Report of the Lake Erie Forage Task Group

March 2002

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Presented to:

Standing Technical Committee
Lake Erie Committee
Great Lakes Fishery Commission

1.0 Charges to the Forage Task Group in 2001-2002

The Forage Task Group (FTG) addressed five major charges from the Lake Erie Committee (LEC) during the 2001-2002 work year:

1) Continue to describe the status and trends of forage fish species and invertebrates in 2000 for each basin of Lake Erie (section **2.0**).

2) Continue the development of an experimental design to facilitate forage fish assessment and standardized interagency reporting (section **3.0**).

   a) Support the use of SCANMAR equipment for interagency calibration of assessment trawl gear. Continue the development of an experimental design to facilitate forage assessment (section **3.1**).

   b) Complete statistical evaluation of species CPE indices and effects upon sampling from physical and environmental features (section **3.2**).

   c) Trawl Comparison Workshop, information on trawl calibration techniques and analysis. (section **3.3**).

3) Conduct bioenergetics simulations to estimate consumption of smelt and other prey fish by predators in Lake Erie (section **4.0**).

4) Continue the fisheries acoustics program to assess pelagic forage fish stocks in the eastern basin. Continue pilot survey investigations using the Lake Erie acoustic system in the central and western basins of Lake Erie (section **5.0**).

   a) Analysis of the eastern basin interagency hydroacoustic survey (section **5.1**).

   b) Continue pilot survey investigations using Lake Erie acoustic system in the central basin of Lake Erie (section **5.2**).

5) Continue the interagency lower-trophic monitoring program that produces annual indices of trophic conditions which can be included with the FTG's annual description of forage status (section **6.0**).

The bracketed numbers printed above in bold face, indicate the subsection where progress on a particular charge is reported in this document.

2.0 Forage Task Group Bullet Statements

Eastern Basin (by L. Witzel, D. Einhouse, J. Markham and C. Murray)

- Rainbow smelt are the principal forage fish species of piscivores in the offshore waters of eastern Lake Erie (Table 2.1). Yearling-and-older (YAO) smelt (predominately age-1) have demonstrated a conspicuous alternate year cycle of increased abundance as evidenced in index bottom trawl surveys conducted annually by OMNR and NYS DEC. In the absence of an abundant yearling cohort of smelt, YOY smelt have remained as the most abundant forage fish component. Yearling smelt abundance was expected to increase during 2001 based on the alternate year pattern of abundance. Trawl collections by NYS DEC in 2001 indicated only a modest increase in abundance of age-1 smelt relative to other alternate year abundant cohorts. Whereas, OMNR survey data show a slightly more improved picture of yearling smelt abundance in 2001. OMNR survey data indicate that the 2001-year class of smelt was one of the strongest observed in the last 10 years. While the mean length of Age 0 smelt decreased in 2001, growth rate of this cohort was near the long-term average (Figure 2.1). Average length of yearling smelt caught during the 2001 OMNR index trawl survey was the highest observed in since 1992.

- Several other species made significant contributions to the forage fish community of eastern Lake Erie in 2001. Most notable of these were gizzard shad, alewife, white bass, trout-perch, emerald shiner, and round goby. YOY recruitment in many of these species was at or near record levels in 2001 compared to the previous 10 to 15 years. Trout-perch continued to be a prominent component of the benthic fish community in southern regions of eastern Lake Erie, but remained conspicuously sparse throughout the Long Point Bay area. Round gobies emerged as a new species among the eastern basin forage fish community during the late 90's. Gobies continued to increase in density at a rapid rate during 2001 to become the most or second most numerically abundant species caught in agency index trawl gear across areas surveyed in eastern Lake Erie.

- During 2001, the USFWS, NYS DEC, and OMNR continued to participate in the eastern basin component of the lake-wide inter-agency Lower Trophic Level Assessment program coordinated through the Forage Task Group. These data have been analyzed and incorporated in the 2001 Forage Task Group database.

- Examination of angler-caught adult walleyes revealed that rainbow smelt have remained the dominant prey of walleyes during the summer. Diet analysis of lake trout and burbot caught during experimental gill net surveys in the eastern basin of Lake Erie, August 2001, revealed diets of 90 % fish in both species. Smelt comprised 99 % of the fish consumed by lake trout and 70 % by burbot. Round gobies were absent in lake trout stomachs, but were a significant (22 %) portion of the diet for burbot.

- Age-2 and age-3 smallmouth bass cohorts sampled in autumn gill net collections were both longer than average for New York's 21-year time series. Age-3 smallmouth bass in 2001 were also the longest ever observed in the entire 21-year time series, exceeding previous highs established in 2000 and 1999, respectively. The 2001 walleye sample was comprised of only a few age-2 individuals, nevertheless it continued a trend of increased age-2 length-at-age observed for walleyes since 1999. Long-term average lake trout growth from three time periods (1986 – 1990, 1991 – 1995, 1996 – 2000) indicate that growth has been consistent to slightly increasing since sampling began in 1985. The majority of the growth occurs by age 10, with fish reaching around 800 mm TL and weighing 6,000 g.

Central Basin (by J. Deller, T. Johnson, and C. Murray)

- In the central basin, overall forage abundance was similar to 2000, down from the previous two years (Table 2.2; 2.3). Young-of-the-year fish comprised the majority of the forage base in both Ohio and Pennsylvania in 2001. In the Pennsylvania waters of the central basin, young-of-the-year smelt and emerald shiners increased from 2000, while an opposite trend occurred in Ohio waters with Clupeid, emerald shiners and rainbow smelt decreasing from 2000. The dramatic decline in smelt and emerald shiners may be in part due to Eastern Ohio trawl stations that were missed due to rough weather conditions. White bass, white perch, and yellow perch had the highest abundance per hectare in the Ohio waters and increased dramatically over 2000. A similar trend for yellow perch occurred in Pennsylvania during 2001. In 2001, the forage base in Ohio was dominated by benthic species (round goby, yellow perch and white perch). The abundance of young-of-the-year walleye increased in Ohio waters of the central basin and is the highest since 1996.

- In the Pennsylvania waters of the central basin, young-of-the-year round goby indices increased to almost twice that seen in 2000. An opposite trend occurred in the Ohio waters where the young-of-year indices decreased to half the numbers seen in 2000. Yearling-and-older indices appear to be stabilizing in the Ohio waters of the central basin, with 2001 abundance slightly higher than in 2000. In the Pennsylvania waters of the central basin, yearling-and-older indices decreased dramatically from 2000, the highest abundance recorded during the time series.

- Walleye diets in the fall have been primarily rainbow smelt, shiners, and clupeids since 1997 (Figure 2.2). Round goby were consumed by walleye in the spring and summer, but were not present in the fall adult diets in the Ohio waters of the central basin. White perch and clupeids increased in walleye diets relative to the past four years. The fall yellow perch diets continue to be primarily *Bythotrephes cederstroemi* and round goby. White perch diets were mostly *B. cederstroemi* (71%) and round goby (12%) by weight. Round goby were significant diet items in smallmouth, yellow perch, white bass, catfish and white perch (Figure 2.3).

- Alewife and emerald shiner mean size increased dramatically over 2000, to some of the largest sizes in the time series. The mean lengths of walleye (age 1+ and age 2+) and yellow perch (age 2+) were also some of the largest in the 1990's.

- Lower trophic level sampling was conducted at eight sites in the central basin. Due to weather and schedule conflicts, only eight samples (four days) were collected in the Ohio waters of the central basin. Preliminary results in the Ohio waters indicate total phosphorous levels decreased from 2000, especially at the nearshore sites. Chlorophyll *a* levels at the nearshore sites decreased dramatically from 2000, while the offshore sites remained similar. At this time, remaining zooplankton and phytoplankton samples are being processed and data will be included in future reports as analyses are completed.

Western Basin (by T. Johnson, J. Tyson and M. Thomas)

- Total phosphorus at stations in the western basin was similar to levels seen in 1999, and lower than those seen in 2000 with a late peak in September. Chlorophyll *a* levels were higher than those seen in 1999 or 2000 and were seasonally variable. Zooplankton densities were similar to those seen in 1999 and 2000 at the offshore station and slightly higher at the inshore station. The non-indigenous zooplankter, *Cercopagis pengoi,* was collected in the western basin at the Lower Trophic Sampling Station 3 (Figure 6.1) on two occasions in 2001. One individual was collected on August 8 and 6 individuals were collected on September 6.

- Overall forage fish catches were similar to or slightly higher than those in 2000, owing primarily to good catches of gizzard shad (primarily in Ontario waters), spottail shiners, white perch and freshwater drum (Figures 2.4 and 2.5). Total forage fish abundance continues to be below long-term averages due primarily to lower white perch abundance. Good year-classes of both walleye and yellow perch were produced in 2001. Abundance of all age-classes of rainbow smelt was low.

- Round goby abundance remained the same or decreased slightly in 2001, as compared to 2000 in western Lake Erie, but increased 4-fold in Lake St. Clair (Figure 2.6). Increased predation on gobies by numerous fish species may limit their abundance in the western basin to well below densities seen in the central basin during their expansion there.

- Mean length of age-0 percids was similar to or slightly higher than in 2000. Mean length of adult percids was higher than that seen in 2000, with the age-2 walleye lengths and weights being the highest on record.

- Fall walleye diets were comprised primarily of gizzard shad and alewife in the west basin, with higher contribution from emerald shiners in the west-central basin. Round gobies continue to contribute to walleye diets, but were found at a much lower frequency. *Hexagenia* continued to be an important component of yellow perch and white perch diets in both August and October,

  2001. Gobies and gizzard shad were the two most important prey fish in yellow perch and white perch diets. Zooplankton contributed very little to both yellow perch and white perch diets.

Lake St. Clair (by M. Thomas)

- Overall, forage fish density was higher in 2001 than in any previous year of the survey. In fact, densities for all functional prey groups were higher than any previously observed in the time period. The reason for the increased forage fish densities in 2001 are unclear.

- The soft-rayed functional forage group has consistently been the largest component of the forage base each year. In 2001, trout-perch and spottail shiners were the dominant species in the soft-rayed functional forage group.

- Alewife accounted for about 60% of the clupeid density. Gizzard shad densities were the highest observed for the time series.

- Round goby densities were the highest observed for the time period. The mean total length of round gobies in Lake St. Clair September trawls was 83 mm, with a size range from 67mm to 115 mm. Round gobies over 120 mm are uncommon in Lake St. Clair. This truncated length distribution is believed to be a result of heavy predation pressure due to the high densities of predators in the lake.

- Lake St. Clair smallmouth bass stomachs examined in 2001 contained mayflies, crayfish, and at least eight different species of forage fish. Round gobies accounted for the largest portion of the smallmouth bass diet. Walleye stomachs contained a less diverse diet, but also included the exotic round goby. Yellow perch were the largest contributor to the walleye diet, accounting for 61% of the total wet weight.

- Lower trophic sampling was conducted at two sites in Lake St. Clair. Samples were collected on 11 dates between May and September. Mean total phosphorous was 0.008 mg/L and mean chlorophyll a concentration was 0.675 ug/L.

3.0 Interagency Trawling Program

An ad-hoc Interagency Index Trawl Group (ITG) was formed in 1992 to review 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 (FTG) continue the work on interagency trawling issues. Progress on these charges is reported below.

3.1 Trawl Calibration (M. Bur)

Use of the SCANMAR acoustical equipment has assisted the Lake Erie management agencies in standardizing their prey fish reporting format (#/ha) by evaluating the actual fishing dimensions of all agency trawl gear. The Great Lakes Science Center (USGS-BRD) has made the SCANMAR equipment available to the Lake Erie agencies at no cost. In 2000, the USGS had the entire system re-calibrated and invested additional monies in storage containers to ensure the equipment is not damaged during transport around the Great Lakes. In 2002, Ohio is planning to use the SCANMAR equipment to measure trawl configuration aboard the new RV Explorer.

Each year demand for the SCANMAR equipment increases. Currently, the equipment is available to the Lake Erie agencies for only a couple of weeks a year, when it is not committed to other Great Lakes projects. In 2002, the Forage Task Group submitted a Coordinated Activities Program proposal to purchase a net mensuration system that would be dedicated to agencies on Lake Erie. A dedicated system would ease the scheduling conflicts with the current system, and enable agencies to collect more accurate data on bottom and midwater trawl performance. The system would also improve the quantification of ground truth operations for annual hydroacoustic surveys in the central and eastern basins.

3.2 Summary of Species CPUE Statistics

(by T. Johnson and J. Tyson)

Interagency trawling has been conducted in Ontario, Ohio and Michigan waters of the western basin of Lake Erie in August of each year since 1987. This interagency trawling program was developed to measure basin-wide recruitment of percids. More recently, the interpretation has been expanded to provide basin-wide community abundance indices, including forage fish abundance and growth. Information collected during the surveys includes length and abundance data on all species collected. A total of 62-90 standardized tows conforming to a depth-stratified (0-6m and >6m) random design are conducted annually by OMNR and ODNR throughout the western basin; results of 67 trawls were used in the analyses in 2001 (Figure 3.1).

In 1992, the ITG recommended that the FTG review it's 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 between agencies. In 1992, in response to the ITG recommendation, the FTG began the standardization and calibration of trawling procedures between 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.

The FTG recognizes the increasing interest in using information from this bottom trawling program to express abundance and distribution of the entire prey fish community of the western basin. Preliminary survey work by OMNR in 1999 demonstrated the potential to underestimate the abundance of pelagic fishes (principally clupeids and cyprinids) when relying solely on bottom trawls. Therefore, as part of the joint trawling exercises described in the *Trawl Comparison Exercise* section, OMNR and ODNR plan to incorporate mid-water trawls and hydroacoustics to estimate the abundance of all available fish species. These exercises are not intended to replace the bottom trawling program but rather estimate the biases in our current approach and explore alternative techniques that may supplement our current long-term program. To this end, the FTG will continue to explore the use of hydroacoustic techniques in the central and western basin of Lake Erie, recognizing the strength of this tool for pelagic fish assessment. However, the shallow depths and complex bathymetry of the western basin provide challenges to implementing a hydroacoustic program in this basin, such that other pelagic sampling techniques may be explored. Both OMNR and ODNR are committed to completing the needed standardization and comparison exercises outlined above and in the *Trawl Comparison Exercise* section below.

