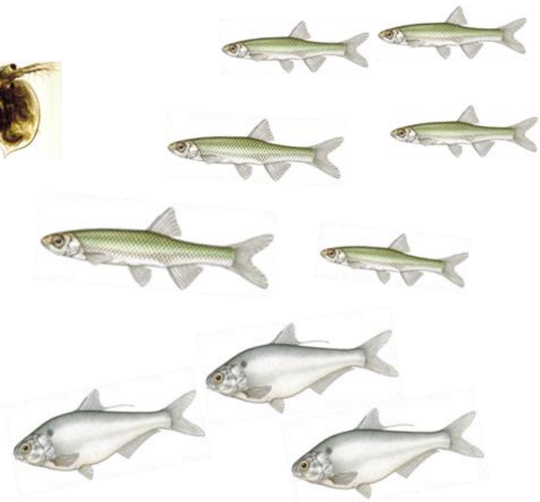
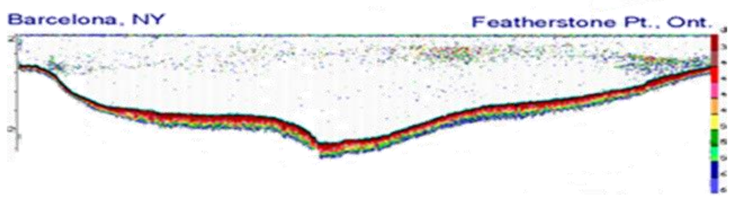
Report of the
Lake Erie
Forage Task Group

March 2015





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Presented to:

Standing Technical Committee
Lake Erie Committee
Great Lakes Fishery Commission

Charges to the Forage Task Group 2014-2015

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 16 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 meters depth for offshore stations only. This index should provide a good measure of relative system production and growth rate potential for fishes, assuming prey resources are not limiting. Mean summer surface temperatures are warmest in the western basin (mean=23.5 °C), becoming progressively cooler in the central (mean = 22.0 °C) and eastern basins (mean = 20.6 °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 series 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 16 year time series. In 2014, the mean summer surface water temperature was below the series-average in the west (22.8 °C) and central (19.6 °C) basins, and average in the east basin (20.6 °C). Central basin temperatures were the lowest in the time-series.

Hypolimnetic Dissolved Oxygen

Dissolved oxygen (DO) levels less than 2.0 mg/L are deemed stressful to fish and other aquatic biota (Craig 2012; Eby and Crowder 2002). Low DO can occur when the water column becomes stratified, which can begin in early June and continue through September in the central and 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 2014, 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 2014, bottom DO reached the sub-2.0 mg/L threshold in the central basin on only one occasion (Station 8 on 8/25/2014, 1.22 mg/L) (Figure 1.0.3).

DO is rarely limiting 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 the Station 25 (Figure 1.0.3). No DO concentrations of less than 7.0 mg/L were recorded in the east basin in 2014.

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 16 year time series, shifting into eutrophic status rather than mesotrophic status (Figure 1.0.4). Annual variability is also the highest in the west basin. In 2014, the mean chlorophyll *a* concentration was 6.4 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 2014 (3.0 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 2014, the mean chlorophyll *a* concentrations were 1.6 µg/L in the nearshore waters of the eastern basin and 2.0 µg/L in the offshore waters. Chlorophyll *a* concentrations are most stable in the eastern basin.

Total Phosphorus

Total phosphorus levels in the west basin have exceeded FCO targets since the beginning of the LTLA monitoring program (Figure 1.0.5). In 2014, total phosphorus concentrations in the west basin decreased slightly to 26.5 µg/L, equaling the lowest measure in the series. Total phosphorus measures have been stable in the west basin for the past three years but remain well above the target range. In the central basin, total phosphorus levels have exceeded FCO targets since 2006 but have been declining in recent years (Figure 1.0.5). In 2014, the central basin experienced another decline in total phosphorus to 15.8 µg/L, and shifting this measure into the desired mesotrophic range for the first time in the past nine years. 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 a declining trend has been evident over the past three years. 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 2014, mean total phosphorus concentrations in the eastern basin decreased in the nearshore waters to7.8 µg/L, which was below the targeted mesotrophic range for the first time in the past eight years. Eastern basin total phosphorus levels also decreased in the offshore waters (7.5 µg/L), reaching the targeted oligotrophic range for only the second time in the past seven years.

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 2.3 m in 2014, which was slightly higher than the previous five years. In contrast, water transparency in the central basin has remained within the targeted mesotrophic range for the entire series, including 2014 (4.6 m) (Figure 1.0.6). Transparency was in the oligotrophic range, which is above FCO targets for the nearshore waters of the eastern basin, from 1999 through 2007, but has been stable and within the FCO targets for the last seven 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 shifted into the mesotrophic range in five of the last six years. In 2014, mean summer Secchi depth was 5.7 m in the nearshore waters of the eastern basin, which was within the targeted mesotrophic range, and 6.3 m in the offshore waters, which was within the targeted oligotrophic range. Mean summer Secchi depths have been steadily increasing in both areas since 2008.

Zooplanktivory 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. Zooplanktivory increased in 2014 and was below the critical size for the first time since 2007. 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.

Zooplankton biomass varies among basins and years. In the western basin, the 2014 mean biomass was 60.4 mg/m^3, which was below the long term average of 89.2 mg/m^3 (Figure 1.0.8). This was the lowest biomass since 2007. In the central basin, the 2014 mean zooplankton biomass declined for the second year to 82.5 mg/m^3. Similar to the west basin, this was the lowest zooplankton biomass since 2007 in the central basin. Looking at larger trends, there appeared to be a gradient of high zooplankton biomass in the west and lower biomass in the east from 1999 to 2007. 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. It is also worth noting that in years with high zooplankton biomass, the zooplanktivory index is low (i.e. low grazing pressure), but the zooplanktivory index indicates high grazing pressure in years with low zooplankton biomass.

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 where 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 2014 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 basin, the lower trophic measures in 2014 fell within the targeted mesotrophic range preferred by percids. In the eastern basin, measures of total phosphorus, chlorophyll *a*, and transparency indicate a borderline mesotrophic/oligotrophic state for the nearshore waters but within the targeted oligotrophic range favored by salmonids in the offshore waters. In general, recent trophic measures indicate Lake Erie productivity has decreased.

Lower Trophic Protocol Review

In 2013-2014, 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 from compliance. A primary reason for drift in field methods was development of new technologies (e.g., integrated tube samplers, continuously-recording sondes for dissolved oxygen, nutrients, etc.). In 2015 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 Kerr 1978).

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

Table 1.0.2. Measures of key lower trophic indicators and current trophic class, by basin, from Lake Erie, 2014. The east basin is separated into nearshore and offshore.

Basin	Phosphorus (µg/L)	Chlorophyll a (µg/L)	Transparency (m)	Trophic Class
West	26.5	6.4	2.3	Eutrophic
Central	15.8	3.0	4.6	Mesotrophic
East - Nearshore	8	1.6	5.7	Oligotrophic
East - Offshore	8	2.0	6.3	Oligotrophic

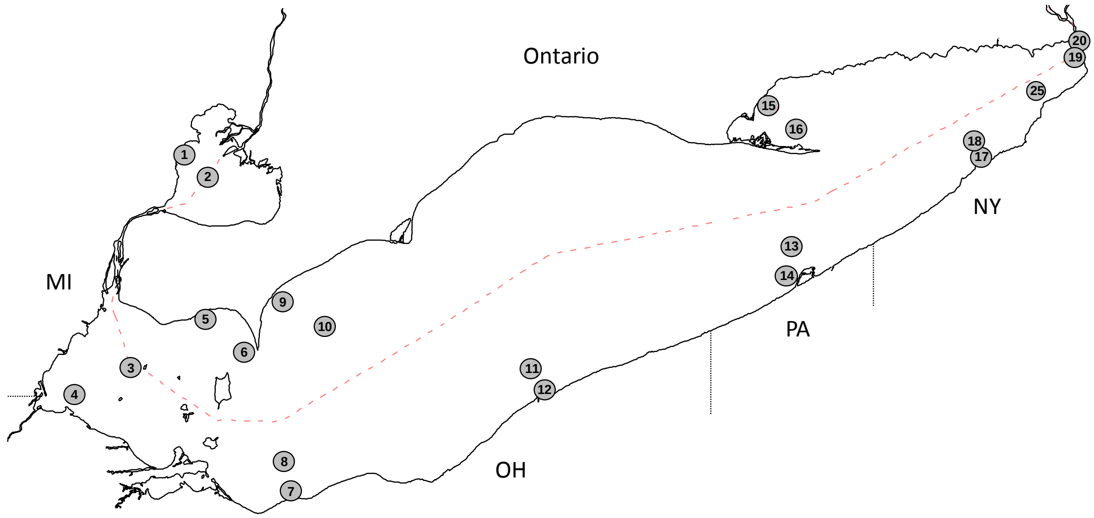

Figure 1.0.1. Lower trophic level sampling stations in Lake Erie and Lake St. Clair. Station 25 was added in 2009.

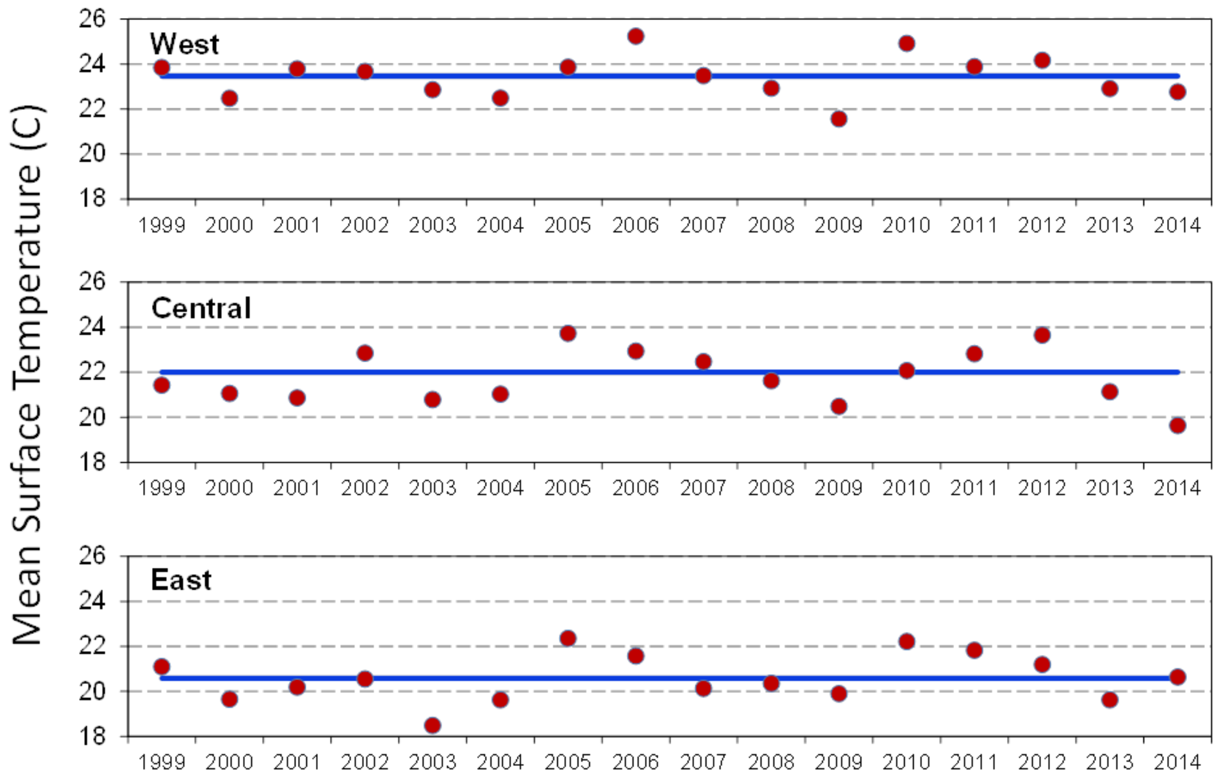

Figure 1.0.2. Mean summer (June-August) surface water temperature (°C) at offshore stations, by basin in Lake Erie, 1999-2014. Dark blue lines represent time-series average water temperature (1999-2012). Data included in this analysis by basin and station: West - 3, 6; Central – 8, 10, 11, 13; East – 16, 18, 19, 25.

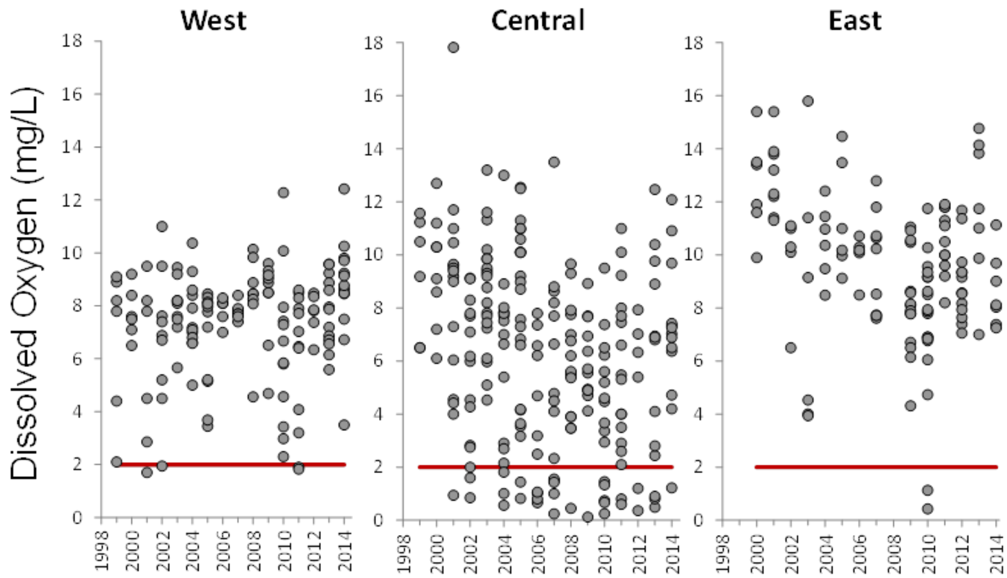

Figure 1.0.3. Summer (June-August) bottom dissolved oxygen (mg/L) concentrations for offshore sites by basin in Lake Erie, 1999-2014. The red horizontal line represents 2 mg/L, a level below which oxygen becomes limiting to the distribution of many temperate freshwater fishes. Data included in this analysis by basin and station: West - 3, 6; Central – 8, 10, 11, 13; East – 16, 18, 19, 25.

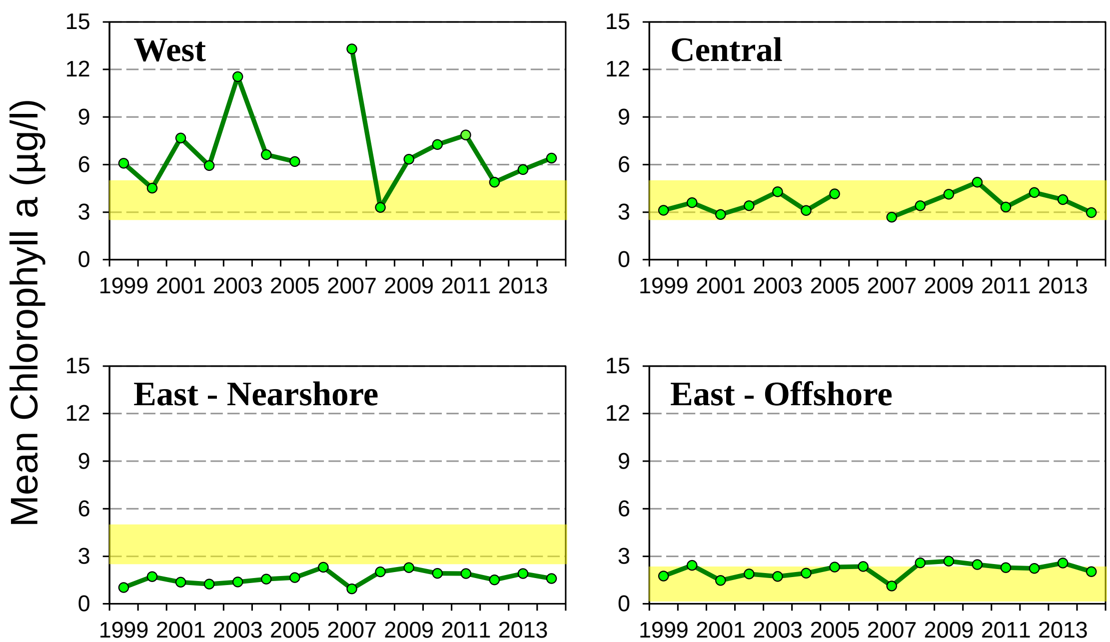

Figure 1.0.4. Mean chlorophyll *a* concentration (µg/L), weighted by month, by basin in Lake Erie, 1999-2014. The east basin is separated into nearshore and offshore. Yellow shaded areas represent targeted trophic class range. For this analysis data from stations 3 through 20, and 25 were included.

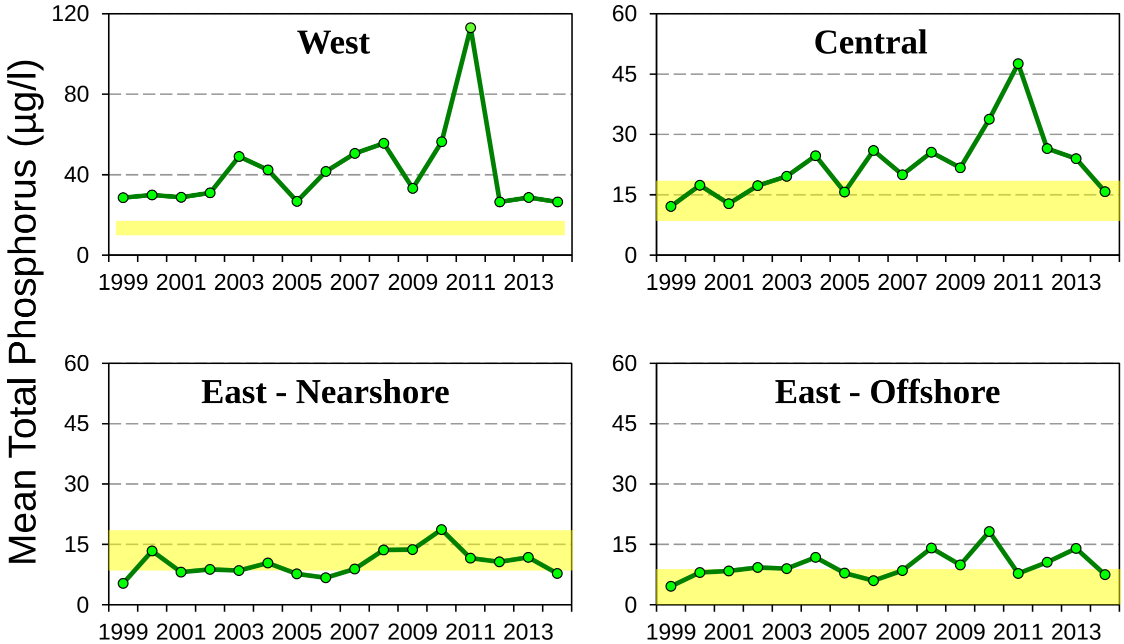

Figure 1.0.5. Mean total phosphorus (µg/L), weighted by month, for offshore sites by basin in Lake Erie, 1999-2014. The east basin is separated into nearshore and offshore. Yellow shaded areas represent the targeted trophic class range. For this analysis data from stations 3 through 20, and 25 were included.

