# Report of the
# Lake Erie
# Forage Task Group

## March 1995

## Members:


| | |
|---|---|
| Larry Witzel | - Ontario Ministry of Natural Resources (OMNR), {Chairman} |
| Mike Bur | - United States National Biological Survey (NBS) |
| Tom Czapla | - United States Fish and Wildlife Service (USFWS) |
| Don Einhouse | - New York State Dept. of Environmental Conservation (NYS DEC) |
| Bob Haas | - Michigan Department of Natural Resources (MDNR) |
| Chuck Murray | - Pennsylvania Fish and Boat Commission (PFBC) |
| Ken Muth | - United States National Biological Survey (NBS) |
| Steve Nepszy | - Ontario Ministry of Natural Resources (OMNR) |
| Les Sztramko | - Ontario Ministry of Natural Resources (OMNR) |
| Mike Thomas | - Michigan Department of Natural Resources (MDNR) |
| Jeff Tyson | - Ohio Department of Natural Resources (ODNR) |


## Presented to:

## Standing Technical Committee
## Lake Erie Committee
## Great Lakes Fishery Commission

# 1.0 Charges to the Forage Task Group in 1994-95

The Forage Task Group (FTG) addressed four major charges from the Lake Erie Committee (LEC) during the 1994-95 work year. These charges were:

1) Prepare a brief report describing the status of forage species in 1994 for each basin of Lake Erie (section **2.0**),

2) Conduct analyses with the interagency trawling program that includes
   a) a procedure for calibration of trawls, incorporating SCANMAR results (section **3.1**),

   b) a continuation of analyses with trawl data sets to determine the most appropriate statistic for describing central tendency (section **3.2**),

   c) a summary of species CPE statistics and biomass estimates from calibrated trawls (section **3.3**),

3) Information regarding the qualitative and quantitative aspect of planktonic and benthic organisms and their roles in the Lake Erie ecosystem is limited. This is an area in which the USFWS is interested in expanding their partnership with Lake Erie management agencies, the FTG would welcome dialogue and a planning meeting to determine informational needs and develop an efficient program (section **4.0**);

4) Evaluate hydroacoustic techniques as a method for producing a basinwide assessment of the distribution and abundance of rainbow smelt in the Eastern Basin (section **5.0**);

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

# 2.0 Status of Forage Species

## 2.1 Prey Fish

### 2.1.1 Eastern Basin ( by L. Witzel)

Prey fishes known to comprise important components of piscivore diets in eastern Lake Erie include rainbow smelt, alewife, gizzard shad, white perch, and spottail and emerald shiners. Relative contributions of these species to the diets of fish predators varies with annual fluctuations in abundance.

The status of prey fish in the eastern basin of Lake Erie has been determined annually by independent bottom trawl assessments conducted in the fall by the Ontario Ministry of Natural Resources (OMNR), New York State Department of Environmental Conservation (NYS DEC), and Pennsylvania Fish and Boat Commission (PFBC). NYS DEC has also conducted a summer (July) trawl survey of deep water stations (< 36 m) since 1987. A systematic bottom trawl survey has been conducted by OMNR (in partnership with the Ontario Fish Producers Association and the Ontario Federation of Anglers and Hunters from 1991 to 1993) to describe the abundance and distribution of rainbow smelt in the eastern basin. In 1994 this survey was less intensive (approximately 50 % of previous surveys), but covered a broader area that included sample sites in New York waters. Indices of relative abundance of forage fish are summarized in agency annual reports to the Lake Erie Committee.

The status of prey species reported below is based largely on annual trawl assessments conducted by OMNR in offshore (using a 10-m trawl) and nearshore (using a 6.1-m trawl) waters of eastern Lake Erie and the Long Point Bay area. All indices of abundance from OMNR trawl surveys are reported as geometric mean catch per trawl hour (GMCPTH).

Smelt are the most abundant prey fish species available to predators in the offshore waters of eastern Lake Erie. Smelt typically comprise 90 percent or more of index trawl catches (by number) and are generally the dominant food item found in the diets of salmonines and walleye.

Fall trawl assessments indicate that recruitment of YOY smelt in 1994 was relatively poor (Table 2.1.1-1). However, agency trawl indices may have underestimated the actual strength of the 1994 year class because YOY smelt seemed to be distributed higher in the water column in 1994 than in previous years. OMNR and NYS DEC reported seeing large concentrations of fish on their depth recorders (Figure 2.1.1-1), but these "showings" were not reflected by the size of the catch in trawls. OMNR sampled some of the suspended concentrations of fish with a mid-water trawl and caught mostly YOY smelt, which were smaller than YOY smelt captured on or near bottom. YOY smelt comprised 61.6 % by number and 19.7 % by weight of the smelt catch in the OMNR eastern basin survey (ON-EB). In Long Point Bay, the proportion of YOY in the total smelt catch was 98.5 % by number and 88.1 % by weight.

Average size of YOY smelt in the OMNR eastern basin trawl survey (Sept. data) increased in 1994 (58.5 mm FL), continuing a trend since 1991 (Figure 2.1.1-2). In contrast, YOY smelt in Long Point Bay were smaller (Sept. data) in 1994 (mean FL=52.5 mm) than 1993 (mean FL=59.1 mm), representing an abrupt shift from a recent trend (since 1991) toward increased growth rate.

Relative abundance of YAO smelt in 1994 decreased considerably from 1993 (Table 2.1.1-1). In Long Point Bay, 1994 catches of YAO smelt were the lowest ever observed. Near record low abundance of YAO smelt was also observed by NYS DEC and PFBC. Eastern basin catches (ON-EB) of YAO smelt were largely made up of the 1992 year class (two-year-old), except in Long Point Bay, where age 1 fish from the 1993 year class was the dominant age group among the few adult smelt caught in 1994. Size of yearling smelt in eastern Lake Erie has increased (even years) and decreased (odd years) on alternate years (Figure 2.1.1-3) Size of yearling smelt increased in 1994 from record low values in 1993. Yearling smelt from the OMNR eastern basin survey (ON-EB) averaged only 88.5 mm FL in September, 1993 compared to 101.5 mm FL in September, 1994. In Long Point Bay a similar increase was observed (93.5 mm FL in October, 1993 vs 101.6 mm FL in October, 1994).

Clupeids typically make up less than three percent (by number) of index trawl catches in the offshore waters of Long Point Bay, and indices of their abundance may not accurately reflect recruitment. Most agencies observed poor recruitment of YOY alewife and gizzard shad in 1994; YOY abundance indices for these species decreased from 1993 to 1994 in all but one trawl survey (Table 2.1.1-1). In that survey (ON-OB), indices were similar (for gizzard shad) or below (for alewife) the species long-term average.

NYS DEC and PFBC trawl surveys indicate that recruitment of YOY emerald shiner was poor in 1994; zero YOY emerald shiners were caught by NYS DEC during their fall assessment work. The OMNR eastern basin survey (ON-EB) also indicated that emerald shiners were less available in 1994 than last year. Long Point Bay surveys showed that abundance of YOY emerald shiner increased in this part of the lake; 1994 indices were above long-term averages (Table 2.1.1-1). Relative abundance of YAO emerald shiner appeared to be low throughout much of the eastern basin in 1994.

All agencies observed poor or decreased recruitment of YOY spottail shiner in 1994 (Table 2.1.1-1); NYS DEC and PFBC, in fact, did not catch any YOY during their fall trawl surveys. The relative abundance of YAO spottail shiner increased in 1994, apparently in response to recruitment of the strong 1993 year class.

Widely conflicting trends in abundance indices of clupeids and shiners between surveys (nearshore vs offshore) and among agencies may be attributable to large variations in catches associated with widely clumped distributions of these species. Furthermore, temporal and spatial variations may be confounded by differential effects exerted on fish distributions by zebra mussels. For instance, increased water clarity may render bottom trawls increasingly less effective in the nearshore , relative to offshore areas of the lake.

Indicators of YOY white perch abundance in 1994 were mixed (Table 2.1.1-1). Long Point Bay surveys indicate that recruitment improved from the previous year and that the 1994 index values were above (ON-OB) or similar (ON-DW) to the long-term average. NYS DEC reported that YOY white perch catches were similar in 1993 and 1994. PFBC and the OMNR east basin surveys indicate there were fewer YOY white perch in 1994 than in previous years.

In summary, the relative abundance of prey fish in 1994 appeared to be well below average levels, due largely to low abundance of YAO smelt. Poor recruitment by shiners and clupeids in 1994 may shift greater forage pressure to smelt in offshore waters in 1995. Low abundance of older (age 2+) smelt and other prey species means that yearling smelt (1994 year class) will likely provide the largest single supply of forage for piscivores in 1995. However, strength of the 1994 year class of smelt is uncertain because of possible underestimation of their abundance (as YOY) by bottom trawls during fall trawl assessments. Their contribution to the forage demand in eastern Lake Erie may not be known until 1995 stock assessments are under way.

### 2.1.2 Central Basin (by J. Tyson and C. Murray)

Fall assessment trawls by the Ohio Department of Natural Resources (ODNR) and PFBC indicted declining trends in the forage base in the central basin in 1994. Although forage assessment procedures are standardized, subtle differences in equipment, deployment of gear and estimators produced similar trends between the two agencies. The overall trend of all major forage species abundance is one of decline. Abundance of YOY rainbow smelt showed modest increases in both ODNR and PFBC over 1993 assessment trawls. ODNR showed an increase in emerald shiners. Gizzard shad, alewife and trout-perch all showed declines in YOY abundance. Spottail shiners were absent from all samples for both agencies. The moderate increases in abundance of smelt and emerald shiners from the previous year's assessment are still less than the ten year average.

Mean fall lengths of all YOY forage species showed increases over last year. Most notable were increases in alewife and drum mean fall length. Otherwise, most notable 1994 YOY Fall prey lengths were at or near the long-term averages, suggesting that zooplankton availability of communities probably have not changed substantially in the past 5 years. The only species that has shown a decreasing trend in length was spottail shiners.

Growth rate of age 1 walleye in the central basin was slightly below the long-term average (1983-1994), whereas growth of age-2 walleye was slightly above the long-term average. Central basin walleye (age-2+) consumed a higher proportion of age-0 smelt (mean % volume) in 1994 than in the previous year, probably indicative of the increased availability of adult smelt due to the moderately strong year-class in 1992. Fall mean lengths of age-1 yellow perch increased slightly over 1993 while age-2 yellow perch has shown an increasing trend since 1987. This may be an indication of a shift in productivity within the nearshore benthic community in the central basin, related to zebra and quagga mussel effects.

As the hydroacoustic work being done by the NYS DEC is further developed, comparisons with trawl assessment may indicate shifts in spatial assemblages of prey species. ODNR will be incorporating mid-water trawls in the future, which could also give added insight to spatial changes of prey species. The observed stability in growth of predators and prey with an apparent decreasing forage base is perplexing. Factors influencing catchability of prey fish species in bottom trawls (increasing water clarity and community restructuring) may be requisite to understanding the apparent decreases in overall prey abundance.

### 2.1.3 Western Basin (by K. Muth)

Annual trawling surveys to determine the relative abundance of YOY and forage fishes are conducted by OMNR, the ODNR, and the National Biological Service (NBS) in the western basin waters of Lake Erie. Surveys conducted in the summer, usually in July and August, provide the first indications of reproductive success and potential recruitment from the new year class for most species. Data collected in the fall, usually in September and October, provide a second abundance estimate after early mortality has occurred and are perhaps more reliable estimates of year class strength. By comparing results from the three independently conducted surveys, we can confirm the reliability of estimated changes in relative abundance.

Summer survey data available from OMNR and NBS suggested reproductive success for important YOY predator species was very good this year while it was low for most forage species. The walleye abundance index was the highest value observed since 1986 when a strong year class was produced (NBS data) and the OMNR data confirmed this high abundance level. The yellow perch index was the highest value ever recorded by NBS since 1960 and both OMNR and ODNR indices were among the highest ever recorded by these agencies. White bass and white perch abundance this year rebounded from low levels in 1993 and 1992 with high summer abundance indices recorded by all agencies. On the other hand, forage fishes did not fare as well this summer with two exceptions. The rainbow smelt index (OMNR data) and the emerald shiner index (NBS data) were among the highest recorded in recent years and show promise of much needed increases in recruitment of these species. Other forage fishes such as spottail shiner, gizzard shad, and alewife had low abundance indices suggesting poor reproductive success. This may be particularly important as clupeids have been the mainstay in the western basin walleye diet in recent years.

Fall abundance indices, in general confirmed relative abundance levels of most species observed in the summer. A strong 1994 year class was produced for walleye and yellow perch, but the yellow perch fall abundance index was somewhat lower than expected. Early mortality of yellow perch may have been high this year. White perch, white bass, emerald shiner, rainbow smelt, trout perch, and freshwater drum indices this fall were usually higher than during the recent 2- to 5-year period. Low fall abundance indices for alewife, gizzard shad, and spottail shiner confirmed that these species will likely provide little forage for western basin piscivores.

The potential reduction of forage fish availability because of poor recruitment from the 1994 year class may be a cause for concern. Emerald shiner and smelt will have to bear the brunt of any increased predation associated with strong year classes of walleye, white bass, yellow perch, and white perch. Growth of these predators may be suppressed if food resources become limited. Alternately, walleye may feed more heavily on yellow perch and restrict stock recovery of this species.

Growth of YOY fish measured in the fall of 1994 was very similar to average growth for most species observed during the last 15-year period. Slow growth of YOY walleye recorded in 1993 (NBS data) was not observed this year, but walleye growth in 1994 still tends to be lower than the high levels observed in the late 1970's and mid-1980's (ODNR and NBS data).

We conclude that the abundance of key forage species in the western basin in 1994 was low, and for most species, below their long term average abundance levels. Given that 1994 represents the second consecutive year of low forage fish abundance, this may translate into changes in the dynamics of piscivorous predators. High abundance of key YOY predator species in 1994 may further increase demands on a reduced forage base.

## 2.2 Predator Diets

### 2.2.1 Walleye (by M. Bur and L. Witzel)

Walleye stomachs were examined for food contents by ODNR and NBS in the western basin by ODNR and OMNR in the central basin, and by NYS DEC and OMNR in the eastern basin. ODNR samples were obtained from index gillnets (kegged and bottom sets) fished at random and fixed (historic) sites across a range of depths during October. NBS samples were obtained from bottom trawls at fixed stations during May and August-October. OMNR samples were obtained from fish, primarily age 3 and older, harvested by anglers during June-August. NYS DEC samples were from index gillnets fished at fixed nearshore locations (5.5 - 11 m) during September and October. Only stomachs from age-1 and older walleye were examined by ODNR and NBS. Figures 2.2.1-1 to 2.2.1-3 show the mean percent volume of the major identifiable food groups found in walleye stomachs for each basin since the mid to late 80's.

Walleye were found to have a diverse intake of prey fish that included clupeids (mostly gizzard shad), smelt, yellow perch, *Morone* spp. (mostly white perch) and emerald and spottail shiners (Figures 2.2.1-1 to -3). Gizzard shad have been the primary prey species for age-1 and older walleye within the western and central basins (ODNR and NBS data). Smelt as a prey item increased in importance from west to east.