Presently, the FTG estimates basin-wide abundance of forage fish in the western basin using information from SCANMAR trials, total trawling distance, and catches from the August interagency trawling. Species-specific abundance estimates (#/ha or #/m^3) 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 an absolute estimate of forage fish abundance and biomass for each species. For reporting purposes, species have been pooled into three functional groups: clupeids (age-0 gizzard shad and alewife), soft-rayed fish (rainbow smelt, emerald and spottail shiners, other cyprinids, silver chub, trout-perch, and round gobies), and spiny-rayed fish (age-0 for each of white perch, white bass, yellow perch, walleye and freshwater drum). However, basin-wide absolute estimates must be viewed with respect to gear and extrapolation biases stated above.

Total forage abundance and biomass increased in the western basin in 2001, relative to 2000 owing primarily to increased catches of clupeids and spiny-rayed fishes in Ontario waters. Spiny-rayed fishes were the dominant prey group collected in 2001 bottom trawls, followed by clupeids, then soft-rayed fishes (Figure 3.2 to 3.4). The large contribution of clupeids from Ohio relative to Ontario is most likely an artifact of extrapolation. Ohio samples are more evenly distributed between depth strata, whereas Ontario samples are still more heavily weighted towards the 6-12 m strata. The increase in the biomass of soft-rayed fishes was primarily a function of an increase in spottail shiner catches at shallow sample locations in Ontario. Changes in biomass for the other functional forage groups were proportional to those seen in abundance (Figure 3.5 to 3.7). Walleye and yellow perch year-classes were above average, while gizzard shad, white perch, white bass, and freshwater drum both experienced large increases in age-0 production.

Spatial maps of forage distribution were constructed using site-specific catches (#/ha) of the functional groups. Abundance contours were generated using inverse distance to power contouring techniques to interpolate abundance between trawl locations. Abundance of clupeids was highest in the north central portion of the basin, a pattern seen in previous years (Figure 3.8a). Very high abundance of gizzard shad occurred offshore from Cedar Creek, Ontario and extended southward to the Bass Islands. Soft-rayed fish (predominantly spottail shiners and trout-perch) were most abundant in the northwest portion of the basin (Figure 3.8b). This pattern similar to that seen in 2000. Spiny-rayed abundance was predominately age-0 white perch and white bass. Peak abundance was seen in the southeast portion of the basin (Figure 3.8c), a pattern similar to that seen in previous years. Total forage abundance averaged 4,850 fish/ha across the western basin, with average clupeids averaging 1,800 fish/ha, soft-rayed fishes averaging 350 fish/ha, and spiny-rayed fishes averaging 2,700 fish/ha (Figure 3.8d).

3.3 Trawl Comparison Exercise (by J. Tyson and T. Johnson)

One of the strengths of the interagency reporting format is that the distribution and abundance of fishes can be represented across the entire basin, irrespective of jurisdictional boundaries that have no influence on fish behavior. However, differences in trawl design, vessel operation, sample processing and interpretation of data can confound the pooling of the data. The SCANMAR exercise has provided a means to calibrate each agency trawl to it's true fishing configuration (height and width of mouth opening); but does not address other potential differences between agency trawling programs. The procedures for addressing these issues were outlined at a workshop conducted in August 2000 by the Forage Task Group, in conjunction with the Ohio Chapter of the American Fisheries Society. Results of the workshop were reported in the 2000 Forage Task Group Report.

Due to logistic constraints, the comparative trawling experiment was not completed in 2001 as scheduled. Therefore, comparative trawling has been tentatively rescheduled for the week of September 9^{th}-14^{th}, 2002 at a location in the western basin.

4.0 Bioenergetics Modeling of Predator Consumption

(T. Johnson, D. Einhouse, J. Markham, L. Witzel)

The bioenergetics sub-group completed the bioenergetics analyses of consumption by walleye in 2001. Limitations with data describing critical population parameters and diet prevented us from including lake trout, burbot and steelhead in the current analyses. The walleye simulations were developed for the entire lake (all three basins) and covered the time period from 1980 through 2000. A modified version of the Walleye Task Group population model provided year and age-specific abundance and mortality for ages 1 through 12+ for all years. Annual differences in size-at-age and water temperature were incorporated into the simulations to more accurately represent inter-annual variation in consumption. We developed an algorithm to describe the inter-basin migratory behavior of walleye, enabling us to incorporate spatial differences in diet, growth rates and water temperature. Energy density (J/g) of walleye and their prey was assumed constant across basins and years. A more detailed description of the configuration of the bioenergetic simulations will be available in a stand-alone document in June 2002.

Overall, walleye consumption (tons fish / year) ranged between 29,139 tons in 2000 and 104,135 tons in 1987, tracking the general trend in walleye abundance (Figure 4.1). In most years, consumption was highest in the west basin and lowest in the east basin. Rainbow smelt were the dominant prey item consumed by walleye in both the east and central basin, while clupeids were the dominant prey in the west basin (Figure 4.2).

We compared our estimates of walleye consumption against the estimated standing stock of prey fish in the east and west basins. In the east basin, walleye consumption accounted for 19 to 74% of the estimated smelt yearling-and-older smelt biomass between 1994 and 2000 (the only period where prey biomass data are available, see Section 5.1, Figure 4.3). Note that no other predators (i.e. lake trout, burbot, and steelhead) are currently included in the analyses. In the west basin, walleye consumption accounted for 40 to >100% of the estimated prey biomass between 1988 and 2000 (for a description of the interagency trawl program see Section 3.2, Figure 4.4). The years where consumption exceeds the standing stock should not be viewed as errors, but rather one must recognize that the consumption estimate is for the entire year, and the standing stock estimates are available only for one point (July or August) by which time much of the annual consumption has already occurred. In addition, measures for both walleye consumption and prey fish biomass contain several assumptions that influence results. Nevertheless, these estimates indicate potential overshoots that suggest very intense predation may occur on the available prey fish.

As improved data become available for other predatory fish (lake trout, burbot, steelhead, smallmouth bass) we expect to complete similar analyses of their lakewide predatory demand. Once all major predators are included in the analyses, we will be able to evaluate constraints to growth and production of piscivores in Lake Erie and make recommendations in terms of management actions (exploitation of prey, stocking of predators) and the effects of ecological change (non-indigenous species, climate change, etc.).

5.0 Acoustic Survey Program

(by D. Einhouse, J. Markham, L. Witzel, and C. Murray)

Introduction

Since 1993, the Forage Task Group has used a fisheries acoustic system as an additional tool to assess forage fish stocks in eastern Lake Erie. These fisheries acoustic surveys have been conducted annually from 1993 to 2001. The 1993 to 1996 surveys were principally summertime efforts using the New York State Department of Environmental Conservation’s 70-kHz single beam echosounder (Simrad EY-M, 7024 transducer). Since 1996, acoustic survey efforts have used a modern 120-kHz split-beam system (Simrad EY-500) that was jointly purchased by the Lake Erie Committee member agencies and the Great Lakes Fishery Commission. The 1998 and 1999 survey used this split-beam system for the ongoing July survey, as well as, basin wide surveys in spring (June) and fall (October) in the eastern basin. After 1999, only the long term July acoustic survey was continued to monitor pelagic forage fish density and distribution in eastern Lake Erie. During August 2000 and 2001, additional survey transects were sampled in the central basin of Lake Erie as a new initiative. The 2001 data collection was coordinated among Forage Task Group member agencies with three research vessels (Argo, Erie Explorer, Kennosay and Perca) participating in various aspects of the data collection and calibration.

Methods

The 120 kHz split beam echo sounder was calibrated at the beginning of the July 2001 eastern basin survey. Acoustic signals are annually processed/analyzed using the EY500/EP500 analysis software (version 5.3, Simrad 1996). This software calculates total volume back scattering strength and single fish target strength (TS) simultaneously by applying 20 and 40 log R TVG functions. Fish densities within -3 dB TS bins were calculated by apportioning the volume back scattering strength to the proportion of single fish echos within each target strength bin. From these split beam data, we selected a subset TS range of -55 dB to -43 dB as an index of (YAO) pelagic forage fish (~ > 50 mm). We believe this acoustic size range is also comparable to a length range for adult-sized forage fish, fully vulnerable to agency trawling programs during summer. We used a -56 dB to -44 dB TS range from the earlier (1994-96) single beam surveys for contrasting pelagic forage fish abundance across the entire time series. Rudstam et al. (1999) found the Simrad EY-M single beam system used prior to 1997 produced similar, but not identical results, in describing target strength and fish density relative to the modern split beam acoustic systems. Although Rudstam et al. (1999) suggested single beam density estimates are 85 to 95% lower than those produced from split beam systems, we have not yet applied any scaling factor for comparing 1993-96 single beam and subsequent split beam results.

Data acquisition throughout the 2001 acoustic survey efforts occurred at night with vessel speeds between 5.0 and 6.0 knots with a transducer affixed to the hull of the acoustic survey vessel (*RV Erie Explorer*). Randomly selected eastern basin Lake Erie acoustic survey transects are shown in Figures 5.1 and 5.2. Acoustic data are stratified vertically by thermal layer (epilimnion, thermocline, hypolimnion), and horizontally by the area encompassed within three depth contours (15 -25 m, 25 -35 m, and >35 m). In the early years of this survey, thermal strata were identified by a temperature profile sampled approximately in the middle of each transect. However, over time it became apparent that a characteristic dense band of fish accompanied by TS distributions changing from predominately smaller to larger targets was a reliable indicator of the thermocline layer. Therefore, in surveys since 1997 we used these indirect thermocline indicators as the primary criteria for defining thermal strata

A companion mid-water trawl survey accompanied the acoustic sampling in eastern and central Lake Erie. In 2001, the eastern basin trawling was conducted aboard the *RV Argo* using a mid-water trawl with fishing dimensions of 36 m^2. The central basin, Lake Erie mid-water trawling was conducted by the *RV Kennosay*. All trawl samples were counted by species and sub-samples of each collection were measured for total length.

Results and Discussion

Analysis and discussion of the 2001 acoustic survey program has been deferred until later in 2002. At that time, the Forage Task Group plans to convene a workshop to analyze results encompassing the entire 9 year time series of the ongoing acoustic survey program. Postponing our annual reporting cycle should provide time to produce a more thorough examination of smelt abundance and distribution from 9 years of acoustic surveys to quantify forage biomass and production in eastern Lake Erie. This effort will include supplemental data collected in 1998 and 1999 that has never been included our ongoing analyses. Expanded acoustic survey efforts in 1998 and 1999 provided an opportunity to conduct fixed station acoustic sampling and more closely examine target strength patterns of smelt cohorts. The 1998 and 1999 surveys were also distributed seasonally, providing spring, summer and fall snapshots of changes in biomass and distribution. This information is expected to be particularly useful for understanding predator demand over the time series (see Bioenergetics Charge). This expanded analysis has been planned for several years but annual constraints on staff time have repeatedly postponed undertaking this larger analysis. Pursuing this initiative during early summer in 2002 and outside the constraints of annual reporting cycle for the Forage Task Group may afford an opportunity to complete and report this initiative as a separate paper.

Acknowledgments

The FTG is grateful to OMNR research vessel captain Gordon Ives, OMNR biologist Becky Sherman, PFBC research vessel captain Paul Atkinson, and NYS DEC staff, Douglas Zeller (research vessel captain), Richard Zimar, and Brian Beckwith (fish and wildlife technicians) for their annual contributions in support of the eastern basin acoustic survey.

Literature Cited

Rudstam, L.G., S. Hansson, T. Lindem, and D.W. Einhouse. 1999. Comparison of target strength distributions and fish densities obtained with split and single beam echo sounders. Fisheries Research 42:207-214.

6.0 Interagency Lower Trophic Level Monitoring Program

(by B. Trometer and T. Johnson)

Introduction and Methods

In 1999, the FTG agencies initiated the first year of the Lower Trophic Level Assessment program (LTLA) within Lake Erie and Lake St. Clair (Figure 6.1). 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 periods, with benthos collected on two dates, once in the spring and once in the fall. In 1999, collections were made at 18 of the 20 stations from 2 to 14 times. In 2000, collections were made at all 20 stations from 3 to 14 times. In 2001, collections were made at all 20 stations from 4 to 12 times. Sampling generally occurred on the beginning of the first week of the sampling period, but sometimes occurred in the second week.

Results for 2001

Water temperature profiles indicate that western basin stations were isothermal all year. Offshore stations (10, 11, 13) in the central basin were stratified from approximately June 25 through September 17. Offshore deep stations (16 and 18) in the eastern basin were stratified from approximately June 4 through end of September. Mean bottom dissolved oxygen for each basin was highest in May, declined through the summer, and started to recover in September after fall turnover (Figure 6.2). Low bottom dissolved oxygen (< 5 mg/L) was measured during the summer at all of the western basin stations and some central basin stations. Measurements under 5 mg/L were recorded in August at stations 3, 4, 5, and 6 in the western basin, and in August and September for stations 7, 8, 9, 10, 11 and 13.

A gradient in water transparency existed from west to east (Figure 6.3). Secchi depths were shallowest in the western basin, ranging from 0.4 and 4.5 meters, increased to 2.0 and 8.0 m in the central basin, and 2.4 and 13.0 m in the eastern basin. Lake St. Clair Secchi depths were similar to western basin Secchi depths ranging from 1.1 to 4.3 m.

