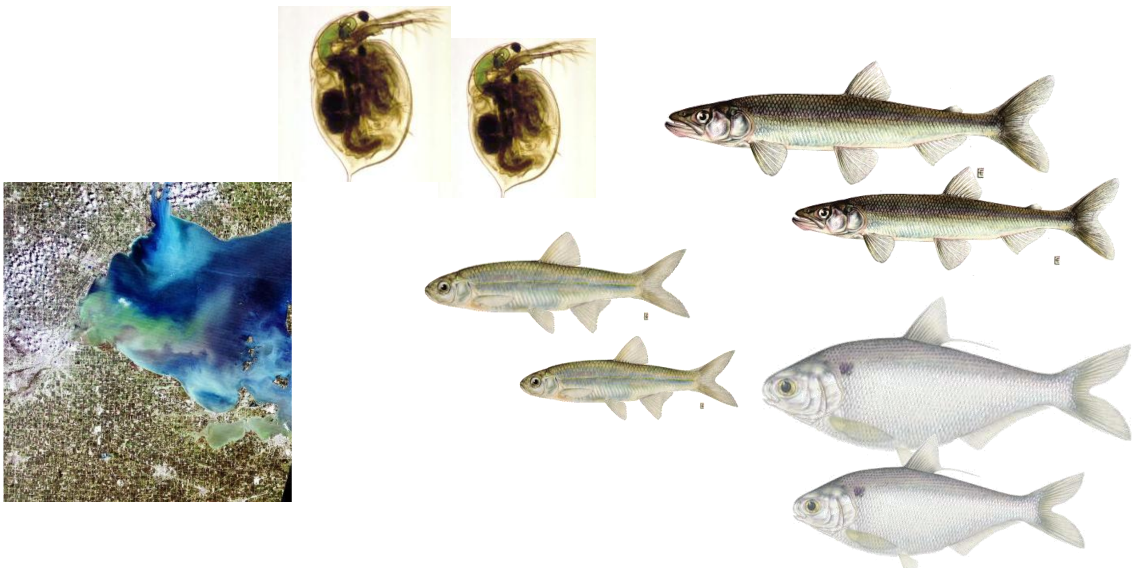
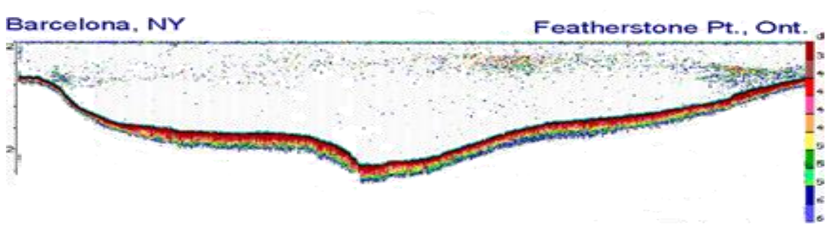
Report of the
Lake Erie
Forage Task Group

March 2012





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Mike Hosack	- Pennsylvania Fish and Boat Commission, (PFBC) {Co-Chair}
John Deller	- Ohio Department of Natural Resources, (ODNR)
Patrick Kocovsky	- United States Geological Survey - Great Lakes Science Center (USGS)
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Presented to:

Standing Technical Committee
Lake Erie Committee
Great Lakes Fishery Commission

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1.0 Charges to the Forage Task Group in 2011-2012

1. Continue to describe the status and trends of forage fish and invertebrates in each basin of Lake Erie.

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

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. Continue the interagency lower-trophic food web monitoring program to produce annual indices of trophic conditions which will be included with the annual description of forage status.

2.0 Status and Trends of Forage Fish Species

2.1 Synopsis of 2011 Forage Status and Trends

General Patterns

- Relative forage abundance was low to moderate in 2011
- Age-0 rainbow smelt increased in the East, and decreased in the Central and West.
- Gizzard shad was above average in East and Central, below average West
- Predator growth was above average in East and Central basins
- Phosphorus levels decreased in east basin, but increased in west and central basins

Eastern Basin

- Forage fish abundance during 2011 was high in New York (NY) and below average in Ontario (ON)
- Age-0 rainbow smelt increased basin-wide; 2011 year class was moderate
- Yearling-and-older (YAO) rainbow smelt density decreased (NY) or remained about the same (ON) in 2011; abundance was below average basin-wide
- Age-0 yellow perch abundance indices were mixed; 2011 year class strength ranked moderately strong (ON) to below average. (NY)
- Age-0 alewife abundance remained below avg.
- Age-0 gizzard shad decreased in 2011 from record high density; above average density basin-wide
- Record high numbers of emerald shiners in New York survey; all age groups below avg. abundance in Ontario
- Spottail shiner remained at low densities throughout basin
- Round goby densities increased (ON) or stayed the same (NY)
- Average length of age-0 rainbow smelt decreased; YAO smelt were about the same size as in 2010; both age groups were below average size in 2011
- Predator diets were diverse, dominated by fish species, primarily rainbow smelt and round goby
- Predator growth remained good; age-2 to -6 smallmouth bass remained at or near record long length-at-age in Long Pt. Bay, ON, and age 2 and 3 bass cohorts in NY near maximum mean lengths
- Lake trout growth remained high and stable.
- Mean density of YAO smelt-size acoustic targets was 9398 fish/hectare in 2011, a 5% decrease from the 2010 and 34% lower than the 2009 estimate
- Yearling-and-older and older smelt-size acoustic targets were most dense in the south half of the basin, west and north of Dunkirk, NY

Central Basin

- Low to moderate forage fish abundance throughout the basin in 2011
- Age-0 and YAO forage density increased from 2010, but was below average
- Rainbow smelt and emerald shiner abundance were below average
- Age-0 yellow perch abundance decreased from 2010 and was below average
- Age-0 gizzard shad increased in west and was well above average
- Round goby abundance was well above average
- Mean length of forage species decreased from 2010, but remained at or above average
- Mean length of walleye was above average for fish up to age 6
- Predator diets were predominantly rainbow smelt, gizzard shad and emerald shiners

West Basin

- Forage abundance and biomass were at low levels
- Age-0 gizzard shad catches increased from 2010, but were still below long term mean
- Age-0 and YAO rainbow smelt catches remain low
- Age-0 emerald shiner decreased from 2010; YAO emerald shiner increased; both were below long-term mean
- Age-0 white perch decreased 69% from 2010, lowest since 2002
- Round gobies increased in 2011, third lowest since first year of invasion (1997)
- Age-0 yellow perch increased from 2010 and walleye recruitment decreased; both were below long-term mean; white bass recruitment decreased and was below long-term mean
- Size of age-0 walleye, yellow perch, white bass, white perch, and smallmouth bass were all near long term means
- Fall walleye diets showed reliance on gizzard shad and emerald shiners

2.2 Eastern Basin (L. Witzel, J. Markham and D. Einhouse)

Rainbow smelt are the principal prey fish species of piscivores in the offshore waters of eastern Lake Erie (Figure 2.2.1). In 2011, rainbow smelt once again was the most abundant forage species captured in fall index bottom trawl surveys in Ontario (OMNR) and the second most abundant forage species in New York (NYS DEC); the PFBC did not perform any bottom trawl assessment in Pennsylvania waters of the east basin during 2011 (Table 2.2.1). Yearling-and-older (YAO) rainbow smelt abundance was average in New York and below average in Ontario with approximately 90% of YAO-members from the 2010 year class (age-1). Age-0 rainbow smelt abundance was about three times greater in New York compared to Ontario; 2011 density estimates were slightly above average in New York, but only about one-half of the long-term average for Ontario's trawl time series. The mean length of age-0 (59 mm FL) rainbow smelt decreased in 2011 (Figure 2.2.2). The mean length of age-1 (101 mm FL) smelt was unchanged from 2010 and remained smaller than average (1984-2010 avg. = 103 mm).

The contribution of non-smelt fish species to the forage fish community of eastern Lake Erie was dominated in 2011 by emerald shiner, age-0 yellow perch, and round goby in Ontario and by emerald shiner, trout perch, round goby, and age-0 yellow perch in New York (Table 2.2.1). Emerald shiner were caught in record high numbers in New York waters, in part due to a single very large trawl catch. Emerald shiner were below average density in Ontario. Spottail shiner abundance remained low throughout all eastern basin regions in 2011 (Table 2.2.1). Episodic high catches of age-0 alewife have been observed in agency trawl assessments, but not in recent years (2000, 2002 in NY, 1999 in ON). Age-0 alewife abundance was below the long-term average for all surveyed areas in 2011. Age-0 gizzard shad abundance increased in Ontario and decreased in New York in 2011 after reaching a record high numeric density in New York last year.

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 from 2000 to 2007 were variable and increasing. Round goby densities have decreased since 2007 and the 2010 estimate ranks as the lowest index observed in Ontario and the second lowest in New York since 2000. The recent decreasing trend in goby abundance was interrupted in 2011 by an increase in Ontario and no significant change in New York (Table 2.2.1).

Rainbow smelt have remained the dominant prey of angler-caught walleye sampled each summer since 1993. Beginning in 2001 prey fish other than rainbow smelt made a small, but measurable, contribution to the walleye diet. Collections beginning in 2006, and continuing in 2007 and 2008, were especially noteworthy because several other prey fish species contributed measurably to walleye diets. Round goby remain the largest component of the diet of adult smallmouth bass caught in New York gill net surveys since 2000. Gobies were first observed in the summer diet of yellow perch in Long Point Bay in 1997 and have been the most common prey fish species found in perch stomachs since about 2002.

Fish species continue to comprise the majority of the diets of both lake trout and burbot caught in experimental gill net surveys during August in the eastern basin of Lake Erie. Rainbow smelt have been the dominant food item in Lean Strain lake trout since coldwater surveys began in the early 1980s in Lake Erie, occurring in 85 – 95% of the stomachs. However, in years of low YAO rainbow smelt abundance such as 2006 and 2010, round goby became prominent in the diets of both Lean and Klondike Strain lake trout. Smelt dominated lake trout diets again in 2011, occurring in 83% of Lean Strain and 71% of Klondike Strain lake trout. Round goby were the only other prominent forage species, occurring in 19% of Lean Strain and 32% of Klondike Strain fish. Round goby occurred more frequently in the diets of Klondike than Lean Strain lake trout during all seven years since 2005 that Klondike Strain individuals have been collected in coldwater index gill nets.

The occurrence of rainbow smelt in burbot stomachs containing food increased to 46% in 2011 (37% in 2010) and was coincident with a decrease in occurrence of round goby from 65% to 50%. Gobies have increased in the diet of burbot since this invasive species first appeared in the eastern basin in 1999. They were the main diet item for burbot in six of the last eight years.

Mean length of age-2 and age-3 smallmouth bass cohorts sampled in 2011 autumn gill net collections (New York) have remained stable over the past 4 years and are among the highest in the 31-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. In 2011, length-at-age for each of age-2 to age-6 smallmouth bass cohorts remained at or near maximum values observed during the 26-year time series of OMNR's Long Point Bay gillnet survey. Length-at-age trends from New York's juvenile walleye (age-1 and age-2) assessment were near long-term average sizes. Mean size-at-age (length and weight) of lake trout in 2011 were consistent with the recent 10-year average (2001 – 2010) and k condition coefficients remain high. Klondike strain lake trout have significantly lower growth rates compared to Lean strain lake trout. Lake trout growth in Lake Erie continues to be stable and among the highest in the Great Lakes.

2.3 Central Basin (J. Deller)

Routine bottom trawl surveys in the central basin began in Ohio in 1990 and Pennsylvania in 1982. The Pennsylvania Fish and Boat Commission was unable to survey the central basin during 2011. In 2011, overall forage abundance in the Ohio waters was 1716 fish per hectare (Figure 2.3.1). The 2011 index increased from 2010, and can be attributed to increases in both age-0 and YAO age groups. The increases from 2010 densities were moderate, and as a result, the overall forage abundance was below the long-term average.

Rainbow smelt and emerald shiners are the primary forage species in the central basin. For both species, age-0 and YAO age groups were below average in most areas of the central basin (Tables 2.3.1 and 2.3.2). Age-0 emerald shiners in western Ohio waters were the only index above the long-term average. Basin-wide indices for age-0 rainbow smelt and emerald shiners were low to moderate, respectively. Yearling-and-older indices for rainbow smelt increased from 2010, but were well below the long-term average. Emerald shiner YAO indices increased in western Ohio, but decreased in eastern Ohio relative to 2010. Basin wide, YAO indices for rainbow smelt and emerald shiners were moderate based on the 10 year time series. The highest densities for rainbow smelt were found in eastern Ohio waters, while emerald shiner densities were highest in the west.

Round goby first appeared in central basin trawl surveys in 1994. Since then, round goby densities have tended to be higher in eastern areas of the basin relative to western areas. This trend continued in 2011, with densities of both age-0 and YAO age groups (Tables 2.3.1 and 2.3.2). Round goby indices in 2011 increased basin wide for both age-0 and YAO age groups compared to 2010. In most areas of the central basin, round goby indices were well above average and were some of the highest indices in the time series. Round goby densities have been increasing in most areas of the basin since 2009.

Age-0 gizzard shad indices in Ohio waters are generally higher in the west areas relative to the east. This trend continued in 2011 with gizzard shad indices increasing in the west and decreasing in the east from 2010 (Table 2.3.1). Gizzard shad abundance in western Ohio increased to a record high density in 2011. Alewife has not been caught in the central basin since 2007, despite being regularly encountered in western Ohio prior to 2004.

Age-0 yellow perch indices decreased basin wide from 2010 and were below average (Table 2.3.1). Yearling-and-older yellow perch indices decreased from 2010 in the west, but increased in the east (Table 2.3.2). Yearling-and-older yellow perch were well below average in the west, and slightly above average in the east. Age-0 white perch indices increased in the west and decreased in the east from 2010. Yearling-and-older white perch indices increased in the west, but were the same as 2010 in the east. Basin wide, both age-0 and YAO white perch densities were below average.

Central basin diets of walleye and white bass from the fall gillnet survey in Ohio continue to be comprised of gizzard shad, rainbow smelt and emerald shiners. Adult walleye diets were in eastern Ohio waters were comprised of emerald shiner (40%), gizzard shad (30%) and rainbow smelt (28%). Adult walleye in western Ohio waters consumed more gizzard shad (79%) compared to walleye in eastern Ohio. The remaining diet of walleye in western Ohio was emerald shiner (15%), rainbow smelt (2.5%) and unidentified fish (2.5%). The composition of age-1 walleye diets was similar to adult walleye but contained a slightly higher proportion of emerald shiners in both east and west areas of Ohio. Basin wide, adult white bass consumed primarily emerald shiners (84% east; 78% west), with minor contributions from round goby, gizzard shad and rainbow smelt. Round goby continue to comprise over 50% of central basin smallmouth bass diets in the fall.

Mean length of walleye collected in Ohio's fall gillnet survey in 2011 was above average up to age-6 and have been above average since 2009. White bass size at age is generally at or below average in western Ohio and at or above average in eastern Ohio waters for all ages. Basin wide, white bass mean size decreased in 2011 for each age up to age-3 from 2010. Mean lengths-at-age of yellow perch from fall surveys in Ohio declined from 2010 and were below average for all age groups. Mean size of most age-0 forage and predator species declined from 2010, but remained at or above average. The only decreasing trend in mean length of age-0 was for rainbow smelt. Rainbow smelt have been decreasing in mean length since 2009 and have been below average four of the last 5 years. The only increase in age-0 mean length from 2010 was for smallmouth bass. Age-0 smallmouth bass have been increasing in mean length since 2008 and have been above average in seven of the last eight years.

During 2011, Lower Trophic Level Assessment samples were collected from May through September in the central basin. These data are included in the Forage Task Group's LTLA database.

2.4 West Basin (E. Weimer and R. Kraus)

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).

2011 Results

In 2011, low levels of hypolimnetic dissolved oxygen were present during the August trawling survey. Hypoxic conditions have been observed during the last three years of interagency bottom trawl assessment at a few of the sampling sites in the west basin. Due to concerns about the potential effects of hypoxia on the distribution of juvenile percids and other species, representatives from task groups, the Standing Technical Committee, researchers from the Quantitative Fisheries Center at Michigan State University and Ohio State University (OSU) developed an interim policy for the assignment of bottom trawl status. Informed by literature (Eby and Crowder 2002, Craig and Crowder 2005) and field study (ODNR /OSU/USGS) concerning fish avoidance of hypoxic waters, an interim policy was agreed upon whereby bottom trawls that occurred in waters with dissolved oxygen less than or equal to 2 mg per liter would be excluded from analyses. The policy has been applied retroactively from 2009. Currently, there is no consensus among task groups on the best way to handle this sort of variability in the estimation of year-class strength in Lake Erie. In part, this situation is hampered by a lack of understanding of how fish distribution changes in response to low dissolved oxygen. This interim policy will be revisited in the future following an improved understanding of the relationship between dissolved oxygen and the distribution of fish species and their various life stages in Lake Erie. Please refer to the Habitat Task Group Report, section 2c, for current research on fish distribution changes in response to seasonal hypoxia (Habitat Task Group 2012). In 2011, three of the 36 Ontario sites surveyed in August had bottom dissolved oxygen levels less than 2 mg/l, while none of the 37 sites in Ohio waters were below this threshold. In total, data from 70 sites were used in 2011 (Figure 2.4.1).

Total forage abundance decreased 55% in 2011 compared to 2010, the lowest level since 1999 (Figure 2.4.2). Declines in soft-rayed fish and spiny-rayed fish (down 28% and 66%, respectively) were responsible for this trend; clupeids increased 6-fold compared to 2010. Because of the composition of the forage fish community in 2011, total forage biomass declined 35%, to levels similar to 2009 (Figure 2.4.3). Relative biomass of clupeid, soft-rayed, and spiny-rayed species was 16%, 4%, and 80%, respectively, and differed from their respective historic averages of 29%, 8%, and 63%. Mean length of most age-0 sportfish in 2011 decreased compared to 2010 (Figure 2.4.4). Lengths of select age-0 species include walleye (137 mm), yellow perch (66 mm), white bass (79 mm), white perch (63mm), and smallmouth bass (79 mm). These lengths are near long-term averages (137 mm, 67 mm, 68 mm, 58 mm, and 79 mm, respectively).

Spatial maps of forage distribution were constructed using FPC-corrected site-specific catches (number/ha) of the functional forage groups (Figure 2.4.5). Abundance contours were generated using kriging techniques to interpolate abundance among trawl locations. Clupeid catches were highest around Sandusky Bay. Soft-rayed fish were most abundant near the mouth of the Detroit River. Spiny-rayed abundance was highest at the mouth of the Detroit River (driven by a high age-0 yellow perch catch at one site in Ontario), but fairly well spread across the west and south portions of the basin. Relative abundance of the dominant species includes: age-0 white perch (54%), age-0 gizzard shad (21%), and age-0 yellow perch (8%). Total forage abundance averaged 2,288 fish/ha across the western basin, decreasing 55% from 2010, below the long-term average (5,219 fish/ha). Clupeid density was 473 fish/ha (average 1,090 fish/ha), soft-rayed fish density was 245 fish/ha (average 568 fish/ha), and spiny-rayed fish density was 2,288 fish/ha (average 3,562 fish/ha).