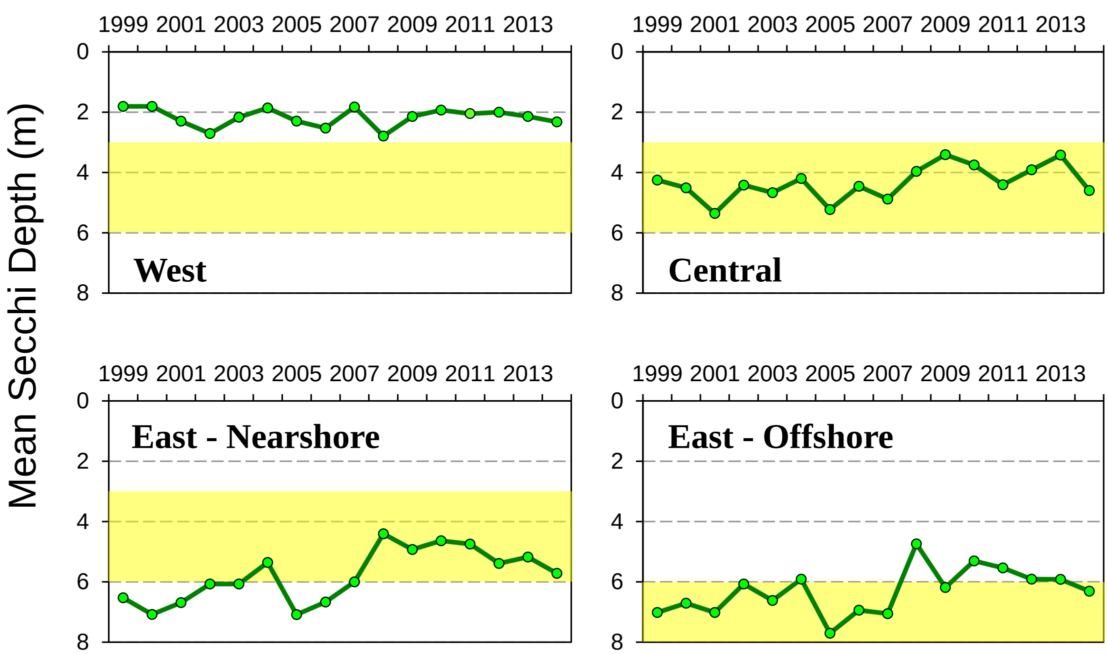

Figure 1.0.6. Mean summer (June-August) Secchi depth (m), weighted by month, by basin in Lake Erie, 1999-2014. The east basin is separated into inshore and offshore. Yellow shaded areas represent the targeted trophic class range. For this analysis data from stations 3 through 20, and 25 were included.

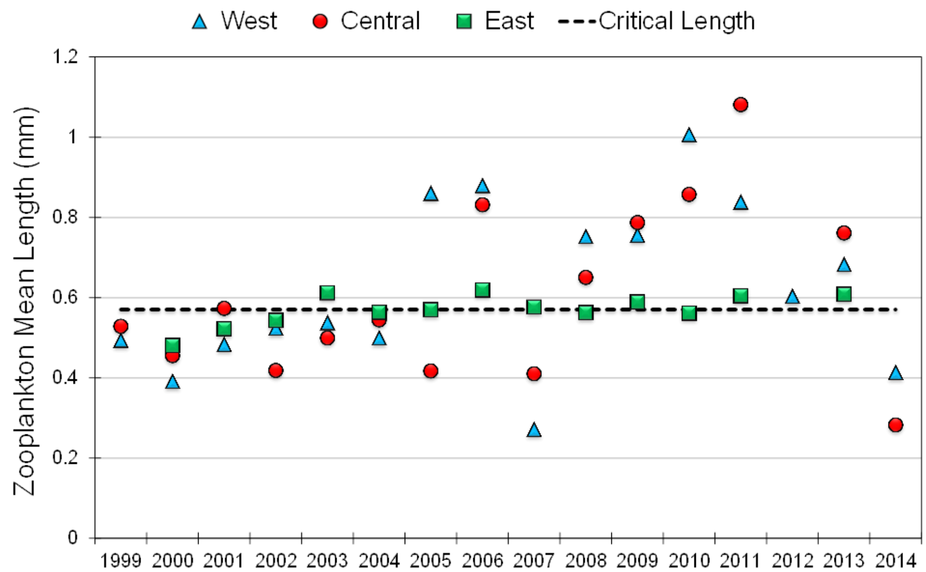

Figure 1.0.7. Mean length of the zooplankton community sampled with a 63 µm plankton net in each basin of Lake Erie, 1999-2014. The horizontal dashed line depicts 0.57 mm; the size below which predation by fish is considered to be intense (Mills et al. 1987, Johannsson et al. 1999). For this analysis data from stations 3 through 6 and 9 through 20 were included.

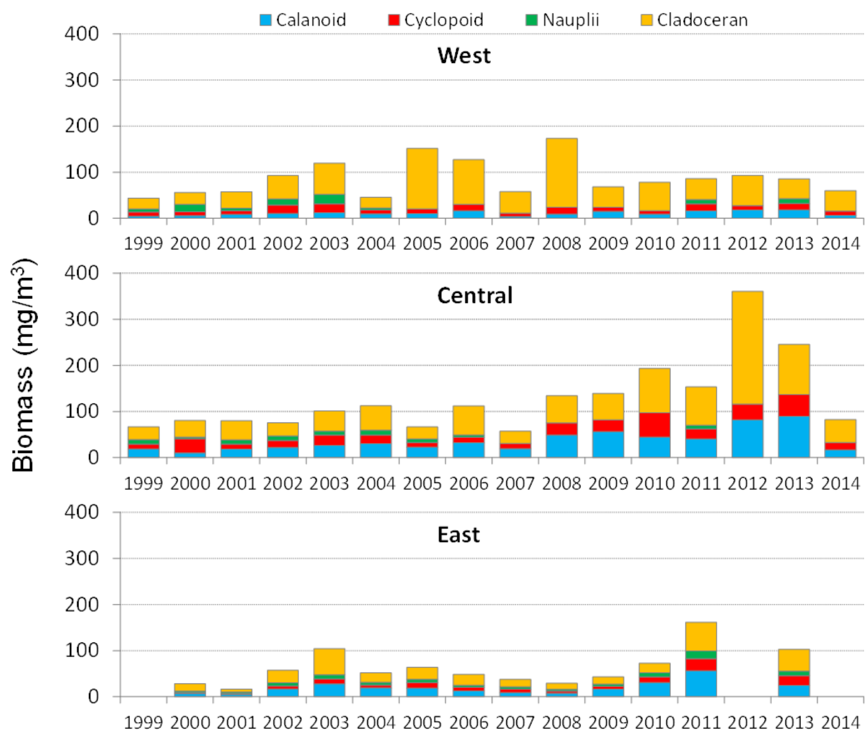

Figure 1.0.8. Mean zooplankton biomass (mg/m^3) by major taxonomic group by basin, 1999 through 2013. There is no data for 1999 and 2012 in the eastern basin. West basin includes stations 3 through 6. Central basin includes stations 7 through14. East basin includes stations 15 through 20. Data excludes 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 2014 Forage Status and Trends

Eastern Basin

- Total forage fish abundance increased during 2014; ranking 95th (2^{nd} highest) and 37th percentile (pctl) in New York's (NY) and Ontario's (ON) bottom trawl assessments, respectively
- Age-0 Rainbow Smelt increased, highest ever in NY and about 5-times > ON index
- Yearling-and-older (age-1+) Rainbow Smelt decreased to lowest (ON) or second lowest (NY) density
- Young-of-the-year (Age-0) Yellow Perch density high in NY (77 pctl), moderate in ON (43 pctl)
- Zero Age-0 Alewife were captured (NY and ON)
- Age-0 Gizzard Shad abundance was low basin wide
- Emerald Shiner density (all age groups) was high in NY, low in ON
- Spottail Shiner remain at low densities throughout the east basin
- Round Goby densities increased in most agency surveys; but remain below 10-year average

Central Basin

- Forage fish abundance similar to 2013 and slightly above average
- Age-0 Yellow Perch abundance increased from 2013, but were below average
- Age-0 Rainbow Smelt abundance is highest since 2008
- Age-0 Emerald Shiner densities were above average for the last three years
- Round Goby abundance increased slightly from 2013, but was below average
- Alewife and Gizzard Shad indices were some of the lowest in the time series

West Basin

- Forage abundance and biomass below average levels
- Age-0 Gizzard Shad catches declined sharply from 2013, near 10- year mean
- Age-0 and age-1+ Rainbow Smelt catches decreased and remain below 10-year mean
- Age-0 and age-1+ Emerald Shiner declined from 2013; below 10-year mean
- Age-0 White Perch similar to 2013 levels; below 10-year mean
- Round Goby abundance increased slightly in 2014; well below 10-year mean
- Age-0 Yellow Perch and Walleye recruitment increased from 2013; both near (Walleye) or above (Yellow Perch) long-term mean; White Bass recruitment decreased and below long-term mean
- Size of age-0 Walleye, Yellow Perch, and White Perch were all near long term means; age-0 White Bass and Smallmouth Bass were smaller than average
- Fall Walleye diets showed reliance on Gizzard Shad and Emerald Shiners

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 2014, the NYSDEC and OMNRF continued long-term trawling programs in their respective jurisdictions that now span some 23 and 31 to 35 years, respectively. A total of 33 trawl tows were sampled across New York waters in 2014 and 110 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 2014.

Rainbow Smelt are the principal prey fish species of piscivores in the offshore waters of eastern Lake Erie and in 2014, Smelt (all ages) once again was the most abundant forage species captured in east basin jurisdictions (Table 2.2.1, Figure 2.2.2). The basin-wide increase was largely due to strong recruitment of the 2014 year class, which produced record high numbers of age-0 Rainbow Smelt in New York and above average numbers in Ontario. Young-of-the-year Rainbow Smelt mean density was 5.4-times greater in New York (5380/ha) than in Ontario (1002/ha). Yearling and older (age 1+) Rainbow Smelt abundance decreased in 2014 to record low density in Ontario's 31-year trawl index time series (4.6/ha) and second lowest density in New York's (24.2/ha) 23-year trawl survey history (Table 2.2.1). Mean length of age-0 (54 mm FL) and age-1 (103 mm FL) Rainbow Smelt decreased slightly in 2014; yearlings were about average length, whereas age-0 smelt were the third smallest observed in Ontario's trawl assessment (Figure 2.2.3).

The contribution of non-smelt fish species to the forage fish community of eastern Lake Erie was dominated in 2014 by Emerald Shiner, Round Goby, and Trout-Perch in New York and by Round Goby in Ontario (Table 2.2.1). Numeric abundance of these forage fish species in 2014 were below average except for Emerald Shiners, which ranked third highest since 1992 in New York's trawl survey (1315/ha, all ages). In sharp contrast, Emerald Shiners (all ages) were far less abundant in Ontario (5.4/ha, all ages) where the 2014 abundance index ranked second lowest since 1992. Spottail Shiner abundance remained low throughout all eastern basin regions in 2014 (Table 2.2.1). Not a single age-0 Alewife was captured by trawl in Ontario or New York and Age-0 Gizzard Shad abundance was low throughout the east basin in 2014. Trout-Perch density in New York decreased for a third consecutive year to 63 fish/ha compared to a long-term average (1992-2013) of 596 fish/ha.

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 2014 increased in most east basin trawl assessments, but in general remained well below average density (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). There are no annual trawl surveys in Ontario waters of the central basin. Trawl locations in Pennsylvania range from 13 to 24 m depth and Ohio trawl locations range from 5 to >20 m depth. 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 2014, a total of 20 trawl tows were completed in the central basin, 12 in Ohio East, and 8 in Ohio West. A complete central basin trawl survey would consist of 63 trawl tows, six in Pennsylvania, 24 in Ohio East and 33 in Ohio West. In 2014, Pennsylvania was unable to conduct a trawl survey and Ohio's research vessel, R/V *Grandon,* was unavailable for most of the survey due to hull and engine repairs.

In 2014, overall forage abundance in the Ohio waters was similar to forage densities in 2013, and were above average for the 25 year survey (Figure 2.3.2). Declines in the soft-rayed and clupeid forage groups were offset by an increase in the density of Rainbow Smelt. Within the spiny-rayed group an increase in age-0 Yellow Perch densities offset a decrease in age-0 White Perch from 2013.

Trends in Rainbow Smelt abundance were not consistent across central basin surveys. Young-of-the-year Rainbow Smelt indices increased in Ohio waters from 2013, and were almost 3 times higher than average (Table 2.3.1). The 2014 age-0 cohort is the largest since 2008 in Ohio waters. Yearling-and-Older Rainbow Smelt indices increased in the Ohio West survey, but decreased in the Ohio East survey compared to 2013 (Table 2.3.2). Indices in both surveys were well below average, with the Ohio East index being the lowest in the 10-year time series.

In 2014, age-0 Emerald Shiner indices were the second (Ohio West) and third (Ohio East) highest in the 10-year time series (Table 2.3.1). Young-of-the-year Emerald Shiner indices have generally been above average for the last three years. Despite high age-0 cohorts in the Ohio west survey, age-1+ indices in 2014 declined for the second year in a row (Table 2.3.2). The Ohio West index is the third lowest in the 10-year time series. The Ohio East index increased from 2013 and was slightly above average.

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 observed again in 2014 for both age-0 and age-1+ Round Goby Ohio indices. The Ohio East indices increased from 2013, but were below average. The Ohio West indices decreased from 2013 and were the lowest in the 10-year time series. Density of both age-0 and age-1+ have been below average since 2012 in Ohio waters.

Young-of-the-year Gizzard Shad patterns were more typical of historic patterns in 2014 with higher densities occurring in Ohio West relative to Ohio East (Table 2.3.1). Gizzard Shad indices decreased in Ohio surveys from 2013. Indices in both surveys were well below average with Ohio West ranked fifth and Ohio East ranked fourth highest in the 10-year time series. Young-of-the-year Alewives are not routinely captured in Ohio and Pennsylvania trawl surveys and were not encountered in either of Ohio's survey areas.

Yellow Perch age-0 indices increased in both Ohio surveys and were average in Ohio West and below average in Ohio East (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 decreased from 2013 and were below average in both Ohio surveys due to the weak cohort in Ohio waters in 2012 (Table 2.3.2).

White Perch indices, both age-0 and age-1+, declined in Ohio surveys in 2014. The only Ohio index that was not the lowest in the 10-year time series was age-0 in the Ohio East survey.

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-finned fish (Rainbow Smelt, Emerald and Spottail Shiners, other cyprinids, Silver Chub, Trout-Perch, and Round Gobies), and spiny-rayed fish (age-0 for each of White Perch, White Bass, Yellow Perch, Walleye and Freshwater Drum).

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

2014 Results

In 2014, 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 2014 (Figure 2.4.1).

Total forage abundance was below average in 2014, lower than in 2013 (Figure 2.4.2). Spiny-rayed species increased 18% compared to 2013, while clupeids and soft-rayed species declined 76% and 49%, respectively. Total forage biomass in 2014 decreased 26% (Figure 2.4.3). Relative biomass of clupeid, soft-rayed, and spiny-rayed species was 31%, 3%, and 66%, 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, near Sandusky Bay. Soft-rayed fish were most abundant near the mouth of the Detroit River and east of Pelee and Kelley's Islands. Spiny-rayed abundance was highest in the central portion of the basin, near the Bass and Middle Sister Islands. Relative abundance of the dominant species includes: age-0 White Perch (53%), age-0 Gizzard Shad (20%), and age-0 Yellow Perch (20%). Total forage abundance averaged 4,276 fish/ha across the western basin, decreasing 46% from 2013, and residing below the long-term average (5,324 fish/ha). Clupeid density was 856 fish/ha (average 1,163 fish/ha), soft-rayed fish density was 211 fish/ha (average 566 fish/ha), and spiny-rayed fish density was 3,209 fish/ha (average 3,595 fish/ha).

Recruitment of individual species is highly variable in the western basin. Young-of-the-year Yellow Perch (860/ha) increased sharply relative to 2013, while age-0 Walleye abundance (29.1/ha) tripled (Figure 2.4.5); above and near long-term means, respectively. Young-of-the-year White Perch (2,284/ha) remained near the 2013 abundance. Young-of-the-year White Bass (18.7/ha) declined sharply and remains well below the long-term mean. Age-0 Smallmouth Bass (0.2/ha) decreased, and remains below the long-term mean. Young-of-the-year and age-1+ Rainbow Smelt decreased in 2014 (53.9/ha and 0.4/ha, respectively). Young-of-the-year Gizzard Shad (855.5/ha) decreased relative to 2013, near the long-term mean, while age-0 Alewife were almost non-existent (Figure 2.4.6). Catches of age-0 (2.9/ha) and age-1+ Emerald Shiners (51.5/ha) decreased, remaining below the long-term mean. Catches of Round Gobies (43.7/ha) increased from 2013, and represents the fourth lowest abundance since their discovery in 1997. Overall, 2013 catches of age-0 and age-1+ Emerald Shiners decreased below long-term means (Figure 2.4.7).

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 (2004-2013) and for the two most recent completed decades. Agency trawl surveys are described below. Pennsylvania FBC (PA-Fa) did not conduct a fall index trawl survey in 2006, 2010, 2011, 2013, and 2014 and the 2008 survey was a reduced effort of four tows sampled in a single day.

