ILLINOIS NATURAL HISTORY SURVEY

Yellow Perch Population Assessment in Southwestern Lake Michigan, Including the Identification Factors that Determine Yellow Perch Year-Class Strength

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Center for Aquatic Ecology, Illinois Natural History Survey

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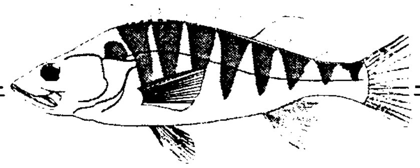

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EXECUTIVE SUMMARY

The objectives of this study are to expand the Illinois Department of Natural Resources (IDNR) annual yellow perch stock assessment data, monitor population densities of age-0 yellow perch, and identify some of the factors likely to have limited yellow perch recruitment since 1989. We collected adult yellow perch as part of a lakewide tagging study and to assess the age and size structure of the population. Age-0 yellow perch were sampled with a bottom trawl, and programs to monitor yellow perch egg skein densities, post-larval yellow perch abundance, and the effect of adult alewife predation on yellow perch larvae were developed. We also examined the possible effect of zooplankton density on larval yellow perch survival in an experiment.

The results of this project will enable fish managers to develop effective management strategies for this important sport and previously commercially fished species. Larval yellow perch sampling will expand our understanding of the early life history of yellow perch in terms of larval fish movements, feeding behavior, and survival. Early life history data will eventually lead to an understanding of factors that affect juvenile survival and future year-class strength.

This report summarizes the 1999 sampling.

1. During 1999 a total of 6,274 yellow perch were tagged from our three sampling sites; Waukegan wiremill, North Lake Forest and Fort Sheridan.

2. The average length of all measured yellow perch was 249 mm (N = 7,007, SD = 34 mm). Only one female yellow perch with a length of 366 mm was collected during 1999 fyke netting. With only one female collected, the male:female ratio of the yellow perch collected in our fyke nets was 7,006:1. All of the 450 yellow perch subsampled for aging were males. The skewness of the sex ratio is likely a function of the sampling gear (because male yellow perch tend to congregate in fyke nets). In addition, size-selective harvest by sport anglers and commercial fishermen has had deleterious impacts on the population sex structure because female yellow perch tend to grow faster and to larger sizes than male yellow perch in Lake Michigan. The proportion of female yellow perch in our samples has declined each year since 1990 to a low of 0.01% in 1999 and may indicate problems with reproductive potential.

3. The majority of yellow perch collected in fyke nets during 1999 were age-4 (15.7%), age-10 (13.7%) and age-11 (23.5%). Over 50% of the yellow perch collected in fyke nets were age-10 and older.

4. Relatively few yellow perch larvae were captured using neuston nets (1999) compared to sampling conducted prior to 1994. Peak larval yellow perch density in our samples occurred on June 7 (21.5 larval yellow perch•100m^{-3}).

5. In 1999 we performed day and night bottom trawls, which sampled approximately 338,884 m^2 (day 178,360 m^2 and night 160,524 m^2). Only 13 age-0 yellow perch were collected and all were collected at night. No yellow perch were collected in day trawls so

stomach content analysis was not conducted. The paucity of age-0 yellow perch may indicate a failure of larval fish to recruit to the sub-adult population.

6. No larval fish were found in the adult alewife stomachs (N = 37) examined in 1999. Of the 37 alewife stomachs collected, only 18 contained identifiable items.

7. Zooplankton samples we collected coincided with larval yellow perch sampling during 1999. The 1999 zooplankton density was similar to densities from 1996-1998 but these densities are much lower than the 1988 densities. This 1988 peak corresponded with the last year of strong yellow perch recruitment in Lake Michigan. During all other years, zooplankton densities were less than half of 1988. The potential relationship between zooplankton density and YOY yellow perch survival indicates that continued monitoring of nearshore zooplankton density is needed to explore the potential role played by food availability in the recruitment success of yellow perch.

8. Yellow perch egg skeins were located south of Waukegan Harbor at the abandoned US Steel intake line during 1999 on May 20 and June 2. On May 20, eggs were newly fertilized but on June 2, eggs were in all stages of development. Egg viability was estimated to be 95% for sampled egg skeins returned immediately to the laboratory and viewed under a dissecting microscope.

9. An experiment revealed that larval yellow perch survival is strongly influenced by zooplankton density. Larval yellow perch survived significantly better when fed at densities of 100 zooplankton/L than at 0, 25, or 50 zooplankton/L. In general, survival of larval yellow perch increased as more zooplankton was available to them.

INTRODUCTION

Yellow perch (*Perca flavescens*) is an important commercial and sport fish throughout much of its range in North America. Its schooling behavior promotes sizable captures in commercial gears such as trap nets and gill nets, and the tendency of yellow perch to congregate near shore in the spring makes this species accessible to shore anglers. The majority of yellow perch harvested in North America are taken from the Great Lakes; yellow perch provide the most important sport fisheries in the four states bordering Lake Michigan, and until 1997 supported large-scale commercial fisheries in three of those states.

Lake Michigan yellow perch have undergone severe fluctuations in abundance in the past few decades. The population in the southern basin increased dramatically in the 1980s (McComish 1986), and the sport and commercial fisheries expanded accordingly. In Illinois waters alone, the estimated annual catch by sport fishermen doubled between 1979 and 1993, from 600,000 to 1.2 million fish (Muench 1981, Brofka and Marsden 1993). Between 1979 and 1989, the commercial harvest in Illinois tripled, in Wisconsin (excluding Green Bay) it increased six-fold, and in Indiana the harvest increased by over an order of magnitude (Baumgartner et al. 1990, Brazo 1990, Hess 1990). However, a federally-funded study recently completed by the Lake Michigan Biological Station (Marsden et al.1993a) indicated that the 1992 yellow perch fishery was primarily supported by a strong year-class spawned in 1988, and that no strong year-class had been produced since then. Few or no young-of-the-year (YOY) yellow perch were found in lakewide sampling efforts during 1994 through 1997 (Hess 1998) but there appears to have been significantly greater survival of the 1998 year class (Makauskas and Clapp 2000). Consequently, the yellow perch population as a whole was composed of larger and older individuals in 1998 than in 1986 (Robillard et al. 1999).

The ability to manage yellow perch is hampered by insufficient information about population size, stock structure, movements, and factors that affect population growth. Evaluation of the best techniques and locations to collect assessment data is necessary to maximize information access. Other federally funded research by the Lake Michigan Biological Station (LMBS) determined that Lake Michigan yellow perch populations are too large and too mobile for single agency mark-and-recapture studies to be viable (Marsden et al. *in review*). Annual assessment data of spring spawning populations at index stations, however, combined with assessments of year-class strength may permit evaluation of the population's relative abundance. These data have been obtained in the past by the Illinois Department of Natural Resources (IDNR) at two gill net index stations, and by LMBS at two sites using fyke nets. Several inadequacies in these data exist, however: (1) there is no index station near the southern border of the Illinois shoreline; (2) data from gill nets and fyke nets are not comparable without direct comparison at the same sites during the same time period; (3) it is unknown where spawning concentrations of yellow perch occur, or how stable such locations (if they exist) are from year to year. If foci of spawning concentrations move from year to year, then data from localized index stations may reflect this movement rather than any real information about population size.

To protect yellow perch stocks, fisheries managers should ideally set harvest targets in accordance with fluctuating population sizes. Assessment of larval and age-0 yellow perch populations may permit prediction of future year-class strength. However, the variances on larval yellow perch abundance data and age-0 catches are very high, and the diel vertical movements of yellow perch larvac and their prey are not well documented in large lakes. Tracking these movements will enhance our understanding of larval fish feeding behavior and early life-stage survival rates, contributing to our ability to monitor year-class strength relative to other years.

The continued decline of the yellow perch population due to reduced recruitment of larvae to the age-0 stage has prompted researchers to narrow the focus of investigation to age-0 interactions and survival. The effect of alewife (*Alosa pseudoharengus*) predation on yellow perch larvae will be investigated. Development of an annual index for yellow perch egg production will provide an measure of reproductive potential and success. Comparing zooplankton species composition and abundance data from samples collected prior to the establishment of zebra mussels and more recently will provide valuable information on the availability of food for emergent yellow perch larvae, and lend an understanding to the effects of alewife predation on yellow perch larvae in the presence of alternate food sources.

The results of this project will strengthen management strategies for this important sport fish species. These findings will be incorporated into yellow perch management strategies by a multi-agency collaboration, which reflects a changing philosophy in the Great Lakes system from jurisdictional to lakewide management.

METHODS

Sampling Gear

Yellow perch sampling in 1999 focused on three methods based on yellow perch size. For larvae and post-larval yellow perch we used a 2 x 1-m neuston net with 500-µm mesh for larvae and 1000-µm for post larvae. As perch became larger (age-0), we used a bottom trawl with a 4.9-m head rope, 38-mm stretch mesh body, and 13-mm mesh cod end. Bottom trawls were performed during the day and at night. We used 1.2 x 1.8-m doubled-ended fyke nets with a 30.5-m leader between two double-throated pots and 38-mm stretched mesh to sample adult yellow perch. In addition to yellow perch sampling, we also collected zooplankton samples to assess food availability for larvae and post-larval yellow perch using a 0.5-m diameter 73-µm mesh plankton net.

