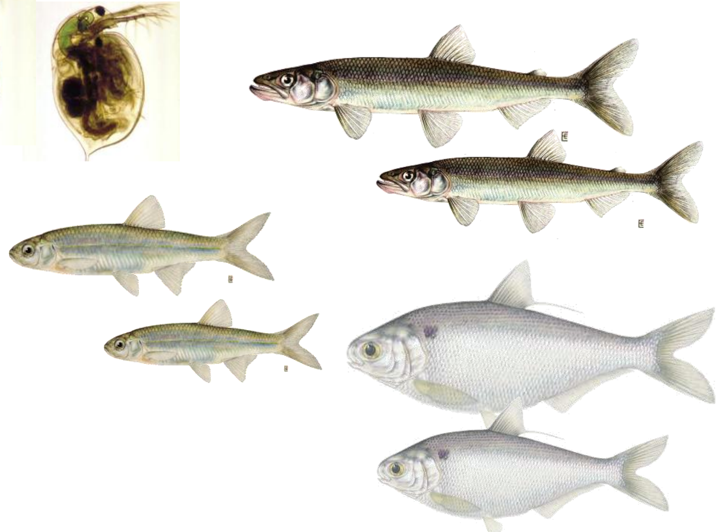
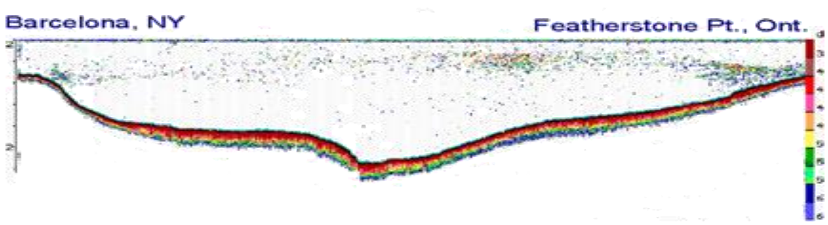
Report of the
Lake Erie
Forage Task Group

March 2014





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Presented to:

Standing Technical Committee
Lake Erie Committee
Great Lakes Fishery Commission

Charges to the Forage Task Group 2013-2014

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. Continue the development of an experimental design to facilitate forage fish assessment and standardized interagency reporting.

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

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

In 1999, the Forage Task Group (FTG) initiated a Lower Trophic Level Assessment program (LTLA) within Lake Erie and Lake St. Clair (Figure 1.0.1). Nine key variables, as identified by a panel of lower trophic level experts, were measured to characterize ecosystem change. These variables included profiles of temperature, dissolved oxygen 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 15 years of data for summer surface temperature, summer bottom dissolved oxygen, chlorophyll *a* concentrations, zooplanktivory, 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 western 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 eastern 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 western, central and nearshore waters of the eastern basin, and oligotrophic conditions that favor salmonids in the offshore waters of the eastern 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 eastern 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 meter 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 are warmest in the western basin (mean=23.5 °C), becoming progressively cooler in the central (mean = 22.0 °C) and eastern basins (mean = 20.7 °C) (Figure 1.0.2). Mean summer surface temperatures range from 21.6 °C (2009) to 25.2 °C (2006) in the western 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 eastern basin. Above average temperatures were evident across all basins in 2005, 2006, 2010, 2011 and 2012; below average temperatures occurred in 2000, 2003, 2004, 2008, and 2009. Increasing trends in summer surface water temperature are not apparent for this 15 year time series. In 2013, the mean summer surface water temperature was below average in all three basins. The average water temperature in the west basin was 22.9 °C, 21.2 °C in the central basin and 19.6 °C 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). DO can become low when the water column becomes stratified, which can begin in early June and continue through September in the central and eastern basins. In the western 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 2013, there were no observations from the western 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 2013, bottom DO was below 2.0 mg/L threshold in the central basin on two occasions at Station 10 (8/16/2013, 0.5 mg/L; 8/30/2013, 0.8 mg/L) and once at Station 11 (8/29/2013, 0.9 mg/L) (Figure 1.0.3).

Dissolved oxygen rarely limits the distribution of fish and other aquatic biota in the eastern 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 7.0 mg/L were recorded in the east basin in 2013.

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 15 year time series, falling into eutrophic status rather than mesotrophic status (Figure 1.0.4). Annual variability is also the highest in the west basin. In 2013, the mean chlorophyll *a* concentration was 5.7 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 2013 (3.8 µg/L) (Figure 1.0.4). In the eastern basin, chlorophyll *a* concentrations in the nearshore waters have been below the targeted mesotrophic level for the entire time series (Figure 1.0.4). This may be due to high levels of grazing by dreissenids (Nicholls and Hopkins 1993) in the nearshore eastern basin waters where biomass of quagga mussels (*Dreissena bugensis*) remains high (Patterson et al. 2005). Conversely, chlorophyll *a* levels in the offshore waters of the eastern basin remain in, or slightly above, the targeted oligotrophic range. In 2013, the mean chlorophyll *a* concentrations were 1.9 µg/L in the nearshore waters of the eastern basin and 2.6 µg/L in the offshore waters. Chlorophyll *a* concentrations are most stable in the eastern basin.

Total Phosphorus

Total phosphorus levels in the western basin have exceeded FCO targets since the beginning of the LTLA monitoring program (Figure 1.0.5). Total phosphorus concentrations in the west basin increased slightly in 2013 to 28.7 µg/L, the fifth lowest in the series, but still well above the target range. In the central basin, total phosphorus levels have been increasing and have exceeded FCO targets since 2006 (Figure 1.0.5). In 2013, the central basin experienced a decline in total phosphorus (24.0 µg/L) for the second consecutive year. In the nearshore waters of the eastern 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 declines have been seen the last three years including 2013. Total phosphorus levels in the offshore waters of the eastern basin show a similar trend to nearshore waters, and have recently risen above the targeted oligotrophic range into the mesotrophic range. In 2013, total phosphorus concentrations in the eastern basin increased slightly in the nearshore waters (11.8 µg/L) but remained within their targeted mesotrophic range, and increased in the offshore waters (14.0 µg/L) and were higher than their targeted oligotrophic range.

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 western basin, for the entire time series (Figure 1.0.6). Mean summer Secchi depth in the western basin was 2.1 m in 2013, which was slightly higher than the past two years. In contrast, water transparency in the central basin has remained within the targeted mesotrophic range for the entire series, including 2013 (3.4 m) (Figure 1.0.6). Eastern basin transparency was in the oligotrophic range from 1999 through 2007, which exceeded FCO targets for the nearshore waters. The eastern basin has been stable and within the FCO targets for the last six years (Figure 1.0.6). In the offshore waters of the eastern basin, water transparency was within the oligotrophic target from 1999 through 2007, but fell into the mesotrophic range in five of the last six years. In 2013, mean summer Secchi depth was 5.2 m in the nearshore waters of the eastern basin, which was within the targeted mesotrophic range, and 5.9 m in the offshore waters, which was slightly below the targeted oligotrophic range.

Zooplanktivory Index and Biomass

Planktivorous fish are size-selective predators, removing larger prey with a resultant decrease in the overall size of the prey community that reflects feeding intensity (Mills et al. 1987). Johannsson et al. (1999) estimated that a mean zooplankton length of 0.57 mm or less sampled with a 63-µm net reflects a high level of predation by fish. Between 1999-2004, predation of zooplankton (zooplanktivory) was high in Lake Erie as the average size of the community was generally less than this critical 0.57 mm size (Figure 1.0.7). Since 2005 in the western basin and 2006 in the central basin, the mean size of the zooplankton community has been greater than the critical size, indicating low zooplanktivory for all years except 2007. This trend continued in 2013 in both the western and central basins with zooplankton mean length remaining above the critical size. In the eastern basin, the zooplanktivory index has been the most stable compared to the other two basins and is generally around the critical size level, including 2013.

Zooplankton biomass varies among basins and years. In the western basin, the 2013 mean biomass was 85.6 mg/m^3, which was slightly below the long term average of 89.4 mg/m^3 (Figure 1.0.8). In the central basin, the 2013 mean zooplankton biomass declined from the time series high in 2012 to 245.5 mg/m^3. However, this was the second highest zooplankton biomass in the series and well above the series average of 123.7 mg/m^3. In the east basin, the 2013 mean biomass was 102.7 mg/m^3, which was the third highest in the series and well above the average of 59.7 mg/m^3. From 1999 to 2007, there appeared to be a gradient of high zooplankton biomass in the west and lower biomass in the east. In addition, cladocerans were more dominant in the west basin than elsewhere. Since 2009, zooplankton biomass has been highest in the central basin with the exception of 2011 when it was highest in the east basin.

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 eastern basin stations, but is very rare at western 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 western 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 western 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 record for the eastern 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 2013 indicate that the western 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 and nearshore eastern basin, the lower trophic measures in 2013 mainly fell within the targeted mesotrophic range preferred by percids. However, it is worth noting that total phosphorus concentrations in the central basin remained in the eutrophic range in 2013. In the offshore waters of the eastern basin, measures of total phosphorus, chlorophyll *a*, and transparency indicate a mesotrophic class that favored percids instead of the targeted oligotrophic range favored by salmonids.

Lower Trophic Protocol Review

In 2013, the FTG conducted a review of field and laboratory protocols to determine the degree of adherence to the original protocols. That review revealed some degree of drift. A primary reason for drift in field methods was development of new technologies (e.g., integrated tube samplers, continuously-recording meters for dissolved oxygen, nutrients, etc.). In 2014 standard protocols will be re-established, a metadata document will be developed to track changes/revisions to the protocols, and a time frame for subsequent reviews will be established.

Table 1.0.1. Ranges of selected lower trophic indicators for each trophic class and associated fish community (Leach et al. 1977; Ryder and Keer 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, 2013. The east basin is separated into nearshore and offshore.

Basin	Phosphorus (µg/L)	Chlorophyll a (µg/L)	Transparency (m)	Trophic Class
West	29	5.7	2.1	Eutrophic
Central	24	3.8	3.4	Mesotrophic
East - Nearshore	12	1.9	5.2	Mesotrophic
East - Offshore	14	2.6	5.9	Mesotrophic

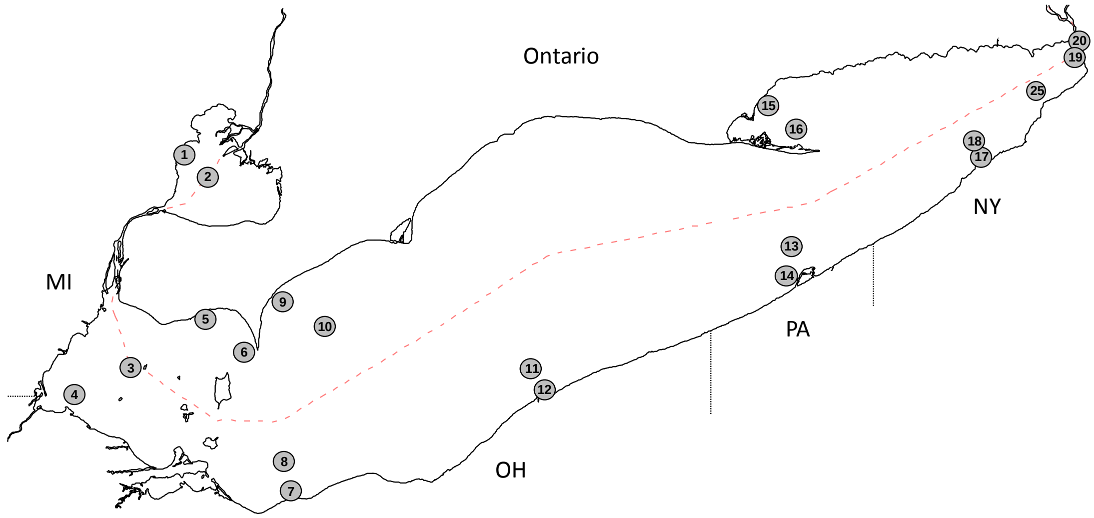

Figure 1.0.1. Lower trophic level sampling stations in Lake Erie and Lake St. Clair. Station 25 was added in 2009.

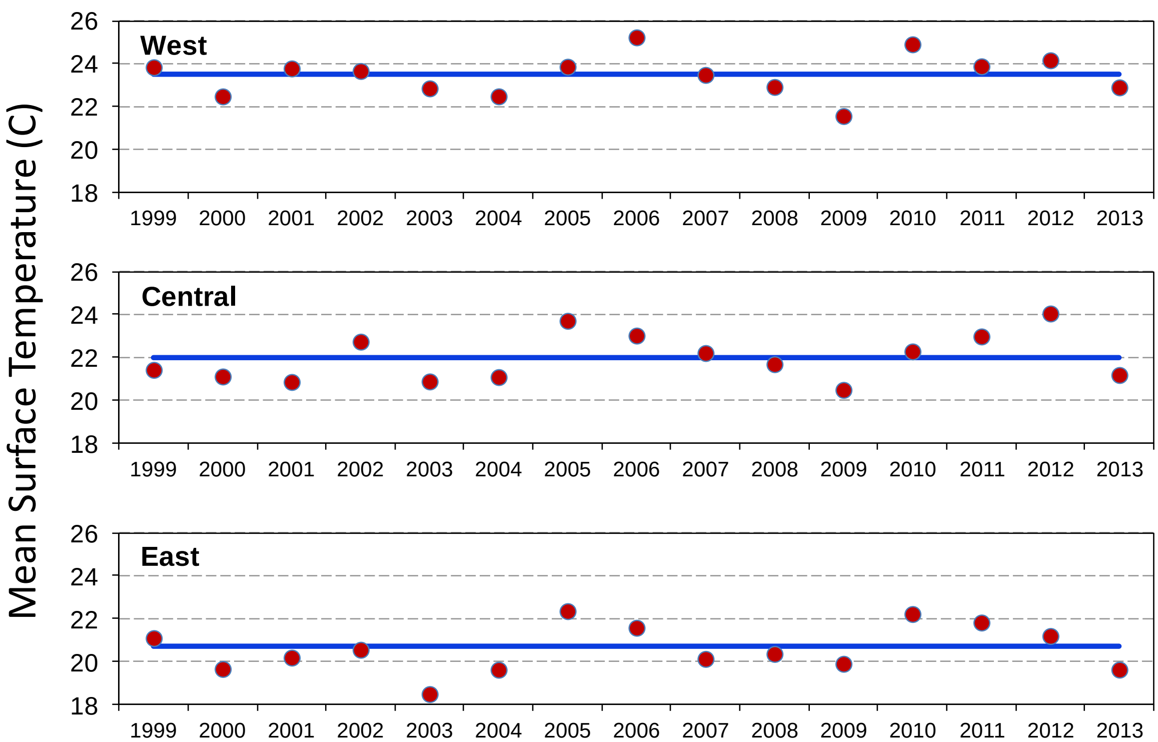

Figure 1.0.2. Mean summer (June-August) surface water temperature (°C) at offshore stations, by basin in Lake Erie, 1999-2013. Dark blue lines represent time-series average water temperature (1999-2012). Data included in this analysis by basin and station: West - 3, 6; Central – 8, 10, 11, 13; East – 16, 18, 19, 25.

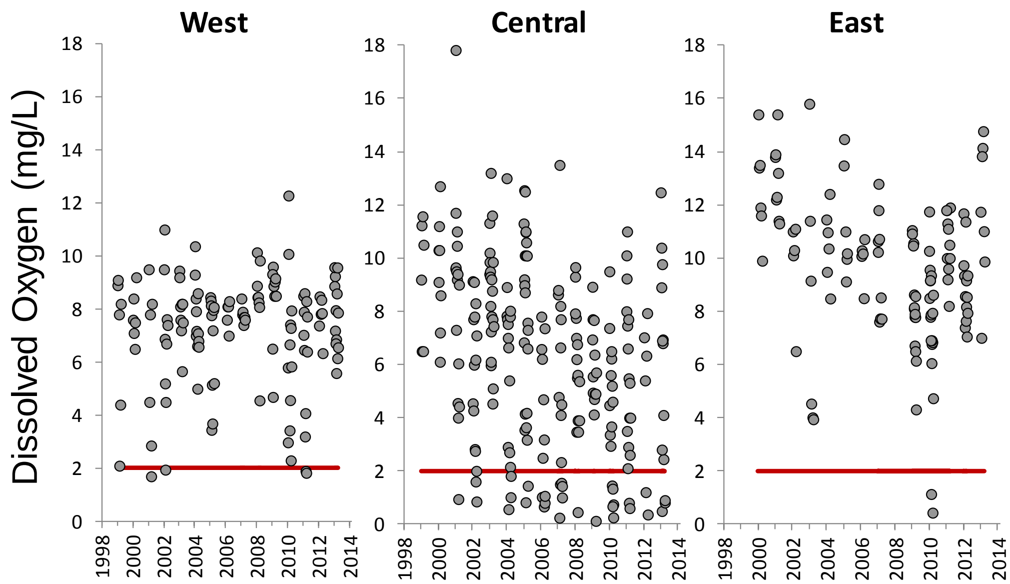

Figure 1.0.3. Summer (June-August) bottom dissolved oxygen (mg/L) concentrations for offshore sites by basin in Lake Erie, 1999-2013. The red horizontal line represents 2 mg/L, a level below which oxygen becomes limiting to the distribution of many temperate freshwater fishes. Data included in this analysis by basin and station: West - 3, 6; Central – 8, 10, 11, 13; East – 16, 18, 19, 25.

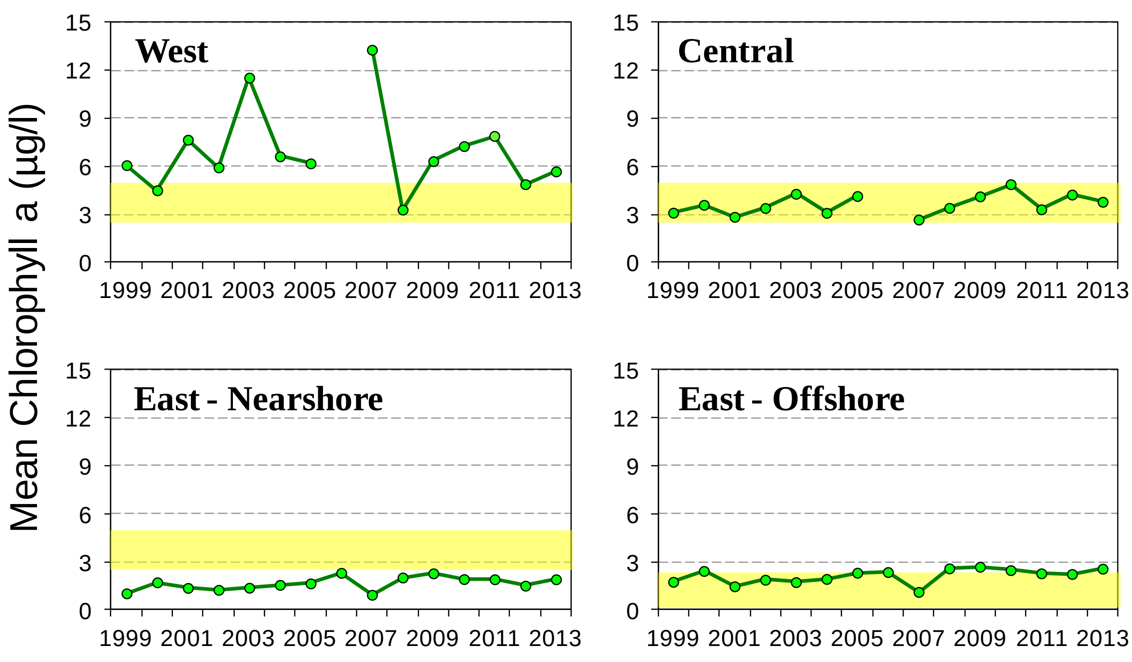

Figure 1.0.4. Mean chlorophyll *a* concentration (µg/L), weighted by month, by basin in Lake Erie, 1999-2013. The east basin is separated into nearshore and offshore. Yellow shaded areas represent targeted trophic class range. For this analysis data from stations 3 through 20, and 25 were included.

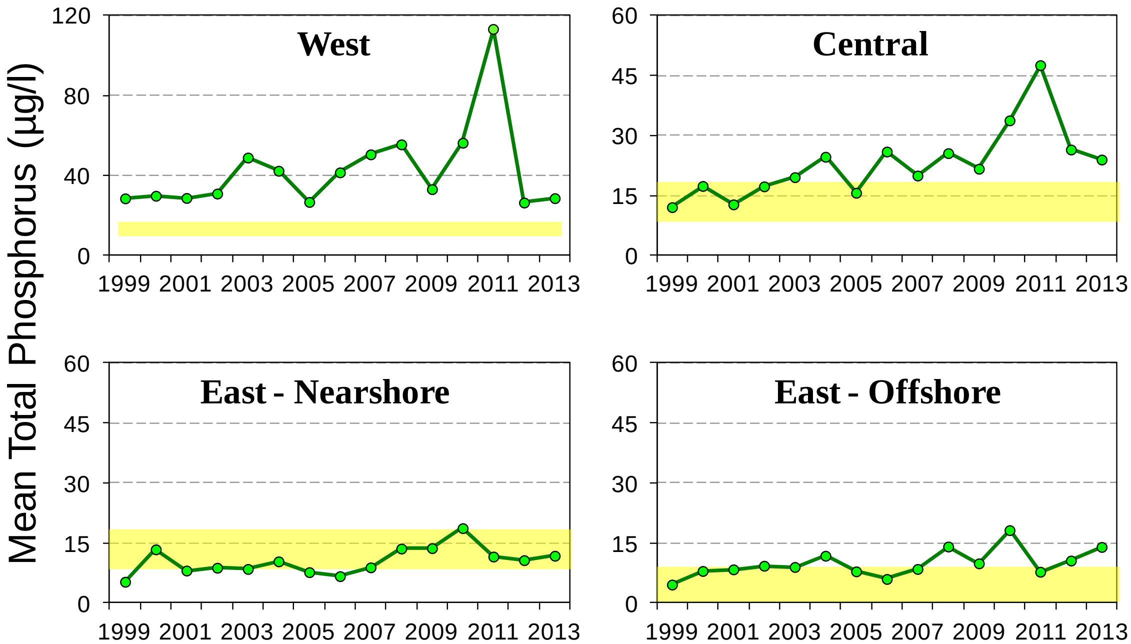

Figure 1.0.5. Mean total phosphorus (µg/L), weighted by month, for offshore sites by basin in Lake Erie, 1999-2013. The east basin is separated into nearshore and offshore. Yellow shaded areas represent the targeted trophic class range. For this analysis data from stations 3 through 20, and 25 were included.

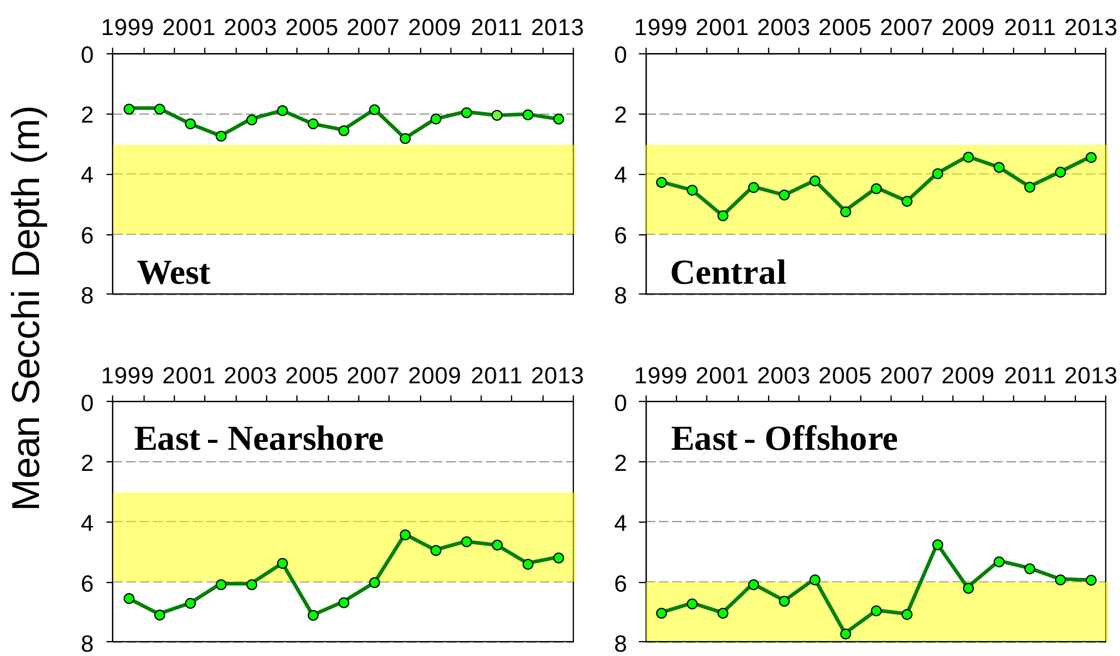

Figure 1.0.6. Mean summer (June-August) Secchi depth (m), weighted by month, by basin in Lake Erie, 1999-2013. The east basin is separated into inshore and offshore. Yellow shaded areas represent the targeted trophic class range. For this analysis data from stations 3 through 20, and 25 were included.