			Year										10-Yr & Long-term Avg. by decade		
Species	Age Group	Trawl Survey	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	10-Yr	2000's	1990's
Rainbow	YOY	ON-DW	1001.6	217.9	1657.7	509.2	326.9	148.2	1293.0	991.3	1256.0	0.9	653.3	1391.5	431.7
Smelt	YOY	NY-Fa	5379.7	736.0	413.6	1580.4	1416.6	71.5	2128.9	2888.1	508.8	1259.7	1215.0	1524.9	1450.9
	YOY	PA-Fa	NA	NA	560.2	NA	NA	47.7	15.1	260.2	NA	47.9	157.2	138.2	550.8
	YAO	ON-DW	4.6	165.3	367.8	277.1	222.7	1654.3	77.3	232.8	136.2	7.6	370.7	360.7	358.6
	YAO	NY-Fa	24.2	44.6	22.2	640.0	997.8	3010.0	546.5	178.3	162.9	395.2	862.2	753.4	581.6
	YAO	PA-Fa	NA	NA	22.3	NA	NA	407.2	1.8	1006.3	NA	0.0	241.7	164.5	378.0
Emerald	YOY	ON-DW	2.9	58.7	438.3	70.3	117.6	54.8	16.0	29.3	452.3	645.7	190.3	463.2	52.3
Shiner	YOY	NY-Fa	512.9	127.6	94.3	2930.1	62.9	48.5	3.7	150.9	778.5	291.4	449.6	194.0	112.4
	YOY	PA-Fa	NA	NA	14.8	NA	NA	1063.0	0.0	81.7	NA	0.5	193.3	264.8	41.0
	YAO	ON-DW	2.5	188.6	119.2	201.1	30.7	40.1	95.2	149.8	4200.3	139.0	605.5	819.0	37.7
	YAO	NY-Fa	801.8	65.4	93.8	1826.2	20.6	156.4	18.2	84.8	925.5	151.4	362.6	290.8	105.4
	YAO	PA-Fa	NA	NA	86.9	NA	NA	1360.3	0.0	4713.1	NA	52.5	1035.5	710.4	14.5
Spottail	YOY	ON-OB	5.0	8.1	19.1	2.5	3.0	3.7	37.8	35.2	19.8	58.7	23.2	119.3	815.9
Shiner	YOY	ON-IB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	1.0	0.2	0.5	113.9
	YOY	NY-Fa	0.1	0.0	1.8	0.7	6.5	0.1	0.3	0.1	0.5	0.5	1.0	5.6	19.9
	YOY	PA-Fa	NA	NA	0.0	NA	NA	1.1	0.0	0.0	NA	0.0	0.2	0.1	4.0
	YAO	ON-OB	0.2	3.0	1.6	0.5	2.1	3.3	7.5	4.1	10.4	3.2	4.6	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	0.2	0.3	2.0	29.0	10.4	5.1	1.5	0.0	4.2	4.3	5.9	6.4	4.0
	YAO	PA-Fa	NA	NA	0.1	NA	NA	0.0	0.0	0.0	NA	0.0	0.0	0.1	7.9
Alewife	YOY	ON-DW	0.0	17.7	707.3	2.1	0.9	0.1	2.3	1.0	78.6	0.1	81.0	22.5	231.2
	YOY	ON-OB	0.0	26.1	6.0	6.8	0.0	1.9	11.9	44.6	711.8	11.0	82.2	82.1	88.5
	YOY	NY-Fa	0.0	218.2	183.8	12.4	15.4	0.0	5.6	22.2	30.3	27.7	52.0	94.2	52.0
	YOY	PA-Fa	NA	NA	4.6	NA	NA	0.0	0.0	8.0	NA	0.0	2.1	1.3	5.2
Gizzard	YOY	ON-DW	0.0	0.0	47.6	18.9	13.3	0.4	86.5	34.6	1.4	1.7	27.3	21.3	7.5
Shad	YOY	ON-OB	0.4	0.3	20.0	3.4	3.8	0.0	4.0	22.0	28.7	1.9	8.5	7.6	13.4
	YOY	NY-Fa	0.6	3.8	4.7	15.0	40.9	5.3	10.8	11.7	14.2	3.7	11.1	11.9	4.3
	YOY	PA-Fa	NA	NA	1.0	NA	NA	0.0	0.0	0.0	NA	0.0	0.2	0.1	0.8
White	YOY	ON-DW	0.0	0.0	0.8	0.0	1.6	0.6	5.4	0.1	0.9	0.1	1.0	2.9	1.8
Perch	YOY	ON-OB	0.0	0.0	0.9	0.0	0.0	0.0	2.1	0.7	1.2	0.4	0.6	2.8	17.6
	YOY	NY-Fa	35.2	4.4	18.3	36.5	157.3	20.2	431.5	34.6	91.9	99.8	89.5	74.3	29.3
	YOY	PA-Fa	NA	NA	380.0	NA	NA	598.5	0.7	444.6	NA	51.2	245.8	256.0	84.2
Trout	All	ON-DW	0.0	0.0	0.0	0.0	0.3	0.8	0.8	0.8	1.1	0.0	0.8	0.9	0.6
Perch	All	NY-Fa	63.3	148.8	338.9	654.3	461.6	516.6	996.4	562.2	520.3	1329.2	607.4	825.1	406.9
	All	PA-Fa	NA	NA	52.2	NA	NA	558.8	0.6	156.9	NA	198.5	187.9	152.1	49.3
Round	All	ON-DW	0.5	14.5	129.0	125.4	9.7	43.6	452.6	973.2	93.3	66.9	223.2	235.9	0.0
Goby	All	ON-OB	98.5	76.3	68.0	103.3	67.6	91.2	63.4	73.9	32.7	28.0	69.9	86.9	0.1
	All	ON-IB	95.4	49.6	80.2	114.6	135.1	280.5	211.8	263.0	34.0	21.0	128.5	120.0	0.1
	All	NY-Fa	136.8	83.9	180.2	165.8	173.3	502.6	466.8	1293.2	846.7	702.7	551.0	654.4	1.0
	All	PA-Fa	NA	NA	31.6	NA	NA	350.1	441.6	2043.8	NA	887.8	780.4	1094.6	38.7

"**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 2004-2014. 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	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Mean
Yellow	OH west	7.7	43.9	8.3	151.0	31.5	1.6	41.1	10.3	69.2	8.9	37.7	37.4
Perch	OH east	1.9	156.2	17.0	177.8	52.8	0.5	96.3	15.1	134.4	8.9	49.1	66.1
	PA	2.4	6.7	-	10.0	863.4	14.2	-	-	487.2	27.8	-	201.7
White	OH west	718.7	1,047.2	388.8	1,096.2	468.1	379.0	254.8	346.6	1,709.6	174.7	135.0	658.4
Perch	OH east	108.0	2,034.5	41.5	1,095.9	91.6	34.6	190.3	72.1	661.9	200.1	99.4	453.1
	PA	2.4	42.3	-	17.8	199.0	146.5	-	-	370.6	2.2	-	111.5
Rainbow	OH west	415.9	8.7	69.6	78.4	735.7	267.8	776.2	29.8	84.4	126.0	747.8	259.3
smelt	OH east	388.9	44.4	513.6	702.4	3,997.7	0.3	421.6	247.3	319.1	12.8	1,709.5	664.8
	PA	20.9	15.9	-	35.1	552.2	23.4	-	-	8.5	131.4	-	112.5
Round	OH west	15.0	40.8	13.7	26.8	19.0	24.5	28.4	100.8	18.2	17.5	6.3	30.5
Goby	OH east	173.9	148.1	41.7	273.1	26.3	1.0	41.8	256.0	53.9	45.8	86.2	106.2
	PA	1011.3	-	-	227.8	227.1	72.2	-	-	2.4	11.4	-	258.7
Emerald	OH west	7.0	567.1	587.2	52.6	36.3	6.1	8.8	414.5	1144.7	2520.5	1369.3	534.5
Shiner	OH east	0.8	279.8	1115.1	63.7	20.2	1.7	234.9	105.4	2188.5	306.2	650.1	431.6
	PA	0.0	17.8	-	0.8	0.0	303.2	-	-	0.0	31.7	-	50.5
Spottail	OH west	0.0	0.1	0.0	2.1	3.4	0.4	0.0	0.6	0.0	0.0	2.5	0.7
Shiner	OH east	0.0	1.1	0.2	0.5	0.2	0.0	0.0	0.3	0.0	0.0	0.0	0.2
	PA	0.0	0.0	-	0.0	0.0	0.0	-	-	0.0	0.0	-	0.0
Alewife	OH west	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	52.1	0.0	5.5
	OH east	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.1	36.1	0.0	3.9
	PA	0.0	0.0	-	0.0	0.0	0.0	-	-	2.8	5.1	-	1.1
Gizzard	OH west	0.5	13.4	36.8	183.8	33.2	52.6	2.6	675.8	98.7	304.2	33.8	140.2
Shad	OH east	0.3	15.7	27.7	15.5	63.1	3.9	8.5	4.2	28.7	39.5	7.3	20.7
	PA	0.0	1.3	-	0.0	0.0	0.0	-	-	0.0	0.0	-	0.2
Trout-	OH west	20.3	0.1	0.2	0.8	0.3	0.3	0.7	1.6	0.0	0.1	0.3	2.4
perch	OH east	1.4	1.6	0.1	5.4	0.1	0.2	1.4	2.7	0.2	0.0	0.6	1.3
	PA	6.7	0.3	-	10.9	126.1	28.1	-	-	0.0	0.0	-	24.6

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

Table 2.3.2 Relative abundance (arithmetic mean number per hectare) of selected age-1+ species from fall trawl surveys in the central basin, Ohio and Pennsylvania, Lake Erie, from 2004-2014. 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	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Mean
Yellow	OH west	224.2	19.2	4.6	20.7	53.4	20.2	11.9	6.3	7.4	34.9	15.4	40.3
Perch	OH east	45.2	132.3	11.9	37.0	26.4	139.4	12.4	55.5	23.3	109.5	24.2	59.3
	PA	18.3	1.9	-	27.4	76.4	120.9	-	-	100.1	75.0	-	60.0
White	OH west	93.1	34.0	66.9	24.0	78.0	45.8	32.6	25.8	45.8	195.9	5.8	64.2
Perch	OH east	27.0	20.1	34.7	16.8	36.6	282.3	44.8	49.8	7.7	546.9	4.4	106.7
	PA	6.2	0.0	-	0.8	4.2	63.3	-	-	6.8	18.6	-	14.3
Rainbow	OH west	320.5	108.5	20.7	43.2	10.5	528.3	18.0	28.3	12.9	17.1	34.9	110.8
Smelt	OH east	1,360.2	30.8	17.3	532.4	64.9	109.1	56.9	216.4	143.1	485.6	15.0	301.7
	PA	9.9	2.6	-	10.7	3.5	408.0	-	-	20.0	25.0	-	68.5
Round	OH west	31.2	38.3	15.4	26.9	63.8	60.4	44.0	68.6	11.8	24.3	6.9	38.5
Goby	OH east	148.8	263.0	71.0	185.6	167.8	19.3	36.0	118.1	27.0	46.3	89.1	108.3
	PA	767.0	206.7	-	361.1	326.6	75.9	-	-	71.4	8.6	-	259.6
Emerald	OH west	1.7	266.7	500.6	300.0	561.2	127.7	51.5	138.2	998.8	298.0	55.8	324.4
Shiner	OH east	0.4	479.6	406.0	27.8	1,159.4	167.8	375.1	149.7	433.2	8.4	333.5	320.7
	PA	0.0	123.0	-	769.5	28.0	171.5	-	-	9.0	17.2	-	159.7
Spottail	OH west	5.8	0.2	0.8	1.6	2.4	1.9	0.0	20.7	0.0	0.5	1.7	3.4
Shiner	OH east	0.2	3.8	0.6	0.6	2.9	0.0	0.0	3.1	3.0	2.9	0.0	1.7
	PA	0.0	0.0	-	0.0	0.0	0.0	-	-	0.0	0.0	-	0.0
Trout-	OH west	10.8	17.1	7.5	4.2	3.3	0.9	0.7	3.3	1.6	3.3	0.6	5.3
perch	OH east	7.7	76.2	4.3	6.7	8.4	1.5	5.0	7.9	11.7	1.0	0.4	13.0
	PA	5.2	4.1	-	16.0	61.7	127.3	-	-	30.4	9.6	-	36.3

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

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

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

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

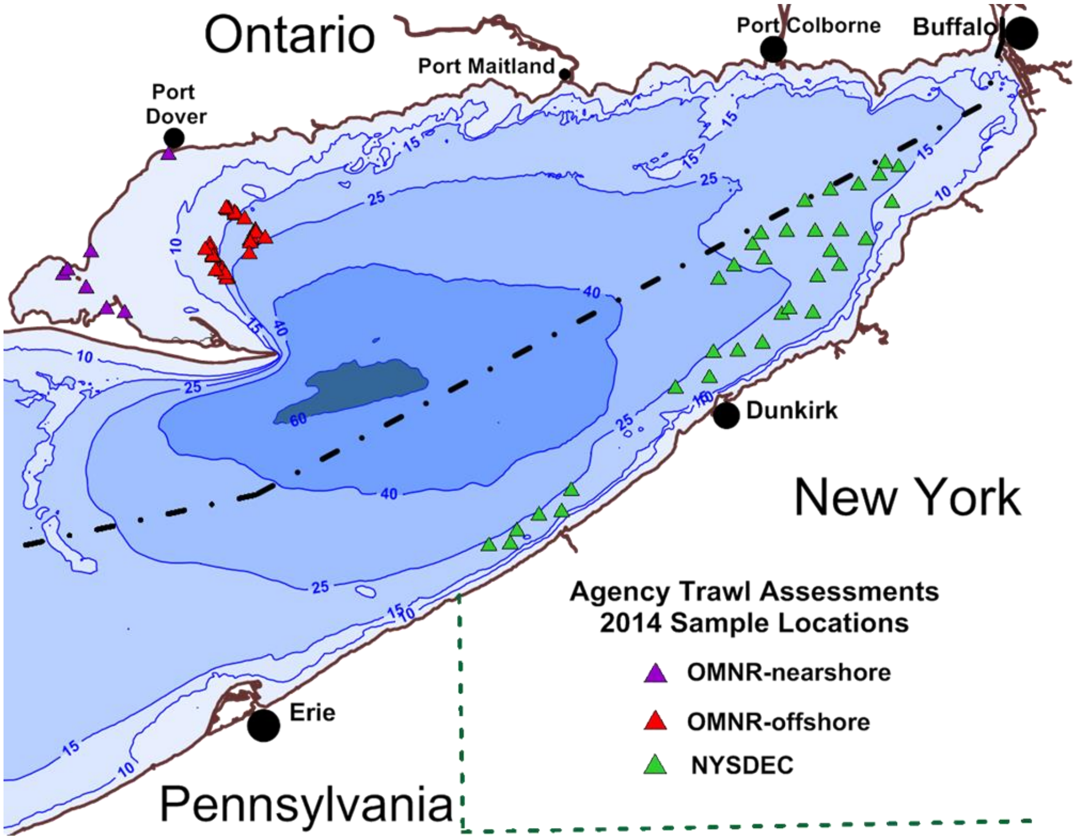

Figure 2.2.1 Locations sampled with standard index bottom trawls by Ontario (OMNRF) and New York (NYSDEC) to assess forage fish abundance in eastern Lake Erie during 2014.

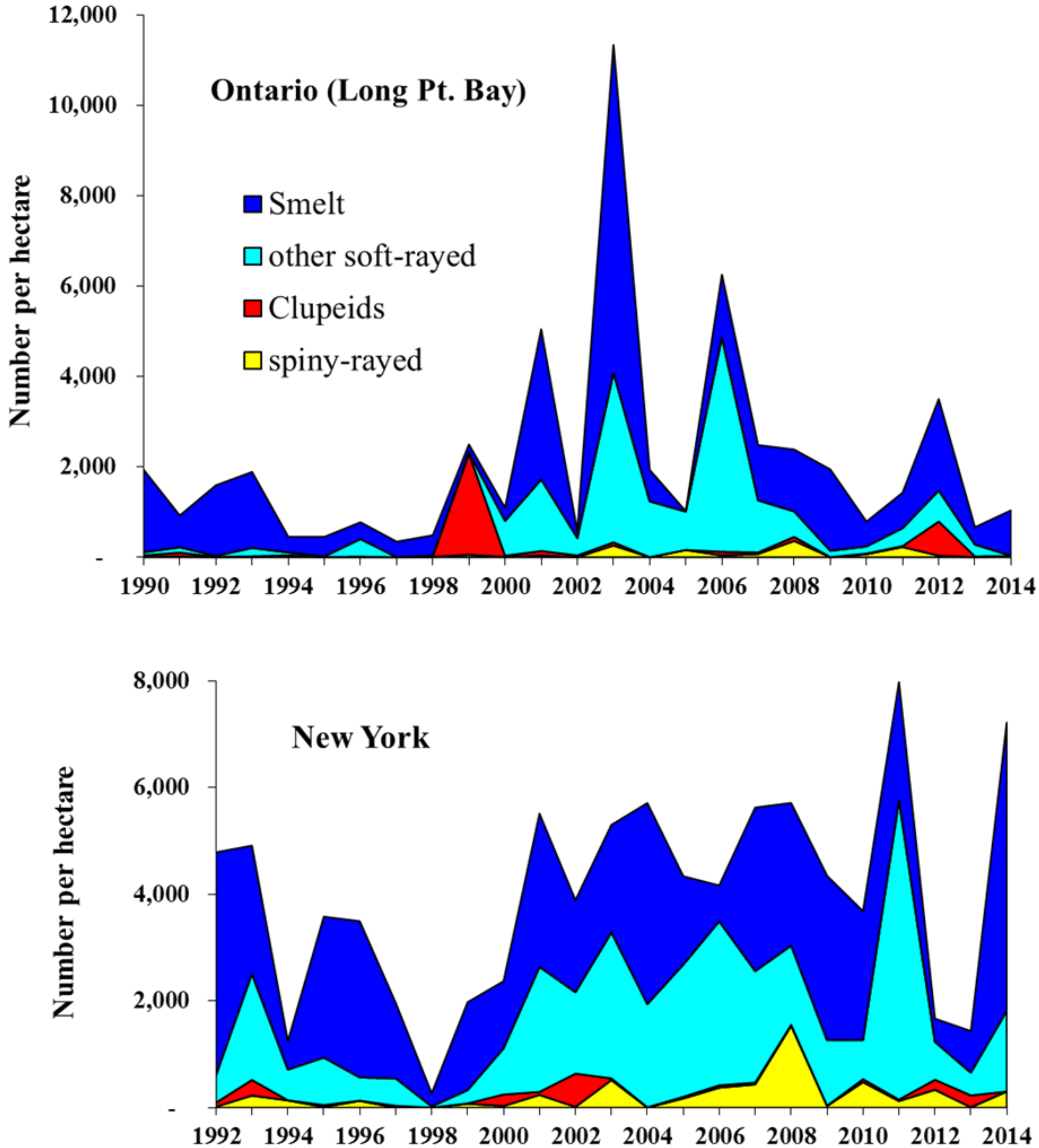

Figure 2.2.2 Mean density of prey fish (number/ha) by functional group in the Ontario and New York waters of the eastern basin, Lake Erie, 1990-2014.

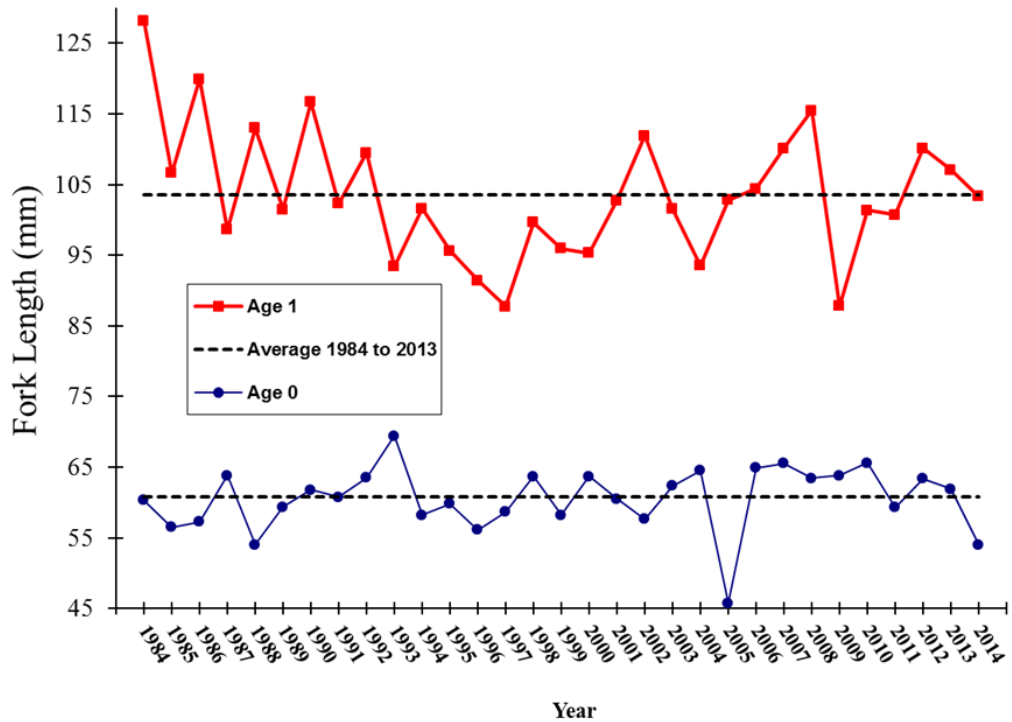

Figure 2.2.3 Mean fork length of age-0 and age-1 Rainbow Smelt from OMNRF index trawl surveys in Long Point Bay, Lake Erie, October 1984 to 2014.