A west to east gradient also existed for total phosphorus and chlorophyll *a* concentrations (Figures 6.4 and 6.5). Concentrations of both total phosphorus and chlorophyll *a* were generally lowest in the eastern basin and highest in the western basin. Chlorophyll *a* concentrations were more variable in the western and central basins than in the eastern basin. Lake St. Clair total phosphorus and chlorophyll a concentrations were similar to Lake Erie eastern basin. Phytoplankton samples were collected and archived for all stations.

Zooplankton samples were collected at all stations and benthic samples collected from 13 stations, but analysis of those samples for 2001 is incomplete. Information will be presented in this report when all the data is available.

Zooplankton Density and Biomass, 1999-2000

The majority of zooplankton collections from 1999 and 2000 have been analyzed. Monthly mean abundance and biomass are shown in Figures 6.6 and 6.7 for the 3 major zooplankton groups. Seasonal trends were similar for both years in each basin. Cyclopoid copepods were higher in abundance and biomass in the western and central basins with peaks observed in June and July in the western basin and May and June in the central basin. Calanoid copepods were lowest in biomass in the western basin, although abundance was similar in all three basins. Although calanoid copepod abundance increased seasonally to peak in August, the biomass did not show the same trend. Cladoceran abundance was greatest in the western basin and lowest in the eastern basin. Seasonal peaks in abundance and biomass were observed in June and July in all three basins.

Zooplankton analysis for 2001 collections has been completed only for stations 3 and 4. The non-indigenous zooplankter, *Cercopagis pengoi,* was found in two samples from station 3 on two occasions, 1 specimen collected on August 8 and 6 specimens collected on September 6.

7.0 Lakewide Round Goby Distribution (by B. Haas and J. Tyson)

Round goby (*Neogobius melanostomus*), first discovered in St. Clair River in 1990, became established in the central basin of Lake Erie in 1994. Because of the prolific nature of this exotic species, as well as the potential trophic and competitive impacts of the round goby, the Forage Task Group constructed distribution maps of round gobies based upon agency bottom trawling data (Figure 7.1). Round goby abundance data (#/ha) were obtained from OMNR, ODNR, PFBC, and NYSDEC bottom trawl surveys conducted from August-October of each year. A total of 1902 trawls were included in the analysis, with 186-375 sites being sampled per year across the lake. A large area in the northern half of the central basin was not sampled with bottom trawls, therefore this area was blanked out. Grid contours of goby density were generated using kriging techniques with a 300 X 300 grid density.

Round gobies were first observed at relatively low densities in the central basin of Lake Erie in 1994. However, within two years, the round goby population had increased by two orders of magnitude. Concurrent with the increases in abundance, there was also an east and westward expansion, such that the majority of the central basin had established populations of round gobies by 1996. By 1997 and 1998, round gobies were becoming well established in the western basin and western portions of the eastern basin. By 1999, with the expansion of the round goby into Long Point Bay and New York waters, all agency bottom trawl surveys had recorded round gobies.

In 1999, round goby abundance appeared to be higher in the central basin relative to other areas of Lake Erie. Round gobies comprised 10% and 95% of the total catch in Ohio and Pennsylvania bottom trawls in the central basin, respectively. Densities of round gobies ranged from 0-8000 gobies per hectare. However, bottom trawls most likely underestimate true round goby abundance because of the gobies' preference for rocky habitat that is difficult to sample. The peak abundance of round gobies in the western basin in 1999 demonstrates this. This peak was generated from a single trawl that was torn, while trawling on rocky substrate. Therefore, these site-specific density estimates should be treated as minimum estimates. Basin-wide goby abundance, however, is likely higher in the central basin due to the much higher percentage of rocky substrate in the central basin, relative to the western basin. Eastern basin abundance estimates may rival those of the central basin in the future, due to an abundance of rocky substrate and *Driessena.*

In 2000, round goby are well established in all areas of the lake that are currently being sampled. Goby populations continued to increase their range and abundance in the eastern basin of Lake Erie. In areas other than the eastern basin, goby abundances have remained the same or decreased relative to 1999. Declines are particularly noticeable in the central basin where they were originally established in 1994. In these areas, goby abundances have declined from a peak of 429/ha in 1998 to 162/ha in 2000. These declines may be due in part to increased predation by piscivores.

Initially, predators in Lakes Erie and St. Clair appeared not to utilize round goby, but now feed on them extensively in all basins, especially the west and central basins. Gobies are now common in the stomachs of yellow perch, smallmouth bass, white bass, freshwater drum, catfish and walleye. It is our opinion that round goby will continue to provide an energy and possibly a contaminant link between zebra mussels and top predators.

Round Goby densities continued to increase in the eastern portions of Lake Erie in 2001 compared to 2000. They have become one of the most abundant species in the index trawl surveys in since their expansion into the eastern basin in 1999. In Lake St. Clair, goby densities have increased dramatically, from 100 per hectare in 2000 to 449 per hectare in 2001. In the central and western areas of the lake, goby densities appear to be stabilizing, having remained the same or declined slightly compared to 2000. Round goby continue to be a large component of predator diets in all areas of lakes Erie and St. Clair.

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 received from the agency responsible for the data collection.

Table 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 in 2001 and 2000. Indicies are reported as arithmetic mean number caught per hectare (NPH) for the age groups young-of-the-year (YOY) and yearling-and-older (YAO). Long-term averages are reported as the mean of the annual trawl indices for survey years during the two previous decades (90's Avg. & 80's Avg.) . Agency trawl surveys are described below.

	Trawl	YOY				YAO			
Species	**Survey**	**2001**	**2000**	**90's Avg.**	**80's Avg.**	**2001**	**2000**	**90's Avg.**	**80's Avg.**
Smelt	ON-DW	2451.7	255.9	475.7	1382.9	701.5	29.9	405.0	969.0
	NY-Fa	2727.7	1184.7	1450.9	NA	138.3	74.4	581.6	NA
	PA-Fa	34.6	136.1	550.8	7058.1	9.2	0.0	378.0	2408.6
Emerald	ON-DW	13.1	3.2	53.6	20.5	1455.7	694.6	46.2	38.1
Shiner	ON-OB	24.0	19.9	113.0	152.3	21.5	19.9	47.7	133.3
	NY-Fa	366.7	43.6	112.4	NA	333.8	42.6	105.4	NA
	Pa-Fa	0.0	0.0	41.0	118.3	0.0	0.0	14.5	45.6
Spottail	ON-OB	46.9	1137.2	696.9	249.3	6.6	45.2	52.6	21.6
Shiner	ON-IB	9.7	2.3	113.3	292.6	1.7	0.3	2.0	9.5
	NY-Fa	40.6	0.1	19.9	NA	7.5	0.1	4.0	NA
	PA-Fa	0.0	0.0	4.0	2.0	0.0	0.0	7.9	12.4
Alewife	ON-DW	76.3	24.5	124.7	21.4	NA	NA	NA	NA
	ON-OB	0.3	16.8	60.9	51.4	NA	NA	NA	NA
	NY-Fa	16.2	214.5	52.0	NA	NA	NA	NA	NA
	PA-Fa	0.0	0.0	7.7	16.6	NA	NA	NA	NA
Gizzard	ON-DW	14.7	0.3	5.1	15.3	NA	NA	NA	NA
Shad	ON-OB	5.8	6.0	9.6	24.2	NA	NA	NA	NA
	NY-Fa	39.7	0.1	4.2	NA	NA	NA	NA	NA
	PA-Fa	0.0	0.0	0.9	74.3	NA	NA	NA	NA
White	ON-DW	6.0	0.0	2.1	5.6	NA	NA	NA	NA
Perch	ON-OB	3.9	6.1	14.1	28.7	NA	NA	NA	NA
	NY-Fa	19.3	0.7	29.4	NA	NA	NA	NA	NA
	PA-Fa	716.6	7.8	101.1	955.0	NA	NA	NA	NA
Trout [a]	ON-DW	0.0	0.0	0.1	0.5	0.0	0.0	0.5	1.9
Perch	NY-Fa	1015.3	496.7	419.6	NA	NA	NA	NA	NA
	PA-Fa	16.2	9.7	23.2	NA	12.2	0.0	26.0	NA
Round [a]	ON-DW	66.1	50.0	0.0	0.0	NA	NA	NA	NA
Goby	ON-OB	128.6	24.1	0.1	0.0	NA	NA	NA	NA
	ON-IB	111.4	18.2	0.0	0.0	NA	NA	NA	NA
	NY-Fa	383.9	247.1	28.3	0.0	191.5	35.2	3.9	0.0
	PA-Fa	2159.5	1350.6	30.3	0.0	1239.4	0.0	5.6	0.0

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

[a] Ontario (ON-) trawl indices for round goby and New York State DEC (NY-) trawl indices for trout perch reported as "all ages" under YOY.

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.

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 from 1984 to 1989; 90's Avg. is from 1990 to 1999.

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.

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.

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.

Table 2.2. Relative abundance (arithmetic mean number per hectare) of selected young-of-the-year species from fall trawl surveys in the central basin, Ohio and Pennsylvania waters of Lake Erie, from 1990-2001.

		Year												
Species	Agency	1990 [a]	1991 [a]	1992 [a]	1993 [a]	1994 [a]	1995	1996	1997	1998	1999	2000	2001	Mean
Alewife	OH	0.3	5.1	23.1	0	8.7	12.2	8.5	18.1	4.7	15.9	34.9	22.2	12.8
	PA	0	-	174	-	0	0	0	0	0	0	0	0	17.4
Gizzard	OH	38.1	4.6	9.5	3	17	1.2	92.7	13	33.9	45.2	64.4	25	29
Shad	PA	41	-	0	-	0	0	0	0	0	0	0	0	4.1
Rainbow	OH	1008.9	15.1	612.4	20.7	1045	843.7	1366.1	470	678.9	207.2	579.4	1.1	570.7
Smelt	PA	1128	-	8205	-	953	107	5422	10	30	2	15	450	1632.2
Emerald	OH	106.9	59.8	42.7	2.6	14.9	27.5	38.3	66	1822.6	365.7	291.8	22.5	238.4
Shiner	PA	366	-	34	-	0	54	4	0	6	0	0	11	47.5
Spottail	OH	0.7	0.1	0.4	5.5	8.4	1	15.1	5.8	1.3	4.1	0.2	2.5	3.7
Shiner	PA	0	-	0	-	0	20	0	0	0	1	0	0	2.1
Trout-	OH	10.1	4.7	46.2	5	0	6.6	11.2	1.1	0.8	3.7	0.5	0.7	7.5
Perch	PA	0	-	214	-	1	25	7	0	23	10	23	7	31
White	OH	1981.7	1378.3	192.8	86.6	261.3	35.9	330.7	107.5	69.7	155.4	227.4	390.3	434.8
Perch	PA	1528	-	887	-	76	136	332	0	0	8	76	31	307.4
White	OH	38.4	10.9	0.5	33.1	122.6	16.9	60.3	19.9	40.7	105.5	20.7	89.4	46.6
Bass	PA	17	-	0	-	7	4	0	0	0	0	96	16	14
Yellow	OH	35.4	6.5	34.2	12.7	48.2	6.2	112.9	6.2	55.7	39.9	9.3	73.5	36.7
Perch	PA	9	-	125	-	567	52	354	0	14	7	16	329	147.3
Round	OH	-	-	-	-	3	29.3	35.1	98.7	171.6	128.9	81.3	41.4	73.7
Goby	PA	-	-	-	-	0	0	0	1	744	1114	781	1486	515.8

[a] Fairport values have been scaled to compare with trawl equipment used prior to 1995.

Table 2.3. Relative abundance (arithmetic mean number per hectare) of selected yearling-and-older species from all trawl surveys in the central basin, Ohio and Pennsylvania waters of Lake Erie from 1990-2000.

		Year												
Species	Agency	1990 [a]	1991 [a]	1992 [a]	1993 [a]	1994 [a]	1995	1996	1997	1998	1999	2000	2001	Mean
Alewife	OH	0	0.1	0.1	0	0	0.2	0	0	0.1	0	0.7	0	0.1
	PA	0	-	61	-	0	0	0	0	0	0	0	0	6.1
Gizzard	OH	0.7	0.3	0.3	0.7	0	1.8	0	0.1	0.1	0.5	2.6	0.1	0.6
Shad	PA	1	-	0	-	0	0	0	0	0	0	0	0	0.1
Rainbow	OH	17.4	91.6	24.8	95.6	33	157.5	80.2	346.4	79	922.4	125.3	35.8	167.4
Smelt	PA	43	-	541	-	4	506	30	0	0	0	6	0	113
Emerald	OH	54.3	70.6	2.9	5.5	4.3	37.4	15.2	87.5	739.4	465.2	440.6	39.3	163.5
Shiner	PA	3	-	241	-	1	18	0	0	0	0	29	0	29.2
Spottail	OH	1.5	0.7	0.7	0.3	5.4	9	10	9	13.5	6	7.2	1.8	5.4
Shiner	PA	18	-	0	-	0	18	0	0	0	0	0	0	3.6
Trout-	OH	7	11.8	16.8	9.6	10.4	13.8	10.3	13.8	14.5	8	12.4	2.7	10.9
Perch	PA	64	-	133	-	7	53	0	0	0	0	12	0	26.9
White	OH	79.8	222.2	140.7	1.4	0.8	22.5	13.6	39.6	2.3	30.1	65.3	11.3	52.5
Perch	PA	42	-	61	-	0	2	2	0	0	1	0	0	10.8
White	OH	0.1	0	0.4	0	0	2.9	0.3	14.1	0.3	3.2	17.6	1.7	3.4
Bass	PA	5	-	0	-	3	0	0	0	0	1	1	74	8.4
Yellow	OH	19.3	14.5	20.8	21.6	6.3	47.4	29.5	63.2	34.5	49.5	63.7	23.5	32.8
Perch	PA	51	-	58	-	2	192	12	0	0	7	3	0	32.5
Round	OH	-	-	-	-	2.7	51.5	142.4	331.8	150.6	98.9	81	88.3	118.4
Goby	PA	-	-	-	-	0	0	0	0	33	0	124	17	21.8

[a] Fairport values have been scaled to compare with trawl equipment used prior to 1995.