The proportion of alewife in walleye diets has increased in the western basin over the past five years (ODNR data). Peaks in the relative consumption of alewife in both the western and central basins in 1992 were probably due to high abundance of YOY. In the western basin, mean percent volume of emerald shiners in walleye diet in 1993 and 1994 remained fairly constant despite an apparent decrease in abundance of this prey species. This may indicate a preference for emerald shiners.

In the central basin, walleye diet as assessed by ODNR and OMNR were quite different.

ODNR data indicate that walleye consumed almost exclusively clupeids, whereas in OMNR samples, smelt was the principal prey fish and clupeids were relatively insignificant, except in 1992. This discrepancy may be attributed to differences in sampling gear (size selectivity), methods, season, daytime (day vs night), and where walleye were collected in the central basin in relation to north-south and east-west gradients in prey fish abundance. Yellow perch were a minor component of the walleye's diet throughout Lake Erie in the last 5 to 10 years.

### 2.2.2 White Perch and Yellow Perch

White perch and yellow perch were examined for food contents by NBS in the western basin and by OMNR in Long Point Bay, Lake Erie. Long Point Bay samples were obtained from index gillnets fished for 24-h periods, weekly from May to October since 1986. Western Basin samples were from bottom trawls fished at a few index stations during May and August-October, since 1989.

#### Western Basin (by M. Bur)

The diet of yellow perch in the western basin from 1989 to 1993 consisted mostly of macrobenthic invertebrates (Figure 2.2.2-1). Mollusks were an important food, usually comprising between 20 and 25 of the mean percent volume. Zebra mussels were present in the diet of yellow perch in all five years, usually between 6 and 17 mean percent volume. Amphipods comprised as much as 28% of the diet. Chironomids, which historically (1970's and 80's) were a major component, made up less than 10 percent of the stomach volume of yellow perch. Zooplankton was a minor component in 1990-92 (< 12%), and a major one in 1989 (36 %) and 1993 (46 %). The relative contribution of prey fish in the diet of yellow perch has shown a progressive decline.

The main food of white perch was zooplankton (*Daphnia* spp. and *Bythotrephes cederstroemi*) and macrozoobenthos (chironomids and amphipods). *Bythotrephes cederstroemi* were found in white perch stomachs from all years except 1991 and comprised up to 31 % of the mean percent volume (Figure ). Amphipods made up from 1 to 16 % of the diet in a particular year. Chironomids accounted for 6 to 16 % of the food volume. Fish were not an important food item in most years, except in 1990 when they contributed 50 % of the mean percent volume. Mollusks were not as important a food item in white perch as they were to yellow perch. Zebra mussels usually comprised less than 2 % of the food volume in white perch stomachs.

#### Long Point Bay (by A. Cook)

The number of yellow perch stomachs sampled per year from Long Point Bay ranged between 375 and 1,706. Benthic invertebrates, predominately *Gammarus* spp. and chironomids, contributed the highest mean volumes (Figure 2.2.2-2). *Gammarus* spp. ranged from 16 to 43 % (mean percent volume) per year, and was generally most prevalent in the spring and fall. Chironomids were most abundant in the spring and contributed average volumes between 13 and 24 % annually. Zooplankton, primarily *Bythotrephes cederstroemi*, was important in most years (3-31 %), particularly during summer (as much as 64 %). The portion of fish in the diet of yellow perch was relatively constant from year to year (6-19 %). Most of the fish component in yellow perch stomachs was unrecognizable. Of the fish that could be identified, smelt, johnny darter, sculpins and yellow perch were the most common. Few zebra mussels or other bivalves were observed in yellow perch stomachs.

The number of white perch stomachs sampled per year from Long Point Bay ranged from as few as 17 (1991) to 662 (1986). The principal prey groups found were *Gammarus* spp., *Bythotrephes cederstroemi* and chironomids (Figure 2.2.2-2). As was found in yellow perch, the relative importance of each group varied seasonally. *Gammarus* spp. was a major part of the diet in spring (29 - 56 %) and fall (26 - 67 %), and to a lesser extent during summer (5 - 29 %). Chironomids contributed substantially to the diet in spring (11 - 30 %), but less in the summer (5 - 18 %). *Bythotrephes cederstroemi* was the most important diet item in the summer (26 - 64 %), except in 1992 (14 %), as was the case for yellow perch. Prey fish appeared to represent a smaller fraction of the entire diet in white perch than yellow perch. Incidence of zebra mussels in white perch stomachs was rare. The data indicate considerable overlap between the diets of white perch and yellow perch.

## 2.3 Zooplankton Abundance and Distribution

### 2.3.1 Maumee River and Huron River Estuaries (by B. Haas)

Zooplankton, phytoplankton, and nutrients were sampled twice each week in May and June of 1994 in Lake Erie's Western Basin estuaries of the Maumee (Ohio) and Huron (Michigan) rivers as part of a larger study of five estuaries in the lower Great Lakes. This was the fifth year of a Michigan Department of Natural Resources sampling program, begun in 1990, designed to examine the dynamics of plankton populations in the estuaries of three good and two questionable walleye spawning rivers. Plankton population characteristics will eventually be correlated with walleye year class success to search for causative relationships.

The Maumee and Huron River estuaries experienced relatively cold water temperatures and high transparency conditions during May and June of 1994 relative to the previous four years (Table 2.3.1-1). These physical conditions were matched by low concentrations of nitrate-nitrogen, phosphorus, silica, and total organic carbon (TOC). In 1994, most of the nutrients were found at their lowest levels during the five year study.

Density of planktonic algae was the highest on record in the Maumee Estuary in 1994 and approached the highest in the Huron Estuary. Zooplankton density was also much higher than ever before in the Maumee and Huron estuaries. Daphnids were especially abundant, being found at 2-4 times higher density compared to the other years. Mean length of zooplankton was also the highest observed during the study.

Zooplankton populations appeared to be very good for survival of fish fry during May and June of 1994 compared to previous years. If a strong year class of walleye was produced in 1994, better food quality and quantity for fry may have been one of the causative agents.

### 2.3.2 Western Basin (by J. Tyson)

Zooplankton were sampled monthly by ODNR in the western basin using a conical 0.5-m plankton net with 80 micron mesh. Vertical hauls were made through the entire water column at four historic stations each year since 1988. Only samples to 1991 have been examined.

Zooplankton densities appeared to be slightly higher in 1991 (Figure 2.3.2-1). However samples were collected earlier in the year after 1989. Size and density of zooplankton show a positive relationship; both tended to decrease with time in most years. This may be due to size-selective predation by YOY fishes during late June and July.

## 3.0 Interagency Trawling

An ad-hoc task group, called the Interagency Index Trawl Group (ITG) was formed in 1992 to 1) review the interagency index trawl program in western Lake Erie and recommend standardized trawling methods for measuring fish community indices, and 2) lead in the calibration of agency index trawling gear using SCANMAR acoustical instrumentation. Upon their termination in March 1993, the ITG recommended that work on interagency trawling issues be continued by the FTG on four matters. Progress on these charges are reported below.

### 3.1 Calibration of Bottom Trawls (by L. Witzel)

In July 1995 the FTG, lead by K. Muth, will be coordinating field experiments to mensurate agency trawl gear using SCANMAR instrumentation. Field testing will be conducted in two areas of the lake, the western basin (based at Put-in-Bay, Sandusky OH) and Long Point Bay in the eastern basin (based at Port Dover, Ont.). This work is an extension of an earlier (1992) pilot exercise (Witzel et al. 1994). The principal objective of the proposed and earlier SCANMAR tests was to achieve a basis for calibration of agency trawl gear that would facilitate development of a central interagency data base .

R. Knight (in Witzel et al. 1994) reviewed the results of the 1992 pilot tests and proposed the following steps to address this charge. Firstly, he recommended that each agency measure (using SCANMAR) the opening of their trawl at the usual (survey standard) towing speed and scope, to determine the variability of area fished across a range of representative locations. Secondly, joint trawling experiments should be conducted to develop correction factors to apply to relative abundance estimates for each species of interest. And thirdly, design and implement gear research to examine factors that affect trawl efficiency.

Proposed testing in 1995 will attempt to examine some of the needs identified by Knight. A more specific and structured experimental design will be applied in the coming tests than were used by individual agencies in 1992. Additionally, testing will be done to examine the bias (added catch) associated with trawl catch during gear deployment and retrieval. Trawls may catch fish during the setting and lifting phase for which effort (trawl time) has not been included. Distributional characteristics (patchiness) of fish species may also be examined if time permits. Information on patchiness would be relevant to work being done on another FTG charge (see section 3.2).

### 3.2 Central Tendency Statistics

Resource management agencies on Lake Erie typically report the relative abundance of selected fish species from index trawls as an arithmetic mean or geometric mean catch per unit effort (catch per trawl-hour). B. Haas has been leading a charge to determine the most appropriate statistic for describing relative abundance. He has written a computer program that simulates trawl catches of fish from populations of known size and distribution characteristics. The arithmetic mean, geometric mean, and median are generated from multiple trawl-catch simulations. These statistics are then evaluated on the basis of how close they compare to the known (true) population size. Development and application of the trawl-catch simulation program is continuing and no results were available for this report.

### 3.3 Summary of Species CPE Statistics (by J. Tyson)

Interagency trawl data from Michigan, Ohio, and Ontario waters were analyzed by Mark Kershner (a PhD student at the Ohio State University) to generate biomass estimates of forage fish species in the western basin. Interagency trawling was conducted in August from 1987-1994 and was comprised of species specific length and abundance data collected in the western basin of Lake Erie. Total effort was 80-100 stratified random standardized tows per year. Tows were stratified into four depth strata (0-3 m, 3-6 m, 6-9 m, and >9 m).

From previous work done using SCANMAR equipment to obtain measurements on trawl mouth opening and total trawling distance, Mark was able to assign a volume sampled to each tow. Using the volumetric estimate of abundance in combination with the length data he computed a trawl specific biomass for each species collected. Next, using water volumes calculated for each of the sample areas and the depth strata, total species specific biomass estimates were extrapolated to the entire western basin.

Using the total species specific biomass estimates, Mark plotted the total prey biomass available to piscivores across the years sampled (Figure 3.3-1) by sampling area (e.g. Ohio vs Ontario) and also biomass estimates for both sampling areas combined. He also computed a forage group specific biomass estimate (e.g. clupeids, soft-rayed, etc.) for Ontario and Ohio data separately and combined (Figure 3.3-2). These plots indicated that annual trends in total forage biomass and group-specific biomass were similar between sampling areas, although biomass estimates were consistently higher in Ohio waters.

Total prey biomass estimates were examined using analysis of variance to determine whether there were significant effects from year, sampling area, and depth strata. Tukey's pair-wise comparison for means separation, showed that the 0-3 m and 3-6 m depth strata were significantly different from the two deepest strata (6-9 m and >9 m) indicating that future sampling may be streamlined into two depth strata (0-6 m and 6->9 m). Further analyses indicated that there were highly significant differences between sampling areas, which suggests that the interagency approach is probably necessary to insure coverage of Ohio and Ontario waters. Analyses also showed that annual variability of biomass was significant.

Mark will be meeting with Forage Task Group members in the near future to determine what additional analyses are needed to address specific questions relating to the current charge.

## 4.0 Role of Invertebrate Communities (by T. Czapla)

This charge attempts to examine the roles and trophic relationships of planktonic and benthic communities within the Lake Erie ecosystem. As a first step toward addressing this charge we initiated a mail survey to determine the extent and nature of past and ongoing assessments of invertebrate populations. A survey letter/questionnaire was sent to 45 contacts at various government, academic and private institutions throughout the Lake Erie drainage area in 1993. Contacts were asked to describe the experimental design, sampling methodology, data analyses and level of reporting of their respective surveys.

Over the past two years we received 21 (46.7%) responses. One of the respondents reported no collections made in Lake Erie by their institution. The following table is a summary of responses categorized by fauna type (phytoplankton, zooplankton, and benthos), basin and study type (zebra mussel or other).

| | Fauna | | | Basin | | | Specific Study Type | |
|---|---|---|---|---|---|---|---|---|
| Response | Phyto | Zoo | Ben | West | Central | East | Zebra mussel | Continuous |
| Number | 11 | 10 | 11 | 17 | 9 | 7 | 4 | 9 |
| Percent | 24.4 | 22.2 | 24.4 | 37.8 | 20.0 | 15.6 | 8.9 | 20.0 |

The three categories of lower trophic levels have been collected and studied evenly by a variety of agencies and researchers. When the responses were categorized by basin, the predominance of lower trophic level studies has been in the West Basin and declines toward the Eastern Basin. However, all lower trophic levels have been monitored throughout the lake at various times. Currently, nine contacts reported ongoing work from either the collections they have made, which have not been processed or analyzed and reported, or they are truly continuous monitoring programs. Only four studies are involved with zebra mussel impacts. The overall responses were better than anticipated, yet we feel there may be studies locked in thesis material which was not very accessible.

Over 200 publications have been identified concerning the lower trophic levels of Lake Erie. Most of these are still being read, and an annotated bibliography may be one of the useful products created from this exercise. A key objective of the literature review will be to identify materials that examine relationships and trends over time of the lower trophic levels.

# 5.0 Mid-Summer Hydroacoustic Survey of the Eastern Basin

(by D. Einhouse and L. Witzel)

## 5.1 Introduction

The FTG became interested in fisheries acoustic methods as a previously unexplored opportunity to implement a standardized, interagency survey of rainbow smelt stocks in the eastern basin. The potential benefits of acoustic surveys are high sampling power and high precision in estimating fish abundance. Applications of this technology are restricted to only limnetic species and species discrimination is considered to be poor. These limitations do not seem to be an issue in an assessment of the eastern Lake Erie smelt resource. Potential deterrents relating to the high initial investment and need for specialized expertise currently have been addressed by NYS DEC. The 1993 and 1994 surveys were implemented with a single beam echosounder that has a lower cost than the more modern, highly sophisticated sonars. Although dual-beam and split-beam sonars (should) give more accurate target strength (TS) estimates, the scientific literature suggests single beam technology also give reliable estimates of fish population abundance (Parkinson et al. 1994). FTG biologists have acquired a serviceable knowledge of single beam acoustic methods and our comfort with this technology continues to increase as our experience enters a third year. Fortunately, ample technical support remains available through cooperative ties between NYS DEC's and Dr. Lars Rudstam at Cornell University, a noted expert in acoustic technology, particularly with single beam equipment.

The specific objective of this acoustic survey was to more fully respond to the FTG's 1993 charge to evaluate acoustic techniques as an assessment tool for smelt in eastern Lake Erie. Witzel et al. (1994) reported that a more limited 1993 acoustic survey showed considerable promise for acoustics as a smelt assessment tool. However, some aspects of the 1993 survey results required further examination including the 1) surprisingly poor precision of acoustic abundance estimates, 2) unexpectedly low smelt abundance estimates, and 3) difficulty in establishing species composition from companion mid-water trawl catches. The 1994 survey expanded sampling effort considerably relative to 1993 to address the first two concerns. Also, the NBS conducted trawl calibration exercises with SCANMAR apparatus to establish optimal fishing requirements to address the third concern. As in 1993, this charge was addressed as an interagency endeavour with NYS DEC and NBS responsible for data acquisition. OMNR, NYS DEC and Cornell University participated in data reduction, analysis and reporting results.