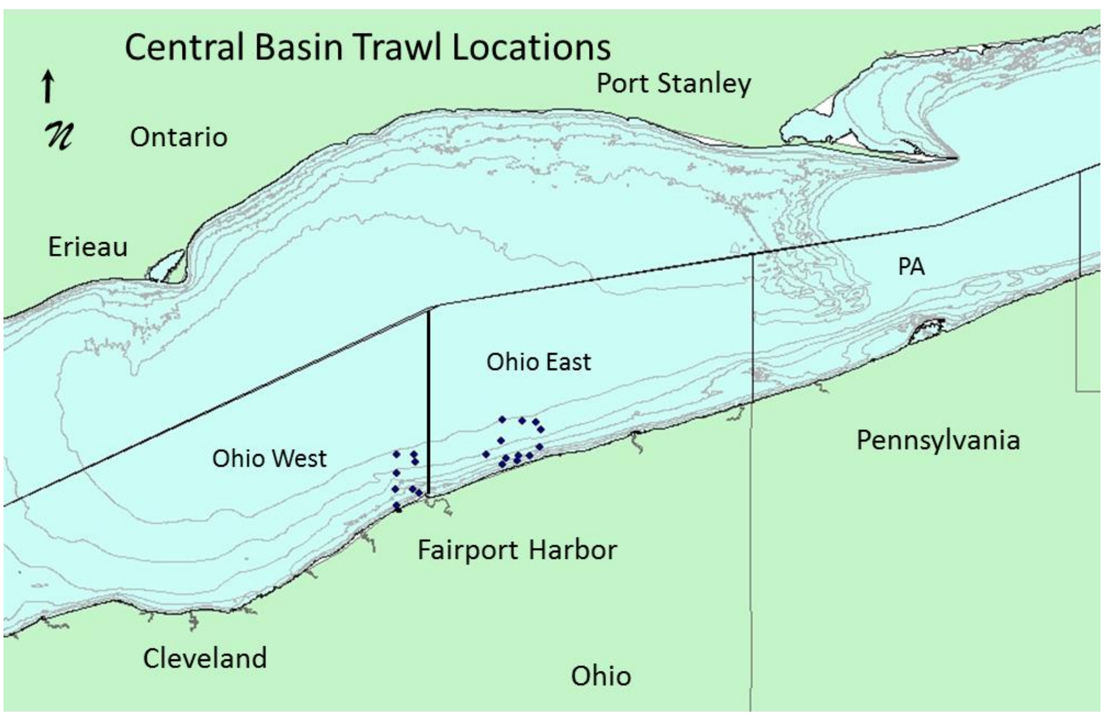

Figure 2.3.1 Locations sampled with index bottom trawls by Ohio (ODNR) to assess forage fish abundance in central Lake Erie during 2014. Pennsylvania (PFBC) was not able to conduct a trawl survey in 2014

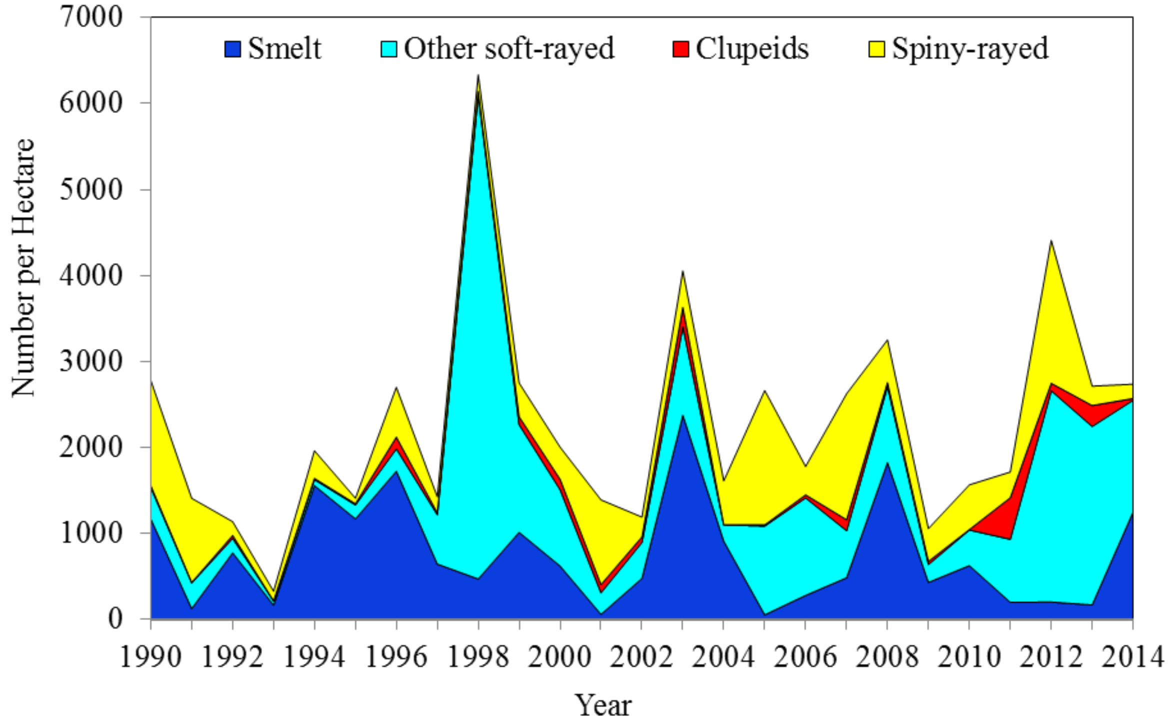

Figure 2.3.1 Mean density of prey fish (number/hectare) by functional group in the Ohio waters of the central basin, Lake Erie, 1990-2014.

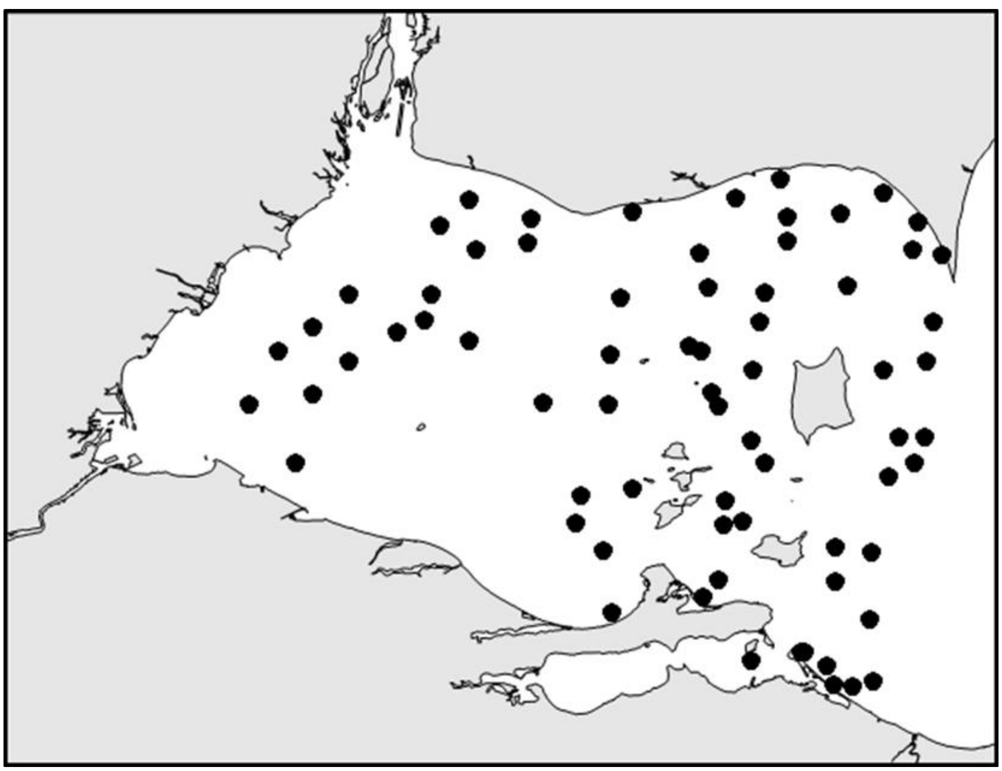

Figure 2.4.1. Trawl locations for the western basin interagency bottom trawl survey, August 2014

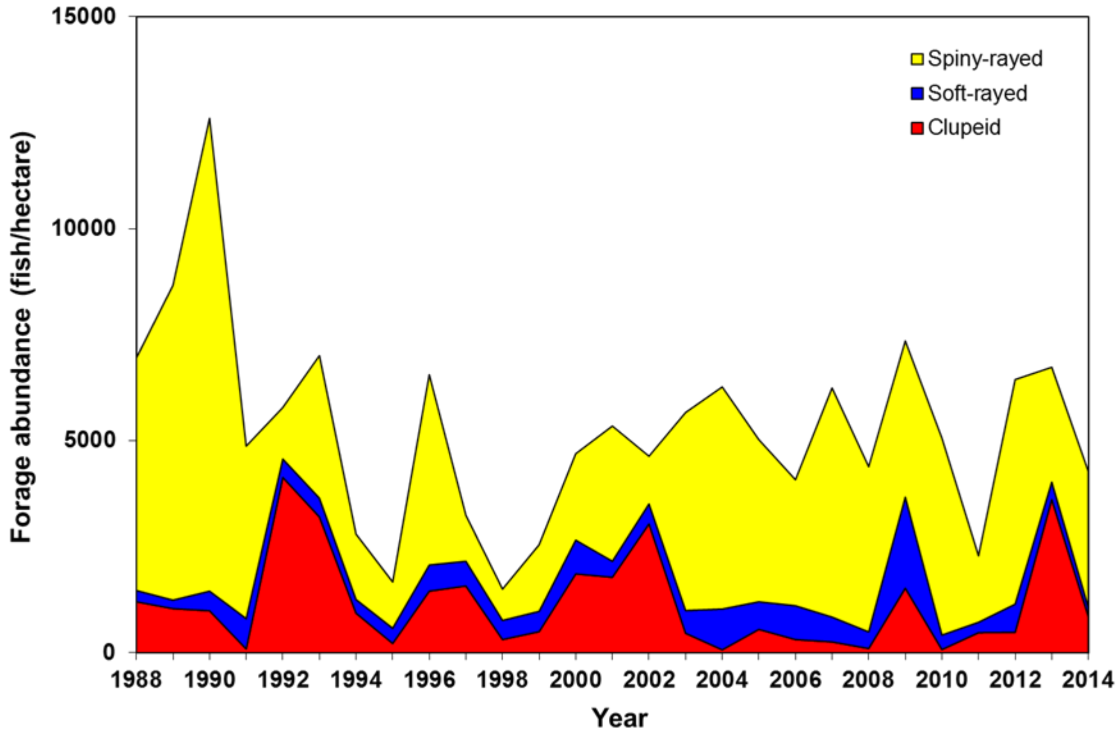

Figure 2.4.2. Mean density (number/ hectare) of prey fish by functional group in western Lake Erie, August 1988-2014.

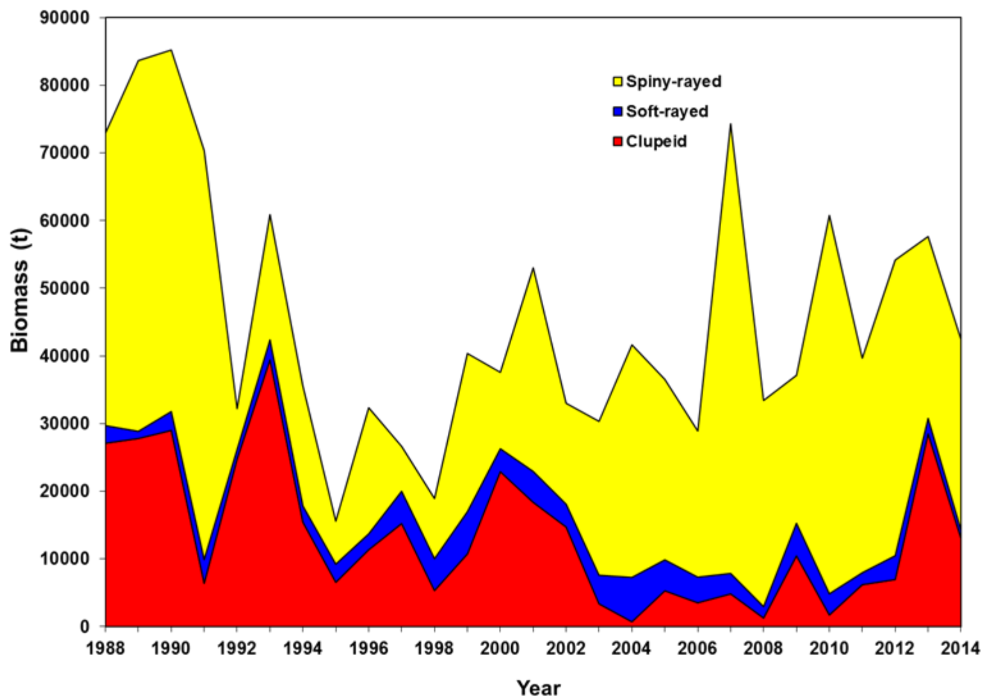

Figure 2.4.3. Mean biomass (tonnes) of prey fish by functional group in western Lake Erie, August 1988-2014.

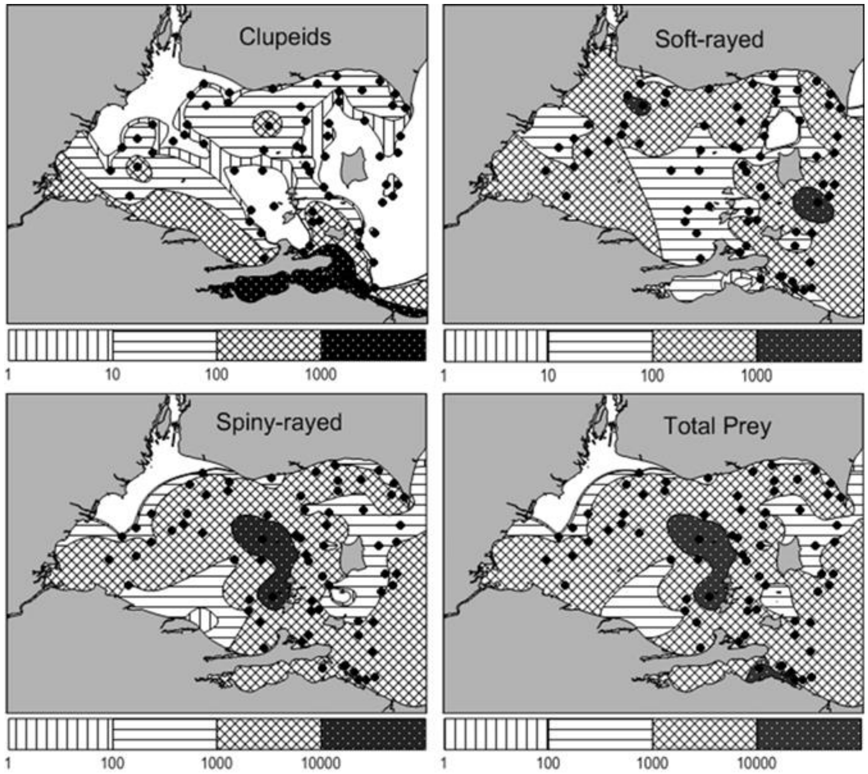

Figure 2.4.4. Spatial distribution of clupeids, soft-rayed, spiny-rayed, and total forage abundance (individuals per hectare) in western Lake Erie, 2014. Black dots are trawl sites, white areas are estimates of zero abundance, and contour levels vary with the each functional fish group.

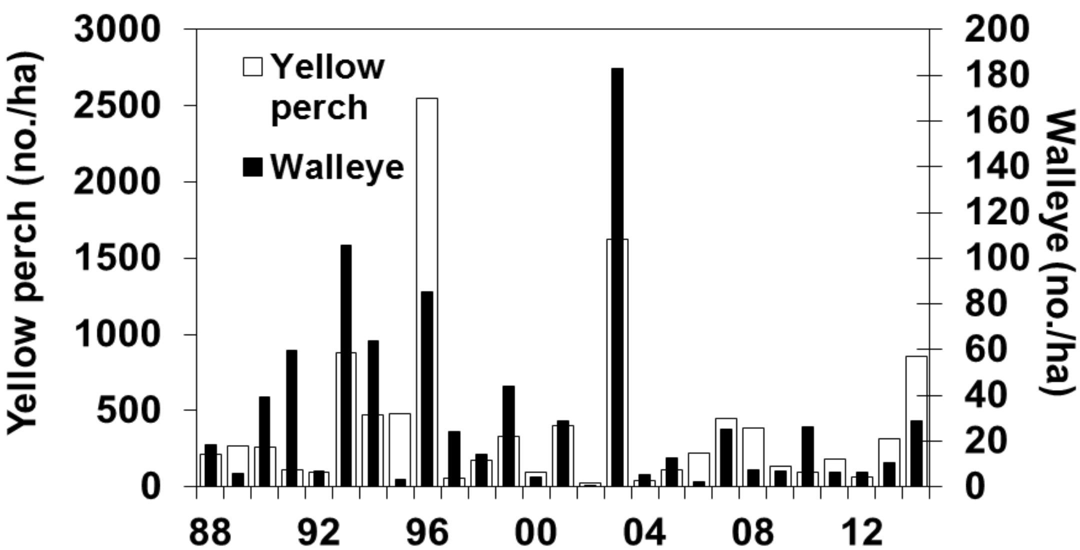

Figure 2.4.5. Density of age-0 Yellow Perch and Walleye in the western basin of Lake Erie, August 1988-2014.

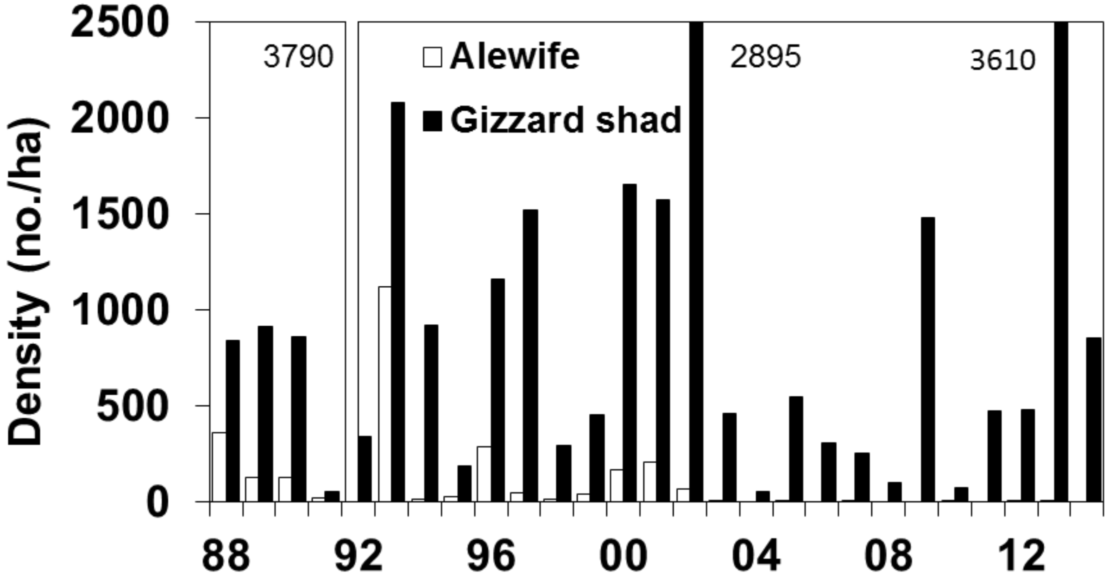

Figure 2.4.6. Density of age-0 Alewife and Gizzard Shad in the western basin of Lake Erie, August 1988-2014.