Supplemental Index Gillnetting

In conjunction with IDNR, an index station in the southern portion of Illinois waters, northeast of Calumet Harbor was established to sample spawning yellow perch during 1994-1999. Sampling at the Calumet Harbor index station was conducted by J. Camalick, with IDNR and LMBS personnel on board his boat. Gillnets were set at depths of 7.2, 10.8 m, and at 14.6 and 18.3 m the following day. All nets were fished for approximately 24 h. All fish in all nets were counted, and subsamples of 25 yellow perch were collected from each gill net panel. If the total catch for any panel was less than 25, all yellow perch in that panel were sampled. Individual yellow perch were weighed to the nearest 10 g, measured to the nearest 5 mm, and dissected to determine reproductive status (i.e., ripe, green, or spent); ages were estimated from sagittal otoliths.

Movement Patterns of Adult Yellow Perch

In 1999 adult yellow perch were collected in fyke nets at three sites: Waukegan wiremill (US Steel), North Lake Forest, Fort Sheridan (Figure 1). From the fyke net catches a subsample of perch was preserved to obtain population structure information. Of the remaining perch ~1,000 maximum per net were tagged using individually numbered Floy tags, measured for total length, and externally examined to determine sex and reproductive status. All fish, except the subsampled yellow perch, were released. Recaptured yellow perch from our sampling and from commercial and sport catches were assessed for distance from tagging site and time at liberty.

Yellow Perch Population Structure

Biological data (i.e., length, weight, sex, and maturity) were obtained from all subsampled yellow perch, and the ages of the yellow perch were estimated from sagittal otoliths (Robillard and Marsden 1996).

Yellow Perch Egg Sampling

In 1999, scuba divers swam transects along the abandoned US Steel water intake line, located 1.9 km south of Waukegan Harbor (Figure 1) where perch egg skeins were counted. Divers usually explored an area approximately 4 m wide along the intake during each transect. Eggs were subsampled from each egg skein and transported back to the laboratory where the percentage of viable eggs was estimated using a dissecting microscope.

Larval and Post-larval Yellow Perch Sampling

In 1999, a 2 x 1 m neuston net was towed at the surface at night between May 19 and July 7 at the 5 and 10-m (bottom depth) larval perch sampling sites, south of Waukegan Harbor. A calibrated General Oceanics™ standard flowmeter mounted in the mouth of the net was used to determine the volume of lake water sampled. Mean volume of water sampled during each neuston net tow was 1,628 m^3. Larval fish were counted in the laboratory and identified to genus, or species when possible.

Age-0 Yellow Perch Sampling

Day and night trawling for age-0 yellow perch was conducted approximately weekly at four depth stations (3, 5, 7.5 and 10 m) from late July through October, 1999. All sampling occurred north of Waukegan Harbor, at a speed of approximately 2 $m \cdot sec^{-1}$. Approximately 4460 m^2 of the lake bottom was sampled for each 0.9-km transect. Age-0 yellow perch and non-target species were recorded if collected. Age-0 yellow perch were measured to the nearest 1 mm and frozen for later examination of stomach contents; some age-0 yellow perch were measured post-preservation.

Alewife Predation on Yellow Perch Larvae

In 1999, adult alewives were sampled concurrent with the peak of larval yellow perch hatch. A gillnet, composed of three 30.5-m panels with stretched measures of 25.4, 38, and 44 mm, was suspended 0.5 m below the surface of the water and fished for approximately 30 min. Samples were usually collected at either one 10-m (bottom depth) and one 5-m (bottom depth) site, or at two 10-m (bottom depth) larval ye llow perch sampling sites.

All alewife were measured to the nearest 1 mm TL. Specimens were dissected to determine sex and maturity, and the entire digestive tract was preserved in 95% ethanol until examination. The stomachs were examined for the presence or absence of phytoplankton, zooplankton, amphipods and isopods, insect larvae, and larval fish. These taxa, except for phytoplankton, were quantified. If present, intact larval fish were identified to lowest possible taxon.

Zooplankton Sampling

Zooplankton was sampled weekly from May 19 to September 22 and on the same nights as larval fish collections (June – July) in 1999. Replicate, vertical lifts were collected at the two 10-m (bottom depth) larval yellow perch sampling sites with a 0.5-m diameter, 73-µm mesh net. Mean volume of water filtered in each vertical lift was 1.9 m^3. Earlier zooplankton samples (1988-1990) were collected with a vertical tow of a 0.5-m diameter, 153-µm mesh net at depths ranging from 8 to 10.

In the laboratory, zooplankton were enumerated and identified into the following categories: cladocerans to genus (*Daphnia* and *Bosmina* to species), cyclopoid copepodites, calanoid copepodites, copepod nauplii, Macrothrididae spp., Sididae spp., and rotifers. Uncommon taxa were noted. For each sample, up to three 5-ml subsamples were taken from adjusted volumes that provided a count of at least 25 individuals of the most dominant taxa. Upon completion of each subsample, counting ceased for each taxon in which 100 individuals were additively counted.

Age-0 Yellow Perch Diet

Age-0 yellow perch collected by bottom trawl in 1999 were frozen for stomach analysis. Prior to dissection, total length (mm) and weight (g) were recorded; otoliths were removed and preserved for future analysis. Full and empty stomach weights (g) were recorded, enabling calculation of the weight of food in yellow perch stomachs. Stomach contents were enumerated and identified. Zooplankton identification followed the methods we described in the zooplankton sampling section, while benthic invertebrates were identified as an amphipod, chironomid, and all others to order.

Larval Yellow Perch Survival Experiment

We conducted an experiment to examine the possible influence of zooplankton density on survival of newly-hatched yellow perch. Yellow perch eggs were collected from Lake Michigan on June 2 and allowed to hatch in the laboratory. Five newly-hatched yellow perch larvae were placed into individual 38-L aquaria. We established four zooplankton treatments, with five replicate aquaria in each treatment. Zooplankton treatments were 0, 25, 50, and 100 zooplankton/L. These zooplankton densities represent a foodless control (0/L), recent densities (1996-1998) of zooplankton present in Lake Michigan when larval yellow perch are present (25/L), the density of zooplankton present in Lake Michigan during the last year of strong yellow perch recruitment (1988; 50/L), and a density of zooplankton commonly assumed to permit good larval fish growth and survival (100/L; Mathias and Li 1982). Larval fish were fed daily to maintain zooplankton at the appropriate treatment levels by estimating zooplankton consumption and then adding zooplankton to maintain the established treatments. Zooplankton were taken directly from Lake Michigan to provide larval fish with the same food resource they would experience in the lake. The experiment was run for 7 days, until over 50% mortality occurred in at least two of the four treatments.

RESULTS

Supplemental Index Gillnetting

The supplemental index gillnetting was not accomplished in 1999 because of contractor illness.

Movement Patterns of Adult Yellow Perch

A total of 33,120 yellow perch were tagged during 1996-1999 of which 6,274 were tagged in 1999 (Table 1). Agency (LMBS, IDNR, Wisconsin DNR, Michigan DNR, Ball State University, Beak Consultants Incorporated) sampling accounted for the majority (94%) of 1999 recaptures. Recaptured fish were tagged in 1996-1999 with most recaptures being from 1998 tagging (Table 2). The average distance from tagging location to recapture location was 11 km (SD 26 km) and the maximum distance was 313 km.

Yellow Perch Population Structure

The yellow perch subsampled from fyke nets (N=450) consisted of ages 1 to 19 but over 50% of the subsampled yellow perch were age-10 and older. The 1988 year-class made up the greatest portion (23.5%) of the subsampled perch (Figure 2). Two other year classes were also relatively important: 1989 (13.7%) and 1995 (15.7%). Only 2 perch from the 1992-year class were present in the subsample, suggesting minimal recruitment of that year-class.

Mean length of yellow perch we captured in fyke nets during 1999 was 249 mm (N = 7,007; SD = 34 mm). When compared to mean lengths from 1994 to 1998, the mean length of yellow perch was the largest in 1999 (Figure 3). The sex of the perch collected (N = 7,007) was extremely skewed toward males, with only one female collected or 0.01% of the yellow perch catch (Table 3). Mean length-at-age for male yellow perch was greatest for age-7 (Table 4). The mean length-at-age increases rapidly during early ages (1-4) but levels off in older fish ages 5-19 (Figure 4).

Yellow Perch Egg Sampling

Divers found yellow perch egg skeins during May and June, 1999. All eggs were found at sites with cobble substrate, and were generally within a shallow cavity formed by cobbles, lodged among rocks, or laid across the top of the cobble-covered water intake lines (Table 6). Several developmental stages of eggs were found, and eggs were estimated to be 95% viable.

Larval and Post-larval Yellow Perch Sampling

Larval yellow perch were captured in low abundance relative to previous sampling efforts (Figure 5). Average daily densities of larval yellow perch between May 5 and July 22, 1999 ranged from 0 to 21.5 fish•100m^{-3}, compared to densities of over 100 fish•100m^{-3} prior to 1994 (Marsden et al. 1993a, and unpub. data). The peak density of larval perch occurred on June 7, 1999, when daily average density was 21.5 fish•100m^{-3} (Range: 0 to 64.8 fish•100m^{-3}).

Age-0 Yellow Perch Sampling

No age-0 yellow perch were collected in the day trawls but 13 age-0 yellow perch were collected at night. There was slightly more effort applied on day trawls where 178,360 m^2 was covered compared to 160,524 m^2 at night. The CPE of night trawling was 8.1 fish•100,000 m^{-2}.

In general, the same fish species were collected during day and night trawls but the percent composition of species was different. During day trawls alewives and nine-spine stickleback were similar in percent composition but at night percent composition shifted away from alewives toward nine-spine sticklebacks (Figure 7).

