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

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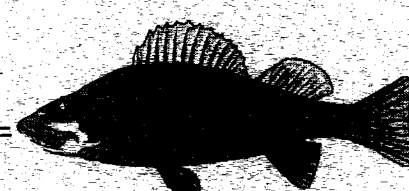

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EXECUTIVE SUMMARY

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 growth and survival of larval yellow perch under different zooplankton treatments and examined prey selection by larval yellow perch 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 2000 sampling.

1. During 2000 a total of 1,855 yellow perch were tagged from three sampling sites; Waukegan wiremill (US Steel), North Lake Forest and Fort Sheridan.

2. The average total length of all measured yellow perch was 235 mm (N = 2,554, SD = 48 mm). The female:male ratio of the yellow perch collected in our fyke nets was 20.1:1 or 5%. The proportion of female yellow perch in 2000 was the highest seen in many years, primarily due to the 1998 year class appearing in our fyke nets.

3. The majority of yellow perch collected in fyke nets during 2000 were age-2 (41.8%), age-11 (9.0%) and age-12 (12.8%).

4. Yellow perch egg skeins were counted south of Waukegan Harbor at the abandoned Waukegan wiremill (US Steel) intake line during 2000 on May 23, June 1, 7, and 19. On May 23, eggs were newly fertilized but on June 1 and later, 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.

5. Relatively few yellow perch larvae were captured using neuston nets in 2000 compared to sampling conducted prior to 1994. Peak larval yellow perch density in our samples occurred on June 15 (19.1 larval yellow perch•$100m^{-3}$).

6. In 2000 we conducted day and night bottom trawls, which sampled approximately 254,163 m^2 (day 164,983 m^2 and night 89,180 m^2). Only 4 age-0 yellow perch were collected and all but one came from night trawls. With only one yellow perch collected during the day,

no stomach content analysis was conducted. The paucity of age-0 yellow perch may indicate a failure of larval fish to recruit to the sub-adult population.

7. No larval fish were found in the adult alewife stomachs (N = 86) examined in 2000 but two unidentifiable items were found, which could have been larval fish. Of the 86 alewife stomachs collected, 78 contained identifiable items.

8. Collection of Zooplankton samples coincided with larval yellow perch sampling during 2000. The 2000 zooplankton density was less than half that of previous years (1996-1999) and an order of magnitude 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 role played by food availability in the recruitment success of yellow perch.

9. We conducted laboratory experiments during the summer of 2000 that quantified the effects of zooplankton taxa on larval yellow perch growth and prey selection. Growth of small larvae (5-7 mm) did not differ among four zooplankton taxa (cladoceran, adult copepod, copepod nauplii, and rotifer). Growth of larger larvae (7-18 mm) was best while feeding on either adult or immature copepods. Selection of 9-13 mm larvae was positive for cladocerans, neutral for adult copepods, and negative for copepod nauplii and rotifers.

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 multiple 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) 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 larvae 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 a measure of reproductive potential and success.

Concurrent with this decline in recruitment, the zooplankton density in southern Lake Michigan has been consistently lower, and the assemblage structure has shifted. Specifically, near-shore densities of zooplankton in southern Lake Michigan during 1989–1998 have been consistently lower than 1988 densities, the last year of strong yellow perch recruitment (Robillard et al. 1999). Furthermore, the zooplankton taxonomic composition in June has shifted from abundant cladocerans (about 30 % by number) mixed with large-bodied copepods during 1988–1990 to abundant smaller copepods and rotifers but few cladocerans during 1996-1998. To determine how this shift in the zooplankton assemblage in southern Lake Michigan influences growth and survival of larval yellow perch, we conducted a series of experiments that quantified the effects of zooplankton taxa on growth, and determined the patterns of prey selection for larval yellow perch.

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 2000 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 mesh for post-larvae. As yellow 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 conducted 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.

Movement Patterns of Adult Yellow Perch

In 2000 adult yellow perch were collected in fyke nets at three sites: Waukegan wiremill, 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 ~700 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 2000, scuba divers swam transects along the abandoned Waukegan wiremill water intake line, located 1.9 km south of Waukegan Harbor (Figure 1) where yellow 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 2000, a 2 x 1 m neuston net was towed at the surface at night, weekly 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 1,445 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, 2000. 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 were 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; age-0 yellow perch were measured post-preservation.

Alewife Predation on Yellow Perch Larvae

In 2000, 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 yellow perch sampling sites. In addition to gillnets sets, alewife were also collected in night bottom trawls.

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 15 to November 8 and on the same nights as larval fish collections (June-July) in 2000. 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 vertical tows of a 0.5-m diameter, 153-µm mesh net at depths ranging from 8 to 10 meters.

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 20 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 2000 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 Experiment

Growth and Survival - Yellow perch eggs were collected from southern Lake Michigan during late May and early June 2000. During the initial experiment, 40-50 yellow perch eggs were randomly placed into 38-L aquaria to hatch. At approximately two days post-hatch, zooplankton treatments (cladoceran, copepod, copepod nauplii, rotifer or food-less control) were established in each aquarium (n=20, 4 replicate aquaria per treatment). Treatment taxon and density (minimum of 50/L) were sampled and subsequently adjusted every one to three days. This experiment was terminated at 5 days due to excessive mortality. Data were collected for newly-hatched to 7 mm larval yellow perch. Subsequent to this initial experiment, another experiment (herein referred to as experiment 2) was conducted to gather growth data on larvae 7-20 mm. Experiment 2 had identical treatments, statistical design, and methods to the initial experiment. Data were collected on larvae up to 18 mm.

Prey Selection - Prey selection of larval yellow perch was measured to determine if patterns of prey choice change during the larval period, and to identify taxa most frequently selected. We expect that prey selection will follow patterns found in the growth experiments; that is larvae will select prey that will facilitate the best growth. Larval yellow perch were starved for at least 12 hours and then introduced into 38-L aquaria with equal densities (50 / L) of rotifers, copepod nauplii, adult copepods, and cladocerans. This prey density was chosen because in similar experiments with larval walleye, Mayer and Wahl (1997) found no significant effect of prey density on prey selection. After 1 h of foraging, the larvae were removed and preserved immediately in ethanol for later diet analysis. To obtain an appropriate range of sizes that quantified changes during the larval period, 50 replicate trials on small (approximately 6-10 mm), medium (approximately 11-15 mm), and large (larger than 15 mm) larvae were conducted. Stomach contents of these larvae were removed using a fine probe and dissecting scope. The diet items were identified to genus for cladocerans, nauplii or mature for copepods, and genus for rotifer using a dissecting scope.

Statistical Analysis - Changes in fish length during the initial experiment investigating larval growth were compared using one-way ANOVA, with the significance level of 0.05. Because of mortality during experiment 2, larvae could not be sampled at established intervals (i.e., sacrificing 3-5 larvae in each experimental unit every 5 days). Thus, growth data were collected by measuring mortalities collected at approximately 08:00 daily every morning, and sacrificing all larvae that survived to 15 days. We felt that growth measurements of larval mortalities would represent actual growth as influenced by treatments (i.e., larvae did not die due to treatment effects) if growth was determined to be linear during the duration of the experiment (including live fish sacrificed at day 15). For example, if regression analysis showed a significant positive correlation for all fish in a given treatment, then growth was considered linear. To conduct this analysis, all four replicates of a given treatment were pooled. Experimental day and larval length were not correlated in the control treatment (as expected- indicating growth was not linear or positive), and thus, was eliminated from further analysis. The slopes (growth rates) of the remaining four zooplankton treatments were compared using confidence intervals to determine differences in growth rate.

Prey selectivity was calculated using Chesson's coefficient of selectivity:

$$\alpha = \frac{r_i / n_i}{\sum_{i=4}^{m} r_i / n_i}$$

where r_i is the number of food type i in the predator's diet, n_i is the number of food type i in the environment and m is the number of prey types available (Chesson 1983). Alpha values greater than 1/m (random feeding) indicate positive selection. Mean alpha values were calculated for each trial (1-5 subsample fish / aquaria- our replicate and experimental unit). These values were then pooled to determine the overall alpha value for a prey type, and tested against random feeding (1/m) by t-tests.

RESULTS

Movement Patterns of Adult Yellow Perch

A total of 34,975 yellow perch were tagged during 1996-2000 of which 1,855 were tagged in 2000 (Table 1). Agency (LMBS, IDNR, Wisconsin DNR, Michigan DNR, Ball State University, Beak Consultants Incorporated) sampling accounted for the majority (61.4%) of 2000 recaptures.

Recaptured fish were tagged in 1996-2000 with most recaptures being from 1999 tagging (Table 2). The average distance from tagging location to recapture location was 33 km (standard deviation (SD) = 59 km) and the maximum distance was 291 km for all recaptures in 2000.

Yellow Perch Population Structure

The yellow perch subsampled from fyke nets (N=589) consisted of ages-2 to 16 but 61.4% of the subsampled yellow perch were age-2 to age-5. The 1998 year-class made up the greatest portion (41.7%) of the subsampled perch (Figure 2). One other year-class made up over 10% of the catch: 1988 at 12.8%. Only 1 perch from the 1992 year-class was present in the subsample, suggesting minimal recruitment of that year-class.

Mean length of adult yellow perch we captured in fyke nets during 2000 was 235 mm (N = 2,554; SD = 48 mm). When compared to mean lengths from 1994 to 1999, the mean length of yellow perch in 2000 (235mm), was an intermediate value (Figure 3). Since 1994 the trend had been for mean length to increase each year. In 2000 mean length actually decreased for the first time since 1994. The sex of the perch collected (N = 2,554) was skewed toward males, with the female:male being 5% (Table 3). Mean length-at-age for male and female yellow perch was greatest for age-6 (Table 4). In both sexes the mean length-at-age increased rapidly until age 5 but then leveled off in older fish ages (6-19; Figure 4). Compared to earlier years (1997-1999), fyke net CPE in 2000 was the lowest.