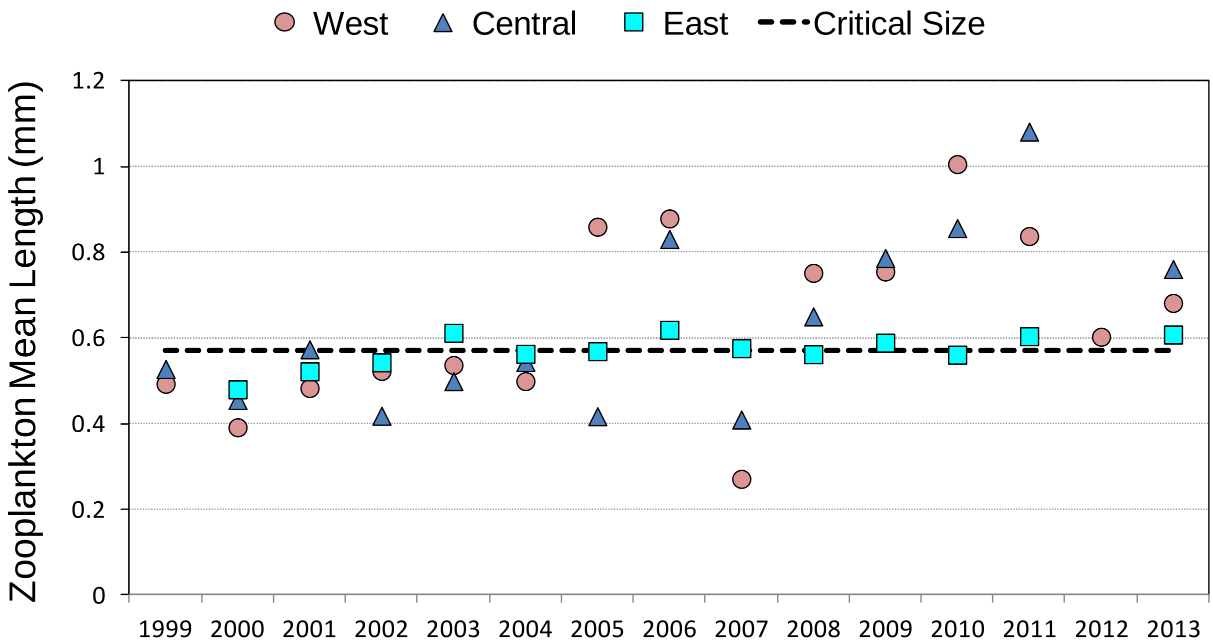

Figure 1.0.7. Mean length of the zooplankton community sampled with a 63 µm plankton net hauled through the epilimnion of each basin of Lake Erie, 1999-2013. The horizontal dashed line depicts 0.57 mm; the size below which predation by fish is considered to be intense (Mills et al. 1987, Johannsson et al. 1999). For this analysis data from stations 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 were included.

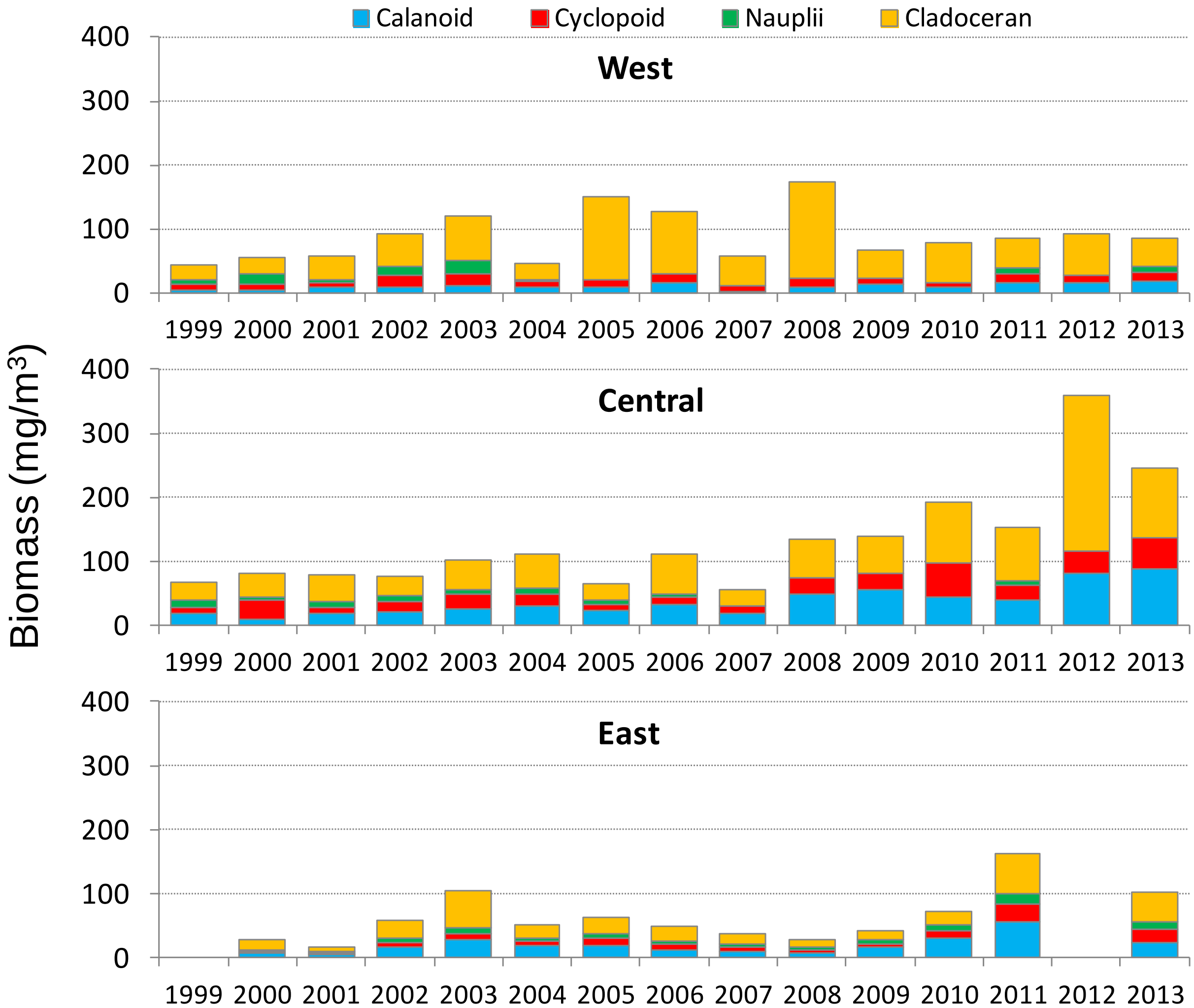

Figure 1.0.8. Mean zooplankton biomass (mg/m^3) by major taxonomic group by basin, 1999 through 2013. There is no data for 1999 and 2012 in the eastern basin. West basin includes stations 3, 4, 5, and 6. Central basin includes stations 7, 8, 9, 10, 11, 12, 13, and 14. East basin includes stations 15, 16, 17, 18, 19, and 20. Data excludes rotifers, and veligers. Harpacticoid zooplankton comprise a miniscule biomass for some 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 2012 Forage Status and Trends

General Patterns

- Relative forage abundance was below average in east and central basins, above average in west basin
- Rainbow Smelt densities below average in all jurisdictions.
- Age-0 Yellow Perch indices were below average in east and central basins, and were at the average in the west basin
- Age-0 Alewife abundance increased and was above average in most jurisdictions

Eastern Basin

- Total forage fish abundance during 2013 was low, ranking seventh and third lowest, respectively in Ontario's (ON) and New York's (NY) bottom trawl assessments
- Age-0 Rainbow Smelt decreased 87% in ON and increased 78% in NY compared to 2012, but was below the series average in both jurisdictions
- Yearling-and-older (age-1+) Rainbow Smelt density was below average basin wide
- 2013 Yellow Perch year class was the third (ON) and fourth (NY) weakest since 1992
- Age-0 Alewife abundance was low in ON, but third highest in NY's abundance index
- Age-0 Gizzard Shad abundance was low basin wide
- Emerald Shiner density (all age groups) was below average in ON and NY
- Spottail Shiner remain at low densities throughout the east basin
- Round Goby densities decreased in most agency surveys; remain below 10-year average

Central Basin

- Forage fish abundance declined from 2012
- Decrease in forage abundance was primarily due to age-0 White Perch
- Age-0 Yellow Perch abundance decreased from 2012 and was below average
- Rainbow Smelt abundance is similar to 2012, below average
- Round goby abundance was below average basin wide
- Alewife and Gizzard Shad indices were some of the highest in the time series

West Basin

- Forage abundance and biomass at above average levels
- Age-0 Gizzard Shad catches increased sharply from 2012, well above average
- Age-0 and age-1+ Rainbow Smelt catches increased, but remain below average
- Age-0 Emerald Shiner declined and age-1+ increased from 2012
- Age-0 White Perch decreased by almost half of 2012 levels; below average
- Round Gobies abundance declined in 2013; second lowest since first year of invasion (1997)
- Age-0 Yellow Perch and Walleye recruitment increased from 2012; both are near average
- White Bass recruitment decreased and are below average

2.2 Eastern Basin (L. Witzel and J. Markham)

Forage fish abundance and distribution in eastern Lake Erie is determined chiefly from annual bottom trawl assessments conducted independently by the basin agencies (also see East Basin Hydroacoustic Survey section of this report). During 2013, the NYSDEC and OMNR continued long-term trawling programs in their respective jurisdictions that now span some 22– and 30- to 34–years, respectively. A total of 32 trawl tows were sampled across New York waters in 2013 and 69 trawl tows were completed in nearshore and offshore areas of Long Point Bay during Ontario's various trawl assessments (Figure 2.2.1). PFBC did not operate trawl gear in Pennsylvania waters of the east basin during 2013.

Rainbow Smelt are the principal prey fish species of piscivores in the offshore waters of eastern Lake Erie (Figure 2.2.2). Despite below average densities in 2013, Rainbow Smelt once again was the most abundant forage species captured in east basin jurisdictions (Table 2.2.1). Yearling-and-older (age-1+) Rainbow Smelt abundance ranked fourth lowest in New York's 22-year trawl time series. Yearling-and-older Rainbow Smelt densities were higher in Ontario, but still only ranked in the 41st percentile of their 30-year time series. Yearling-and-older Rainbow Smelt from the moderately strong 2012 year class accounted for 85% of the age-1+ Rainbow Smelt catch in Ontario's October trawl assessment. Young-of-the-year Rainbow Smelt mean density in 2013 was 3.4 times greater in New York than Ontario, however the 2013 year class ranked near or below the lower third of all years surveyed in the respective jurisdictions. Mean length of age-0 (62 mm FL) and age-1 (107 mm FL) Rainbow Smelt decreased slightly in 2013 but both cohorts remained larger than average (Figure 2.2.3).

The contribution of non-smelt fish species to the forage fish community of eastern Lake Erie was dominated in 2013 by Emerald Shiner, Alewife, and Round Goby in Ontario and by Emerald Shiner, Alewife, Trout Perch, and Round Goby in New York (Table 2.2.1). Numeric abundance of these forage fish species in 2013 were below average except for age-0 Alewife, which ranked third highest in New York's trawl survey. Spottail Shiner abundance remained low throughout all eastern basin regions in 2013 (Table 2.2.1). Age-0 Gizzard Shad abundance was low throughout the east basin in 2013. Trout-Perch density in New York decreased for a second consecutive year, averaging 149 Trout-Perch/hectare compared to a long-term average (1992-2012) of 597/hectare.

Round Goby emerged as a new species among the eastern basin forage fish community during the late 1990's. Round Goby numbers continued to increase at a rapid rate and by 2001 were the most or second most numerically abundant species caught in agency index trawl gear across areas surveyed in eastern Lake Erie. Annual Round Goby abundance estimates were variable and increasing from 2000 to 2007, and variable and decreasing after 2007. Goby abundance during 2013 decreased in all east basin trawl assessments except for one of Ontario's nearshore surveys. In general, Round Goby densities during 2013 were at or near their lowest level observed since peak abundance in 2007 (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 in the central basin (Figure 2.3.1). Trawl locations in Pennsylvania range from 13 to 24 m and Ohio trawl locations range from 5 to >20 m. 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 2013, a total of 63 trawl tows were completed in the central basin, 6 tows in Pennsylvania, 33 in Ohio East, and 24 in Ohio West.

In 2013, overall forage abundance in the Ohio waters decreased from 2012 when forage indices were well above average (Figure 2.3.2). Clupeids were the only prey group that increased from 2012 and Rainbow Smelt indices remained about the same. The largest decline from 2012 was in the spiny-rayed group and was due specifically to an order of magnitude decrease in the age-0 White Perch cohort in western Ohio (Table 2.3.1).

Trends in Rainbow Smelt abundance were not consistent across central basin surveys. Young-of-the-year Rainbow Smelt indices increased in Ohio West and Pennsylvania, but decreased in the Ohio East survey. Pennsylvania had the only age-0 Rainbow Smelt index that was above the 10-year mean in 2013. Both the Ohio East and Ohio West indices have been below average since 2009 and 2010, respectively. Trends in age-1+ Rainbow Smelt indices were opposite that of age-0; with decreases in Ohio West and Pennsylvania, and an increase in Ohio East compared to 2012. The Ohio East index was the only age-1+ Rainbow Smelt index that was above the 10-year mean. Basin wide Rainbow Smelt abundance is about the same as in 2012, below the 10-year mean.

Trends in age-0 Emerald Shiner indices in 2013 were similar to age-0 Rainbow Smelt. Both the Ohio West and Pennsylvania indices increased from 2012, while the Ohio East index decreased. The Ohio West index was the only age-0 Emerald Shiner index that was above the 10-year mean. Yearling-and-older indices decreased in Ohio West and Ohio East, but increased in Pennsylvania. Ohio West was the only age-1+ index that was above the 10-year mean.

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. This pattern was not observed for either age-0 or age-1+ Round Goby indices in 2013. The highest abundance of both age groups occurred in eastern Ohio, while Pennsylvania had some of the lowest indices in the time series. Young-of-the-year indices increased from 2012 in Pennsylvania and were the same as 2012 in Ohio surveys. Yearling-and-older Round Goby densities increased in Ohio surveys, but decreased in Pennsylvania from 2012. Round Goby indices were below the 10-year mean throughout the basin, despite some modest increases from 2012.

Alewife densities in the central basin did not follow typical patterns in 2013. Age-0 Alewives were captured in both Ohio and Pennsylvania trawl surveys (Table 2.3.1). This is the first occurrence of the species being caught basin wide since 2002. The highest densities of age-0 Alewives were found in western Ohio, and there was a declining trend in abundance from west to east in the central basin. This is the opposite of 2012, where age-0 Alewife abundance was highest in Pennsylvania and lowest in Ohio. Basin wide, 2013 Alewife indices were the highest in the time series. Young-of-the-year Gizzard Shad patterns were more typical of historic patterns in 2013. Gizzard Shad indices increased in Ohio surveys from 2012 and were the second highest in the time series. Young-of-the-year Gizzard Shad abundance continues to show a declining trend from western Ohio to eastern Ohio. Gizzard shad are not routinely caught in Pennsylvania trawl surveys.

Yellow Perch age-0 indices declined across the basin from 2012 and were well below the 10-year mean. The highest catch per hectare for age-0 Yellow Perch occurred in Pennsylvania, while eastern Ohio and western Ohio indices were about the same (Table 2.3.1). Since 2005, Yellow Perch cohorts in the central basin have tended to be strongest in the east relative to the west. Yearling-and-older indices for Yellow Perch increased from 2012 and were above average across the basin (Table 2.3.2). The age-1+ increase is due to the stronger than average basin-wide cohort from 2012.

White Perch indices showed trends similar to Yellow Perch in the central basin in 2013. Age-0 White Perch indices declined in all areas of the central basin from 2012 and were well below the 10-year mean (Table 2.3.1). White Perch age-0 indices were the lowest in the time series in western Ohio and Pennsylvania. In western Ohio, there was an order of magnitude decline in age-0 abundance from 2012. Yearling-and-older White Perch indices increased from 2012 and were at or above average across the basin (Table 2.3.2). Similar to Yellow Perch, the basin wide increase in age-1+ White Perch is due to the very strong 2012 cohort.

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 initiated, and fishing power correction (FPC; Table 2.4.1) factors 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/ha or number/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 FPC-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 their various life stages in Lake Erie. Please refer to the Habitat Task Group Report, section 2c, for current research on fish distribution changes in response to seasonal hypoxia (Habitat Task Group 2012).

2013 Results

In 2013, hypolimnetic dissolved oxygen levels were not below the 2 mg per liter threshold at any site during the August trawling survey. In total, data from 70 sites were used in 2013 (Figure 2.4.1).

Total forage abundance was above average in 2013, slightly higher than in 2012 (Figure 2.4.2). Clupeids increased 7.5 times over 2012, while soft-rayed and spiny-rayed species declined 38% and 49%, respectively. Total forage biomass in 2013 increased 6% (Figure 2.4.3). Relative biomass of clupeid, soft-rayed, and spiny-rayed species was 49%, 4%, and 47%, respectively, and differed from their respective historic averages of 29%, 7%, and 64%. Spatial maps of forage distribution were constructed using FPC-corrected site-specific catches (number/ha) 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 along the south shore, from Maumee Bay to Cedar Point. Soft-rayed fish were most abundant near the mouth of the Detroit River and near Sandusky Bay. Spiny-rayed abundance was highest near Maumee Bay. Relative abundance of the dominant species includes: age-0 Gizzard Shad (54%), age-0 White Perch (34%), and age-0 Yellow Perch (5%). Total forage abundance averaged 6,734 fish/ha across the western basin, increasing 4% from 2012, and remaining above the long-term average (5,325 fish/ha). Clupeid density was 3,613 fish/ha (average 1,163 fish/ha), soft-rayed fish density was 410 fish/ha (average 565 fish/ha), and spiny-rayed fish density was 2,710 fish/ha (average 3,596 fish/ha).

Recruitment of individual species is highly variable in the western basin. Young-of-the-year Yellow Perch (314.1/ha) increased sharply relative to 2012, while age-0 Walleye abundance (10.6/ha) doubled (Figure 2.4.5); both remain below long-term means. Young-of-the-year White Perch (2,262/ha) declined to less than half the 2012 abundance. Young-of-the-year White Bass (73.4/ha) decreased and remains below the long-term mean. Age-0 Smallmouth Bass (0.7/ha) increased, but remains below the long-term mean. Age-0 and yearling-and-older Rainbow Smelt increased in 2013 (73.0/ha and 1.0/ha, respectively). Young-of-the-year Gizzard Shad (3,610/ha) increased dramatically relative to 2012, well above the long-term mean, while age-0 Alewife had their highest abundance since 2002 (2.9/ha; Figure 2.4.6). Catches of age-0 Emerald Shiners (14.6/ha) decreased, while age-1+ Emerald Shiners (204.7/ha) decreased slightly compared to 2012. Overall, 2013 catches of age-0 Emerald Shiners decreased below the long-term mean and age-1+ Emerald Shiners remained well above the long-term mean (Figure 2.4.7). Catches of Round Gobies (27.7/ha) decreased from 2012, and represents the second lowest abundance since their discovery 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 (2003-2012) 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 and 2013, and the 2008 survey was a reduced effort of four tows sampled in a single day.

Species	Age Group	Trawl Survey	Year										10-Yr & Long-term Avg. by decade		
			2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	10-Yr	2000's	1990's
Rainbow	YOY	ON-DW	217.9	1657.7	509.2	326.9	148.2	1293.0	991.3	1256.0	0.9	132.2	1337.3	1391.5	431.7
Smelt	YOY	NY-Fa	736.0	413.6	1580.4	1416.6	64.9	2128.9	2889.6	507.9	1259.6	1146.1	1314.1	1524.9	1450.9
	YOY	PA-Fa	NA	560.2	NA	NA	47.7	15.1	260.2	NA	47.9	12.3	219.4	138.2	550.8
	YAO	ON-DW	165.3	367.8	277.1	222.7	1654.3	77.3	232.8	136.2	7.6	565.6	374.7	360.7	358.6
	YAO	NY-Fa	44.6	22.1	640.1	997.8	3016.6	546.5	176.9	162.9	395.2	2624.1	886.4	753.4	581.6
	YAO	PA-Fa	NA	22.3	NA	NA	407.2	1.8	1006.3	NA	0.0	12.3	211.8	164.5	378.0
Emerald	YOY	ON-DW	58.7	438.3	70.3	117.6	54.8	16.0	29.3	452.3	645.7	20.3	523.2	463.2	52.3
Shiner	YOY	ON-OB	0.2	23.8	1.1	0.0	0.0	0.5	1.2	12.4	1.1	258.3	29.8	27.6	3.2
	YOY	NY-Fa	127.9	94.3	2930.1	62.9	48.5	3.7	150.9	778.5	291.4	7.8	459.8	194.0	112.4
	YOY	PA-Fa	NA	14.8	NA	NA	1063.0	0.0	81.7	NA	0.5	0.0	331.9	264.8	41.0
	YAO	ON-DW	188.6	119.2	201.1	30.7	40.1	95.2	149.8	4200.3	139.0	891.2	607.1	819.0	37.7
	YAO	ON-OB	21.3	12.4	16.1	0.0	4.8	3.0	84.3	499.6	0.1	73.8	70.1	72.0	4.6
	YAO	NY-Fa	65.3	93.8	1826.2	20.6	156.4	18.2	84.8	925.5	151.4	284.2	400.6	290.8	105.4
	YAO	PA-Fa	NA	86.9	NA	NA	1360.3	0.0	4713.1	NA	52.5	0.0	910.1	710.4	14.5
Spottail	YOY	ON-OB	8.1	19.1	2.5	3.0	3.7	37.8	35.2	19.8	58.7	43.8	29.8	119.3	815.9
Shiner	YOY	ON-IB	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	1.0	0.2	0.2	0.5	113.9
	YOY	NY-Fa	0.0	1.8	0.7	6.5	0.1	0.3	0.1	0.5	0.5	0.1	2.4	5.6	19.9
	YOY	PA-Fa	NA	0.0	NA	NA	1.1	0.0	0.0	NA	0.0	0.0	0.2	0.1	4.0
	YAO	ON-OB	3.0	1.6	0.5	2.1	3.3	7.5	4.1	10.4	3.2	10.4	4.9	10.8	74.6
	YAO	ON-IB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	2.0
	YAO	NY-Fa	0.3	2.0	29.0	10.4	5.1	1.5	0.0	4.1	4.3	2.5	6.4	6.4	4.0
	YAO	PA-Fa	NA	0.1	NA	NA	0.0	0.0	0.0	NA	0.0	0.0	0.0	0.1	7.9
Alewife	YOY	ON-DW	17.7	707.3	2.1	0.9	0.1	2.3	1.0	78.6	0.1	0.3	79.3	22.5	231.2
	YOY	ON-OB	26.1	6.0	6.8	0.0	1.9	11.9	44.6	711.8	11.0	1.5	81.3	82.1	88.5
	YOY	NY-Fa	218.3	183.8	12.4	15.4	0.0	5.6	22.2	30.8	27.7	4.4	30.6	94.3	52.0
	YOY	PA-Fa	NA	4.6	NA	NA	0.0	0.0	8.0	NA	0.0	0.0	2.2	1.3	7.7
Gizzard	YOY	ON-DW	0.0	47.6	18.9	13.3	0.4	86.5	34.6	1.4	1.7	0.2	27.3	21.3	7.5
Shad	YOY	ON-OB	0.3	20.0	3.4	3.8	0.0	4.0	22.0	28.7	1.9	1.0	9.0	7.6	13.4
	YOY	NY-Fa	3.8	4.7	15.0	40.9	5.3	10.8	11.7	14.1	3.7	0.6	13.5	11.9	4.2
	YOY	PA-Fa	NA	1.0	NA	NA	0.0	0.0	0.0	NA	0.0	0.0	0.1	0.1	0.9
White	YOY	ON-DW	0.0	0.8	0.0	1.6	0.6	5.4	0.1	0.9	0.1	0.0	2.6	2.9	1.8
Perch	YOY	ON-OB	0.0	0.9	0.0	0.0	0.0	2.1	0.7	1.2	0.4	0.2	2.0	2.8	17.6
	YOY	NY-Fa	4.4	18.3	36.5	157.3	20.2	431.5	34.6	91.9	99.8	1.0	92.9	74.3	29.4
	YOY	PA-Fa	NA	380.0	NA	NA	598.5	0.7	444.6	NA	51.2	0.0	285.5	256.0	101.1
Trout	All	ON-DW	0.0	0.0	0.0	0.3	0.8	0.8	0.8	1.1	0.0	1.7	0.8	0.9	0.6
Perch	All	NY-Fa	148.8	338.9	654.3	461.6	517.0	996.4	561.2	519.4	1317.3	545.9	731.7	826.0	410.0
	All	PA-Fa	NA	52.2	NA	NA	558.8	0.6	156.9	NA	198.5	160.3	197.7	152.1	50.9
Round	All	ON-DW	14.5	129.0	125.4	9.7	43.6	452.6	973.2	93.3	66.9	323.8	237.6	235.9	0.0
Goby	All	ON-OB	76.3	68.0	103.3	67.6	91.2	63.4	73.9	32.7	28.0	94.4	73.7	86.9	0.1
	All	ON-IB	49.6	80.2	114.6	135.1	280.5	211.8	263.0	34.0	21.0	95.4	126.4	120.0	0.1
	All	NY-Fa	83.9	180.2	165.8	173.3	502.6	466.8	1293.2	846.5	707.0	1094.5	604.3	651.7	35.9
	All	PA-Fa	NA	31.6	NA	NA	350.1	441.6	2043.8	NA	887.8	927.5	724.2	1094.6	30.3

"**NA**" denotes that reporting of indices was Not Applicable or that data were Not Available.

