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

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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. 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 experimentally whether significant performance (growth, foraging, susceptibility to predation) differences occur between yellow perch larvae with and without inflated swim bladders.

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 2002 sampling in four different study areas.

Study 101. Expand and improve annual assessments of the yellow perch spawning population in southwestern Lake Michigan

1. The average total length of yellow perch collected in our spring fyke nets was 221.1 mm (N = 985, standard deviation (SD) = 39.8 mm). The percent female of the yellow perch collected in our fyke nets was 3.8%. This percent female in 2002 is a decrease from the high in 2001 of 10.3%.
2. No yellow perch were tagged during 2002 but 38 were recaptured. The majority of recaptures in 2002 were from fish tagged in 1999. The average distance from tagging location to recapture location was 13.0 km (SD = 45.1 km) and the maximum distance was 265.8 km. The average number of days between tagging and recapture was 1446 (SD=468); the maximum number of days was 2355 (~6.45 yrs).
3. The majority of yellow perch collected in fyke nets during 2002 were age 4 (77.6%).

Study 102. Sampling for eggs, larvae, and older YOY of yellow perch

1. Relatively few yellow perch larvae were captured using neuston nets in 2002 compared to sampling conducted prior to 1994. Peak larval yellow perch density ($48.9/100m^3$) in our samples occurred on June 17.
2. Yellow perch egg skeins were counted south of Waukegan Harbor at the abandoned Waukegan wiremill (US Steel) intake line during 2002 on May 14, 22, 29, 30 and June 6, 10, 12, 17. On the first day (May 14) of sampling no eggs were found. On May 22, eggs newly fertilized were found. By June 10, eggs were found in all stages of development. On June 17, most of the egg skeins were in late stages of development but a single newly

fertilized skein was observed. Egg viability was estimated to be >90% for egg skeins returned immediately to the laboratory and viewed under a dissecting microscope.
3. In 2002, our daytime bottom trawling sampled approximately 240,786 m^2 and collected 368 age-0 yellow perch.

Study 103. Identification of the potential role alewife predation plays to determine yellow perch year-class strength

1. Alewife CPE for gillnet sets (N=11) averaged 9.37 fish/hour with a standard deviation of 10.2; CPE for bottom trawl sampling (N=2) was 4.71/1,000m^2 of bottom swept with a standard deviation of 2.86.
2. No larval fish were found in the adult alewife stomachs (N=150) sampled in 2002. Of alewife stomachs examined, 117 contained food items.

Study 104. Effects of food availability on larval and early juvenile yellow perch survival and growth

1. Collection of zooplankton samples coincided with larval yellow perch sampling during 2002. The 2002 zooplankton density was less than half that of previous years (1996-2000) 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.
2. Stomachs of 117 age-0 yellow perch were examined in 2002. The dominant diet items by numbers were *Bosmina* sp. and copepod zooplankton.
3. Yellow perch larvae grow nearly twice as fast when they successfully inflate their swim bladders shortly after hatching as compared to larvae that fail to do so. The presence of inflated swim bladders in yellow perch larvae positively affects prey selection and capture efficiency, which directly promotes their faster growth and leads to increased survival. Yellow perch larvae with inflated swim bladders grew faster, consumed more prey and more evasive types of prey than did fish without inflated swim bladders.
4. Invertebrates were sampled on three dates in 2002. Peak total invertebrate density was 1.14/cm^2, which occurred on August 28.

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 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 significantly greater survival of the 1998 year-class occurred and it now is the dominant year-class in the population (Makauskas and Clapp 2000).

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. 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 1989–2001 have been consistently lower than 1988 densities, the last year of strong yellow perch recruitment (Dettmers et al. 2003; Pientka et al. 2002). 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.

In earlier studies, we evaluated how this shift in the zooplankton assemblage in southern Lake Michigan influences growth and survival of larval yellow perch, using laboratory experiments (Pientka et al. 2002, Pientka et al. 2001). One observation made during these experiments was that some yellow perch larvae failed to inflate their swim bladder. Swim bladder inflation is usually associated with the nutritional state of the fish larvae and can affect the eventual survival of these fish to later life stages. Therefore, we explored the relative success of yellow perch larvae that did or did not inflate their swim bladders. We explicitly examined growth and foraging (prey selection and capture efficiency) of perch larvae with and without inflated swim bladders. The difference in performance of larval perch with and without inflated swim bladders in these areas (growth and foraging) will give us a better understanding of factors controlling recruitment.