Table 2.4 Estimated abundance (#/hectare) of functional prey fish groups in Lake St. Clair, from Michigan DNR August trawls, 1996-2001.

	Year						
	1996	1997	1998	1999	2000	2001	Mean
Clupeids	196.9	29.3	22.4	19	22.9	305.4	99.3
Soft-rayed (w/o round goby)	1621.2	1520.1	596.3	306.4	314.2	2024.8	1063.8
Spiny-rayed	401.1	159.7	203.9	87.4	58	441.4	225.3
Round goby	51.1	55	83.5	99	100.4	449.2	139.7

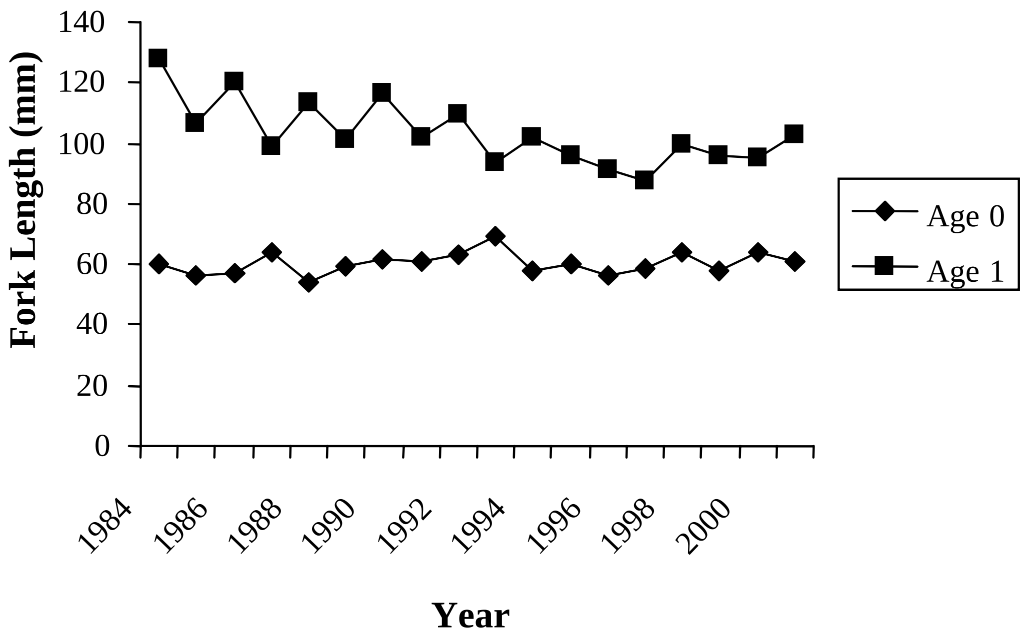

Figure 2.1 Mean fork length age 0 and age1 rainbow smelt from OMNR index trawl surveys in Long Point Bay, Lake Erie, October 1984 to 2000.

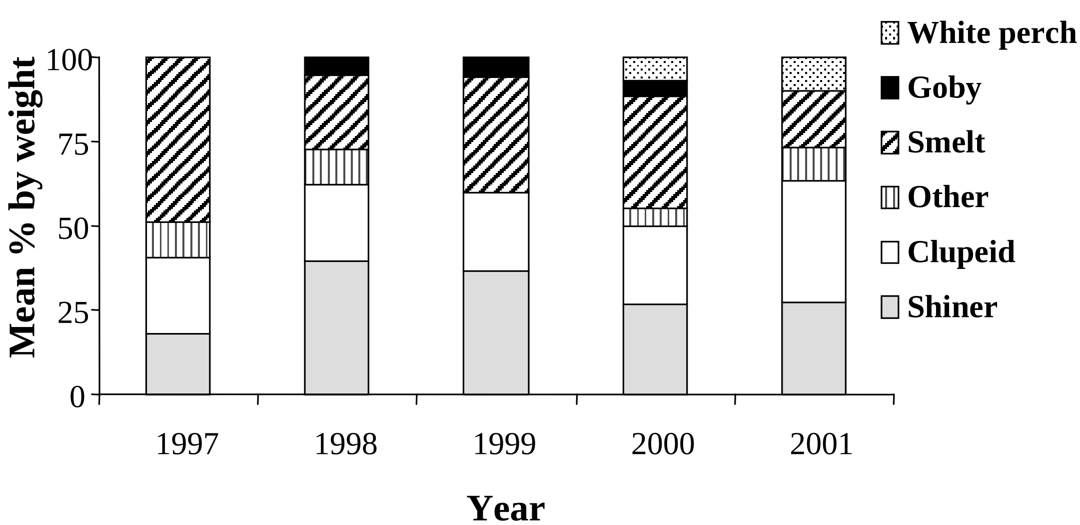

Figure 2.2 Diet composition (mean % by weight) of adult walleye from fall bottom trawl surveys in the central basin, Lake Erie, 1997-2001.

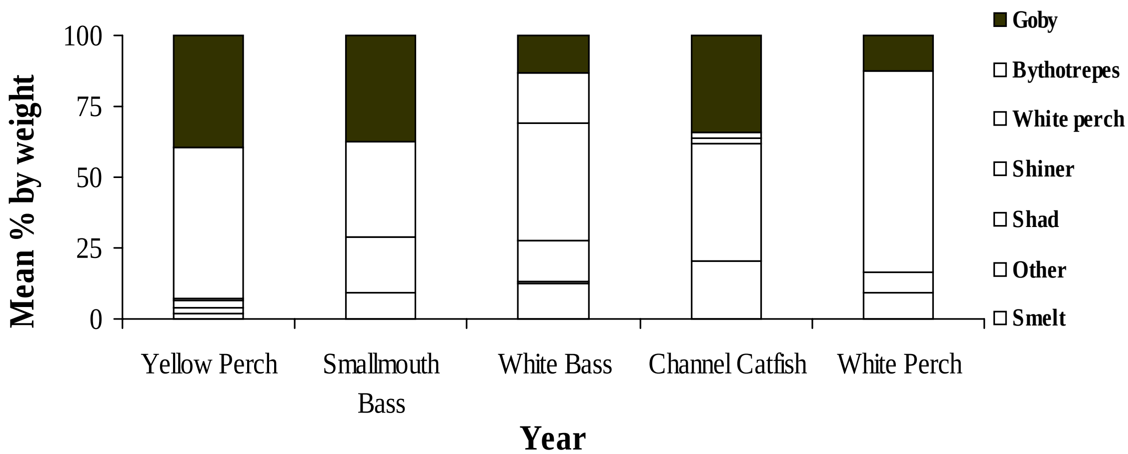

Figure 2.3 Diet composition (mean % by weight) for selected species from Ohio fall bottom trawl surveys in the central basin, Lake Erie, 2001.

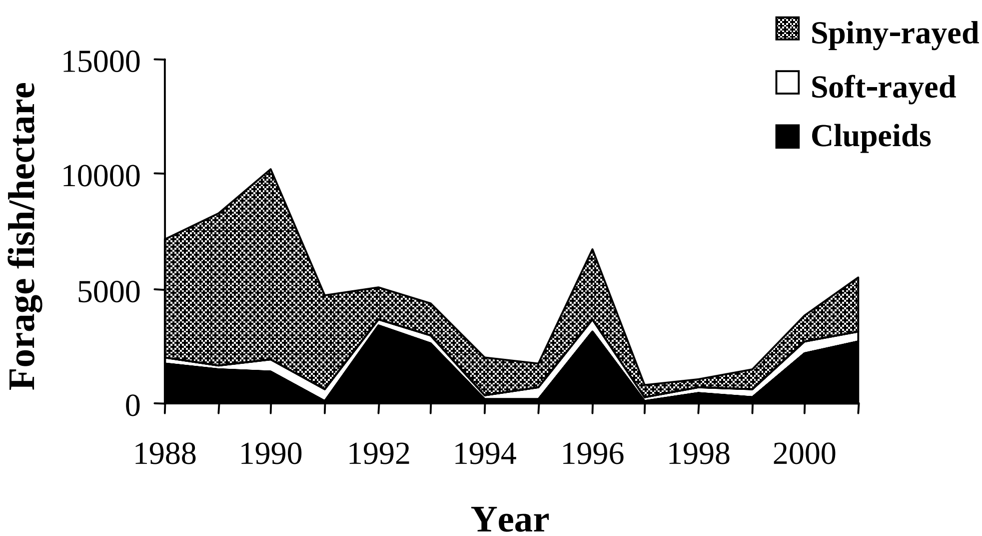

Figure 2.4. Mean abundance (#/hectare) of functional prey fish groups in Ontario waters of the western basin, Lake Erie, 1988-2001.

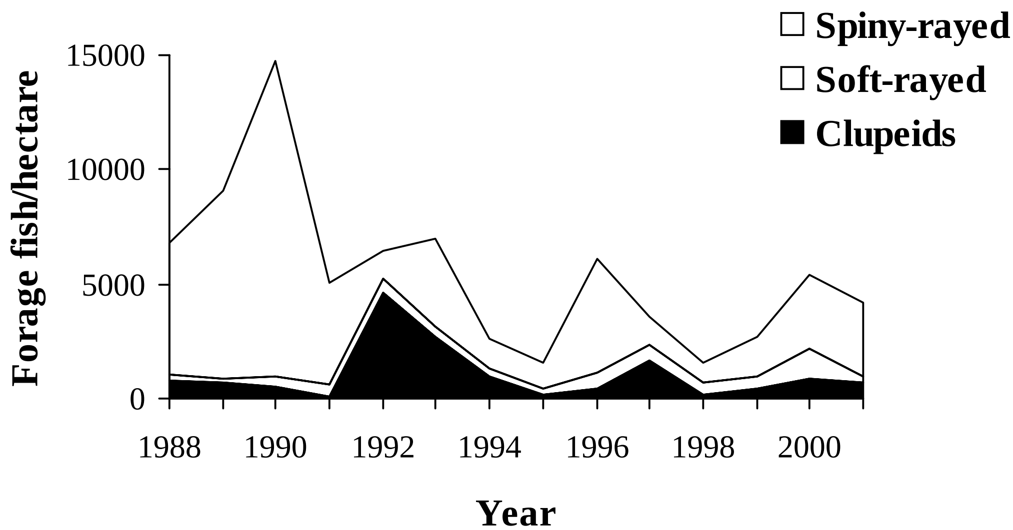

Figure 2.5. Mean abundance (#/hectare) of functional prey fish groups in Ohio waters of the western basin, Lake Erie, 1988-2001.

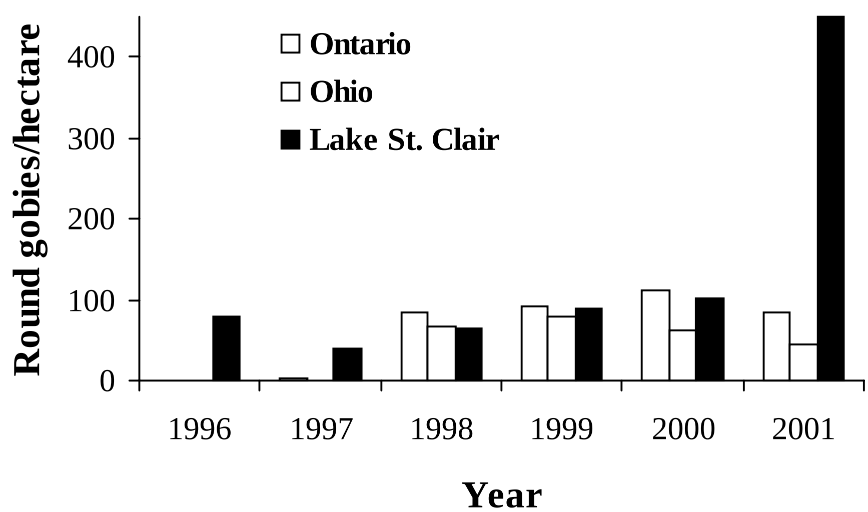

Figure 2.6. Mean abundance (#/hectare) of round gobies from August agency trawls in Lake St. Clair and the western basin of Lake Erie, 1996-2001.

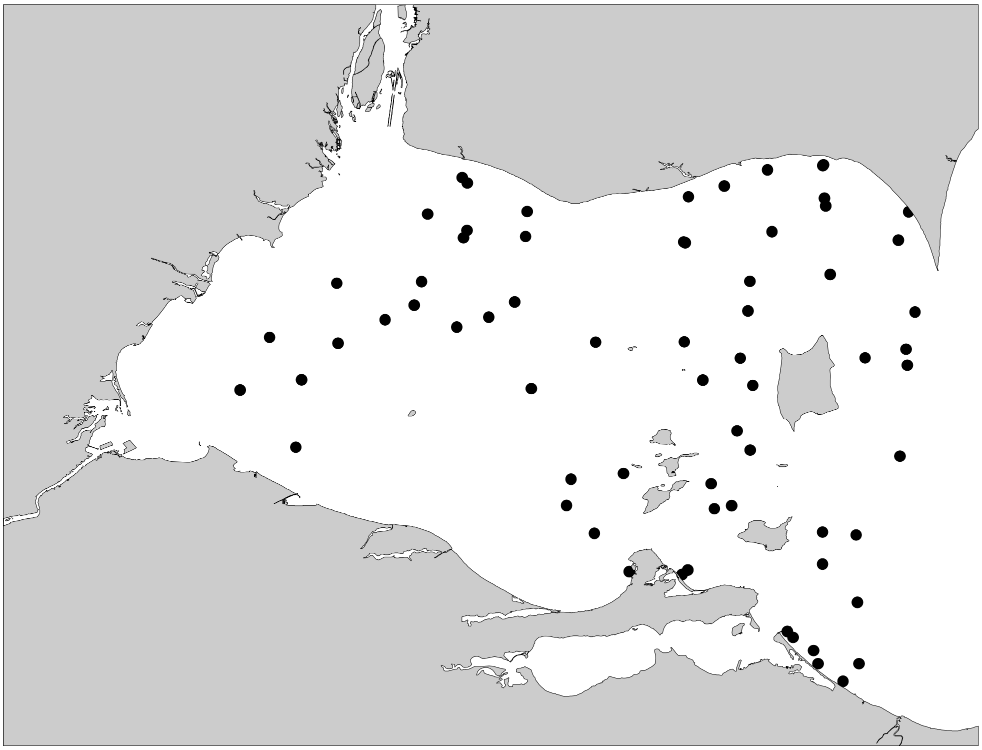

Figure 3.1. Trawl locations for western basin interagency trawl survey, August, 2001.