Alewife Predation on Yellow Perch Larvae

Stomach and intestinal tract contents from a total of 197, 355, 61, and 18 adult alewives were examined from samples collected in 1996, 1997, 1998, and 1999, respectively. At most, 4.5% of the alewife stomachs contained larval fish in any year (Table 5). The greatest number of fish larvae found in a single stomach was 4; usually, only a single larval fish was found. Of all larval fishes found in the stomach contents of alewife, only two could be identified with any certainty as larval yellow perch. Fish larvae were less digested in alewife collected during dusk than those collected one or more hours after sunset. *Bythotrephes cederstroemi* tail spines were often found as a compacted mass wedged into the stomach. In 1999, *Bythotrephes cederstroemi* tail spines were found in 27.8% of the alewife stomachs.

Zooplankton Sampling

Mean zooplankton density during June-July,1988, (54/L) was at least double the mean zooplankton density at this same time during 1989-1990, and 1996-1999 (Figure 8). June through July mean density in 1999 (29/L) was similar to those from 1996-1998. However, the expanded sampling in 1999 demonstrated several peaks in density; the first of which occurred on July 7, due to copepod nauplii (17/L) and rotifers (15/L), whereas the next peak on July 28 was due to abundant rotifers (65/L; Figure 9). Each successive smaller peak was due to numerous rotifers. Copepod nauplii dominated the nearshore zooplankton assemblages from May to July, however *Bosmina* grew increasingly important and were dominant during August and September of 1999 (Figure 10). Still, *Bosmina* density remained much lower than the 1988-1990, trends. *Daphnia* were present from July through September, however at a very low density (<0.5/L). Other cladocerans (e.g., *Polyphemus*, *Ceriodaphnia*, *Leptodora*, *Diaphanosoma*, *Chydoridae*) also were more commonly found in samples during 1988-1990 but rarely observed in samples collected since 1996. *Cercopagis pengoi*, a water flea native to the Ponto-Caspian region, was first observed in our samples on September 7, 1999. The first accounts of this exotic in North America were reported in Lake Ontario during July of 1998. In 1999, *Cercopagis pengoi* densities were very low (<0.05/L) during September, but even at these low densities it is still a cause for concern. The presences of this and other exotic zooplankton may have a great impact on the zooplankton assemblage and food-web dynamics in Lake Michigan.

Age-0 Yellow Perch Diet

Diet analysis was not performed because no age-0 yellow perch were collected during daylight hours.

Larval Yellow Perch Survival Experiment

Yellow perch survival differed among zooplankton treatments in our experiment (ANOVA, df = 3,16, F = 11.53, P = 0.003). Specifically, larval yellow perch survived better at densities of 100 zooplankton/L than all other zooplankton treatments (Tukey's multiple comparisons, $P < 0.05$). Survival of larval yellow perch was over 80% when fed 100 zooplankton/L but dropped to 30% at 50/L and 20% at 25/L (Figure 11). Essentially all larvae starved within 7 days when they were not fed (only 1 of 20 larvae survived). Although we could not statistically differentiate larval yellow perch survival among the lower three treatments, survival tended to be greater as the amount of food available increased. These effects happen quickly, within 7 days of first feeding.

CONCLUSIONS

The 1999 sampling with fyke nets collected 8,519 yellow perch at three sites: Waukegan wiremill (US Steel), North Lake Forest, and Fort Sheridan. Compared to earlier sampling (1994 – 1998) catch numbers were lower but 1999 sampling focused on only three areas instead of the previous six. Yellow perch sex ratio from fyke nets was qualitatively similar to earlier years, with males making up the majority of the catch. Only one female was collected in 1999 giving this year the lowest percent females (0.01%) of the past five years. Fyke nets are known to skew sex ratios because male perch tend to congregate in the nets, so the fyke net sex ratio likely do not accurately represent the population's sex ratio. Furthermore, because our sampling in 1999 occurred at fewer sites and during a narrower time window than previous years our ability to directly compare sex ratios across years is limited. However, we do believe that relatively few adult females are present in the spawning population, based on the low numbers of larval yellow perch collected.

The age structure of fyke net catches during 1999 is similar to earlier work. The strong year class of 1988 still makes up a large portion of the sample. Two recent year classes, 1995 and 1997, are important components of the current population but are quite weak compared to the strong 1988 year class. Over 50% of the subsampled yellow perch were age-10 and older, suggesting continued recruitment limitation during 1990s. Under optimal conditions of population stability, the greatest proportion of fish sampled would be smaller and younger than those captured during our sampling. Yellow perch age and length data from our sampling confirm that, due to reduced juvenile survival during the past several years and limited recruitment of juvenile fish to the adult population.

More perch were tagged in 1999 (6,274) than in 1998 (4,902) but our catch during these two years was less than in 1996 and 1997. This trend further suggests a continued reduction in the adult yellow perch population. The percent of tag returns by sport anglers has continued to decrease from a high of 39% in 1996 to 6% in 1999.

Yellow perch egg skeins collected at the US Steel intake line, south of Waukegan Harbor, were 95-100% viable. Given the relatively high viability of eggs, it is likely that the current decline of yellow perch is not attributable to factors that may adversely affect pre-hatch stage yellow perch (e.g., toxins in sediments, genetic flaws).

Larval yellow perch abundance was much lower during 1994 through 1999, compared to the abundance observed prior to 1994 (Marsden et al. 1993a). This severe reduction of larval yellow perch may indicate that the reduced abundance of adult female yellow perch, coupled with predation by alewife and reduced availability of food resources, effectively slows the ability of yellow perch to quickly recruit sufficient new members to the fishable population.

The density of age-0 yellow perch in 1999 decreased sharply from the 1998 density (0.54 YOY• $1000m^2$) suggesting that 1998 may be a comparatively strong year class but not sufficiently strong to support expended fishing on it own. The paucity of age-0 yellow perch observed since 1994 may partly result from decreased abundances of yellow perch larvae; however, failure of larval fish to be recruited to the sub-adult population may also be the result of starvation or predation. Increased water clarity observed in the past four years, which is likely due in part to filtration by zebra mussels, may directly affect age-0 catches by increasing avoidance of sampling gear. To reduce net avoidance trawling can be performed at night, which should result in an increased catch. Our 1999 trawling confirmed that night sampling is more affective at sampling age-0 yellow perch than day trawls. However, earlier work found that night trawling did not increase catch rates (Robillard et al. 1996). We will continue to evaluate day vs. night catches as time and manpower permit.

The increased water clarity is a consequence of reduced plankton populations that may indirectly limit available food for developing larval yellow perch. Water clarity may also affect larval yellow perch survival by increasing their susceptibility to predation by visual feeders such as alewife.

We have not adequately assessed the effect of alewife predation on yellow perch larvae due to the near-absence of available larval yellow perch as prey. No alewife had larval fish as a component of stomach contents during 1999. Since 1996, the maximum occurrence of larval fish is alewife stomachs has been 5.4%. Several years of effort at higher densities of yellow perch larvae will be necessary to place any confidence on the percent of yellow perch recruitment lost to predation by alewife.

Mean zooplankton densities were significantly higher in 1988 in comparison to 1989-1990 and 1996-1999. There does appear to be some consistency in years 1996-1999, where mean densities were around 25-30/L. The expanded sampling season in 1999 demonstrated several peaks in density, none of which coincided with the peak of larval yellow perch abundance. Copepod nauplii dominate the nearshore zooplankton assemblage from May to July, however *Bosmina* become increasingly abundant and dominated the samples during August and September of 1999. Alewife predation and competition for food resources may play a role in zooplankton assemblage changes. Invasions of exotic species, such as the zebra mussel, are a potential cause of the decline in zooplankton densities. Zebra mussels invaded the southwestern area of Lake Michigan in 1988, with substantial numbers appearing by 1993 (Marsden et al. 1993b). Changes in nutrients, such as phosphorus, have also occurred within the lake. Yearly variation could explain some variation in taxonomic composition, however, mean densities differ too much from 1988 to be considered natural variation.

A new exotic zooplankton species, *Cercopagis pengoi*, a water flea native to the Ponto-Caspian region, was found in Illinois waters of Lake Michigan during 1999. The first accounts of this exotic in North America were reported in Lake Ontario during July of 1998. Currently, *Cercopagis pengoi* densities are very low (<0.05/L) but the presence of this and other exotic species may have important impacts on the zooplankton assemblage and food-web dynamics in Lake Michigan.

Survival of age-0 yellow perch into the fall is positively correlated with the density of zooplankton present during June, suggesting that survival of larval yellow perch may be limited by low food availability. However, these data are not conclusive, especially because only one year (1988) of high zooplankton abundance exists and may exert undue leverage on the relationship.

Our experiment revealed that survival of first-feeding yellow perch is strongly dependent on the density of zooplankton food available to them. When more food is available, larval yellow perch survived better. This result indicates that the pattern we have observed in the field with greater yellow perch recruitment occurring in years with more zooplankton present is driven in part by zooplankton availability. Our result does not preclude the possibility that other mechanisms are also involved in regulating yellow perch recruitment success, but it does strongly indicate that zooplankton abundance is an important determinant of yellow perch recruitment success.