Yellow Perch Egg Sampling

Divers found yellow perch egg skeins during May and June, 2000. All eggs were found on 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 (Table 5). 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 sampling efforts before 1994 (Figure 5). Average daily densities of larval yellow perch between May 15 and July 27, 2000 ranged from 0 to 19.11 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 15, 2000, when daily average density was 19.11 fish•100m^{-3} (Range: 10.4 to 34.3 fish•100m^{-3}). With the exception of 1998 (relatively high), larval yellow perch densities from 1994 to 2000 were similar but at much lower levels than the late 1980s.

Age-0 Yellow Perch Sampling

Only one age-0 yellow perch was collected in day trawls and three were collected at night. There was more effort applied on day trawls where 164,983 m^2 was covered compared to 89,180 m^2 at night. The CPE for trawling during the day was 0.6 fish•100,000 m^{-2} and at night 3.4 fish•100,000 m^{-2}. The CPE for daytime trawling in 2000 is similar to past years (1994-2000) with exception of 1998 where CPE was relatively high (Figure 6).

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 dominated the catch but at night spottail shiners became the dominant species (Figure 7).

Alewife Predation on Yellow Perch Larvae

Stomach and intestinal tract contents from a total of 197, 355, 61, 18, and 86 adult alewives were examined from samples collected in 1996, 1997, 1998, 1999, and 2000 respectively. Of the 86 alewives examined in 2000, 78 contained diet items (69 bottom trawl and 9 gillnets). Since 1996 at most 4.5% of the alewife stomachs contained larval fish in any year (Table 6). 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 2000, *Bythotrephes cederstroemi* tail spines were found in 29.5% of the alewife stomachs.

Zooplankton Sampling

Mean zooplankton density during June-July, 1988 (54/L) was at least double that of mean June-July zooplankton density during 1989-1990, and 1996-1999 (Figure 8). In addition, the mean zooplankton density at this same time during 2000 (9/L) was over five times lower than the mean zooplankton density during 1988, and at least three times less than the 1989-1990, and 1996-1999 samples. However, similar to the 1999 sampling period, the expanded sampling during 2000 demonstrated several peaks in zooplankton mean density; the first of which occurred on June 22, due to a spike of cyclopoid copepodites (20.37/L or 44%), whereas the next peak on July 19 was due to copepod nauplii (5.81/L or 37%) and rotifers (3.92/L or 25%; Figure 9). During August there were two noticeable peaks. The first was due to *Bosmina* (8.03/L or 46%) and copepod nauplii (3.97/L or 25%); the second peak was due to *Bosmina* (3.03/L or 17%) and abundant rotifers (10.23/L or 56%). A smaller peak occurred on September 28 with copepod nauplii (4.32/L or 31%) and rotifers (4.46/L or 32%) present at similar densities. The last observed peak in mean zooplankton density occurred on October 10, which consisted of copepod nauplii (4.76/L or 40%) and calanoid copepodites (3.76/L or 31%).

Copepod nauplii and cyclopoid copepodites dominated the nearshore zooplankton assemblages during May and June (Figure 10). Whereas cyclpoid copepodites decreased in abundance throughout the remainder of the sampling period, copepod nauplii remained a consistent component of the zooplankton community. Calanoid copepodites became increasingly abundant from September through November whereas *Bosmina* and rotifers were the dominant taxa during August. Daphnia spp. were present during June through November, however, at a very low density (<0.5/L). Other cladocerans (e.g., *Polyphemus*, *Ceriodaphnia*, *Leptodora*, *Diaphanosoma*, *Chydoridae*) were commonly found in samples during 1988-1990 but rarely observed in samples collected since 1996.

Cercopagis pengoi, the fishhook water flea native to the Ponto-Caspian region, was first observed in our samples on September 7,1999. *Cercopagis pengoi* was found in early July samples during the 2000 sampling period; however, densities for 2000 have yet to be determined. It is still uncertain to what extent this and other exotic zooplankton may exert on the zooplankton assemblage and food-web dynamics in Lake Michigan.

Along with zooplankton density and species composition, timing of the zooplankton peak can also be important. During the spring zooplankton levels experience a peak (Figure 9) but how does this compare with larval fish densities? To explore this we examined the timing of both zooplankton and larval fish density during the this past year (2000) and the last year with somewhat successful recruitment of yellow perch to age-0 (1998). In 1998 the peak zooplankton density (~90 per liter) occurred roughly 12 days after the peak in larval fish (Figure 11). In 2000 the peak in zooplankton (~ 40 per liter) occurred only 5 days after peak in larval fish (Figure 11). In the future this type of comparison will be performed on additional years.

Age-0 Yellow Perch Diet

Diet analysis was not performed because only a single age-0 yellow perch was collected during daylight hours.

Larval Yellow Perch Experiment

Larval yellow perch growth immediately post-hatch (5-7 mm) was not significantly affected by prey taxon (Figure 12). Growth rates of larval yellow perch feeding on copepods in Experiment 2 were significantly greater than when feeding on other taxa (Figure 13). Further, growth in the nauplii treatment was intermediate to growth rates observed among copepods and cladocerans and rotifers. Growth rates of larval yellow perch feeding on cladocerans and rotifers were not significantly different. Four of the five treatments showed a significant positive correlation between experimental day and larval yellow perch growth (Table 7). Thus, the overall influence of zooplankton taxon on growth during the early larval period of yellow perch appears to be minimal immediately post-hatch, and copepods become more important as larval size increased.

Prey selection patterns of yellow perch larvae (9-13 mm) revealed that cladocerans are strongly selected, while copepod nauplii and rotifers were not selected, and selection of adult copepods did not differ from random (Figure 14). However, out of a total of 28 trials, only seven were successful and most of these were on medium-sized larvae, and further experiments are planned for summer 2001.

CONCLUSIONS

The 2000 sampling with fyke nets collected 2,554 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 and 2000 sampling focused on only three areas instead of the previous six (Figure 6). Since 1997 these three areas have been sampled annually and CPE in 2000 was the lowest of any year. In 1997-1999, the 1988 year class dominated the fyke net catches but in 2000 the 1998 year class became dominant. The reduction in fyke net CPE may be due to the decreased numbers of the 1988 year class sampled but may also reflect the reduced effort we exerted. The 2000 yellow perch female:male sex ratio from fyke nets was the highest observed in the past six years (5%) but over half of all the females caught were from the 1998 year class. This

1998 year class may be very important for future spawning events and as such should be protected to the extent possible.

The age structure of fyke net catches during 2000 was very different than earlier work. The 1988 year class historically dominated the catch but in 2000 the 1998 year-class made up the majority (41.7%). The perch population is shifting toward younger fish, with over 61% of the catch being age-5 and under. For optimal conditions of population stability, the greatest proportion of fish sampled should be smaller and younger, which occurred in 2000 for the first time since the 1980s. Even with this shift towards younger individuals, the population may still be unstable because individuals from a single year class dominant the catch and relative numbers (CPE from fyke nets) may be decreasing.

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 2000, 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 possible 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 CPE of age-0 yellow perch in 2000 increased from 1999 but was still much lower than the 1998 CPE (0.54 YOY•$1000m^{-2}$) suggesting that 1998 may be a comparatively strong year class but not sufficiently strong to support extensive fishing on its 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 eight 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 2000 trawling suggests that night sampling is more effective at sampling age-0 yellow perch than day trawls but CPE were extremely low in both day and night 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 in part 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 2000. Since 1996, the maximum occurrence of larval fish in 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 1996-2000. There does appear to be some consistency in years 1996-1999, where mean densities were around 25-30/L. The 2000 zooplankton densities were the lowest found in all the years LMBS has sampled. The expanded sampling season in 2000 demonstrated several peaks in density, none of which coincided with the peak of larval yellow perch abundance. Copepod nauplii dominated the nearshore zooplankton assemblage from May to July, however *Bosmina* and rotifers became increasingly abundant and dominated samples during August and September of 2000. 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, which is native to the Ponto-Caspian region, was found in Illinois waters of Lake Michigan during 1999 (Charlebois et al. 2001). 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.

During laboratory experiments, growth of larval yellow perch during early life stages appears best when feeding on adult and immature copepods. Given the recent food web changes in Lake Michigan mediated by exotic species, changes in the zooplankton species composition that reduce abundance of small copepods may negatively affect growth and ultimately recruitment of larval yellow perch. Similar growth expriments are planned for summer 2001 to further investigate the effects of zooplankton taxa on growth of larval yellow perch.

Although prey selection patterns apparently differed from expected, based on results from the growth experiments, these data are based on medium-sized larvae. We believe that there is a possible ontogenetic change in capture efficiency wherein larval yellow perch become more efficient at capturing cladocerns as larvae grow. We suggest that overall growth patterns did not reflect this switch due to a time lag between an increase in capture efficiency and growth. Growth of larvae in the cladoceran treatments was probably initially depressed (due to decreased capture efficiencies), and at approximately 10-15 mm growth began to increase. However, experiment duration was not long enough to capture the effects of this switch. Hence, we plan on conducting further experiments on yellow perch growth and prey selection during summer 2001. Further, we plan on conducting experiments that quantify the foraging behavior (capture efficiency, handling time, reaction distance, etc.) of larval yellow perch feeding on cladocerans, copepods, copepod nauplii, and rotifers. These behavioral experiments should help provide mechanisms to explain patterns of prey selection and growth.