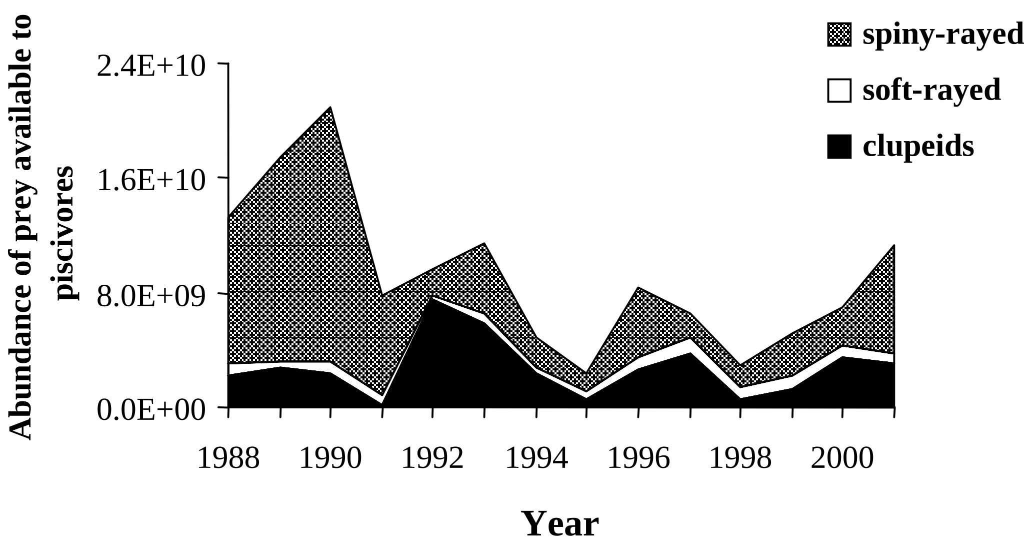

Figure 3.2. Estimated absolute abundance of prey fish by functional category in waters of the western basin, Lake Erie, 1988-2001.

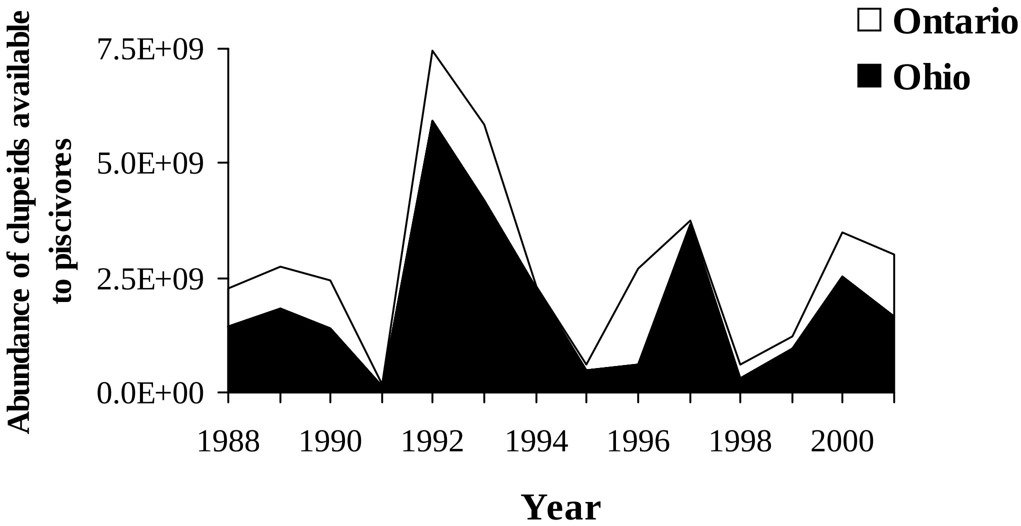

Figure 3.3. Estimated absolute abundance of clupeids in Ohio and Ontario waters of the western basin, Lake Erie, 1988-2001.

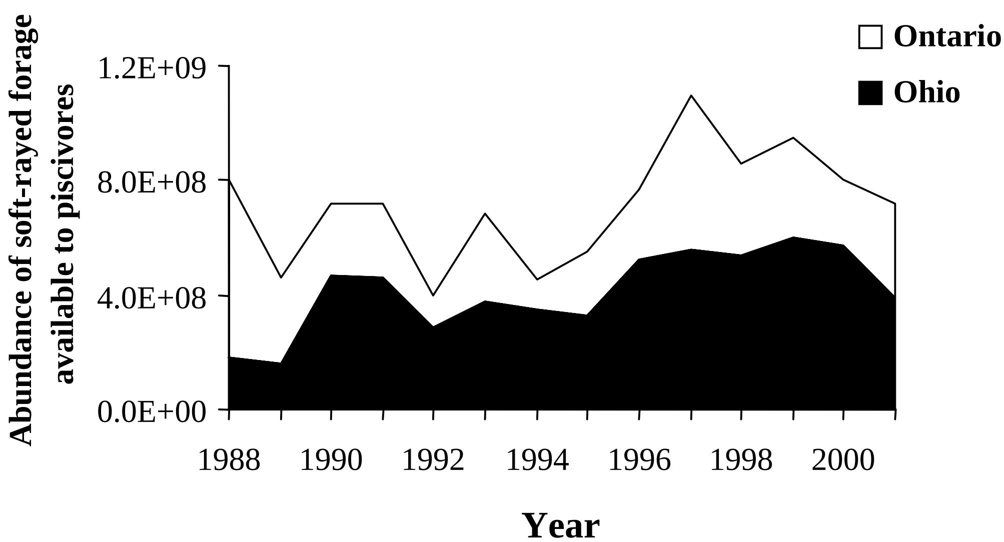

Figure 3.4. Estimated absolute abundance soft-rayed forage in Ohio and Ontario waters of the western basin, Lake Erie, 1988-2001.

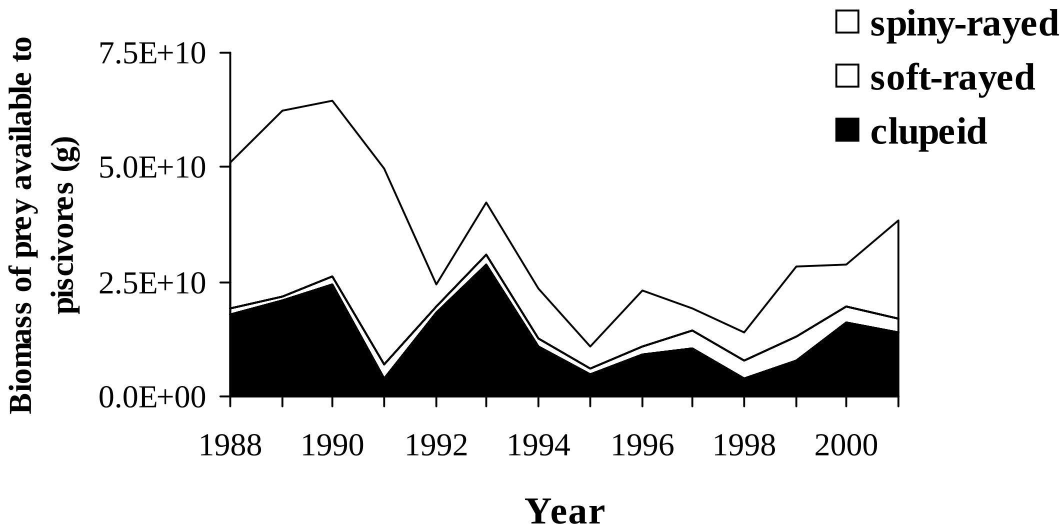

Figure 3.5. Estimated absolute biomass of prey by functional category in waters of the western basin, Lake Erie, 1988-2001.

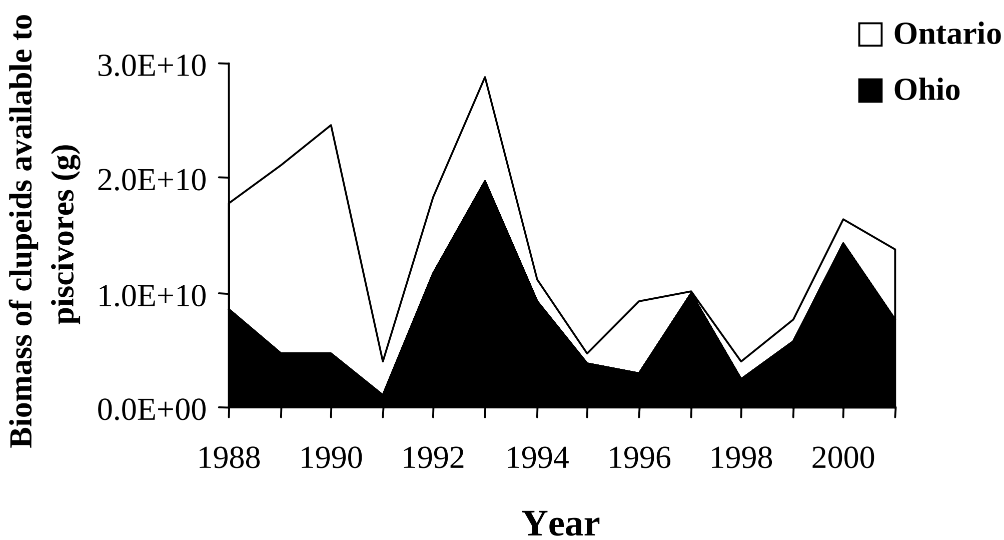

Figure 3.6. Estimated absolute biomass of clupeids in Ohio and Ontario waters of the western basin, Lake Erie, 1988-2001.

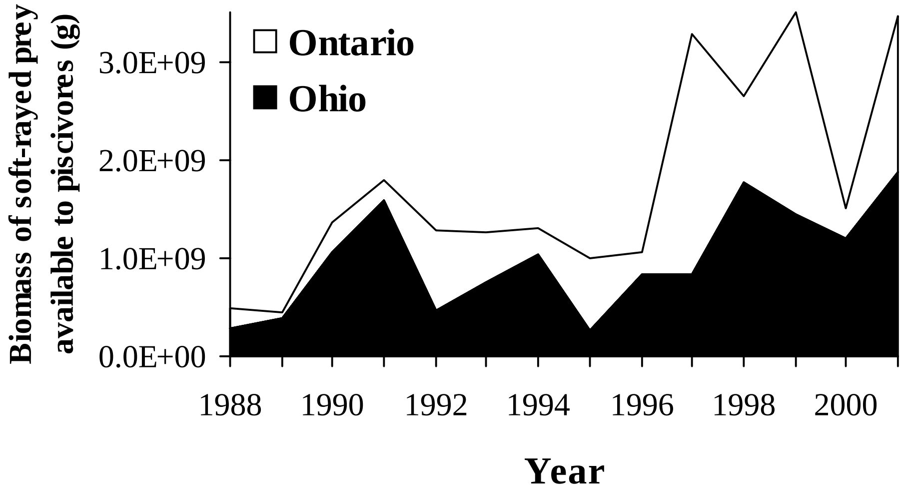

Figure 3.7. Estimated absolute biomass of soft-rayed prey in Ohio and Ontario waters of the western basin, Lake Erie, 1988-2001.