## 5.2 Methods

The 1994 mid-summer, fisheries acoustic survey of Lake Erie's eastern basin was conducted from July 13 to 18, 1994. The location of acoustic transects completed during this survey is shown in Figure 5.2-1. The survey area covered a linear distance of 274 km surveyed at night. A single transect (42 35) was replicated during the day for a distance of 17 km. Nighttime, midwater trawl collections and temperature profiles were conducted concurrently with acoustic data acquisition. All trawling was conducted at the command of the acoustic vessel (Argo) directed on areas of high fish densities indicated on the echogram.

The single beam acoustic system used for this survey was a 70-kHz echosounder (Simrad EY-M, 7024 transducer). Signal calibration was conducted at the beginning and end of the survey period by suspending a known target in the sound beam. Voltage responses from these two calibration events suggest the echosounder was stable throughout this survey. Data acquisition occurred at a vessel speed of 6.5 knots with a transducer affixed to a towed body 1-m below the lake surface. Acoustic signals were collected at 40logR TVG (Time Varied Gain) and recorded on cassette tape for subsequent processing in the lab.

The Hydro Acoustic Data Analysis System (HADAS) developed by Lindem (1983) was used to digitize and convert signals to fish abundances by a deconvolution algorithm for single fish echoes. Reduced data describing fish density by target strength (TS) was stratified by thermal zone and bottom depth contour (18-25 m, 25-35 m, >35 m) for analysis. One of the improvements made to the 1994 survey was to extend the overall length of (north-south) transects to the 18-25 m stratum. We have defined coldwater habitat as the thermocline and deeper layers.

## 5.3 Results

Mid-water trawl tows that accompanied the acoustic survey remained largely ineffective for a second consecutive year. Most trawl tows did not collect any fish. Scant collections of small fish included only age-0 and age-1 smelt. The few age-0 smelt in the sample ranged between 20 to 30 mm total length and were not readily retained by the trawl. The only large fish captured by the mid-water trawl was an adult walleye.

Daytime bottom trawling in hypolimnion waters was also conducted only one week prior to the acoustic survey as part of another independent assessment that occurred in New York waters. This bottom trawl survey found predominantly yearling-and-older (YAO) smelt sampled from bottom, hypolimnion waters. Two years of mid-water and bottom trawl collections have consistently described YAO smelt as essentially the only small fish species residing in coldwater habitat during this July survey (Table 5.3-1).

Overall, acoustic echograms confirmed the expected distribution of pelagic, small fish during day and night periods. Figure 5.3-1 compares day and night echograms of one acoustic transect surveyed only a few hours apart in July, 1994. The abundant fish echos observed during nighttime hours is characteristic of small pelagic fish as concentrations disperse and some fish ascend from the bottom. The dense band of signals on the nighttime echogram in the upper third of the water column identifies a concentration of fish in the thermocline. Figure 5.3-2 contrasts echograms from approximately the same area in 1993 and 1994. High densities of small fish concentrated in the thermocline in 1994, and this observation was less conspicuous during 1993 for most of the areas surveyed.

Acoustic fish density estimates were pooled into "small" and "large" fish categories, based on measured TS of individual fish. We used the FTG 1993 acoustic data analysis methods (Witzel et al. 1994) for classification of fish in categories based on target strength. Initially, fish with TS from -56 to -44 dB were classified as "small" and those greater than -44 dB were pooled as "large" fish. We assumed that the small fish in coldwater habitat were predominantly rainbow smelt.

Frequency distributions of TS for all layers of the water column described the highest density of fish in the smallest TS bins (Figure 5.3-3). This TS distribution was shifted to smaller targets in 1994, relative to 1993, for all layers of the water column. The predominance of similar-sized YAO smelt in hypolimnion trawl tows during both survey years suggested the difference in TS distributions was attributable to either; 1) very small fish that could not be retained by the bottom trawl or 2) differences in the performance of the acoustic system or analytical processes between each survey year.

Re-examination of 1993 and 1994 calibration files for these acoustic surveys by L. Rudstam (pers. comm.) found the 1993 TS signals to be assigned to -2 dB larger bins for a given voltage than during 1994, suggesting that the system drifted slightly, or one of the calibration efforts was somewhat less accurate. Also, this 70 kHz acoustic system has difficulty assigning signals to the particularly small TS bins. These possible problems or limitations do not compromise the effectiveness of the two surveys, but direct comparison of results between years should be done cautiously until further calibration exercises and a review of results can be performed.

The possible emergence in 1994 of abundant small fish in hypolimnion waters with a size frequency distribution smaller than YAO smelt remains an open question because the mid-water trawling was ineffective and fish less than 40 mm were not retained by the bottom trawl gear. High densities of very small targets in the epilimnion and thermocline are perhaps YOY smelt based on 1) scant mid-water trawl collections, 2) subsequent bottom trawling results collected during autumn (see section 2.1), and 3) our previous experience sampling the eastern basin fish community. Rudstam (pers. comm.) found YAO smelt TS distributions from Lake Champlain to be very similar to 1993 TS distributions observed in YAO smelt habitat (coldwater) in Lake Erie. Based on this observation, and other available data suggesting YOY smelt were much less abundant during 1993, we defined a YAO smelt TS distribution as ranging from -52 to -44 dB for direct comparisons of 1993 and 1994 density estimates. This definition of YAO smelt TS excluded a large fraction of the total small fish density in the -56 to -54 dB range in 1994 (Figure 5.3-4), but these small targets remained a much smaller fraction of the 1993 observations. Excluding these small targets likely eliminated some YAO smelt observations, but hopefully reduced possible confusion with YOY smelt or other fish.

Mean density estimates of YAO smelt-sized fish (-52 to -44 dB) by strata were expanded to the total surface area encompassed by each depth stratum to provide estimates of total fish abundance (Table 5.3-2). Abundance estimates of 1993 data were recalculated using the 1994 definition of YAO sized-smelt. A direct comparison of abundance estimates between years for YAO smelt-sized fish in coldwater habitat showed that approximately 30 % fewer fish were present within the 25-35 m depth stratum and 83% more were available in the >35 m stratum in 1994 than the previous year (Figure 5.3-5). The 18-25 m depth strata, surveyed in only 1994, added about 91 million fish. Across all depth strata surveyed, total numeric abundance of YAO smelt-sized fish in coldwater habitat was higher in 1994 (388 million) than 1993 (305.8 million). When all thermal habitat (ie. epilimnion and deeper layers) were considered in the estimate, 1993 (514.7 million) had higher total abundance compared to 1994 (437 million)(Figure 5.3-6). At present, absolute abundance estimates of YAO smelt from acoustical data remain in doubt because of their apparent wide overlap in TS distribution with smaller fish. As such, abundance estimates provided in this report are best viewed as indicators of relative abundance.

Precision of acoustic density estimates attributable to YAO smelt was much improved in 1994 (+/- 13 %), relative to 1993 (+/- 34 %), expressed as 95 percent confidence limits as a percent of the mean density (Table 5.3-2). The 1994 sampling effort that achieved this improved precision was approximately 2.3 times greater than the 1993 effort, measured as total linear distance of acoustic transects.

## 5.4 Discussion

The three specific issues that the 1994 acoustic survey more fully addresses include 1) improvement of precision of 1994 estimates, 2) more attention to requirements necessary for achieving absolute abundance estimates, and 3) another year of mid-water trawl experience to establish species composition. The first two issues were more satisfactorily addressed in 1994 by increasing overall sampling effort and expanding the spatial coverage of the survey to more fully encompass eastern Lake Erie YAO smelt habitat. The high precision of 1994 acoustic density estimates generally provide confidence limits otherwise unattainable from ongoing trawl surveys. As a lakewide survey, acoustic estimates are probably less subject to distributional biases of individual agency trawl surveys that have operated unilaterally in various jurisdictional waters. The one notable exception to this history is a basinwide survey conducted by OMNR since 1991.

Although precision of density estimates was improved, identification of a TS range assignable to YAO smelt emerged as a new issue in 1994. Overlapping TS distributions among age/size groups of smelt and perhaps other species suggest that YAO smelt biomass estimation is presently unresolved. Clearly, successful mid-water trawl collections would assist resolution of this species discrimination issue. We believe our poor success with the mid-water trawling portion of this assessment is mostly attributable to insufficient fishing power and we expect this problem to be resolved by using a significantly larger trawl beginning in 1995.

The 1994 survey was useful in more clearly identifying the benefits and limitations of acoustic survey assessment techniques as applied to the eastern basin Lake Erie smelt resource. High precision and the prospect of absolute abundance estimates are notable outputs, but specialized knowledge of acoustic methods is also required to properly analyze and interpret results. The FTG is receiving this technical support through New York's ongoing alliance with Cornell University's Warmwater Fisheries Unit (Dr. Lars Rudstam). As our experience continues, FTG biologists would eventually attain the skills to pursue acoustic methods with less reliance on external technical support.

Acoustic methods employed during 1994 appear to represent an appropriate standard for pursuing an ongoing, annual survey. Additionally, data reduction and analysis processes are now more clearly defined and some steps have been automated with SAS programs. The base 1994 survey can continue as an annual FTG program if member agencies commit the staff time that was expended in 1994.

An additional annual acoustic survey in October may have additional value to include 1) framing the period of peak predator consumption, 2) estimating YOY smelt abundance, and 3) establishing independent estimates of smelt production and mortality. A few additional resources will be required to conduct a second yearly acoustic survey. Specifically, to efficiently digitize large quantities of signals, real time signal processing is a necessity. Fortunately, signal processing needs are not a demanding requirement. Digitizing hardware can be installed in an AT or 286 personal computer. Additionally, the digitizing hardware we currently use is borrowed, as needed, from Dr. Lars Rudstam. Although our current program can perhaps continue with this arrangement for the near future, we should eventually purchase signal processing hardware if acoustic assessments remain as a long term activity. Conducting two acoustic surveys a year will also require some additional staff time for data reduction and analysis. New York will continue to contribute vessel time and use of the Simrad EY-M as needed to conduct these surveys.

Finally, conventional data analysis methods employed to date will likely give way to a spatial statistics approach such as available through software such as Spline Survey Designer (Stolyarenko 1992) or EVA (Petitgas and Prampart 1993). Since segments of acoustic transects do not usually meet the assumption of independent samples and instead are auto-correlated, a geo-statistical approach represents a more appropriate form of data analysis. Preliminary trials with EVA applied to 1994 Lake Erie acoustic survey data produced high precision (+/- 9 %) with mean density estimates.

## 6.0 Acknowledgements

The Forage Task Group would like to thank Andy Cook (OMNR, Lake Erie Management Unit, Port Dover) for his assistance in preparation of Section 2.2.2 and for proof reading this report.

## 7.0 References

Lindem, T. 1990. Hydro Acoustic Data Acquisition System (HADAS) Instructional Manual. Lindem Data Acquisition, Oslo.

Love, R. H. 1977. Target strength of an individual fish at any aspect. J. Acoust. Soc. Am. 62: 1397-1403.

Parkinson, E. A., B. E. Reiman and L. G. Rudstam. 1994. Comparison of acoustic and trawl methods for estimating density and age composition of kokanee. Transactions of the American Fisheries Society 123:(6) 841-854.

Petitgas P. and A. Pranpart. 1993. EVA (Estimation VAriance) A geostatistical software on IBM-PC for structure characterization and variance computation. ICES. CM1993/D-65.

Stolyarenko, D.A. 1992. Two dimensional spline approximation on local integral measurements. Analysis and design of acoustic fish surveys. Computational Statistics and Data Analysis 14: 509-514.

Witzel, L., M. Bur, T. Czapla, D. Einhouse, R. Haas, R. Kenyon, R. Knight, K. Muth, S. Nepszy, L. Sztramko, M. Thomas. 1994. Report of the Forage Task Group. 1994 Report to the Lake Erie Committee and the Great Lakes Fishery Commission 15 pp.

Table 2.1.1-1 Indices of relative abundance of six forage fish species in Eastern Lake Erie from bottom trawl surveys conducted by Ontario, New York, and Pennsylvania in 1994 and 1993. Indicies are reported for the age groups, young-of-the-year (YOY) and yearling-and-older (YAO) or as "All Ages". A long-term average (LT Avg) is reported in some cases.

| | Trawl | YOY | | | YAO | | | All Ages | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Survey | 1994 | 1993 | LT Avg | 1994 | 1993 | LT Avg | 1994 | 1993 | LT Avg |
| Smelt | ON-DW | 265 | 146 | 421 | 4.4 | 469 | 97.0 | | | |
| | ON-EB | 12.8 | 43.5 | 114 | 9.3 | 74.8 | 57.6 | | | |
| | NY-Su | | | | 3953 | 18887 | 17632 | | | |
| | NY-Fa | 1016 | 1803 | | 168 | 2729 | | | | |
| | PA-Fa | 533 | 56 | | | | | | | |
| Emerald Shiner | ON-DW | 2.4 | 2.2 | 1.8 | 0.5 | 6.9 | 4.6 | | | |
| | ON-OB | 2.2 | 0.5 | 1.1 | 1.4 | 0.5 | 1.2 | | | |
| | ON-EB | | | | | | | 0.4 | 0.7 | 0.4 |
| | NY-Fa | 0.0 | 1134 | | 0 | 1219 | | | | |
| | Pa-Fa | 0.3 | 2 | | | | | | | |
| Spottail Shiner | ON-OB | 110 | 261 | 28.3 | 8.9 | 2.9 | 3.1 | | | |
| | ON-IB | 3.2 | 7.4 | 8.6 | 0.3 | 0.3 | 0.9 | | | |
| | NY-Fa | 0 | 268 | | 22 | 20 | | | | |
| | PA-Fa | 0 | 4 | | | | | | | |
| Alewife | ON-DW | 0.6 | 1.1 | 4.2 | | | | | | |
| | ON-OB | 1.0 | 0.3 | 1.7 | | | | | | |
| | ON-EB | | | | | | | 0 | 0.1 | 0.8 |
| | NY-Fa | 1 | 543 | | | | | | | |
| | PA-Fa | 0 | 1 | | | | | | | |
| Gizzard Shad | ON-DW | 0.5 | 0.5 | 1.9 | | | | | | |
| | ON-OB | 2.4 | 0.8 | 2.2 | | | | | | |
| | ON-EB | | | | | | | 0 | 0.2 | 0.1 |
| | NY-Fa | 3 | 46 | | | | | | | |
| | PA-Fa | 0.4 | 2 | | | | | | | |
| White Perch | ON-DW | 1.2 | 1.0 | 1.1 | | | | | | |
| | ON-OB | 7.1 | 0.8 | 2.1 | | | | | | |
| | ON-EB | 0.4 | 4.1 | 0.7 | | | | | | |
| | NY-Fa | 192 | 194 | | | | | | | |
| | PA-Fa | 17.8 | 265 | | | | | | | |

**Ontario Ministry of Natural Resources Trawl Surveys**

ON-DW Trawling is conducted weekly during September and October at 4 fixed stations in the offshore waters of Outer Long Point Bay using a 10-m trawl with a 13-mm mesh cod end liner. Indices are reported as GMCPTH and LT Avg is for the period 1984 to 1993.

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. Indices are reported as GMCPTH and LT Avg is for the period 1980 to 1993.

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. Indices are reported as GMCPTH and LT Avg is for the period 1980 to 1993.

ON-EB A systematic survey of Ontario's Eastern Basin waters conducted during September using 10-m trawl with a 13-mm mesh cod-end. Indices are reported as GMCPTH and LT Avg is for the period 1991 to 1993.