Recruitment of individual species is highly variable in the western basin. Age-0 yellow perch (178.0/ha) increased relative to 2010, while age-0 walleye (6.5/ha) decreased (Figure 2.4.6); both remain well below long-term means. The increase in the yellow perch index is largely driven by a high catch at one site near the Detroit River in Ontario. Age-0 white perch (1244.6/ha) decreased sharply to the lowest index since 2002. Age-0 white bass (70.1/ha) decreased well below the long term mean, as did age-0 smallmouth bass (0.8/ha). Age-0 and yearling-and-older (YAO) rainbow smelt remained low in 2011 (2.8/ha and 1.0/ha, respectively). Age-0 gizzard shad (473.3/ha) increased dramatically relative to 2010, yet remained below the long term mean, while alewife remain missing (Figure 2.4.7). Catches of age-0 emerald shiners (22.4/ha) and YAO emerald shiners (24.1/ha) remain below long term means. Catches of round gobies (50.0/ha) increased from 2010, but are well below their mean abundance since their discovery in 1997. Catches of yearling and adult yellow perch and age-0 freshwater drum declined in 2011. Overall, 2011 catches of age-0 and YAO shiners declined or remained similar to 2010 (Figure 2.4.8). Lengths of age-0 walleye, yellow perch, white perch, and smallmouth bass all declined in 2011, while age-0 white bass lengths were unchanged relative to 2010.

Adult walleye diets taken from fall gillnet catches were dominated by gizzard shad (91%) and unidentified fish remains (9%) in the western basin. Yearling walleye relied on gizzard shad (56%), emerald shiner (20%) and unidentified fish remains (24%). In 2011, spring and autumn diet analysis of age-2-and-older yellow perch showed benthic macroinvertebrates had the greatest occurrence (94.2 and 90.2 % respectively) with Chironomidae, *Dreissena sp*., and *Hexagenia sp*. found most often. Zooplankton were also found in spring and autumn diet content (25.0 and 26.8% respectively) with *Leptodora kindtii* occurring most in the spring (16.3%) and *Bythotrephes sp.* occurring most in the autumn (18.3%). Fish were found within the diet contents least frequently, representing 16.3% of the diet items in the spring and 15.9% in the autumn, with round gobies found most often (10.6 and 8.5% respectively). Historically, zooplankton occurrence was considerably higher in the spring and benthic macroinvertebrate occurrence highest in the fall. However, in 2011, no noticeable difference was found between the occurrence of zooplankton, benthic macroinvertebrates, and fishes in the diet analysis of age-2-and-older yellow perch in Lake Erie between spring and autumn diet content analysis.

Average basin-wide water temperature for Ohio waters was cooler in 2011 than the previous year, with peak surface temperature (27.2°C) recorded on July 27. Spring warming rate (May 5 to June 3) was 0.25°C per day, lower than 2010. Seasonally averaged basin wide Secchi depth declined from 2010, averaging 1.2 m [range 0.1m (September 9) to 4.0m (July 11)]. Western basin bottom dissolved oxygen levels averaged 8.0 mg/l [range 0.5 (July 27) to 11.5mg/l (May 5)], similar to the previous year. Ecological indices useful in interpreting the state of the western basin resource are discussed in Section 5.0 (“Interagency lower trophic level monitoring”).

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 three 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, and 2011 and the 2008 survey was a reduced effort of four tows sampled in a single day.

	Age	Trawl	Year										Long-term Average by decade		
Species	**Group**	**Survey**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2000's**	**1990's**	**1980's**
Smelt	**YOY**	ON-DW	509.2	326.9	148.2	1293.0	991.3	1256.0	0.9	132.2	7058.1	142.5	1391.5	431.7	1278.2
	YOY	NY-Fa	1580.4	1416.6	64.9	2128.9	2889.6	507.9	1259.6	1146.1	1733.4	1606.6	1524.9	1450.9	NA
	YOY	PA-Fa	NA	NA	47.7	15.1	260.2	NA	47.9	12.3	592.2	98.0	138.2	550.8	7058.1
	YAO	ON-DW	277.1	222.7	1654.3	77.3	232.8	136.2	7.6	565.6	205.8	5.9	360.7	358.6	814.7
	YAO	NY-Fa	640.1	997.8	3016.6	546.5	176.9	162.9	395.2	2624.1	282.1	117.0	753.4	581.6	NA
	YAO	PA-Fa	NA	NA	407.2	1.8	1006.3	NA	0.0	12.3	32.4	6.5	164.5	378.0	2408.6
Emerald	**YOY**	ON-DW	70.3	117.6	54.8	16.0	29.3	452.3	645.7	20.3	3388.0	9.5	463.2	52.3	16.9
Shiner	**YOY**	ON-OB	1.1	0.0	0.0	0.5	1.2	12.4	1.1	258.3	0.0	0.2	27.6	3.2	16.2
	YOY	NY-Fa	2930.1	62.9	48.5	3.7	150.9	778.5	291.4	7.8	229.7	19.5	194.0	112.4	NA
	YOY	PA-Fa	NA	NA	1063.0	0.0	81.7	NA	0.5	0.0	1163.4	74.4	264.8	41.0	118.3
	YAO	ON-DW	201.1	30.7	40.1	95.2	149.8	4200.3	139.0	891.2	204.7	247.8	819.0	37.7	33.5
	YAO	ON-OB	16.1	0.0	4.8	3.0	84.3	499.6	0.1	73.8	6.7	13.6	72.0	4.6	3.0
	YAO	NY-Fa	1826.2	20.6	156.4	18.2	84.8	925.5	151.4	284.2	444.5	466.4	290.8	105.4	NA
	YAO	PA-Fa	NA	NA	1360.3	0.0	4713.1	NA	52.5	0.0	157.6	105.6	710.4	14.5	45.6
Spottail	**YOY**	ON-OB	2.5	3.0	3.7	37.8	35.2	19.8	58.7	43.8	74.1	16.6	119.3	815.9	570.6
Shiner	**YOY**	ON-IB	0	0.0	0.0	0.0	0.5	0.1	1.0	0.2	0.4	0.0	0.5	113.9	608.0
	YOY	NY-Fa	0.7	6.5	0.1	0.3	0.1	0.5	0.5	0.1	13.2	1.0	5.6	19.9	NA
	YOY	PA-Fa	NA	NA	1.1	0.0	0.0	NA	0.0	0.0	0.0	0.0	0.1	4.0	2.0
	YAO	ON-OB	0.5	2.1	3.3	7.5	4.1	10.4	3.2	10.4	5.9	12.0	10.8	74.6	30.7
	YAO	ON-IB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.1	2.0	10.3
	YAO	NY-Fa	29.0	10.4	5.1	1.5	0.0	4.1	4.3	2.5	4.8	34.2	6.4	4.0	NA
	YAO	PA-Fa	NA	NA	0.0	0.0	0.0	NA	0.0	0.0	0.0	0.8	0.1	7.9	12.4
Alewife	**YOY**	ON-DW	2.1	0.9	0.1	2.3	1.0	78.6	0.1	0.3	0.5	35.3	22.5	231.2	19.6
	YOY	ON-OB	6.8	0.0	1.9	11.9	44.6	711.8	11.0	1.5	17.6	12.2	82.1	88.5	36.5
	YOY	NY-Fa	12.4	15.4	0.0	5.6	22.2	30.8	27.7	4.4	3.9	617.6	94.3	52.0	NA
	YOY	PA-Fa	NA	NA	0.0	0.0	8.0	NA	0.0	0.0	2.5	0.8	1.3	7.7	16.6
Gizzard	**YOY**	ON-DW	18.9	13.3	0.4	86.5	34.6	1.4	1.7	0.2	68.6	3.2	21.3	7.5	15.3
Shad	**YOY**	ON-OB	3.4	3.8	0.0	4.0	22.0	28.7	1.9	1.0	5.1	1.6	7.6	13.4	18.7
	YOY	NY-Fa	15.0	40.9	5.3	10.8	11.7	14.1	3.7	0.6	27.8	5.5	11.9	4.2	NA
	YOY	PA-Fa	NA	NA	0.0	0.0	0.0	NA	0.0	0.0	0.0	0.8	0.1	0.9	74.3
White	**YOY**	ON-DW	0.0	1.6	0.6	5.4	0.1	0.9	0.1	0.0	16.2	0.0	2.9	1.8	5.4
Perch	**YOY**	ON-OB	0.0	0.0	0.0	2.1	0.7	1.2	0.4	0.2	14.6	0.0	2.8	17.6	31.1
	YOY	NY-Fa	36.5	157.3	20.2	431.5	34.6	91.9	99.8	1.0	37.7	6.2	74.3	29.4	NA
	YOY	PA-Fa	NA	NA	598.5	0.7	444.6	NA	51.2	0.0	523.9	0.0	256.0	101.1	NA
Trout	**All**	ON-DW	0.0	0.3	0.8	0.8	0.8	1.1	0.0	1.7	2.7	0.7	0.9	0.6	2.4
Perch	**All**	NY-Fa	654.3	461.6	517.0	996.4	561.2	519.4	1317.3	545.9	1392.6	886.0	826.0	410.0	NA
	All	PA-Fa	NA	NA	558.8	0.6	156.9	NA	198.5	160.3	256.6	0.0	152.1	50.9	NA
Round	**All**	ON-DW	125.4	9.7	43.6	452.6	973.2	93.3	66.9	323.8	158.8	127.0	235.9	0.0	0.0
Goby	**All**	ON-OB	103.3	67.6	91.2	63.4	73.9	32.7	28.0	94.4	114.2	150.9	86.9	0.1	0.0
	All	ON-IB	114.6	135.1	280.5	211.8	263.0	34.0	21.0	95.4	28.6	56.2	120.0	0.1	0.0
	All	NY-Fa	165.8	173.3	502.6	466.8	1293.2	846.5	707.0	1094.5	613.4	135.9	651.7	35.9	0.0
	All	PA-Fa	NA	NA	350.1	441.6	2043.8	NA	887.8	927.5	387.3	43.9	1094.6	30.3	0.0

"**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; 80's Avg. is for the period 1984 to 1989; 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; 80's Avg. is for the period 1984 to 1989; 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; 80's Avg. is for the period 1984 to 1989; 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; 80's Avg. is for the period 1984 to 1989; 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 2001-2011. Ohio West (OH West) is the area of the central basin from Huron, OH, to Fairport Harbor, OH. Ohio East (OH East) is the area of the central basin from Fairport Harbor, OH to the Ohio-Pennsylvania state line. PA is the area of the central basin from the Ohio-Pennsylvania state line to Presque Isle, PA.

		Year											
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean
Species	Survey												
Yellow	OH west	114.6	6.0	149.0	8.7	37.8	10.0	167.0	37.3	1.3	41.1	8.7	57.3
Perch	OH east	13.6	2.5	47.5	1.9	156.2	18.9	177.8	52.8	0.5	96.3	14.1	56.8
	PA	388.4	11.9	788.0	2.4	-	-	10.0	863.4	14.2	-	-	296.9
White	OH west	779.7	293.0	310.1	759.7	1002.5	440.4	1381.2	544.9	506.1	254.8	368.3	627.2
Perch	OH east	57.6	5.9	61.8	108.0	2034.5	46.1	1095.9	91.6	34.6	190.3	84.8	372.6
	PA	26.6	80.7	173.8	2.4	-	-	17.8	199.0	146.5	-	-	92.4
Rainbow	OH west	2.3	274.7	1753.9	352.1	10.7	94.3	98.1	635.2	293.5	776.2	42.4	429.1
smelt	OH east	0.0	218.1	2914.1	388.9	44.4	570.7	702.4	3997.7	0.3	421.6	256.1	925.8
	PA	377.4	152.9	177.6	20.9	-	-	35.1	552.2	23.4	-	-	191.4
Round	OH west	43.9	37.8	22.6	13.9	37.2	19.0	26.9	17.4	25.9	28.4	102.8	27.3
Goby	OH east	39.6	64.7	57.5	173.9	148.1	46.3	273.1	26.3	1.0	41.8	258.9	87.2
	PA	1577.8	289.3	75.3	1011.3	-	-	227.8	227.1	72.2	-	-	497.3
Emerald	OH west	50.5	39.4	477.6	7.0	567.1	587.2	52.6	36.3	6.1	8.8	414.5	183.3
Shiner	OH east	2.2	0.5	903.1	0.8	279.8	1115.1	63.7	20.2	1.7	234.9	105.4	262.2
	PA	8.5	38.1	81.8	0.0	-	-	0.8	0.0	303.2	-	-	61.8
Spottail	OH west	5.9	1.6	0.0	0.0	0.2	0.0	3.1	3.7	0.6	0.0	0.6	1.5
Shiner	OH east	0.7	0.2	0.5	0.0	1.1	0.2	0.5	0.2	0.0	0.0	0.4	0.3
	PA	0.0	0.0	0.0	0.0	-	-	0.0	0.0	0.0	-	-	0.0
Alewife	OH west	50.8	59.7	0.1	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0	11.5
	OH east	0.0	1.1	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.5
	PA	0.0	0.4	0.0	0.0	-	-	0.0	0.0	0.0	-	-	0.1
Gizzard	OH west	60.3	24.6	402.6	0.6	12.3	32.7	195.0	35.7	50.9	2.6	770.3	81.7
Shad	OH east	1.8	12.3	20.4	0.3	15.7	30.7	15.5	63.1	3.9	8.5	4.0	17.2
	PA	0.0	0.0	0.0	0.0	-	-	0.0	0.0	0.0	-	-	0.0
Trout-	OH west	2.0	1.4	2.0	20.3	0.1	0.2	0.8	0.3	0.3	0.7	1.6	2.8
perch	OH east	0.0	0.3	1.4	1.4	1.6	0.1	5.4	0.1	0.2	1.4	2.7	1.2
	PA	7.8	45.6	78.0	6.7	-	-	10.9	126.1	28.1	-	-	43.3

\- The Pennsylvania Fish and Boat Commission was unable to sample in 2005, 2006, 2010 and 2011.

Table 2.3.2 Relative abundance (arithmetic mean number per hectare) of selected yearling-and-older species from fall trawl surveys in the central basin, Ohio and Pennsylvania, Lake Erie, from 2001-2011. Ohio West (OH West) is the area of the central basin from Huron, OH, to Fairport Harbor, OH. Ohio East (OH East) is the area of the central basin from Fairport Harbor, OH to the Pennsylvania state line. PA is the area of the central basin from the Ohio-Pennsylvania state line to Presque Isle, PA.

		Year											
Species	Survey	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean
Yellow	OH west	5.7	51.7	3.2	216.5	18.3	4.2	19.8	56.6	20.7	11.9	5.5	40.9
Perch	OH east	0.4	38.3	1.2	45.2	132.3	12.5	37.0	26.4	139.4	12.4	50.5	44.5
	PA	41.3	37.5	75.6	18.3	-	-	27.4	76.4	120.9	-	-	56.8
White	OH west	21.7	91.5	28.2	83.9	34.1	32.4	27.1	76.5	42.0	32.6	25.0	47.0
Perch	OH east	0.4	176.2	12.0	27.0	20.1	38.5	16.8	36.6	282.3	44.8	45.1	65.5
	PA	2.4	38.5	28.6	6.2	-	-	0.8	4.2	63.3	-	-	20.6
Rainbow	OH west	55.6	45.3	29.4	320.5	89.8	8.9	40.4	9.6	419.4	18.0	35.8	103.7
Smelt	OH east	3.3	320.9	370.3	1360.2	30.8	17.3	532.4	64.9	109.1	56.9	176.0	286.6
	PA	0.0	6.2	22.1	9.9	-	-	10.7	3.5	408.0	-	-	65.8
Round	OH west	54.8	39.2	25.4	27.0	33.6	20.4	26.3	57.9	58.0	44.0	63.7	38.7
Goby	OH east	88.4	54.3	127.1	148.8	263.0	78.9	185.6	167.8	19.3	36.0	123.8	116.9
	PA	55.2	238.3	59.1	767.0	-	-	361.1	326.6	75.9	-	-	269.0
Emerald	OH west	106.3	233.9	54.9	1.5	233.6	162.7	418.7	495.0	99.5	51.5	171.6	185.8
Shiner	OH east	0.7	133.2	432.0	0.4	479.6	451.1	27.8	1159.4	167.8	375.1	145.2	322.7
	PA	0.0	107.4	217.5	0.0	-	-	769.5	28.0	171.5	-	-	184.8
Spottail	OH west	3.5	6.6	1.6	5.3	0.3	1.2	2.3	2.3	3.1	0.0	23.5	2.6
Shiner	OH east	1.1	5.9	1.0	0.2	3.8	0.7	0.6	2.9	0.0	0.0	4.1	1.6
	PA	0.0	2.2	0.0	0.0	-	-	0.0	0.0	0.0	-	-	0.3
Trout-	OH west	3.2	27.2	12.2	14.0	13.5	3.3	5.5	4.8	0.8	0.7	3.9	8.5
perch	OH east	2.2	8.5	2.9	7.7	76.2	4.8	6.7	8.4	1.5	5.0	8.9	12.4
	PA	0.6	81.2	50.9	5.2	-	-	16.0	61.7	127.3	-	-	49.0

\- The Pennsylvania Fish and Boat Commission was unable to sample in 2005, 2006, 2010 and 2011.