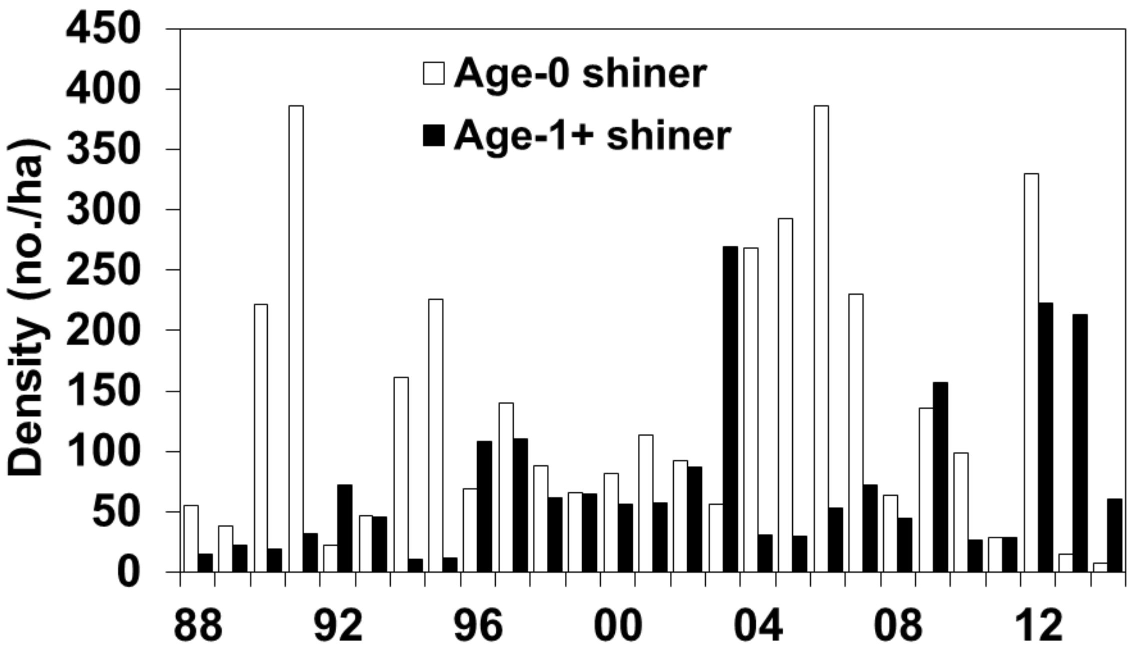

Figure 2.4.7. Density of age-0 and age-1+ shiners (*Notropis* spp.) in the western basin of Lake Erie, August 1988-2014.

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, 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 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 east basin survey years 2007 to 2013 and we describe the major elements of acoustic data collection during the 2014 survey. The raw data from this most recent survey effort have not been processed so results were not available for this report.

In general, standard survey procedure has 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 2014, the east basin acoustic team renewed one of its two Echoview software licenses.

The 2014 Survey

In most years since 1997, the east basin survey has been accomplished as a two-agency endeavor. 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 OMNRF'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.

A full complement of 12 survey transects requires a minimum of five nights to sample. Acoustic data collection occurred during darkness from approximately one-half hour after sunset to one-half hour before sunrise centered on a few days before and after the new moon in July, which was the 26th in 2014. Acoustic sampling during 2014 began July 24th and ended 10 days later on August 2nd (Figure 3.1.1). Persistent poor weather conditions precluded sampling on five consecutive nights from July 25th to 30th, resulting in only three full nights of sampling completed during the 2014 survey. Eight of 12 transects were sampled totaling some 188 kilometers; the two most eastern (59025, 59080) and western (58530, 58470) transects were not sampled (Figure 3.1.1). Approximately 900,000 KB of raw acoustic data were recorded including about 53,000 KB of stationary sampling at the ends of some transects to assess target strength (TS) variability of individual fish tracks. A total of 20 water temperature-depth profiles were sampled across all transects in 2014. Companion mid-water trawl collections to obtain representative samples of the pelagic forage fish community for apportioning of acoustic targets was limited to a single night (August 1-2) during the 2014 survey due to constraints in NYSDEC budget and accompanying travel restrictions .

Acoustic data were processed using the Myriax Echoview 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 Rainbow 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 customized SAS (SAS 2006) program that scanned 1-m depth layers in each sample interval in a downward progression and selected the first occurrence where the proportion of age-0- to ALL-size Rainbow 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 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 were generated 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 four years from 2010 to 2013 (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 basin-wide average density of age-0 Rainbow Smelt-size targets in warm-water habitat was 18,889 fish/ha and 800-m interval density estimates 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 OMNRF, ODNR, and USGS have collaborated to conduct joint hydroacoustic and midwater trawl surveys in central Lake Erie since 2004. In 2014 we were not able to follow the established protocol and sample design (Forage Task Group 2005) due to hull and engine repairs to the ODNR R/V *Grandon.* We were also presented with the opportunity to run acoustic transects with the United States Environmental Protection Agency (USEPA) research vessel R/V *Lake Guardian*. After consultation with Forage Task Group members and participating agencies, it was decided to run a comparison of acoustic data collection from three different sized vessels. The comparison was designed to assess fish avoidance of vessels during acoustic data collection. The three vessels conducting the exercise were USEPA R/V *Lake Guardian* (53x12 m), USGS R/V *Muskie* (23x6 m) and ODNR *R/V North River* (8x3 m). Each vessel collected data simultaneously along three parallel transects 0.5 to 1 km apart on three consecutive nights. Data are currently being analyzed and will be reported when completed and peer reviewed. All data and analysis reported here are from the USGS R/V *Muskie*. 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).

Hydroacoustics

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. Although the protocol for this survey specifies beginning at the 10-m contour, sampling started and ended at the 13- to 15-m contours to accommodate operational guidelines for the R/V *Lake Guardian*.

Hydroacoustics data were collected with BioSonics DTX® echosounders and BioSonics Visual Acquisition (release 6.0) software. Data from the R/V *Muskie* were collected using a 120-kHz, 8.2-degree, split-beam transducer mounted inside a through hull transducer tube at a depth of 1.5 m below the water surface.

Sound was transmitted at four pulses per second with each pulse lasting 0.4 milliseconds. Global Positioning Systems (GPS) coordinates from the R/V *Muskie* were collected using a Garmin ® GPSMAP 76Cx and GPS coordinates were interfaced with the echosounders to obtain simultaneous latitude and longitude coordinates. We used the temperature readings from just above the thermocline to calculate speed of sound in water 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 beneath the first bottom echo for each transect.

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

Results

Three complete cross-lake transects were sampled between 21 July and 24 July, 2014 with hydroacoustics and midwater trawls (Figure 3.2.1). The remaining transects were not completed due to weather and vessel repair.

A total of 21 midwater trawls were completed during the survey. Rainbow Smelt, Yellow Perch and Emerald Shiner were the primary species caught in most midwater trawls (Table 3.2.1). White Bass was the only other species that comprised the majority of an individual trawl catch. Other species caught in midwater trawls included Gizzard Shad, Sea Lamprey, White Perch, Walleye, and Freshwater Drum.

Acoustic TS distributions, by depth, showed differences in TS across depth strata. As in previous years, depth layers were determined from TS-depth distributions in 2014. 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 2014. The highest densities of age-0 Rainbow Smelt, Yellow Perch, White Bass and all ages of Emerald Shiner were primarily in the upper layer, shallower than 15 m. Yearling and older Rainbow Smelt densities were generally higher in the trawls fished deeper than 15 m.

Spatial distribution across transects varied by species and age group. Emerald Shiner and age-0 Rainbow Smelt tended to be uniformly distributed across the basin on all three transects (Figure 3.2.2, 3.2.3). Yearling-and-older Rainbow Smelt densities were highest on the northern end of the eastern transect, relative to the western transects (Figure 3.2.3). Highest densities of age-0 White Bass were found in the northern and eastern areas of the basin (Figure 3.2.5). Young of the year Yellow Perch densities were highest in the southern areas of the basin (Figure 3.2.6).

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 8.6 mg/l off Erieau, Ontario. Based on target distributions from whole-transect echograms, and past experience that highest densities of targets tended to be near the thermocline, the thermocline depth was irregular and fluctuated along the entire lengths of all three transects (Figure 3.2.7). Temperature and dissolved oxygen profiles collected by the R/V *Keenosay* during the acoustic survey support the thermocline patterns on the echograms.

Discussion

The thermocline fluctuation along the middle and west transect in 2014 were unusual and have not been documented in echograms from previous years. Data collected on the west transect by USGS three days prior to the start of the acoustic survey suggest higher winds and colder than normal air temperatures might be the cause of the fluctuation. Similar to the thermocline depth, in 2014, both the TS-depth distribution and the species composition of midwater trawls was different from historic patterns. As in previous years, the 15 m depth layer used for acoustic analysis was determined from TS-depth distributions. However, the partition between large and small targets in acoustic data was not as obvious as in the past as smaller targets were frequently encountered below the thermocline. In most years, there is a strict pattern of large and small targets separated by the thermocline. Historically, trawl catches also reflect the acoustic pattern, with larger species (age-1+ Rainbow Smelt) being caught almost exclusively below the thermocline. Age-0 Rainbow Smelt were caught throughout the water column on all three transects, which suggests a large cohort (also supported by bottom trawl surveys reported in Section 2.0).

Emerald Shiner and age-1+ Rainbow Smelt were also distributed differently than in past years. On the middle and east transects, both species distributions were similar to historic patterns, with Emerald Shiner above the thermocline and age-1+ Rainbow smelt below the thermocline. On the west transect, distributions changed, with Emerald Shiner being caught throughout the water column and age-1+ Rainbow Smelt generally absent from the trawl catch. The species distribution on the west transect is unusual and may be an effect of the extreme thermocline fluctuations.

Hydroacoustics has been used to assess forage fish in central Lake Erie for approximately 12 years. The current design of hydroacoustic data collection in central Lake Erie includes 8 north- to-south-oriented, cross-lake transects between the 10-m depth contours. Ideally two hydroacoustic vessels each collect data along 4 transects, paired with two additional vessels using midwater trawls to collect fish specimens to identify fish species and relative abundances. The stated objective of the survey is to produce a basin-wide snapshot of abundance of pelagic species, primarily Rainbow Smelt and Emerald Shiner. Surveys have been conducted during the new moon phase in July. Sampling is conducted during the new moon because of effects of moonlight on diel vertical migration of Rainbow Smelt, which is in response to movements of prey in response to light level.

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

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

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

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 21-22 and 25, 2014 (Figure 3.3.1). All transects were surveyed using an older, BioSonics DT-E surface unit belonging to the Michigan Department of Natural Resources (MiDNR) 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 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 2014 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 R/V *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 as the data were collected 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):

Total length = 10 ^ ((Target Strength + 26.1)/19.1) * 1000

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

Results

In 2014, 143 km of Lake Erie were surveyed, resulting in the collection of 1.1 gb of data. Western basin forage fish density and biomass estimates were moderate in 2014, averaging 12,594 fish per hectare and 19 kg per hectare, respectively (Figure 3.3.2). Forage fish densities were generally higher along the northern portions of each transect. Statistical testing (ANOVA) indicated that density in 2014 was significantly higher than in 2005, 2008, and 2011($F_{7, 864} = 41.3$, $P < 0.0001$), lower than 2007 and 2013, and similar to levels in 2006 and 2009. Biomass showed the same pattern ($F_{7, 864} = 43.1$, $P < 0.0001$). Most (96%) forage fish in the survey were estimated to be between 30-109 mm.

Table 3.2.1. Percent composition of fish captured in trawl samples collected by the R/V *Keenosay*, in the central basin Lake Erie in July, 2014.

Transect	Trawl ID	Depth	Latitude	Longitude	Rainbow Smelt age 0	Yellow Perch age 0	White Bass age 0	Rainbow Smelt age 1+	Emerald Shiner all ages	Other all ages
58100	1001	11	42.3696	81.0064	27	2	4	12	55	0
58100	1002	12	42.3722	81.0076	59	5	4	0	32	0
58100	1003	5	42.3165	80.5846	10	76	9	0	4	1
58100	1004	10	42.3091	80.5813	58	25	16	0	1	0
58100	1005	13	42.3179	80.5847	32	13	4	49	1	0
58100	1006	5	42.2427	80.5543	12	83	4	0	0	1
58100	1007	11	42.2331	80.5507	74	19	7	0	0	0
58100	1008	14	42.2426	80.5526	47	35	5	11	1	1
58100	1009	17	42.2318	80.5505	28	24	9	38	0	0
57850	2001	5	42.3375	81.2831	10	3	12	0	74	1
57850	2002	9	42.3276	81.2766	1	0	3	1	95	0
57850	2003	5	42.2939	81.2639	2	32	0	0	67	0
57850	2004	10	42.2980	81.2655	10	9	12	0	69	0
57850	2005	16	42.2984	81.2658	0	16	13	69	0	2
57850	2006	15	42.2020	81.2299	23	32	43	0	2	0
57600	3001	12	42.0459	81.4500	15	12	4	0	64	5
57600	3002	16	42.0358	81.4378	35	16	7	0	39	3
57600	3003	8	42.0349	81.4338	5	19	10	0	64	2
57600	3004	10	42.1240	81.4827	8	49	10	0	33	1
57600	3005	14	42.1189	81.4788	27	35	9	7	18	4
57600	3006	5	42.1552	81.4957	20	3	16	0	55	7

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 2014. 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.

		57350		57600		57850	
Age group	Species	Lower	Upper	Lower	Upper	Lower	Upper
Age 0	Rainbow Smelt	185	1064	481	1646	927	734
	Yellow Perch	84	699	220	1020	657	975
	White Bass	37	717	97	1052	734	902
Age 1	Rainbow Smelt	1.4	0	3.7	0	381	14
All ages	Emerald shiner	207	3410	540	6179	117	6789

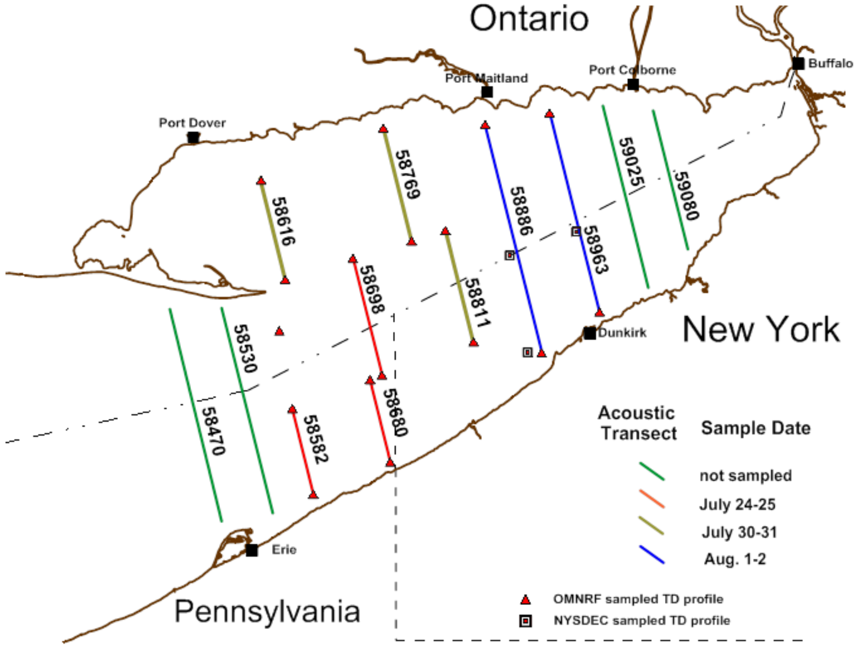

Figure 3.1.1. July 2014 eastern basin Lake Erie inter-agency acoustic survey transects and temperature profile sites sampled by the Ontario Ministry of Natural Resources (OMNRF) research vessel, RV *Erie Explorer*.

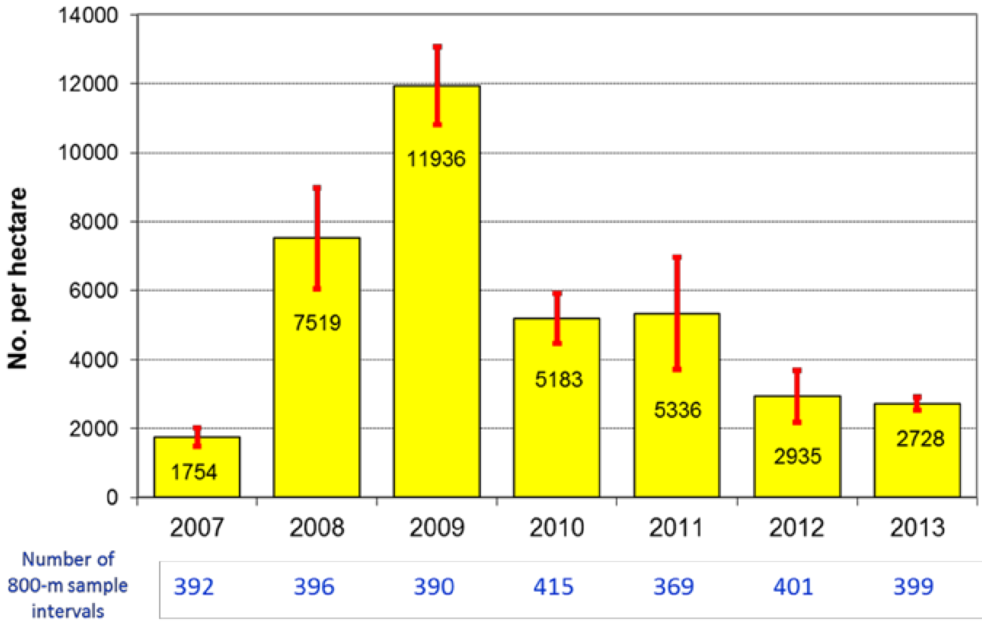

Figure 3.1.2. Mean density (Number per hectare) estimates of pelagic forage fish in cold-water habitat (all species, age-1+ Rainbow Smelt-sized) with a 120-kHz split-beam echosounder during July fisheries hydroacoustic assessments of eastern Lake Erie, 2007 - 2013. Density estimates were derived from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

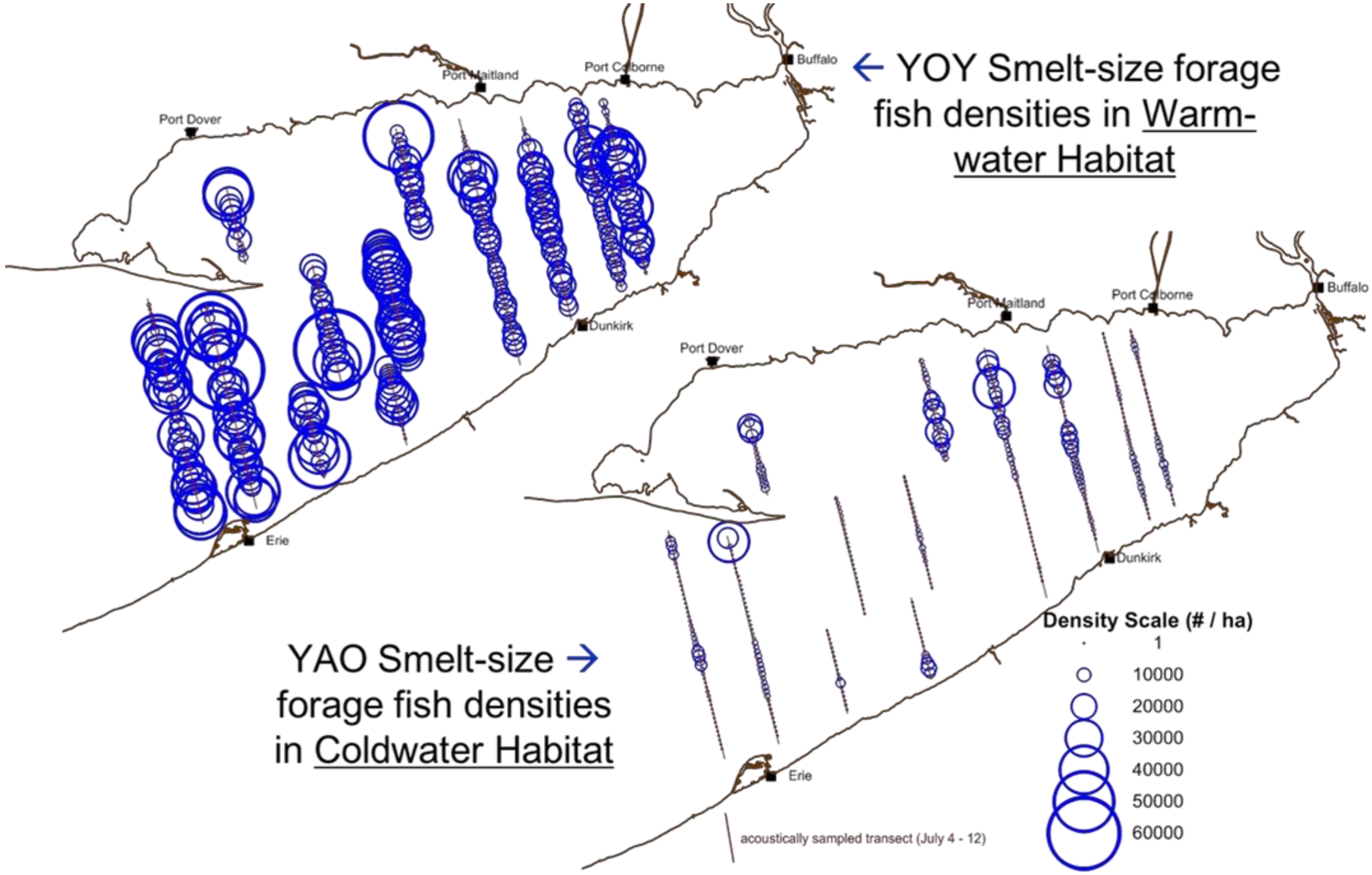

Figure 3.1.3. Relative density of age-0 (upper-left map) and age-1+ (lower-right map) Rainbow Smelt-size pelagic forage fish in warm-water (epilimnion) and cold-water (metalimnion and hypolimnion) habitat, respectively. Bubble size is proportionate to fish density (Number/ha) per 800-m interval along transects sampled with a 120-kHz split-beam echosounder during July fisheries acoustic surveys in eastern Lake Erie, 2013.