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. Indices are reported as NPH; 90's Avg. is for the period 1990 to 1999; 00's Avg. is for the period 2000 to 2009.

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. Indices are reported as NPH; 90's Avg. is for the period 1990 to 1999; 00's Avg. is for the period 2000 to 2009.

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. Indices are reported as NPH; 90's Avg. is for the period 1990 to 1999; 00's Avg. is for the period 2000 to 2009.

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. Indices are reported as NPH; 90's Avg. is for the period 1992 to 1999; 00's Avg. is for the period 2000 to 2009.

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. Indices are reported as NPH; 90's Avg. is for the period 1990 to 1999; 00's Avg. is for the period 2000 to 2009.

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 2002-2013. 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	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Mean
Yellow	OH west	149.0	8.7	37.8	10.0	167.0	37.3	1.3	41.1	8.7	75.8	9.2	53.7
Perch	OH east	47.5	1.9	156.2	18.9	177.8	52.8	0.5	96.3	14.1	134.4	8.9	70.0
	PA	788.0	2.4	6.7	-	10.0	863.4	14.2	-	-	487.2	27.8	310.3
White	OH west	310.1	759.7	1002.5	440.4	1381.2	544.9	506.1	254.8	368.3	1896.4	192.6	746.4
Perch	OH east	61.8	108.0	2034.5	46.1	1095.9	91.6	34.6	190.3	84.8	661.9	200.1	441.0
	PA	173.8	2.4	42.3	-	17.8	199.0	146.5	-	-	370.6	2.2	136.1
Rainbow	OH west	1753.9	352.1	10.7	94.3	98.1	635.2	293.5	776.2	42.4	76.2	117.8	413.3
smelt	OH east	2914.1	388.9	44.4	570.7	702.4	3997.7	0.3	421.6	256.1	319.1	12.8	961.5
	PA	177.6	20.9	15.9	-	35.1	552.2	23.4	-	-	8.5	131.4	119.1
Round	OH west	22.6	13.9	37.2	19.0	26.9	17.4	25.9	28.4	102.8	19.8	19.6	31.4
Goby	OH east	57.5	173.9	148.1	46.3	273.1	26.3	1.0	41.8	258.9	53.9	45.8	108.1
	PA	75.3	1011.3	-	-	227.8	227.1	72.2	-	-	2.4	11.4	269.3
Emerald	OH west	477.6	7.0	567.1	587.2	52.6	36.3	6.1	8.8	414.5	1144.7	2520.5	330.2
Shiner	OH east	903.1	0.8	279.8	1115.1	63.7	20.2	1.7	234.9	105.4	2188.5	306.2	491.3
	PA	81.8	0.0	17.8	-	0.8	0.0	303.2	-	-	0.0	31.7	57.7
Spottail	OH west	0.0	0.0	0.2	0.0	3.1	3.7	0.6	0.0	0.6	0.0	0.0	0.8
Shiner	OH east	0.5	0.0	1.1	0.2	0.5	0.2	0.0	0.0	0.4	0.0	0.0	0.3
	PA	0.0	0.0	0.0	-	0.0	0.0	0.0	-	-	0.0	0.0	0.0
Alewife	OH west	0.1	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	53.9	0.5
	OH east	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.1	36.1	0.4
	PA	0.0	0.0	0.0	-	0.0	0.0	0.0	-	-	2.8	5.1	0.4
Gizzard	OH west	402.6	0.6	12.3	32.7	195.0	35.7	50.9	2.6	770.3	119.1	269.7	162.2
Shad	OH east	20.4	0.3	15.7	30.7	15.5	63.1	3.9	8.5	4.0	28.7	39.5	19.1
	PA	0.0	0.0	1.3	-	0.0	0.0	0.0	-	-	0.0	0.0	0.2
Trout-	OH west	2.0	20.3	0.1	0.2	0.8	0.3	0.3	0.7	1.6	0.0	0.1	2.6
perch	OH east	1.4	1.4	1.6	0.1	5.4	0.1	0.2	1.4	2.7	0.2	0.0	1.5
	PA	78.0	6.7	0.3	-	10.9	126.1	28.1	-	-	0.0	0.0	35.7

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

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 2002-2013. 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	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Mean
Yellow	OH west	3.2	216.5	18.3	4.2	19.8	56.6	20.7	11.9	5.5	8.5	40.0	36.5
Perch	OH east	1.2	45.2	132.3	12.5	37.0	26.4	139.4	12.4	50.5	23.3	109.5	48.0
	PA	75.6	18.3	1.9	-	27.4	76.4	120.9	-	-	100.1	75.0	60.1
White	OH west	28.2	83.9	34.1	32.4	27.1	76.5	42.0	32.6	25.0	58.9	213.3	44.1
Perch	OH east	12.0	27.0	20.1	38.5	16.8	36.6	282.3	44.8	45.1	7.7	546.9	53.1
	PA	28.6	6.2	0.0	-	0.8	4.2	63.3	-	-	6.8	18.6	15.7
Rainbow	OH west	29.4	320.5	89.8	8.9	40.4	9.6	419.4	18.0	35.8	15.3	18.8	98.7
Smelt	OH east	370.3	1360.2	30.8	17.3	532.4	64.9	109.1	56.9	176.0	143.1	485.6	286.1
	PA	22.1	9.9	2.6	-	10.7	3.5	408.0	-	-	20.0	25.0	68.1
Round	OH west	25.4	27.0	33.6	20.4	26.3	57.9	58.0	44.0	63.7	13.2	21.9	37.0
Goby	OH east	127.1	148.8	263.0	78.9	185.6	167.8	19.3	36.0	123.8	27.0	46.3	117.7
	PA	59.1	767.0	206.7	-	361.1	326.6	75.9	-	-	71.4	8.6	266.8
Emerald	OH west	54.9	1.5	233.6	162.7	418.7	495.0	99.5	51.5	171.6	1128.6	348.9	281.8
Shiner	OH east	432.0	0.4	479.6	451.1	27.8	1159.4	167.8	375.1	145.2	433.2	8.4	367.2
	PA	217.5	0.0	123.0	-	769.5	28.0	171.5	-	-	9.0	17.2	188.3
Spottail	OH west	1.6	5.3	0.3	1.2	2.3	2.3	3.1	0.0	23.5	0.0	0.8	4.0
Shiner	OH east	1.0	0.2	3.8	0.7	0.6	2.9	0.0	0.0	4.1	3.0	2.9	1.6
	PA	0.0	0.0	0.0	-	0.0	0.0	0.0	-	-	0.0	0.0	0.0
Trout-	OH west	12.2	14.0	13.5	3.3	5.5	4.8	0.8	0.7	3.9	1.6	3.3	6.0
perch	OH east	2.9	7.7	76.2	4.8	6.7	8.4	1.5	5.0	8.9	11.7	1.0	13.4
	PA	50.9	5.2	4.1	-	16.0	61.7	127.3	-	-	30.4	9.6	42.2

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

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

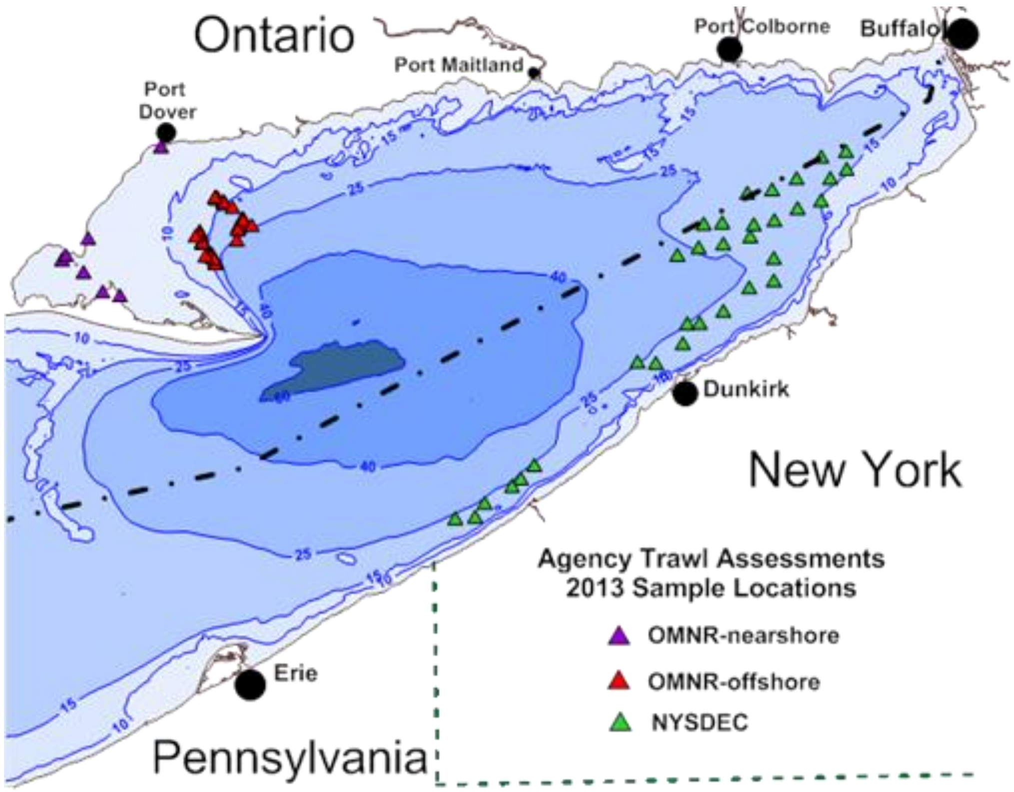

Figure 2.2.1 Locations sampled with standard index bottom trawls by Ontario (OMNR) and New York (NYSDEC) to assess forage fish abundance in eastern Lake Erie during 2013.

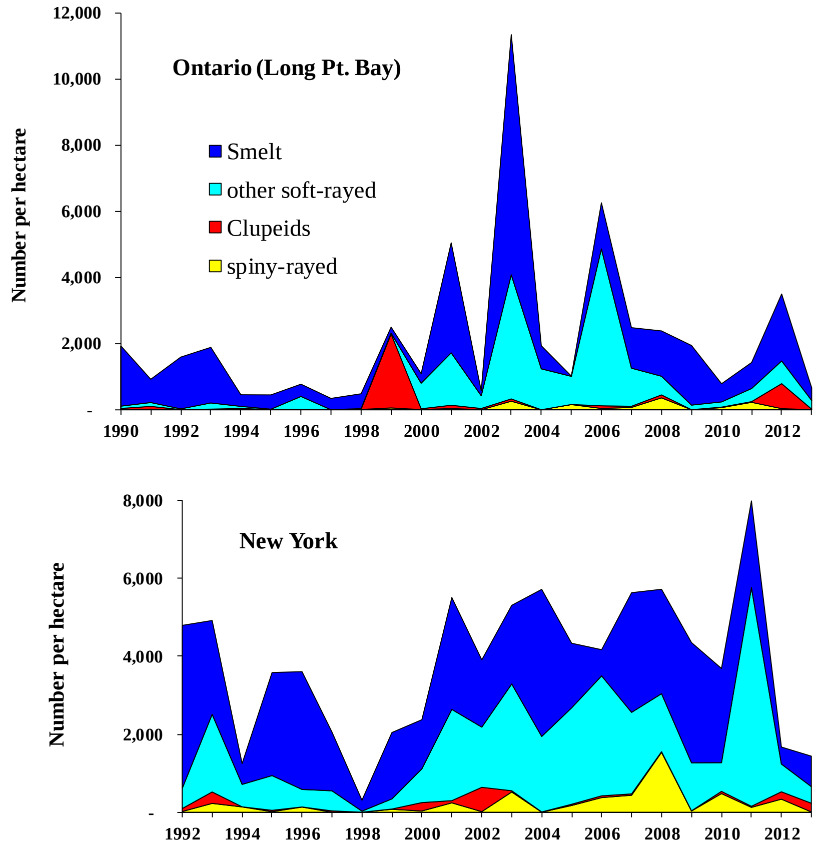

Figure 2.2.2 Mean density of prey fish (no./ha) by functional group in the Ontario and New York waters of the eastern basin, Lake Erie, 1990-2013.

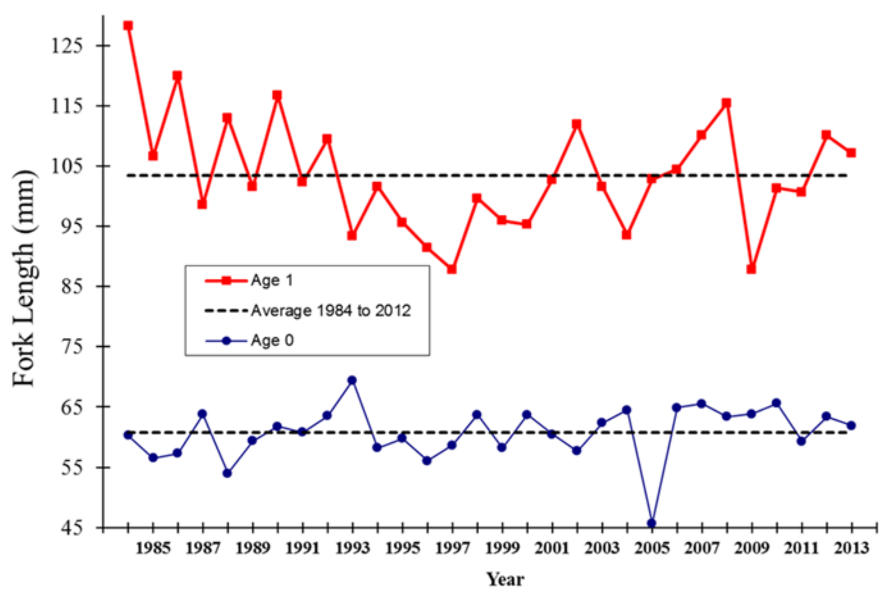

Figure 2.2.3 Mean fork length of age 0 and 1 Rainbow Smelt from OMNR index trawl surveys in Long Point Bay, Lake Erie, October 1984 to 2013.

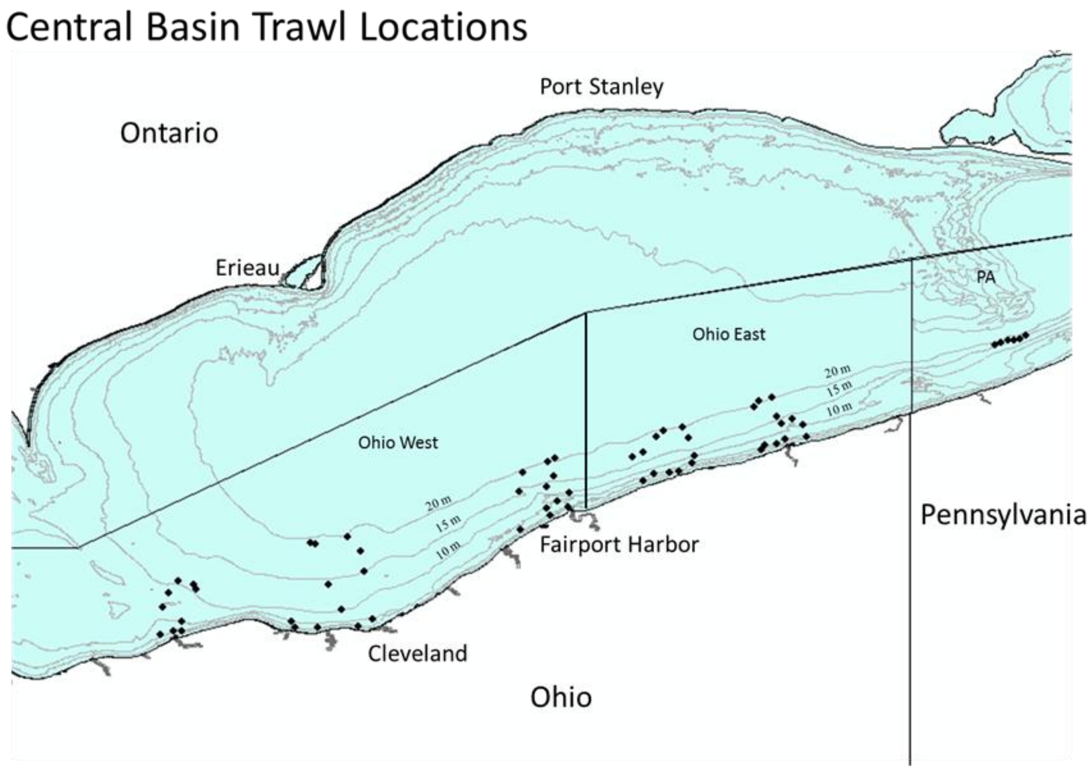

Figure 2.3.1 Locations sampled with index bottom trawls by Ohio (ODNR) and Pennsylvania (PFBC) to assess forage fish abundance in central Lake Erie during 2013.

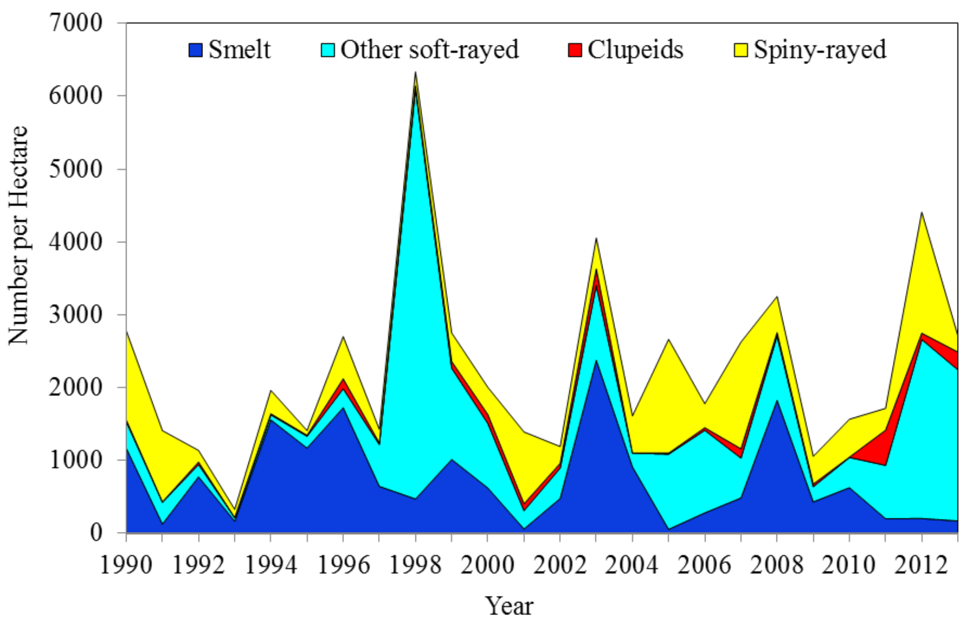

Figure 2.3.1 Mean density of prey fish (number./hectare) by functional group in the Ohio waters of the central basin, Lake Erie, 1990-2013.