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

Vessel	Species	Age group	Trawl Hauls	Mean CPUE (#/ha)	FPC	95% CI	Apply rule [a]
R.V. Explorer	Gizzard shad	Age 0	22	11.81	2.362	-1.26-5.99	Y
	Emerald shiner	Age 0+	50	67.76	1.494	0.23-2.76	Y
	Troutperch	Age 0+	51	113.20	0.704	0.49-0.91 z	Y
	White perch	Age 0	51	477.15	1.121	1.01-1.23 z	Y
	White bass	Age 0	50	11.73	3.203	0.81-5.60	Y
	Yellow perch	Age 0	51	1012.15	0.933	0.62-1.24	N
	Yellow perch	Age 1+	51	119.62	1.008	0.72-1.30	N
	Walleye	Age 0	51	113.70	1.561	1.25-1.87 z	Y
	Round goby	Age 0+	51	200.27	0.423	0.22-0.63 z	Y
	Freshwater drum	Age 1+	51	249.14	0.598	0.43-0.76 z	Y
R.V. Gibraltar	Gizzard shad	Age 0	29	14.22	1.216	-0.40-2.83	Y
	Emerald shiner	Age 0+	43	51.30	2.170	0.48-3.85	Y
	Troutperch	Age 0+	45	82.11	1.000	0.65-1.34	N
	White perch	Age 0	45	513.53	0.959	0.62-1.30	N
	White bass	Age 0	45	21.88	1.644	0.00-3.28	Y
	Yellow perch	Age 0	45	739.24	1.321	0.99-1.65	Y
	Yellow perch	Age 1+	45	94.56	1.185	0.79-1.58	Y
	Walleye	Age 0	45	119.17	1.520	1.17-1.87 z	Y
	Round goby	Age 0+	45	77.36	0.992	0.41-1.57	N
	Freshwater drum	Age 1+	45	105.21	1.505	1.10-1.91 z	Y
R.V. Grandon	Gizzard shad	Age 0	29	70.87	0.233	-0.06-0.53 z	Y
	Emerald shiner	Age 0+	34	205.43	0.656	-0.04-1.35	Y
	Troutperch	Age 0+	35	135.93	0.620	0.42-0.82 z	Y
	White perch	Age 0	36	771.40	0.699	0.44-0.96 z	Y
	White bass	Age 0	36	34.92	0.679	0.43-0.93 z	Y
	Yellow perch	Age 0	36	1231.63	0.829	0.58-1.08	Y
	Yellow perch	Age 1+	36	123.35	0.907	0.58-1.23	Y
	Walleye	Age 0	36	208.59	0.920	0.72-1.12	Y
	Round goby	Age 0+	36	161.78	0.501	0.08-0.92 z	Y
	Freshwater drum	Age 1+	36	58.82	2.352	1.51-3.19 z	Y
R.V. Musky II	Gizzard shad	Age 0	24	8.80	1.885	-1.50-5.26	Y
	Emerald shiner	Age 0+	47	32.29	3.073	0.36-5.79	Y
	Troutperch	Age 0+	50	62.35	1.277	0.94-1.62	Y
	White perch	Age 0	50	255.71	2.091	1.37-2.81 z	Y
	White bass	Age 0	46	8.35	4.411	0.90-7.92	Y
	Yellow perch	Age 0	50	934.03	1.012	0.77-1.26	N
	Yellow perch	Age 1+	50	34.94	3.452	1.23-5.67 z	Y
	Walleye	Age 0	50	63.70	2.785	2.24-3.33 z	Y
	Round goby	Age 0+	49	66.87	1.266	0.39-2.14	Y
	Freshwater drum	Age 1+	49	1.60	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

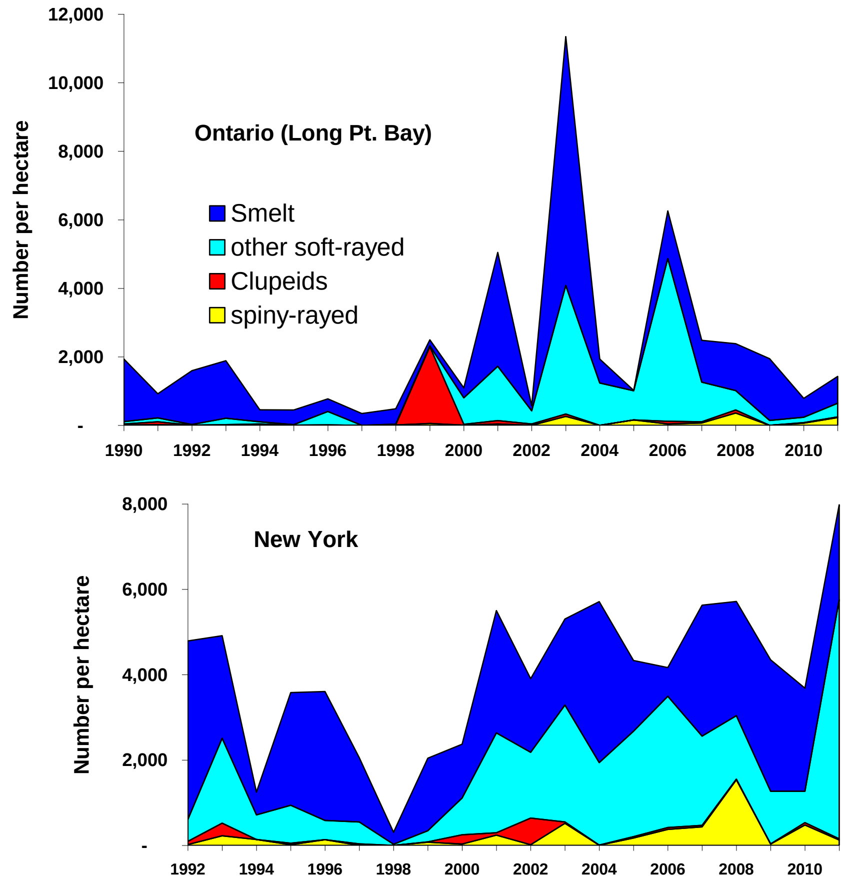

Figure 2.2.1 Mean density of prey fish (no./ha) by functional group in the Ontario and New York waters of the eastern basin, Lake Erie, 1990-2011.

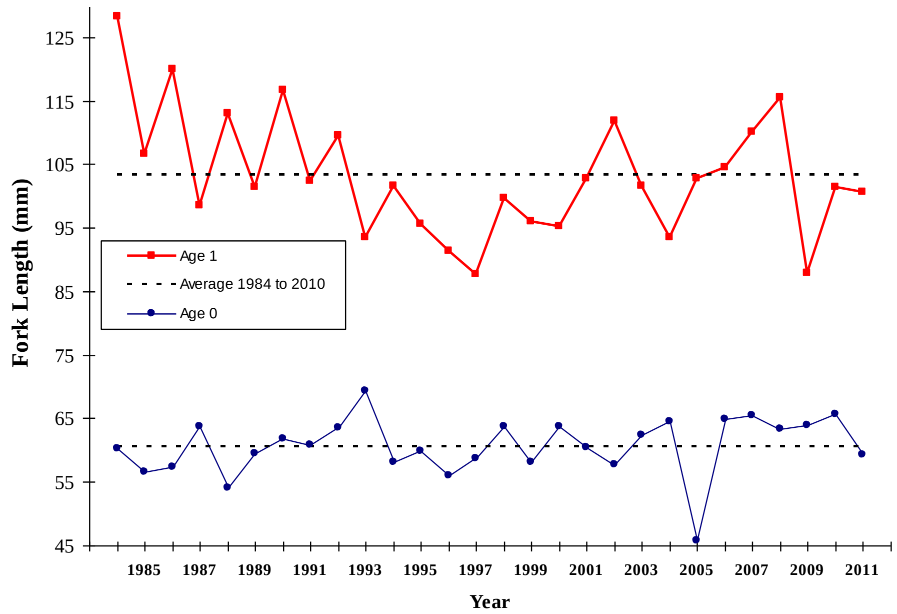

Figure 2.2.2 Mean fork length of age 0 and 1 rainbow smelt from OMNR index trawl surveys in Long Point Bay, Lake Erie, October 1984 to 2011.

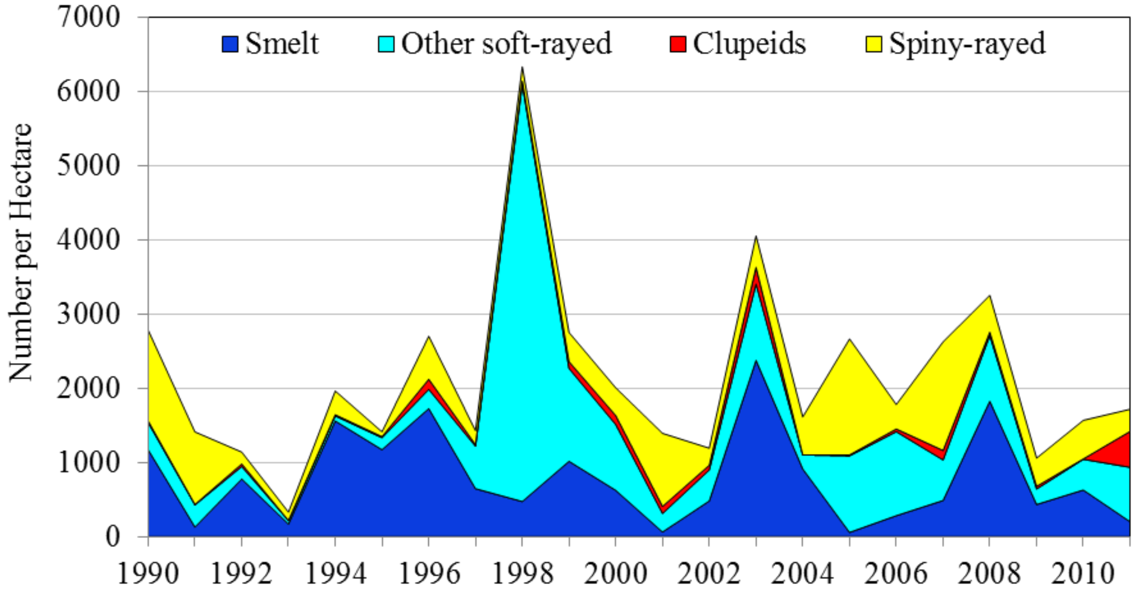

Figure 2.3.1 Mean density of prey fish (no./ha) by functional group in the Ohio waters of the central basin, Lake Erie, 1990-2011.

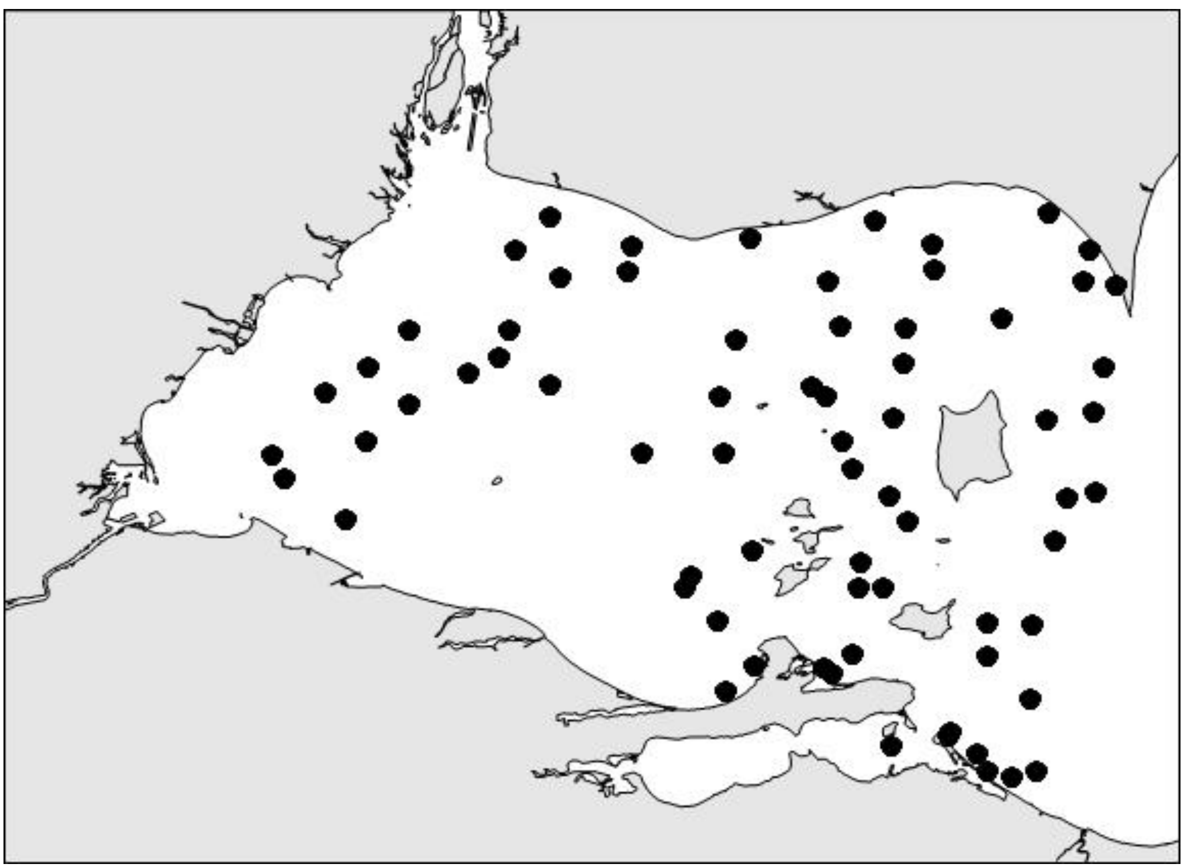

Figure 2.4.1. Trawl locations for the western basin interagency bottom trawl survey, August 2011.

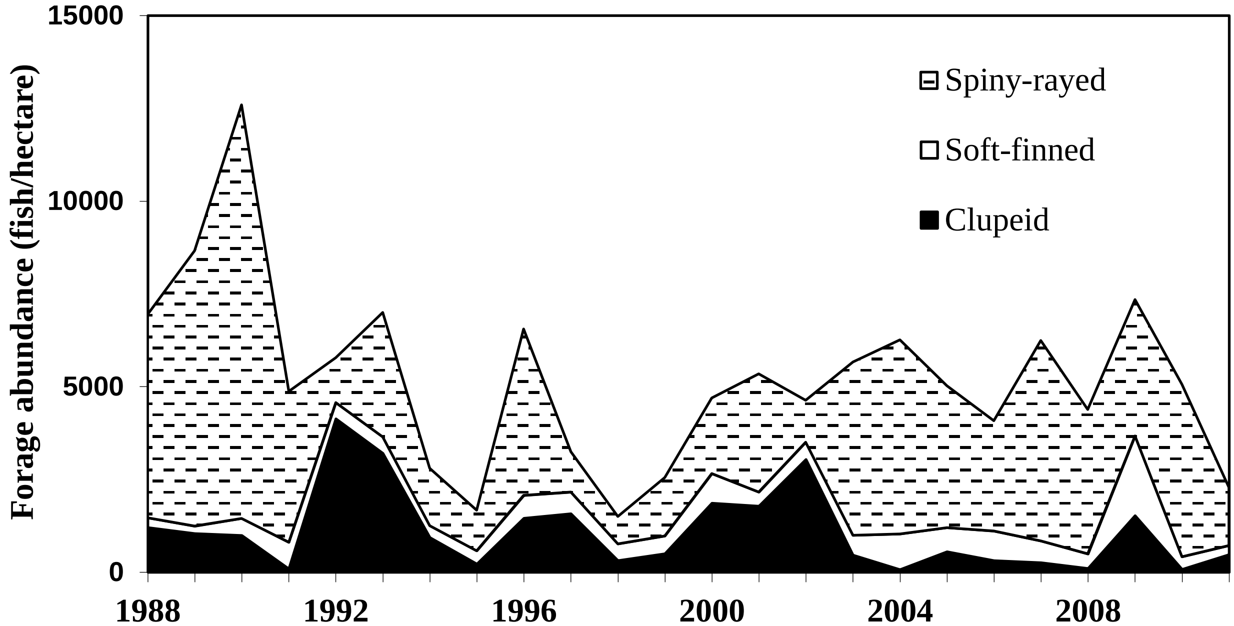

Figure 2.4.2. Mean density (no. / ha) of prey fish by functional group in western Lake Erie, August 1988-2011.

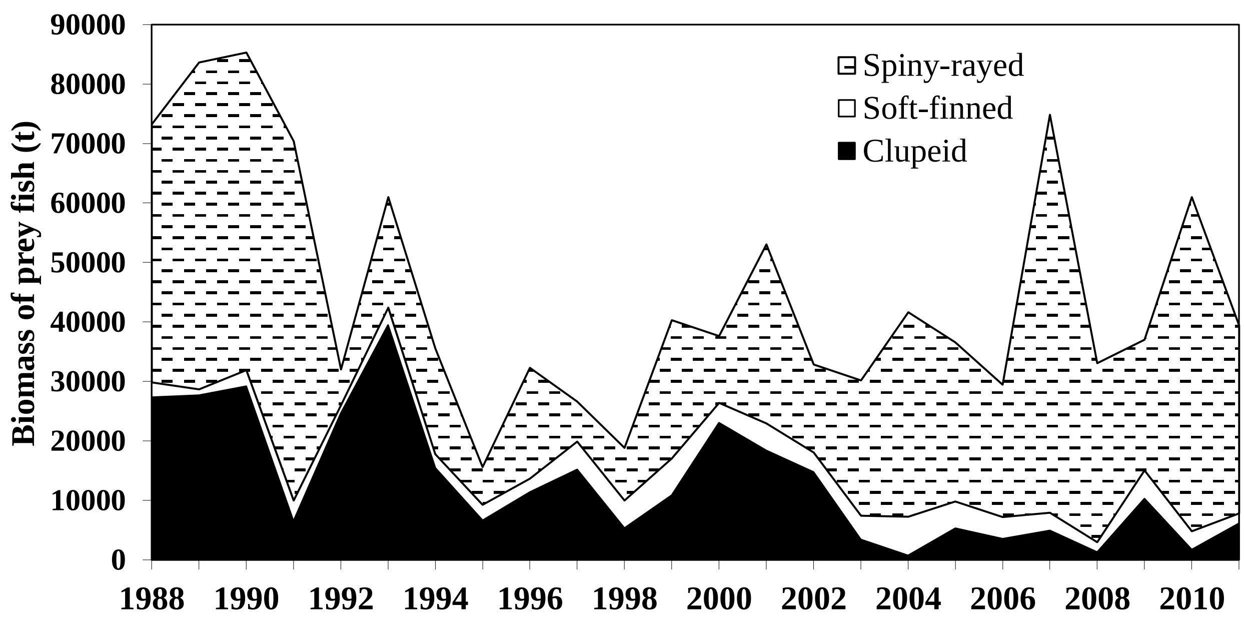

Figure 2.4.3. Mean biomass (tonnes) of prey fish by functional group in western Lake Erie, August 1988-2011.

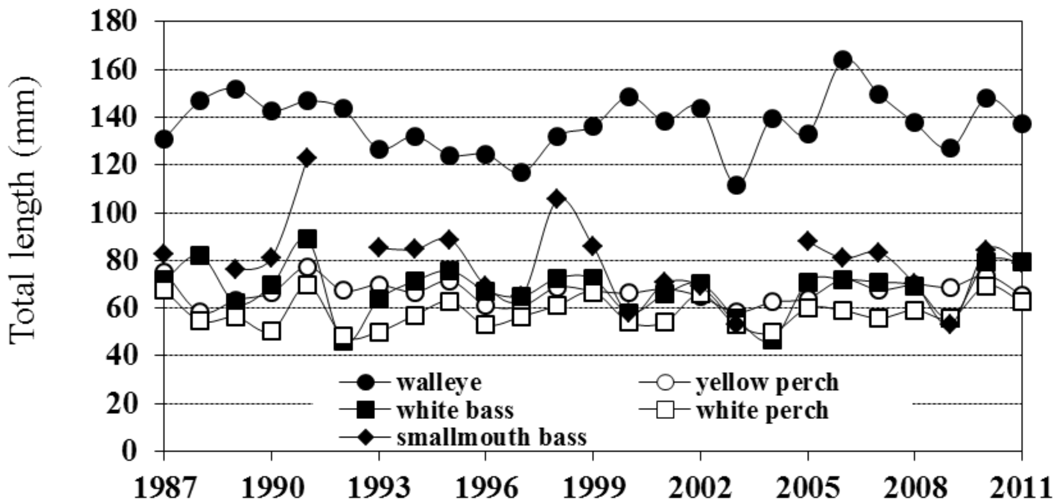

Figure 2.4.4. Mean total length (mm) of select age-0 fishes in western Lake Erie, August 1987- 2011.