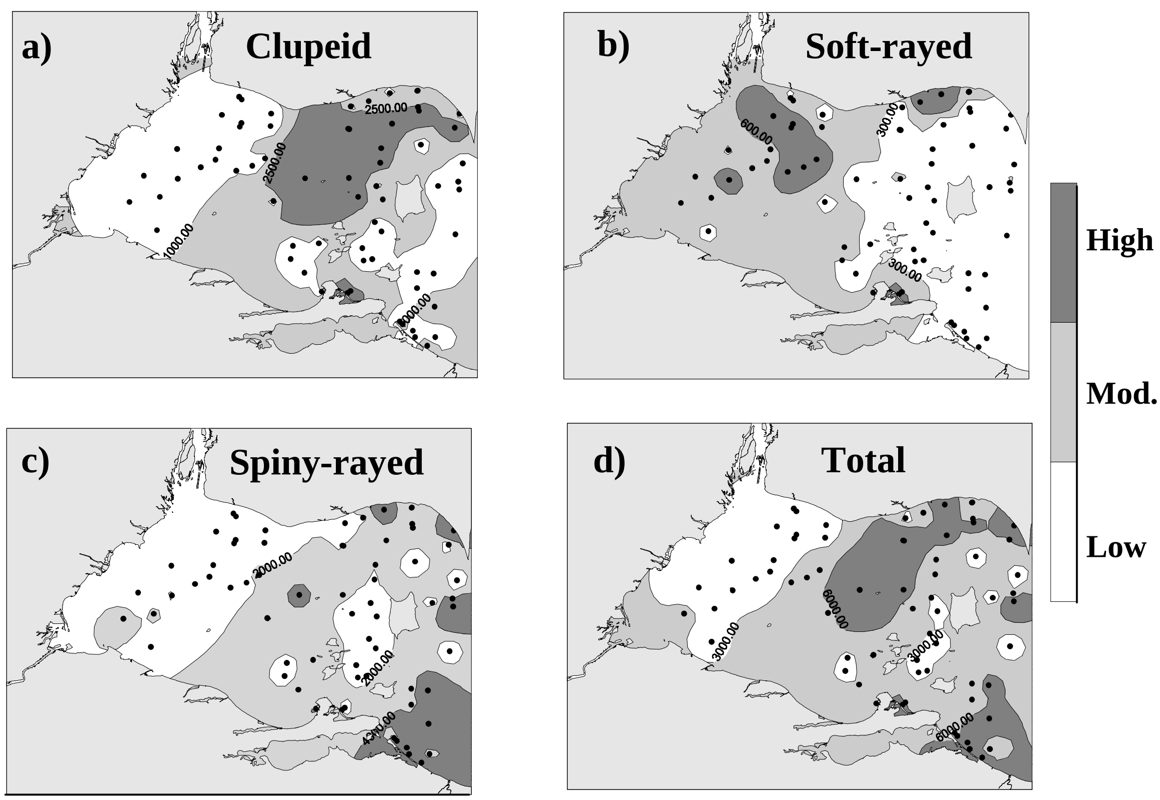

Figure 3.8. Spatial distribution of clupeids (a), soft-rayed forage (b), spiny-rayed forage (c), and total forage (d) in western basin of Lake Erie, August, 2001. Contour levels vary for each functional prey category and are noted on each figure.

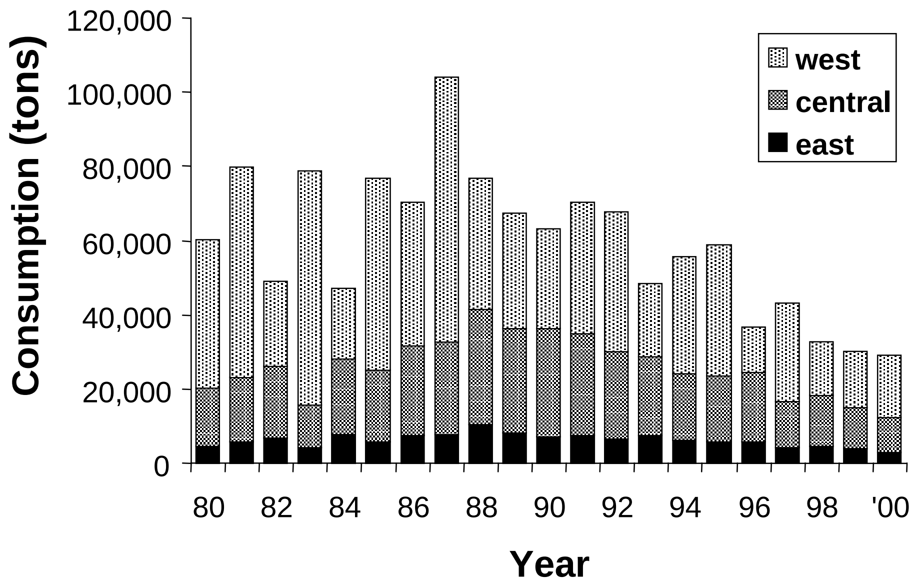

Figure 4.1 Walleye consumption of prey fish (tons/year) by basin 1980-2000.

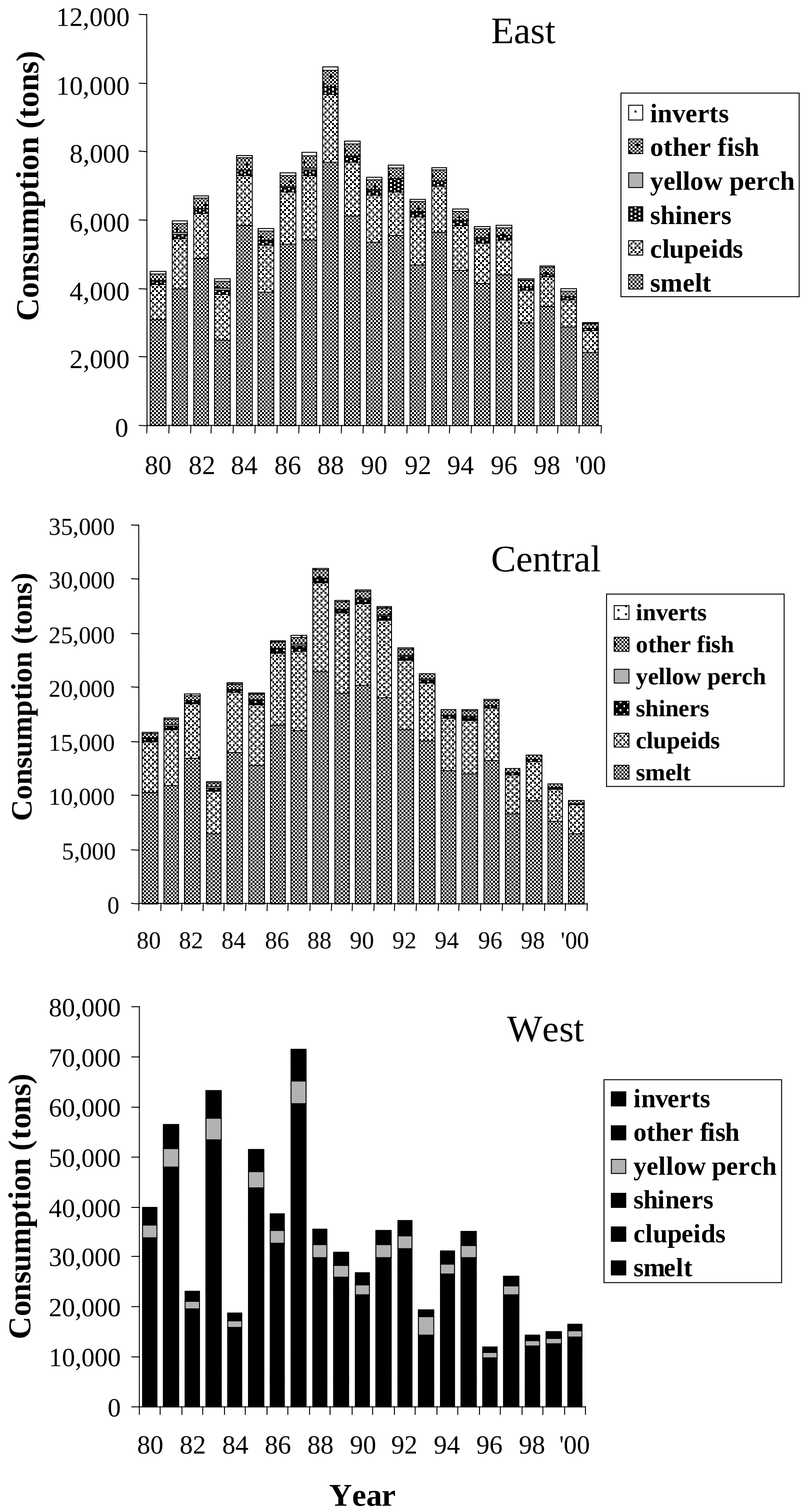

Figure 4.2 Walleye consumption of prey fish (tons/year) within each basin, by prey type 1980-2000.

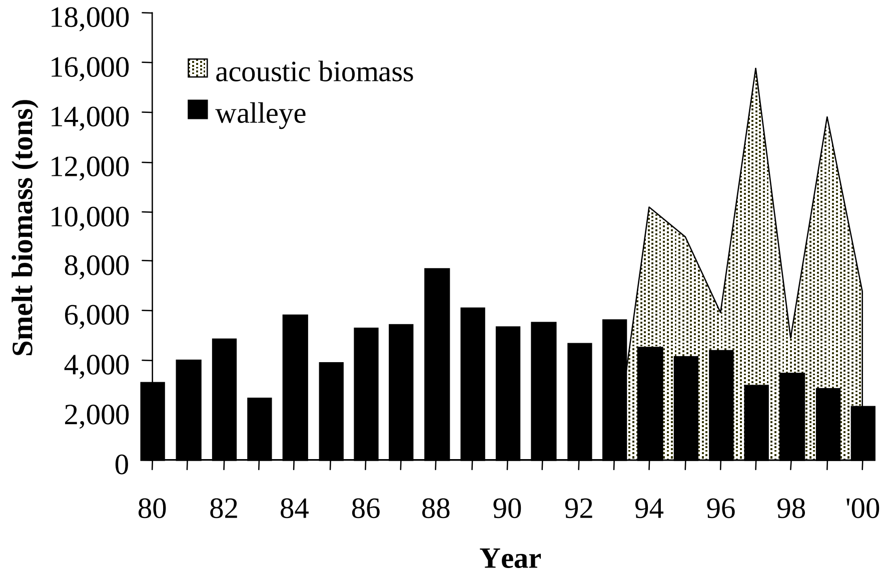

Figure 4.3 Walleye consumption of yearling-and-older smelt (tons, 1980-2000) in the eastern basin relative to yearling-and-older smelt abundance estimated by hydroacoustics (1993-2000).

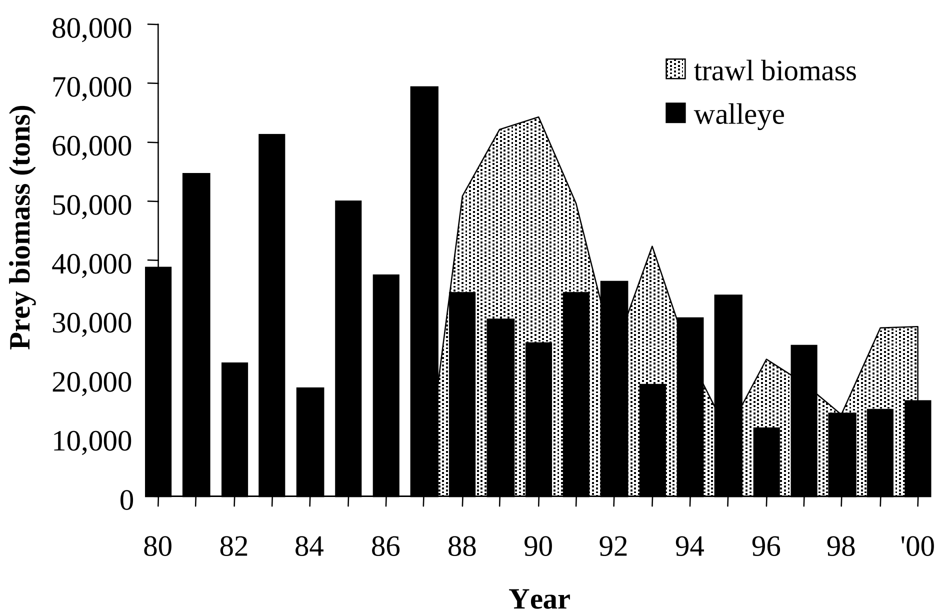

Figure 4.4 Walleye consumption of all prey types (tons, 1980-2000) in the western basin relative to prey abundance estimated by the interagency trawl program (1988-2000).

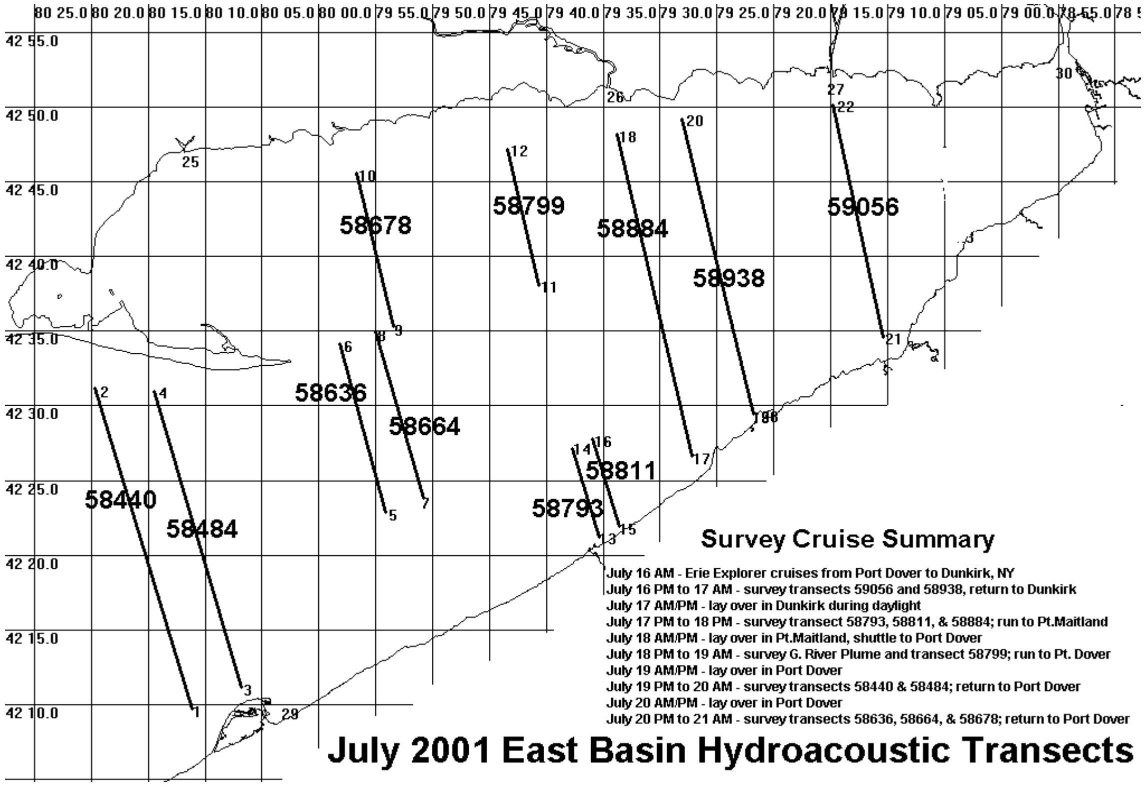

Figure 5.1. Approximate acoustic sampling locations during July, 2001 fisheries acoustic survey of the eastern basin Lake Erie.