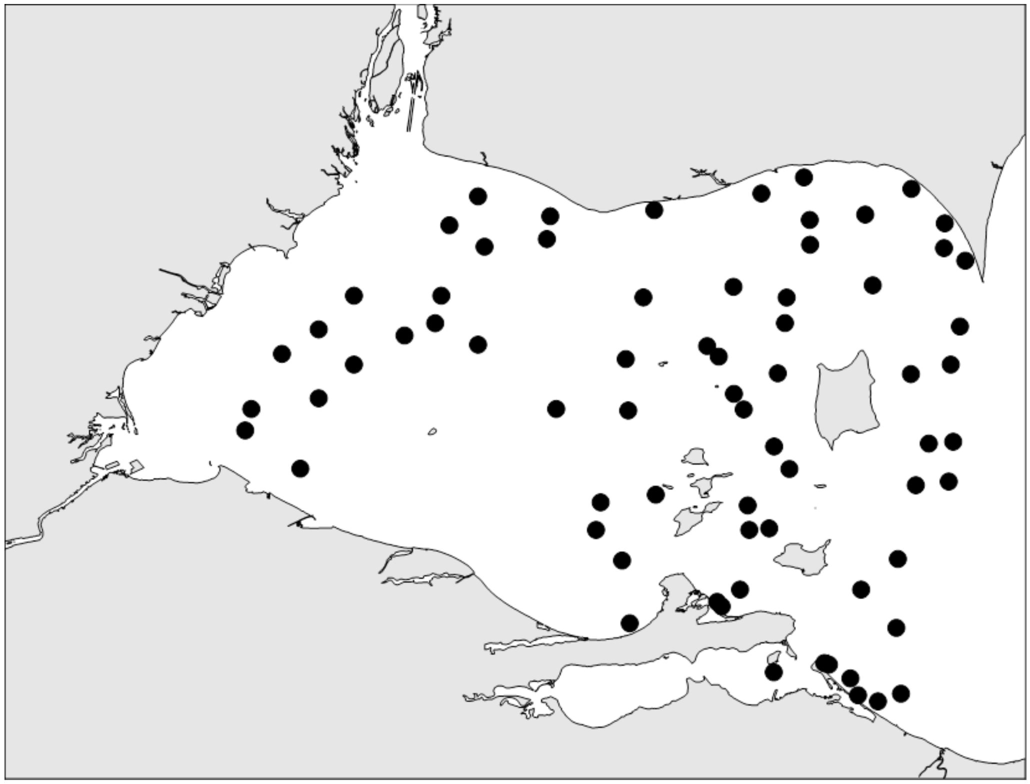

Figure 2.4.1. Trawl locations for the western basin interagency bottom trawl survey, August 2013

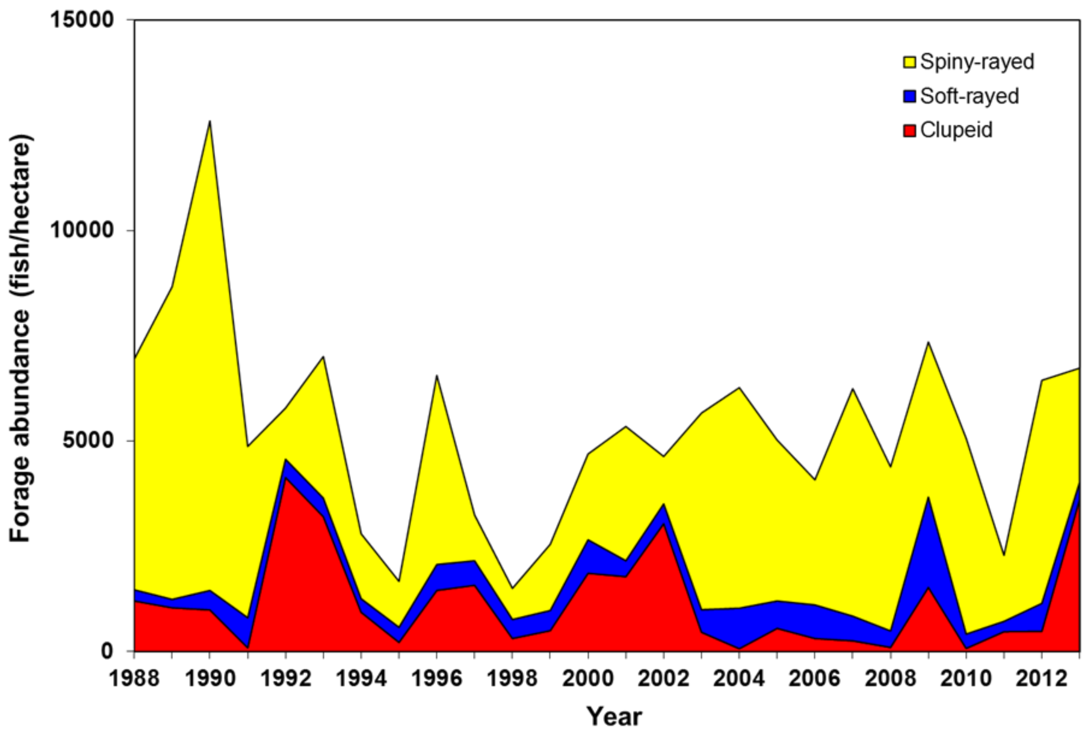

Figure 2.4.2. Mean density (fish/ hectare) of prey fish by functional group in western Lake Erie, August 1988-2013.

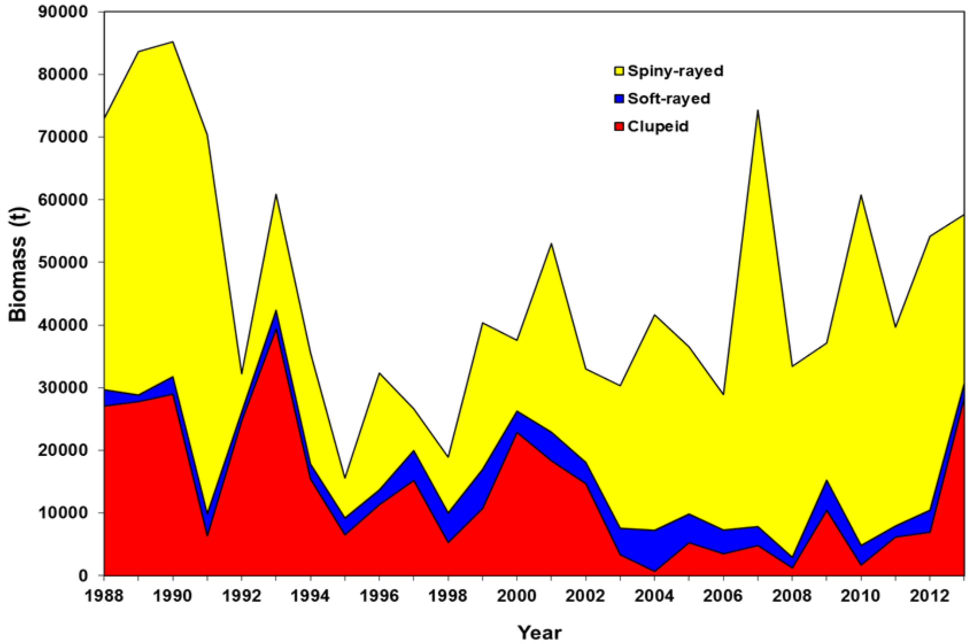

Figure 2.4.3. Mean biomass (tonnes) of prey fish by functional group in western Lake Erie, August 1988-2013.

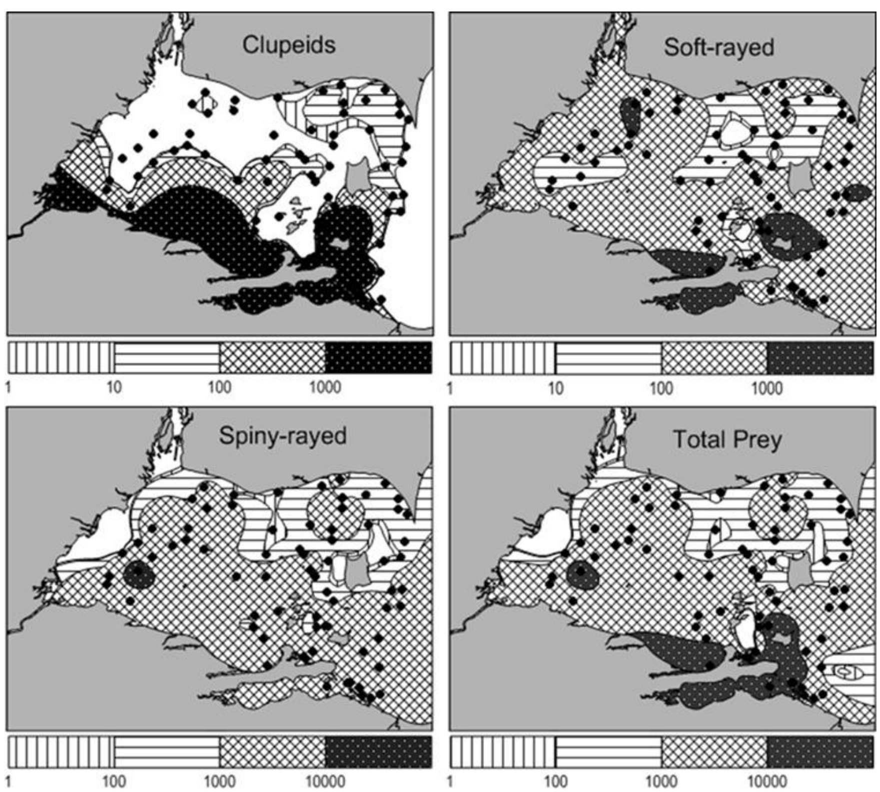

Figure 2.4.4. Spatial distribution of clupeids, soft-rayed, spiny-rayed, and total forage abundance (individuals per hectare) in western Lake Erie, 2013. Black dots are trawl sites, white areas are estimates of zero abundance, and contour levels vary with the each functional fish group.

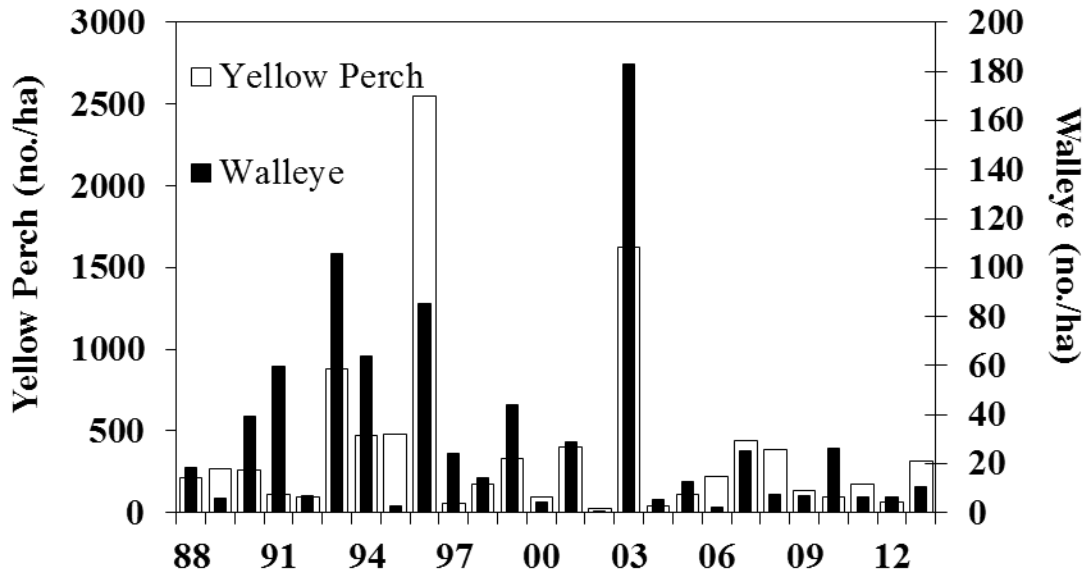

Figure 2.4.5. Density of age-0 Yellow Perch and Walleye in the western basin of Lake Erie, August 1988-2013.

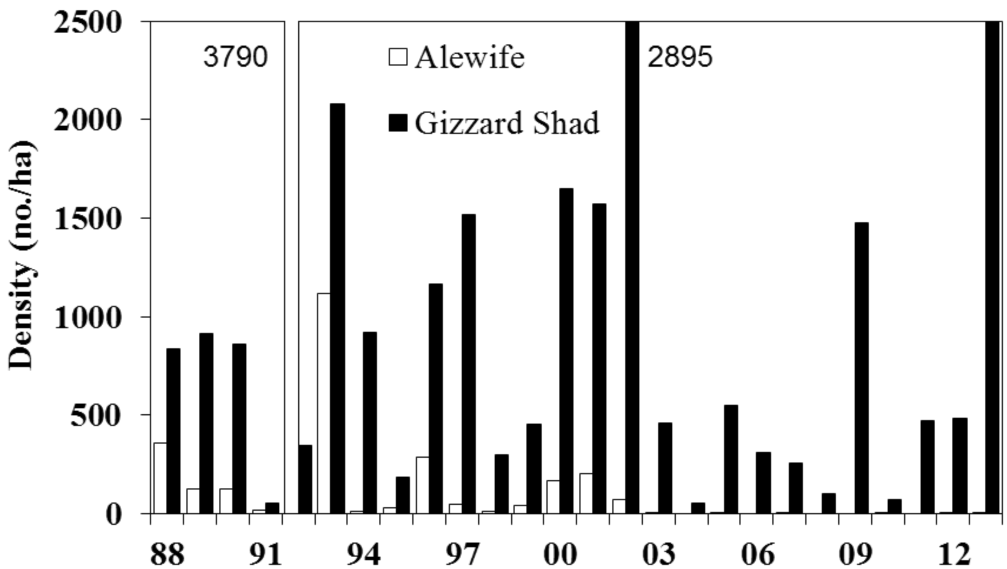

Figure 2.4.6. Density of age-0 Alewife and Gizzard Shad in the western basin of Lake Erie, August 1988-2013.

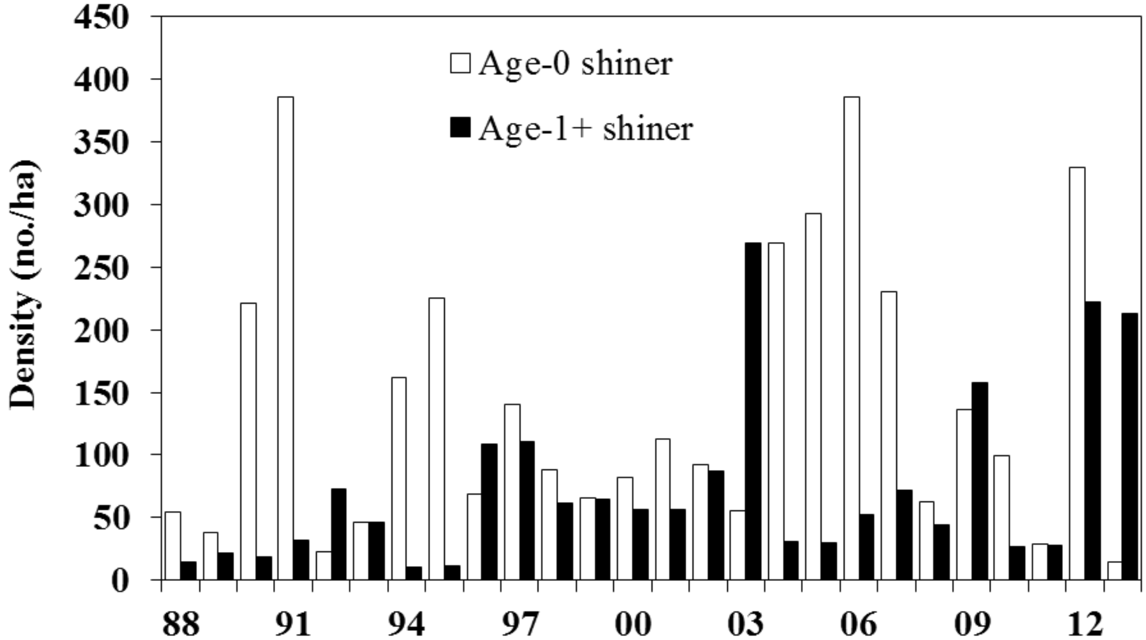

Figure 2.4.7. Density of age-0 and age-1+ shiners (*Notropis* spp.) in the western basin of Lake Erie, August 1988-2013.

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 Acoustic Survey (L. Witzel and D. Einhouse)

Introduction

Beginning in 1993, a midsummer East Basin fisheries acoustic survey was implemented to provide a more comprehensive evaluation of the distribution and abundance of Rainbow Smelt. This initiative has been pursued under the auspices of the Lake Erie Committee's Forage Task Group (FTG), and is a collaboration of the Ministry of Natural Resources (OMNR, Port Dover, ON), New York State Department of Environmental Conservation (NYSDEC, Dunkirk, NY) and Cornell University's Warmwater Fisheries Unit through coordinated management efforts facilitated by the Great Lakes Fishery Commission (GLFC).

One of the more prominent advancements in the development of an acoustic survey program was achieved when Lake Erie's FTG was successful in being awarded a grant to purchase a modern signal processing and data management system for inter-agency fisheries acoustic surveys on Lake Erie (Einhouse and Witzel 2003). The new data processing system (Echoview) arrived in 2002. In 2003, Lake Erie representatives from NYSDEC and OMNR attended a training workshop to attain proficiency in this new software. The newly trained biologists then hosted a second workshop to introduce this signal processing system to the Lake Erie FTG. During 2005 FTG members upgraded the Lake Erie acoustic hardware system through the purchase of a Simrad EY60 GPT/transducer. In 2008, 2009, and 2010 several members of Lake Erie's FTG participated in an ongoing series of workshops, devoted to the development of Standard Operating Procedures (SOP) for hydroacoustic surveys in the Great Lakes region (Parker-Stetter et al. 2009, Rudstam et al. 2009). Completion of the 2008 workshop represented a benchmark event toward implementation of the SOPs in Lake Erie basin acoustic surveys, and specifically for the East Basin, then proceeding to re-processing an acoustic data series beginning in 1997 and applying new standards. A primary focus of the 2009 workshop was to compare present-day acoustic methods used in various acoustic assessments across the Great Lakes with results from following the SOP. In a recent publication by the acoustic study group, three recommendations from the SOP were evaluated in several hydroacoustic assessments across the Laurentian Great Lakes and found to significantly influence density estimates of target species, but the degree of influence was lake dependent (Kočovský et al. 2013). Additional GLFC funds were awarded to the Great Lake Acoustic Study Group to convene a workshop that will begin the development of standard protocols for conducting acoustic assessment-based ground-truth trawling operations. This latest workshop was successfully completed at the Lake Erie Biological Station USGS Great Lakes Science Centre, Sandusky, Ohio during September 27 – October 1, 2010.

Survey Methods and Acoustic Series Standardized Analysis

Procedures for the east basin acoustic survey have now been completed largely through the support of GLFC sponsored project "Study group on fisheries acoustics in the Great Lakes". At this time the principal investigators for Lake Erie's east basin survey are incorporating the new SOP for each survey year, and then re-computing fish densities based on these new standards. Among these standard data processing elements is the use of the N_v index (Sawada *et al.* 1993), a type of data quality control filter to remove possible bias associated with overestimates of in-situ target strength that can occur at high fish densities if multiple echoes (superimposed) are falsely detected as single targets (Rudstam et al. 2003). Additionally, a standard objective method has now been developed to ascribe passive noise thresholds for each survey transect. Documentation of our data collection and processing methods is long overdue and progress continues along with accompanying results for the entire split-beam time series of the Eastern Lake Erie Acoustic Survey (since 1997).

At this writing the acoustic data series from 1998 to 2003 and from 2007 to 2013 has been re-processed and analyzed using our new survey standards. We previously reported results for the 1999 to 2003 survey years in the 2009 Forage Task Group annual report (Forage Task Group 2009). In this report we highlight results for the seven most recent east basin survey years 2007 to 2013.

In general, standard survey procedures have been in-place for offshore transect sampling of eastern Lake Erie since 1993. This midsummer, mobile nighttime survey is implemented as an interagency program involving multiple vessels to collect acoustic signals of pelagic fish density and distribution, with an accompanying mid-water trawling effort to characterize fish species composition.

In 2013, the east basin acoustic team renewed both Echoview software licenses.

The 2013 Survey

In most years since 1997, the east basin survey has been accomplished as a two-agency endeavour. Acoustic data acquisition to determine fish densities and distribution were measured with a modern scientific echosounder. The current system consists of a Simrad EY60 120 kHz split-beam GPT, with a 7-degree beam transducer mounted on a fixed pole in a down facing orientation approximately 1 m below the water surface on the starboard side of OMNR's research vessel, *RV Erie Explorer.* Acoustic data were collected at 250 watts power output, 256 µsec pulse duration, and 3 per second ping rate. Precise navigation of randomly selected acoustic transects was accomplished through an interface of the vessel's GPS system to a personal computer (PC) running marine navigation software (Nobeltec Navigation Suite ver7) and the ship's autopilot. The same GPS unit was also connected to a second PC running the Simrad ER60 software controlling the EY60 echosounder. Geo-referenced raw acoustic data were logged to 10-megabyte size files on the host PC.

The 2013 survey was completed in five nights from July 4 to 12; acoustic sampling was suspended due to poor weather on two nights during this period (Figure 3.1.1). A full complement of twelve acoustic transects were sampled totaling 322 kilometers. Approximately 1,453,240 KB of raw acoustic data were recorded including about 88,500 KB of stationary sampling at the ends of some transects to assess target strength (TS) variability of individual fish tracks. A total of 30 water temperature-depth profiles were sampled across all transects in 2013. Companion mid-water trawl collections to obtain representative samples of the pelagic forage fish community for apportioning of acoustic targets was suspended during the 2013 survey due to constraints in NYSDEC budget and accompanying travel restrictions (Figure 3.1.1).

Acoustic data were processed using the Myriax Echoview (v5.4) software. Single target fish echoes within the acoustic size ranges from >-70 to -59 dB and >-59 to -40 dB were used to define age-0 and age-1+ Rainbow Smelt age groups, respectively. Acoustic echograms were partitioned into two depth strata, epilimnion and meta-hypolimnion, based on an approximate depth of the 18-Celsius isotherm (from TD profiles) and from a pre-analysis of the relative proportion of age-0-size Rainbow Smelt to ALL-size Smelt (age-0 + age-1+: >-70 to -40 dB) by 1-m depth layers for each sample interval (800-m horizontal segments). This pre-analysis of TS distributions was accomplished within a specialized SAS (SAS 2006) program that scanned 1-m depth layers in each sample interval within a specified depth range in a downward progression and selected the first occurrence where the proportion of age-0- to ALL-size Smelt targets was less than 40%. The lower bound of this 1-m depth layer established a preliminary depth for defining the boundary between the two thermal strata (epilimnion and meta-hypolimnion). The SAS-derived Epi-Meta strata boundary was then formatted as a line-definition file and imported into Echoview. This line was then visually examined in the various echogram types (S_v, TS, single target detections) to see how well it spatially delineated age-0 Rainbow Smelt located primarily in the epilimnion from age-1+ Rainbow Smelt located primarily in the metalimnion and hypolimnion. If necessary, and with knowledge of the thermal structure, the line was adjusted to better delineate the two Rainbow Smelt age (size) groups. The final epi-meta boundary line was then referenced to create the two thermal strata across all sample intervals within acoustic transects exhibiting thermal stratification. If coldwater habitat was not apparent the sample interval was considered to be entirely epilimnion.

We applied a -80 dB minimum threshold to the raw ping volume back scattering variable (S_v). Mean S_v data and *in situ* single target detection distributions by analysis cell (thermal strata by 800-m sample interval) were exported to external text delimited files and then imported into a SAS program for computation of fish densities for age-0 and age-1+ Smelt-size acoustic targets. We used Sawada *et al.'s* (1993) N_v index to detect for potential bias from the inclusion of multiple echoes in the *in situ* TS distributions in all analysis cells. If an N_v index for an individual analysis cell exceeded the N_v threshold of 0.1, we replaced the mean backscattering cross section value, sigma (σ_{bs}) for that cell with an average mean sigma calculated from strata cells that had good N_v's (<0.1) as recommended in the SOP (Rudstam et al. 2009). Estimates of basin-wide mean fish density and absolute abundance for age-1+ Smelt-size targets was achieved using a one-stage Cluster Analysis in SAS (Proc Surveymeans; SAS 2004).

Acoustic Series Results 2007–2013

In previous years of reporting pelagic forage fish abundance we routinely included warm water habitat (epilimnion) in annual estimates of age-1+ Smelt-size acoustic targets. However, without a companion mid-water trawl component consistently performed in our annual acoustic program we reasoned a more prudent option would be to report on age-1+ Rainbow Smelt abundance for only cold-water habitat (metalimnion and hypolimnion). In years when mid-water trawling was done, Rainbow Smelt, mostly yearling and older cohorts, made up the majority (>95%) of the fish species caught in cold-water habitat, and age-0 Rainbow Smelt were found mostly in warm-water habitat (epilimnion) along with several other pelagic species.

Basin-wide acoustic estimates of total pelagic forage fish density for the acoustic size range of age-1+ Rainbow Smelt (>-59 to -40 dB) in cold-water habitat was highest in 2009 (11,936 fish/ha) and lowest in 2007 (1,754 fish/ha) for the most recent seven-year period (Figure 3.1.2). The mean density of age-1+ Rainbow Smelt-size forage fish in cold-water habitat decreased by 7% in 2013 (from 2,935 fish/ha in 2012).