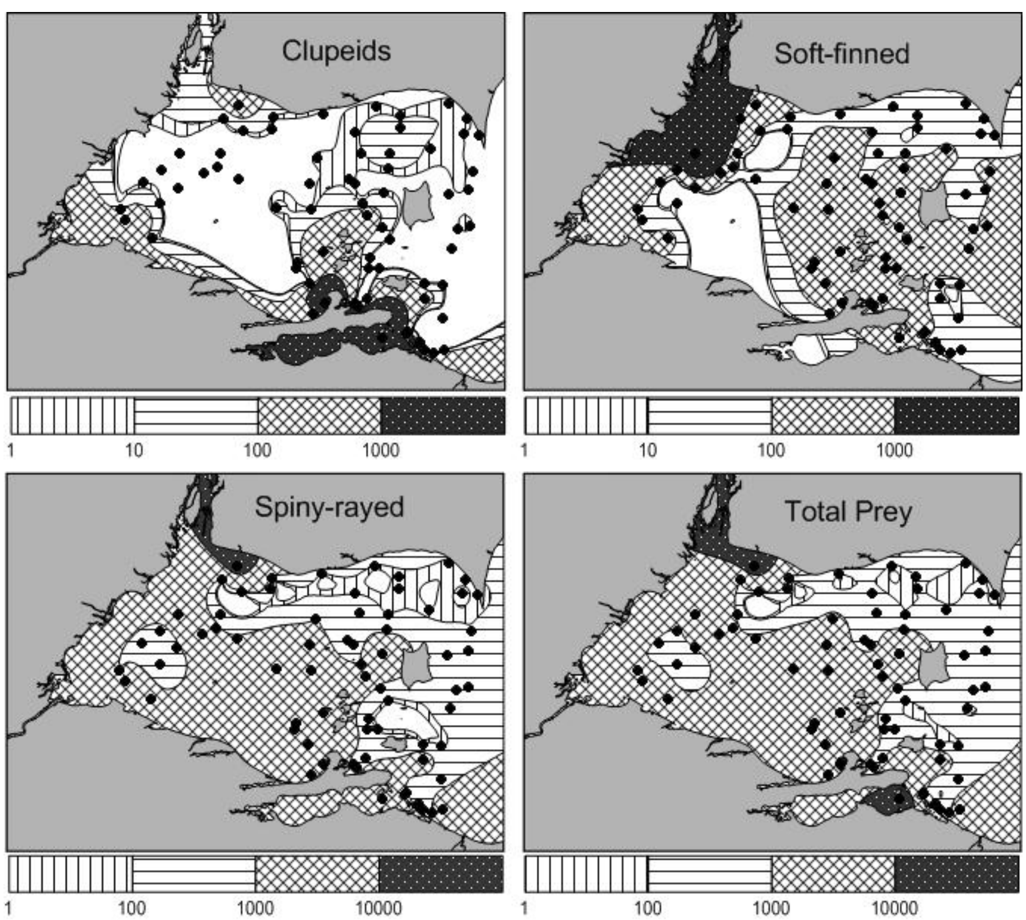

Figure 2.4.5. Spatial distribution of clupeids, soft-finned, spiny-rayed, and total forage abundance (individuals per hectare) in western Lake Erie, 2011. Black dots are trawl sites, and contour levels vary with the each functional fish group.

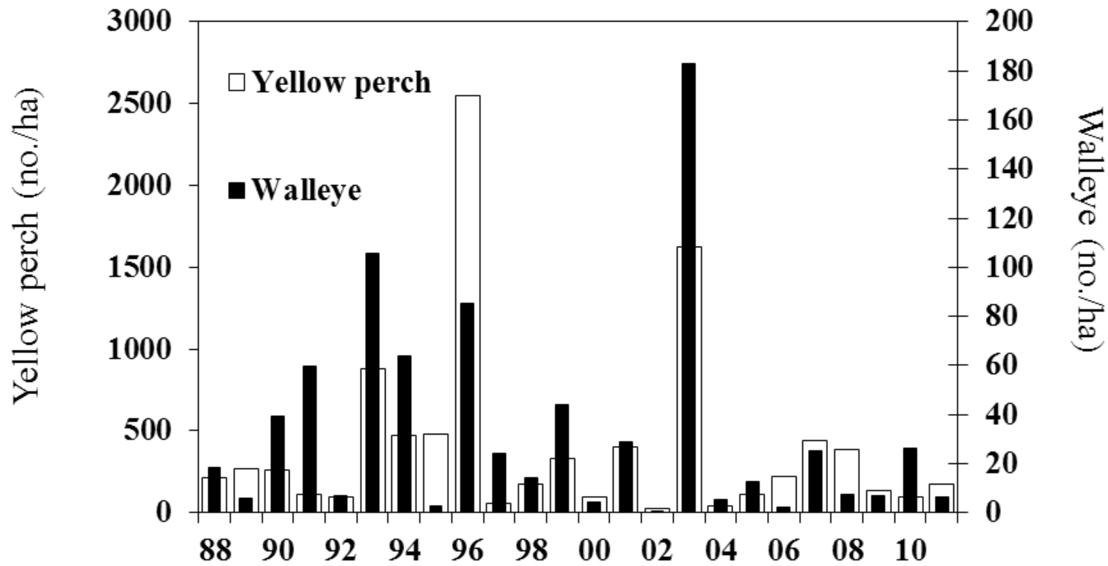

Figure 2.4.6. Density of age-0 yellow perch and walleye in the western basin of Lake Erie, August 1988-2011.

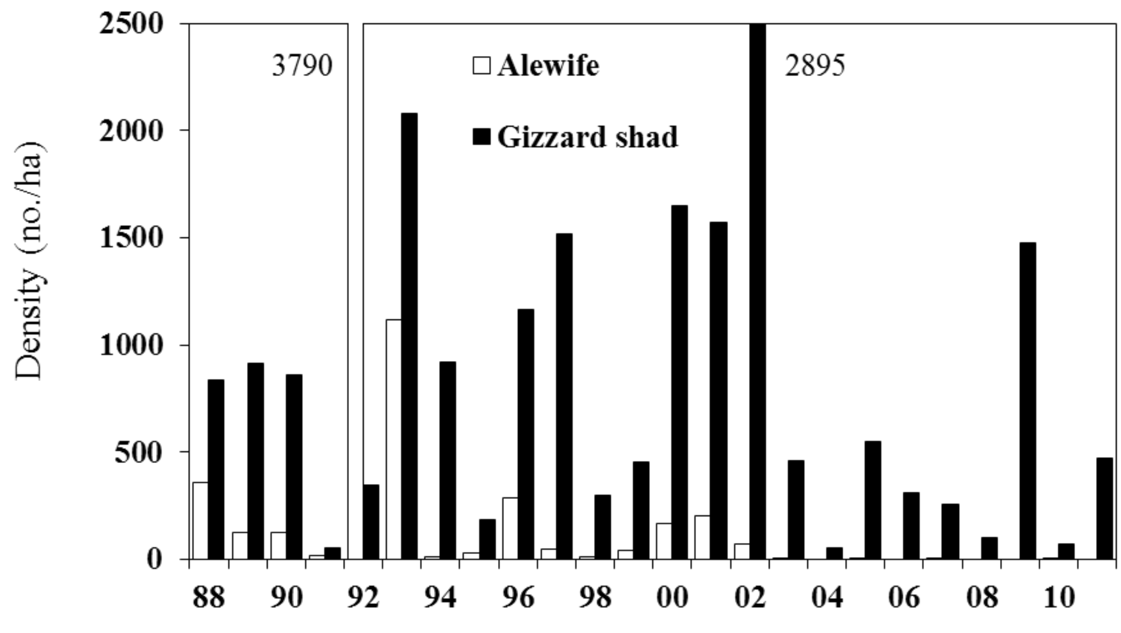

Figure 2.4.7. Density of age-0 alewife and gizzard shad in the western basin of Lake Erie, August 1988-2011.

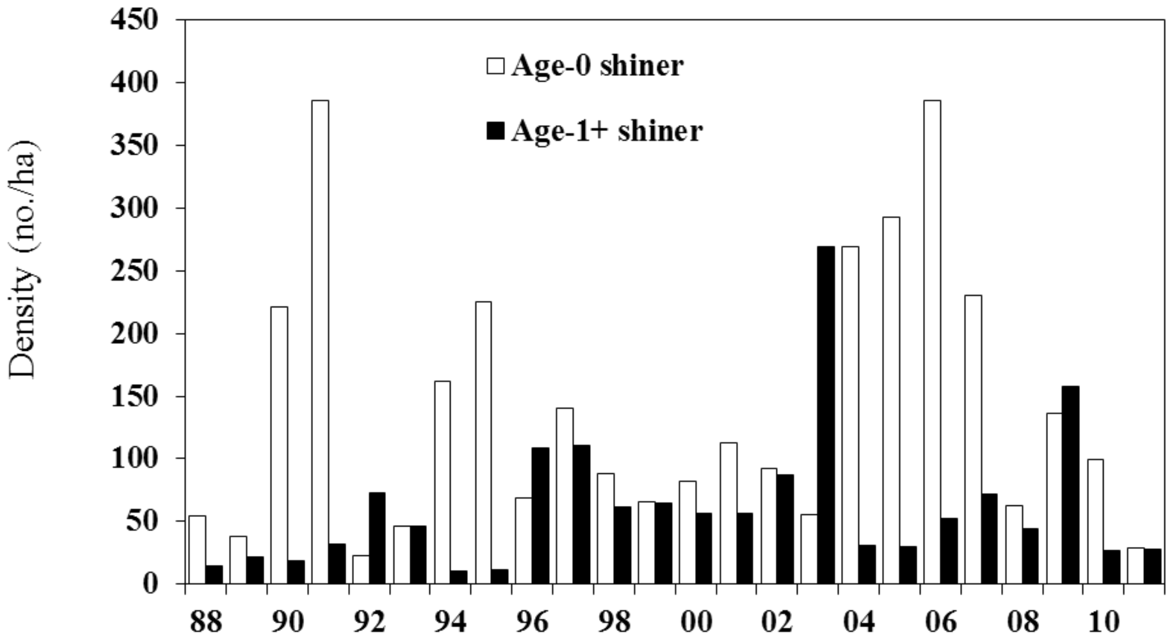

Figure 2.4.8. Density of age-0 and age-1+ shiners (*Notropis* spp.) in the western basin of Lake Erie, August 1988-2011.

3.0 Interagency Trawling Program

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

.

3.1 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.

3.3 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.

To date, this has only been done in the Western basin. 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.

In 2012, the USGS-Sandusky office will launch a new vessel, and this may offer an opportunity to standardize trawls across the entire lake. This exercise would involve using the new Musky as the standard vessel in the western basin, and then using this boat in more central locations in both the central and eastern basins for calibration exercises.

Plans for this exercise are underway with possible implementation beginning in 2013.

4.0 Hydroacoustic Survey Program

4.1 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 FTG, and is a collaboration of neighboring East Basin Lake Erie jurisdictions 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 New York State Department of Environmental Conservation and the Ontario Ministry of Natural Resources also 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 SOP's in Lake Erie basin acoustic surveys, and specifically for the East Basin, then proceeding to re-processing an acoustic data series beginning in 1997 and applying new standards. A primary focus of the 2009 workshop was to compare present-day acoustic methods used in various acoustic assessments across the Great Lakes with results from following the SOP and further publications by the principal investigators within this study group are anticipated (Kocovsky et al. in review). 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 Center, 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 for examining estimates of fish abundance in densely concentrated areas to diminish possible bias associated with extrapolating abundance based on mean in-situ target strength (Rudstam et al. 2003). Additionally, a standard objective method has now been developed to ascribe passive noise thresholds for each survey transect. A complete description of our data collection and processing methods will be forthcoming in a separate document with accompanying results for the entire split-beam time series of this acoustic survey (since 1997).

At this writing the acoustic data series from 1998 to 2003 and from 2007 to 2011 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 five most recent east basin survey years 2007 to 2011.

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

In 2012, we expect to resume standardized reanalysis of acoustic data for the remaining backlog of survey years 1997 and 2004 through 2006. The entire 1997 to 2011 data time series is expected to be thoroughly reported in a separate document with an accompanying description of survey methods and data processing procedures. Upon completion of this overview document, subsequent results will be updated annually in Lake Erie's FTG Report.

The 2011 Survey

In recent years, the east basin survey has been accomplished as a two-agency endeavour. Acoustic data acquisition to determine fish densities and distribution were measured with a modern scientific echosounder. The current system consists of a Simrad EY60 120 kHz split-beam GPT, with a 7-degree beam transducer mounted on a fixed pole in a down facing orientation approximately 1 m below the water surface on the starboard side of the Ontario Ministry of Natural Resources (OMNR) research vessel, *RV Erie Explorer*. Acoustic data were collected at 300 watts power output, 256 μsec pulse duration, and 2 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)-based navigation software program (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 that controlled all operations of the echosounder. Geo-referenced raw acoustic data were logged to 10-megabyte size files on the host PC.

The 2011 survey was completed in five nights from July 20 to 28; acoustic sampling was suspended due to poor weather on three nights during this period (Figure 4.1.1). A full complement of twelve acoustic transects were sampled totaling 167 nautical miles. Approximately 864,400 KB of raw acoustic data were recorded including some 58,200 KB of stationary sampling at the ends of some transects to assess target strength (TS) variability of individual fish tracks. A total of 28 water temperature-depth profiles were sampled across all transects in 2011. Companion mid-water trawl collections to obtain representative samples of the pelagic forage fish community for apportioning of acoustic targets did not occur during the 2011 survey due to New York State DEC budget constraints.

Acoustic data were processed using the Myriax Echoview 3.45 software. 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 smelt (-70 to -59 dB) to ALL-size smelt (age-0 + YAO: -70 to -40 dB) by 1-m depth layers for each 800-m transect interval. This pre-analysis of TS distributions was accomplished within a specialized SAS (SAS 2006) program that scanned each 1-m depth layer within a specified depth range in a downward progression and selected the first occurrence where the proportion of age-0 to ALL-size smelt targets was less than 40%. The lower bound of this 1-m depth layer established a preliminary depth for defining the boundary between the two thermal strata (epilimnion and meta-hypolimnion). The SAS-derived Epi-Meta strata boundary was then formatted as a line-definition file and imported into Echoview. This line was then visually examined in the various echogram types (S_v, TS, single target detections) to see how well it spatially delineated age-0 rainbow smelt, located primarily in the epilimnion from deeper YAO 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 smelt age (size) groups. The final epi-meta boundary line was then referenced to create the two thermal strata across all intervals of acoustic transects exhibiting thermal stratification. If coldwater habitat was not apparent the 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 interval) were exported to external text delimited files and then imported into a SAS program for computation of fish densities for age-0 and YAO 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 YAO smelt-size targets was achieved using a one-stage Cluster Analysis in SAS (Proc Surveymeans; SAS 2004).

Acoustic Series Results 2007–2011

Basin-wide acoustic estimates of pelagic YAO rainbow smelt-size density was highest in 2009 (14226/ha) and lowest in 2007 (5015/ha) for the most recent five-year period (Figure 4.1.2). Mean density of YAO-size smelt decreased slightly in 2011 (9398/ha; 9865/ha in 2010) but was still about twice the 2007 density estimate.

Acoustic survey results using the new SOP to describe trends in densities of pelagic forage fish are shown in Table 4.1.1, along with a series of independent bottom trawl measures of YAO rainbow smelt. The synchrony of year-to-year abundance fluctuations between acoustic pelagic fish densities and independent bottom trawl abundance measures for the dominant pelagic forage species (rainbow smelt) in eastern Lake Erie lend support to the veracity of acoustic assessment estimation techniques for pelagic forage fish. It was very constructive to see good agreement of acoustic densities of YAO pelagic forage fish and our independent trawl measures of YAO rainbow smelt abundance.

The spatial distribution of pelagic fish densities for the YAO acoustic size range is shown in Figure 4.1.3. The distribution of sampled acoustic transects through this 2007 to 2011 period shows consistent full spatial coverage of the east basin survey area. Also, this figure demonstrates the spatial distribution of pelagic forage fish densities can markedly differ across years. In 2011, YAO-size smelt densities were greatest in the south-half of the east basin along a band extending from the south shore near the New York-Pennsylvania State border to a point roughly situated near the international boundary north of Dunkirk, NY. This band of high smelt density extended across three transects 58723, 58813, and 58927 (Figures 4.1.1 and 4.1.3). YAO-size smelt density in these three transects combined, averaged 20,440 per hectare with a maximum interval (intervals are 800-m sections of transect) density per transect of 92562, 100480, and 76617 fish/ hectare, respectively.

The mid-basin region between Port Maitland, ON and Dunkirk, NY exhibited high densities in 2009 and 2010 as well. In 2008, YAO-size smelt densities were greatest in a region south of Long Point. In 2007, YAO-size 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.

Perspective

A comprehensive analysis of our full series of acoustic survey findings has been planned for several years, but annual constraints on staff time have repeatedly postponed a complete analysis of acoustic data. However, at this time most of the hurdles related to specialized acoustic processing and analysis methodology have been resolved and the east basin investigators are continuing efforts started in 2008 to analyze and report on 15 years of acoustic survey results. Furthermore, upon completion of these new analyses, Forage Task Group acoustic survey investigators currently pursuing somewhat independent efforts in the eastern, central and western basins expect to eventually integrate their analysis and reporting efforts to produce a lake wide July snapshot of pelagic fish density and distribution for Lake Erie.

On another front, the east basin acoustic team is currently seeking to upgrade its license and user agreement for the Echoview software. The version currently being used EV3.45 is outdated and incompatible with Windows 7. This software, last updated in 2005 will soon be replaced by EV5.1, which will provide many improvements in functionality and efficiency and is paramount to maintaining our standard data processing methods, data continuity across survey years and comparability with other acoustic assessments on Lake Erie and the Great Lakes.

4.2 Central Basin Acoustic Survey (J. Deller and P. Kocovsky)

The Ontario Ministry of Natural Resources (OMNR), Ohio Department of Natural Resources (ODNR) and the U.S. Geological Survey (USGS) have collaborated to conduct joint hydroacoustic and midwater trawl surveys in central Lake Erie since 2004. The 2011 central basin acoustic survey was planned according to the protocol and sample design established at the hydroacoustic workshop held in Port Dover, Ontario in December 2003 (Forage Task Group 2005). That survey design calls for eight cross-basin transects on which both hydroacoustic and trawl data are collected. Beginning in 2008 all hydroacoustic data were collected following recommendations in the Standard Operating Procedures for Fisheries Acoustics Surveys in the Great Lakes (GLSOP; Parker-Stetter et al. 2009). The primary purpose of this effort is to estimate densities of rainbow smelt and emerald shiner, which are the primary pelagic forage species in the central basin.

Hydroacoustics

Hydroacoustic data were collected from the USGS *R/V Musky II* and the ODNR-DOW *R/V Grandon*. Acoustic transects corresponding to Loran-C TD lines were sampled from one half hour after sunset (around 2130) to no later than one half hour before sunrise, depending on length of the transect and vessel speed. Sampling started and ended at the 10-m contour. Starting location of sampling alternated from the northern shore to the southern shore on alternating nights.

Hydroacoustics data from both vessels were collected with BioSonics DTX® echosounders and BioSonics Visual Acquisition (release 5.1) software. The *R/V Musky II* were collected using a 120-kHz, 7.1-degree, split-beam transducer and data from the *R/V Grandon* were collected with a 122-kHz, 7.6-degree, split-beam transducer. The transducers on both vessels were mounted to the starboard hull roughly equidistant between the bow and stern with the *R/V Musky II* transducer 1 m below the water surface and the *R/V Grandon* transducer 1.3 meters below the surface. Sound was transmitted at 1 pulse per second (pps) at alternating pulse durations of 0.1 milliseconds (ms), 0.2 ms, 0.3 ms, and 0.4 ms (i.e., each second one pulse lasting 0.1 ms, one pulse lasting 0.2 ms, one pulse lasting 0.3 ms, and one pulse lasting 0.4 ms was transmitted). In past surveys we transmitted sound at 4 pps and 0.4 ms. We altered our protocol in 2010 and 2011 to collect data at shorter pulse durations because shorter pulse durations can better discern individual targets in dense fish layers (Parker-Stetter et al. 2009), which are common near the thermocline in central Lake Erie. Longer pulse durations can result in biased *in situ* TS estimates, which further result in biased density estimates. For this report we use only data collected at 0.4 ms to remain comparable with past practice. We will calculate densities at each pulse duration to determine if shorter pulse durations result in reduced bias in *in situ* target strength estimates and use those results to inform future data collection. Global Positioning Systems (GPS) coordinates from the *R/V Musky II* were collected using a Garmin ® GPSMAP 76Cx, and from the *R/V Grandon*, a Lowrance Ifinder. Both vessels interfaced GPS coordinates with the echosounders to obtain simultaneous latitude and longitude coordinates. Thermal profiles were taken on each transect for calculating the speed of sound in water for use in data analysis. We used the temperature just above the thermocline because the largest proportion of fish occurred nearest this depth in the water column. Because temperature is not uniform from surface to bottom this necessarily results in slight error in estimated depth of fish targets. Selecting temperature nearest the thermocline where fish were densest results in the least cumulative error in depth of fish targets. Prior to data collection we used a standard tungsten-carbide calibration sphere designed specifically for 120 kHz transducers to calculate a calibration offset for calculating target strengths. Background noise was estimated by integrating total sound from passive listening data collected just prior to acoustic sampling from the *R/V Musky II*. Background noise from *R/V Grandon* data was estimated from integrating Sv data in areas where no fish targets were present.