**New York Department of Environment Conservation Trawl Surveys**

NY-Su Trawling is conducted at 14 stations in stratified waters (< 36 m) during July using a 10-m trawl with a 9.5-mm mesh cod end liner. Indices are reported as arithmetic mean catch per trawl hour and LT Avg is for the period 1987 to 1993.

NY-Fa Trawling is conducted at 30 nearshore (15-28 m) stations during October using a 10-m trawl with a 9.5-mm mesh cod end liner. Indices are reported as arithmetic mean catch per trawl hour and LT Avg is not reported for this survey, which started in 1991.

**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 geometric mean catch per tow.

Table 2.3.1-1 Size and density of zooplankton collected and level of nutrients measured in the estuaries of the Maumee and Huron Rivers, Lake Erie from 1990 to 1994.

| | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|
| **Maumee River** | | | | | |
| Secchi (m) | 0.42 | 0.34 | 0.42 | 0.36 | 0.59 |
| Temperature (°C) | 15.20 | 17.20 | 17.30 | 17.30 | 16.10 |
| Nitrate/Nitrite (mg/L) | 4.91 | 4.63 | 6.36 | 2.80 | 2.41 |
| Phosphorus (mg/L) | 0.16 | 0.20 | 0.15 | 0.19 | 0.12 |
| Silica (mg/L) | 2.11 | 2.16 | 1.80 | 1.50 | 0.83 |
| TOC (mg/L) | -- | 7.63 | 14.48 | 7.88 | 6.13 |
| Zooplankton | | | | | |
| Density (#/L) | 12.85 | 15.31 | 25.60 | 23.70 | 37.13 |
| Mean length (mm) | 0.69 | 0.62 | 0.61 | 0.50 | 0.84 |
| **Huron River** | | | | | |
| Secchi (m) | 0.88 | 0.53 | 0.83 | 0.72 | 0.73 |
| Temperature (°C) | 15.70 | 18.30 | 17.00 | 15.90 | 14.70 |
| Nitrate/Nitrite (mg/L) | 0.41 | 0.52 | 0.48 | 0.39 | 0.36 |
| Phosphorus (mg/L) | 0.05 | 0.07 | 0.06 | 0.08 | 0.06 |
| Silica (mg/L) | 0.83 | 0.62 | 0.58 | 0.62 | 0.40 |
| TOC (mg/L) | -- | 4.01 | 4.77 | 4.99 | 4.31 |
| Zooplankton | | | | | |
| density (#/L) | 8.19 | 5.87 | 5.82 | 8.75 | 12.68 |
| Mean Length (mm) | 0.40 | 0.41 | 0.34 | 0.31 | 0.69 |

Table 5.3-1. Summary of mid-water and bottom trawl catches to characterize species composition in offshore areas (>25 m contour) of the eastern basin of Lake Erie during July 1993 and 1994.

| YEAR | GEAR | TIME | TOWS | NUMBER OF YAO SMELT | NUMBER OF OTHER FISH | PERCENT YAO SMELT |
|---|---|---|---|---|---|---|
| 1993 | MIDWATER | NIGHT | 1 | 75 | 11 | 87.2% |
| 1993 | MIDWATER | NIGHT | 2 | 108 | 5 | 95.6% |
| 1993 | MIDWATER | NIGHT | 3 | 369 | 4 | 98.9% |
| 1993 | BOTTOM | DAY | 37 | 95556 | 108 | 99.9% |
| 1994 | BOTTOM | DAY | 25 | 14012 | 303 | 97.9% |

Table 5.3-2. Estimated abundance of YAO smelt-sized fish (TS of -52 to -44 dB) in coldwater habitat in the eastern basin of Lake Erie during July, 1993 and 1994. These estimates are directly comparible for only particular depth strata and not as total density estimates. The assigned TS range also likely excludes some YAO smelt density that could be confused with other fish. Confidence limits (95%) are expressed as percent of the total abundance estimate.

| DEPTH CONTOUR | SMALL FISH ABUNDANCE IN THERMOCLINE AND HYPOLIMNION LAYERS (TARGET STRENGTH RANGE -52 to -44 dB) | | | |
|---|---|---|---|---|
| | 1993 | | 1994 | |
| | ABUNDANCE | (conf. int) | ABUNDANCE | (conf. int) |
| 18 TO 25 m | not sampled | -- | 90,941,356 | 31.7% |
| 25 TO 35 m | 232,341,856 | 43.8% | 162,442,500 | 25.8% |
| 35 TO 65 m | 73,481,544 | 31.6% | 134,615,243 | 14.8% |
| TOTAL | 305,823,400 | 34.1% | 387,999,099 | 13.1% |

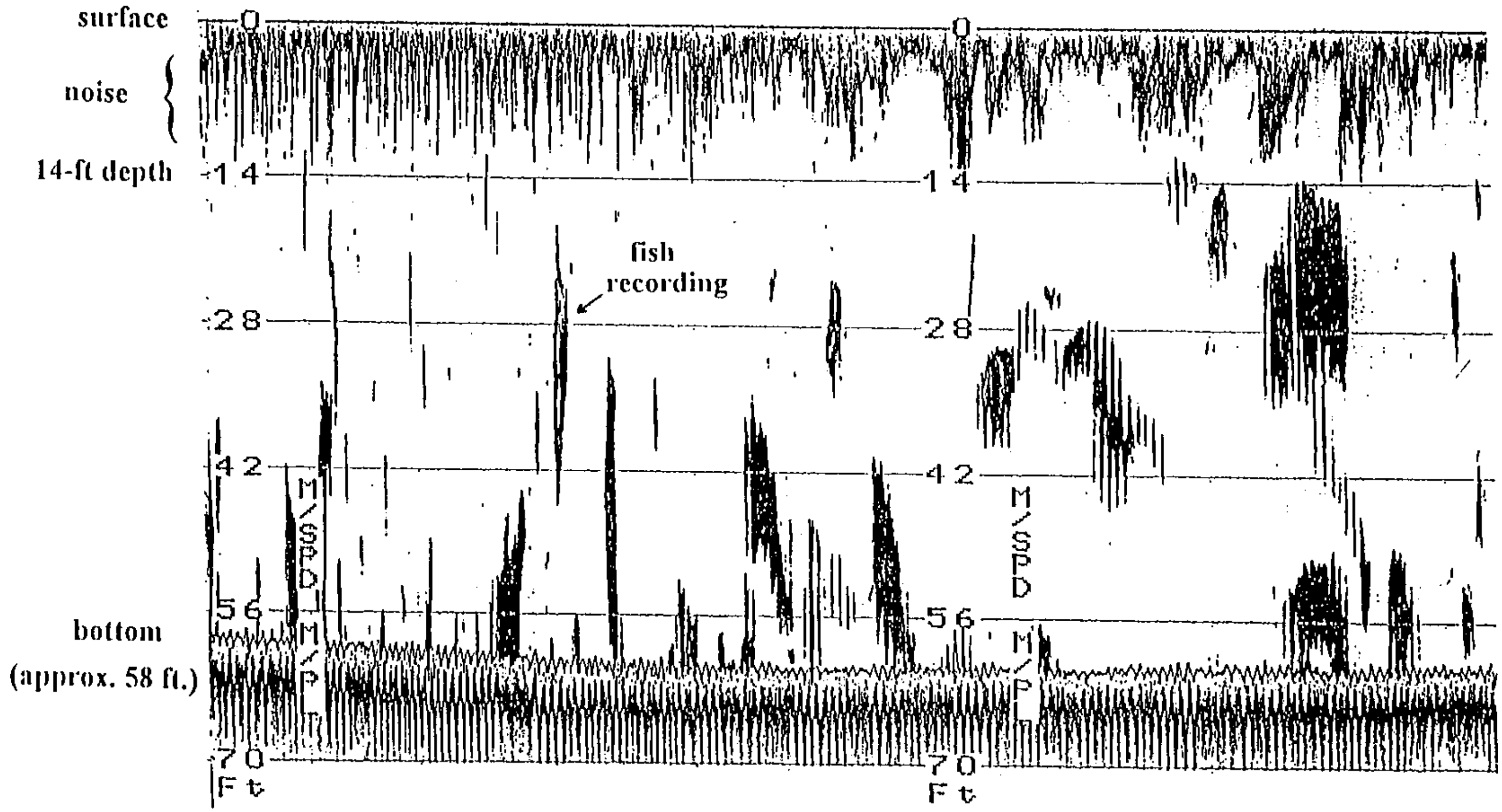



Figure 2.1.1-1 Paper recording from a depth sounder taken during index trawling in Long Point Bay, Lake Erie on September 27, 1994. Dark, vertically elongated images extending upward from the lake bottom and suspended in the water column below 14-ft depth are probably young-of-the-year smelt.

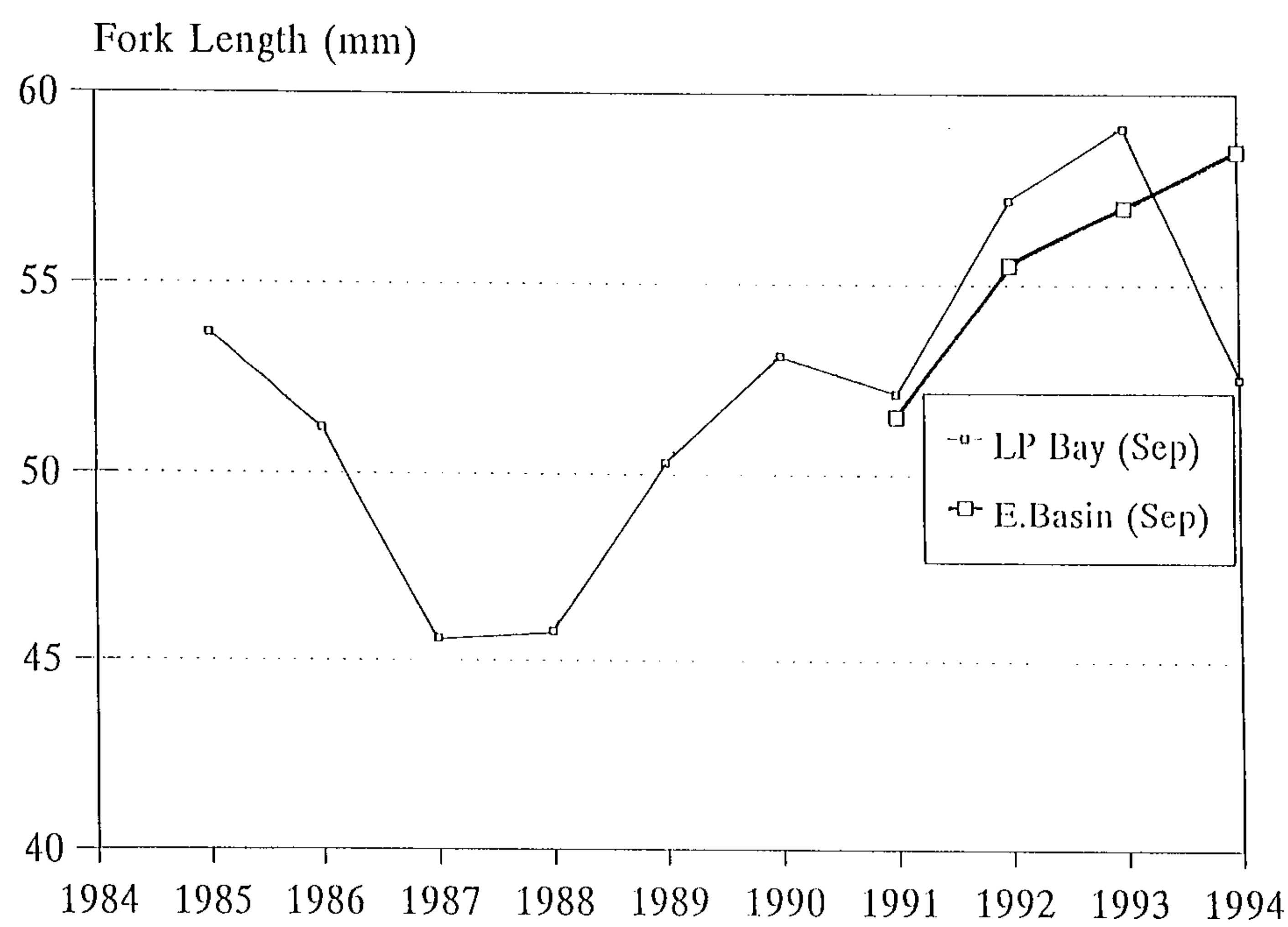



**Figure 2.1.1-2 Mean fork length (mm) of young-of-the-year rainbow smelt from OMNR index trawl surveys in Long Point Bay and the eastern basin, Lake Erie during September, 1985 to 1994.**