Because the density of zooplankton present in Lake Michigan is critical to yellow perch recruitment success, it is important for fishery managers to recognize the impact that exotic species have had on the Lake Michigan food web during the last decade. Zebra mussels filter the water column, feeding on algae that might otherwise support zooplankton. Furthermore, exotic zooplankton predators like *Bythotrephes cederstroemi* and the newly arrived *Cercopagis pengoi* further alter the zooplankton assemblage. These continuing changes in the lower trophic levels of Lake Michigan directly affect the success of fish like yellow perch if they alter the abundance and/or composition of zooplankton present when larval yellow perch begin feeding.

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REFERENCES

Brazo, D. C. 1990. Fisheries research and management report for the Indiana waters of Lake Michigan, 1989. Report to the Great Lake Fishery Commission. Lake Michigan Committee Meeting, March 1990.

Brofka, W. and J. E. Marsden. 1993. Creel survey of the Illinois waters of Lake Michigan. Annual report to the Illinois Department of Natural Resources. Illinois Natural History Survey Technical Report 93/4. 40 pp.

Hess, R. 1990. Fisheries research and management report for the Illinois waters of Lake Michigan, 1989. Report to the Great Lake Fishery Commission. Lake Michigan Committee Meeting, March 1990.

Hess, R. 1998. Status of Yellow Perch in Lake Michigan and Yellow Perch Task Group Progress report. Annual report to the Lake Michigan Technical Committee. Great Lakes Fishery Commission meeting, May 1997, Thunder Bay, ONT. 19 pp.

Makauskas, D., and D. Clapp. 2000. Status of Yellow Perch in Lake Michigan and Yellow Perch Task Group Progress report. Annual report to the Lake Michigan Technical Committee. Great Lakes Fishery Commission meeting, March 2000, Ann Arbor, Michigan. 33 pp.

Marsden, J. E., W. A. Brofka, and W. H. Horns. In review. Seasonal movements of yellow perch in Lake Michigan. Trans. Am. Fish. Soc.

Marsden, J. E., W. Brofka, D. Makauskas, and W. H. Horns. 1993a. Yellow perch supply and life history. Final report to the Illinois Department of Conservation. Illinois Natural History Survey Technical Report 93/12. 46 pp.

Marsden, J. E., N. Trudeau, and T. Keniry. 1993b. Zebra mussel study on Lake Michigan. Final report to the Illinois Department of Conservation. Illinois Natural History Survey Technical Report 93/14. 51 pp.

Li, S., and J. A. Mathias. 1982. Causes of high mortality among cultured larval walleyes. Transactions of the American Fisheries Society 111:710-721.

McComish, T. S. 1986. A decade of dramatic change in the yellow perch population in Indiana waters of Lake Michigan. Presented to a joint meeting of the Indiana, Illinois, and Michigan chapters of the American Fisheries Society, March 1986.

Muench, B. 1981. 1979 Sport fishing creel survey on the Illinois portion of Lake Michigan. Technical Report, Division of Fisheries and Wildlife, Illinois Department of Conservation. 17p.

Robillard, S. R., T. Kassler, and J. E. Marsden. 1996. Yellow perch population assessment in southwestern Lake Michigan, including evaluation of sampling techniques. Annual report to the Illinois Department of Natural Resources. Illinois Natural History Survey Technical Report 96/7. 23 pp.

Robillard, S. R., and J. E. Marsden. 1996. Comparison of otolith and scale ages for yellow perch from Lake Michigan. J. Great Lakes Res. 22:429-435.

Robillard, S. R., A. Weis, and J. M. Dettmers. 1999. Yellow perch population assessment in southwestern Lake Michigan, including evaluation of sampling techniques and the identification factors that determine yellow perch year-class strength. Annual report to the Illinois Department of Natural Resources. Illinois Natural History Survey Technical Report 99/5. 57 pp.

Table 1. Location and number of yellow perch tagged, 1996-1999.

		Year			
Site	Location (lat./long.)	1996	1997	1998	1999
Kenosha, WI	42° 33.680 / 087° 48.529	0	5	0	0
Camp Logan	42° 28.400 / 087° 47.708	0	12	0	0
North of Waukegan	42° 22.719 / 087° 49.388	0	33	117	0
South of Waukegan	42° 21.096 / 087° 48.788	756	0	0	0
Waukegan wiremill	42° 20.244 / 087° 49.462	0	1,571	1,236	1,151
North Chicago	42° 19.795 / 087° 49.033	272	99	296	0
Great Lakes Naval Base	42° 18.290 / 087° 49.396	381	0	0	0
Lake Bluff	42° 16.772 / 087° 49.502	4,210	0	0	0
North Lake Forest	42° 15.280 / 087° 49.015	3,522	4,075	1,657	2,209
South Lake Forest	42° 13.950 / 087° 48.435	712	551	504	0
Fort Sheridan	42° 12.789 / 087° 47.792	3,609	1,851	1,092	2,914
Chicago Harbor	41° 54.100 / 087° 36.500	0	285	0	0
All Sites		13,462	8,482	4,902	6,274

Table 2. Recapture source and year of recapture for yellow perch tagged by LMBS during 1996-1999. Agency recaptures include yellow perch recaptured by LMBS, IDNR, Wisconsin DNR, and Michigan DNR, and Ball State University, and Beak Consultants Incorporated.

Recapture Year / Source		Tag Year / Number Tagged 1996 N = 13,462	1997 N = 8,482	1998 N = 4,902	1999 N=6,274
1996					
	agency	322			
	sport	278			
	commercial	115			
1997					
	agency	318	387		
	sport	46	58		
	commercial	97	0		
1998					
	agency	137	202	85	
	sport	16	11	9	
	commercial	0	0	0	
1999					
	agency	92	149	163	135
	sport	6	5	6	18
	commercial	0	0	0	0

Table 3. Total number of adult yellow perch and percentage of female yellow perch captured in fyke nets by LMBS, 1994-1999.

Sample year	N	Percent female
1994	10,756	1.6
1995	12,086	0.2
1996	22,014	1.1
1997	14,135	0.3
1998	6,187	0.4
1999	8,519	0.0

Table 4. Mean length-at-age, standard error, and number of fish in each age class for male yellow perch, 1999.

Age	Length (mm)	SE of Length	Number
1	140	3	5
2	192	2	43
3	237	7	8
4	251	2	70
5	250	7	17
6	260	8	6
7	281	2	2
8	276	4	13
9	268	3	37
10	267	3	61
11	255	2	104
12	255	5	23
13	255	4	25
14	260	8	9
15	233	8	8
16	248	9	6
17	242	3	3
18	261	---	1
19	259	6	2

Table 5. Percent occurrence of prey items in adult alewife stomachs containing food. Alewife were sampled during the hatch of yellow perch larvae, using graded-mesh gill nets set for 30 min after dusk outside Waukegan Harbor. [a] Not enumerated. [b] Amphipods and isopods were not differentiated in 1996. [c] Copepods and cladocerans were not differentiated in 1996, but lumped into the broad category of zooplankton.

Prey taxa	1996 N = 197	1997 N = 355	1998 N = 61	1999 N = 18
amphipods	4.6 [b]	7.9	19.4	0.0
B. cederstroemi	2.0	15.8	0.0	27.8
chironomid larvae	47.2	62.8	79.0	61.1
cladocerans	*** [c]	5.4	69.4	0.0
copepods	72.6 [c]	33.5	50.0	0.0
D. polymorpha	0.0	0.0	0.0	5.6
Hydracarina spp.	*** [a]	*** [a]	9.8	5.6
isopods	4.6 [b]	0.3	3.2	0.0
larval fish	2.5	4.5	1.6	0.0
phytoplankton	60.4	*** [a]	*** [a]	*** [a]
terrestrial insects	*** [a]	31.0	49.4	50.0

Table 6 . Summary of 1999 egg census dives, and viability and developmental stage of egg skeins.

	Date	Site	Substrate	Depth range (m)	Transect length (m)	No. YP egg skeins	Percent viable eggs	Stage of development
1999	10 May	US Steel intake	Cobble	7 - 8	30	0		
	20 May	US Steel intake	Cobble	7 - 9	105	11	95 - 100	a
	2 June	US Steel intake	Cobble	7 - 9	105	14	95 - 100	b , c
	2 June	US Steel intake	Cobble	5 - 7	105	6	95 - 100	b ,c, d
	15 June	US Steel intake	Cobble	7 – 8	105	0		
	15 June	US Steel intake	Cobble	7	20	0		

Developmental stages: [a] newly fertilized; [b] tail forming; [c] eyed and developed; [d] fully formed and hatching.