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TABLES

Table 1. Location and number of yellow perch tagged, 1996-2000.

Site	Location (lat./long.)	Year 1996	1997	1998	1999	2000
Kenosha, WI	42° 33.680 / 087° 48.529	0	5	0	0	0
Camp Logan	42° 28.400 / 087° 47.708	0	12	0	0	0
North of Waukegan	42° 22.719 / 087° 49.388	0	33	117	0	0
South of Waukegan	42° 21.096 / 087° 48.788	756	0	0	0	0
Waukegan wiremill	42° 20.244 / 087° 49.462	0	1,571	1,236	1,151	693
North Chicago	42° 19.795 / 087° 49.033	272	99	296	0	0
Great Lakes Naval Base	42° 18.290 / 087° 49.396	381	0	0	0	0
Lake Bluff	42° 16.772 / 087° 49.502	4,210	0	0	0	0
North Lake Forest	42° 15.280 / 087° 49.015	3,522	4,075	1,657	2,209	547
South Lake Forest	42° 13.950 / 087° 48.435	712	551	504	0	0
Fort Sheridan	42° 12.789 / 087° 47.792	3,609	1,851	1,092	2,914	615
Chicago Harbor	41° 54.100 / 087° 36.500	0	285	0	0	0
All Sites		13,462	8,482	4,902	6,274	1,855

Table 2. Recapture source and year of recapture for yellow perch tagged by INHS during 1996-2000. Agency recaptures include yellow perch recaptured by LMBS, IDNR, Wisconsin DNR, and Michigan DNR, Ball State University, Beak Consultants Incorporated.

	Tag Year / Number tagged				
Recapture Year / Source	1996 N = 13,462	1997 N = 8,482	1998 N = 4,902	1999 N=6,274	2000 N=1,855
1996					
agency	322				
sport	278				
commercial	115				
1997					
agency	318	824			
sport	46	149			
commercial	97	23			
1998					
agency	137	288	244		
sport	16	62	60		
commercial	0	33	64		
1999					
agency	92	216	254	377	
sport	6	68	96	121	
commercial	0	4	10	17	
2000					
agency	22	34	28	65	10
sport	1	29	27	38	6
commercial	0	0	1	0	0

Table 3. Total number of adult yellow perch and percentage of female yellow perch captured in fyke nets by LMBS, 1994-2000.

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
2000	2,554	5.0

Table 4. Mean length-at-age, standard error, and number of fish in each age class for yellow perch sampled during fyke netting in 2000.

	Female			Males		
Age	Length (mm)	SE of Length	Number	Length (mm)	SE of Length	Number
1	---	---	---	---	---	---
2	202.3	3.4	64	185.5	1.7	179
3	262.8	6.4	12	244.4	3.8	37
4	290.0	12.7	4	261.8	7.0	5
5	311.5	7.27	11	270.1	3.6	47
6	358.0	---	1	278.7	3.3	15
7	---	---	---	277.6	15.7	5
8	---	---	---	264.0	---	1
9	274.0	---	1	274.4	5.3	15
10	335.0	---	1	269.8	6.0	32
11	322.0	---	1	265.2	3.1	52
12	285.7	5.3	6	266.6	2.4	67
13	---	---	---	258.9	4.0	16
14	255.0	---	1	270.8	7.4	8
15				250.0	17.0	2
16				247.0	---	1

Table 5. Summary of 2000 egg census dives at US Steel intake over cobble substrate, including viability and developmental stages of egg skeins.

Date	Depth range (m)	Transect length (m)	No. YP egg skeins	Percent viable	Stage of development
May 15	7 – 9	200+	0		
May 23	7 – 9	200	3	90 – 100	a
June 1	7 – 10	200	16	80 – 100	a, b, c, d
June 7	7 – 10	200	67	90 – 100	a, b, c, d
June 19	6 – 10	200	5	90 – 100	a, d

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

Table 6. 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.

	Sample Year				
Prey taxa	1996 N = 197	1997 N = 355	1998 N = 61	1999 N = 18	2000 N = 78
amphipods	4.6 [b]	7.9	19.4	0.0	29.5
B. cederstroemi	2.0	15.8	0.0	27.8	29.5
chironomid larvae	47.2	62.8	79.0	61.1	67.9
cladocerans	*** [c]	5.4	69.4	0.0	57.7
copepods	72.6 [c]	33.5	50.0	0.0	57.7
D. polymorpha	0.0	0.0	0.0	5.6	12.8
Hydracarina spp.	*** [a]	*** [a]	9.8	5.6	6.4
isopods	4.6 [b]	0.3	3.2	0.0	0.0
larval fish	2.5	4.5	1.6	0.0	0.0
phytoplankton	60.4	*** [a]	*** [a]	*** [a]	*** [a]
terrestrial insects	*** [a]	31.0	49.4	50.0	11.5

Table 7. Summary statistics of Growth Experiment 2.

	Model				95% Confidence intervals		
Treatment	DF	F	P	Slope	Upper	Lower	Grouping
Copepod	62	222.78	0.0001	0.53	0.60	0.46	A
C. Nauplii	52	245.05	0.0001	0.36	0.41	0.31	B
Cladoceran	41	65.53	0.0001	0.23	0.29	0.17	C
Rotifer	25	50.84	0.0001	0.15	0.19	0.11	C
Control	42	0.002	0.9605	N/A	N/A	N/A	N/A

Figures

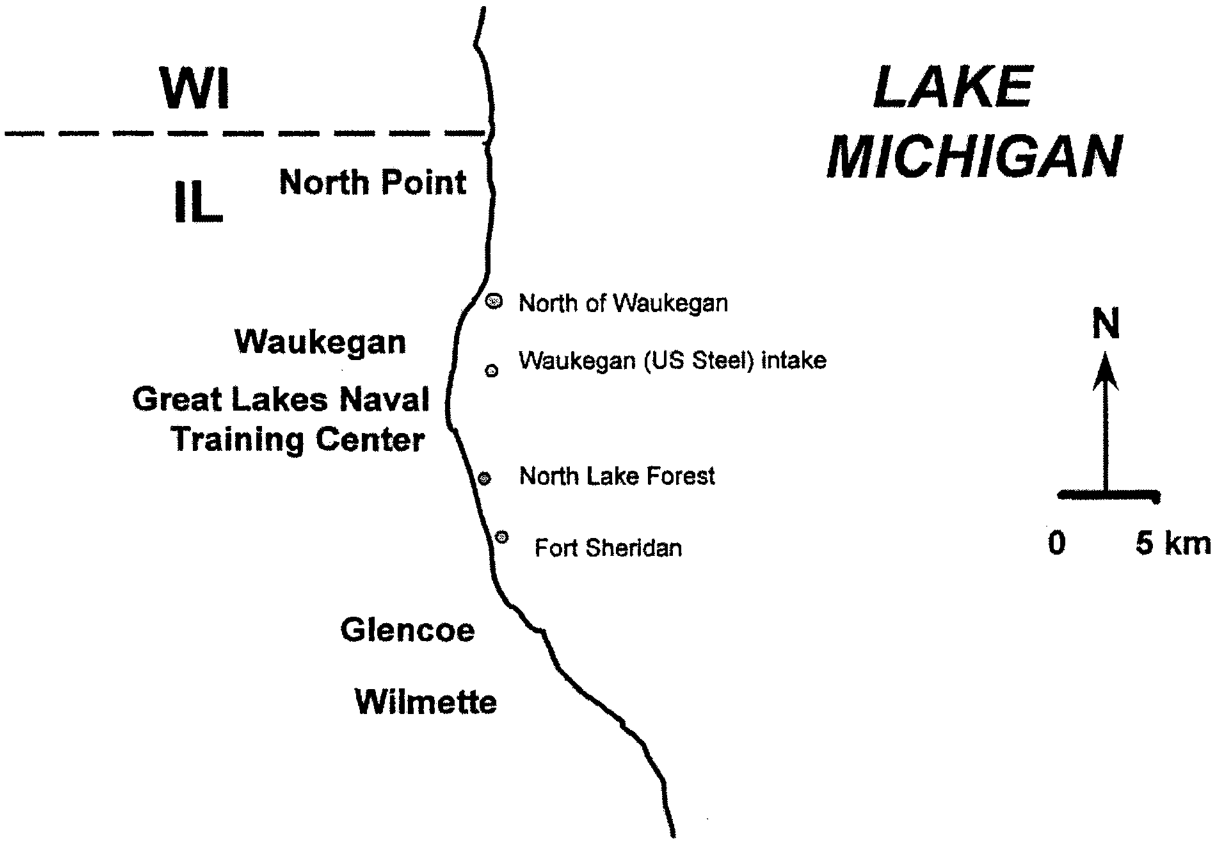

Figure 1. Lake Michigan 2000 yellow perch sampling sites.