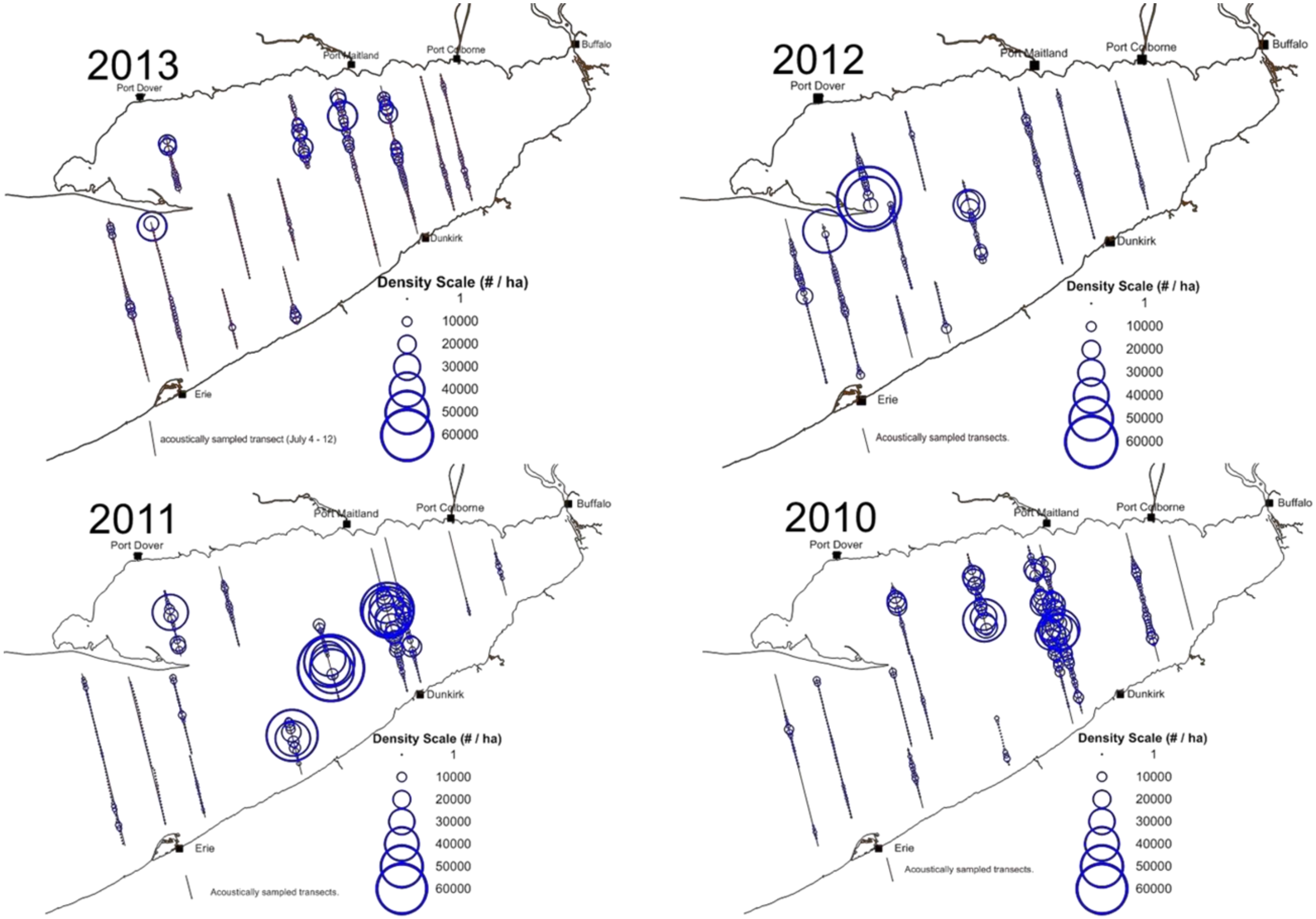

Figure 3.1.4. Relative density (Number/ha) of pelagic forage fish in coldwater habitat (all species, age-1+ Rainbow Smelt-size) per 800-m interval along transects sampled with a 120-kHz split-beam echosounder during July fisheries acoustic surveys in eastern Lake Erie, 2009 to 2013.

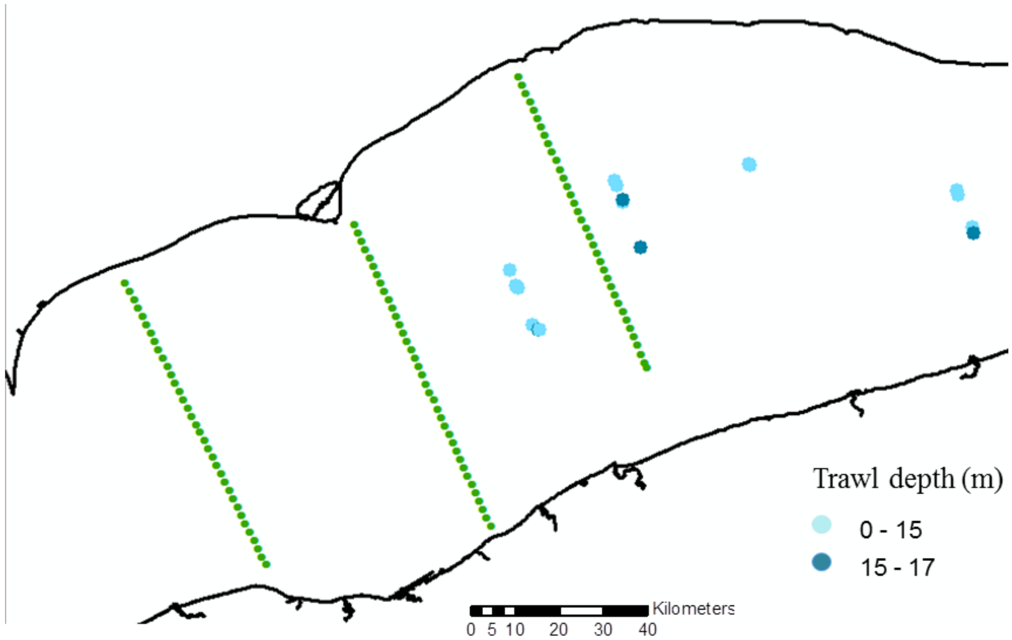

Figure 3.2.1 Hydroacoustic transects and midwater trawling stations in the central basin, Lake Erie, July 21-24, 2014. Transect numbers are Loran-TD lines.

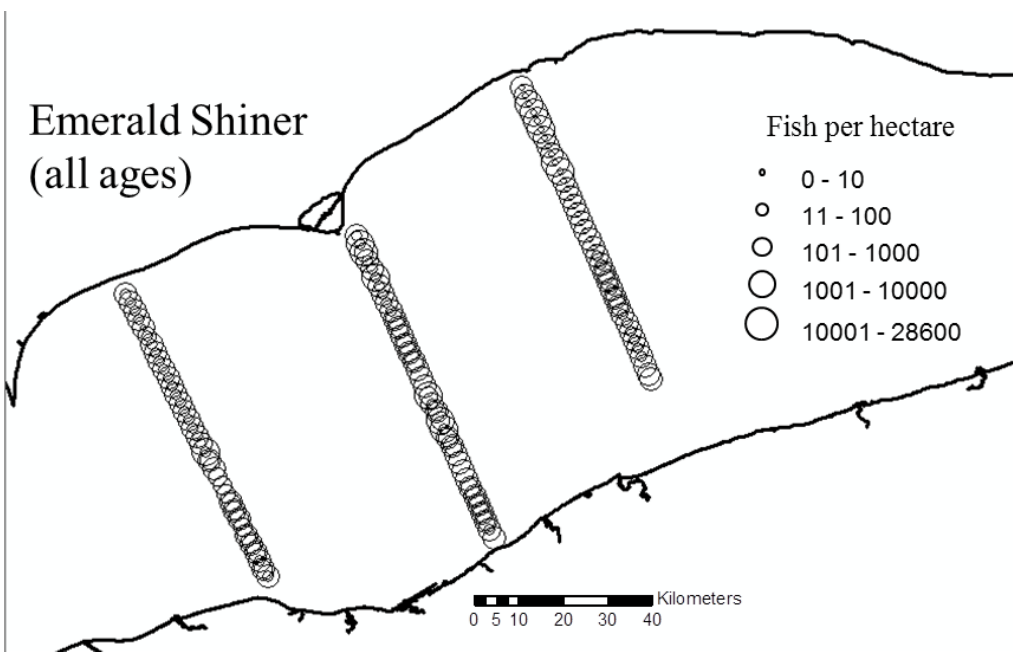

Figure 3.2.2. Density estimates of Emerald Shiner (fish/ha) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 2 km segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2014.

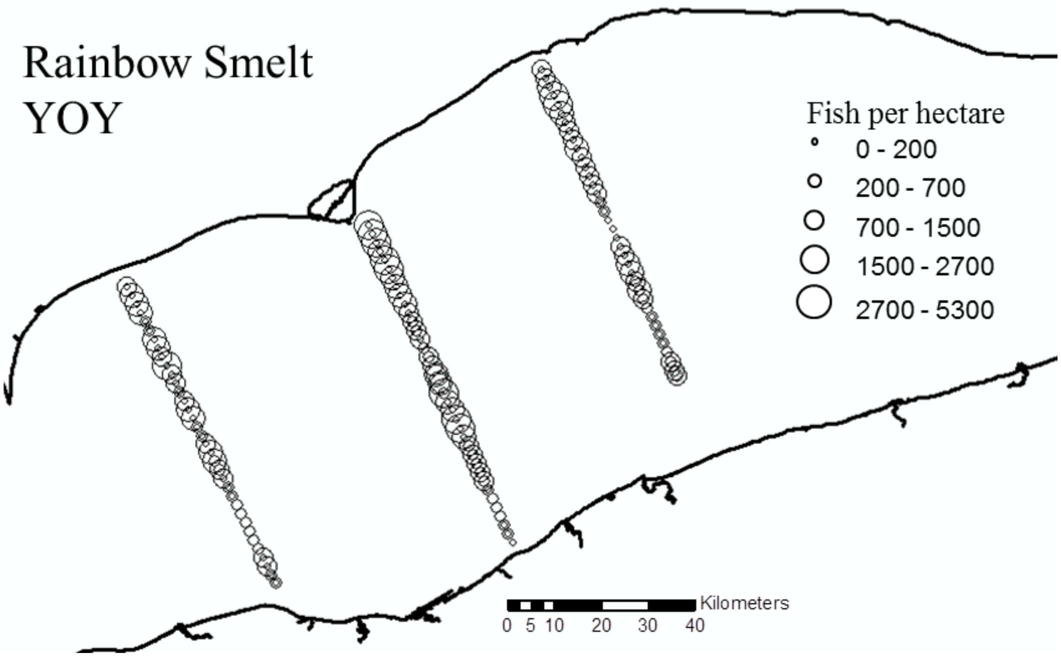

Figure 3.2.3. Density estimates of age-0 Rainbow Smelt (fish/ha) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 2 km segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2014.

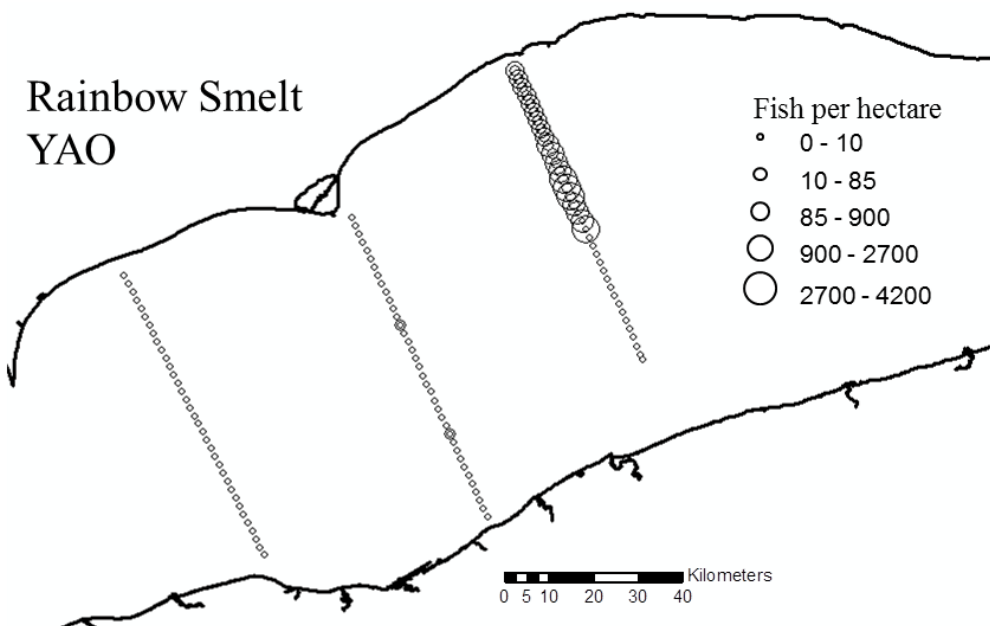

Figure 3.2.4. Density estimates of age-1+ Rainbow Smelt (fish/ha) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 2 km segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2014.

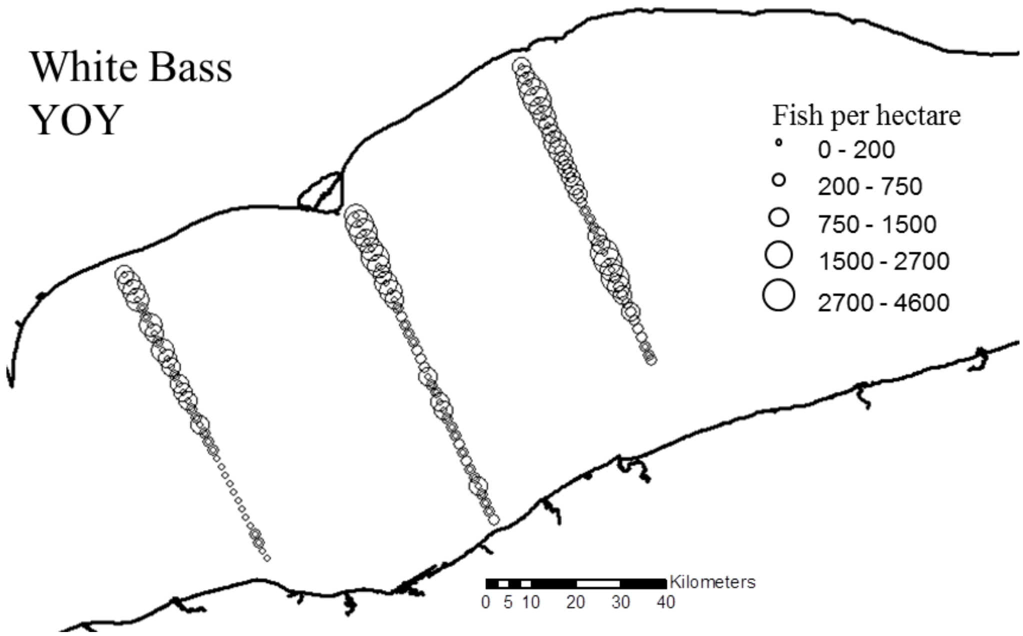

Figure 3.2.5. Density estimates of age-0 White Bass (fish/ha) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 2 km segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2014.

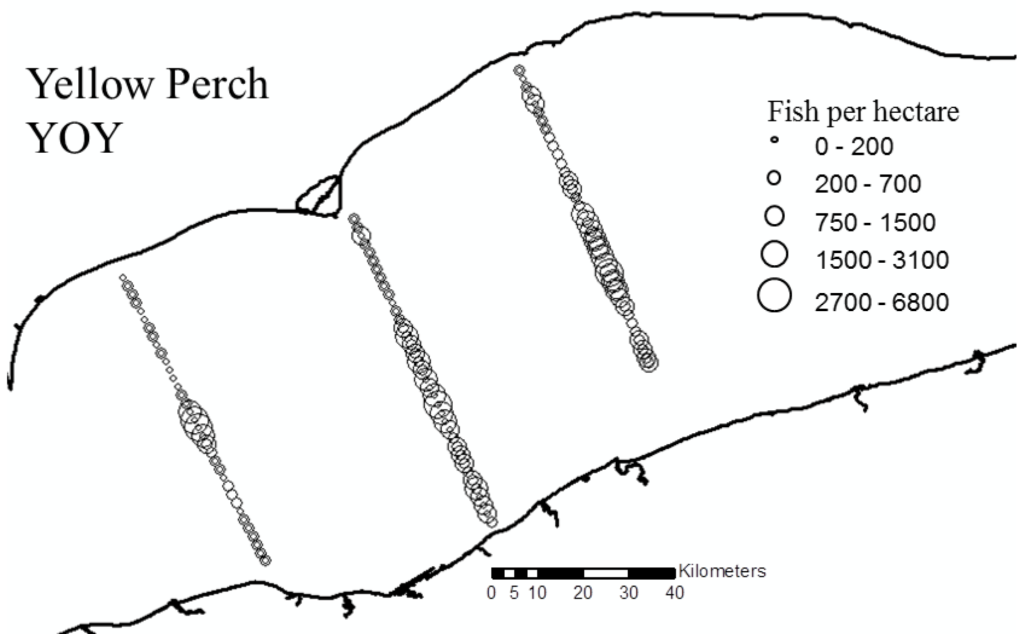

Figure 3.2.6. Density estimates of age-0 Yellow Perch (fish/ha) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 2 km segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2014.