Analysis of hydroacoustic data was conducted following guidelines established in the GLSOP (Parker-Stetter et al. 2009) using EchoView ® version 4.9 software or version 5.1. 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 either 500-m or 1000-m; longer distances were used when there were fewer single targets. 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 -75 dB. This value permitted inclusion of all targets at least -69 dB within the half-power beam angle. We used -69 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 >0.1, the mean TS of the entire stratum within a transect where Nv values were <0.1 was used (Rudstam et al. 2009).

Density estimates for age-0 and YAO rainbow smelt and YAO emerald shiner were estimated by multiplying acoustic density estimates within each cell by proportions calculated from trawls. For each cell we used proportions of each species and age group from the trawl sample from the same water stratum and from a similar total water depth that was nearest the cell.

Trawling

The R/V Keenosay, (OMNR) and *R/V Musky II* (USGS) conducted midwater trawling concurrent with acoustic data collection. The *R/V Musky II* conducted four 10-minute trawls in Ohio waters on one transect, while the *R/V Keenosay* conducted up to eight 20-minute trawls per transect in Ontario waters. Both vessels used trawls of the same design for all trawling. Whenever possible, trawl vessels attempted to distribute trawl effort above and below the thermocline to adequately assess species composition throughout the water column. 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 and yearling-and-older (age-1+) for forage species and age-2-or-older (2+) for predator species. Total lengths were measured from a subsample of individuals from each species and age group.

Results

Four cross-lake transects were sampled between 5 July and 8 July 2011 (Figure 4.2.1). Mechanical problems with the R/V Grandon prevented completion of the three eastern most transects. Acoustic data collection on the western most transect was canceled due to weather conditions. Trawling was completed by OMNR on all four prescribed transects. ODNR was able to trawl two transects and USGS was able to trawl on one transect (Figure 4.2.1). Crew shortages prevented additional trawling aboard the Musky II.

Trawl catches were dominated by rainbow smelt and emerald shiner (Table 4.2.1). Both species' distributions were more segregated by depth this year compared to 2010. Species other than rainbow smelt and emerald shiner included unidentified cyprinidae, white perch, white bass, walleye, round goby, steelhead, gizzard shad and freshwater drum.

Emerald shiner, age-0 rainbow smelt and YAO rainbow smelt segregated into distinct layers of the water column, with age-0 rainbow smelt and emerald shiner in the epilimnion and YAO rainbow smelt in the thermocline and hypolimnion. Most trawl catches were composed of either YAO rainbow smelt or both age-0 rainbow smelt and emerald shiner (Table 4.2.1).

Acoustic TS distributions by depth showed distinct differences in TS distributions across depth strata. The depth of the break varied considerably, from as shallow as 11 m to as deep as 18 m. Hence there is no absolute depth separating fish layers and the layers do not necessarily correspond to the epi- and hypolimnia. We refer instead to upper and lower fish layers.

Similar to previous years, upper layers were dominated by age-0 rainbow smelt and YAO emerald shiner (Table 4.2.2). Lower layers were dominated by YAO rainbow smelt (Table 4.2.2). Age-0 rainbow smelt densities were highest in Ohio waters on transects 57725 and 57850, east and west of Fairport Harbor, OH (Figure 4.2.2). Yearling-and-older rainbow smelt densities were higher in Canadian waters on the eastern transects relative to the western transects (Figure 4.2.3). Overall, densities were highest for emerald shiner (Figure 4.2.4).

Discussion

The 2011 hydroacoustics results were similar to most years in terms of depth distributions of the two primary species. Hydroacoustic target size increased with depth and there was usually a distinct break in target density around the thermocline. Typical to central basin surveys, age-0 rainbow smelt and emerald shiners were caught above the thermocline, while YAO rainbow smelt were caught below the thermocline. Midwater trawl catches in 2010 showed a much less distinct species distribution with age-0 rainbow smelt and emerald shiners being caught in large proportions throughout the water column

Acoustic density estimates also did not suffer from the potential of biased *in situ* target strength estimates as in past years. Since 2004 up to 85% of in situ target strength estimates have been biased in dense fish layers, which typically were near the thermocline. In 2010 fewer than 14% of analytic cells were biased and in 2011, fewer than 2% of analytic cells were biased. Low bias of *in situ* estimates of target strength were likely a result of lower overall fish densities and fish being more widely distributed by depth. Bottom trawl surveys suggest the overall forage population is below average in the central basin in 2011. Hydroacoustic data showed 2011 densities up to 40,000 fish per hectare, an increase from 2010, but still well below densities of over 100,000 fish per hectare in 2008. Dissolved oxygen profiles found no evidence of hypoxia, which could cause fish to congregate tightly around the thermocline.

Hydroacoustic data have been collected at pulse durations less than 0.4 ms in 2010 and 2011. We report only those density estimates from data collected at 0.4 ms pulse duration so data are comparable to past years. The data we collected at shorter pulse durations will be analyzed to determine if bias of target strength estimates can be further reduced. We will also assess how density estimates are affected by collecting data at different pulse durations.

4.3 West Basin Acoustic Survey (E. Weimer)

Introduction

A standardized inter-agency fishery acoustics program has been used to assess forage community abundance and distribution in the eastern basin of Lake Erie since 1993. The acoustic survey was expanded to the central basin in 2000 (Forage Task Group 2004). In 1997, a pilot program was conducted by Sandusky Fisheries Research Unit staff adjacent to Sheldon's Marsh in July to assess the feasibility of using acoustic technology in the shallow waters of the western basin. The pilot study showed much promise and results indicated an offshore to nearshore gradient in forage-sized fish abundance. As charged by the LEC, since 2004 a pilot western basin acoustic survey has been initiated to explore the utility of using down-looking sonar for assessing pelagic forage fish abundance in the west basin. These data have been used in conjunction with current survey data to develop a standardized acoustic sampling program for the west basin of Lake Erie that will complement the ongoing acoustic surveys in the central and eastern basins and facilitate an annual lake snapshot of pelagic forage fish abundance and biomass.

Methods

Following a one year hiatus caused by equipment malfunctions, the western basin hydroacoustic survey was conducted again in 2011. Of the three proposed cross-basin transects, all were completed July 19-27th except the northern half of Transect 3(eastern transect; Figure 4.3.1), which was lost due to equipment failure. Data was collected using a BioSonics DTX echosounder employing a single, downward-facing, 6.8-degree, 201-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 target strength. 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. Data were collected at a ping rate of 10 pings/second, a pulse length of 0.2 ms, and a minimum threshold of -70 dB. Water temperature and dissolved oxygen level was recorded at the surface, 2-m depth, and bottom of the water column at the beginning of each transect; 2-m water temperature was included in data settings in Visual Acquisition to calculate sound speed and absorption coefficients. 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. Only targets with acoustic returns larger than -60 dB were included in analysis. Total length was estimated from target strength using Love's dorsal aspect equation (Love 1971):

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

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

Results

One hundred ten kilometers were surveyed during 2011, with 3.196 GB of data collected. Mean western basin fish density and biomass estimates in the western basin were 1,158 fish per hectare and 5.8 kg per hectare, respectively. Densities were lowest in Transect 3, but larger-bodied fish compared to the other transects lead to similar biomass levels (Figure 4.3.2). Compared with previous years with when similar surveys were completed, 2011 fish densities were the lowest of the series. Biomass estimates for all three transects were similar to the 2008 survey, but generally lower than 2006 and 2007. Fifty-seven percent of fish surveyed were estimated to be 30-59 mm TL, lower than previous years; 91% were between 30-109 mm.

Table 4.1.1. Indices of relative abundance of pelagic forage fish species in eastern Lake Erie from a basin-wide acoustic survey from 2007 to 2011, compared with bottom trawl survey results for rainbow smelt conducted by Ontario, New York and Pennsylvania during the same period. Indices are reported as arithmetic mean number caught per hectare (NPHa) for the yearling-and-older (YAO) age group.

		Number per hectare				
Sampling Method	**East Basin Index Stratum**	**2011**	**2010**	**2009**	**2008**	**2007**
Btm. Trawl YAO Smelt	**ON-DW**	**277**	**223**	**1654**	**77**	**233**
Btm. Trawl YAO Smelt	**NY-Fa**	**640**	**998**	**3017**	**546**	**177**
Btm. Trawl YAO Smelt	**PA-Fa**			**407**	**2**	**1006**
Btm. Trawl YAO Smelt	**basin trawl avg. (area weighted)**	**359**	**438**	**1939**	**214**	**301**
Acoustic YAO-smelt size fish	**East Basin (all thermal strata)**	**9398**	**9865**	**14226**	**12430**	**5015**

Ontario Ministry of Natural Resources Trawl Survey

ON-DW	Trawling is conducted weekly during Oct. at 4 fixed stations in offshore waters of Outer Long Point Bay using a 10-m trawl.

New York State Department of Environmental Conservation Trawl Survey

NY-Fa	Trawling is conducted at 30 nearshore (15-30 m) stations during Oct. using a 10-m trawl

Pennsylvania Fish and Boat Commission Trawl Survey

PA-Fa	Trawling is conducted at nearshore (<22 m) and offshore (>22 m) stations during Oct. using a 10-m trawl.

Inter-agency East Basin Acoustic Survey

East Basin Acoustic	Acoustic survey encompassing Ontario, Pennsylvania and New York waters with cross-basin transects > 15-m depth contour (Figure 4.1.2).

Table 4.2.1. Percent composition of fish captured in trawl samples collected by the *R/V Keenosay*, *R/V Musky II* and *R/V Grandon* in the central basin Lake Erie in July, 2011. *R/V Keenosay* trawl ID numbers are 1001-4005. *R/V Musky II* trawl ID numbers are 201-204. *R/V Grandon* trawl ID numbers are 730-735. Layer was determined from distribution of acoustic target size to depth along each transect. Upper layer refers to target sizes similar to AGE-0 rainbow smelt. Lower layer refers to target sizes similar to YAO rainbow smelt. Layer was assigned to trawl data based on the depth and transect where the trawl was fished. Species composition from trawl data was applied to acoustic data based on layer and transect.

Transect	Trawl ID	Trawl depth (m)	LAT	LONG	Layer	Emerald shiner All	Freshwater drum YAO	Round goby ALL	Rainbow smelt AGE-0	Rainbow smelt YAO	White perch YAO	Yellow perch AGE-0
58100	1001	15	42.3927	-80.9165	Lower	0	0	0	0	1.000	0	0
58100	1002	15	42.3867	-80.9218	Lower	0.014	0	0	0	0.986	0	0
58100	1003	11	42.3870	-80.9215	Upper	0.953	0	0	0	0.023	0.023	0
58100	1004	5	42.4173	-80.9248	Upper	1.000	0	0	0	0	0	0
58100	1005	9	42.5675	-80.9847	Upper	0.894	0	0.001	0	0.102	0	0
58100	1006	7	42.5688	-80.9810	Upper	0.992	0	0.002	0	0.001	0.002	0.001
58100	1007	5	42.5627	-80.9892	Upper	0.993	0	0	0	0	0	0
58100	1008	7	42.6108	-81.0090	Upper	0.346	0	0	0.004	0.643	0	0
58100	1009	5	42.6117	-81.0127	Upper	0.682	0	0.006	0	0.263	0.028	0
57850	2001	5	42.5670	-81.4733	Upper	0.037	0	0	0	0.955	0.003	0
57850	2002	8	42.5503	-81.4663	Upper	0.270	0	0	0	0.724	0.003	0
57850	2003	13	42.4903	-81.4397	Lower	0.056	0	0	0	0.889	0	0
57850	2004	11	42.4750	-81.4332	Upper	0.786	0	0	0.143	0	0	0
57850	2005	5	42.4862	-81.4453	Upper	0.912	0	0	0.059	0	0.029	0
57850	2006	16	42.3373	-81.3730	Lower	0	0	0	0	1.000	0	0
57850	2007	13	42.3137	-81.3660	*	0.357	0	0	0.357	0.286	0	0
57850	2008	10	42.3250	-81.3680	Upper	0.889	0.056	0	0	0	0.056	0
57850	2009	5	42.3037	-81.3562	Upper	1.000	0	0	0	0	0	0
57600	3001	7	42.2580	-81.8297	Upper	0.122	0	0	0	0.874	0.002	0
57600	3002	5	42.2410	-81.8252	Upper	0.995	0	0	0	0.004	0.001	0
57600	3003	5	42.2223	-81.8117	Upper	0.996	0	0	0	0	0.002	0.002
57600	3004	8	42.2092	-81.8042	Upper	0.986	0.004	0	0.007	0.004	0	0
57600	3005	7	42.2223	-81.8072	Upper	0.985	0.002	0	0.010	0	0.001	0.001
57475	4001	15	41.9108	-82.1393	Lower	0.908	0	0	0	0.092	0	0
57475	4002	5	41.9088	-82.1397	Upper	0.992	0	0	0.004	0	0	0
57475	4003	14	42.0525	-82.2148	Lower	0.636	0.030	0	0.182	0.121	0	0.030
57475	4004	5	42.0587	-82.2177	Upper	0.960	0	0	0	0	0.040	0
57475	4005	6	42.1538	-82.2600	Upper	0.996	0.001	0	0	0.002	0.001	0
57850	201	3	42.4858	-81.4391	Upper	0.097	0	0	0.903	0	0	0
57850	202	11	42.4118	-81.4051	Upper	0.095	0	0	0.524	0.381	0	0
57850	203	16	42.1444	-81.2923	Lower	0	0	0	0	1.000	0	0
57850	204	11	42.0726	-81.2610	Upper	0	0	0	0.917	0	0	0.083
57725	730	15	42.0737	-81.5067	Lower	0	0	0	0	0.999	0	0.001
57725	731	17	41.9663	-81.4548	Lower	0.002	0	0	0	0.996	0	0.001
57725	732	8	41.8825	-81.4177	Upper	0	0	0	0	1.000	0	0
57975	733	9	41.9208	-80.9703	Upper	0	0.587	0	0	0.187	0	0.20
57975	734	17	42.0228	-81.0177	Lower	0	0.001	0	0	.998	0	0.001
57975	735	14	42.0810	-81.0473	Lower	0	0.002	0	0	0.998	0	0

*Trawl depth was the same as layer separation depth

Table 4.2.2. Mean acoustic density (fish/hectare) by species and age class for hydroacoustic transects in central Lake Erie, July 2011.

Upper layer		LORAN TD line				
Species	Life stage	57475	57600	57725	57850	57975
Emerald shiner	All	24264	11849	2783	9466	0
Rainbow smelt	AGE-0	68	87	1549	13576	3904
	YAO	23289	10312	717	1321	0
Yellow perch	AGE-0	0	534	140	1071	355
Other[1]		376	56	12	381	0

Lower layer		LORAN TD line				
Species	Life stage	57475	57600	57725	57850	57975
Emerald shiner	All	1613	17	9	9	0
Rainbow smelt	AGE-0	183	0	0	0	0
	YAO	231	891	1223	1595	611
Yellow perch	AGE-0	30	0	0	0	0
Other[1]		30	2	9	9	0

1 Other species include: YAO freshwater drum, YAO yellow perch, round goby, walleye, white perch, white bass, steelhead, whitefish and gizzard shad.

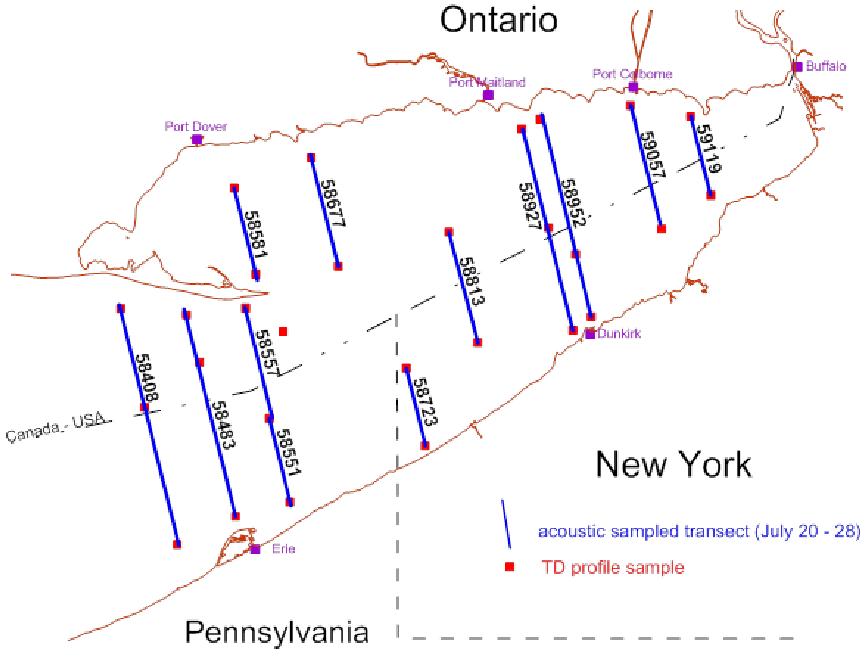

Figure 4.1.1. July 2011 eastern basin Lake Erie inter-agency acoustic survey transects, mid-water trawl and temperature profile sites sampled by the Ontario Ministry of Natural Resources (OMNR) research vessel, *RV Erie Explorer* .

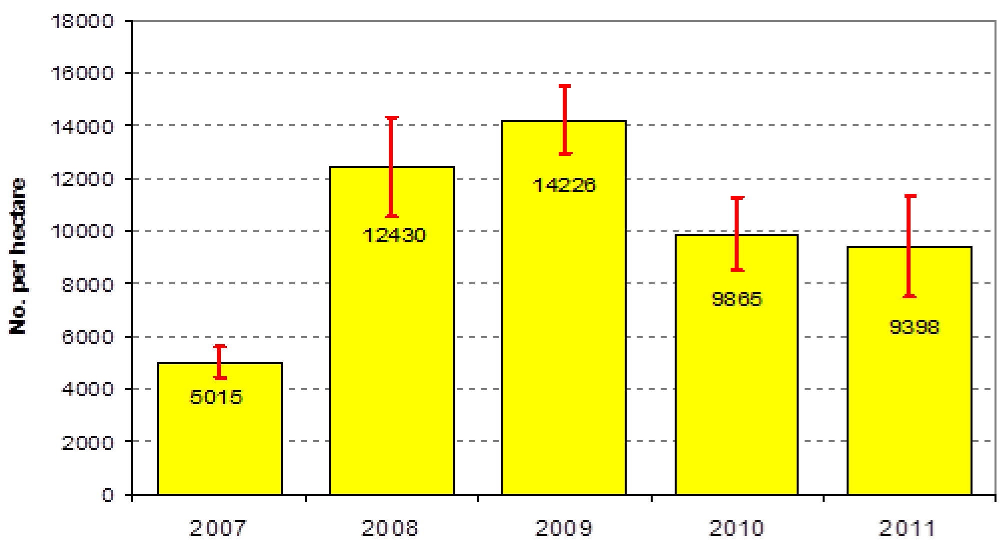

Figure 4.1.2. Mean density (Number per hectare) estimates of pelagic YAO rainbow smelt-sized forage fish sampled with a 120-kHz split-beam echosounder during July fisheries hydroacoustic assessments of eastern Lake Erie, 2007 - 2011. Density estimates were derived from a spatially stratified cluster analysis of acoustic transects comprised of 800-m length sample units. Standard error (of mean) bars shown.