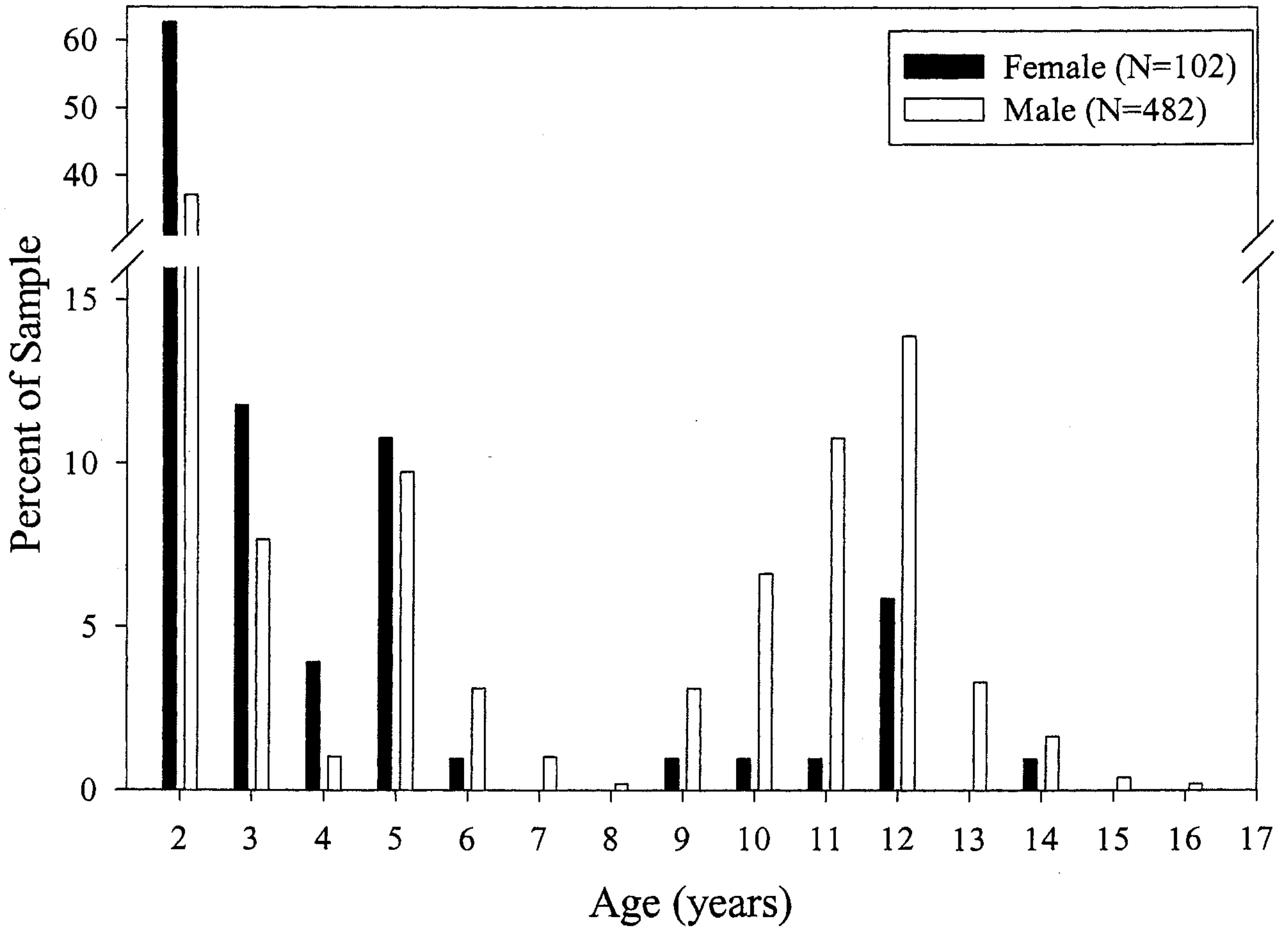

Figure 2. Age-distribution of adult yellow perch sampled using fyke nets near Lake Bluff, IL, 2000.

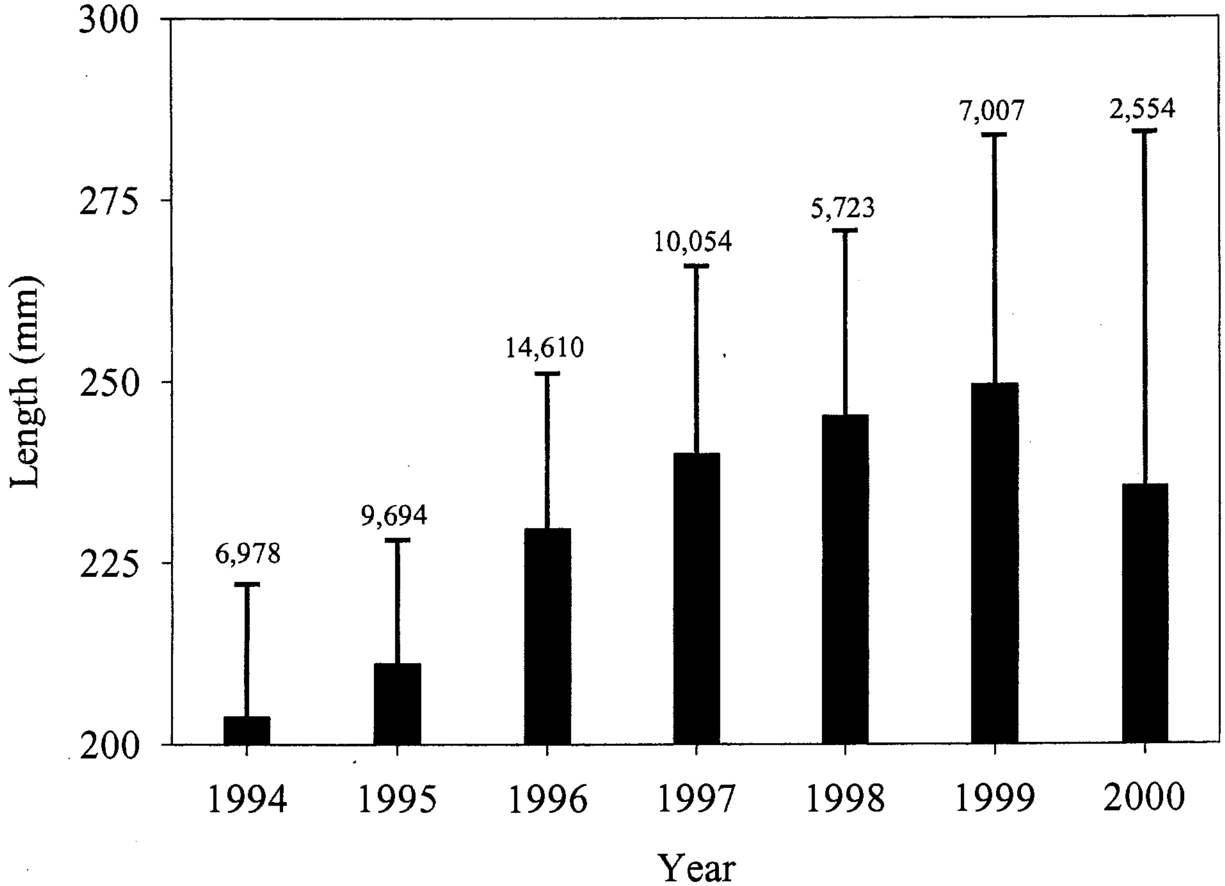

Figure 3. Mean length and standard deviation of adult yellow perch sampled using fyke nets near Lake Bluff, IL, 1994 – 2000. Sample size above bar.

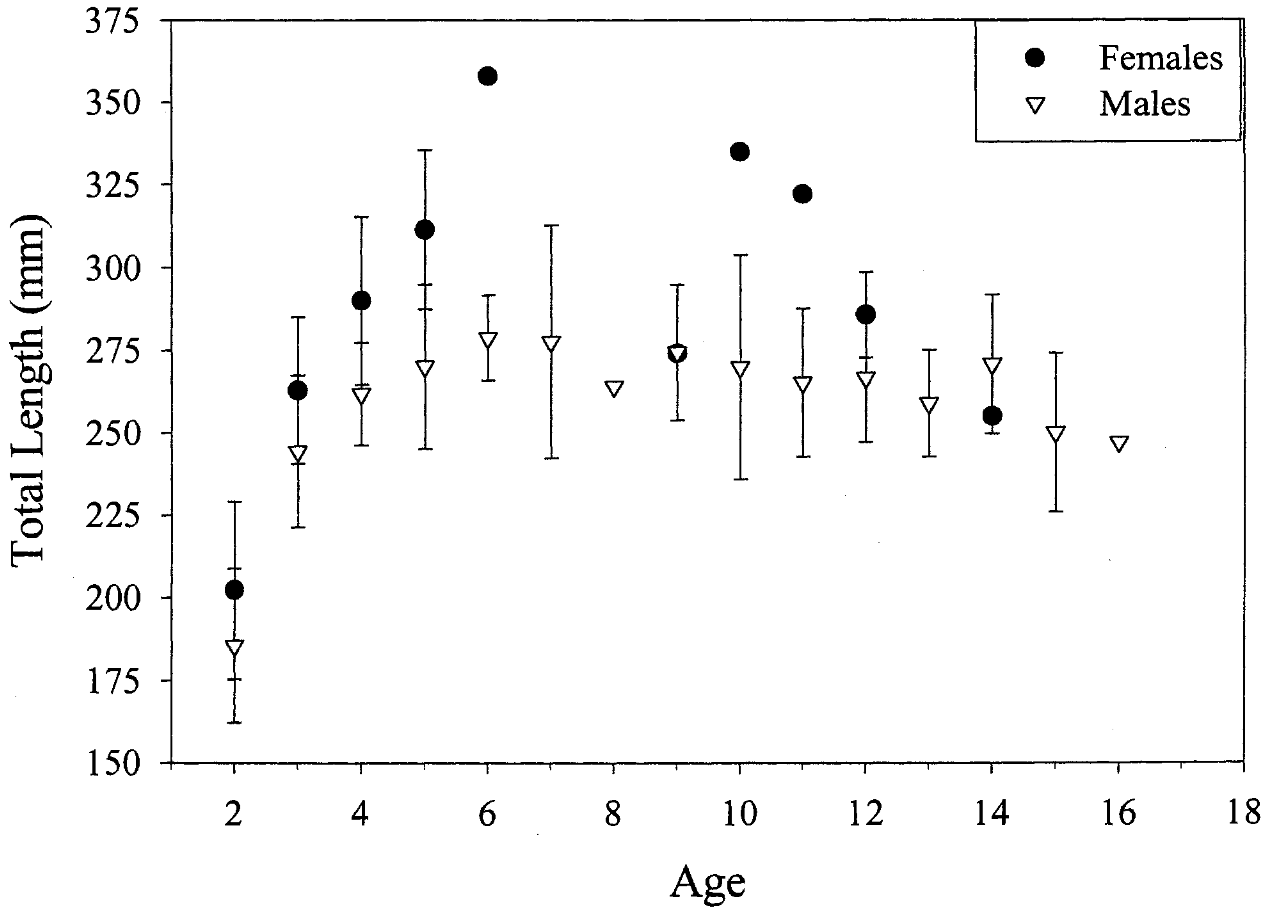

Figure 4. Mean length-at-age (± 1 standard error) for yellow perch collected during fyke netting in 2000.