Maps of pelagic forage fish densities by 800-m sample intervals for the last four years (Figures 3.1.3 and 3.1.4) and for earlier reported years (Forage Task Group 2009, 2011) indicate ongoing assessment efforts have consistently achieved full spatial coverage of the east basin acoustic survey area. These figures also demonstrate that the spatial distribution of pelagic forage fish abundance can markedly differ across years. In 2013, age-1+ Rainbow Smelt-size forage fish (all species in cold-water habitat) densities were highest in Canadian waters south of Port Maitland

and south of Long Point. Low densities were observed in Pennsylvania waters and in the deepest region of the basin (Figures 3.1.3). A total of 399 800-m horizontal intervals were sampled across 12 transects in 2013 with an average bottom depth of 31 m. Forage fish density estimates (age-1+ Rainbow Smelt-size) across 800-m sample intervals of cold-water habitat ranged from zero fish/ha (observed in Transects 58707, 59002, and 59034) to 33,576 fish/ha (in transect 58863) with 25 or <7% of the sample intervals yielding density estimates >10,000 fish/ha (Figure 3.1.3). These very high density observations in cold-water (>10,000 fish/ha) were distributed across six different transects of which 80% (20 of 25) occurred in the three transects nearest to Port Maitland (58787, 58863, 58944). The single greatest interval density observed in the 2013 east basin survey occurred on transect 58863 (33,576 fish/ha), approximately 5 km south of the north end (Figure 3.1.3). Yearling-and-older Rainbow Smelt-size densities immediately north and south of this intervals were 7,646 and 9,339 fish/ha, respectively.

The basin-wide average density of age-0 Rainbow Smelt-size targets in warm-water habitat was 18,889 fish/ha. Young-of-the-Year Rainbow Smelt-size densities were consistently high across all basin areas in 2013 (Figure 3.1.3). Transects with the lowest and highest average age-0 Rainbow Smelt-size density were 59002 (13,867 fish/ha) and 58736 (30,831/ha), respectively. Non-Rainbow Smelt fish species likely contributed significantly to the small fish density estimates in warm-water habitat in the 2013 survey, but this cannot be confirmed in absence of mid-water trawl collections.

The mid-basin region between Port Maitland, ON and Dunkirk, NY exhibited high forage fish densities in 2011, 2010, and 2009 (Figure 4.1.3). In 2008, age-1+ Rainbow Smelt-size forage fish densities were greatest in a region south of Long Point (Forage Task Group 2011). In 2007, age-1+-size Rainbow Smelt densities were comparatively much lower and evenly distributed throughout the east basin (Forage Task Group 2011). This improved knowledge that the East Basin Lake Erie pelagic fish resource can differ spatially across years reinforces the added value of this broad inter-agency approach to forage fish assessment relative to the unilateral efforts of independent trawling programs conducted by three east basin jurisdictions.

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

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 2013 central basin acoustic 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 acoustic 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. Sampling started and ended at the 10-m contour.

Hydroacoustics data, from both vessels, were collected with BioSonics DTX® echosounders and BioSonics Visual Acquisition (release 5.1) software. Data from the *R/V Muskie* were collected using a 120-kHz, 8.2-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. Starting with the 2010 survey, we altered our protocol to collect data at multiple pulse durations to facilitate a sensitivity analysis of single target detection parameters to determine optimal pulse duration when fish aggregations are dense. Shorter pulse durations can better discern individual targets in dense fish layers (Parker-Stetter et al. 2009) which are common near the thermocline in central Lake Erie. Longer pulse durations can result in biased *in situ* target strength (TS) estimates, which further result in biased density estimates.

Sound was transmitted at 1 pulse per second (pps) at alternating pulse durations of 0.1 milliseconds (ms), 0.2 ms, 0.3 ms, and 0.4 ms (i.e., each second, one pulse lasting 0.1 ms, one pulse lasting 0.2 ms, one pulse lasting 0.3 ms, and one pulse lasting 0.4 ms was transmitted). In surveys prior to 2010, sound was transmitted at 4 pps and 0.4 ms. For this report, we use only data collected at 0.4 ms to remain comparable with past practices. We will calculate densities at each pulse duration, to determine if shorter pulse durations result in reduced bias in *in situ* target strength estimates, and use those results to inform future data collection. Global Positioning Systems (GPS) coordinates from the *R/V Muskie* were collected using a Garmin ® GPSMAP 76Cx, and from the *R/V Grandon*, a Garmin 17HVS. Both vessels interfaced GPS coordinates with the echosounders to obtain simultaneous latitude and longitude coordinates. Thermal profiles were taken on each transect to calculate the speed of sound in water for use in data analysis. We used the temperature just above the thermocline because the largest proportion of fish occurred nearest this depth in the water column. Because temperature is not uniform from surface to bottom, this necessarily results in slight error in estimated depth of fish targets. 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, we used a standard tungsten-carbide calibration sphere, designed specifically for 120-kHz transducers, to calculate a calibration offset for calculating target strengths. Background noise was estimated by integrating total sound from passive listening data collected just prior to acoustic sampling from the *R/V Muskie*. Background noise from *R/V Grandon* data was estimated from integrating Sv data below the first bottom echo in areas where no fish targets were present.

Analysis of hydroacoustic data was conducted following guidelines established in the GLSOP (Parker-Stetter et al. 2009) using Echoview ® version 5.1 software. Proportionate area backscattering coefficient and single targets identified using Single Target Detection Method 2 (Parker-Stetter et al. 2009) were used to generate density estimates for distance intervals. Distance intervals for each transect were 500 m. Depth strata were established based on similarity of distributions of single target strength. 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 threshold was -74 dB. This value permitted inclusion of all targets at least -68 dB within the half-power 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 age-0 and yearling and older Rainbow Smelt and Emerald Shiner were estimated 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 eight 20-minute trawls on four transects in Ontario waters concurrent with the *R/V Muskie* acoustic data collection. The R/V Grandon conducted up to three 20-minute midwater trawls in Ohio waters on the remaining four transects. Whenever possible, trawl vessels attempted to distribute trawl effort 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.

Results

Four complete cross-lake transects and two partial transects were sampled between 8 July and 15 July, 2013 with hydroacoustics and midwater trawls (Figure 3.2.1). The remaining transects were not completed due to weather, lost gear during poor weather, and vessel commitments to other projects.

A total of 38 midwater trawls were completed during the survey. Rainbow Smelt and Emerald Shiner were the primary species caught in most midwater trawls (Table 3.2.1). Freshwater Drum was the only other species that comprised the majority of an individual trawl catch. Other species caught in midwater trawls included Alewife, Gizzard Shad, Rainbow Trout, White Perch, White Bass, Walleye, and White Sucker, Yellow Perch.

Acoustic TS distributions, by depth, showed differences in TS across depth strata. The depth of the change in TS distribution ranged from 12-15 m among transects. Target strength distributions within each transect did not vary enough to warrant splitting transects into sections for analysis. Highest acoustic densities occurred in the upper depth layers relative to the lower layer of each transect (Table 3.2.2). Species and age group composition of the trawl catch tended to separate by depth in 2013. The highest densities of Emerald Shiner were primarily in the upper layers, shallower than 13 m, while Rainbow Smelt densities were generally higher in the trawls fished deeper than 13 m.

Spatial distribution across transects varied by species and age group. Emerald Shiner densities tended to be highest in the nearshore areas of transects compared to offshore areas (Figure 3.2.2). Age-0 Rainbow Smelt densities were higher in the eastern transects relative to the western transects in July 2013 (Figure 3.2.3). Highest densities of age-1+ Rainbow Smelt were found in the southern and eastern areas of the basin (Figure 3.2.4). Acoustic densities of Emerald Shiner and both age groups of Rainbow Smelt declined from 2012.

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 5.2-mg/l off Erieau, Ontario.

Discussion

In 2013, vertical species distribution based on midwater trawls was more typical of historic patterns compared to 2012. Midwater trawls run from the *R/V Keenosay* on the northern sections of transects showed a slightly different vertical species distribution compared to trawls run from the *R/V Grandon* on the southern sections of transects. Species distribution from the *R/V Keenosay* was typical of historic patterns compared to R/V Grandon trawls. Midwater trawls from the *R/V Keenosay* found Emerald Shiner was located primarily in depths shallower than 13 m. Age-0 Rainbow Smelt were generally caught in and above the thermocline, from 13-18 m. Age-1 Rainbow Smelt were caught primarily below the thermocline, at depths greater than 17 m. Midwater trawls from the *R/V Grandon* caught large proportions (>40% individual trawl catch) of age-1+ Rainbow Smelt much higher in the water column compared to trawls from the *R/V Keenosay*. Temperature and dissolved oxygen profiles did not find any areas of low oxygen that would affect the distribution of species as was found in 2012 (Forage Task Group 2013). Thermocline depths ranged from 11-17 m and tended to be deeper on the northern sections of transects compared to the southern sections in similar depth strata. The depth of the thermocline is the most likely explanation for the difference in species distribution between the two trawling vessels.

As in previous years, age-1+ Emerald Shiners were located primarily in the upper layers of the water column. The highest Emerald Shiner densities were generally located on the shallower, nearshore ends of transects. Emerald Shiner densities on the western most transect were more uniform across the basin compared to other transects. This transect is the shallowest, and rarely covers habitat deeper than 20 m, which is similar to the nearshore ends of central and eastern transects. Age-0 Emerald Shiners were too small to recruit to the midwater trawls during the 2013 survey and were not included in the analysis as they were in 2012.

Acoustic densities of Rainbow Smelt have declined and spatial distribution patterns have changed from 2012. Age-0 Rainbow Smelt densities in 2013 tended to be higher in the eastern and southern areas of the central basin, compared to 2012 (Forage Task Group 2013), where densities were higher in the northern and western areas. Age-1+ Rainbow Smelt densities tended to be higher on the southern portions of transects compared to the northern areas in 2013. In 2012, age-1+ densities were highest on transects that were the furthest east and west in the central basin.

Hydroacoustic data have been collected at pulse durations less than 0.4 ms since 2010. We report only those density estimates from data collected at 0.4 ms pulse duration so data are comparable to past years. The data we collected at shorter pulse durations will be analyzed to determine if bias of target strength estimates can be further reduced. We will also assess how density estimates are affected by collecting data at different pulse durations.

3.3 West Basin Acoustic Survey (E. Weimer)

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 cross-basin transects were surveyed July 15-18, 2013 (Figure 3.3.1). The western transect was surveyed on the night of July 15-16 using the Lake Erie BioSonics DT-X surface unit, which malfunctioned partway through. Due to this malfunction, data from this transect was not included in the final analyses. The eastern and middle transects were surveyed using an older, BioSonics DT-E surface unit belonging to the Michigan Department of Natural Resources Lake St. Clair Fisheries Research Station. The continued issues with the Lake Erie BioSonics DT-X surface unit remains troubling; plans to test the unit on the Inland Research unit acoustic survey boat (to determine whether the Lake Erie survey vessel is generating electrical interference) during the fall were postponed due to scheduling issues; we intend on re-scheduling this test in the spring. As of now, the surface unit has been replaced by BioSonics, so testing further testing will focus on the transducers and cables. Regardless of the outcome of this testing, it is encouraging to have access to functional hydroacoustic survey equipment, and we thank the MiDNR for the loan of their equipment and will plan on using it for surveys in the future.

Data was collected in 2013 using a single, downward-facing, 7.5-degree, 123-kHz split-beam transducer, a Garmin global positioning system, and a Panasonic CF-30 laptop computer. The acoustic system was calibrated before 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 fixed pole located on the port side of the boat amidships. The transducer was mounted 1 m below the surface. Data were collected using BioSonics Visual Acquisition 5.0.4 software. Collection settings during the survey were 10 pings/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 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 to identify sample location.

Data were analyzed using the Myriax software Echoview 4.5 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):

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

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

Results

In 2013, 103 km of Lake Erie were surveyed, resulting in the collection of almost 1 GB of data. Western basin forage fish (acoustic targets between -60dB and -38dB) density and biomass estimates from the two completed transects were very high in 2013, averaging 25,474 fish per hectare and 44 kg per hectare, respectively (Figure 3.3.2). Statistical testing (ANOVA) indicated that density in 2013 was significantly higher than in 2005, 2008, 2009, and 2011($F_{6, 721} = 42.6$, $P < 0.0001$), and similar to levels in 2006 and 2007. Biomass in 2013 was higher than all years but 2007 ($F_{6, 721} = 44.1$, $P < 0.0001$). High estimates may reflect the strong presence of age-0 Gizzard Shad in 2013; in addition, a significant hatch of aquatic invertebrates (mayflies and midges) occurred both nights, which increases the number of forage-fish sized targets (-60dB to -38dB). Most (86%) forage fish in the survey were estimated to be 20-59 mm TL; 98% were between 20-109 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, 2013. *R/V Keenosay* trawl ID numbers are 1001-4009. *R/V Grandon* trawl ID numbers are 730-732.

Transect	Trawl depth	Trawl ID	Latitude	Longitude	Rainbow Smelt age-0	Rainbow Smelt age-1+	Emerald Shiner	Yellow Perch age-0	Freshwater Drum age-1+	Other
58100	19	1001	42.3885	-80.9145	2	95	0	0	0	3
58100	19	1002	42.3967	-80.9312	0	99	0	0	0	1
58100	15	1003	42.3952	-80.9347	95	3	0	2	1	0
58100	12	1004	42.3945	-80.9368	93	0	1	3	0	3
58100	14	1005	42.5355	-80.9728	6	23	69	1	0	1
58100	12	1006	42.5315	-80.9802	0	0	100	0	0	0
58100	8	1007	42.5335	-80.9867	2	0	91	6	0	1
58100	11	1008	42.6202	-81.0197	0	32	67	0	0	1
58100	8	1009	42.6202	-81.0220	1	0	98	0	0	1
57850	6	2001	42.5610	-81.4740	8	3	83	0	0	6
57850	9	2002	42.5603	-81.4765	3	9	86	0	1	1
57850	14	2003	42.4907	-81.4428	39	37	23	0	0	1
57850	12	2004	42.4843	-81.4520	9	1	88	1	1	0
57600	9	3001	42.2538	-81.8323	11	8	80	0	0	1
57600	6	3002	42.2595	-81.8287	3	0	94	0	0	3
57600	12	3003	42.2142	-81.8045	3	0	83	10	0	4
57600	9	3004	42.2117	-81.8028	9	0	66	0	0	25
57600	15	3005	42.2133	-81.8038	43	0	7	43	0	7
57600	18	3006	42.0735	-81.7517	50	36	5	9	0	0
57600	16	3007	42.0853	-81.7423	90	0	1	8	0	1
57600	13	3008	42.0863	-81.7292	83	0	1	15	0	1
57350	18	4001	41.9005	-82.1463	40	30	0	30	0	0
57350	18	4002	41.8862	-82.1383	59	3	9	12	3	14
57350	15	4003	41.9045	-82.1482	50	0	19	13	0	18
57350	5	4004	41.9157	-82.1545	9	0	74	0	0	17
57350	18	4005	42.0287	-82.2105	45	28	1	14	9	3
57350	15	4006	42.0133	-82.1997	49	1	2	40	7	1
57350	5	4007	42.0357	-82.2073	2	0	81	7	0	10
57350	10	4008	42.1502	-82.2637	0	0	98	2	0	0
57350	5	4009	42.1350	-82.2557	0	0	88	1	0	11
57975	13.1	725	42.2088	-81.1100	45	50	3	0	3	0
57975	7.6	726	42.1217	-81.0667	69	16	3	0	0	12
57975	3.7	727	42.0415	-81.0270	72	6	9	0	0	13
57725	12.5	728	41.8445	-81.3997	88	0	11	0	0	1
57725	13.4	729	41.9057	-81.4293	5	44	1	0	50	0
57725	18.3	730	41.9828	-81.4347	0	89	0	0	0	11
57475	7.6	731	41.6868	-81.8213	13	74	0	0	9	4
57475	11.9	732	41.7425	-81.8502	7	92	0	0	0	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 2013. 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.

		Transect											
		57350		57475		57725		57850		57975		58100	
Age group	Species	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Age-0	Rainbow Smelt	2852	143	163	526	631	797	1597	64	5737	481	14299	182
	Yellow Perch	256	52	25	158	0	160	78	64	0	8	344	3
Age-1+	Rainbow Smelt	556	251	861	63	4352	40	602	823	2236	126	1277	1017
	Emerald Shiner[1]	1331	9	1194	81	0	120	11932	11	750	0	4760	0
	Freshwater Drum	617	1	41	34	349	40	120	4	65	3	4	1

1 all ages of Emerald Shiner are combined under YAO

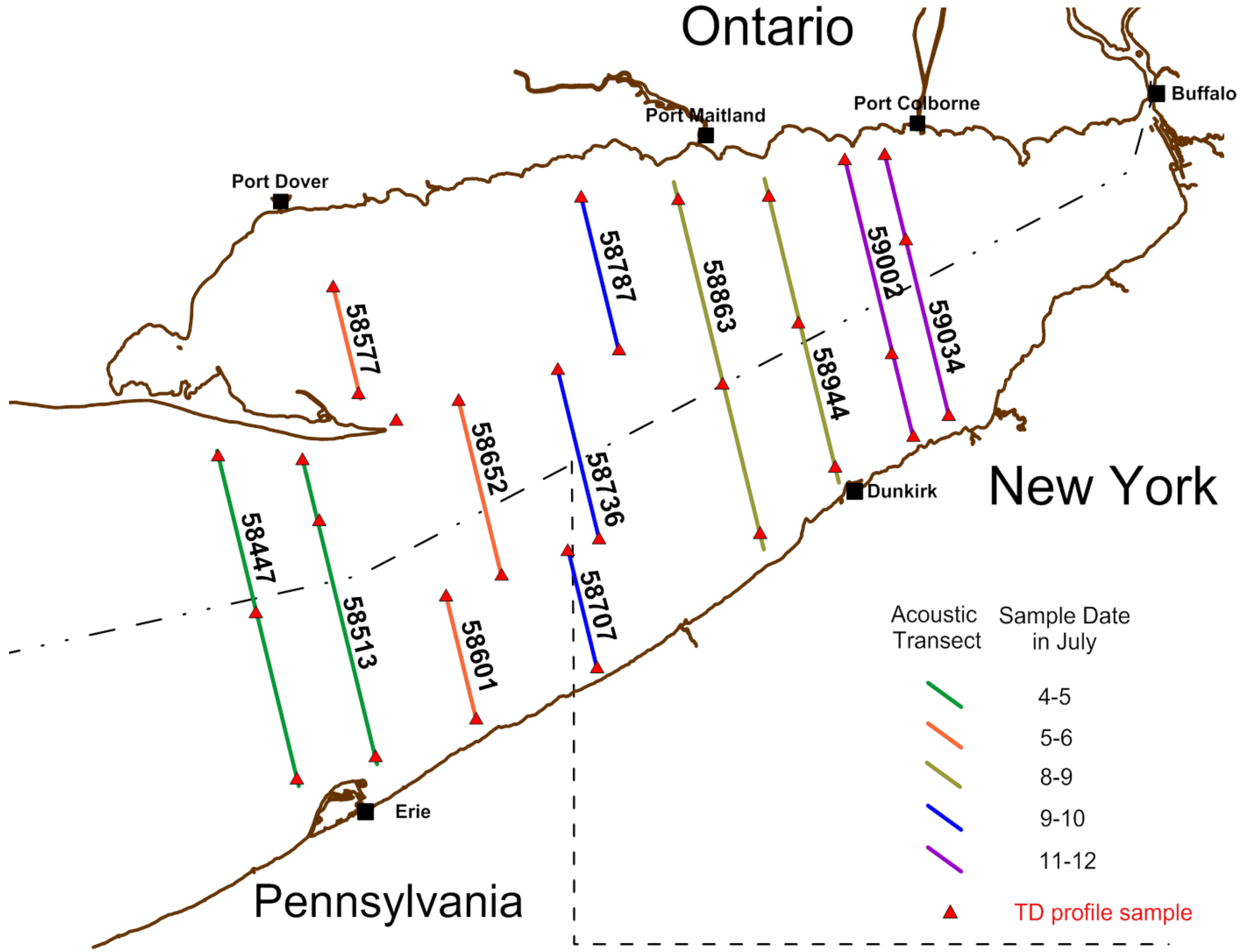

Figure 3.1.1. July 2013 eastern basin Lake Erie inter-agency acoustic survey transects and temperature profile sites sampled by the Ontario Ministry of Natural Resources (OMNR) research vessel, RV Erie Explorer .

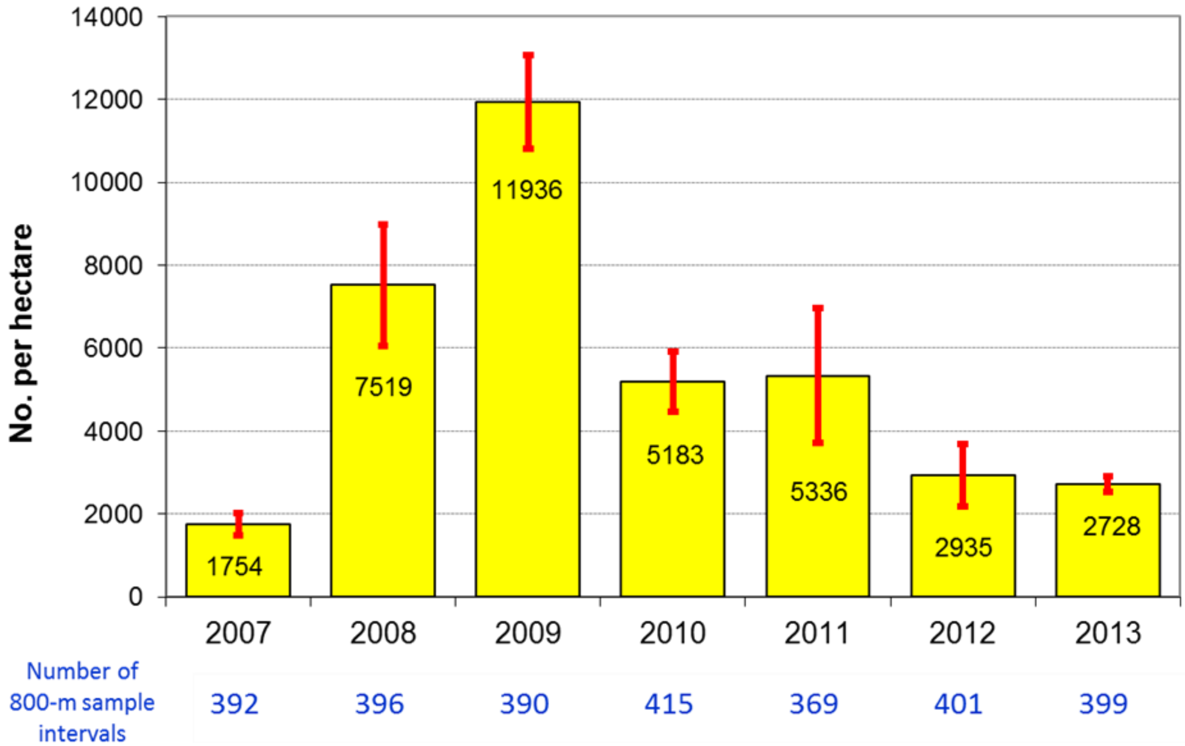

Figure 3.1.2. Mean density (Number per hectare) estimates of pelagic forage fish in cold-water habitat (all species, age-1+ Rainbow Smelt-sized) with a 120-kHz split-beam echosounder during July fisheries hydroacoustic assessments of eastern Lake Erie, 2007 - 2013. Density estimates were derived from a spatially stratified cluster analysis of acoustic transects comprised of 800-m horizontal sample intervals. Standard error (of mean) bars shown.