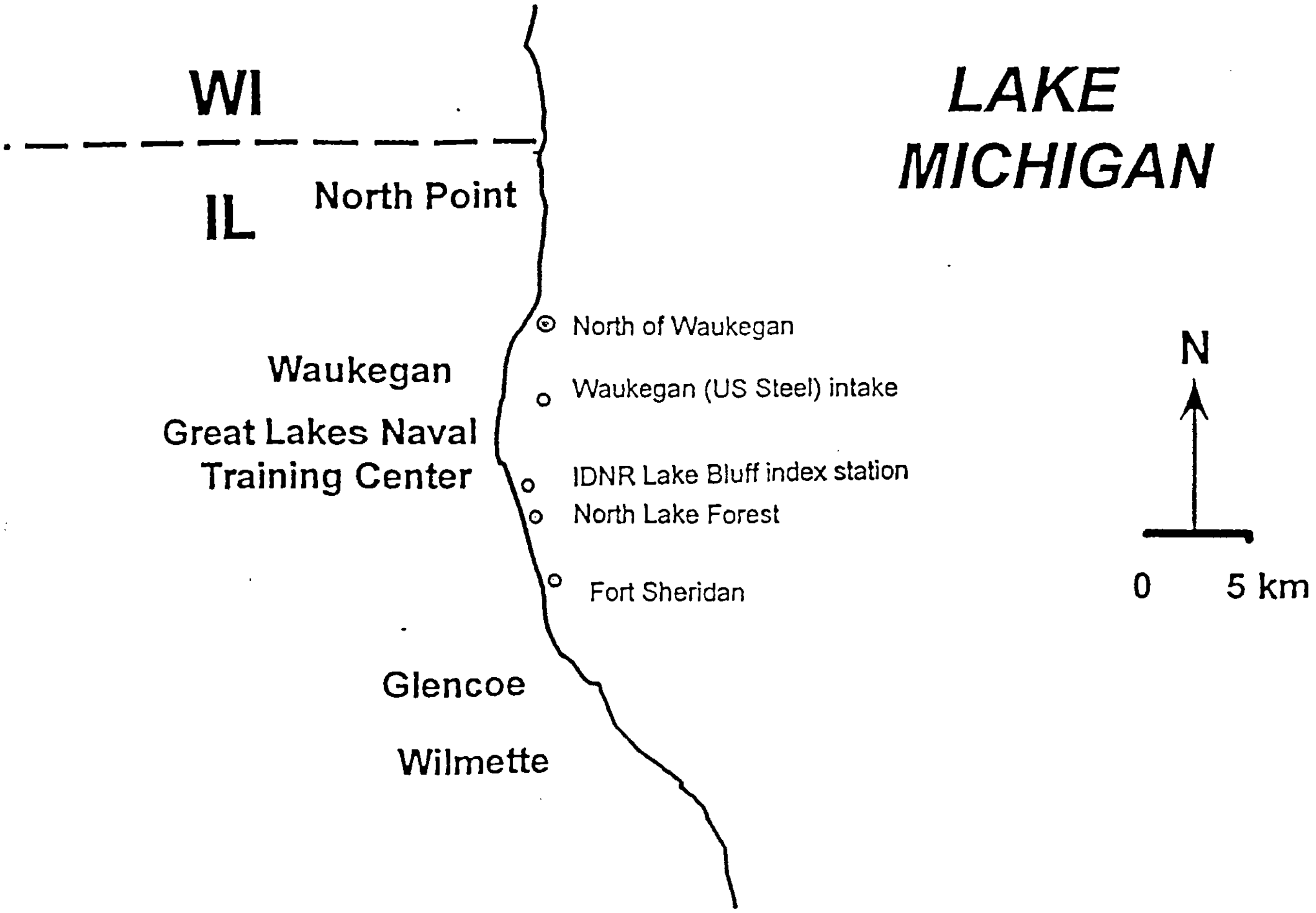

Figure 1. Lake Michigan 1999 yellow perch sampling sites.

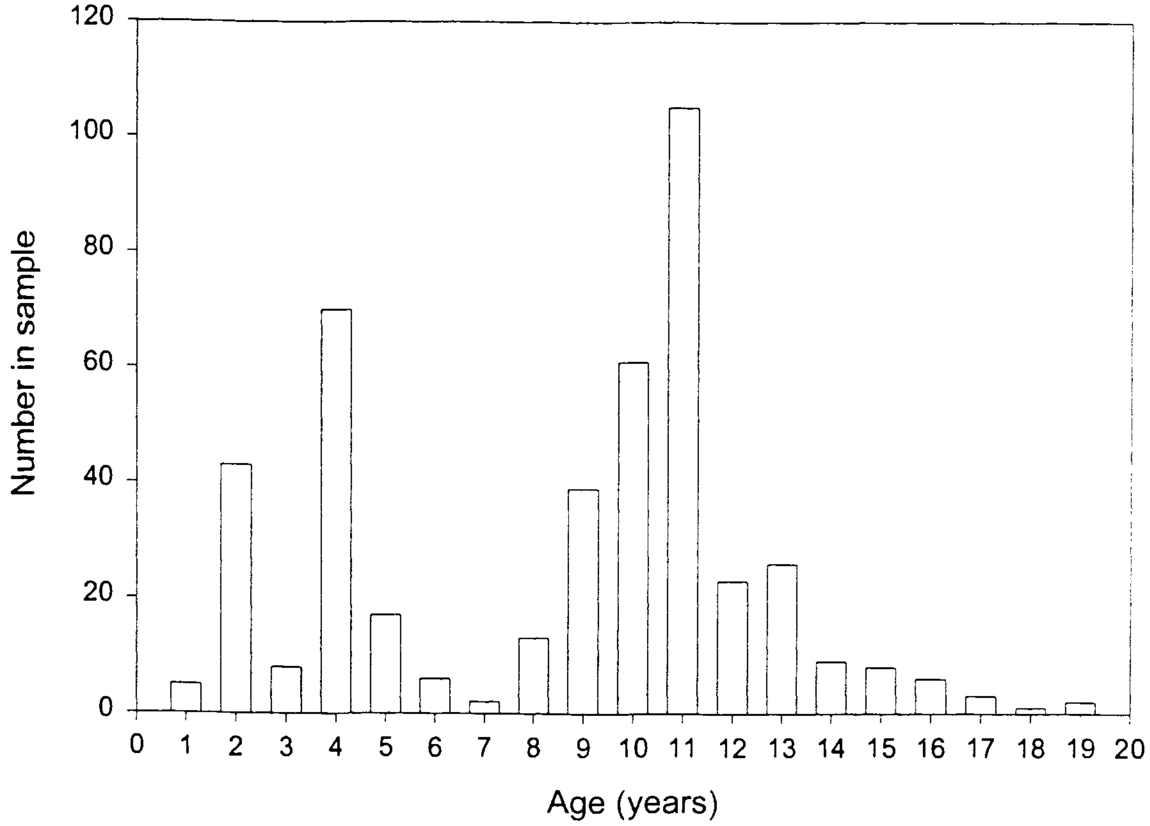

Figure 2. Age-distribution of adult male yellow perch sampled using fyke nets near Lake Bluff, IL, 1999.

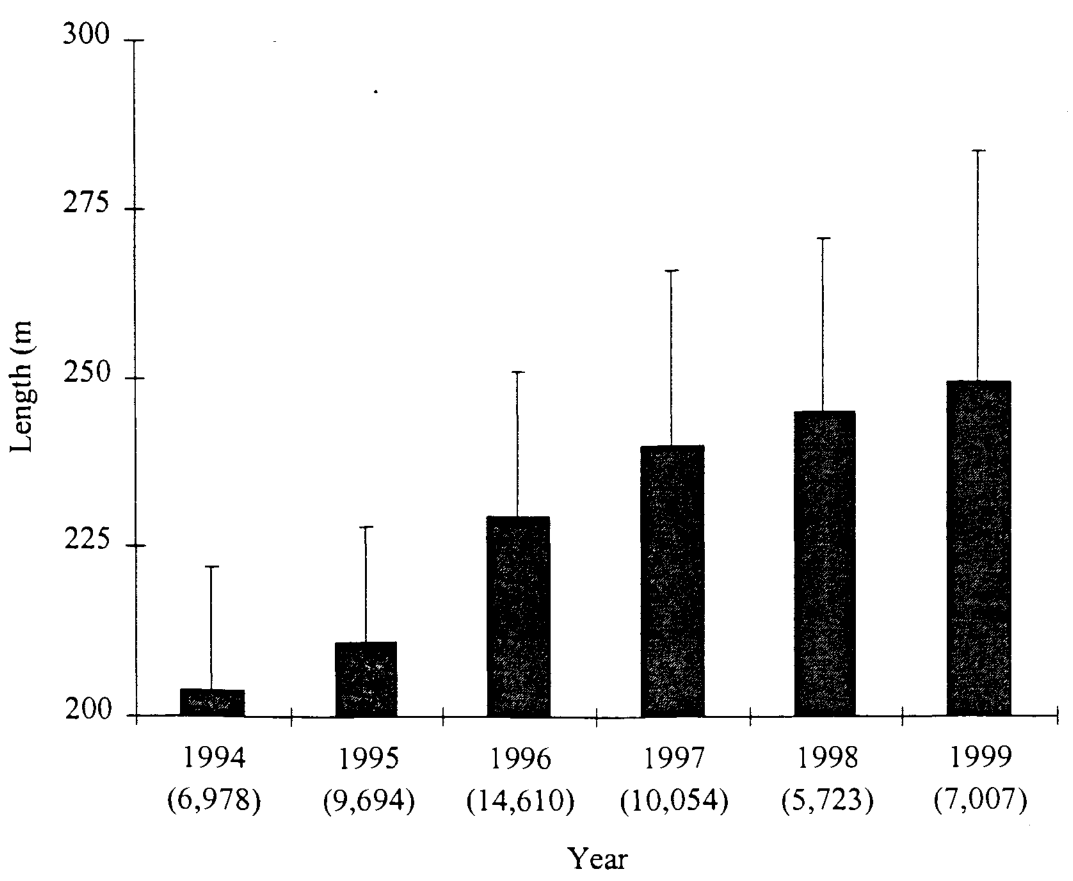

Figure 3. Mean length of adult yellow perch sampled using fyke nets near Lake Bluff, IL, 1994-1999. Sample sizes are in parentheses.