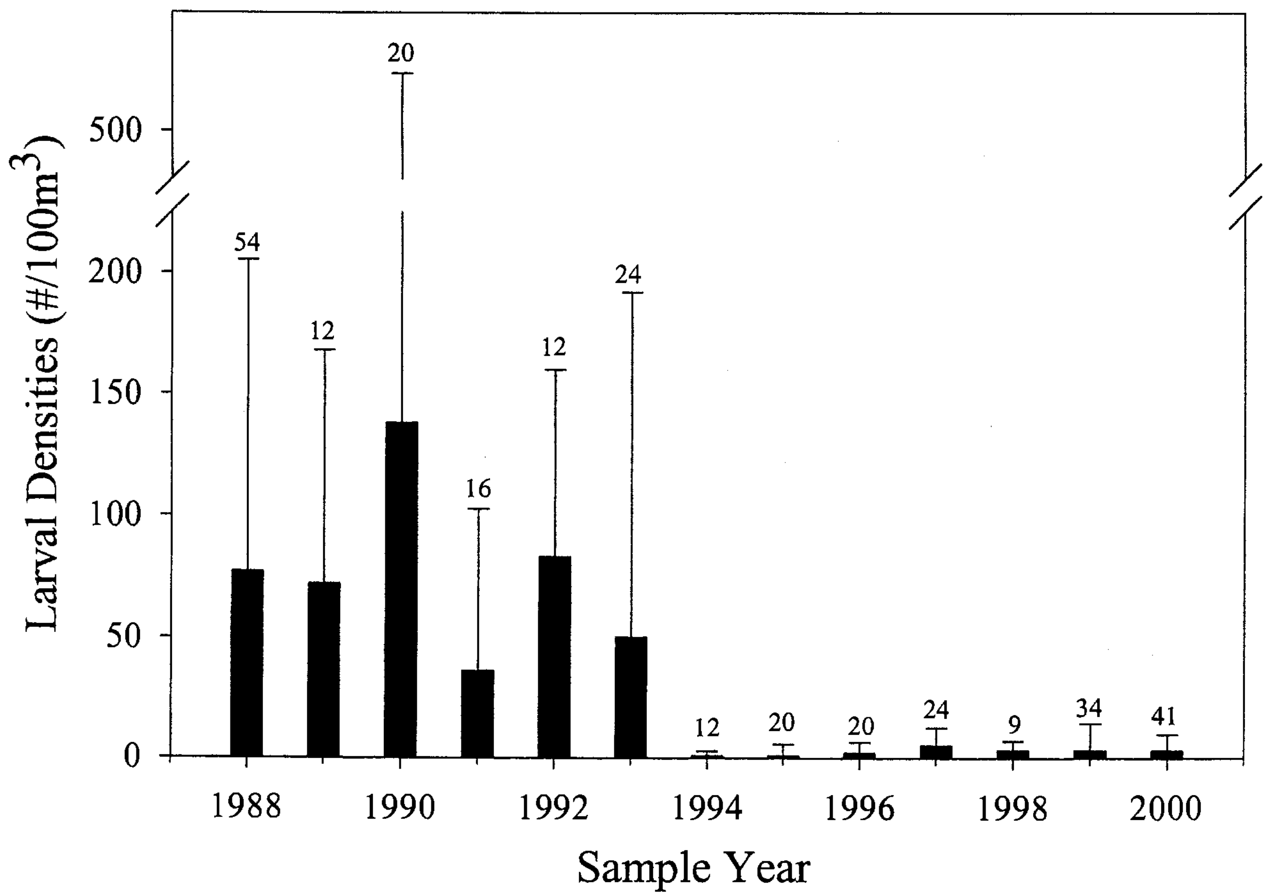

Figure 5. Abundance of yellow perch larvae near Waukegan Harbor, IL, 1988 to 2000. Sample size above bar.

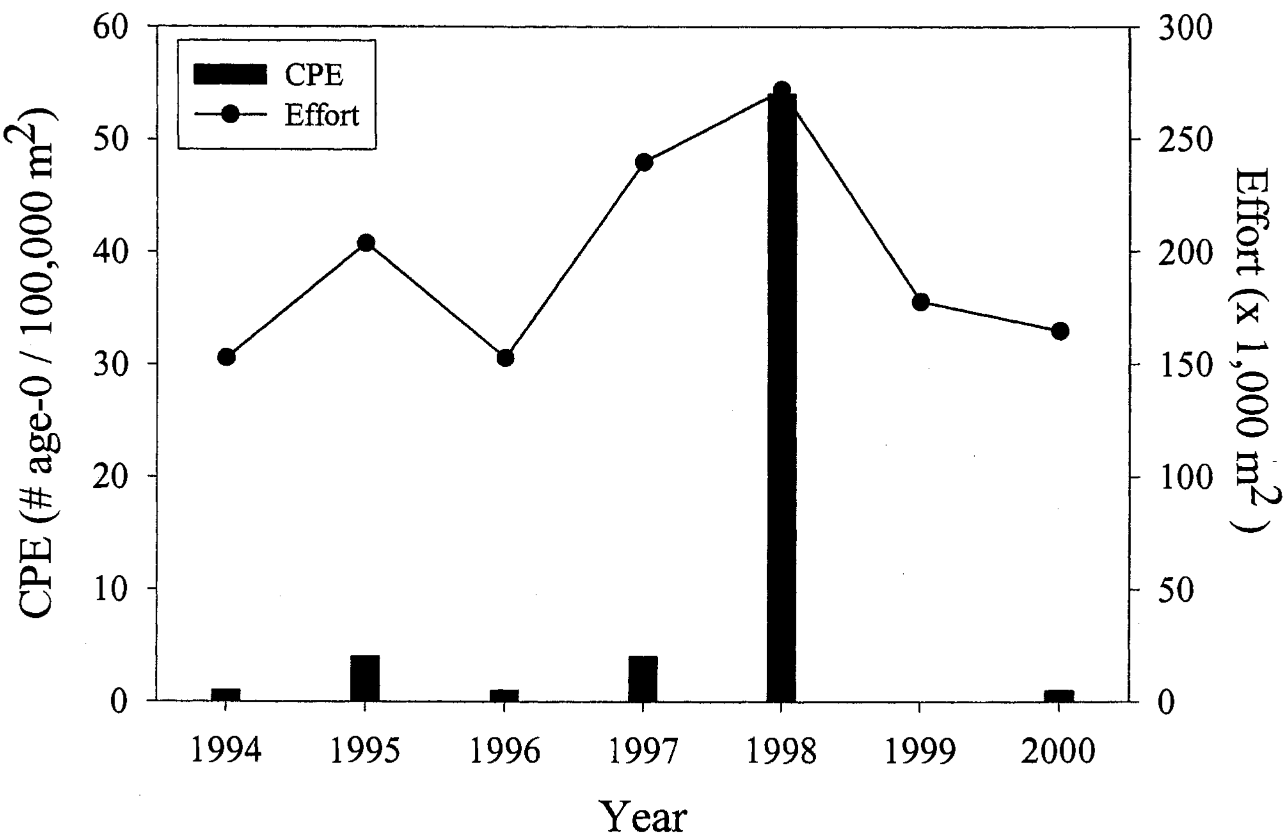

Figure 6. Abundance of age-0 yellow perch caught in daytime bottom trawls north of Waukegan Harbor, IL, 1994 to 2000.