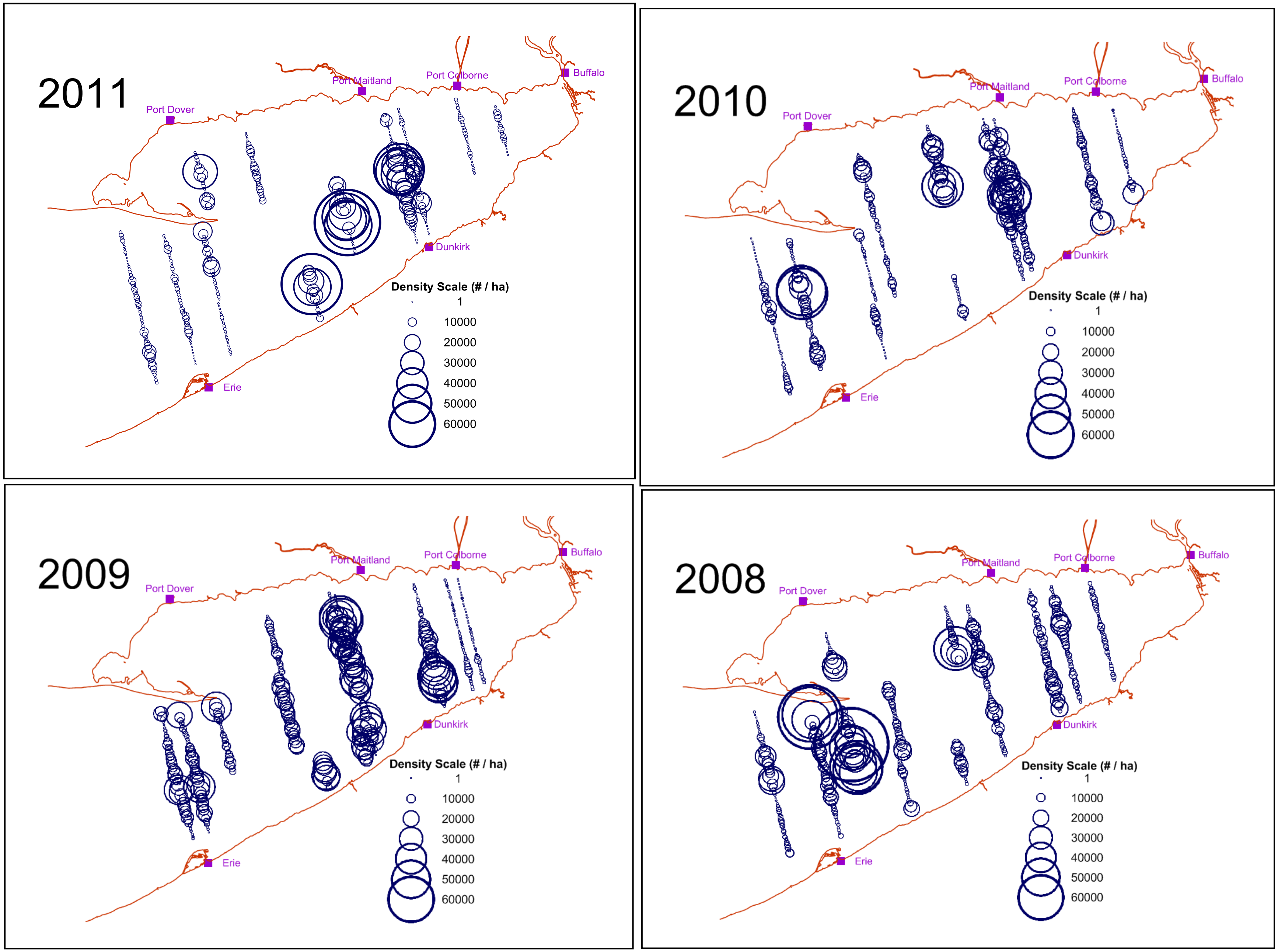

Figure 4.1.3. Relative density (No. fish / ha) of pelagic, YAO rainbow smelt-sized forage fish per 800-m interval along transects sampled with a 120-kHz split-beam echosounder during July fisheries acoustic surveys in eastern Lake Erie, 2008 to 2011.

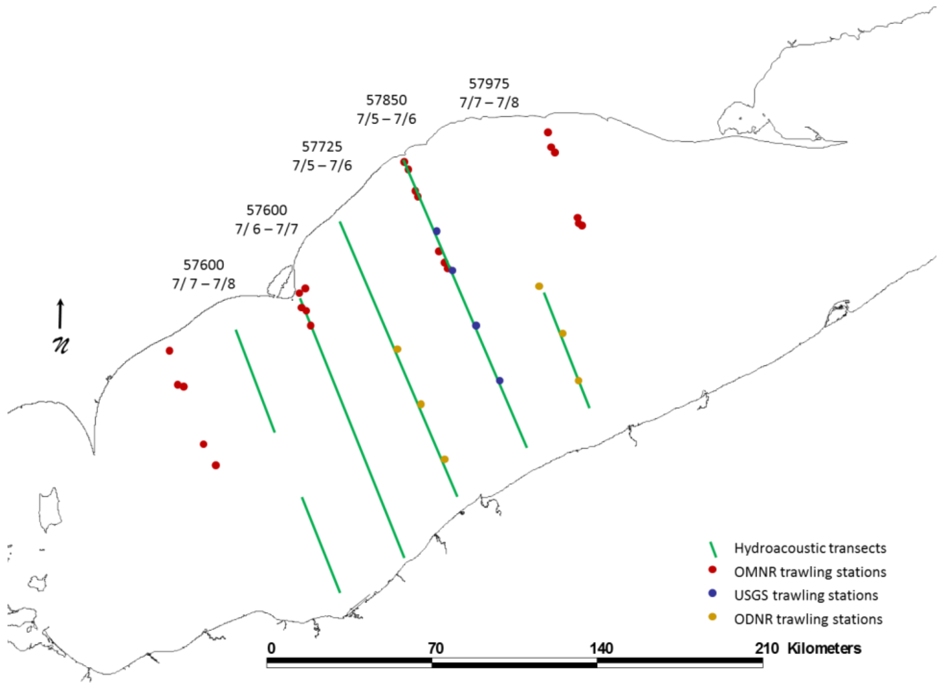

Figure 4.2.1 Hydroacoustic transects and midwater trawling stations in the central basin, Lake Erie, July 5-8, 2011. Transect numbers are Loran-TD lines.

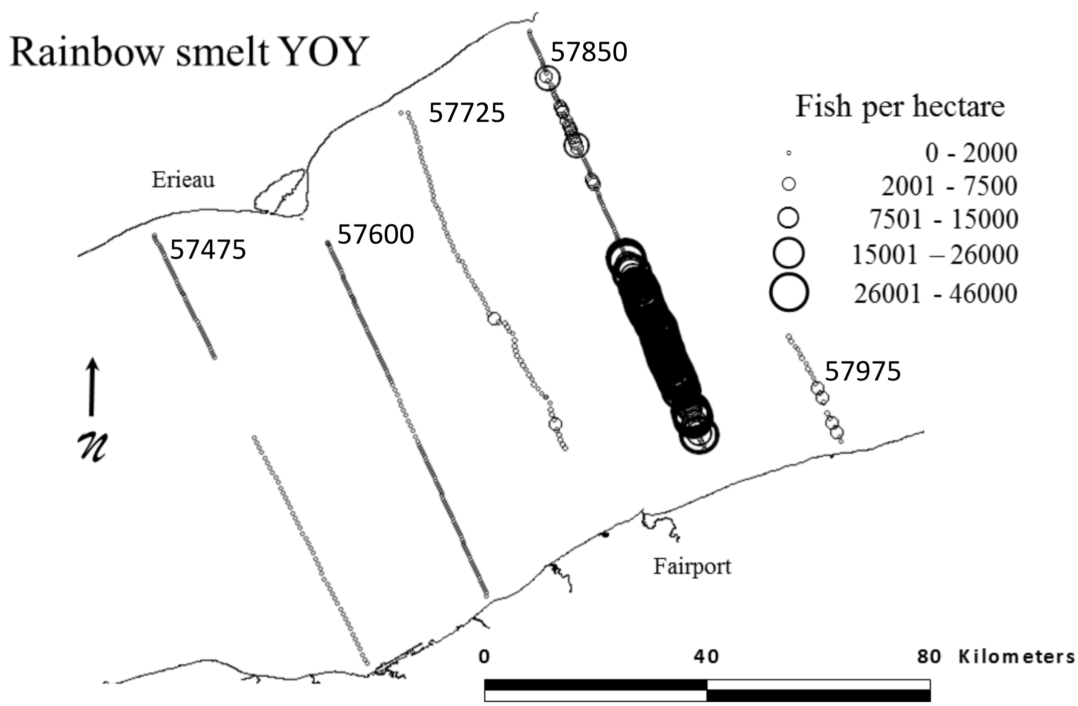

Figure 4.2.2. Density estimates of age-0 rainbow smelt (fish * ha^{-1}) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 500-m or 1000-m segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2011.

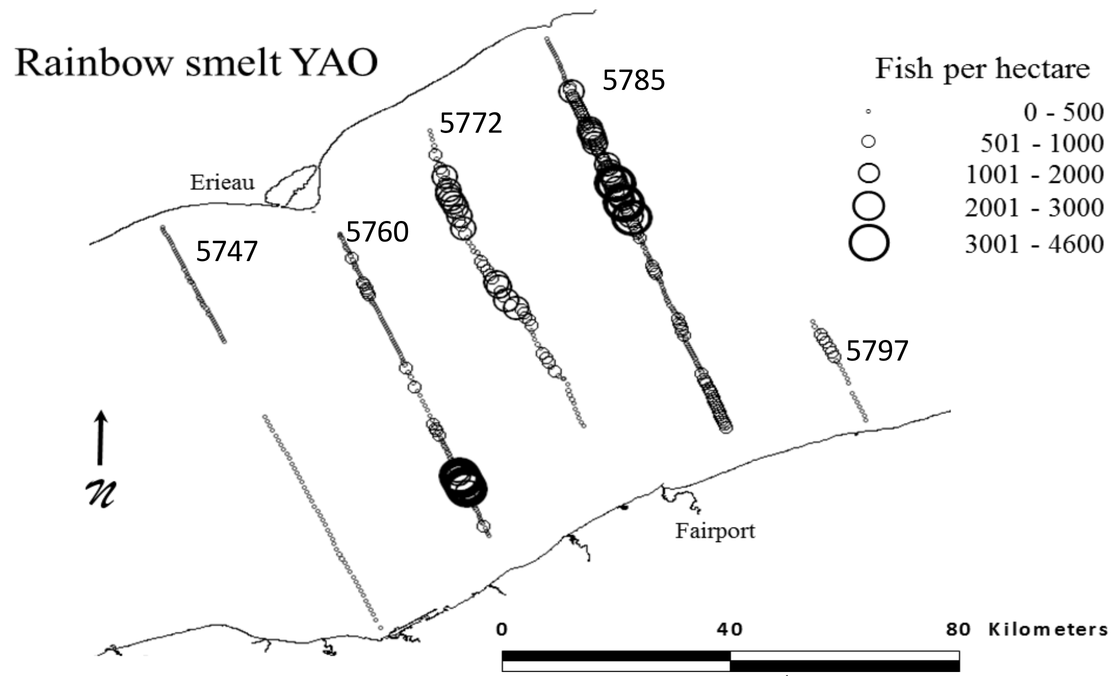

Figure 4.2.3 Density estimates of YAO rainbow smelt (fish * ha^{-1}) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 500-m or 1000-m segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2011.

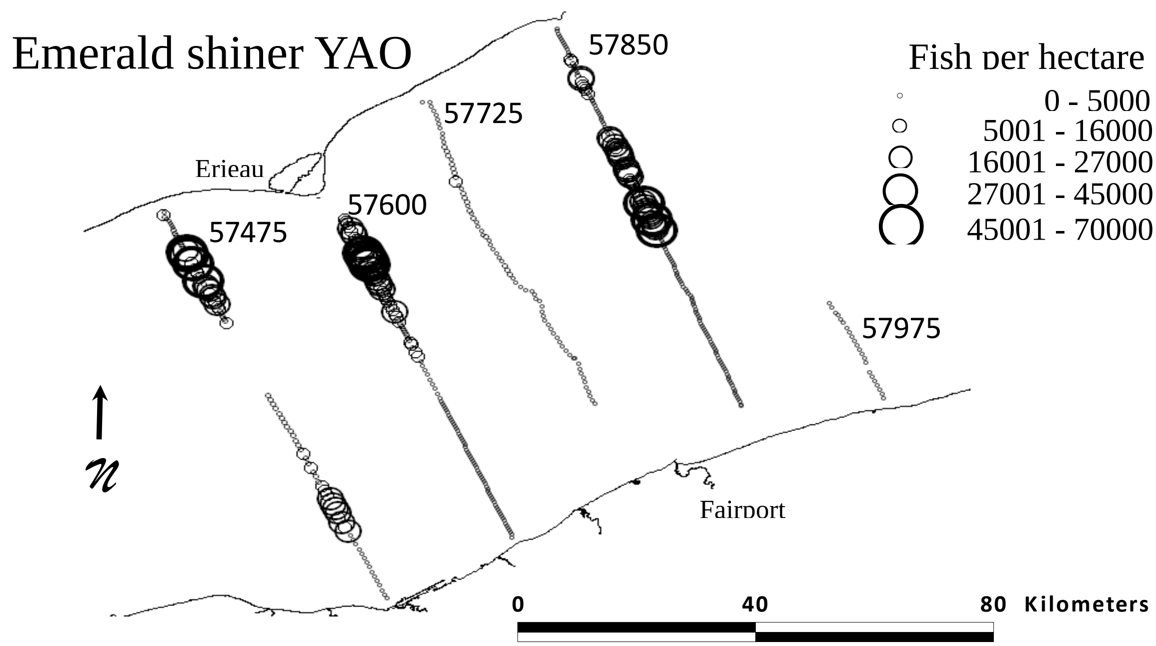

Figure 4.2.4 Density estimates of YAO emerald shiner (fish * ha^{-1}) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 500-m or 1000-m segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2011.

Figure 4.3.1. Spatial abundance of forage fish along three western basin hydroacoustic transects, July 2011. Equipment failure ended the survey midway through the eastern transect. Legend densities are in fish per hectare.

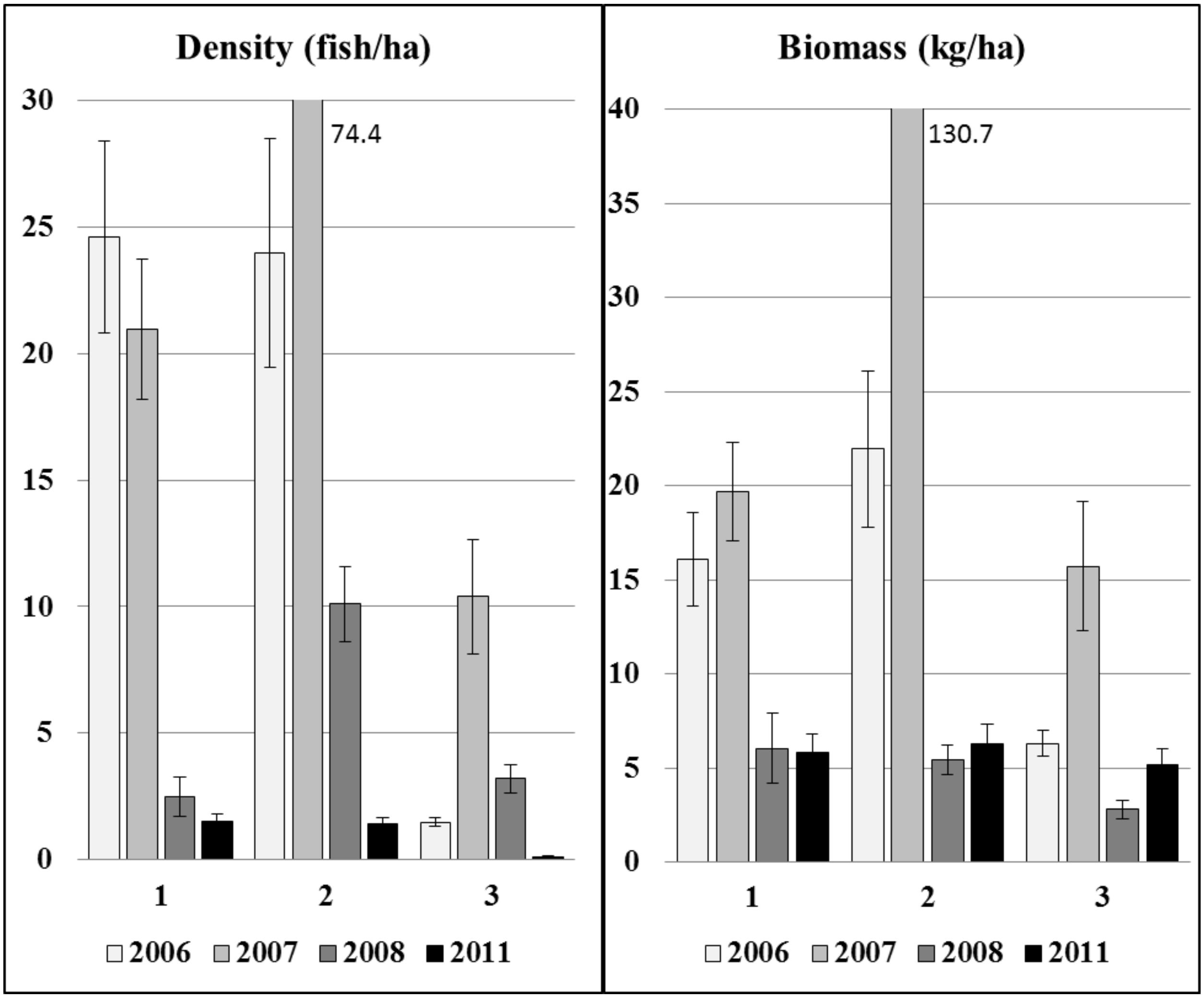

Figure 4.3.2. Mean fish density (#/ha; A) and biomass (kg/ha; B) along three western basin transects during the annual hydroacoustic survey, 2006-2011. Results from 2009 and 2010 are not represented due to insufficient data. Error bars are standard errors.

5.0 Interagency Lower Trophic Level Monitoring Program, 1999-2011

(B. Trometer, and J. Markham)

In 1999, the FTG initiated a Lower Trophic Level Assessment program (LTLA) within Lake Erie and Lake St. Clair (Figure 5.0.1). 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), 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 events, with benthos collected on two dates, once in the spring and once in the fall. For this report, we will summarize the last 13 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 of data, 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 5.0.1). 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 5.0.1). 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 range 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 measured at one meter or less below the surface for offshore stations only. This index should provide a good measure of relative system production and growth rate potential for fishes, assuming prey resources are not limiting. Mean summer surface temperatures across all years are warmer in the western basin (22.7 C) and progressively get cooler in the central (21.9 C) and eastern basins (20.6 C; Figure 5.0.2). Mean surface temperatures range from 21.2 C in 2004 to 24.3 C in 2010 in the western basin, 20.1 C in 2003 to 23.8 C in 2005 in the central basin, and 18.9 C (2004) to 22.5 C (2005) in the eastern basin. Above average temperatures were evident across all basins in 2005, 2006, 2010, and 2011; below average temperatures occurred in 2000, 2003, 2004, 2008, and 2009. Although warmer temperatures are more prevalent in the latter half of the time series, the trends are not significant. In 2011, the mean summer surface water temperature was higher than the long-term average in all three basins (west 23.5 C, central 22.8 C, and east 21.8 C).