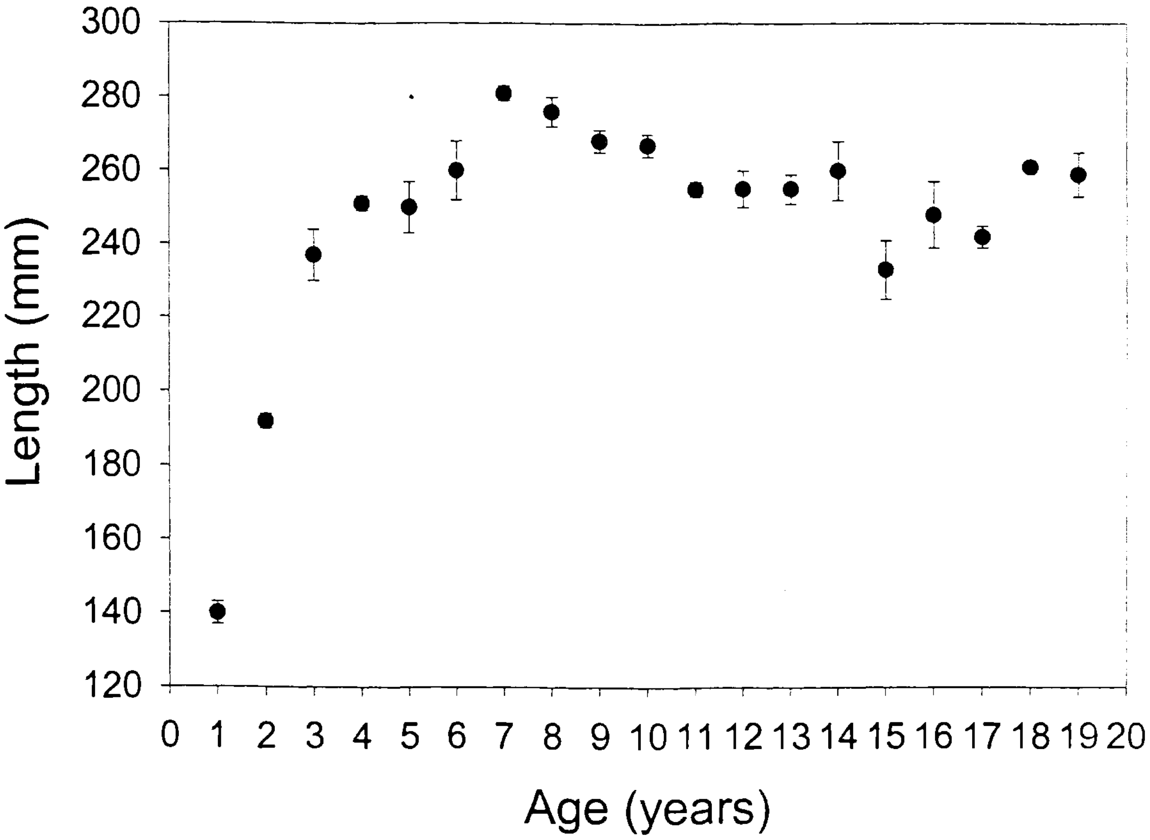

Figure 4. Mean length-at-age (± 1 standard error) for male yellow perch collected during fyke netting in 1999.

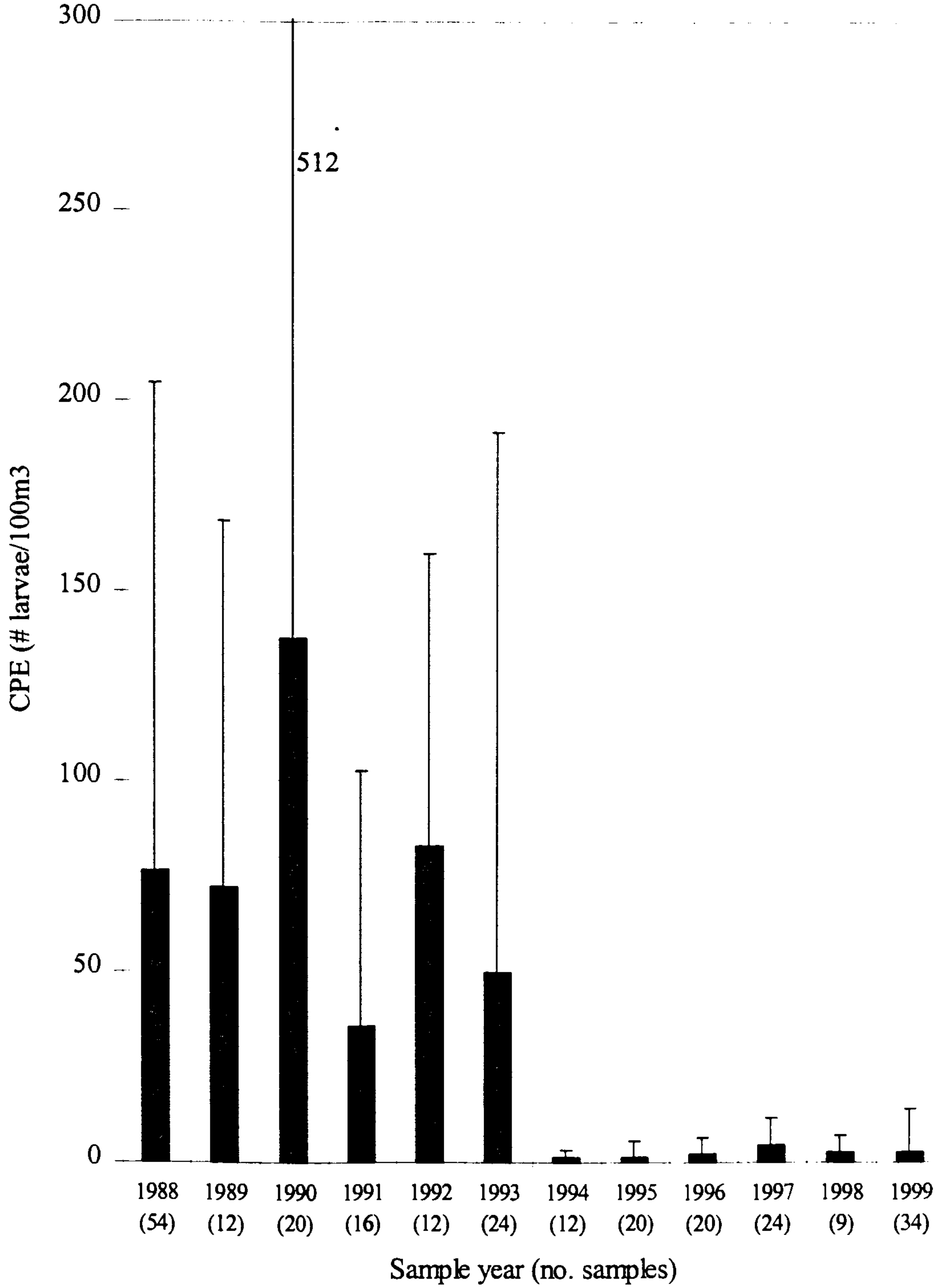

Figure 5. Abundance of yellow perch larvae near Waukegan Harbor, IL, 1988-1999.