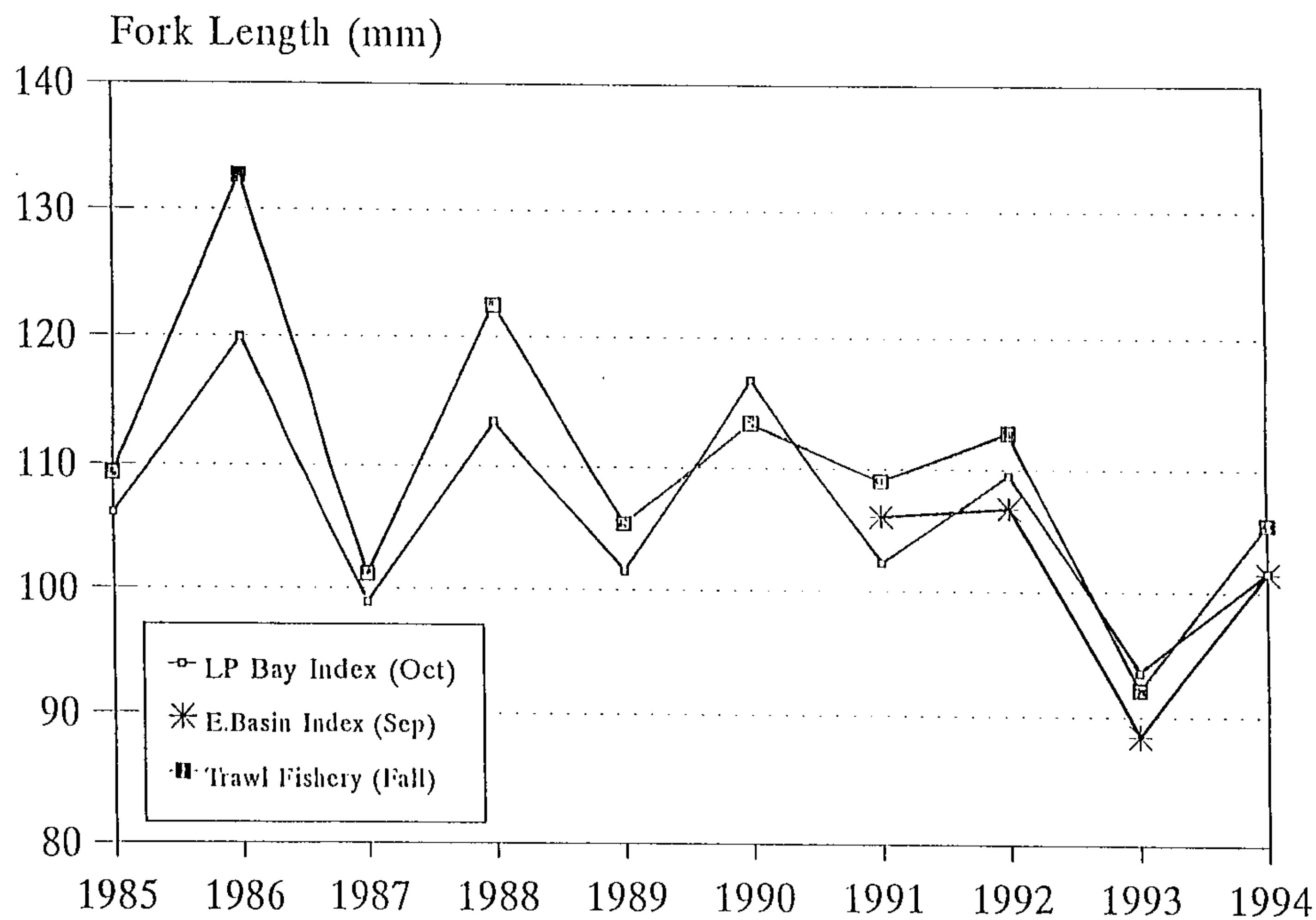
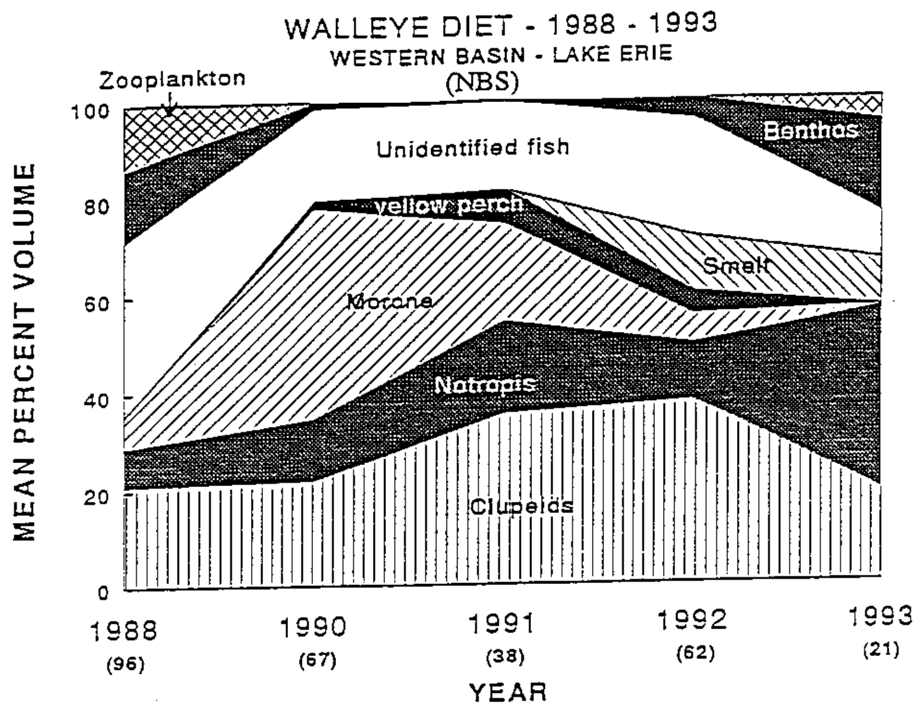



**Figure 2.1.1-3 Mean fork length (mm) of yearling rainbow smelt from OMNR index trawl surveys in Long Point Bay (October) and the eastern basin (September), and the commercial trawl fishery (September-December) in eastern Lake Erie, 1985 to 1994.**



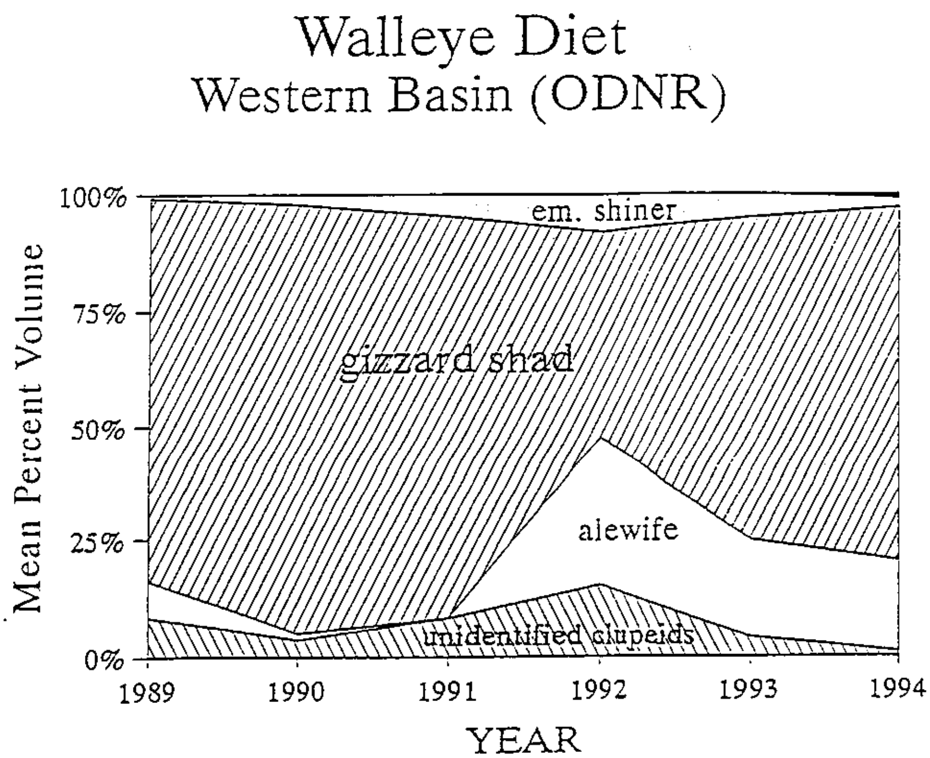
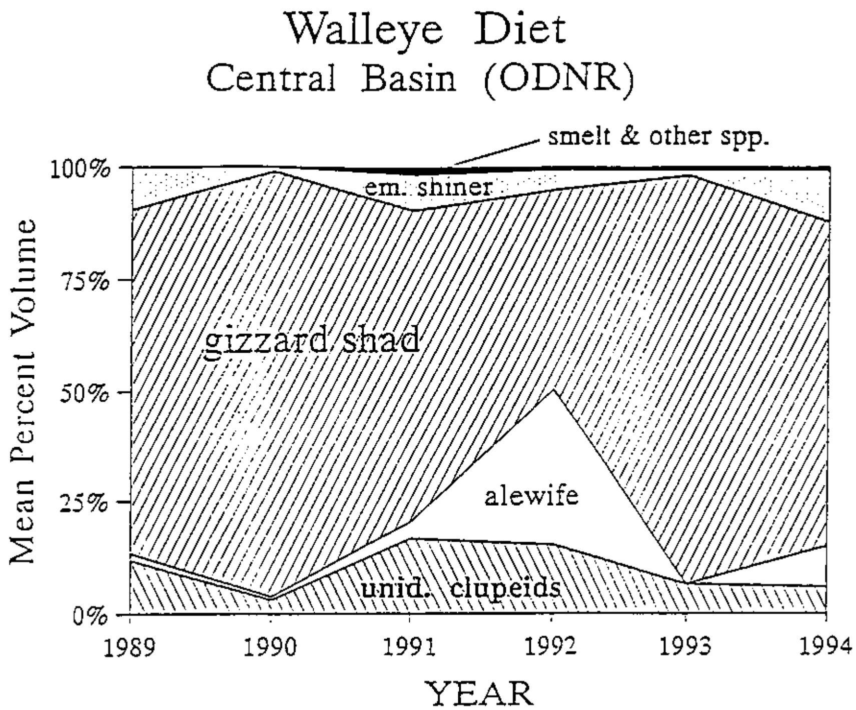




**Figure 2.2.1-1 Food items identified from the stomach contents of walleye in the western basin of Lake Erie by the National Biological Service (NBS) and the Ohio Department of Natural Resources (ODNR), 1988-1994.**



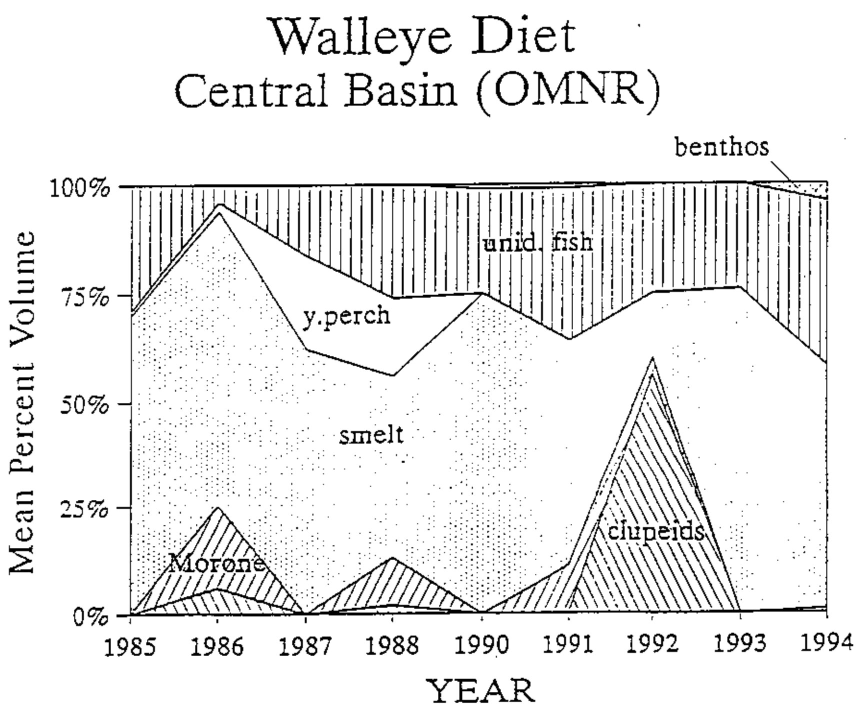
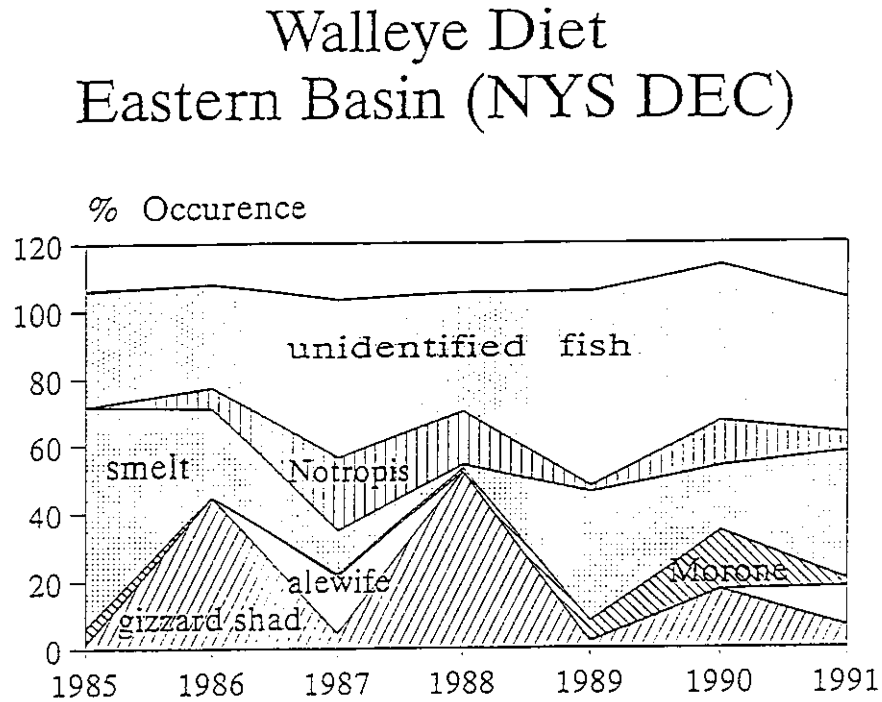




**Figure 2.2.1-2 Food items identified from the stomach contents of walleye in the central basin of Lake Erie by the Ohio Department of Natural Resources (ODNR) and the Ontario Ministry of Natural Resources, 1985-1994.**



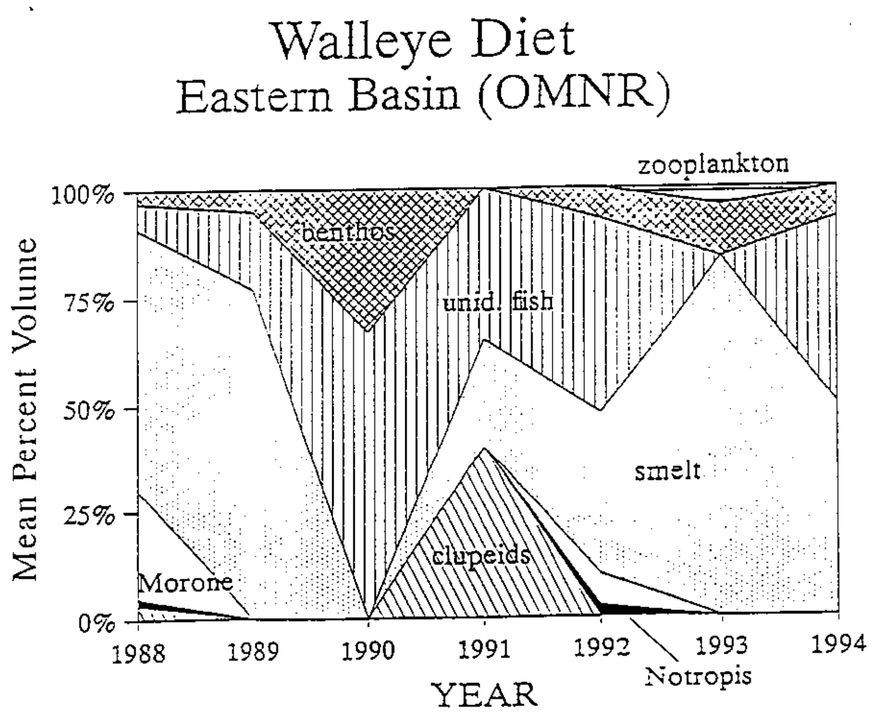




**Figure 2.2.1-3** **Food items identified from the stomach contents of walleye in the eastern basin of Lake Erie by the New York State Department of Environmental Conservation (NYS DEC) and the Ontario Ministry of Natural Resources (OMNR), 1985-1994. Diet composition was measured as percent occurrence by NYS DEC (top) and as mean percent volume by OMNR (bottom).**

