby, White Perch).

To assist with this task and to provide invasive species expertise, the FTG added two new members. Dave Marson with Department of Fisheries and Oceans/Pêches et Océans Canada and Andrew Briggs with the US Fish and Wildlife Service. Both have invasive species experience or duties.

In 2016, we stated our primary products would be 1) a list of potentially injurious aquatic species to track and 2) creation of a non-native-species database to track abundance and distribution of non-native aquatic species. The FTG has adopted the USFWS service list of injurious freshwater species (https://www.fws.gov/injuriouswildlife/11-freshwater-species.html) as the primary species to track. All of those species are believed to be presently absent from Canadian and US waters, with the exception of Prussian Carp, which are abundant and spreading in rivers in southern Alberta (Elgin et al. 2014, Docherty 2016). We also include Bighead Carp, Silver Carp, and Black Carp as species that are currently absent but potentially damaging to Lake Erie, Grass Carp, which are present and reproducing in at least on Lake Erie tributary (Embke et al. 2016), and Rudd, which have reproducing populations in Ontario and New York waters connected to Lake Erie. We also have a secondary list in preparation of "candidate species," and we will include other non-native species not on the injurious species or candidate lists as they are reported.

In 2016, FTG members reported 5 species on the Injurious Species list or other unusual non-native species. Three Pacu were reported to Michigan DNR by anglers in Lake St. Clair. One Piranha was reported in a private pond within the Lake Erie basin. Neither of these species is believed to pose a threat as neither is particularly well adapted to tolerating cold winter water temperatures. One Shovelnose Catfish (*Chrysichthys sharpii*), native to southern Africa was reported from the River Raisin. The IUCN (International Union for Conservation of Nature and Natural Resources (http://www.iucnredlist.org/static/categories_criteria_3_1) classifies this species as least concern. Rudd were captured in Nanticoke Creek (N=8), Grand River (N=154), Welland River (N=32), and Long Point Bay (N=2) in Ontario. Rudd have been captured in and are reproducing in the upper Niagara River, but no records of Rudd were reported from New York waters in 2016. Forty-five Grass Carp were reported from Michigan (N=23), New York (N=5), Ohio (N=7), and Ontario (N=10) waters of Lake Erie or its connected waterways in 2016. The majority were reproductively-capable diploid fish. All of the triploid fish came from Lake Gibson, ON, which connects to the Welland Canal. All Grass Carp captured in ON and NY waters were killed, while all captured in MI and OH were released alive following surgical implantation of acoustic tags as part of collaborative research to track Grass Carp movements.

Protocol for Use of Forage Task Group Data and Reports

- The Forage Task Group (FTG) 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. 2016. Report of the Lake Erie Forage Task Group, March 2017. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Acknowledgments

The Forage Task Group would like to thank Dr. Lars Rudstam (Cornell University), and Dr. Dave Warner (USGS-GLSC) for their continued support of hydroacoustic surveys, section 4.0; and Jason Robinson (NYSDEC), Derek Chamberlin (Ohio State University), Andy Cook (OMNRF), Betsy Bodamer-Scarbro, Bill Edwards, Taylor Stewart (USGS-LEBS) for contributions to multiple sections of this report.

Literature Cited

Bur, M. T., M. Klarer, and K. A. Krieger. 1986. First records of a European cladoceran, *Bythotrephes cederstroemi*, in Lakes Erie and Huron. Journal of Great Lakes Research 12 (2):144-146.

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

Craig, J.K. and L.B. Crowder. 2005. Hypoxia-induced habitat shifts and energetic consequences in Atlantic croaker and brown shrimp on the Gulf of Mexico shelf Mar Ecol Prog Ser Vol. 294: 79?94.

Docherty, C. H. 2016. Establishment, spread and impact of Prussian Carp (*Carassius gibelio*), a new invasive species in Western North America. Master's Thesis, University of Alberta, 69 pp.

Eby, L.A., and L.B. Crowder. 2002. Hypoxia-based habitat compression in the Neuse River Estuary: context-dependent shifts in behavioral avoidance thresholds. Can. J. Fish. Aquat. Sci. 59:952-965.

Elgin, E. L., H. R. Tunna, and L. J. Jackson. 2014. First confirmed records of Prussian carp, *Carassius gibelio* (Bloch, 1782) in open waters of North America. BioInvasions Records 3:275-282.

Embke, H.S., P. M Kočovský, C. A. Richter, J. J. Pritt, C. M. Mayer, S. S. Qian. 2016. First direct confirmation of Grass Carp spawning in a Great Lakes tributary. J. Great Lakes Res. 42, 899-903.

Forage Task Group. 2015. Report of the Lake Erie Forage Task Group, March 2015. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Forage Task Group. 2014. Report of the Lake Erie Forage Task Group, March 2013. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Forage Task Group. 2005. Report of the Lake Erie Forage Task Group, March 2005. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission, Ann Arbor, Michigan, USA.

Horppila J., T. Malined, and H. Peltonen. 1996. Density and habitat shifts of a roach (*Rutilus rutilus*) stock assessed within one season with cohort analysis, depletion methods, and echosounding. Fisheries Research 28:151-161.

Kraus, R.T., Knight, C.T., Farmer, T.M., Gorman, A.M., Collingsworth, P.D., Warren, G.J., Kocovsky, P.M., and J.D. Conroy. 2015. Dynamic hypoxic zones in Lake Erie compress fish habitat, altering vulnerability to fishing gears. Canadian Journal of Fisheries and Aquatic Sciences 72 (6): 797-806.

Leach, J.H., M.G. Johnson, J.R.M. Kelso, J. Hartman, W. Numan, and B. Ents. 1977. Responses of percid fishes and their habitats to eutrophication. J. Fish. Res. Board. Can. 34:1964-1971.

Love, R. H. 1971. Dorsal aspect target strength of an individual fish. J. Acoust. Soc. Am. 49: 816-823.

Muzinic, C. J. 2000. First record of *Daphnia lumholtzi* Sars in the Great Lakes. Journal of Great Lakes Research 26(3):352-354.

Parker-Stetter, S. L., L. G. Rudstam, P. J. Sullivan and D. M. Warner. 2009. Standard operating procedures for fisheries acoustic surveys in the Great Lakes. Great Lakes Fish. Comm. Spec. Pub. 09-01.

Rudstam, L. G., Parker-Stetter, S. L., Sullivan, P. J., and Warner, D. M. 2009. Towards a standard operating procedure for fishery acoustic surveys in the Laurentian Great Lakes, North America. – ICES Journal of Marine Science 66.

Rudstam, S. L., S. L. Parker, D. W. Einhouse, L. D. Witzel, D. M. Warner, J. L. Stritzel, D. L. Parrish, and P. J. Sullivan. 2003. Application of in situ target –strength estimations in lakes: examples from Rainbow Smelt surveys in Lakes Erie and Champlain. ICES Journal of Marine Science, 60: 500-507.

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

Ryder, R.A., and S.R. Kerr. 1978. Adult Walleye in the percid community - a niche definition based on feeding behavior and food specificity. Am. Fish. Soc. Spec. Pub. 11.

Sawada, K., M. Furusawa, and N. J. Williamson. 1993. Conditions for the precise measurement of fish target strength *in situ*. Journal of the Marine Acoustical Society of Japan, 20: 73-79.

Therriault, T. W., I. A. Grigorovich, D. D. Kane, E. M. Haas, D. A. Culver, and H .J. MacIsaac. 2002. Range expansion of the exotic zooplankter *Cercopagis pengoi* (Ostroumov) into western Lake Erie and Muskegon Lake. Journal of Great Lakes Research 28(4):698-701.

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