Hypolimnetic Dissolved Oxygen

Dissolved oxygen (DO) levels less than 2 mg/L are deemed stressful to fish and other aquatic biota (Craig 2012; Eby and Crowder 2002). Hypolimnetic DO can become low when the water column becomes stratified, which can begin in early June and continue through September in the central and eastern basins. In the western basin, shallow depths allow wind mixing to penetrate to the bottom, generally preventing thermal stratification. As a result, there are relatively few summer observations of low hypolimnetic DO concentrations in the time series (Figure 5.0.3). In 2011, DO was below the 2 mg/L threshold on two occasions in the west basin; at station 3 on 7/27/2011 (1.9 mg/L) and at station 6 on 8/9/2011 (1.8 mg/L).

Low dissolved oxygen is more of an issue in the central basin. It happens almost annually at the offshore stations (8, 10, 11 and 13) and occasionally at inshore stations as well. Dissolved oxygen of less than 2 mg/L has been observed as early as mid-June and can persist until late September before fall turnover remixes the water column. In 2011, bottom DO was below 2 mg/L threshold in the central basin on only two occasions at station 8 (7/26/2011, 0.8 mg/L; 8/8/2011, 0.6 mg/L) (Figure 5.0.3).

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 2 mg/L threshold was in 2010 at the new station 25 on July 14 and again on August 13 (Figure 5.0.3). No DO concentrations of less than 8 mg/L were recorded in the east basin in 2011.

Chlorophyll *a*

Chlorophyll *a* concentrations indicate biomass of the phytoplankton resource, ultimately representing production at the lowest level. For mesotrophic status in the west, central, and nearshore eastern basins, chlorophyll *a* concentrations should range between 2.5-5.0 µg/L. Chlorophyll *a* concentrations should be less than 2.5 µg/L in the offshore eastern basin to be classified as oligotrophic (Leach *et al*. 1977). In the west basin, mean chlorophyll *a* concentrations have mainly been above targeted levels in the 13 year time series, falling into eutrophic status rather than mesotrophic status (Figure 5.0.4). Annual variability is also the highest in the west basin. Chlorophyll *a* concentrations in 2011 were 7.9 µg/L in the west basin and have been increasing for the past three years.

In the central basin, chlorophyll *a* concentrations have been within the targeted mesotrophic range for the entire time series, and that trend continued in 2011 (3.3 µg/L) (Figure 5.0.4). In the eastern basin, chlorophyll a concentrations in the nearshore waters have been below the targeted mesotrophic level for the entire time series (Figure 5.0.4). 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 2011, chlorophyll *a* concentrations were 1.9 µg/L in the nearshore waters of the eastern basin and 2.4 µg/L in the offshore waters.

Total Phosphorus

Total phosphorus levels in the western basin have exceeded FCO targets since the beginning of this monitoring program (Figure 5.0.5). Total phosphorus concentrations in the west basin dramatically increased in 2011 to 113.0 µg/L, a time-series high. In four of the last five years, total phosphorus levels in the west basin have been in the hyper-eutrophic range.

In the central basin, total phosphorus levels have been on the increase and have exceeded FCO targets since 2006 (Figure 5.0.5). Similar to the west basin, the central basin experienced a dramatic increase in total phosphorus in 2011 to a time series high of 47.6 µg/L. In the nearshore waters of the eastern basin, total phosphorus levels have remained stable and within the targeted mesotrophic range for the entire time series (Figure 5.0.5). However, a gradual increasing trend is evident since 2006. Total phosphorus levels stable 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 2011, total phosphorus concentrations in the eastern basin decreased in both nearshore waters (11.8 µg/L) and offshore waters (8.9 µg/L) and were within their targeted trophic levels.

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 5.0.6). Mean summer Secchi depth readings in the western basin were 2.0 m in 2011. In contrast, water transparency in the central basin has remained within the targeted mesotrophic range for the entire series, including 2011 (4.4 m; Figure 5.0.6). Transparency was in the oligotrophic range, which is above FCO target range for the nearshore waters of the eastern basin from 1999 through 2007, but has been stable and within the FCO targets for the last four years (Figure 5.0.6). In the offshore waters of the eastern basin, water transparency was within the oligotrophic target range from 1999 through 2007, but fell into the mesotrophic range in both 2008 and 2010. In 2011, mean summer Secchi depth readings was 4.8 m in the nearshore waters of the eastern basin, which was within the targeted mesotrophic range, and 5.5 m in the offshore waters, which was below the targeted oligotrophic range.

Zooplanktivory Index

Fish are size-selective predators of zooplankton, 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. For 1999-2004, zooplankton predation was high in Lake Erie, as the average size of the community was generally less than this critical 0.57 mm size (Figure 5.0.7). Since 2005 in the western basin and 2006 in the central basin, the mean size of the zooplankton community has been below the critical size, indicating low feeding intensity, for all years except 2007.

The trend of low feeding intensity continued in 2011 in both the western and central basins. In the eastern basin, the zooplanktivory index has been the most stable and is generally at the critical size level.

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 510/m^3 and were generally higher from July through September.

Cercopagis pengoi was first collected in Lake Ontario in 1998, and by 2001 was collected in western basin of Lake Erie (Therriault et al. 2002). They first appeared in west basin samples 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/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 this sampling effort in August 2001 at stations 5 and 6, and at station 9 by September 2001. It was collected at stations 5 and 6 in 2002, and at stations 5, 6, 8 and 9 in 2004. Data is not available for these stations from 2005 through 2008. In 2007 it was found at station 18, the first record for the eastern basin. Densities were relatively low ranging from 0.002 to 61/m^3.

Fish Community Ecosystem Targets

Measures of lower trophic indicators (total phosphorus, transparency, chlorophyll *a*) in 2011 indicate that the western basin is eutrophic to hyper-eutrophic. Current conditions favor a centrarchid (bass, sunfish) and cyprinid (carp, minnows) fish community instead of the desired percid (walleye, yellow perch) fish community (Table 5.0.2). In the central and nearshore eastern basin, the lower trophic measures in 2011 mainly fell within the targeted mesotrophic range preferred by percids. However, it is worth noting that total phosphorus concentrations in the central basin were high in the eutrophic range in 2011. In the offshore waters of the eastern basin, 2011 total phosphorus and chlorophyll *a* measures indicate an oligotrophic class that favors salmonids while transparency indicates a shift towards a mesotrophic class that favors percids.

Microcystis blooms in western Lake Erie (E. Weimer and J. Chaffin)

Following decades of eutrophication and annual blooms of cyanobacteria, the passage of the Great Lakes Water Quality Agreement in 1972, and the pollution control measures that lead to substantially reduced phosphorus and phytoplankton levels in Lake Erie and limited cyanobacteria biomass. However, the past decade has witnessed increases in total phytoplankton and the return of cyanobacteria blooms in the western basin. Unlike previous blooms, which were dominated by nitrogen-fixing species like *Anabaena* spp. and *Aphanizomenon* spp., current blooms consist of

Microcystis spp., a non-nitrogen fixer. While bloom intensity since the mid-1990s has varied, the annual occurrence of *Microcystis* blooms has created concern among managers that Lake Erie is once again becoming eutrophic.

Causes of *Microcystis* blooms and eutrophication in western Lake Erie have been linked to several potential sources. Watershed practices have increased the amount of biologically available phosphorus flowing into the western basin, and small tributaries are providing a potential source of *Microcystis* to the lake. Turbidity, particularly suspended sediments in and around Maumee Bay, provides ideal growth conditions for *Microcystis*, because it can float near the surface while other phytoplankton sink out of the sunlight. Invasive *Dreissenid* mussels selectively avoid cyanobacteria during feeding, and excreted nutrients, particularly forms of nitrogen and phosphorus, are readily available for uptake by *Microcystis*. Internal lake processes also increase the availability of nutrients.

Researchers are examining factors that influence the presence and intensity of *Microcystis* blooms in Lake Erie, and are searching for management levers that can be used to halt or reverse this trend. The University of Toledo has been monitoring *Microcystis* in Maumee Bay and western Lake Erie since 2002, looking at conditions that promote blooms and the cellular 'health' of the cyanobacteria in an attempt to identify deficiencies that limit growth. Researchers from Ohio State University and collaborators at Ohio State University's, F. Stone Laboratory are looking at the timing and intensity of blooms in the Maumee and Sandusky systems. Researchers from Heidelberg University are examining nutrient loading in tributaries and in Lake Erie, and investigating the effects of toxic microcystins on larval mayflies in the Lake Erie benthos. Researchers at the USGS are developing genetic approaches to rapidly assay *Microcystis* biomass and potential toxicity. NOAA has developed an experimental forecast bulletin for harmful algal blooms in western Lake Erie. These represent just a few of the efforts being made to address this issue.

The Lake Erie lower trophic program has been collecting bi-weekly total phosphorus and phytoplankton samples from May through September in Lake Erie since 1998. These samples coincide with the *Microcystis* increase, and may be valuable in identifying lake wide trends and conditions that favor these increases. As reported in the Lower Trophic section of this report, total phosphorus has shown an increasing trend in the west and central basins (Figure 5.0.5). Most of the phytoplankton data are not available as many samples remain archived due to the financial constraints of processing. Currently, the FTG has a total of 775 phytoplankton samples archived at The Ohio State University's Museum of Biological Diversity. Some phytoplankton samples from Ohio waters of the western and central basins have been processed, but are not currently organized in a useable format. The FTG will organize these data in the upcoming year for use in the 2012 report, and will pursue opportunities to process the archived samples as funding allows.

Table 5.0.1. Ranges of lower trophic indicators for each trophic class and associated fish community (Leach *et al.* 1977; Ryder and Keer 1978).

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

Table 5.0.2. Measures of key lower trophic indicators and current trophic class, by basin, from Lake Erie, 2011. The east basin is separated into nearshore and offshore.

Basin	Phosphorus (µg/L)	Chlorophyll a (µg/L)	Transparency (m)	Trophic Class
West	113	7.9	2.0	Eutrophic/Hyper
Central	48	3.3	4.4	Mesotrophic
East - Nearshore	12	1.9	4.8	Mesotrophic
East - Offshore	9	2.4	5.5	Oligotrophic/Mes

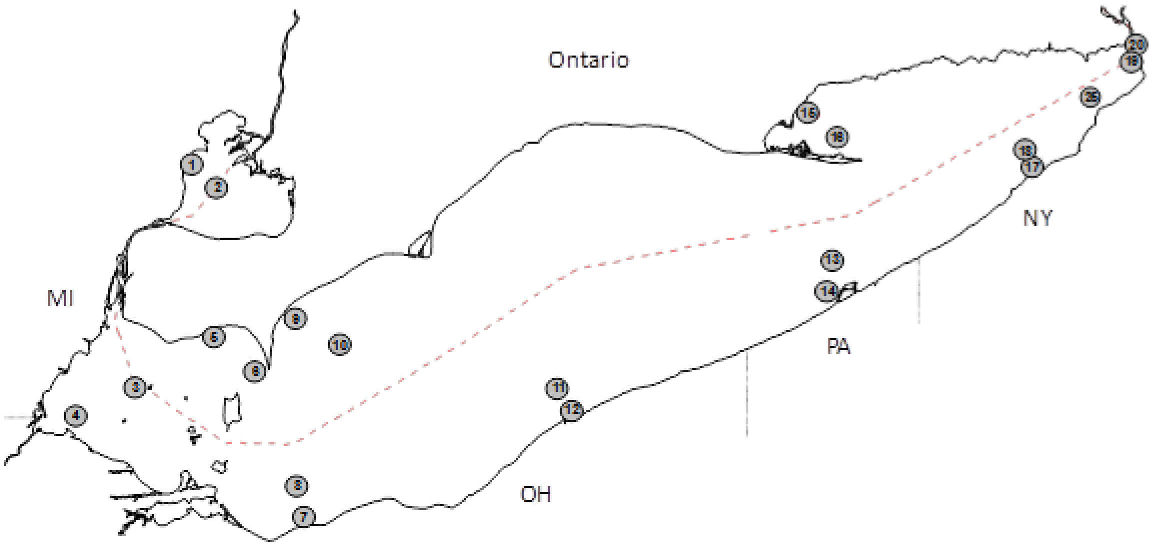

Figure 5.0.1. Lower trophic level sampling stations in Lakes Erie and St. Clair. Station 25 was added in 2009.

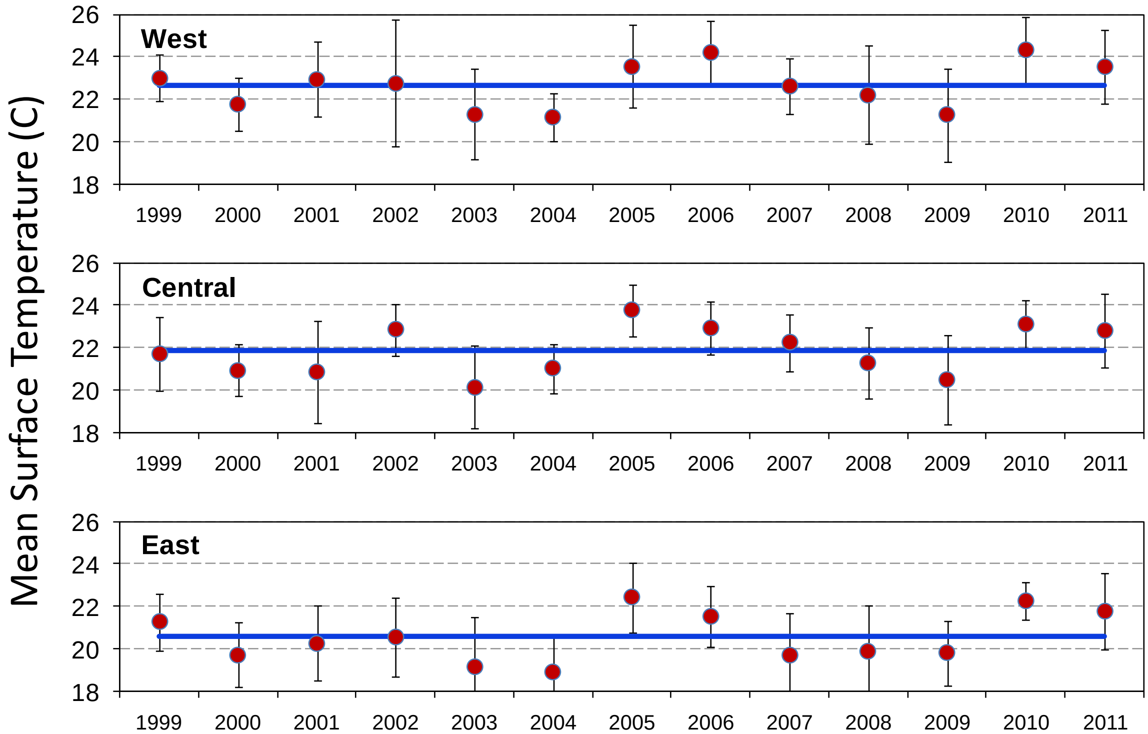

Figure 5.0.2. Mean summer (June-August) surface water temperature (C) at offshore stations, weighted by month, with 95% confidence limits (2 SE's) by basin in Lake Erie, 1999-2011. Dark blue lines represent time series average water temperature. Data included in this analysis by basin and station: West - 3, 6; Central – 8, 10, 11, 13; East – 16, 18, 19, 25.

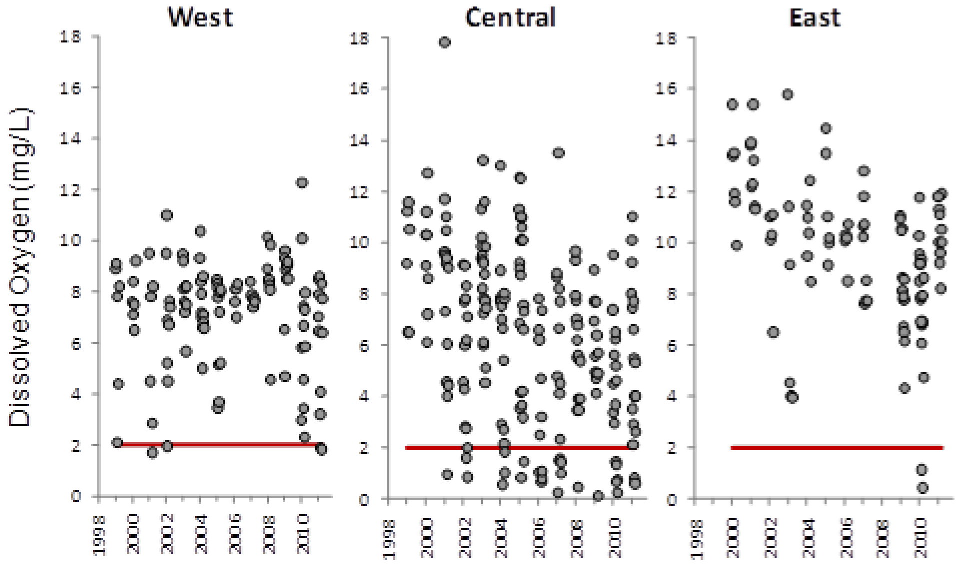

Figure 5.0.3. Summer (June-August) bottom dissolved oxygen (mg/L) concentrations for offshore sites by basin in Lake Erie, 1999-2011. The red horizontal line represents 2 mg/L, a level below which oxygen becomes limiting to the distribution of many temperate freshwater fishes. Data included in this analysis by basin and station: West - 3, 6; Central – 8, 10, 11, 13; East – 16, 18, 19, 25.

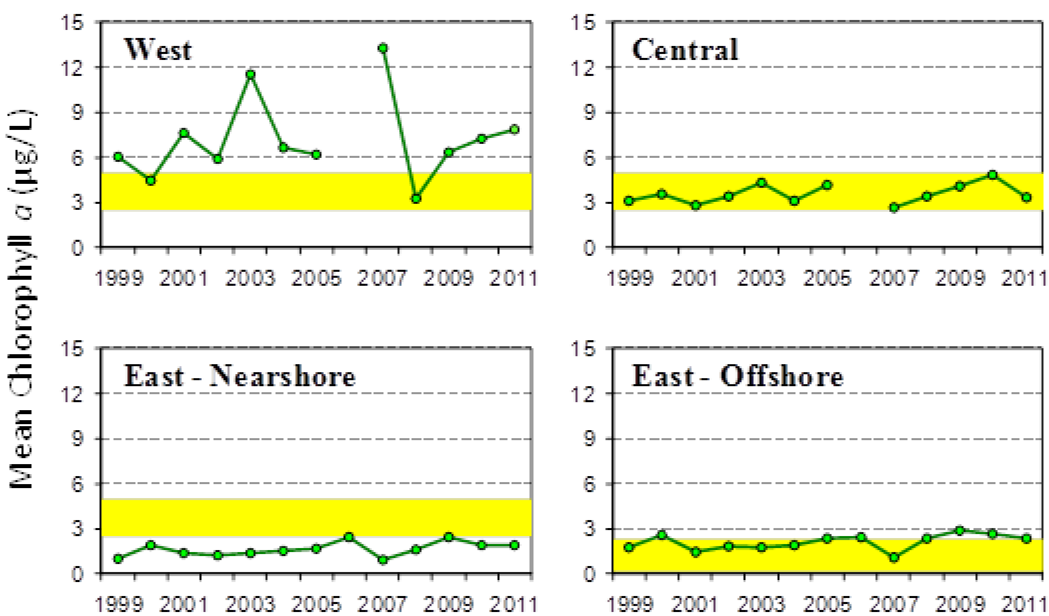

Figure 5.0.4. Mean chlorophyll *a* concentration (ug/L), weighted by month, by basin in Lake Erie, 1999-2011. The east basin is separated into nearshore and offshore. Yellow bars represent targeted trophic class range. For this analysis data from stations 3 through 20 and 25 were included.