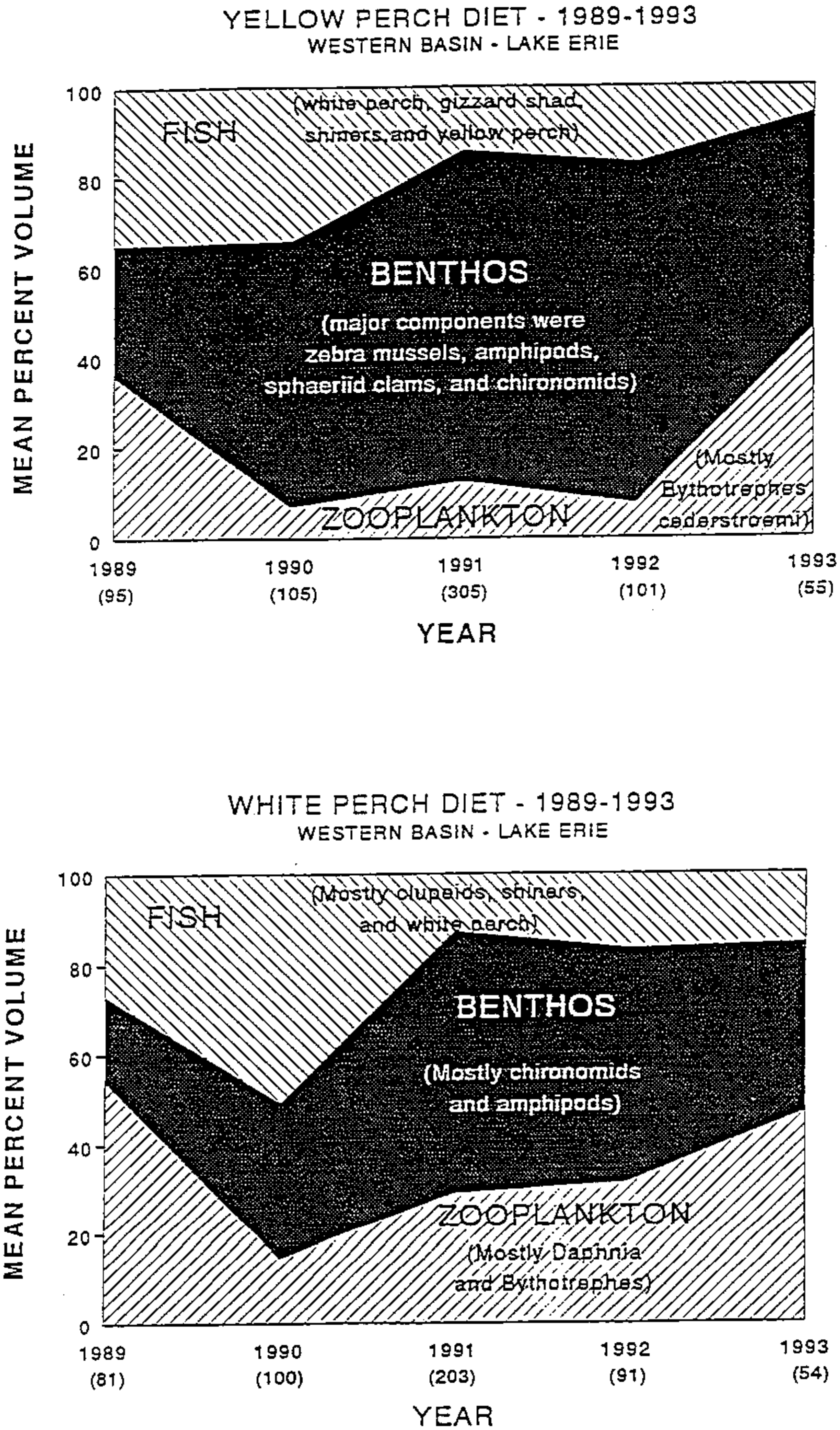
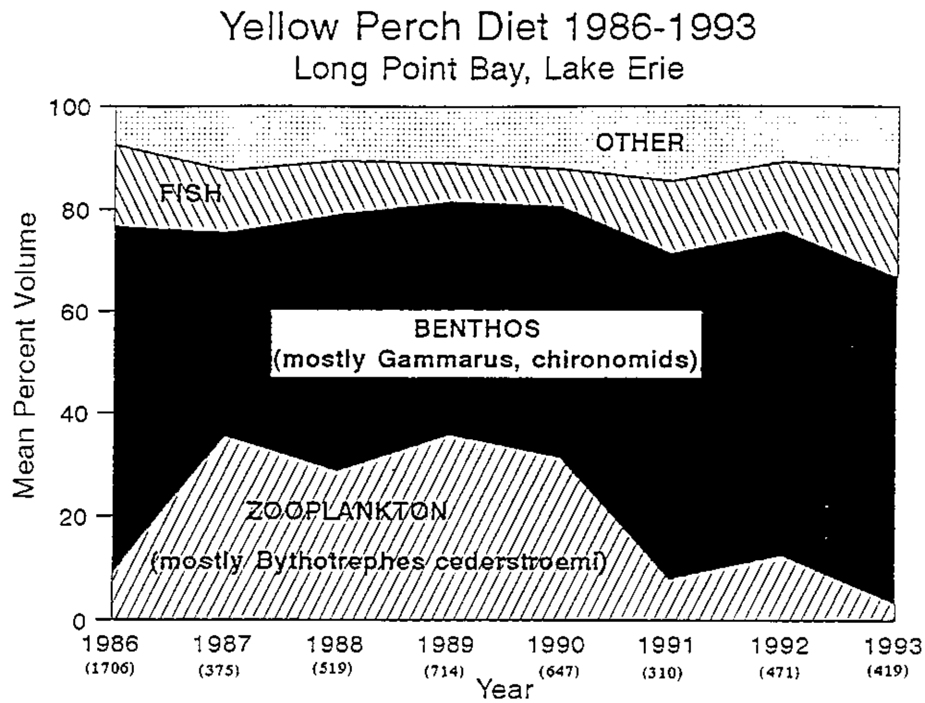



Figure 2.2.2-1 Mean percent volume of three major food groups found in the diet of yellow perch and white perch in the western basin, Lake Erie, 1989-1993 (NBS data).



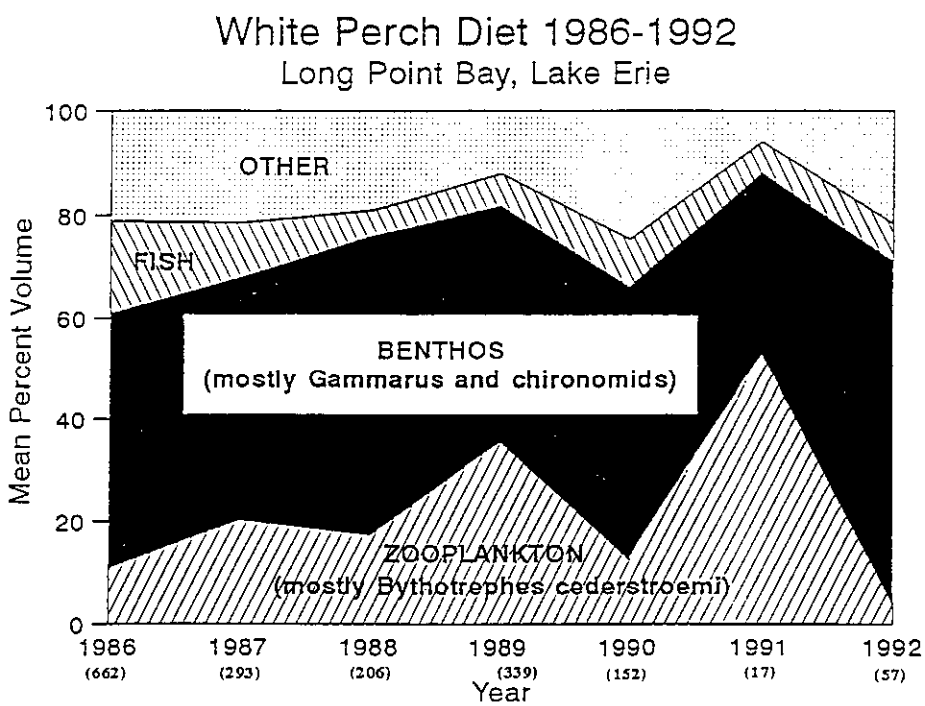




Figure 2.2.2-2 Mean percent volume of three major food groups found in the diet of yellow perch and white perch in Long Point Bay, Lake Erie, 1986-1993 (OMNR data).

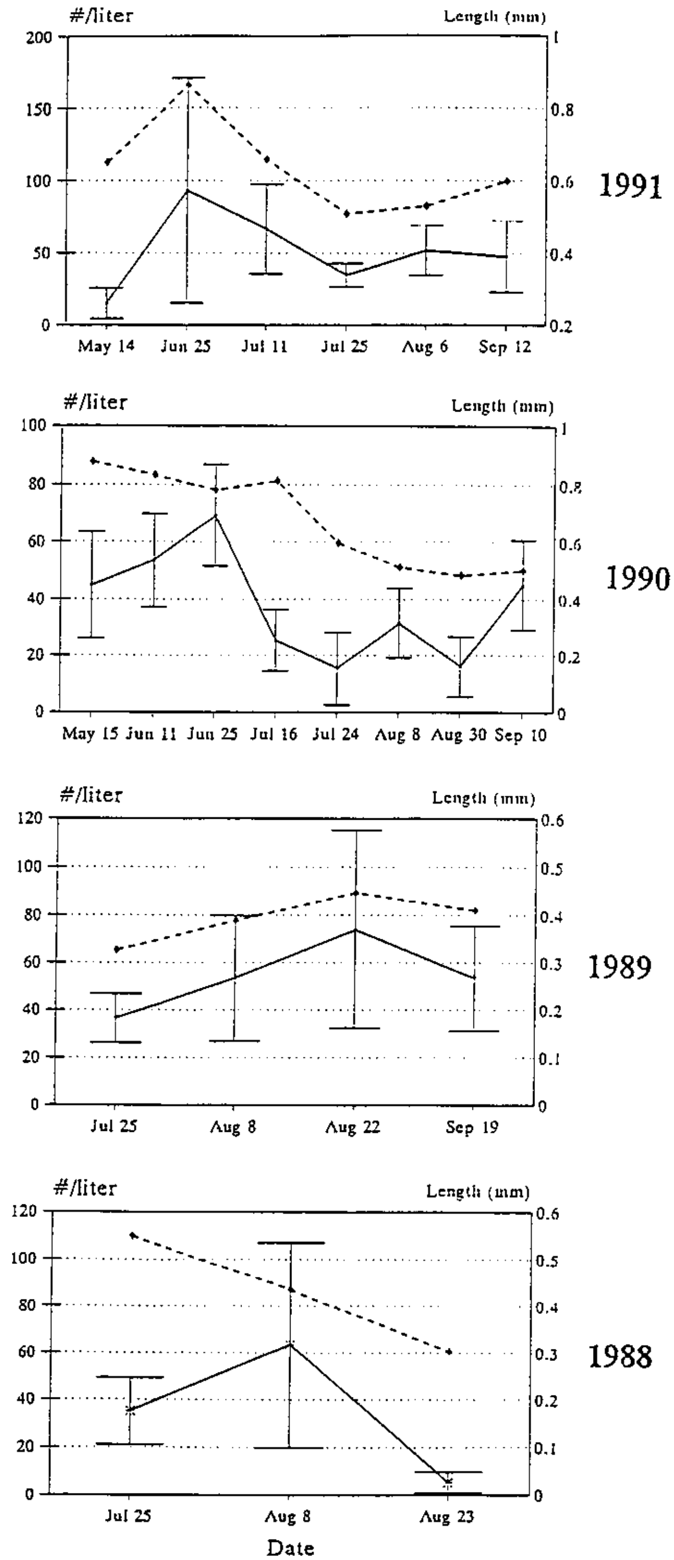



**Figure 2.3.2-1 Total density and size of zooplankton sampled monthly or bi-weekly during summer in the western basin, Lake Erie, 1988-1991 (ODNR data).**

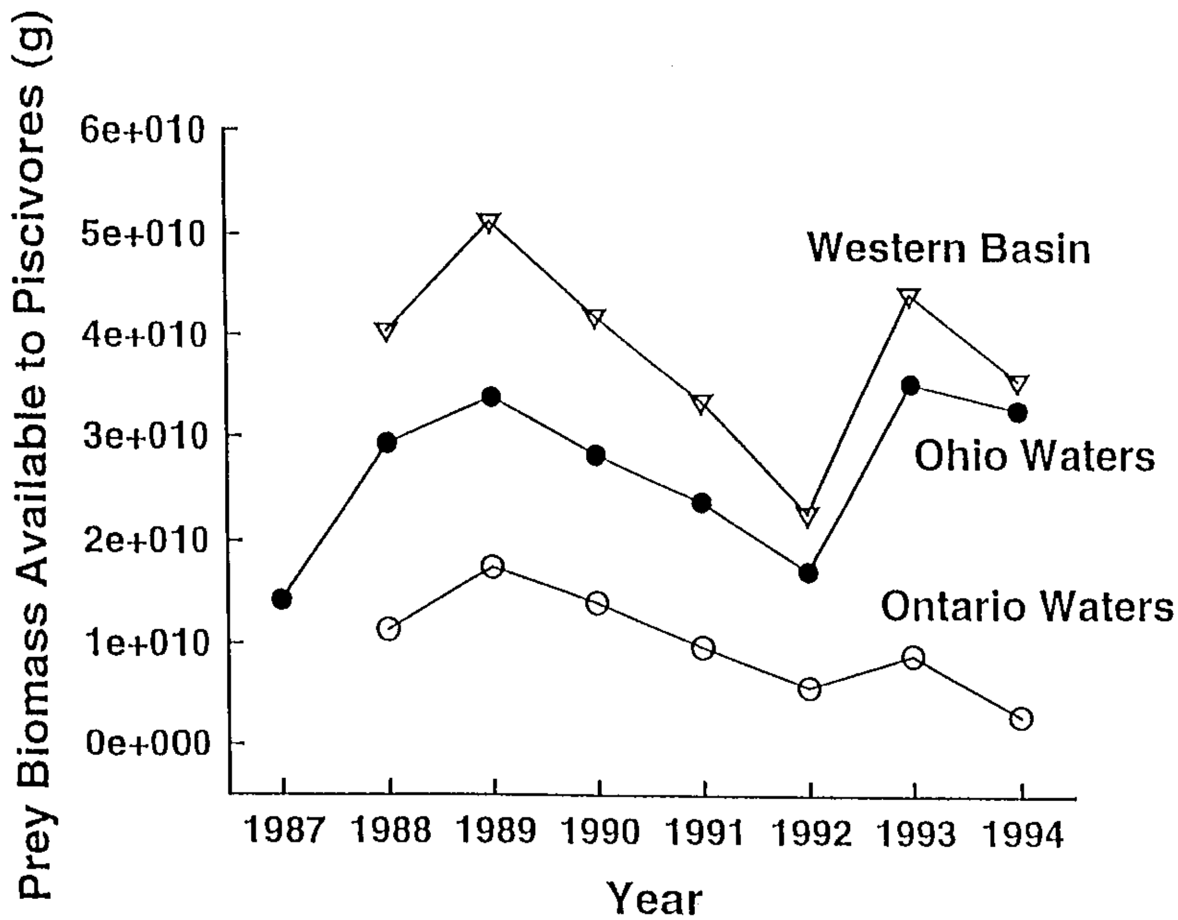



**Figure 3.3-1** Estimated total prey fish biomass in Ontario and Ohio waters of the western basin, Lake Erie, 1987-1994 (unpublished data of M. Kershner, Ohio State University)