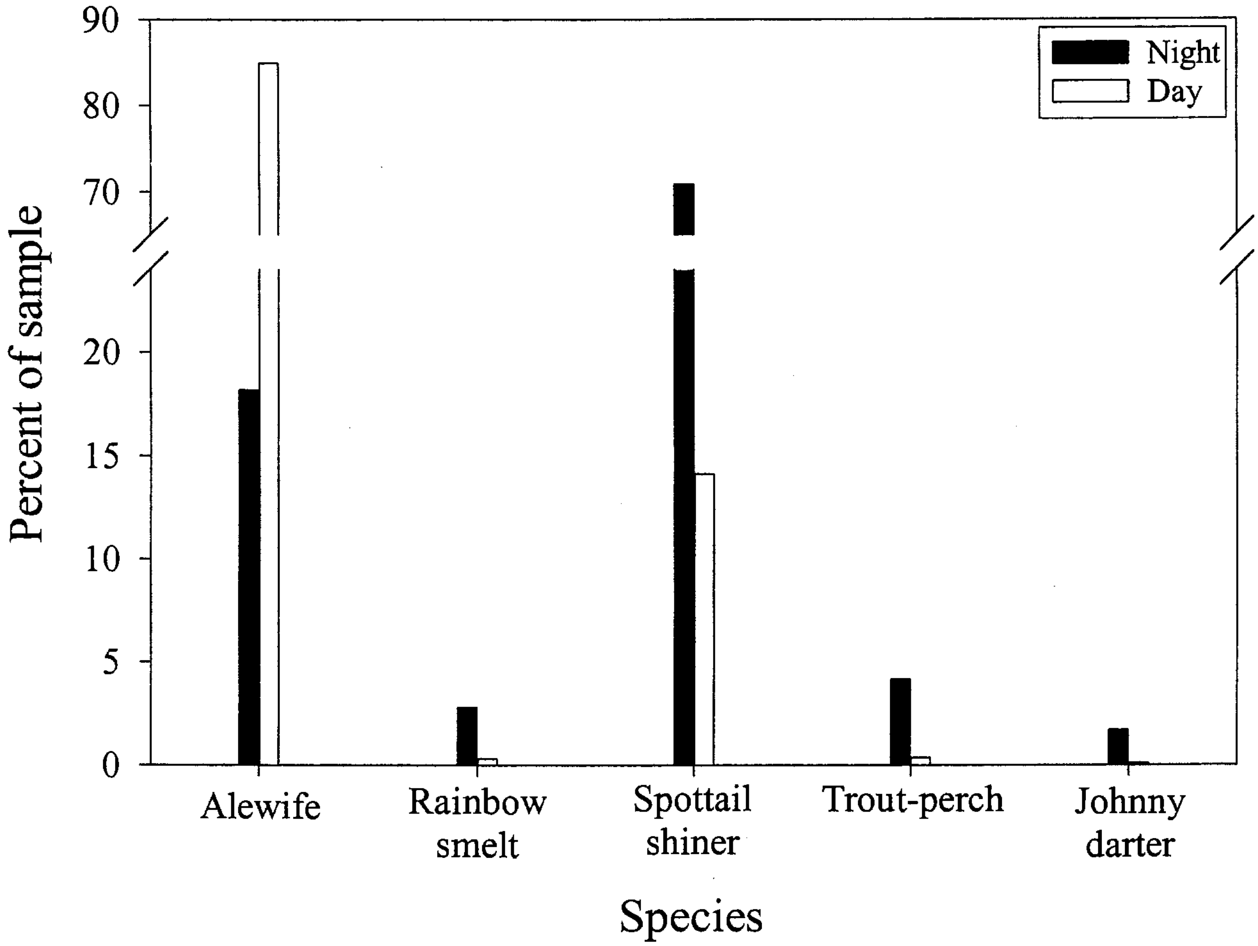

Figure 7. Percent composition of non-target species sampled during day and night bottom trawls north of Waukegan Harbor, IL, 2000.

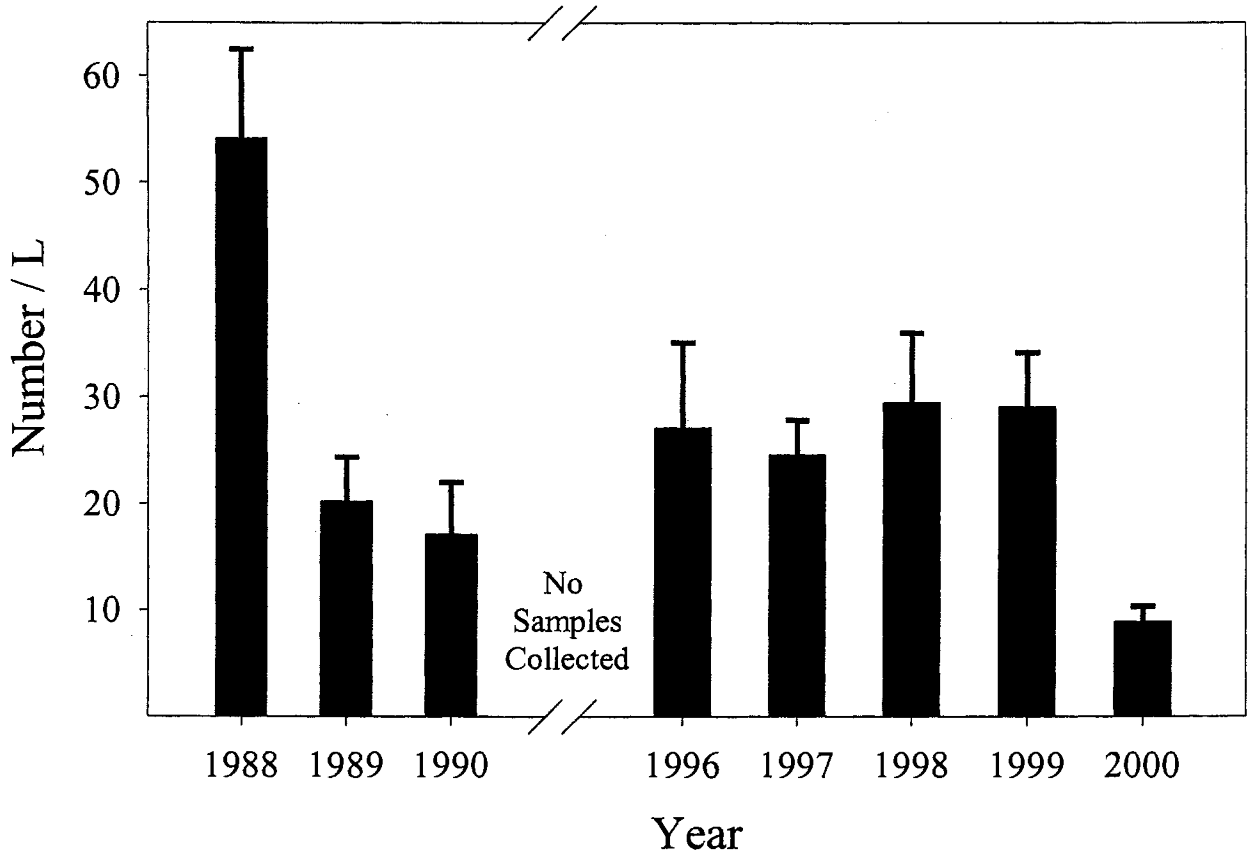

Figure 8. Mean density of zooplankton (+ 1 standard error) present in Illinois waters of Lake Michigan near Waukegan during June through July, 1988 – 1990 and 1996 – 2000.

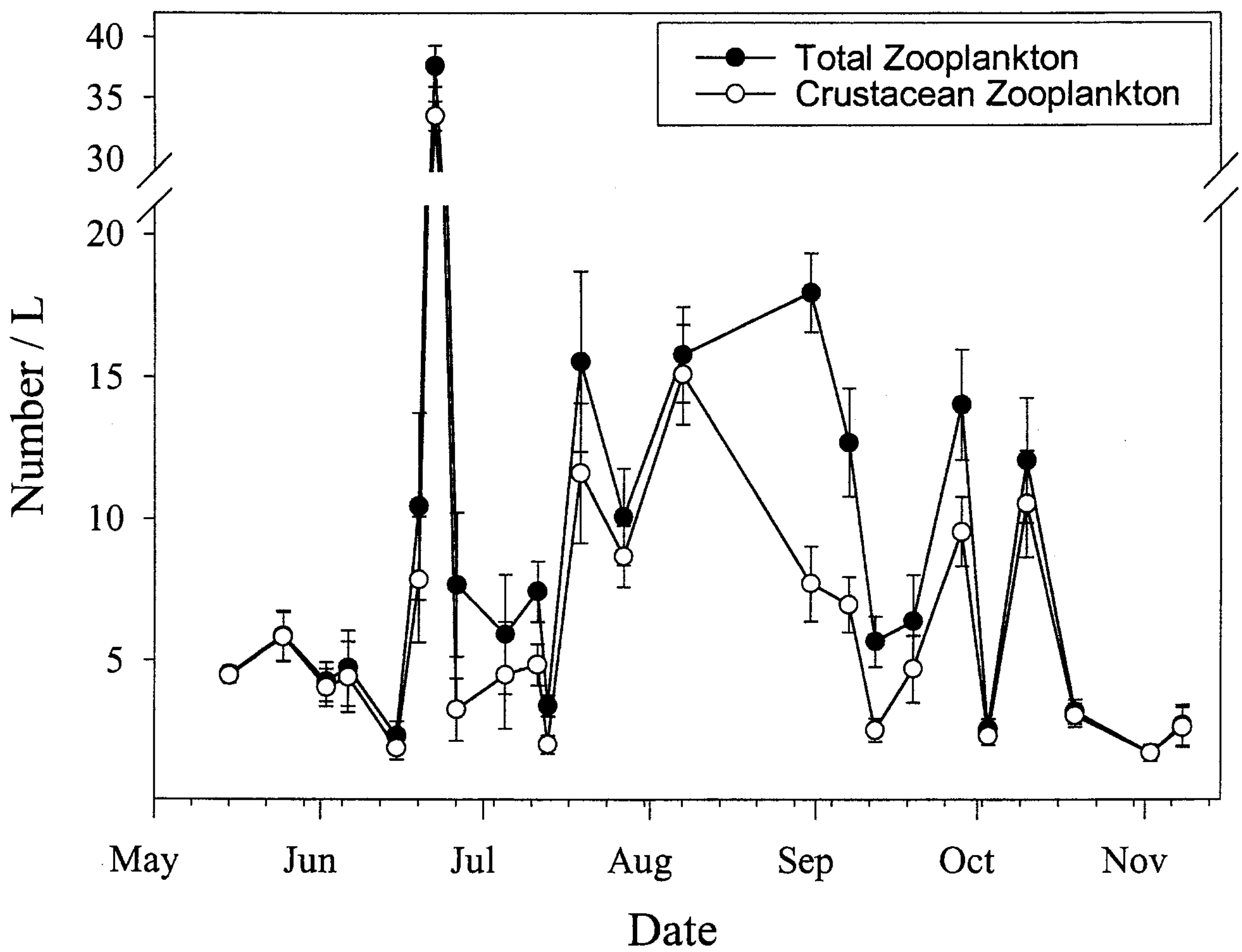

Figure 9. Mean density by date of zooplankton (± 1 standard error) present in nearshore Illinois waters of Lake Michigan around Waukegan during May – November, 2000. Closed circles represent total zooplankton, whereas open circles represent crustacean zooplankton only.