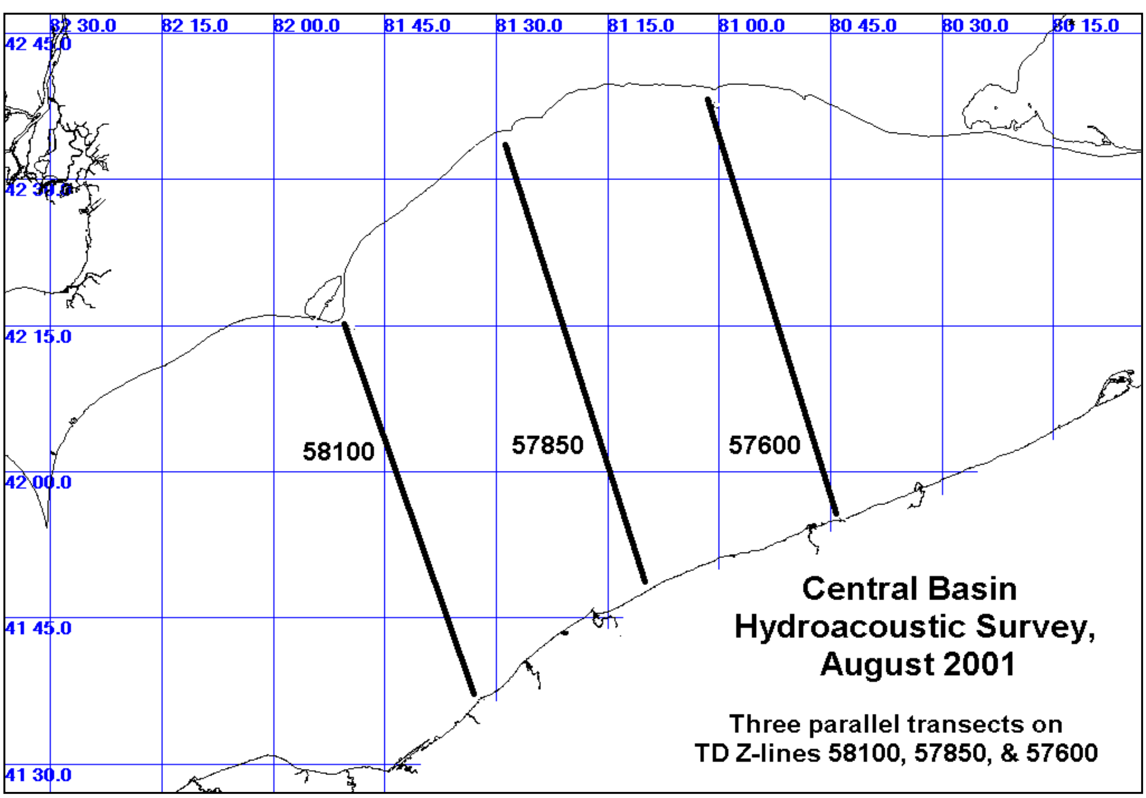

Figure 5.2. Approximate acoustic sampling locations during August, 2001 fisheries acoustic survey of the central basin, Lake Erie.

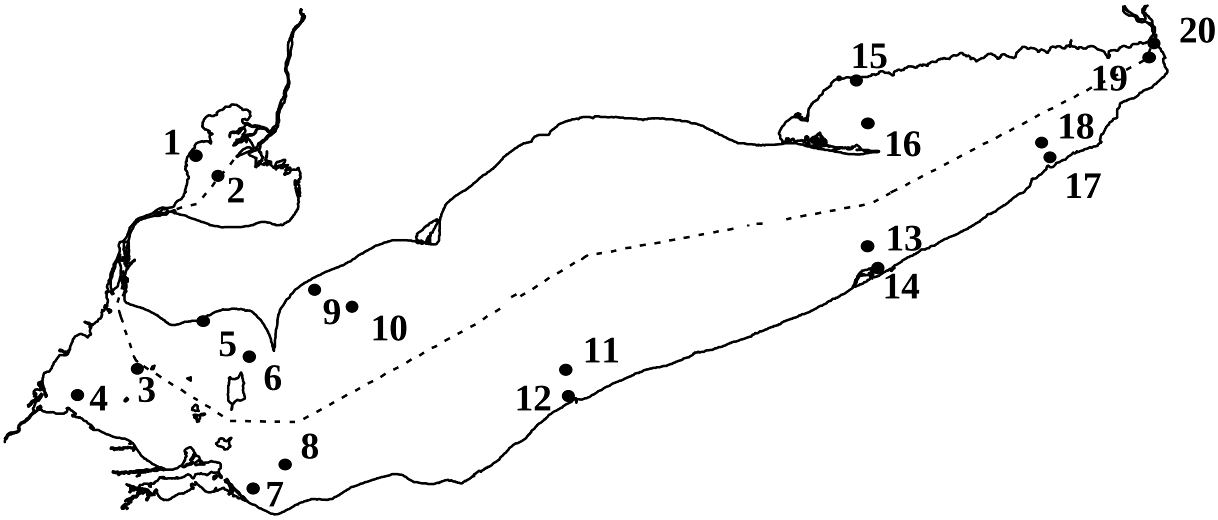

Figure 6.1. Lower Trophic Level sample stations in Lakes Erie and St. Clair, 2001.

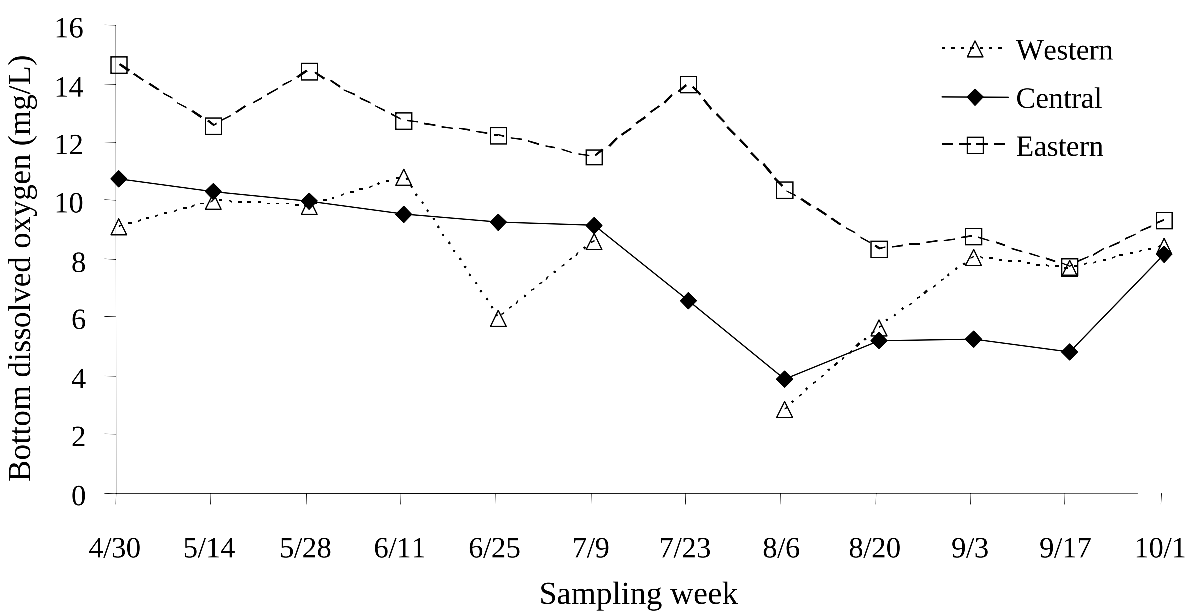

Figure 6.2. Mean bottom dissolved oxygen (mg/L) for each basin by sampling period, 2001. Values are means of measurements recorded within each basin. Western basin, stations 3-6; Central basin, stations 7-14; and Eastern basin, stations 15-20.

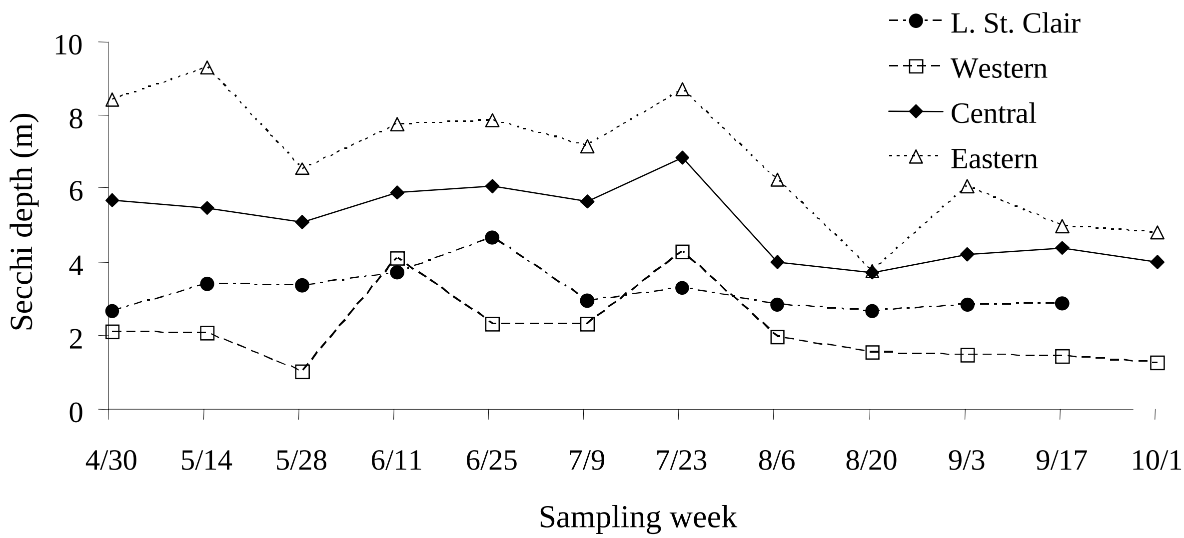

Figure 6.3. Mean Secchi depths (m) from interagency lower trophic level assessment by sampling period for each Lake Erie basin and Lake St. Clair, 2001.

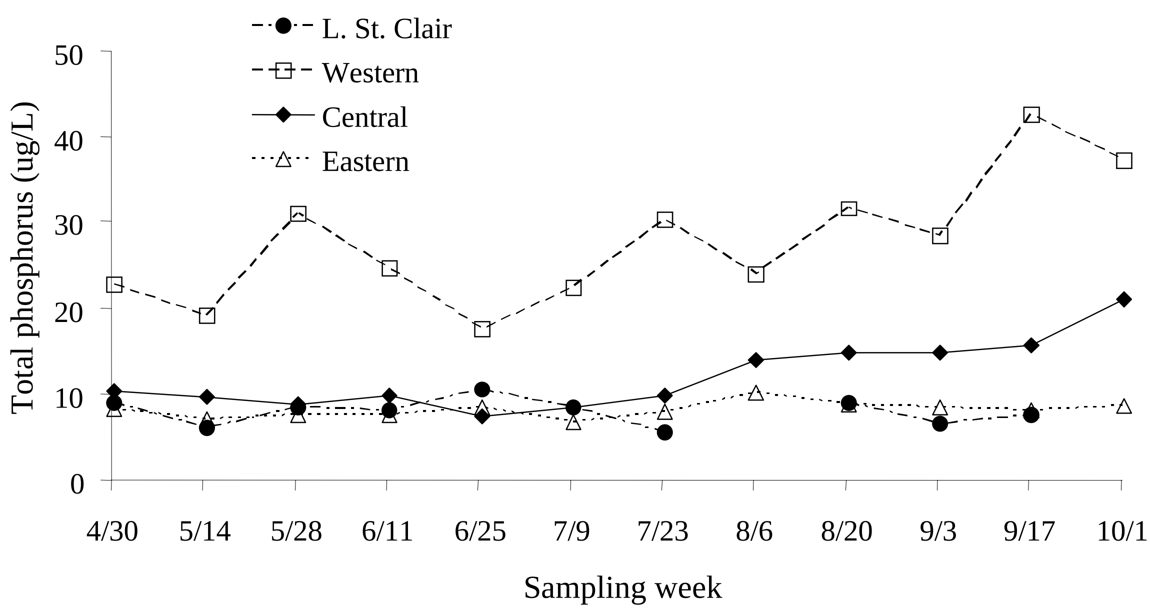

Figure 6.4. Mean total Phosphorus (µg/L) from interagency lower trophic level assessment by sampling period for each Lake Erie basin and Lake St. Clair, 2001