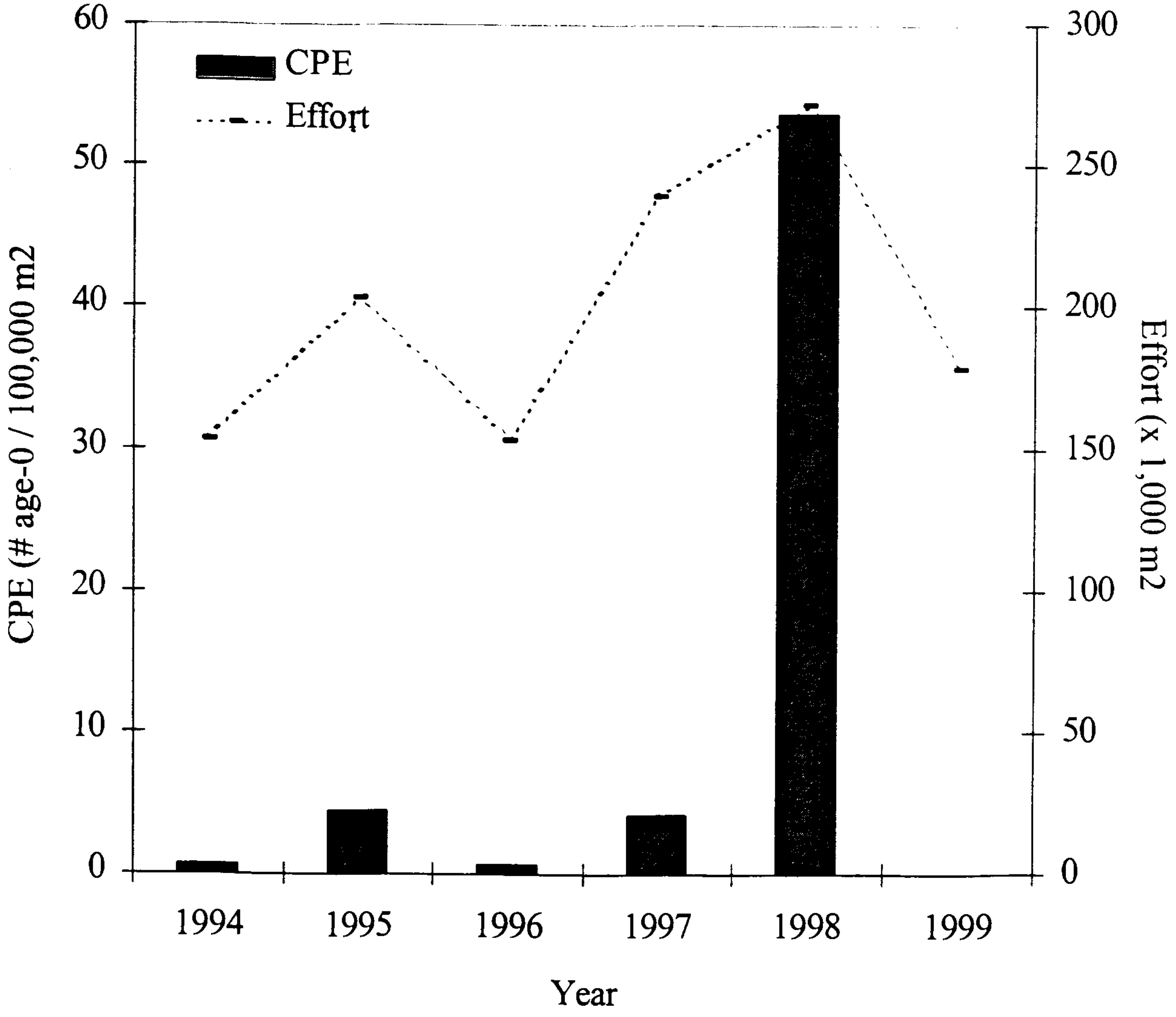

Figure 6. Abundance of age-0 yellow perch caught in daytime bottom trawls north of Waukegan Harbor, IL, 1994-1999.

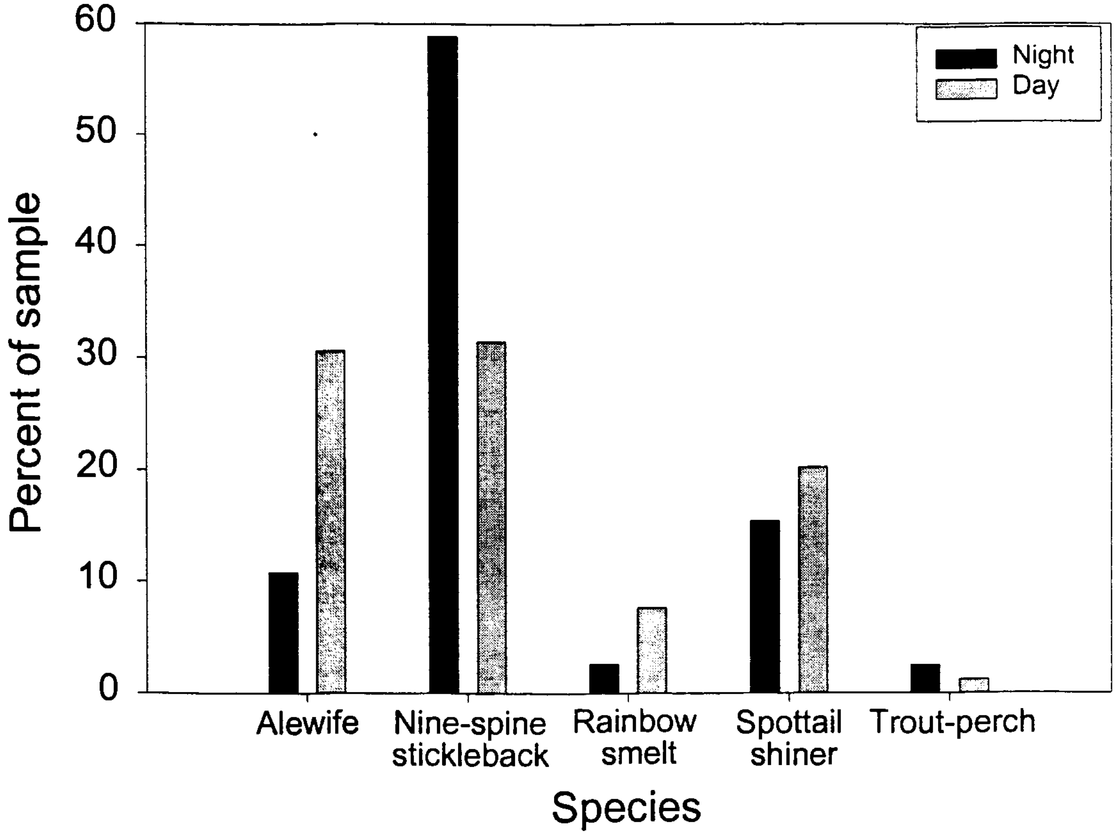

Figure 7. Percent composition of non-target species sampled during day and night bottom trawls north of Waukegan Harbor, IL , 1999.

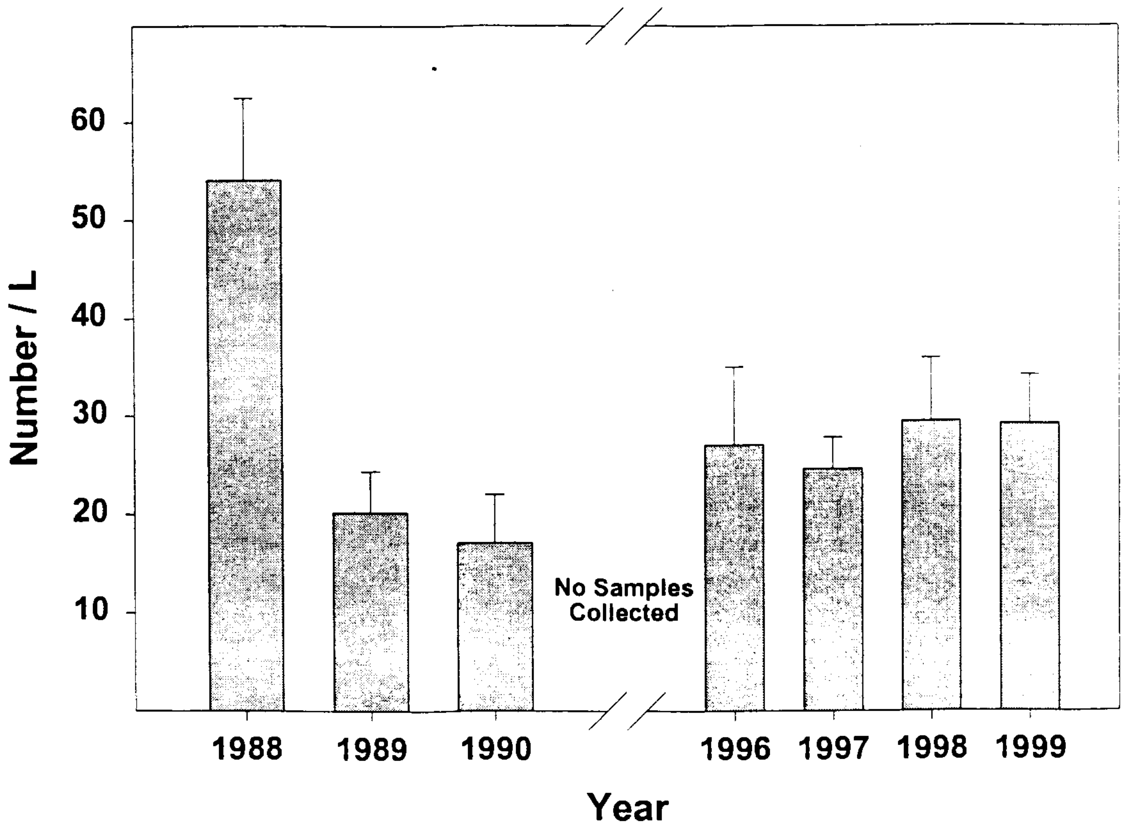

Figure 8. Mean density of zooplankton (± 1 SE) present in Illinois waters of Lake Michigan near Waukegan during June through July, 1988-1990 and 1996-1999.