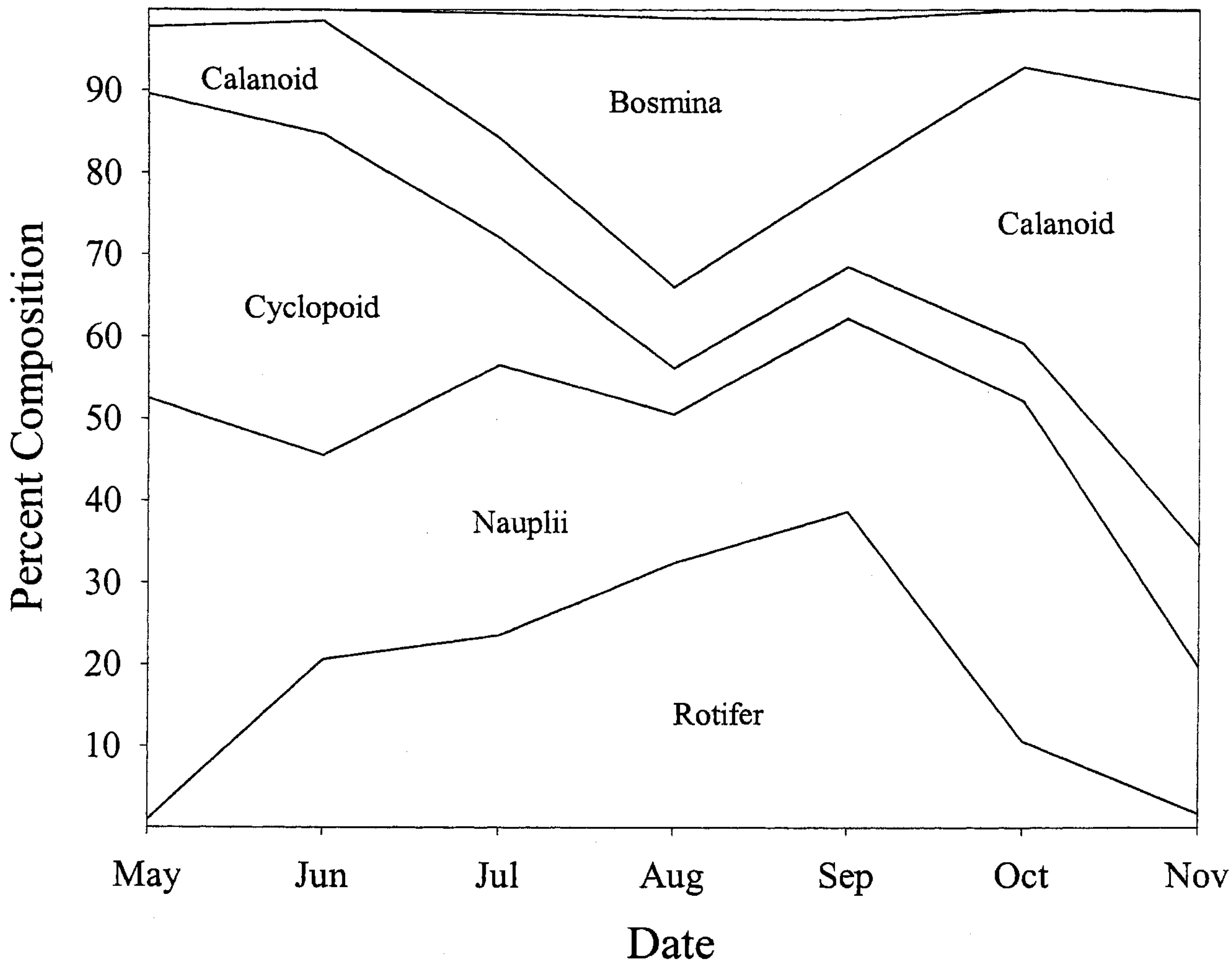

Figure 10. Percent composition of zooplankton present in nearshore Illinois waters of Lake Michigan near Waukegan during May through November, 2000.

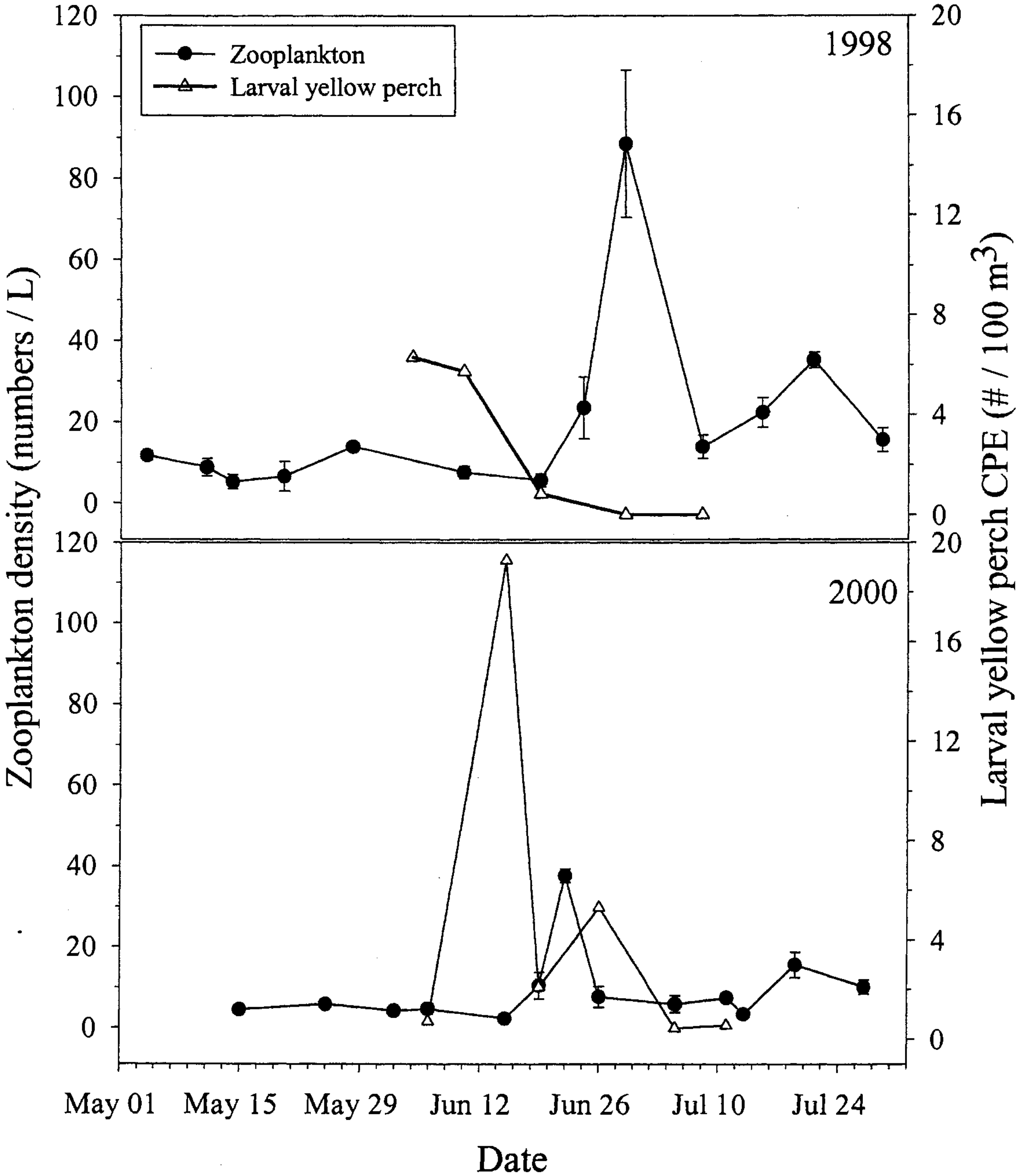

Figure 11. Seasonal patterns of larval yellow perch density and total zooplankton density for 1998 and 2000 in Illinois waters of Lake Michigan near Waukegan.