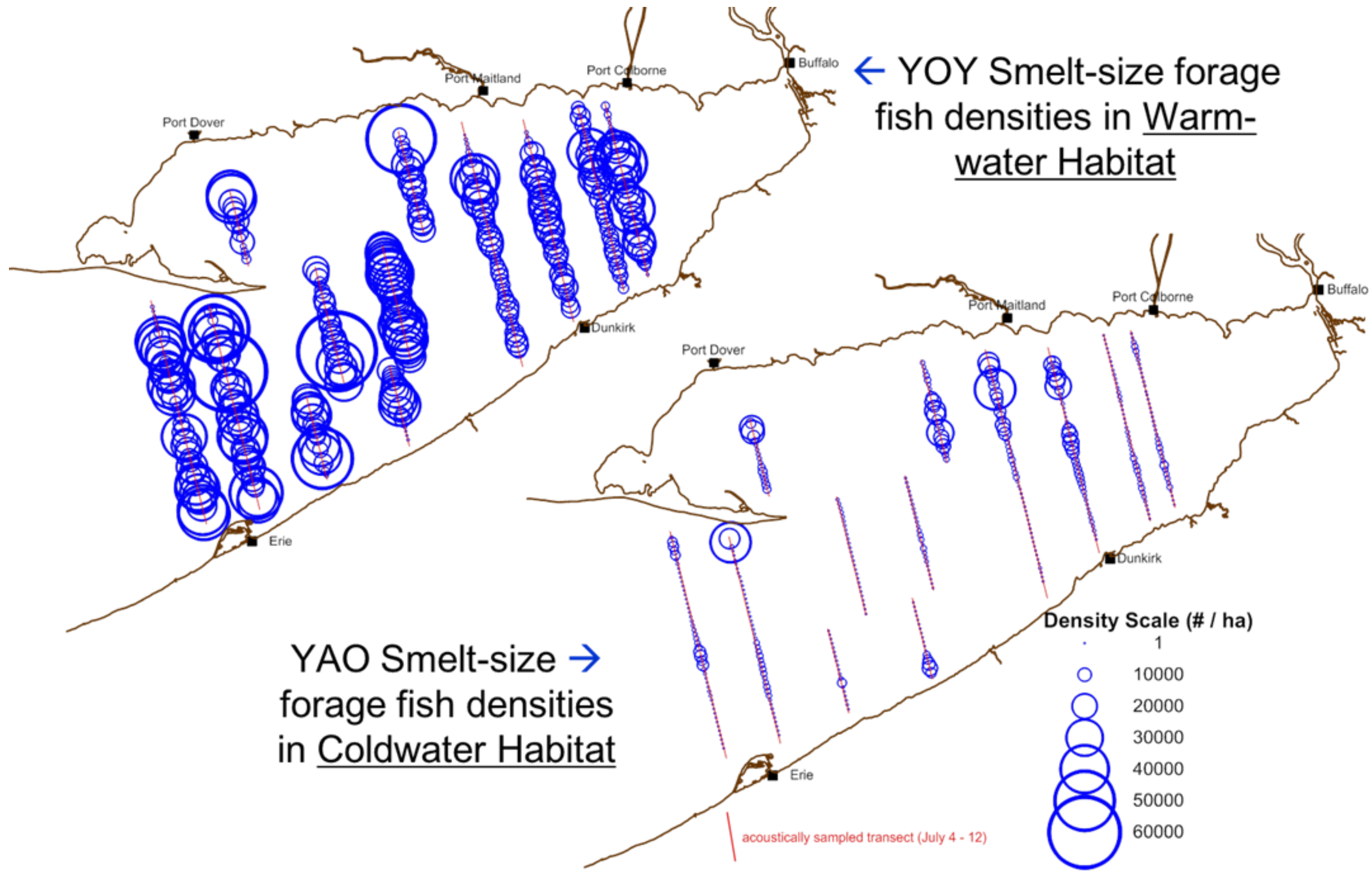

Figure 3.1.3. Relative density of age-0 (upper-left map) and age-1+ (lower-right map) Rainbow Smelt-size pelagic forage fish in warm-water (epilimnion) and cold-water (metalimnion and hypolimnion) habitat, respectively. Bubble size is proportionate to fish density (No./ha) per 800-m interval along transects sampled with a 120-kHz split-beam echosounder during July fisheries acoustic surveys in eastern Lake Erie, 2013.

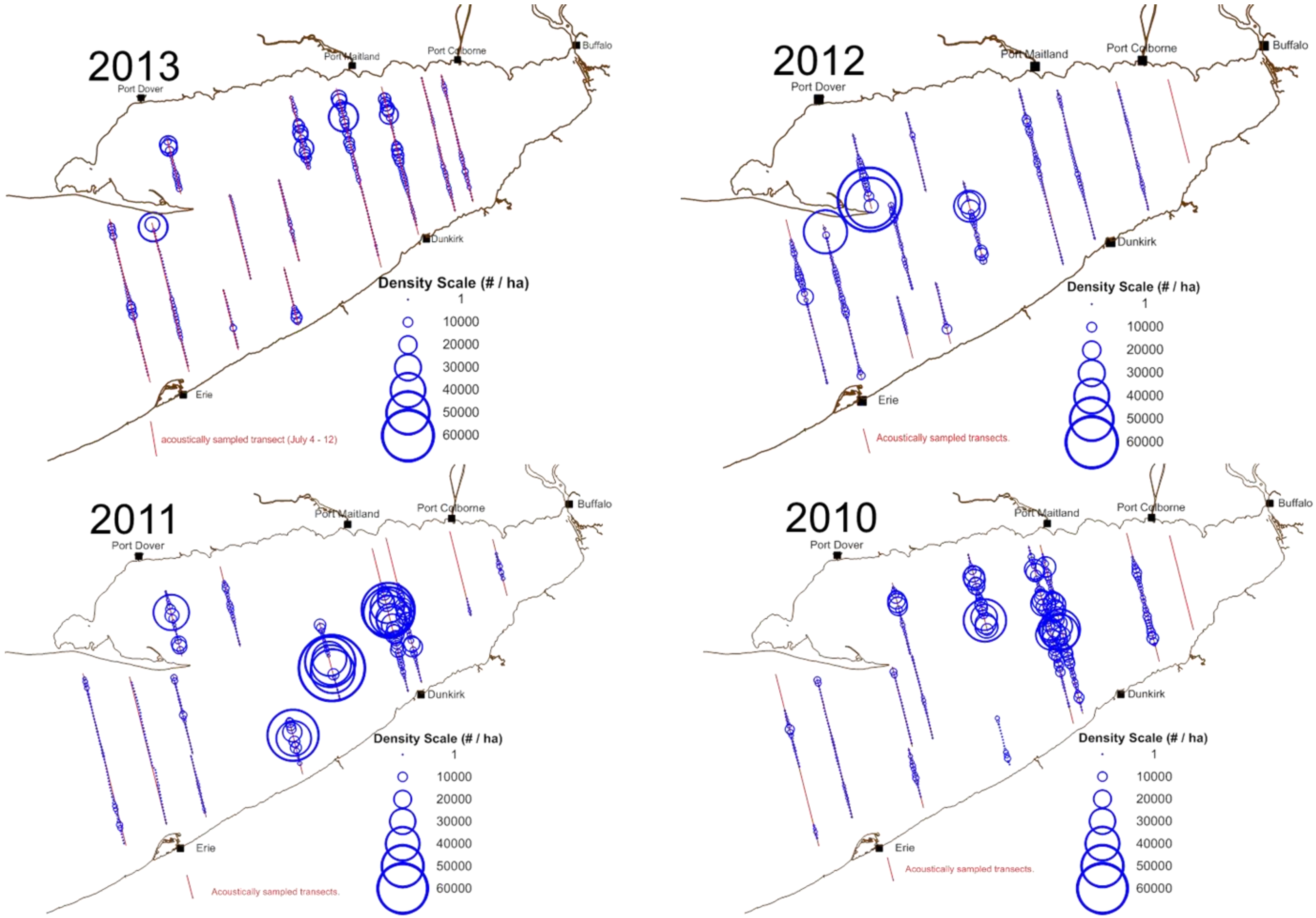

Figure 3.1.4. Relative density (No./ha) of pelagic forage fish in coldwater habitat (all species, age-1+ Rainbow Smelt-size) per 800-m interval along transects sampled with a 120-kHz split-beam echosounder during July fisheries acoustic surveys in eastern Lake Erie, 2009 to 2013.

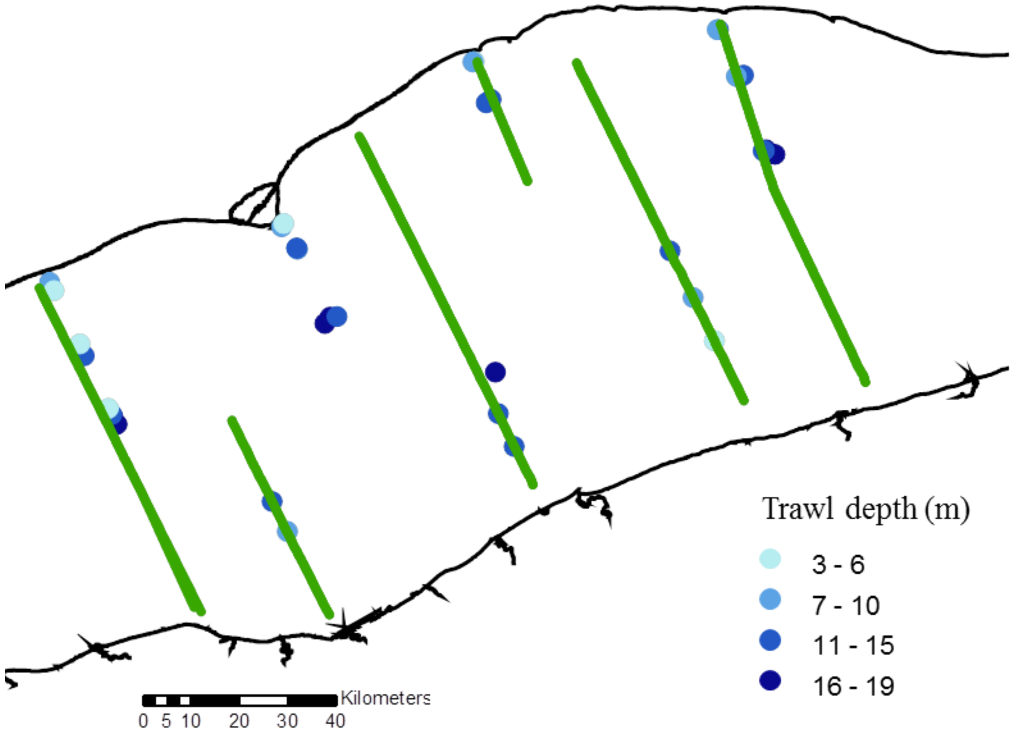

Figure 3.2.1 Hydroacoustic transects and midwater trawling stations in the central basin, Lake Erie, July 8-15, 2013. Transect numbers are Loran-TD lines.

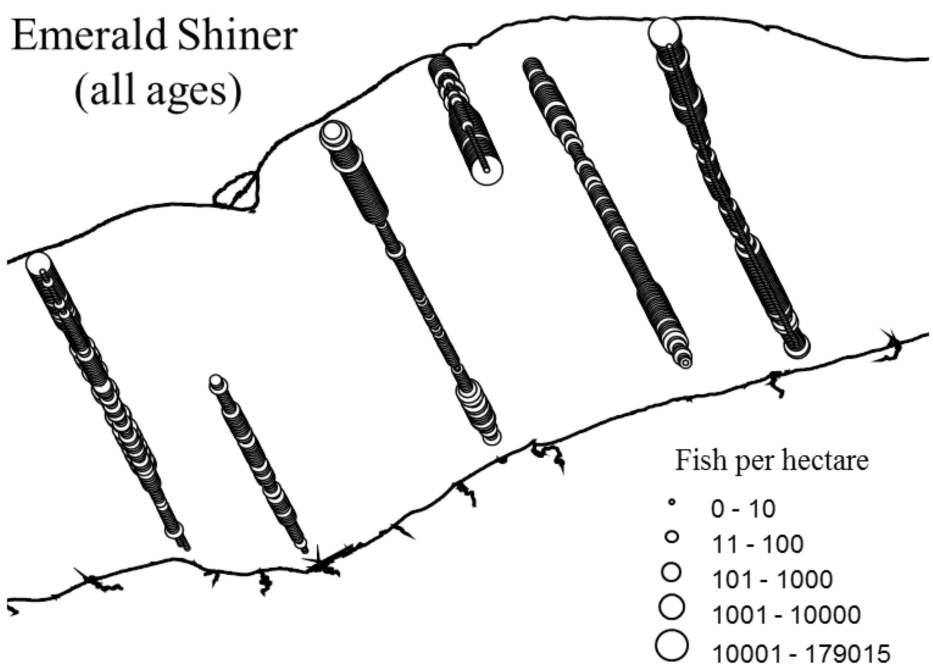

Figure 3.2.2. Density estimates of age-0 Emerald Shiner (fish/ha) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 500-m segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2013.

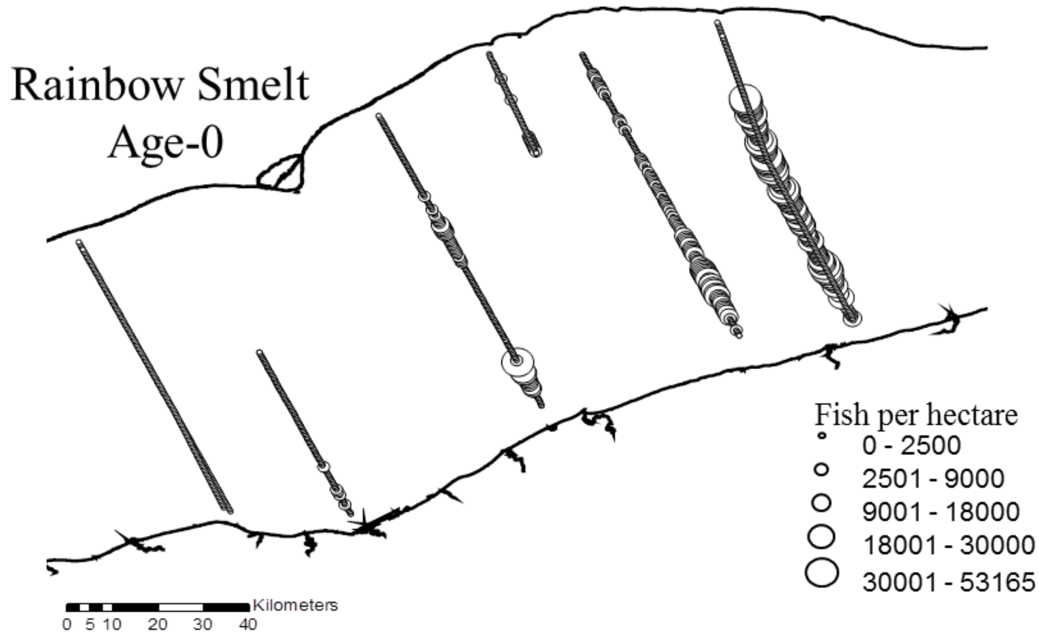

Figure 3.2.3. Density estimates of age-0 Rainbow Smelt (fish/ha) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 500-m segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2013.

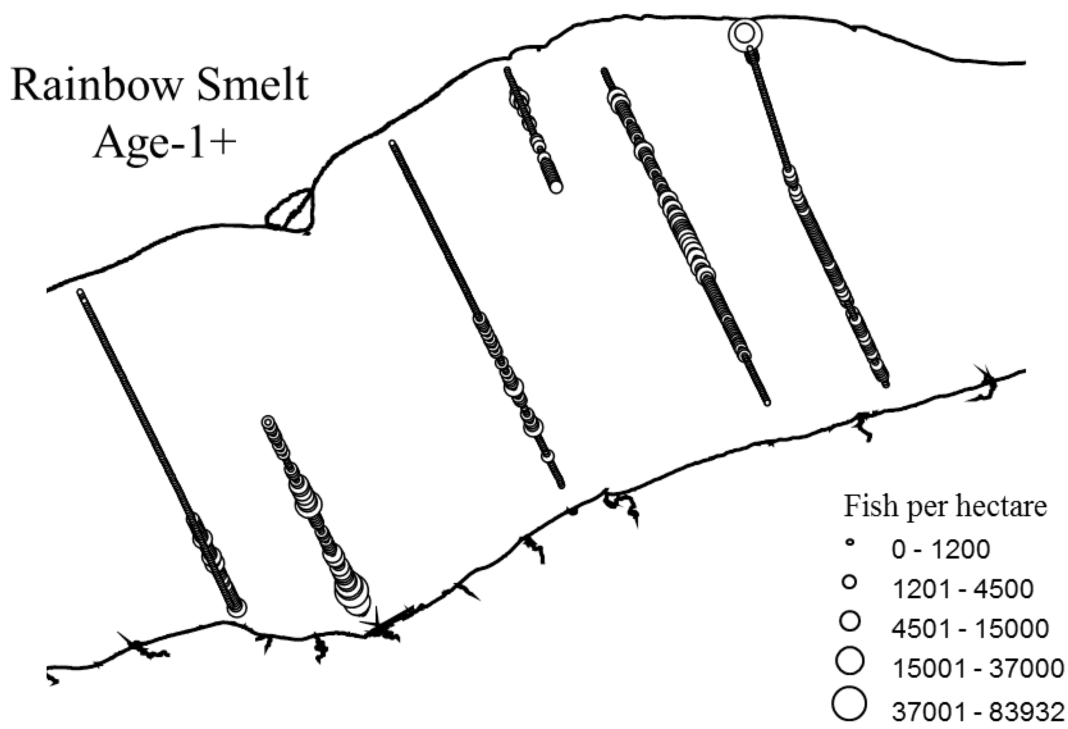

Figure 3.2.4. Density estimates of age-1+ Rainbow Smelt (fish/ha) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 500-m segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2013.

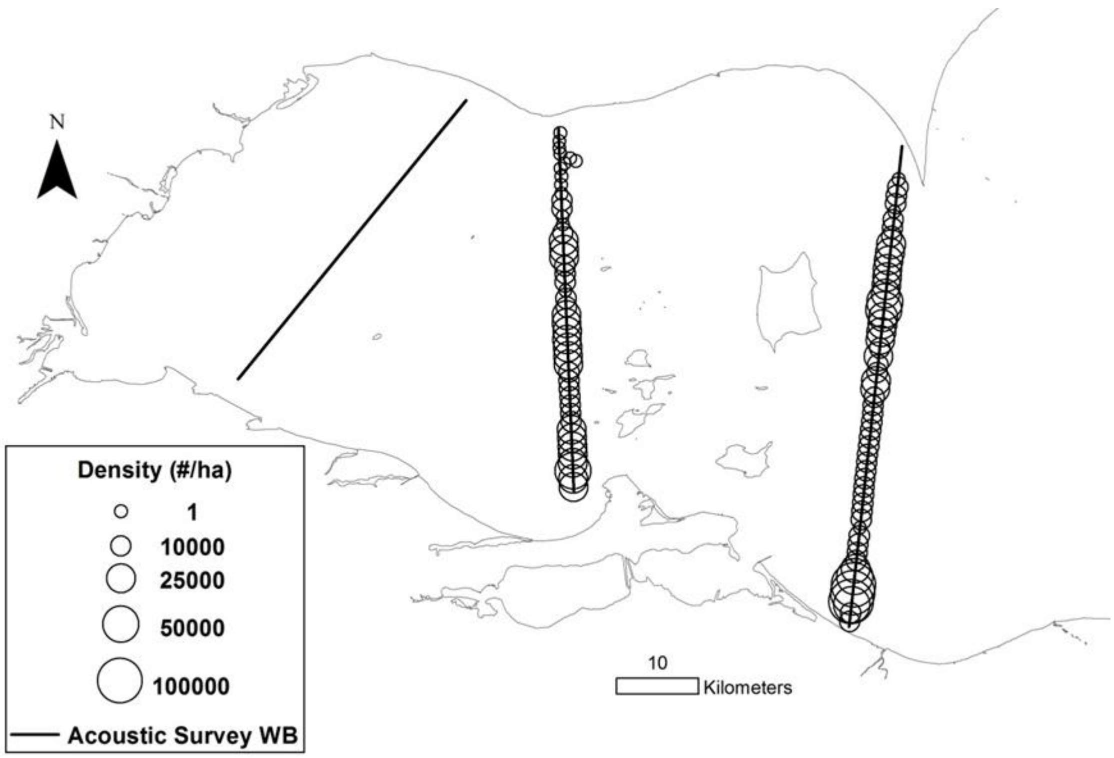

Figure 3.3.1. Acoustic survey transects and associated fish density (#/ha) for the western basin of Lake Erie, 2013. Estimates are for acoustic targets between -60dB and -38dB. Western transect was not surveyed due to equipment failure.

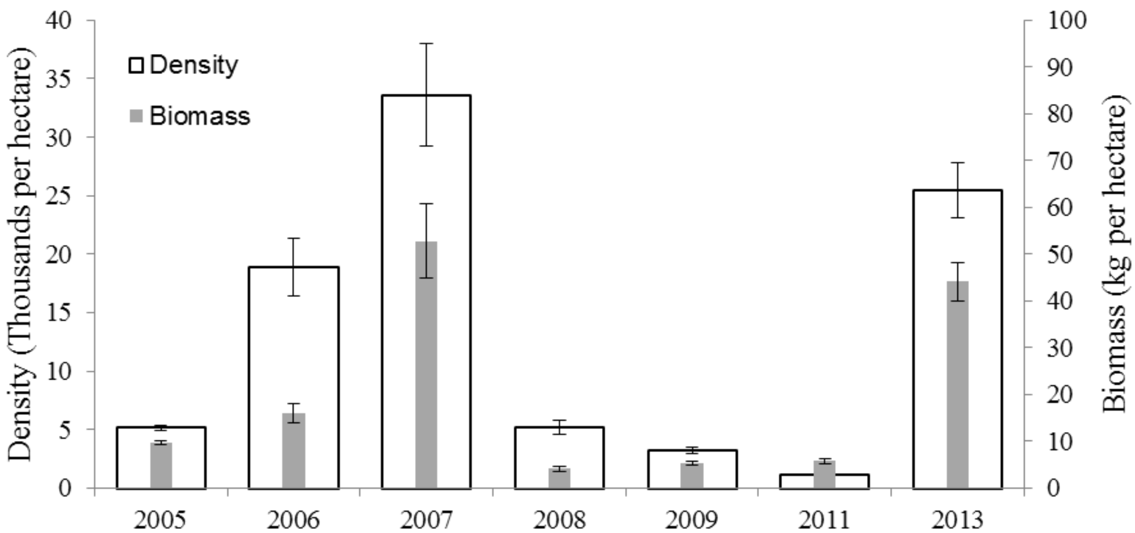

Figure 3.3.2. Mean density (#/ha) and biomass (kg/ha) estimates from the western basin acoustic survey, 2005-2013. Estimates are for acoustic targets between -60dB and -38dB. Error bars are standard errors.

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 (L. Witzel, J. Markham, and Chuck Murray)

Beginning in 1993 to 2013, intermittent, 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 widely from a high of 339 in 2000 to a low of 34 in 2004. The number of non-empty stomachs ranged from 127 in 1995 to only 9 in 2004. During 2013, 311 Walleye stomachs were examined of which 99 (32%) contained food remains, and 84 of these had food items identifiable to genus or species. Throughout most of the 1993 to 2013 time series, Rainbow Smelt represented the majority of the angler-caught adult Walleye diet (Figure 4.1.1). Infrequently, mayfly nymphs (*Hexagenia* spp.) were observed in June and early-July stomach samples during the earlier half of the time series, but they have not been encountered since 2003. The 2001 collections were the first occasion prey fish other than Rainbow Smelt made a notable contribution to the diet. From 2001 to 2003, most of the observed prey fish taxa other than Smelt were clupeid species and Emerald Shiners (Figure 4.1.1). During 2006, 2007 and 2013 at least five fish species were identified in Walleye stomachs. In 2013 samples, the contribution by volume of identifiable species included six fish species; Rainbow Smelt (79.1 %), Emerald Shiner (5.8 %), White Perch (5.5 %), Round Goby (3.9 %), Yellow Perch (2.7 %), and Alewife (1.2 %) (Figure 4.1.1). Also found in some Walleye stomachs were small, nearly unquantifiable amounts of spiny water fleas (*Bythotrephes sp.).*

Round Gobies were first observed in the summer diet of Yellow Perch from Long Point Bay in 1997 and from New York waters in 2000. Gobies have been the most common prey fish species found in perch stomachs since about 2002 (Figure 4.1.2). This exotic prey taxon has been present in 50% or more of non-empty Yellow Perch stomachs since 2008, peaking at 83% occurrence in 2013 in Long Point Bay diet studies (Figure 4.1.2).