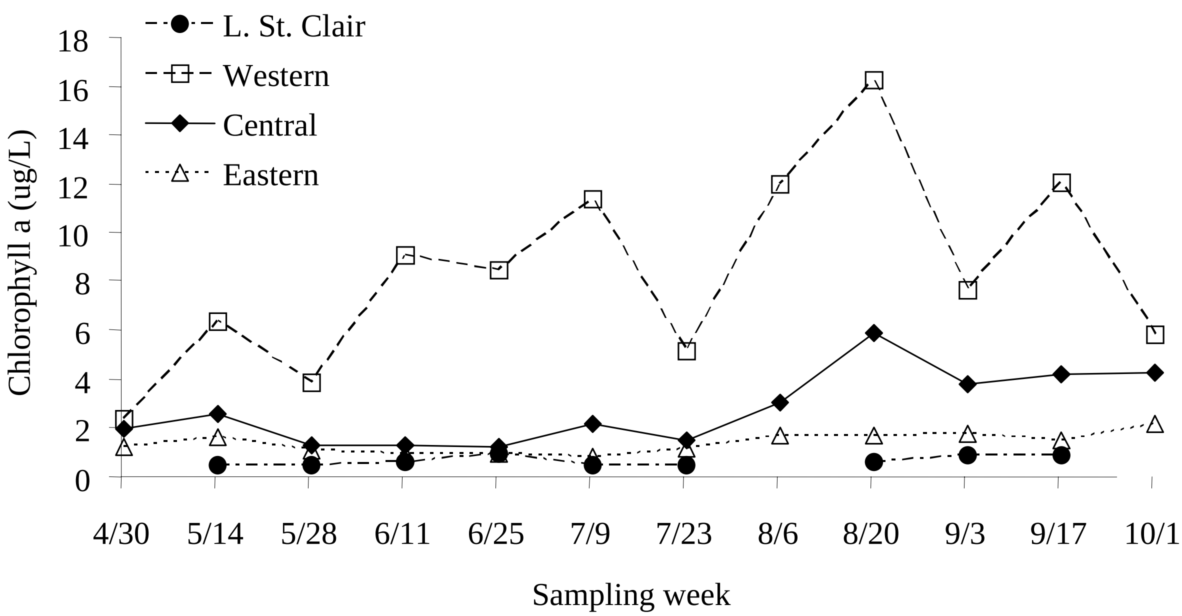

Figure 6.5. Mean Chlorophyll *a* (µg/L) from interagency lower trophic level assessment by sampling period for each Lake Erie basin and Lake St. Clair, 2001

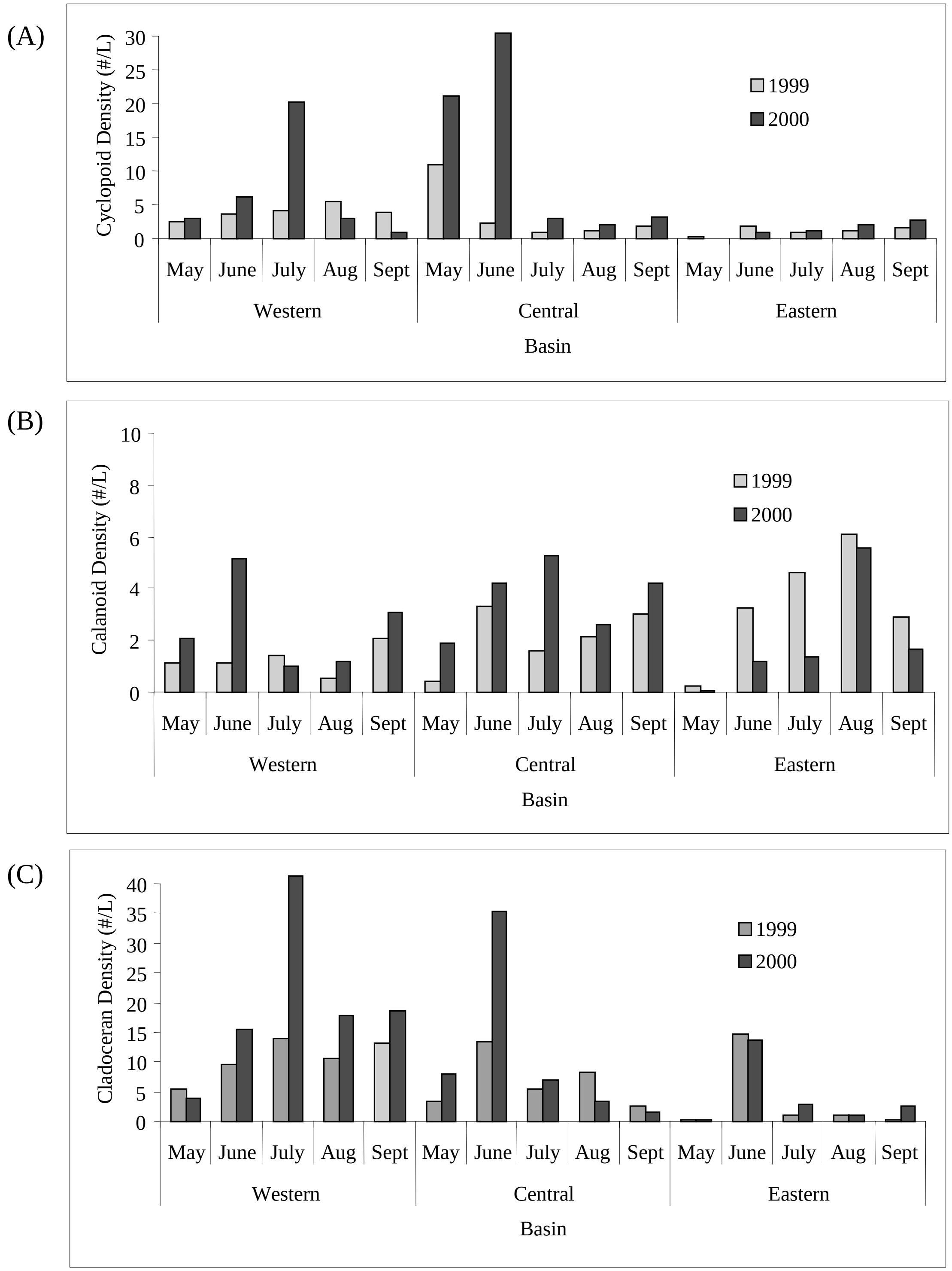

Figure 6.6. Mean monthly zooplankton abundance (number/L) from Lake Erie interagency lower trophic level assessment by basin and month, 1999 and 2000. (A) Cyclopoid copepods; (B) Calanoid copepods; and (C) Cladocerans.

(A)

(B)

(C)

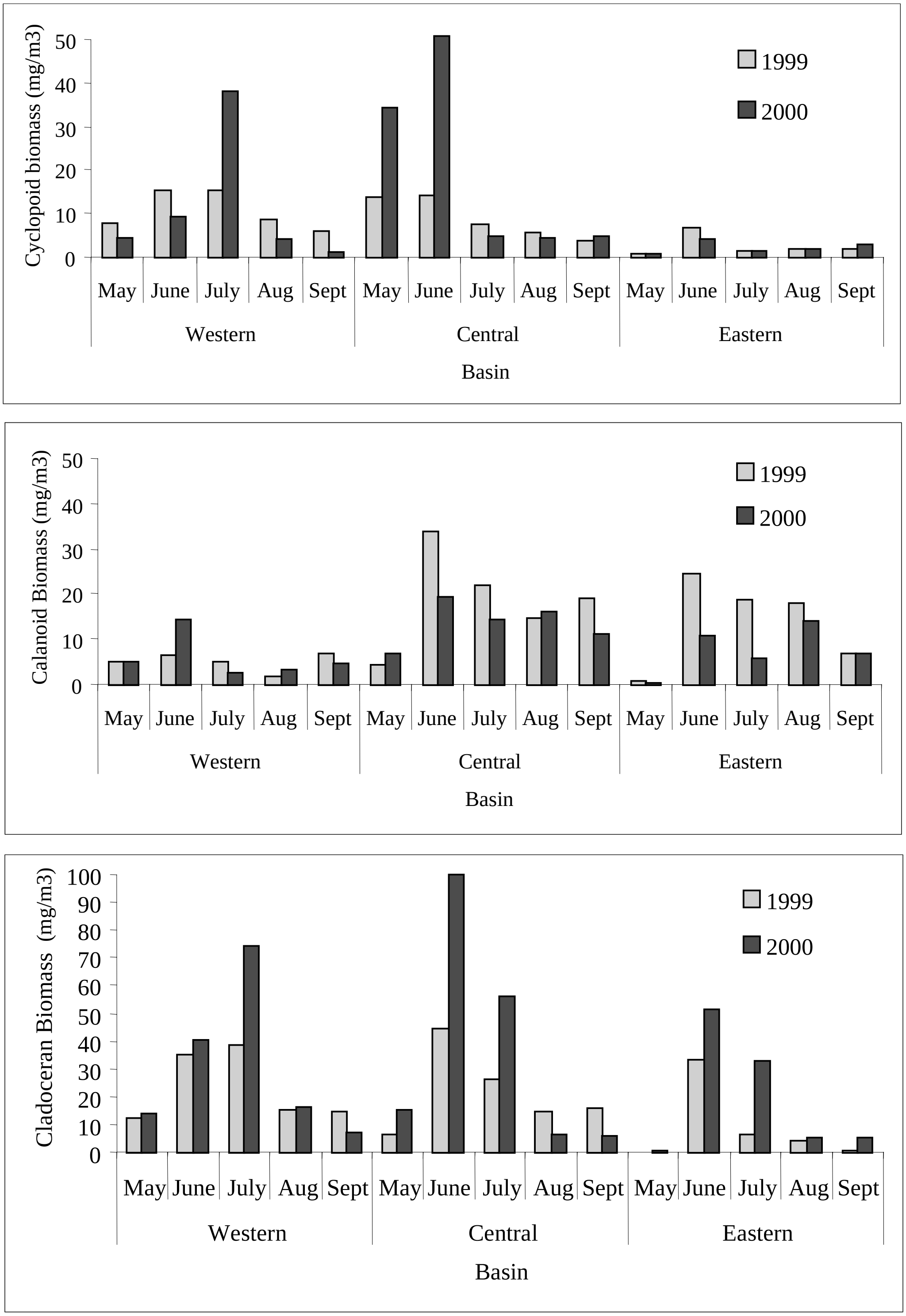

Figure 6.7. Mean monthly zooplankton biomass (mg/m3) from Lake Erie Interagency lower trophic level assessment by basin and month, 1999 and 2000. (A)Cyclopoid copepods; (B) Calanoid Copepods; and (C) Cladocerans.

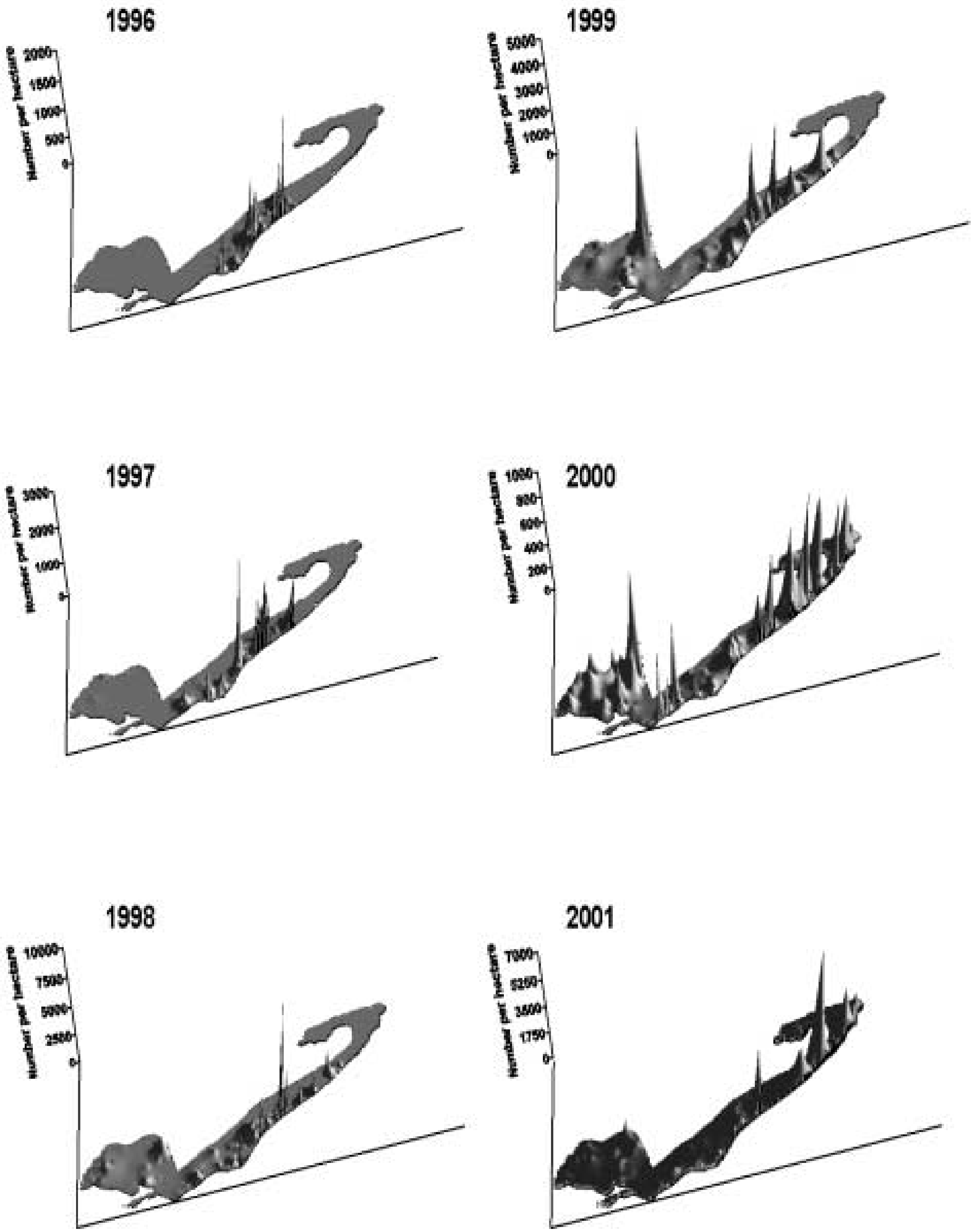

Figure 7.1 Round Goby distribution and abundance from interagency bottom trawls in Lake Erie, 1996-2001.