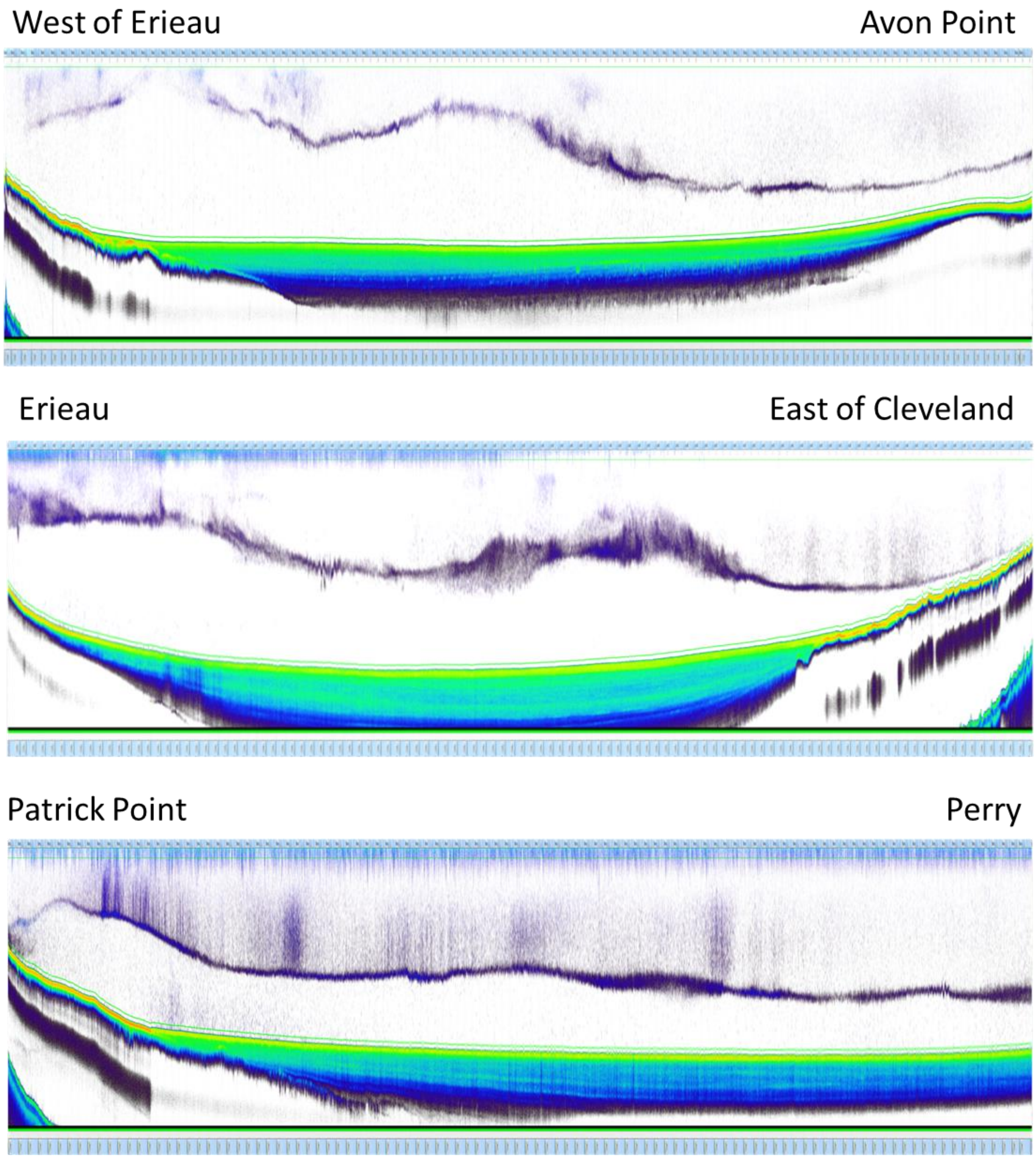

Figure 3.2.7. Echogram files generated from Echoview® software version 5.1 that show total back scattering (Sv) along transects in the central basin, 2014.

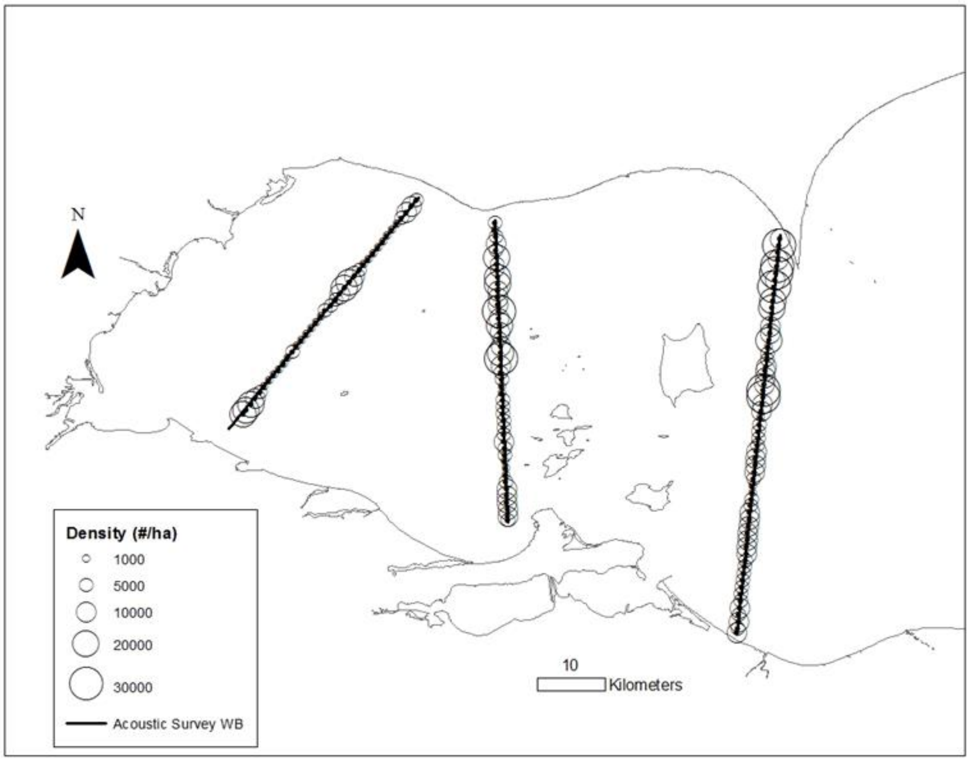

Figure 3.3.1. Acoustic survey transects and associated density (Number/ha) for the western basin of Lake Erie, 2014.

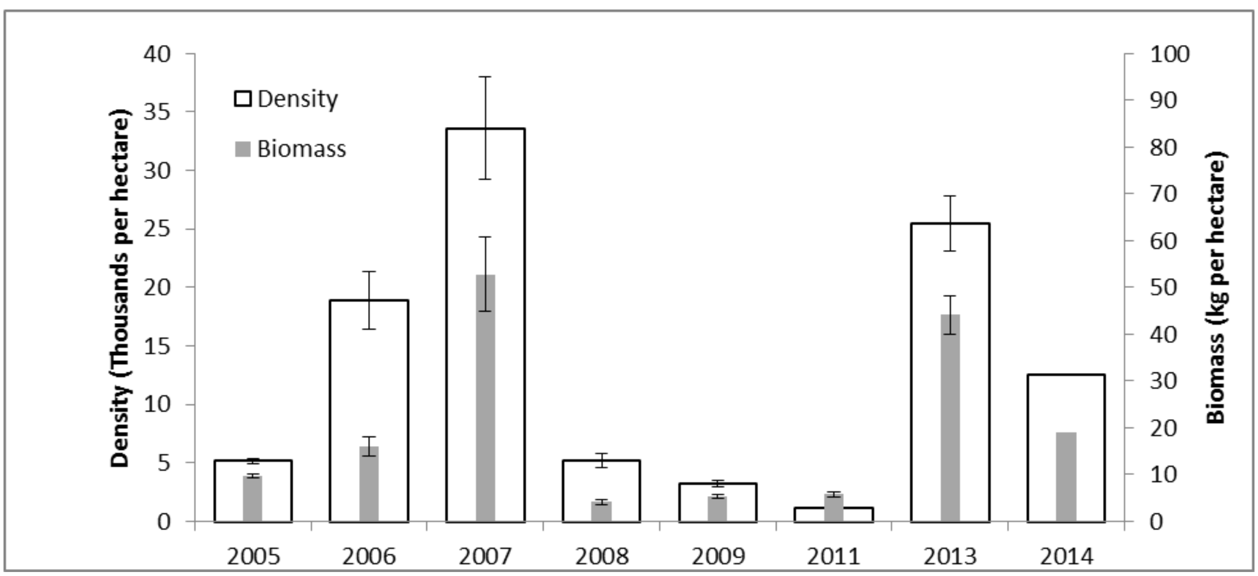

Figure 3.3.2. Mean density (number/ha) and biomass (kg/ha) estimates from the western basin acoustic survey, 2005-2014. Estimates are for acoustic targets between -60dB and -38dB. Error bars are standard errors.

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, and J. Markham)

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 2014, 276 Walleye stomachs were examined of which 58 (21%) contained food remains. Throughout the 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 Rainbow 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 2014 samples, the contribution by volume of identifiable species included three fish species: Rainbow Smelt (82.4 %), Emerald Shiner (2.7 %), and Round Goby (3.8 %) (Figure 4.1.1). Also found in some Walleye stomachs were small, nearly unquantifiable amounts of spiny water fleas (*Bythotrephes sp.)*. The most commonly occurring prey items found in Walleye's diet from summer index gillnets in Long Point Bay during 2014 were Rainbow Smelt (64%), Emerald Shiner (14%), Yellow Perch (7%) and Round Goby (7%).

Round Goby were first observed in the summer diet of Yellow Perch from Long Point Bay in 1997 and from New York waters in 2000. Round Goby 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 and then decreasing slightly during 2014 (79%) 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. Round Goby were first observed in the diet of Smallmouth Bass from the Long Point Bay area in 2001 and during each of the past five 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 netting 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. During 2014, 831 Lean Lake Trout and 67 Klondike Lake Trout stomachs were examined of which 466 (56%) Lean and 28 (42%) Klondike Lake Trout contained food remains. Rainbow Smelt were the dominate forage species again in Lean strain Lake Trout, occurring in 73% of non-empty stomach samples (Figure 4.1.3). Round Goby were the next most abundant diet item (34%). In Klondike strain Lake Trout, Round Goby (64%) and Rainbow Smelt (57%) were about equally abundant. Emerald Shiners (1) and Yellow Perch (4) were the only other identifiable fish species found in 2014, and these were in Lean strain Lake Trout. Round Goby have occurred more frequently in the diets of Klondike than Lean strain Lake Trout during all ten years that Klondike trout have been collected in coldwater index gill nets.

Round Goby have increased in the diet of Burbot since this invasive species first appeared in Lake Erie's eastern basin in 1999, replacing Rainbow Smelt as the main prey item in Burbot diets in nine of the last 12 years (Figure 4.1.4). The occurrence of Rainbow Smelt and Round Goby in Burbot stomachs containing food increased from 12% and 33%, respectively in 2013 to 34% and 52%, respectively in 2014 (Figure 4.1.4).

Growth

Mean length of age-2 and age-3 Smallmouth Bass cohorts sampled in 2014 autumn gill net collections (New York) have remained stable over the past nine years and are among the highest in the 34-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). However, during the most recent 6- or 7-year period, a moderate decreasing trend in size at age is evident among a few age groups of Smallmouth Bass (Figure 4.1.5).

Walleye length at age-1 and age-2 in 2014 from netting surveys targeting juveniles in New York were similar to 2013 and the long-term average. Mean lengths of age-0 Yellow Perch in New York waters were slightly below average in 2014; age-1 mean lengths were slightly above average. In general, both age groups have exhibited stable growth rates over the past nine 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 2014. Mean size-at-age (length and weight) of Lake Trout in 2014 were consistent with the recent 10-year average (2004 – 2013) 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 2014, Rainbow Smelt were absent in Walleye diet samples from the central basin. Adult Walleye diets (by dry weight) were primarily Gizzard Shad (89.7%) and to a lesser extent Emerald Shiner (7.5%). Yearling Walleye showed the opposite preference consuming mostly Emerald Shiner (66.7%) followed by Gizzard Shad (33.3%).

Growth

Mean length of Walleye collected in Ohio's fall gillnet survey in 2014 was above the long-term mean for cohorts up to age 6. White Bass size-at-age declined slightly from 2013 and is generally at or below the long-term mean for all cohorts in 2014.

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

In 2014, adult Walleye diets (by frequency of occurrence) taken from ODNR fall gillnet catches consisted of Gizzard Shad (79%), Emerald Shiners (15%), and White Perch (3%) in the western basin. Yearling Walleye relied on Gizzard Shad (70%), Emerald Shiner (16%), and Yellow Perch (12%). Age-0 Walleye relied on Gizzard Shad. Similarly, MDNR fall index gillnet walleye stomachs were dominated by Gizzard Shad and Emerald Shiners. 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 and fall, benthic macroinvertebrates were found at the highest frequency of diets (75.6% and 51.1%, respectively). The occurrence of zooplankton in diets was 20.5% in spring, and increased to 28.3% in the fall. Fish prey had a 4.2% occurrence in spring diets, and increased in occurrence to 20.4% in fall diets. Chironomids, *Dreissena* spp., and *Hexagenia* spp. were the most prominent benthic macroinvertebrates in spring, whereas *Hexagenia* spp. and gastropods were the most frequently encountered prey taxa in fall diets. The most commonly found zooplankton prey in spring was *Leptodora kindtii* and *Daphnia* spp., and *Bythotrephes* sp. and *Daphnia* spp. in the fall. The occurrence of fish prey greatly increased from spring to fall (4.2% and 20.4% of diets, respectively) with unidentifiable fish remains being the most common prey type in both seasons. There was only one observed *Hemimysis* sp. and no *Cercopagis* sp. identified in Yellow Perch diets from the western basin in 2014. 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 pattern similar to the frequency of occurrence data for Yellow Perch diets. Benthic macroinvertebrates contributed most to Yellow Perch diets in spring (81.1%), followed by zooplankton (13.7%) and fish prey (5.2%). In spring, *Hexagenia* spp. comprised 23.6% of the dry weight and *Dreissena* spp. contributed 22.9%. Our spring sampling coincided with a *Hexagenia* spp. hatching event and many stomachs appeared very full and only contained *Hexagenia* spp. In fall, benthic macroinvertebrate taxa continued to show the highest contribution to diet weights (53.4%), followed by fish prey (23.7%) and zooplankton (23.0%). The major benthic macroinvertebrate taxa contributors in fall diets were *Hexagenia* spp. and *Gastropoda* (29.0%, and 14.5%, respectively). *Bythotrephes* sp. accounted for almost 100% of total zooplankton observed in fall diets. The major fish prey taxa contributor in fall diets was unidentified fish remains (18.4%). 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 sport fish in 2014 varied compared to 2013 (Figure 4.3.1). Lengths of select age-0 species include Walleye (136 mm), Yellow Perch (68 mm), White Bass (62 mm), White Perch (60 mm), and Smallmouth Bass (68 mm). These lengths are near or below long-term averages (139 mm, 67 mm, 67 mm, 58 mm, and 79 mm, respectively).

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

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 several 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, White Bass, and Yellow Perch (Figure 4.4.1). *Hemimysis anomala* can now be reliably collected from harbor piers in the eastern basin of the lake (K. Bowen; DFO-GLLFAS; pers. Comm.), 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. 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. Yellow Perch and White Perch, are examined to some degree in all three surveys; White Bass are examined in the central and eastern surveys, and Rock Bass are only examined in the east. Notably, the spatial coverage of western basin diet collections by the USGS-Lake Erie Biological Station was increased 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. Consumption of *H. anomala* by White Perch was down in 2014 (7.3% of non-empty stomachs) compared to a time-series high of 24.4% in 2013 (Figure 4.4.2). In this survey Rock Bass are the second most consistent consumer, with *H. anomala* annually found in less than 5% of examined fish. 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 greater than 3500 having been examined. White Bass were first observed to utilize *H. anomala* in Long Point Bay in 2010; none were observed in 2014.

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. No Hemimysis were observed by USGS-LEGS in 2013 and the lone observation from the USGS-LEBS survey in 2014 was from a location in proximity to the islands. 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 a single Yellow Perch in 2014 after having examined 153 and 183 White Bass stomachs from the central basin. Overall it can be said that White Perch consume Hemimysis lake-wide, whereas only Yellow Perch from the Central and Western basins are known consumers.

As noted previously, we urge caution when making comparisons between surveys due to 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.

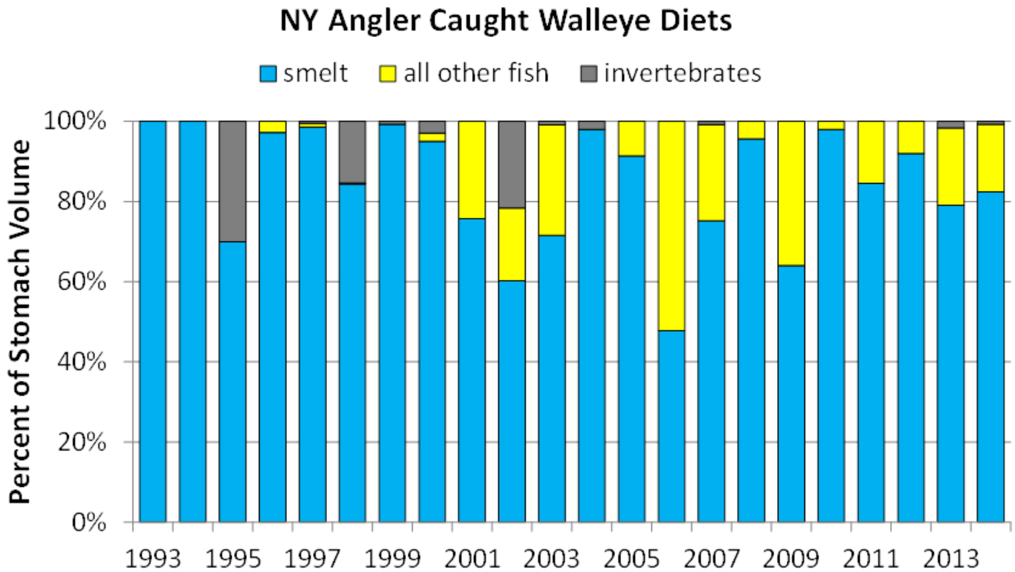

Figure 4.1.1. The percent contribution (by volume) of identifiable prey in stomachs of adult Walleye caught by summertime anglers in New York's portion of Lake Erie, 1993 to 2014.