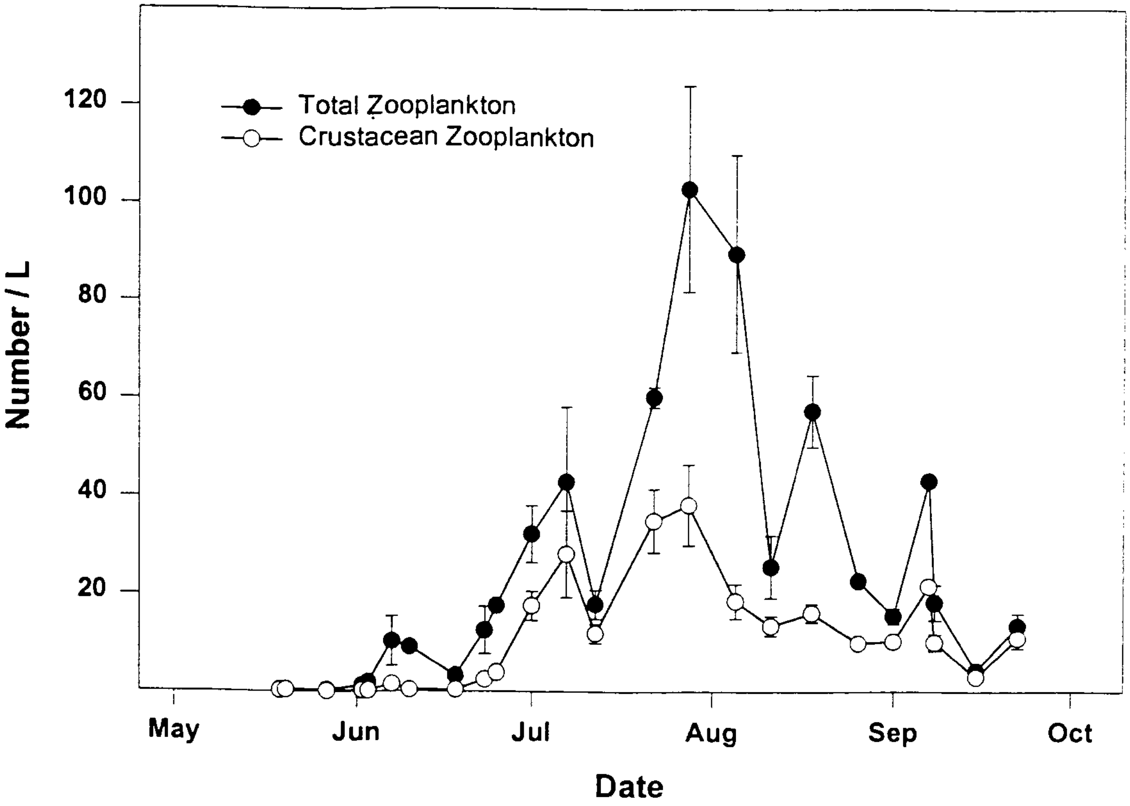

Figure 9. Mean density of zooplankton (± 1 SE) present in nearshore Illinois waters of Lake Michigan around Waukegan during May to September, 1999. Closed circles represent total zooplankton, whereas open circles represent crustacean zooplankton only.

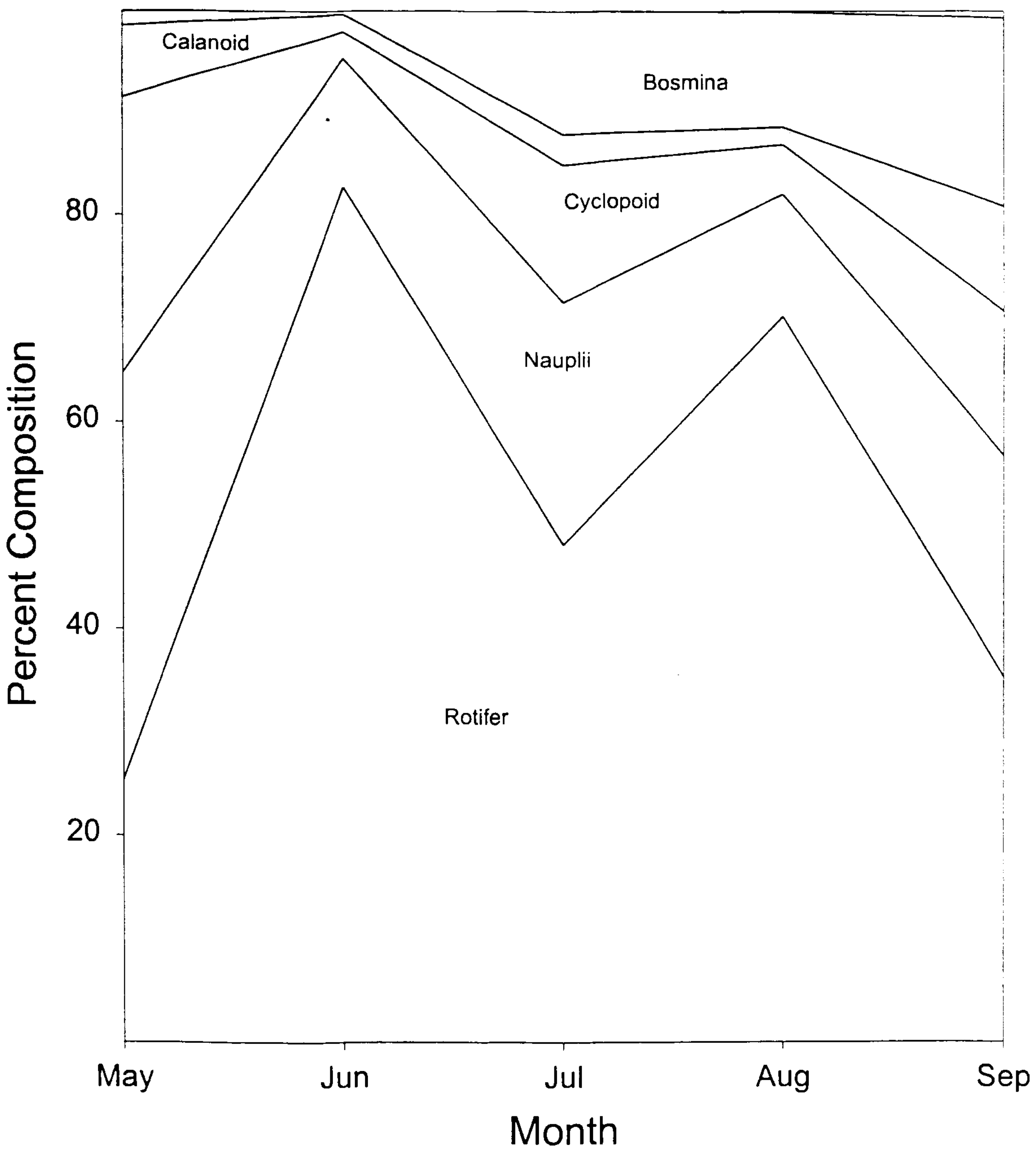

Figure 10. Percent composition of zooplankton present in nearshore Illinois waters of Lake Michigan near Waukegan during May through September, 1999.

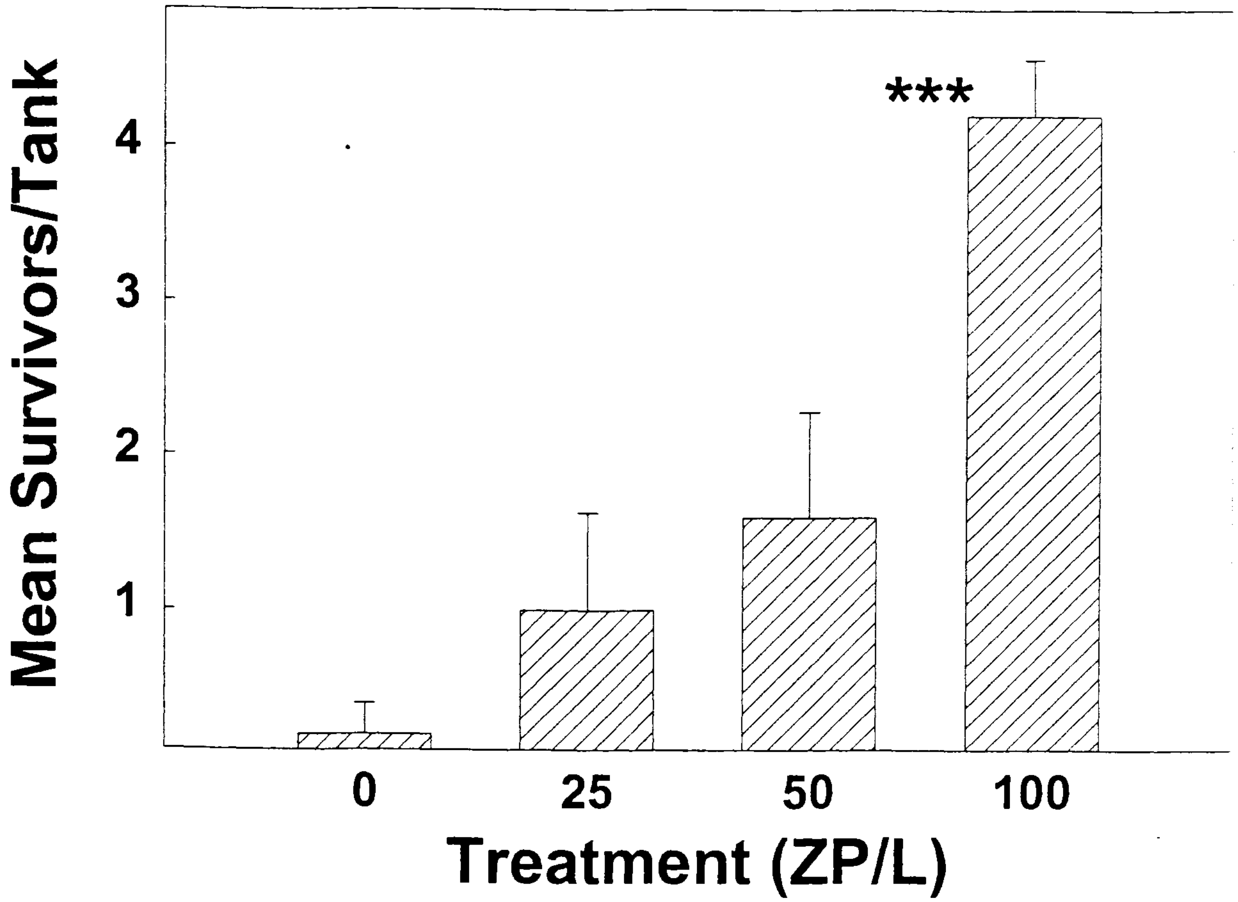

Figure 11. Mean number of larval yellow perch surviving for 7 days per experimental tank (N=5 maximum) when fed different levels of a natural assemblage of Lake Michigan zooplankton. Larval fish fed at 100 zooplankton/L survived better than those in all other treatments. *** indicates significant difference from other treatments (P = 0.003).