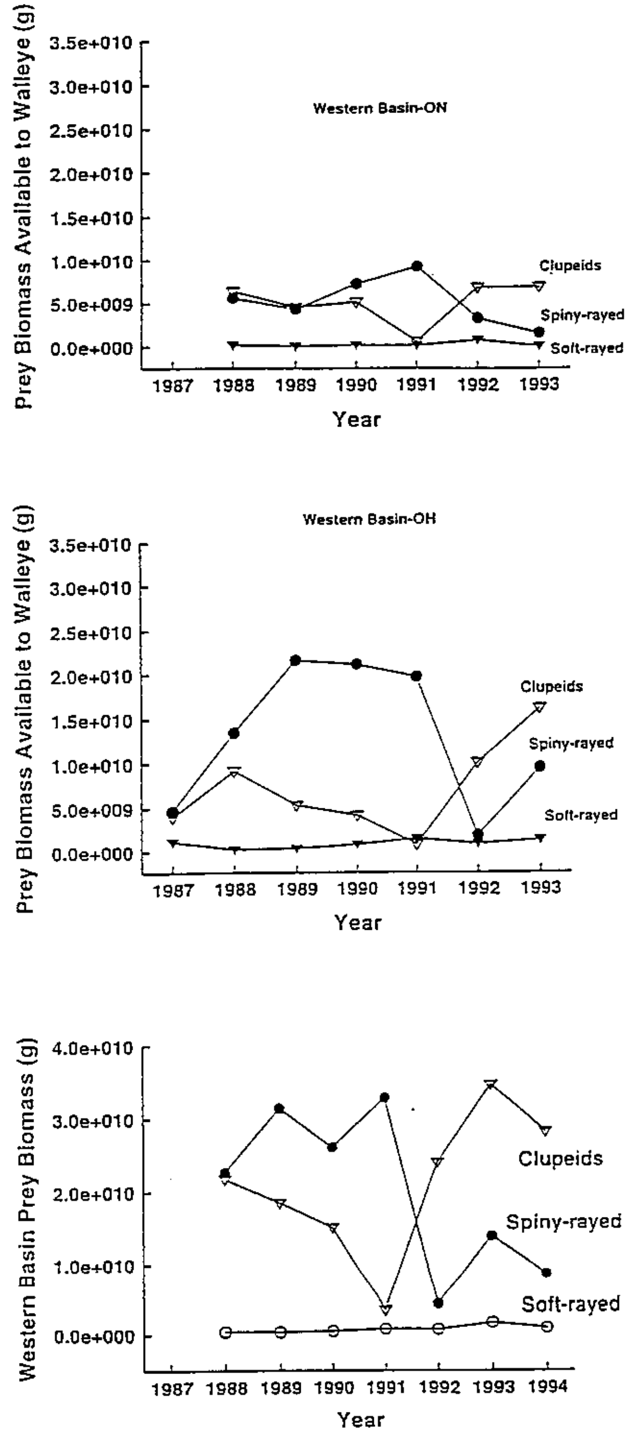



Figure 3.3-2 Estimated biomass of prey fish groups in Ontario and Ohio waters of the western basin, Lake Erie, 1987-1994 (unpublished data of M. Kershner, Ohio State University)

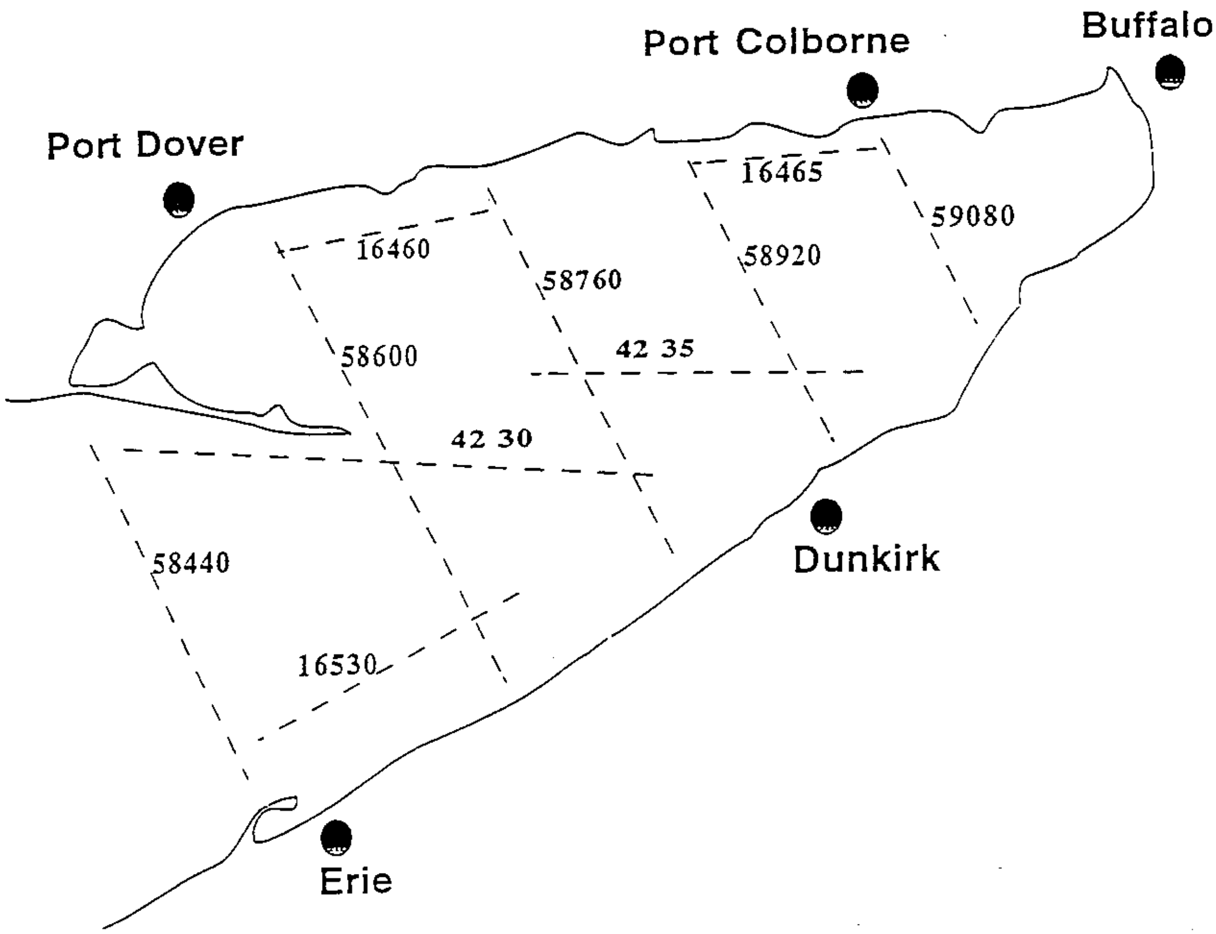



Figure 5.2-1 Location of transects sampled during a July 1994 hydroacoustic survey of the eastern basin, Lake Erie.

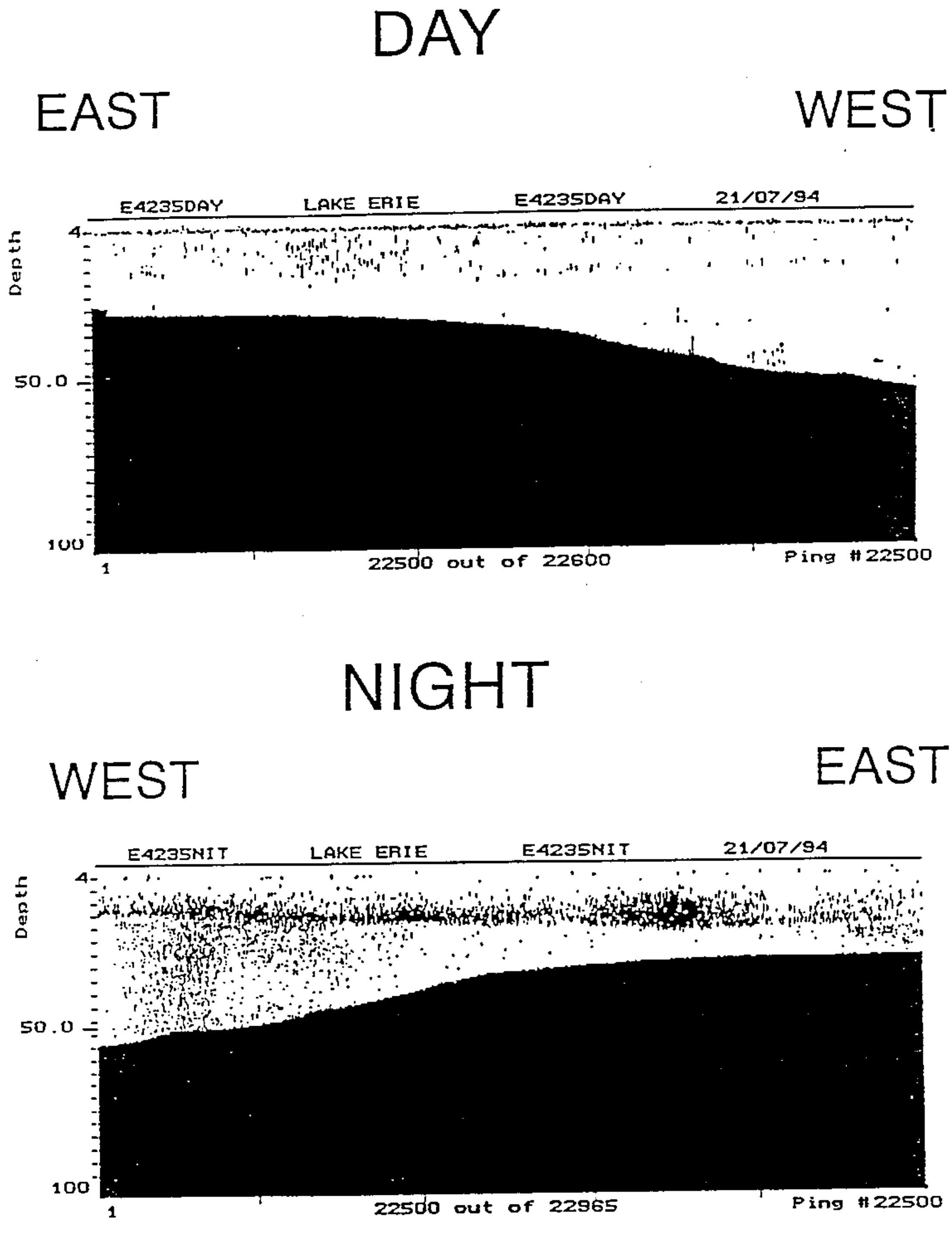



Figure 5.3-1 Echograms of an acoustic transect (42 35, Figure 5.2-1) replicated within three hours during day and night periods in July 1994.