Round Goby have also been the largest component of the diet of adult Smallmouth Bass caught in New York gill net surveys since 2000. Gobies were first observed in the diet of Smallmouth Bass from the Long Point Bay area in 2001 and during each of the past four summers (since 2010), this benthic prey fish was present in 74 to 91% of non-empty bass stomachs examined (Figure 4.1.2).

Fish species continue to comprise the majority of the diets of both Lake Trout and Burbot caught in experimental gillnet surveys during August in the eastern basin of Lake Erie. Rainbow Smelt have been the dominant food item in Lean strain Lake Trout since coldwater surveys began in the early 1980s in Lake Erie, occurring in 85 – 95% of the stomachs. However, in years of low age-1+ Rainbow Smelt abundance such as 2006 and 2010, Round Goby became prominent in the diets of both Lean and Klondike strain Lake Trout. Rainbow Smelt dominated Lake Trout diets again in 2013, occurring in 76% of Lean strain and 78% of Klondike strain Lake Trout (Figure 4.1.3). Round Goby were more prominent in Lake Trout diets during 2013 than 2012, occurring in 18% of Lean strain and 20% of Klondike strain fish. Round Goby have occurred more frequently in the diets of Klondike than Lean strain Lake Trout during all eight years that Klondike trout have been collected in coldwater index gill nets. The only other identifiable prey fish species found in any Lake Trout strain in 2013 was a Yellow Perch from a Lean Lake Trout (Figure 4.1.3).

Round Goby have increased in the diet of Burbot since this invasive species first appeared in the eastern basin in 1999, replacing Rainbow Smelt as the main prey item in Burbot diets in eight of the last 11 years (Figure 4.1.4). The occurrence of Rainbow Smelt and Round Goby in Burbot stomachs containing food decreased from 55% and 45%, respectively in 2012 to 12% and 33%, respectively in 2013. Despite this most recent year decrease, Rainbow Smelt and Round Gobies remained the dominant prey for Burbot (Figure 4.1.4).

Growth

Mean length of age 2 and age 3 Smallmouth Bass cohorts sampled in 2013 autumn gill net collections (New York) have remained stable over the past eight years and are among the highest in the 33-year history of this survey. Beginning in the late 1990's coincident with the arrival of Round Goby, several age classes of Smallmouth Bass in Long Point Bay, Ontario have exhibited a trend of increasing length-at-age (Figure 4.1.5). In 2013, length-at-age for each of age 2 to age 6 Smallmouth Bass cohorts remained at or near maximum values observed during the 28-year time series of OMNR's Long Point Bay gillnet survey.

Length-at-age trends from New York's juvenile Walleye (age-1 and age-2) assessment were near long-term average sizes. Growth rates of juvenile (age-0 and age-1) Yellow Perch in New York waters was average in 2013, and in general they have been stable for the past eight years. Length-at-age of juvenile to age 4 Yellow Perch cohorts were at or near time-series maxima in Ontario's Long Point Bay trawl and gillnet assessments in 2013. Yellow Perch mean size-at-age (length and weight) of Lake Trout in 2013 were consistent with the recent 10-year average (2003 – 2012) and condition coefficients (K) remain high (Figure 4.1.6). Klondike strain Lake Trout have significantly lower growth rates compared to Lean strain Lake Trout (Figure 4.1.6). Lake Trout growth in Lake Erie continues to be stable and among the highest in the Great Lakes.

4.2 Central Basin (J. Deller)

Historically, diets of adult Walleye collected from the fall gillnet survey in Ohio have been comprised of Gizzard Shad, Rainbow Smelt and Emerald Shiner. In 2013, Rainbow Smelt were absent in Walleye diet samples from western Ohio. The proportion (by dry weight) of Gizzard Shad (70%) and Emerald Shiner (20%) in diet samples collected in western Ohio in 2013 was about the same as in 2012 (Figure 4.2.1). Adult Walleye diet composition in eastern Ohio samples showed a decreased reliance on Gizzard Shad in 2013. Adult Walleye diets in 2012 were comprised of 95% Gizzard Shad and 5% Emerald Shiner. Samples collected in 2013 from eastern Ohio gillnets were comprised of 58% Gizzard Shad, 29% Emerald Shiner and 10% Rainbow Smelt.

Round Goby continue to be the most prominent diet item in Smallmouth Bass from Ohio gillnets in the fall. In 2013, Round Goby comprised over 75% (dry weight) of Smallmouth Bass diets basin wide (Figure 4.2.2). The remainder of Smallmouth bass diets was comprised of Emerald Shiner and clupeids. The clupeid component of Smallmouth Bass diets made an interesting switch from west to east. The clupeid component of Smallmouth diets in western Ohio was comprised of Alewives alone (6.8% of total diet items by dry weight). The clupeid component of Smallmouth Bass diets from eastern Ohio was comprised of Gizzard Shad (6.2%) and Alewife (2.9%). This pattern is the opposite of what would be expected based on relative abundance indices discussed in Section 2.3.

Growth

Mean length of Walleye collected in Ohio's fall gillnet survey in 2013 was above the long-term mean for cohorts up to age 9 in western Ohio and through age 3 in eastern Ohio. White Bass size-at-age remains high and is generally at or above the long-term mean for all cohorts in both the east and west areas of Ohio. Mean lengths of most age-0 forage species were at or above average in 2013.

4.3 Western Basin (E. Weimer and M. Rogers)

In 2013, adult Walleye diets (by dry weight) taken from Ohio DNR fall gillnet catches consisted of Gizzard Shad (81%), Emerald Shiners (11%), White Perch (6%), and Alewife (2%) in the western basin. Yearling Walleye relied on Gizzard Shad (49%), Emerald Shiner (51%). Age-0 Walleye consumed Gizzard Shad (91%) and Emerald Shiners (9%). Age-2-and-older Yellow Perch were collected for diet content analysis from the western basin during spring (June) and fall (September) by the U.S. Geological Survey. In spring, benthic invertebrates were found at the highest frequency (88% of diets), however fish prey were the most common in the fall (63% of diets). The occurrence of zooplankton was 20% in spring, but dropped to 2% in the fall. Chironomids and Dreissena spp. were the most prominent benthic invertebrates in spring, whereas bivalves were the most frequently encountered in fall diets. The most commonly found zooplankton prey in spring was Leptodora kindtii and the only zooplankton taxa identified in diets collected in the fall was Bythotrephes sp. The occurrence of fish prey greatly increased from spring to fall (18% and 63% of diets, respectively) with a shift in frequency from Emerald Shiners in spring (9% of diets) to Round Goby in fall (21% of diets), although unidentifiable fish remains were also common in fall. There were no *Hemimysis sp*. or *Cercopagis sp*. identified in Yellow Perch diets from the western basin in 2013. Comparisons to historical data collected in Michigan and Ontario waters suggests a decreasing trend in percent occurrence of zooplankton in spring Yellow Perch diets.

Percent composition by dry weight revealed a very similar pattern as frequency of occurrence data for Yellow Perch diets. Benthic invertebrate prey contributed most to diets in spring and fish prey contributed most in fall. Zooplankton contributed little to Yellow Perch diets (<10%) in both seasons. In spring, *Hexagenia spp*. comprised about 20% of the dry weight and *Dreissena spp*. contributed 10-15% across seasons. Our spring sampling coincided with a *Hexagenia spp*. hatching event and many stomachs appeared very full and they only contained *Hexagenia spp*. Fall fish prey were composed of multiple taxa including Round Goby, Emerald Shiner, Gizzard Shad, White Perch and Trout-perch (in descending order); unidentifiable fish remains were common (20% of dry diet weight on average). An increasing contribution of fish prey to Yellow Perch diets from spring to fall is consistent with our historical observations.

Growth

Mean length of most age-0 sportfish in 2013 decreased compared to 2012 (Figure 4.3.1). Lengths of select age-0 species include Walleye (146 mm), Yellow Perch (66 mm), White Bass (45 mm), White Perch (58mm), and Smallmouth Bass (78 mm). These lengths are near or below long-term averages (139 mm, 67 mm, 68 mm, 58 mm, and 80 mm, respectively).

4.4 *Hemimysis anomala* (T. MacDougall, P. Kočovský, J. Markham, J. Deller)

Hemimysis anomala, commonly called the bloody-red shrimp, is a small shrimp-like mysid crustacean native to European waters, primarily the Black Sea, the Azov Sea, and the Caspian Sea. It was first detected in the Great Lakes in 2006, likely as a result of introduction via ballast water from oceangoing ships. Confirmed observations of *H. anomala* from disparate geographic locations in 2006 (near Muskegon, MI, along the northeast shoreline of Lake Erie and in Lake Ontario near Oswego, New York) suggest that it was established and broadly distributed within the Great Lakes at this point. (NOAA- GLERL; *Hemimysis* fact sheet, February 2007). The Forage Task Group reports on *H. anomala* because of its potential to alter foodwebs by serving as both a food source and as a consumer of zooplankton resources.

Occurrence in Fish Diets

Hemimysis anomala have been observed in the diets of a few Lake Erie fish species. First observed in White Perch in 2006 in Long Point Bay, they have since been observed in the stomachs of Rock Bass and, less frequently, Yellow Perch in western basin waters by 2009 (Figure 4.4.1). In 2010 they were found for the first time in White Bass and Walleye (the Walleye also contained a Rainbow Smelt offering a secondary possible source). *Hemimysis anomala* can now be reliably collected from harbor piers in the eastern basin of the lake (K. Bowen; DFO-GLLFAS; pers com), however no targeted surveys for *H. anomala* regularly occur. Because they are rarely observed other than in fish stomachs, documentation of *H. anomala* occurrence in fish diets has provided the most reliable method for tracking expansion and persistence of this invasive species in Lake Erie. Although there is no spatially comprehensive, lake-wide analysis of fish diets, at least three surveys allow for the consideration of the consumption of *H. anomala* by fish in all three basins (Figure 4.4.2). It should be noted that not all fish species are examined in all three surveys and that the number of individual fish examined varies among surveys and years. However, this data gives us a general picture of spatial differences and trend over time (within surveys). Notably, the spatial coverage of western basin diet collections by the USGS--Lake Erie Biological Station was increased in 2013. Despite this, no fish were observed to have consumed *H. anomala* in the west in 2013.

Diet analysis from a summer gillnet index program in Long Point Bay on the north shore of the eastern basin provides some idea of changes in use by different fish species since 2006. To date, the primary and most consistent consumer of *H. anomala* is White Perch, where *H. anomala* have appeared in diets each year since 2006. In 2013, 24.4% of non-empty White Perch stomachs examined contained *H. anomala*, the highest proportion observed to date, comparable to that seen in 2009 (22.5%) and contrasted with the lowest proportion (5.6%) observed in 2010 (Figure 4.4.3). In this survey Rock Bass are the second most consistent consumer, with *H. anomala* annually found in 2-5% of examined fish from 2007-2012. As in 2006 and 2010, none of the Rock Bass stomachs examined in 2013 contained *H. anomala*. In contrast to surveys in the central and western basins (below) *H. anomala* has not been observed in any Yellow Perch from Long Point Bay over the same time period, despite 2346 non-empty stomachs having been examined. White bass were first observed to utilize *H. anomala* in Long Point Bay in 2010 (2.4% of non-empty stomachs examined). Absent in 2011, they were observed in 5.4 and 1.8 percent of White Bass from the same area in 2012 and 2013, respectively.

Yellow Perch were the first recorded consumers of *H. anomala* in the central basin (5 fish from ODNR surveys of Ohio waters). In 2010 one yellow Perch from the western basin (USGS trawl surveys) was observed to have consumed *H. anomala*. *Hemimysis anomala* has also been found in the stomach of a White Perch taken from east of Pelee Island in the western basin in 2009 (USGS-LEBS surveys), and is the first observation from offshore, western basin waters. This suggests that the islands of the western basin likely also harbor this mysid. In 2011, hemimysis was observed in four Yellow Perch and one White Perch in the western basin at locations including Michigan waters, the most western reports to date. Similarly, USGS-LEBS and ODNR surveys each reported *H. anomala* in both White Perch and Yellow Perch in 2012. ODNR observed *H. anomala* in both Yellow Perch (n=3; 0.8%) and White Bass (n=1, 0.3) in 2013. This represents only the second *H. anomala*-consuming White Bass observed outside of Long Point Bay and, in general is consistent with previous years where proportions of *H. anomala* in fish diets from west and central basin collections have been smaller than those observed in the east. Overall, occurrences of *H. anomala* in White Perch have been recorded in all three basins, with proportions of fish consuming *H. anomala* increasing from west (0.40%) to central (0.99%) to east (5.86%).

As noted previously, we urge caution when making comparisons between surveys due not only differences in sampling protocol and numbers of fish examined, but also to the apparent patchiness of this food resource, possibly linked to substrate preferences. Within the Long Point Bay survey, the vast majority of *H. anomala*-consuming fish are captured over hard rocky bedrock substrate in relatively shallow water, with no occurrences over the portion of the survey area represented by sand substrate. Standardizing protocols between basins might involve only considering stomachs collected in certain areas for *H. anomala* accounting.

By way of comparison between lakes, *H. anomala* in Lake Ontario have been shown to be utilized by rock bass (August) and Yellow Perch (October) to some degree (33% and 2%; respectively) but are predominantly utilized by Alewives (69%-100%) in August, September, and October (Lantry et al. 2010). *Hemimysis anomala* were not observed in the small number (n=4) of White Perch examined from Lake Ontario.

Occurrence in Other Surveys

Outside of fish diets, *H. anomala* can be difficult to locate because the species is nocturnal, preferring to hide in rocky cracks and crevices near the bottom along the shoreline during daylight. It sometimes exhibits swarming behavior, especially in late summer, forming small dense reddish-tinged clouds containing thousands of individuals concentrated in one location and visible just below the surface of the water in a shallow zone (NOAA- GLERL; *Hemimysis* fact sheet, February 2007). As mentioned above, their preference for rocky substrate is also apparent from catches in survey gill nets from Long Point Bay.

In 2007, one free-swimming individual was detected in waters associated with the NRG Energy Steam Station in Dunkirk, NY and underwater video of the lakebed near Hoover Point, Ontario revealed multiple swarms of what appear to be *H. anomala* in 7m depths associated with rocky areas. In November 2008, Lake Trout egg traps captured 58 individuals on Brocton Shoal, a historic Lake Trout spawning area just west of Dunkirk. These samples were collected at depths of 13.7-18.9 m. *Hemimysis anomala* were also collected in egg traps in this same area during 2009 but in lesser numbers. Targeted sampling for *H. anomala*, conducted by the Canadian Department of Fisheries and Oceans (DFO-GLLFAS), along the north shore during 2007 and 2008, regularly found *H. anomala* in large numbers in all three lake basins (K. Bowen, Dept. of Fisheries and Oceans, GLLFAS, pers. comm.). Few (n=2) were caught during a much more intensive deployment of the traps in 2010. In April of 2011, a single individual *H. anomala* was caught in a zooplankton net in School House Bay, Middle Bass Island (Darren Bade, Kent State University, pers. comm.).

Swarms of *H. anomala* were recorded 6.5 km offshore during underwater video surveillance of Nanticoke Shoal in the fall of 2012; the first noted occurrence beyond the nearshore of the eastern basin.

The impact of this species on Lake Erie and the other Great Lakes is still unknown, but based on its history of invasion across Europe, significant impacts are possible. If integrated into the current lake ecosystem, this species has the potential to alter foodwebs by serving as both a food source and as a consumer of zooplankton resources. In its native waters, its main prey item is zooplankton, primarily cladocerans, rotifers, and ostracods. Laboratory studies using Daphnia have shown that *H. anomala* consumes preferentially small and medium-size zooplankton (0.7-1.5 mm), although it can attack larger prey, and also consumes small amounts of algae (Pérez-Fuentetaja, SUNY Buffalo, personal observation). This species has the ability to reduce zooplankton biomass where it is abundant. Due to its lipid content, *H. anomala* is considered a high-energy food source and has the potential to increase the growth of planktivores (Kipp and Ricciardi 2007).

The Forage Task Group will continue to monitor and document the progression of this species and consider its impact on the Lake Erie ecosystem.

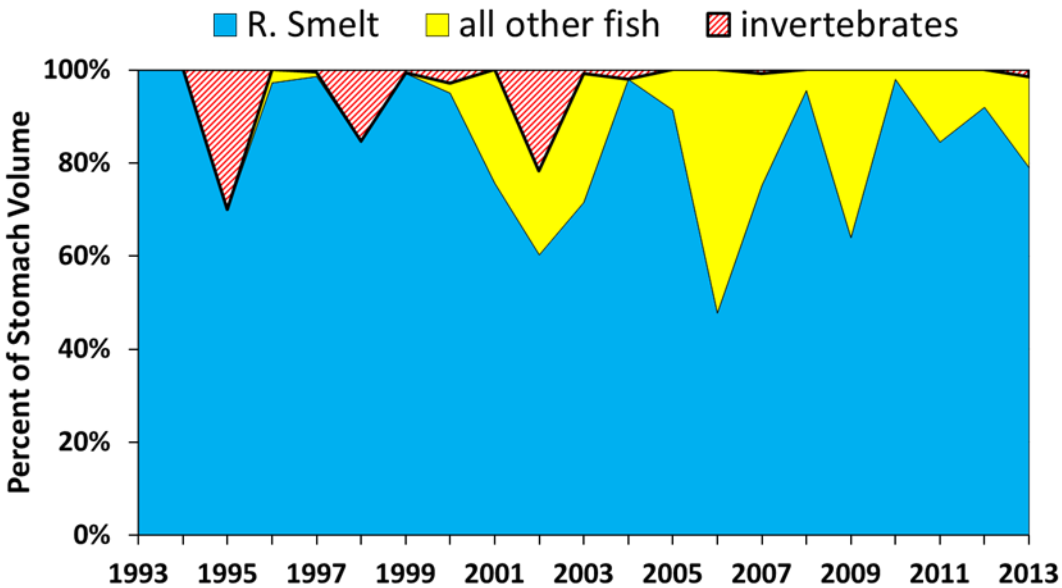

Figure 4.1.1. The percent contribution (by volume) of identifiable prey in stomachs of adult Walleye caught by summertime anglers in New York's portion of Lake Erie, 1993 to 2013.

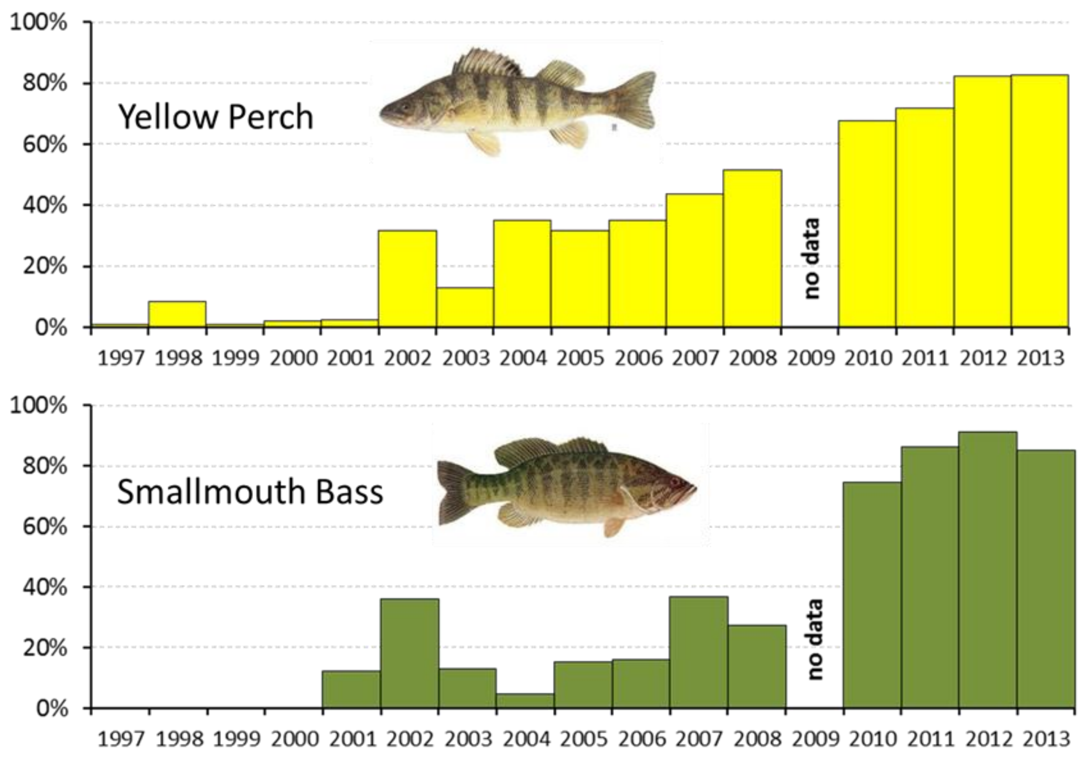

Figure 4.1.2. Percent occurrence of Round Goby in non-empty stomachs of adult Yellow Perch and Smallmouth Bass from OMNR summer index gillnets, Long Point Bay, Lake Erie 1997 to 2013.