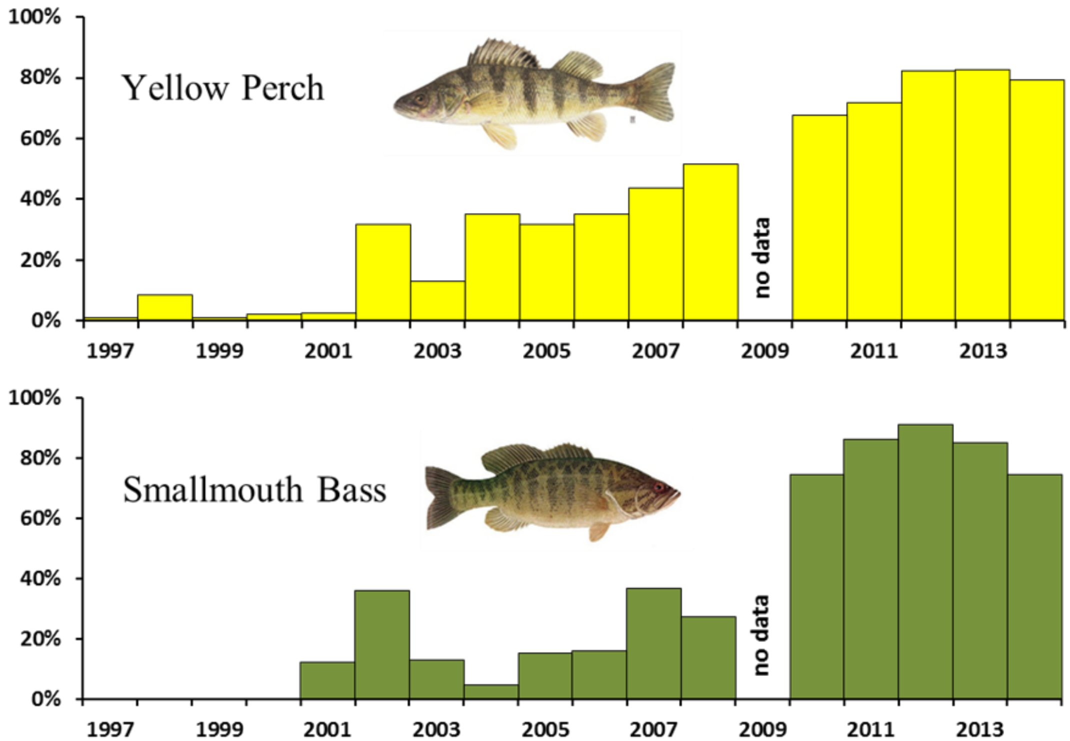

Figure 4.1.2. Percent occurrence of Round Goby in non-empty stomachs of adult Yellow Perch and Smallmouth Bass from OMNRF summer index gillnets, Long Point Bay, Lake Erie 1997 to 2014.

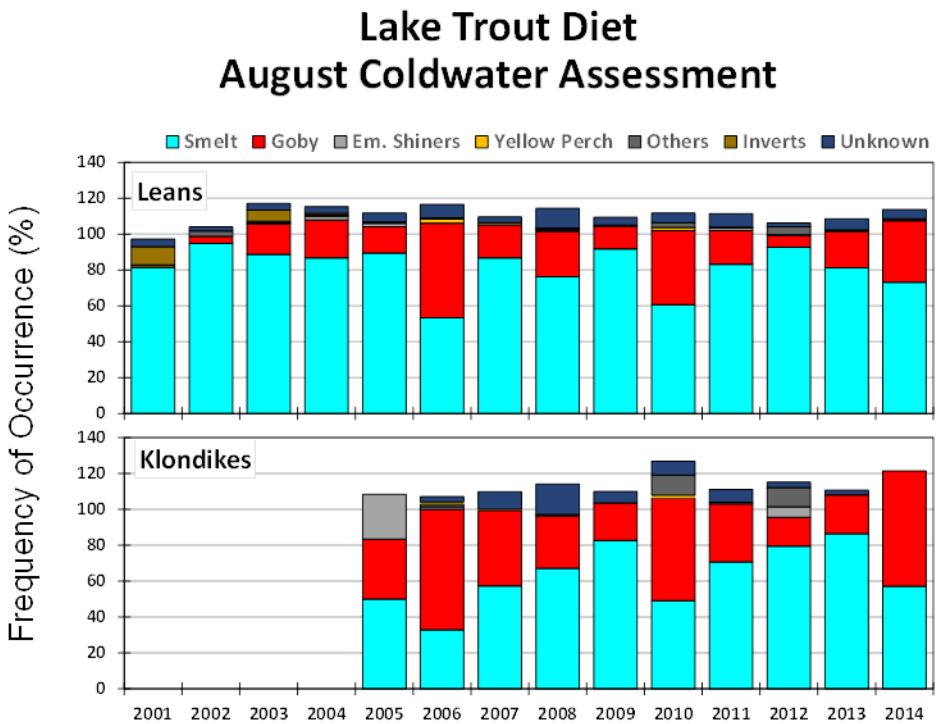

Figure 4.1.3. Percent occurrence of diet items from non-empty stomachs of Lean (N=466) and Klondike (N=28) strain Lake Trout collected in gill nets from eastern basin waters of Lake Erie, August 2014.

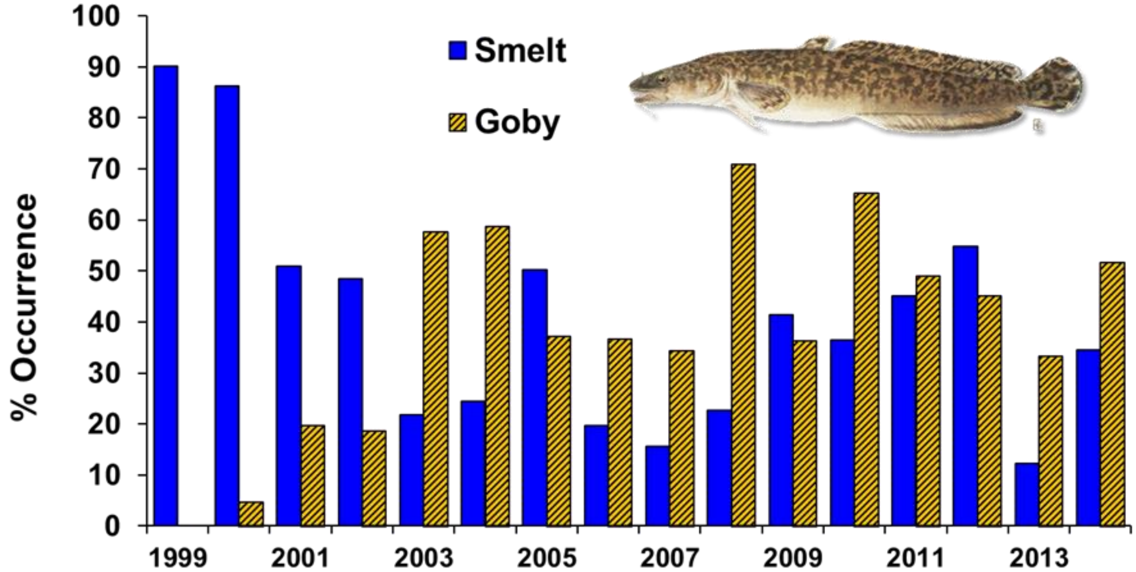

Figure 4.1.4. Percent occurrence of Rainbow Smelt and Round Gobies in the diet of Burbot caught in coldwater index gillnets set during August in the eastern basin of Lake Erie, 1999-2014.

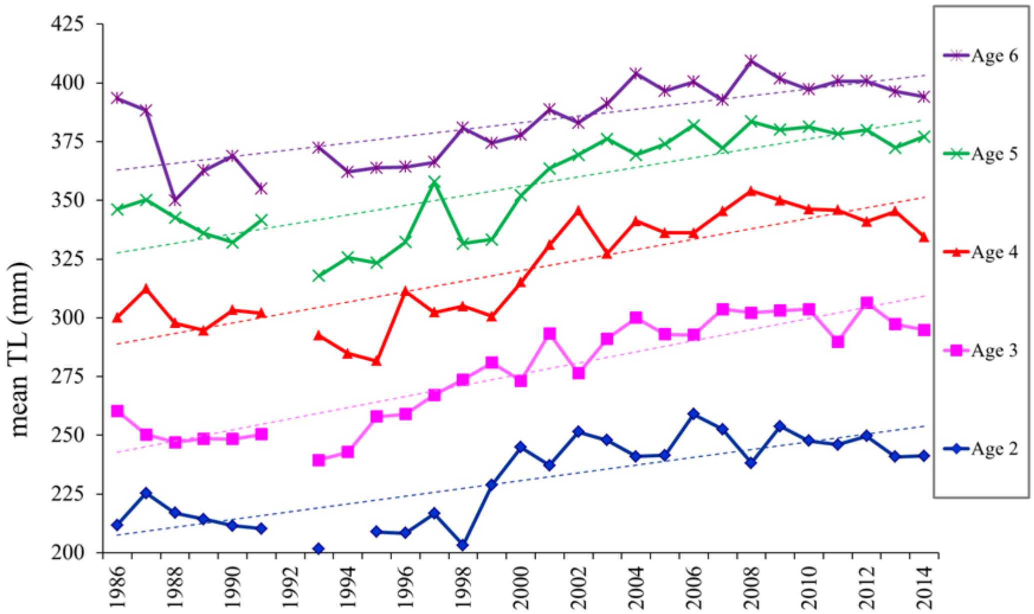

Figure 4.1.5. Smallmouth Bass mean total length (mm) at ages 2 to 6 captured in index gill nets set overnight at 12-30 ft. (3.7-9.1 m) depths during summer months in Long Point Bay, Lake Erie, 1986-2014. Males and females combined. Dashed lines represent linear trend across years for each age class. Smallmouth Bass ages were not available for 1992 samples.

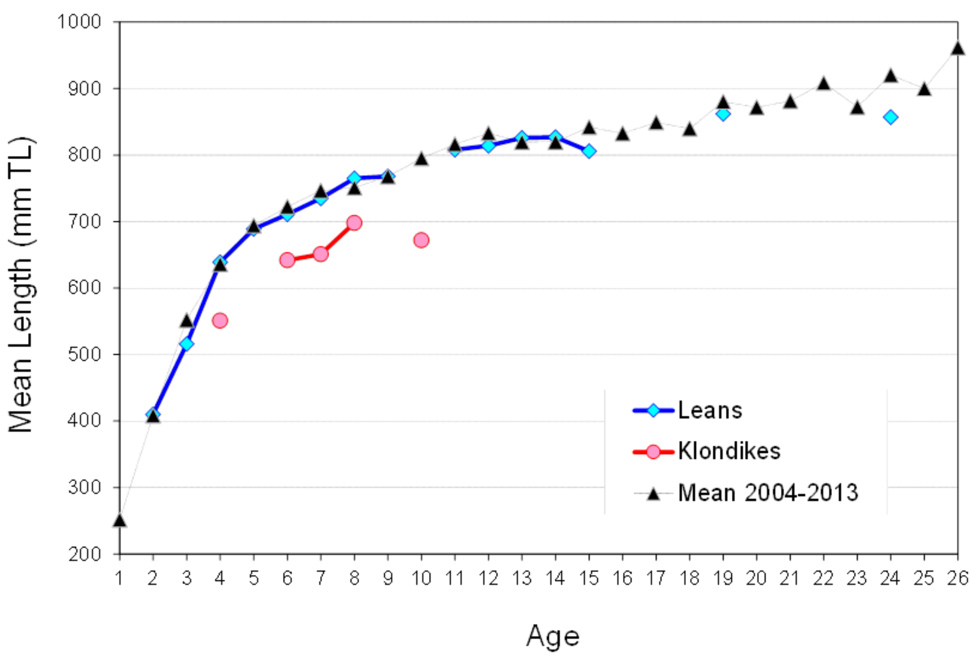

Figure 4.1.6. Mean length-at-age of Lean strain and Klondike strain Lake Trout sampled in assessment gill nets in the eastern basin of Lake Erie, August 2014. The previous 10-year average (2004-2013) from New York waters is shown for current growth rate comparison.

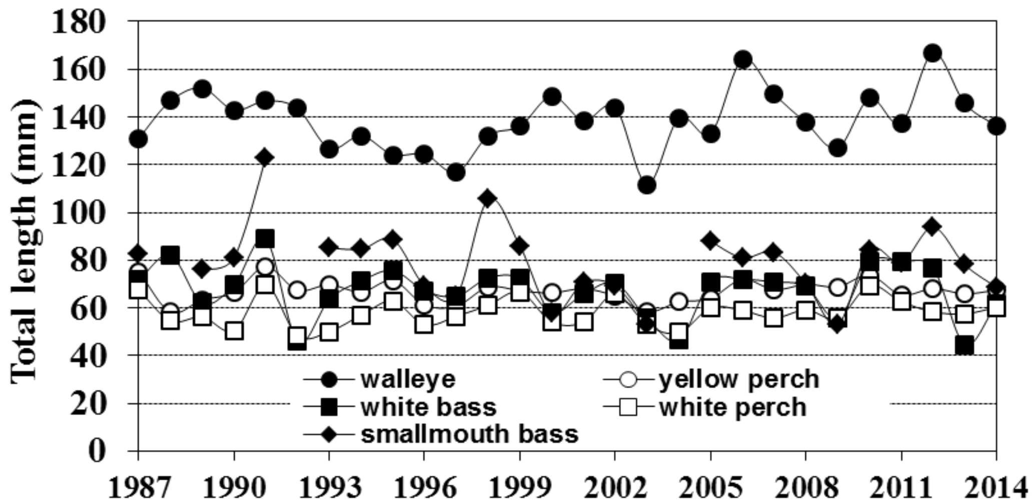

Figure 4.3.1. Mean total length (mm) of select age-0 fishes in western Lake Erie, August 1987- 2014.

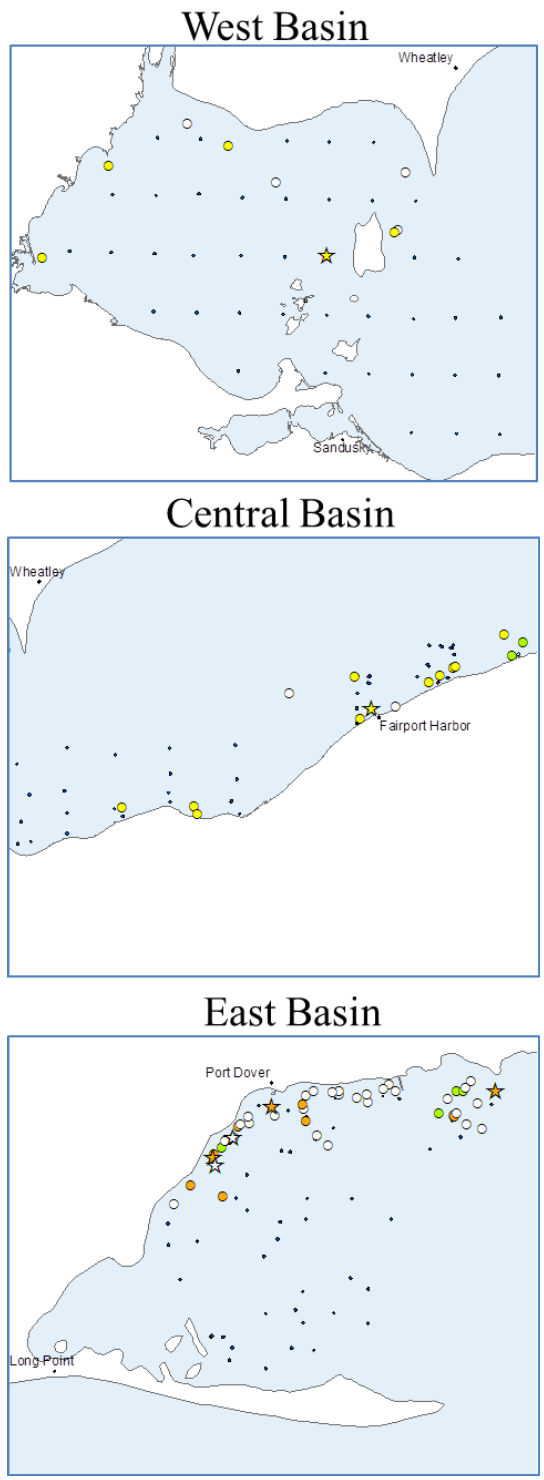

Figure 4.4.1 *Hemimysis anomala* observations fish diets collected during Lake Erie surveys in the west (USGS-LEBS; trawl), central (ODNR; gillnet and trawl) and east (OMNRF; gillnet) lake basins. Observations from 2014 (stars), and 2006-2013 (circles). Survey locations appear as dark dots. Fish species as: White Perch (white); Yellow Perch (yellow); White Bass (green); Rock Bass (orange).

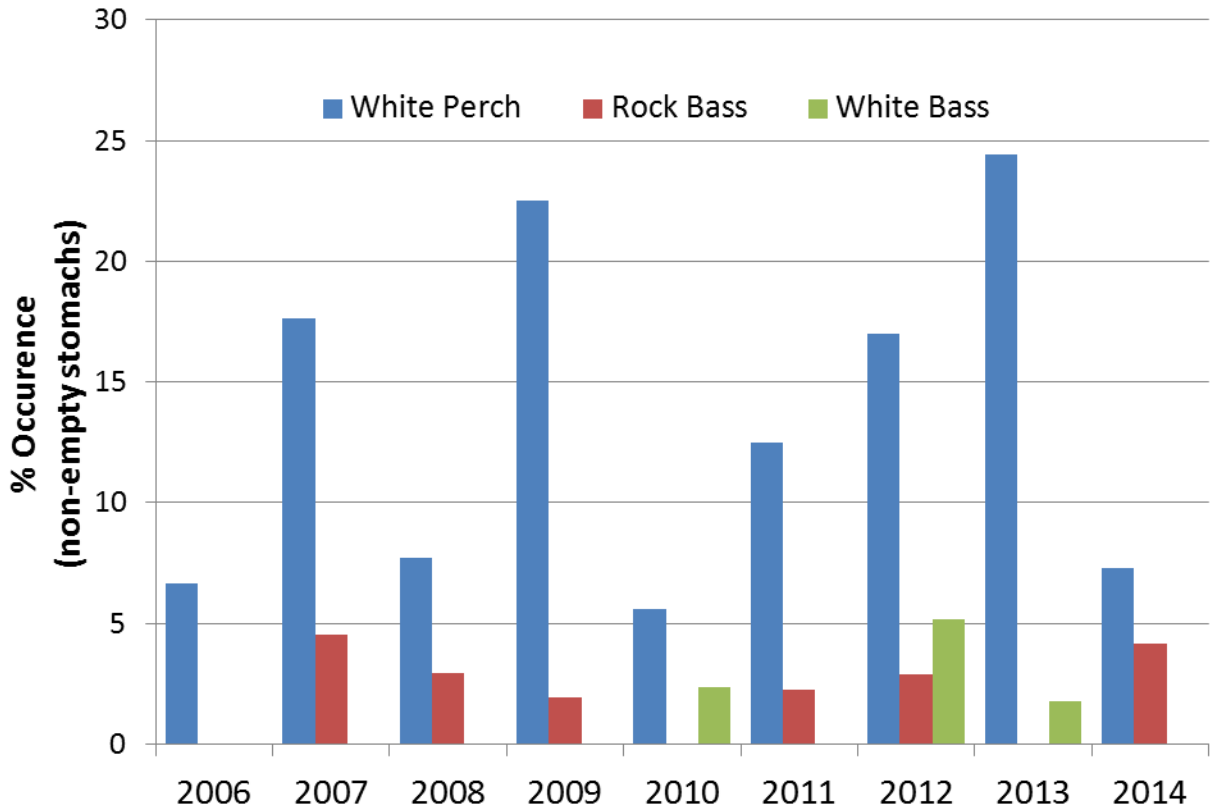

Figure 4.4.2 Occurrence of *Hemimysis anomala* in the diets of three fish species (proportion of fish stomachs examined) captured by gillnet in Long Point Bay, Ontario, 2006 – 2014.

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 2015.

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

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