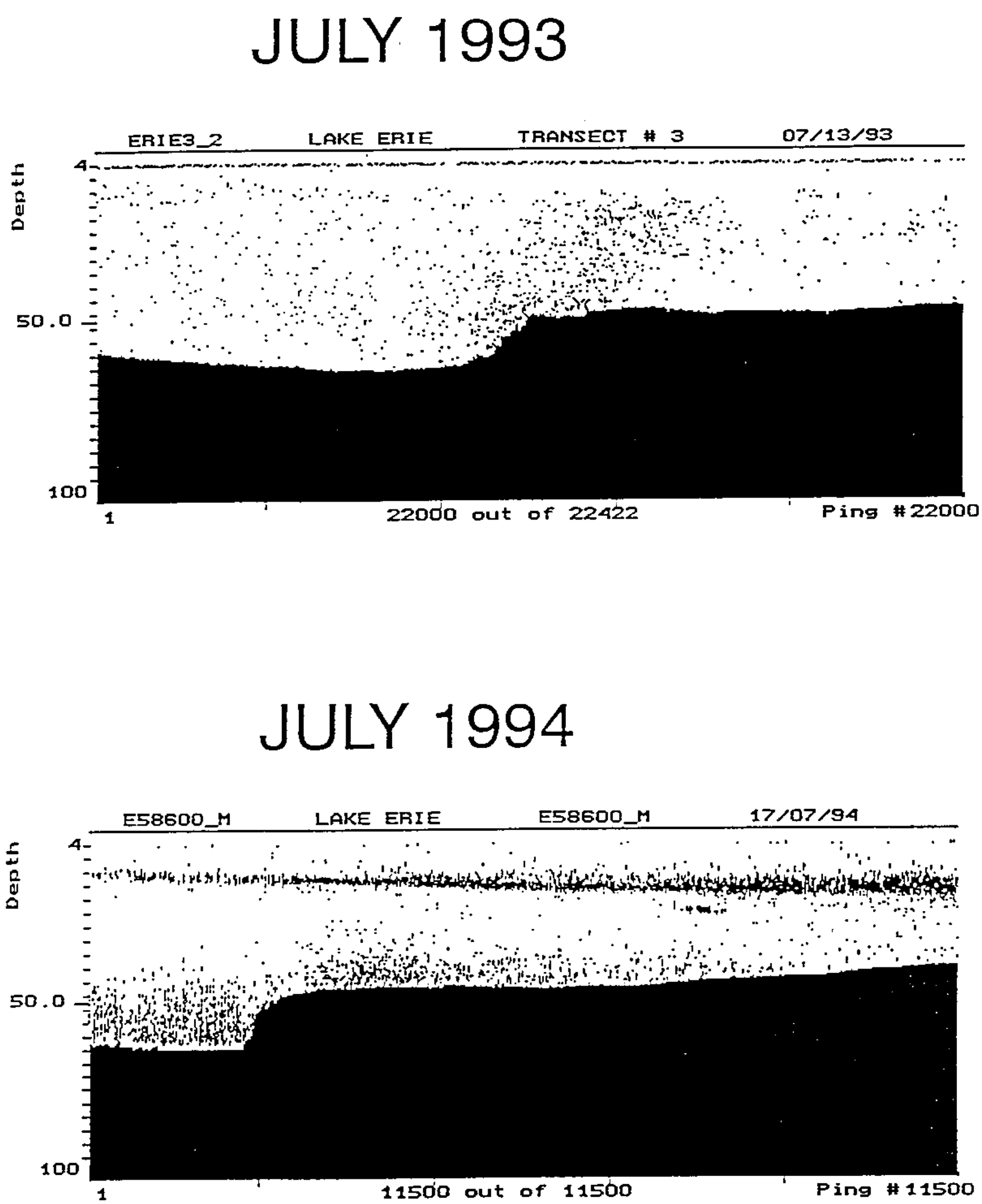



**Figure 5.3-2** Echograms of approximately similar transect sections surveyed in July 1993 and 1994.

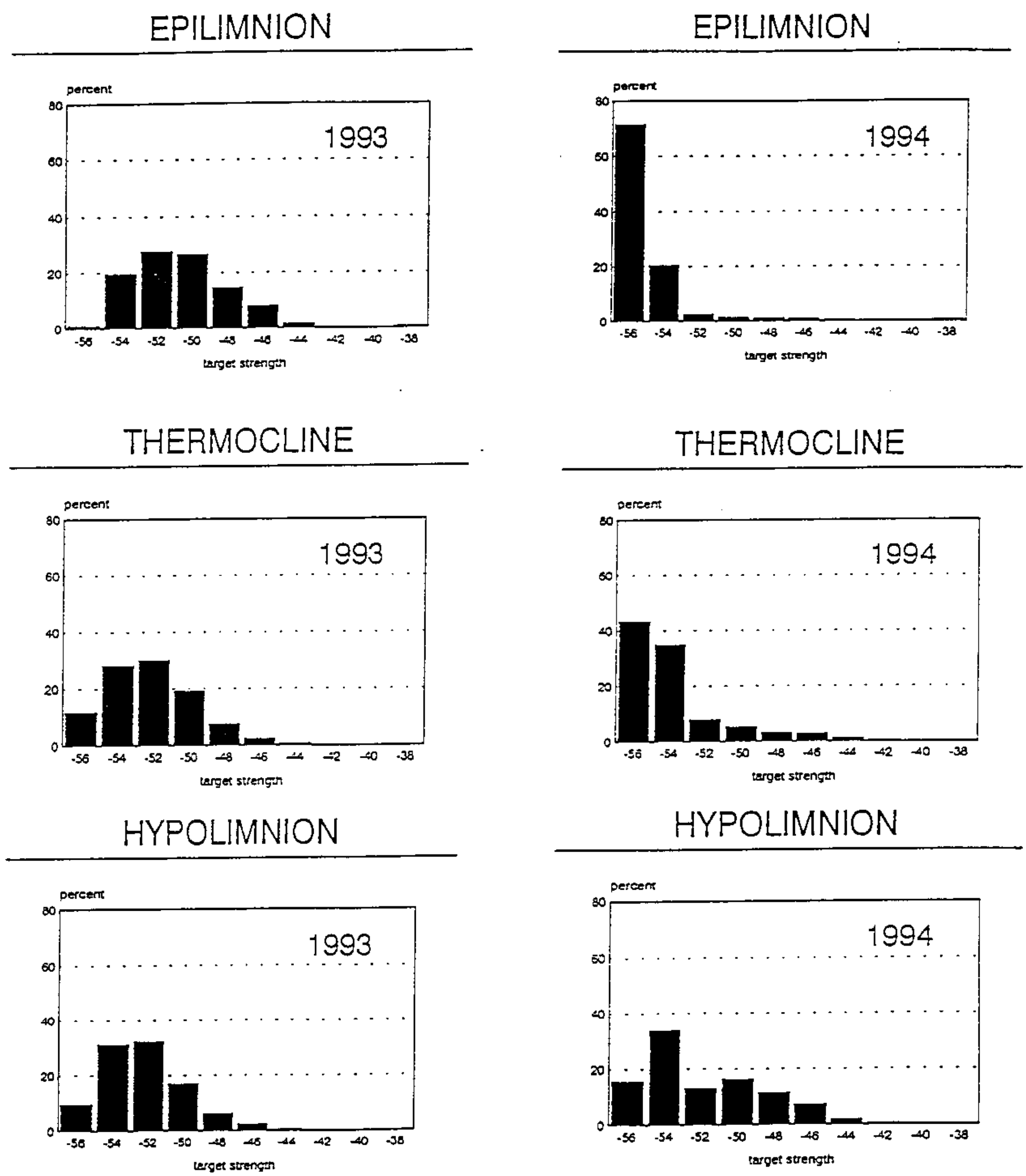



**Figure 5.3-3** Target strength distributions of fish from three thermal strata during hydroacoustic surveys of the eastern basin in July 1993 and 1994

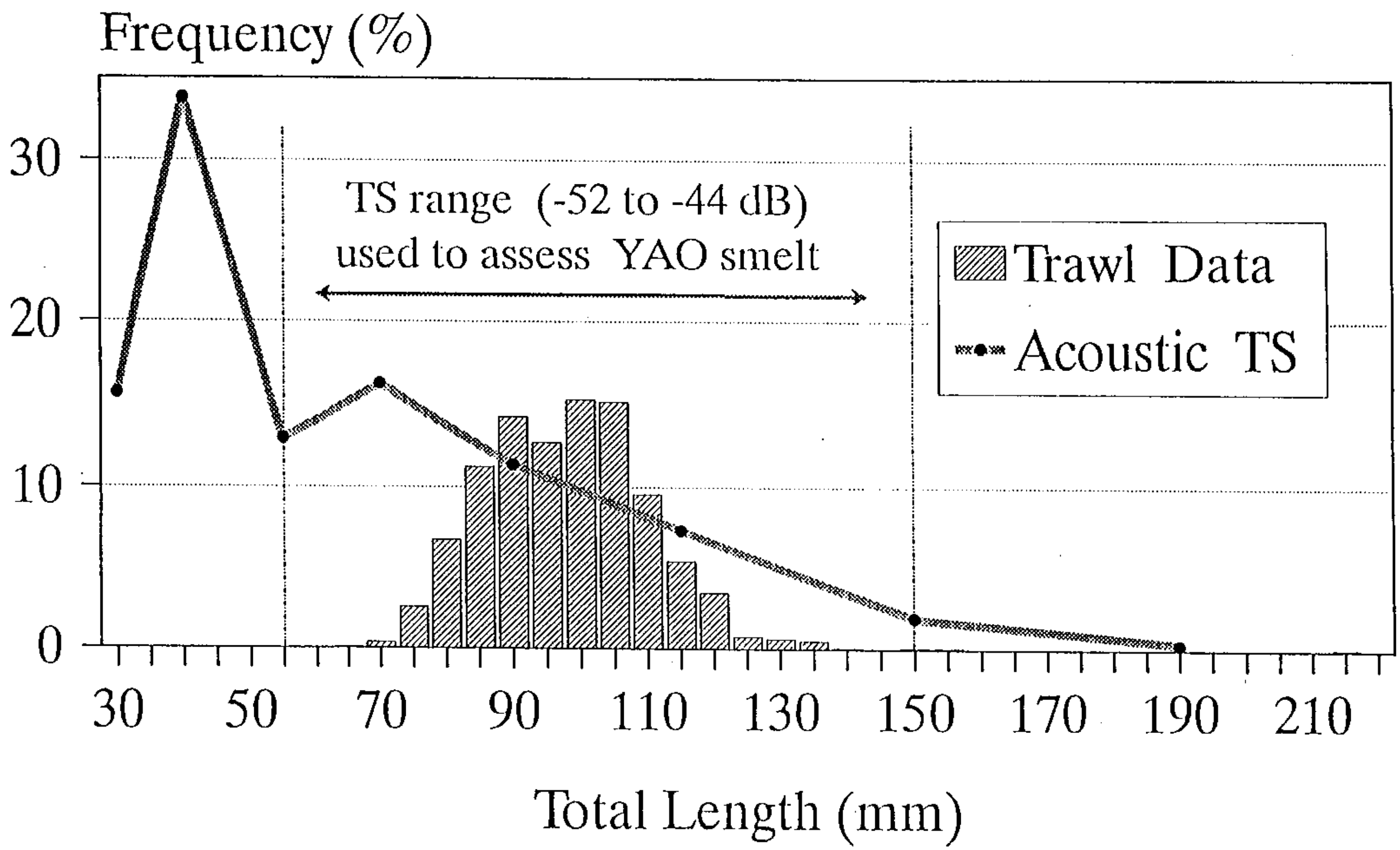



**Figure 5.3-4** A comparison of rainbow smelt length frequencies obtained from a hypolimnion trawl survey and that predicted from hypolimnion acoustic target strength (TS) distributions using Love's (1977) equation, for a July 1994 survey.

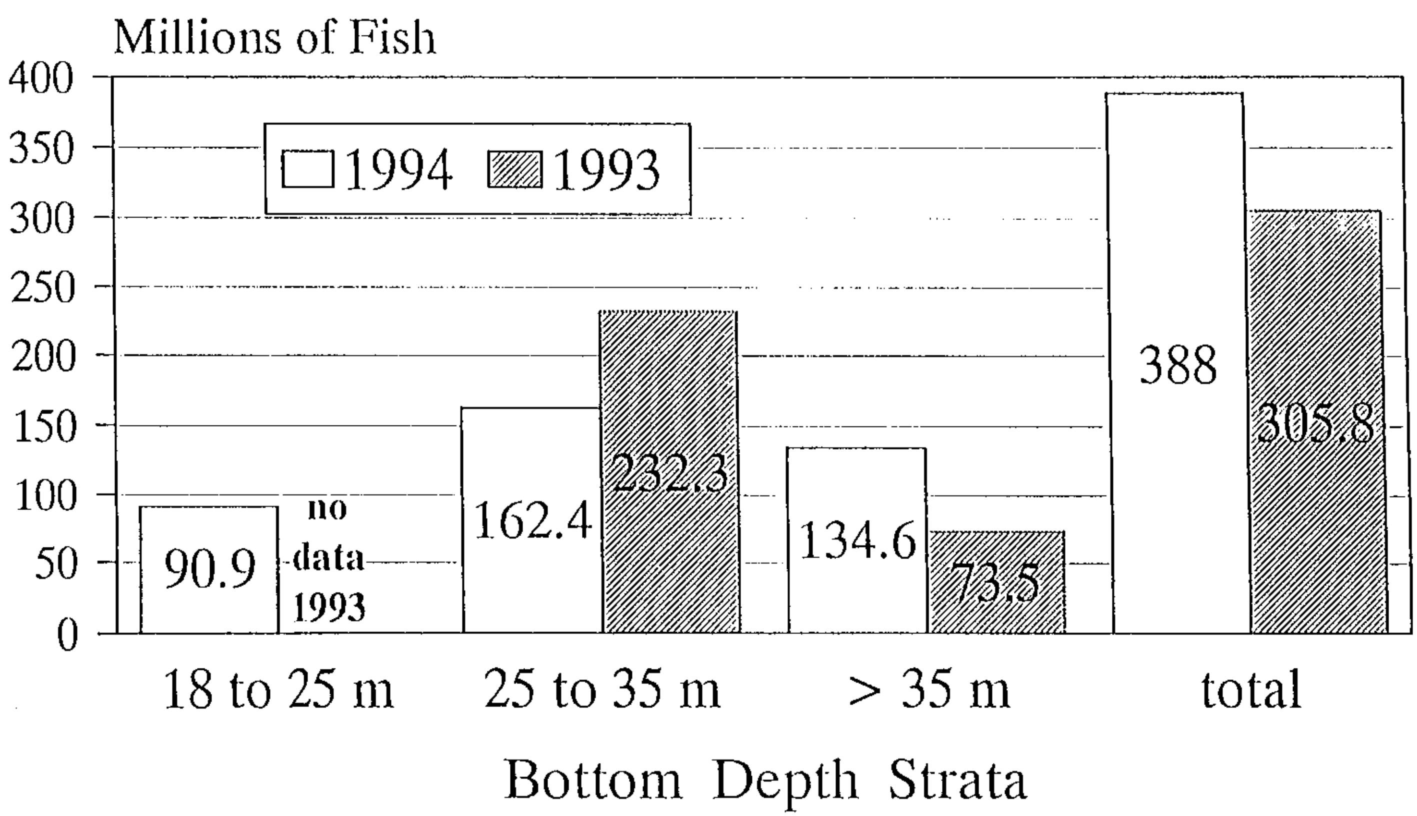



**Figure 5.3-5** Estimated abundance of yearling-and-older (YAO) smelt-sized fish in coldwater habitat (thermocline and deeper layers) for three depth strata (18-25, 25-35, and >35 m) sampled during acoustic surveys of the eastern basin, Lake Erie in 1993 and 1994. The 18-25 m depth stratum was not surveyed in 1993.

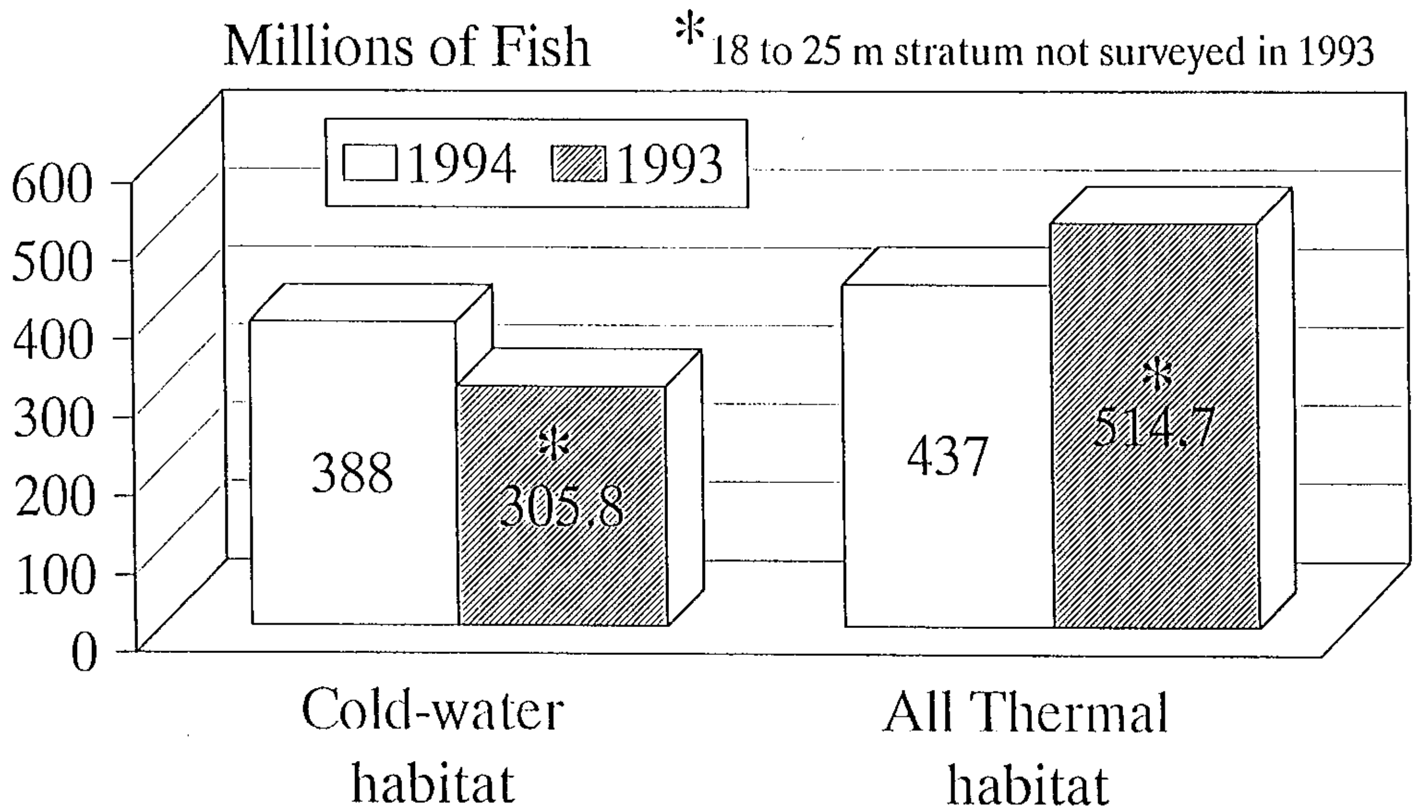



**Figure 5.3-6** Estimated abundance of yearling-and-older (YAO) smelt-sized fish in coldwater habitat (thermocline and deeper layers) and in all thermal layers of the water column during an acoustic survey of the eastern basin, Lake Erie in 1993 and 1994. The 18-25 m depth stratum was not surveyed in 1993.