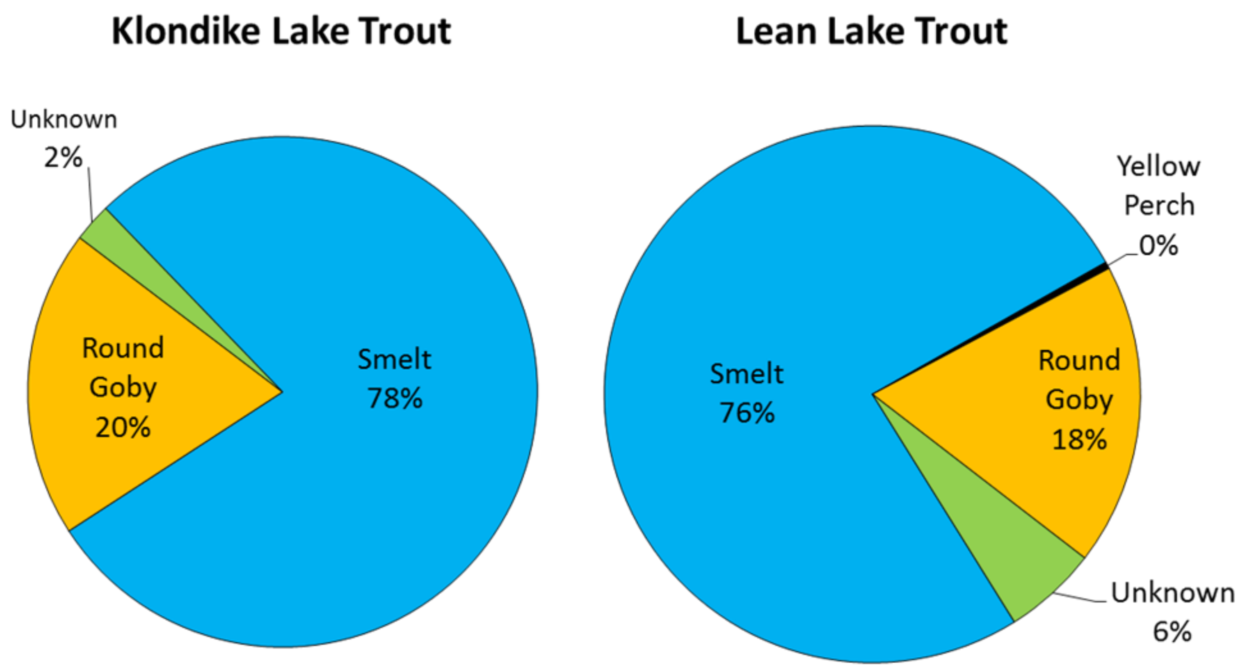

Figure 4.1.3. Percent occurrence of diet items from non-empty stomachs of Lean (N=223) and Klondike (N=37) strain Lake Trout collected in gill nets from eastern basin waters of Lake Erie, August 2013

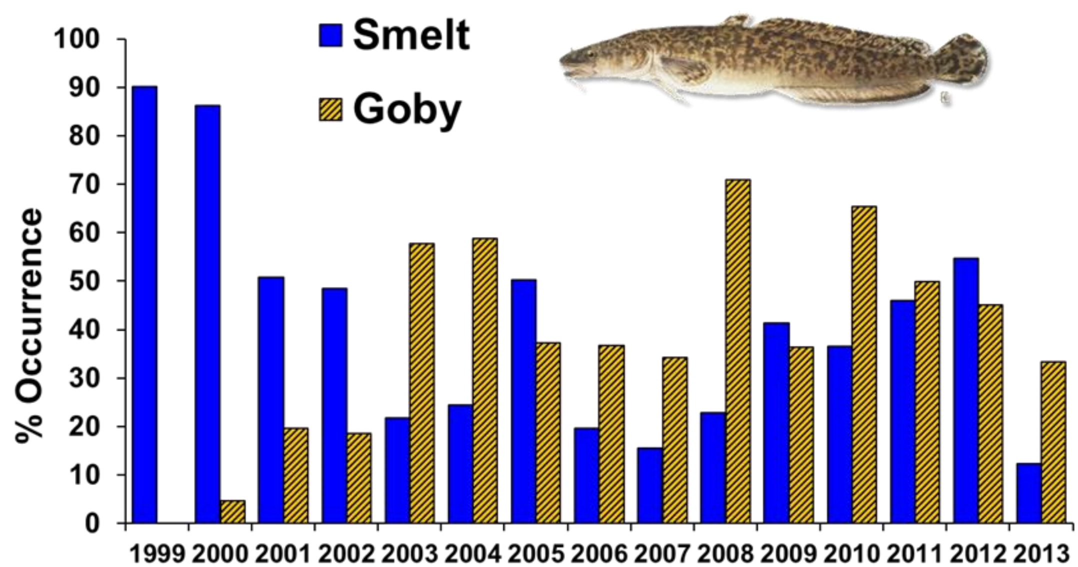

Figure 4.1.4. Percent occurrence of Rainbow Smelt and Round Gobies in the diet of Burbot caught in coldwater index gillnets set during August in the eastern basin of Lake Erie, 1999-2013.

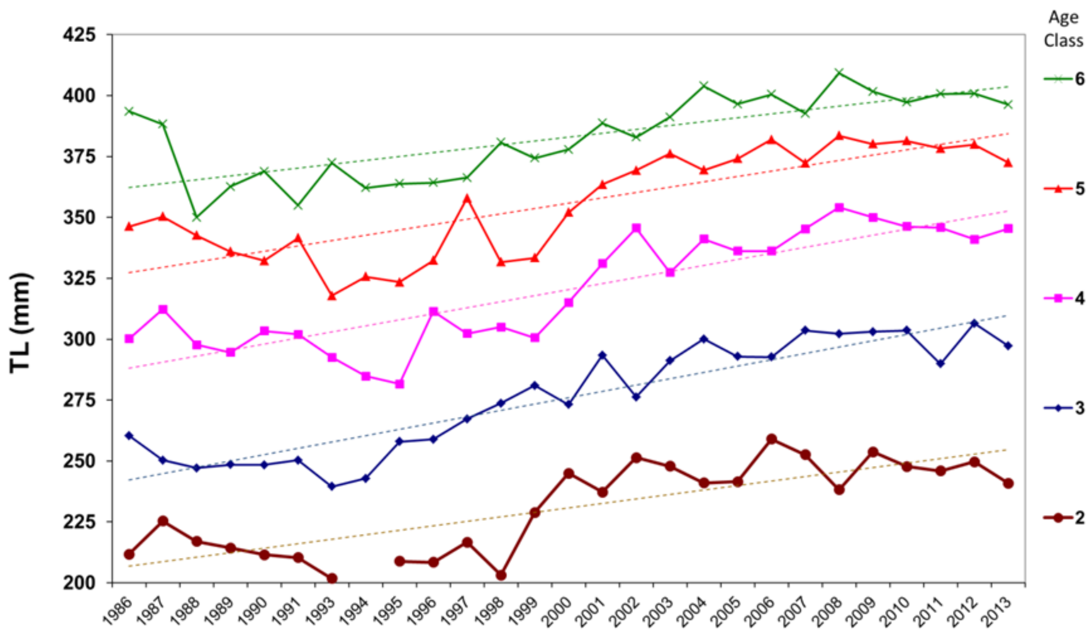

Figure 4.1.5. Smallmouth Bass mean total length (mm) at ages 2 to 6 captured in index gill nets set overnight at 12-30 ft. (3.7-9.1 m) depths during summer months in Long Point Bay, Lake Erie, 1986-2013. Males and females combined. Dashed lines represent linear trend across years for each age class. Smallmouth Bass ages were not available for 1992 samples.

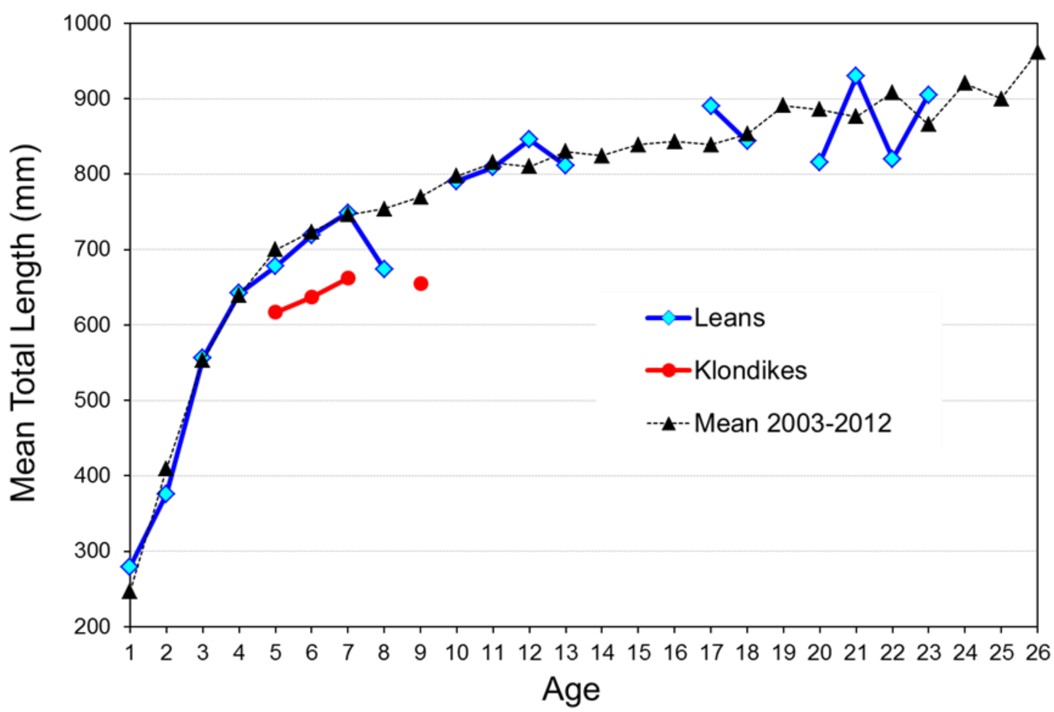

Figure 4.1.6. Mean length-at-age of Lean strain and Klondike strain Lake Trout sampled in assessment gill nets in the eastern basin of Lake Erie, August 2013. The previous 10-year average (2003-2012) from New York waters is shown for current growth rate comparison.

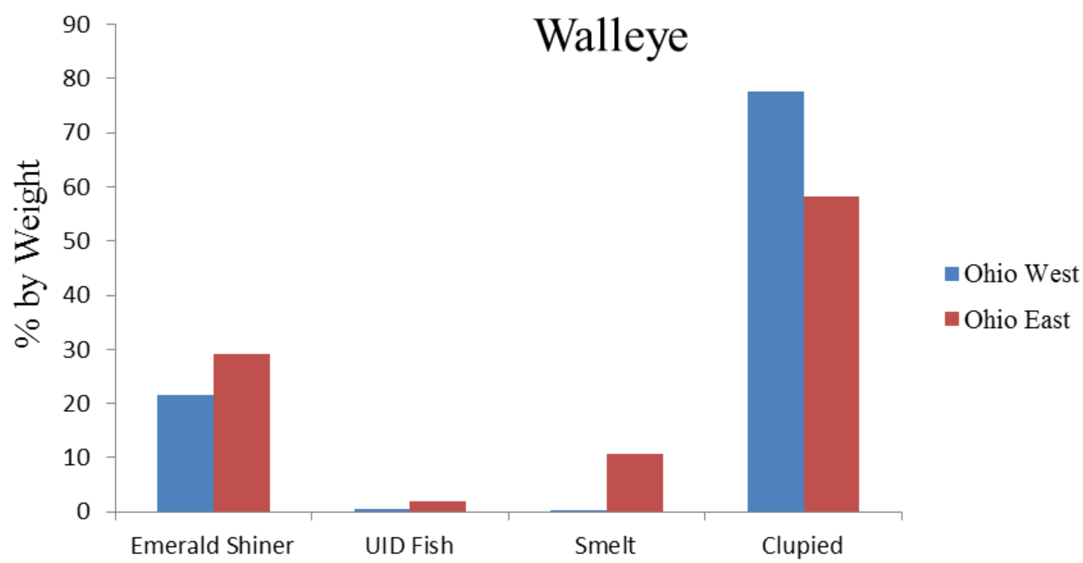

Figure 4.2.1 Walleye diet composition (percent dry weight) from Ohio fall gillnet survey, 2013.

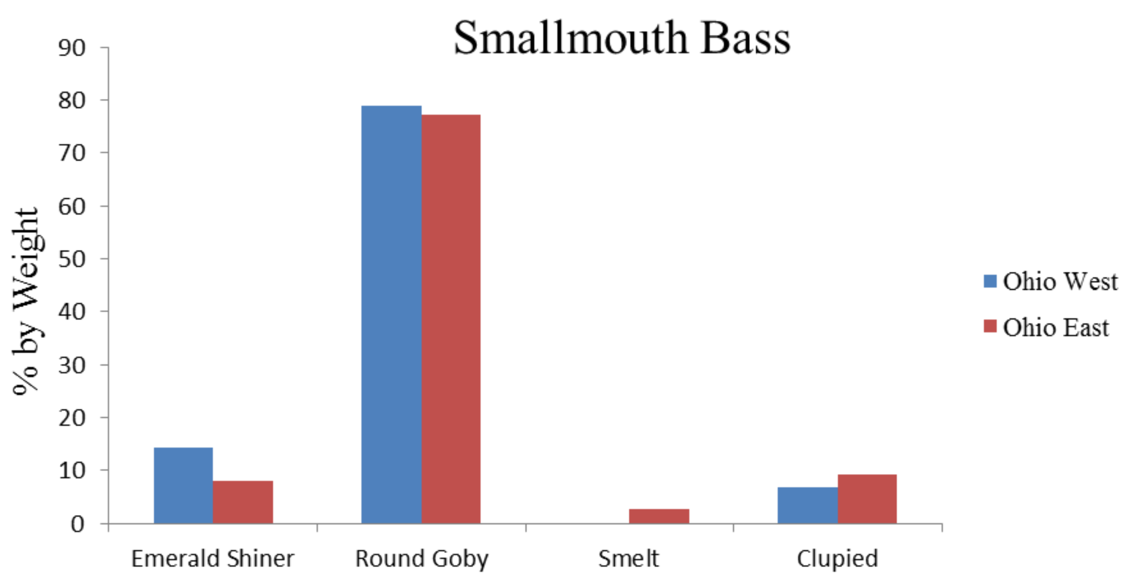

Figure 4.2.2 Smallmouth Bass diet composition (percent dry weight) from Ohio fall gillnet survey, 2013.

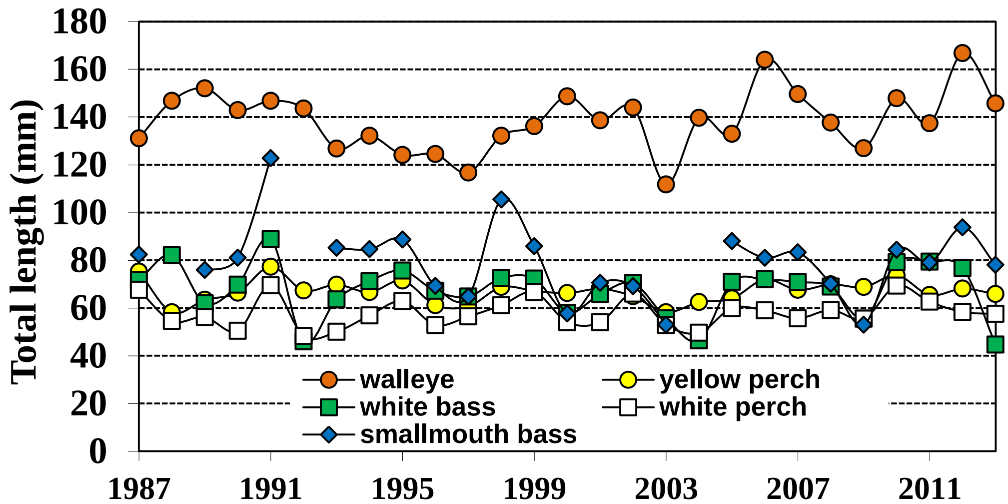

Figure 4.3.1. Mean total length (mm) of select age-0 fishes in western Lake Erie, August 1987- 2013.

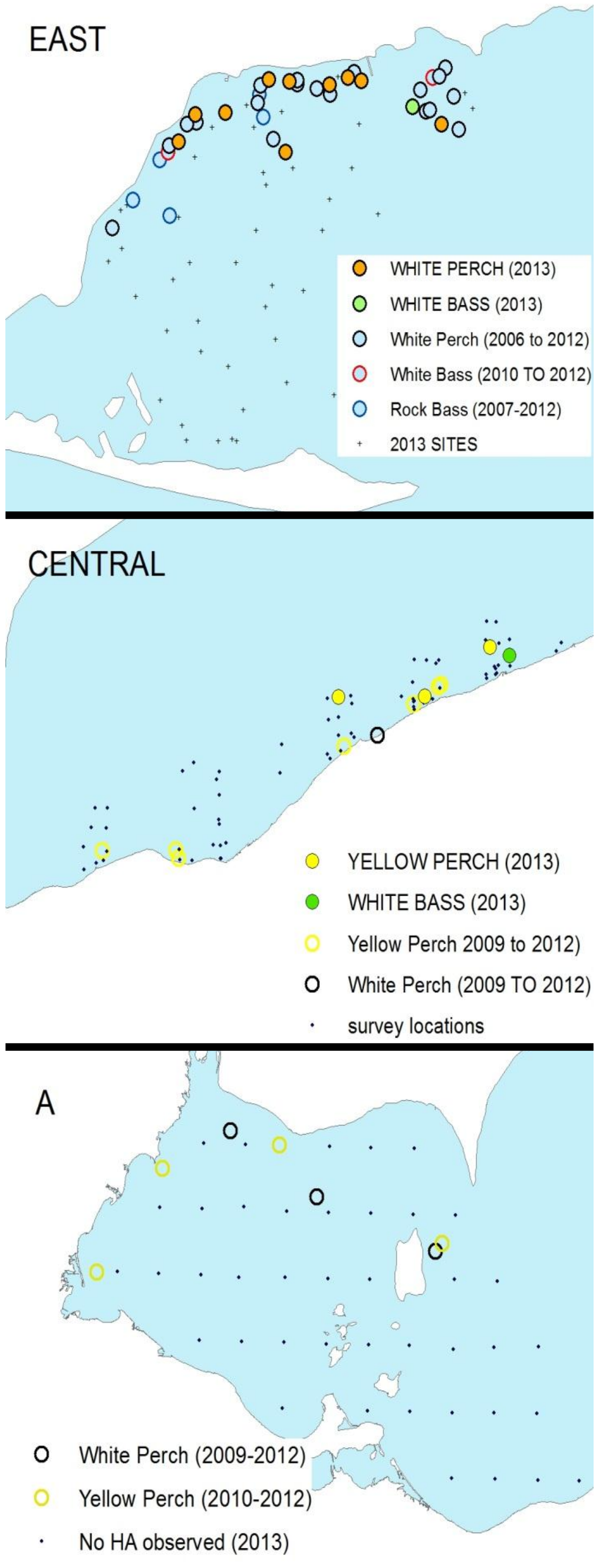

Figure 4.4.1 *Hemimysis anomala* observations in fish diets from Lake Erie, 2006-2013. East locations are from Long Point Bay index gillnet program; Central locations are from ODNR trawl surveys; West locations are from USGS-LEBS trawl surveys.

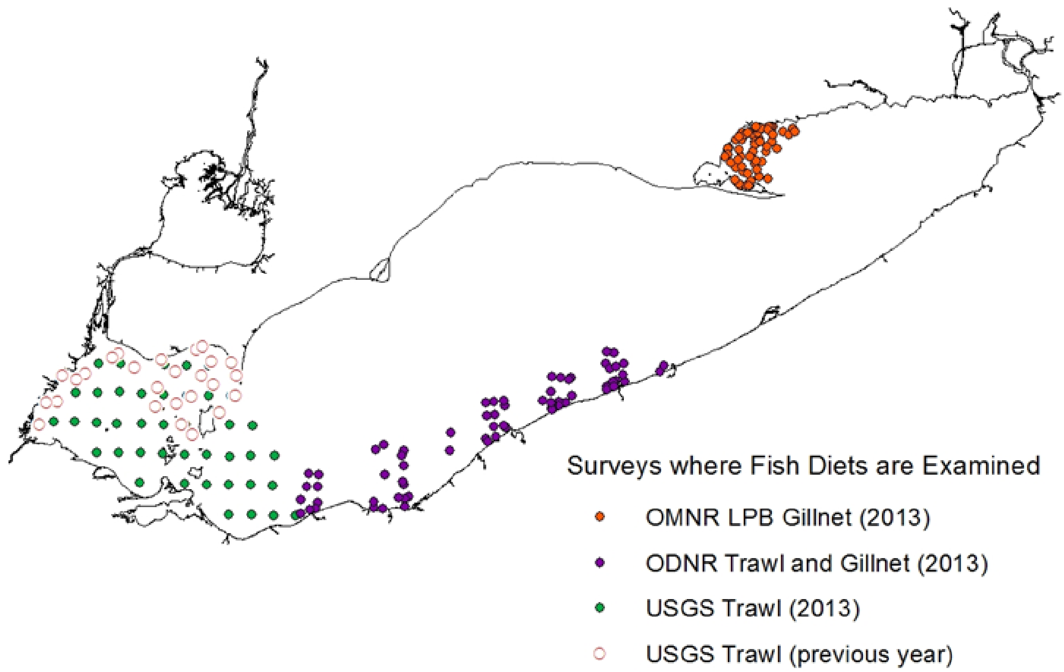

Figure 4.4.2 Locations of trawl surveys where fish diets were examined in 2013.

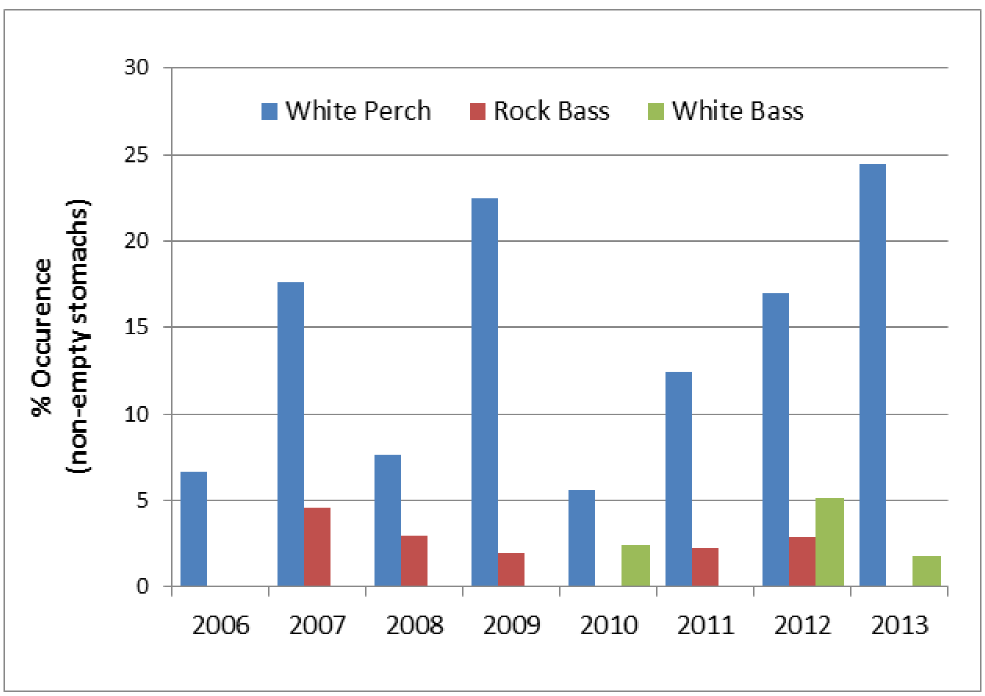

Figure 4.4.3 Occurrence of *Hemimysis anomala* in the diets of three fish species (proportion of fish stomachs examined) captured by gillnet in Long Point Bay, Ontario, 2006 – 2013.

Charge 5: Continue the development of an experimental design to facilitate forage fish assessment and standardized interagency reporting.

An ad-hoc Interagency Index Trawl Group was formed in 1992 to examine the interagency index trawl program in western Lake Erie and recommend standardized trawling methods for assessing fish community indices; and second, to lead the agencies in calibration of index trawling gear using SCANMAR acoustical instrumentation. Before dissolving in March 1993, the ITG recommended the Forage Task Group continue the work on interagency trawling issues. Progress on these charges is reported below.

5.1 Summary of Species CPUE Statistics

The FTG has been estimating 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 since 1988. The latest improvement to the survey incorporated the FPC factors that were developed from the trawl comparison exercise conducted in 2003 (Tyson et al. 2006). The August interagency survey was adopted by western basin agencies as the standard assessment for basin-wide fish community abundance. Data from the interagency survey is now incorporated into the western basin, *Status and Trends of Forage Fish Species,* Section 2.4.

5.2 Trawl Comparison Exercise

In 2003, a west basin trawl calibration exercise occurred that applied fishing power corrections to all trawling vessels in the western basin (Tyson et al. 2006). This exercise allowed western basin agencies the ability to compile all their trawling data together on an even scale, thus giving managers an entire view of forage fishes across the basin and an enhanced percid recruitment index.

In 2012, the USGS-Lake Erie Biological Station (USGS-LEBS) launched a new vessel, the *R/V Muskie* and conducted a trawl comparison exercise with the *R/V Explorer* (ODNR-DOW), *R/V Gibraltar* (Ohio State University), *R/V Muskie* (USGS-LEBS), *R/V Musky II* (USGS-LEBS), and *R/V Keenosay* (OMNR). Initial results indicated that the standard gears for Ohio and Ontario agencies have similar catch rates and there is some concern that applying correction factors may increase the level of error in abundance estimates (Forage Task Group 2013).

Trawl calibration exercises have been planned in the east and central basins involving vessels from ON, NY, PA, and OH with an overall goal of an enhanced recruitment index similar to the west basin survey. However, recent budget issues and logistics have stalled this exercise, and there is some question as to how much improvement developing correction factors for the central and eastern basins would provide given the spatial distribution of agency trawl surveys. The Forage Task Group will work toward answering these questions over the course of 2014.

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

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