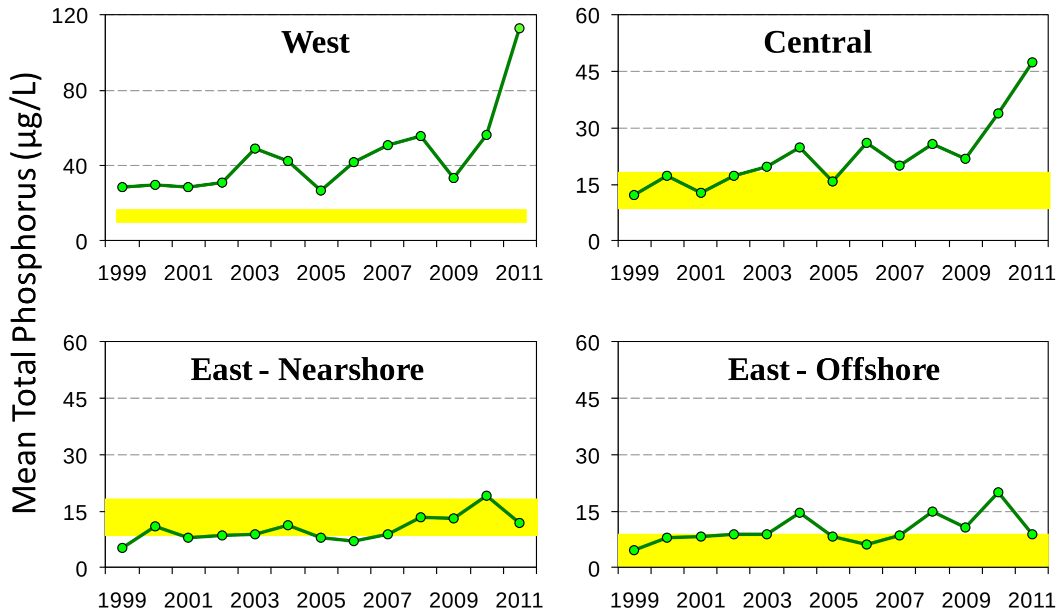

Figure 5.0.5. Mean total phosphorus (µg/L), weighted by month, for offshore sites by basin in Lake Erie, 1999-2011. The east basin is separated into nearshore and offshore. Yellow shaded areas represent the targeted trophic class range. For this analysis data from stations 3 through 20 and 25 were included.

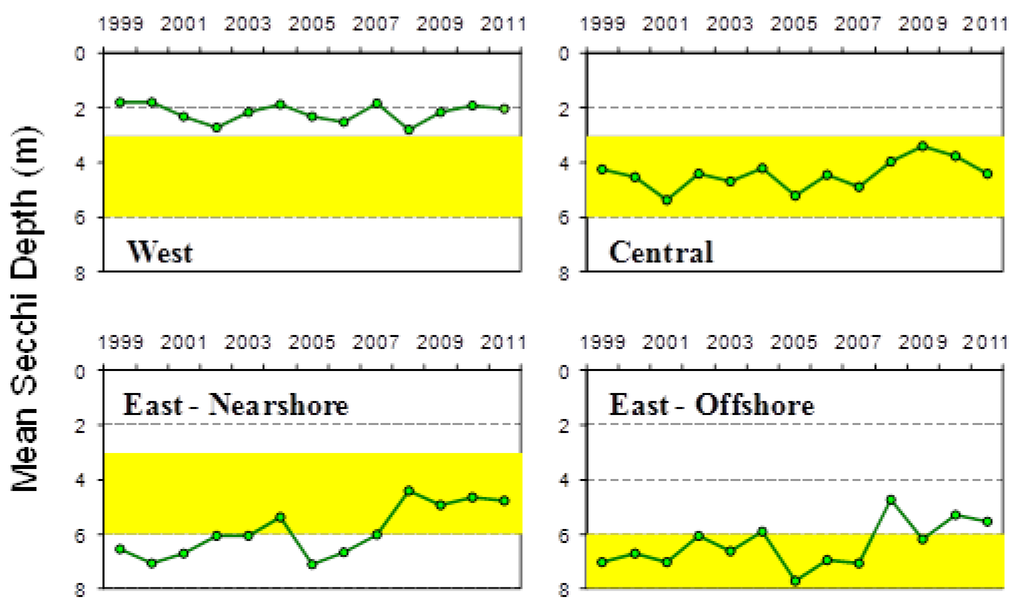

Figure 5.0.6. Mean summer (June-August) Secchi depth (m), weighted by month, by basin in Lake Erie, 1999-2011. The east basin is separated into inshore and offshore. Yellow shaded areas represent the targeted trophic class range. For this analysis data from stations 3 through 20 and 25 were included.

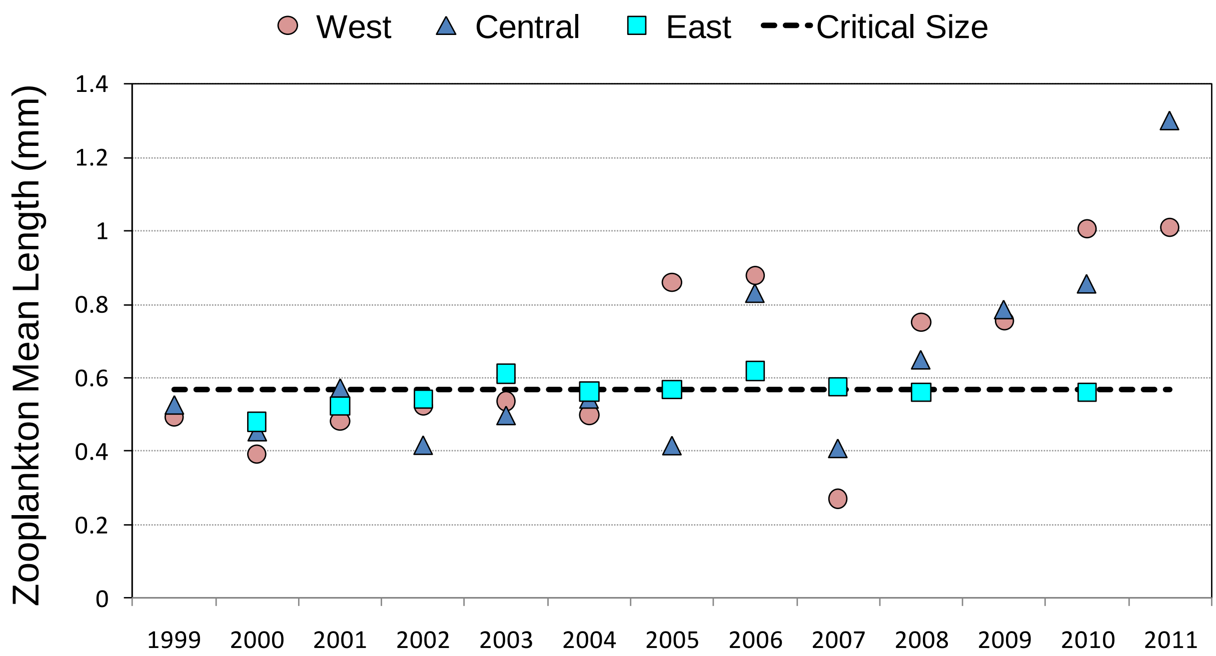

Figure 5.0.7. Mean length of the zooplankton community sampled with a 63 µm plankton net hauled through the epilimnion of each basin of Lake Erie, 1999-2011. The horizontal dashed line depicts 0.57 mm; if the mean size of the zooplankton community is 0.57 mm or less, predation by fish is considered to be intense (Mills *et al*. 1987, Johannsson *et al*. 1999). For this analysis data from stations 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 were included.

6.0 Lakewide Round Goby Distribution

Round goby (*Neogobius melanostomus*), were first discovered in the St. Clair River in 1990, and became established in the central basin of Lake Erie in 1994. In the past, the Forage Task Group has provided annual maps chronicling the spread of round goby throughout Lake Erie. Round goby have become established in all areas of Lake Erie. They are routinely caught in bottom trawl surveys and are common items in predator diet samples. Round goby are now treated as a regular forage species and abundance information is reported in section 2.0, *Status and Trends of Forage Species.* Please refer to previous Forage Task Group reports for information on the yearly spread and distribution of round goby in Lake Erie prior to 2006.

7.0 ***Hemimysis anomala*** (T. MacDougal and 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 *Hemimysis 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 HA was established and broadly distributed within the Great Lakes at this point. (NOAA- GLERL; *Hemimysis* fact sheet, February 2007).

Occurrence in Fish Diets

Hemimysis anomala have been observed in the diets of a limited number of Lake Erie fish species. First observed in white perch in 2006 in Long Point Bay, they had also been observed in the stomachs of rock bass and, less frequently, yellow perch in the western basin waters by 2009 (Figure 7.0.1). In 2010 they were found for the first time in white bass and walleye (the walleye also contained a rainbow smelt offering a secondary possible source). 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 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 hemimysis by fish in all three basins (Figure 7.0.1). It should be noted that not all fish species are examined in all three surveys and that the number of individual fish examined varies between surveys and years. However, this data gives us a general picture of spatial difference and trend over time (within surveys).

Diet analysis from a gillnet index fishing program in Long Point Bay on the north shore of the eastern basin provides some idea of changes in species use since 2006. To date, the primary and most consistent consumer of *H. anomala* is white perch, which has proportionally increased from 3% in 2006 to 14% in 2009. In 2011, white perch continued to be the primary consumer of *H. anomala* in this survey, occurring in 6% of white perch examined (Figure 7.0.2). Rock bass are the second most consistent consumer, being found in 1-3% of examined individuals in 2007-2011 (but not in 2006 or 2010). *H. anomala* have not been observed in any yellow perch from Long Point Bay over the same time period, during which 2764 stomachs were examined.

Conversely, yellow perch were the first known consumers of *Hemimysis anomala* reported 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 surveys), and is the first observation from offshore waters. This suggests that the islands of the western basin likely also harbor this mysid. In 2011, hemimysis was observed in four yellow perch and one white perch in the western basin at locations including Michigan waters, the most western reports to date. Occurrences of *H. anomala* in white perch have been observed in all three basins, with proportions of fish consuming *H. anomala* increasing from west (0.40%) to central (0.99%) to east (5.86%). Occurrences of H. anomala in yellow perch are confined to the central and west where they have been found, respectively in 0.23% and 0.53% of the stomachs examined.

By way of comparison, *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). No Lake Ontario white perch consumed *H. anomala*, although the number examined was small (n=4).

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). Their preference for rocky substrate is also apparent from catches in survey gill nets from Long Point Bay (Figure 7.0.3).

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.). In 2010 these same traps were deployed in association with a subset of the Long Point Bay index gillnets in an attempt to better understand relationships between *H. anomala* abundance, substrate type, presence of fish and consumption by fish. Unfortunately, although *H. anomala* consuming fish were caught, few (n=2) free-swimming *Hemimysis anomala* were trapped. 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.) (Figure 7.0.1).

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 HA 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 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.

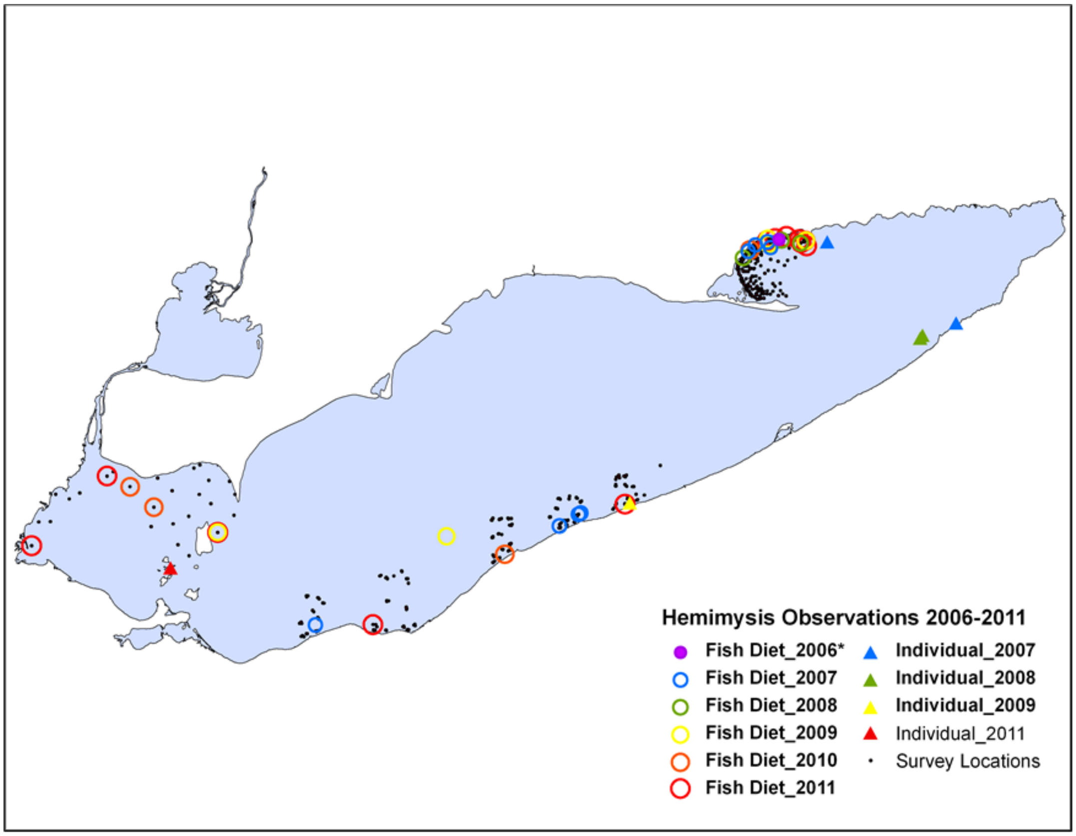

Figure 7.0.1. Distribution of *Hemimysis anomala* observations in Lake Erie, 2006-2011. Survey locations indicate where diet analysis occurs.

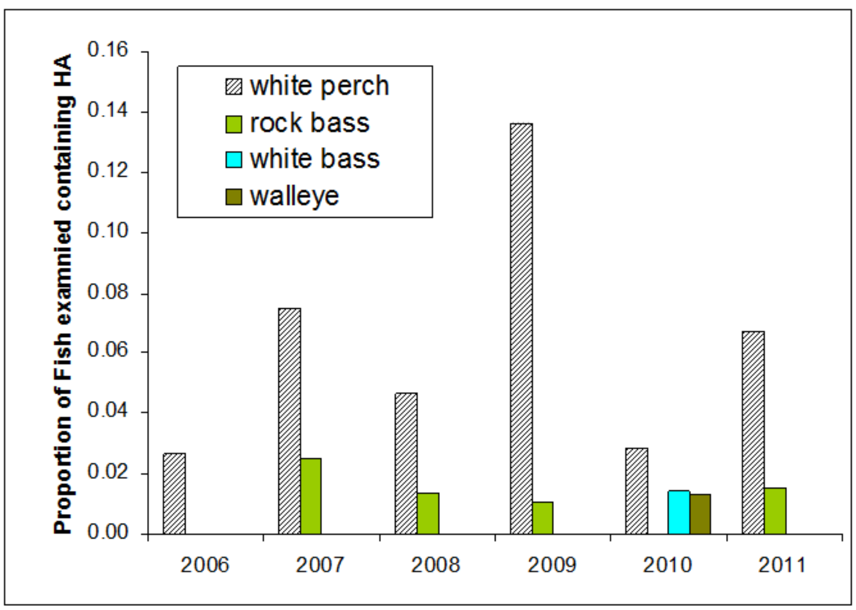

Figure 7.0.2 Occurrence of *Hemimysis anomala* in the diets of four fish species (proportion of fish stomachs examined) captured in by gillnet in Long Point Bay, Ontario,2006 – 2011.

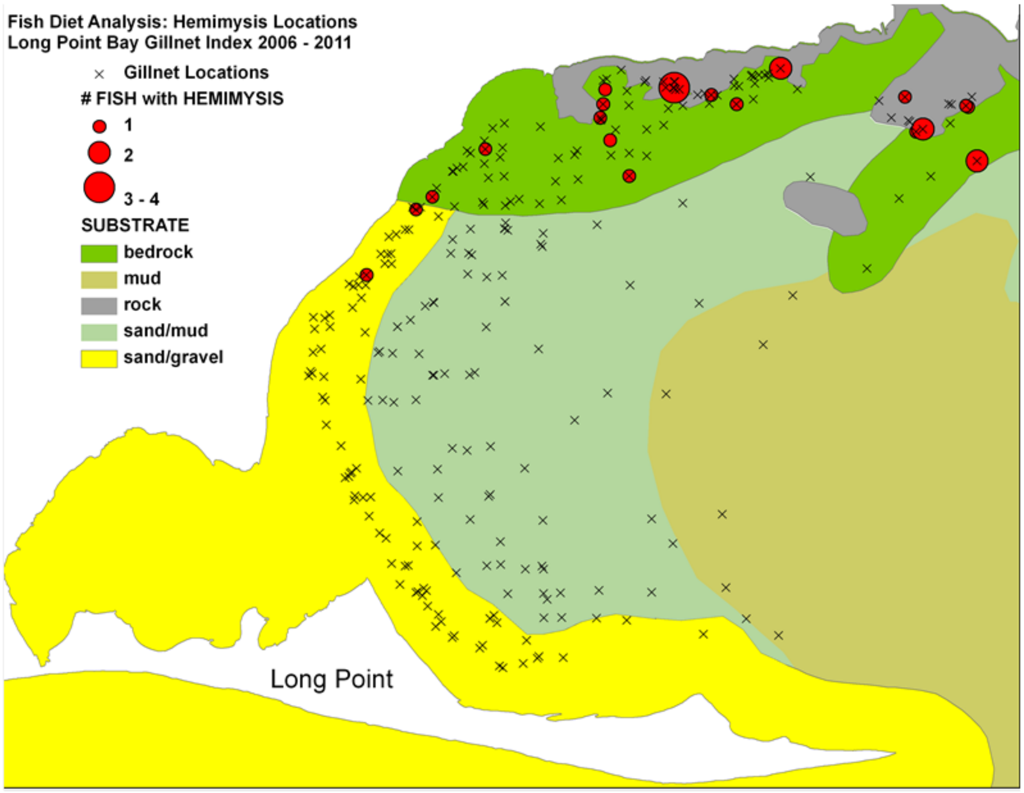

Figure 7.0.3. Distribution and occurrence of *Hemimysis anomala* observed in fish diets in a gillnet survey in Long Point Bay, Lake Erie, 2006 – 2011.

8.0 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.

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