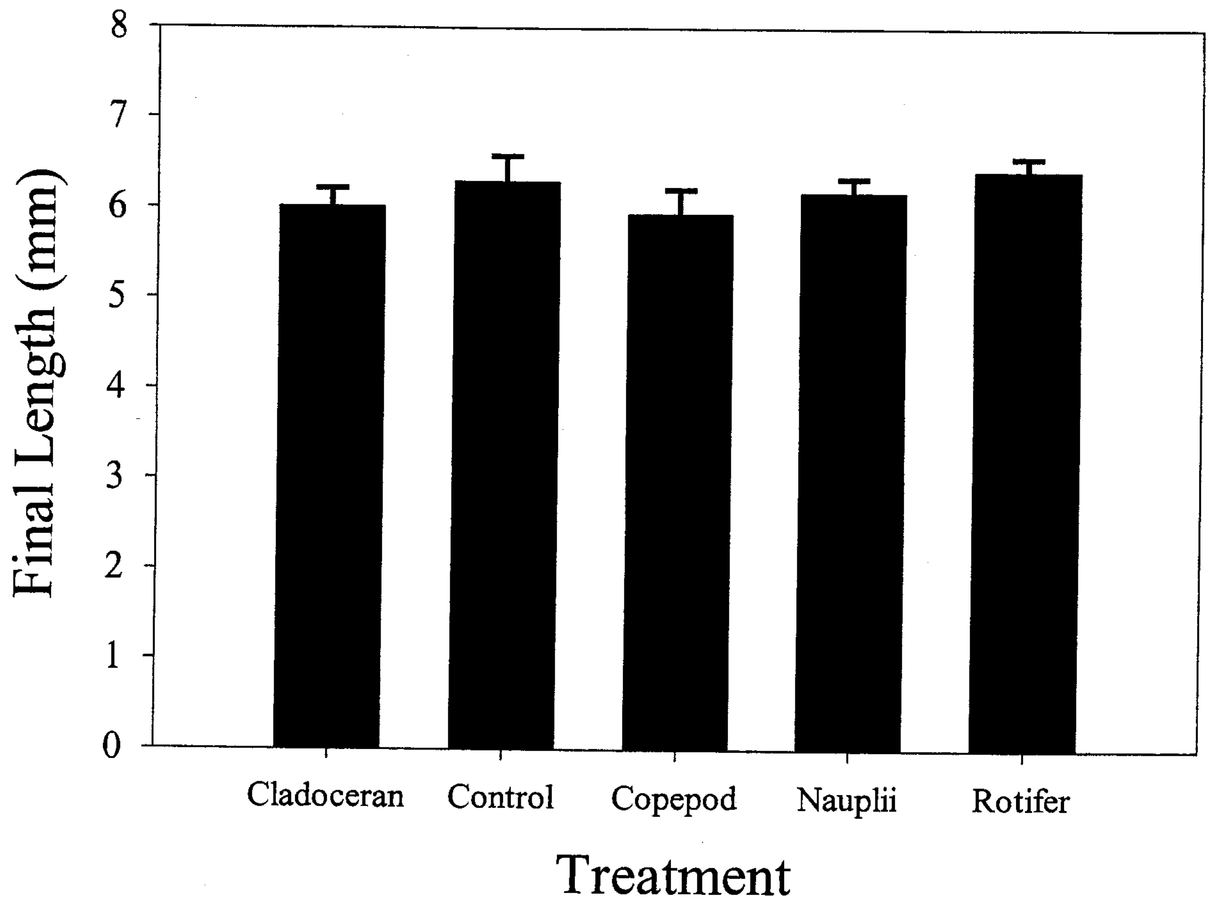

Figure 12. End length of post-hatch larval yellow perch + 1 standard error. These lengths were measured 5 days after innoculation with zooplankton taxa.

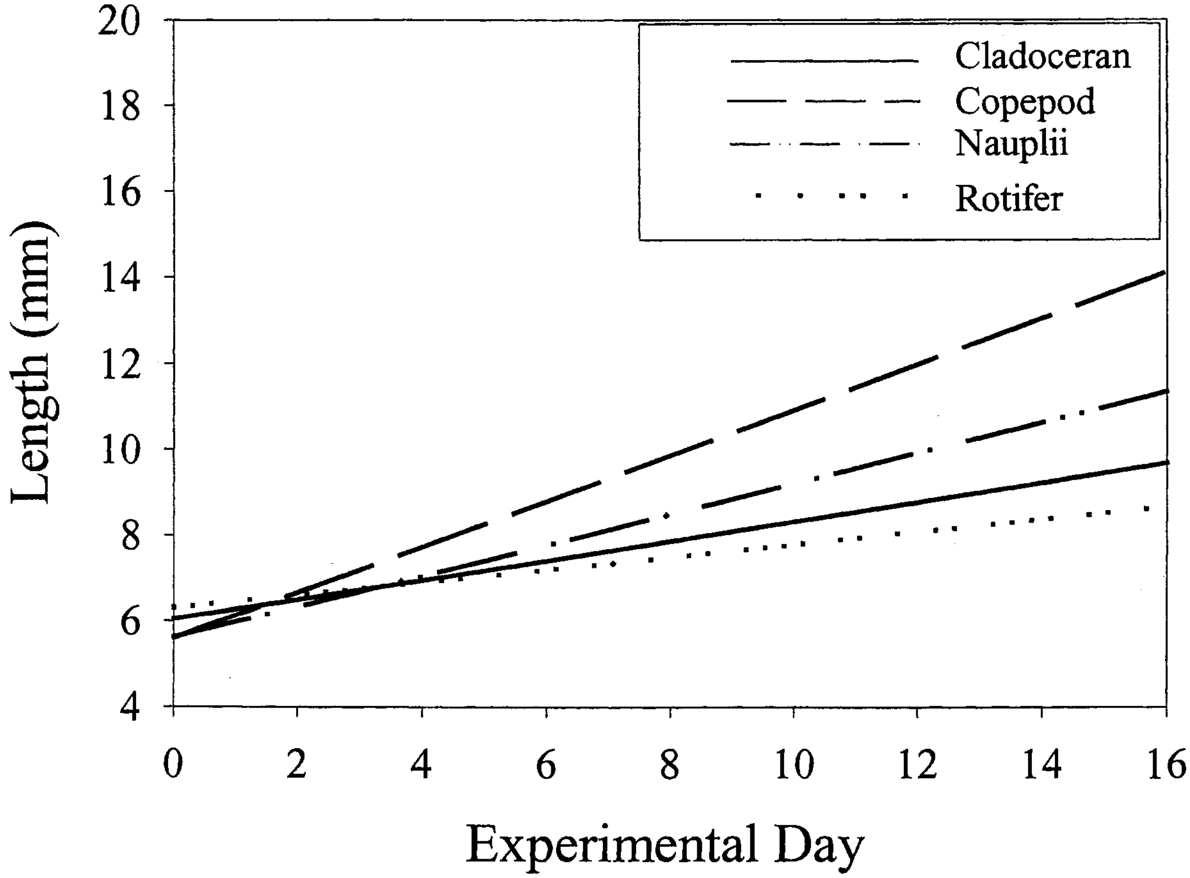

Figure 13. Growth rates of larval yellow perch in experiment 2. Regressions were calculated from pooled data in each treatment (4 replicate experimental units). The slopes were compared via 95 % confidence intervals.

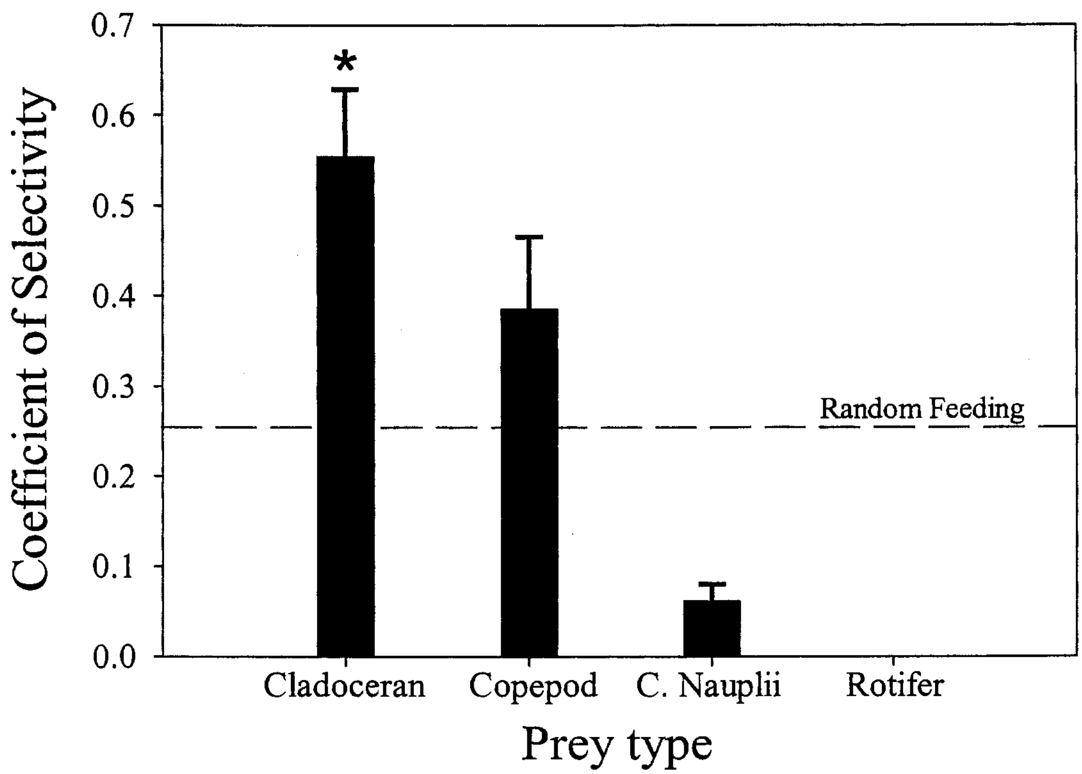

Figure 14. Coefficient of selectivity for larval yellow perch (9-13 mm) feeding on cladocerans, copepods, copepod nauplii, and rotifers.