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

<u>Study 101.</u> Expand and improve annual assessments of the yellow perch spawning population in southwestern Lake Michigan

Job 101.1: Supplemental index gill netting

Index gill nets will be set outside Calumet Harbor by contract with a commercial gill net fisherman (J. Camalick) during the week of index gill netting (Mid May – Early June). LMBS personnel will assist with sampling at the Calumet site.

Job 101.2: Yellow perch aging

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).

Job 101.3: Tagging yellow perch

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 2002, fyke nets were set at three sites: Waukegan wiremill, North Lake Forest, Fort Sheridan (Figure 1). From fyke net catches, a subsample of perch was preserved to obtain population structure information. Of the remaining perch, ~700 maximum per net were measured for total length, and externally examined to determine sex and reproductive status. All fish, except for the subsampled yellow perch, were released. Recaptured yellow perch from our sampling and from sport catches were assessed for distance from tagging site and time at liberty.

Study 102. Sampling for eggs, larvae, and older YOY of yellow perch

Job 102.1: Diel larval fish sampling

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. In 2002, the neuston net was towed at the surface at night, every week or two weeks between May 21 and July 31. Two areas (north and south of Waukegan Harbor) were selected for the neuston tows. Within each area, two tows were performed. One tow was at the surface over 5 meters of water and the other over 10 meters of water. A calibrated General Oceanics™ standard flowmeter was mounted in the mouth of the net to determine the volume of lake water sampled. Mean volume of water sampled during each neuston net tow was 1,444 m^3. Larval fish were counted in the laboratory and identified to genus, or species when possible.

Job 102.2: Yellow perch egg sampling

On each sampling date in 2002, scuba divers generally swam two 120-m transects along the abandoned Waukegan wiremill water intake line, which is located 1.9 km south of Waukegan Harbor (Figure 1). Generally divers explored an area approximately 4 m wide along the intake during each transect. While exploring this area, divers counted the number of egg skeins and collected sub samples of the skeins. The sub samples were transported back to the laboratory where the percentage of viable eggs was estimated using a dissecting microscope.

Job 102.3: Young-of-the-year sampling

We used a bottom trawl with a 4.9-m head rope, 38-mm stretch mesh body, and 13-mm mesh cod end to sample young of the year yellow perch. Daytime bottom trawling for age-0 yellow perch was conducted approximately weekly at four depth stations (3, 5, 7.5 and 10 m) from July 31 through October 15, 2002. All sampling occurred north of Waukegan Harbor, at a speed of approximately 2 m/sec. Approximately 4460 m^2 of the lake bottom were sampled for each 0.9-km transect. All fish collected were counted and on a subsample (30 individuals per species) of the non-target fish, total lengths to the nearest mm were measured. Age-0 yellow perch were counted and frozen for later examination of stomach contents.

Study 103. Identification of the potential role alewife predation plays to determine yellow perch year-class strength

Job 103.1 and Job 103.2: Estimate alewife abundance and alewife diet analysis

In 2002, adult alewives were sampled concurrent with the peak of the 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 to 60 minutes. Gillnets were set either with one at the 10-m site (bottom depth) and the other at the 5-m (bottom depth) site, or both nets were placed at the 10-m (bottom depth) sites. Bottom trawls were also used to collect alewife at our 10-m (bottom depth) site.

All alewife collected were frozen on dry ice and kept frozen until they were processed at the lab. The processing included measuring total length (TL) to nearest mm, weight (g), dissected to determine sex and maturity, and remove the entire digestive tract, which was preserved in 95% ethanol until examination. 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 the lowest possible taxon.

Study 104. Effects of food availability on larval and early juvenile yellow perch survival and growth

Job 104.1: Quantify seasonal zooplankton availability and archived zooplankton samples

Zooplankton in 2002 was generally sampled weekly from May 21 to September 16 and on the same nights as larval fish collections during June-July. 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 8-10m.

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, Macrothridae 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.

Job 104.2: Implications of YOY yellow perch diet and growth to recruitment

Age-0 yellow perch collected by bottom trawl in 2002 were frozen for stomach analysis. Prior to dissection, total length (mm) and weight (g) were recorded; otoliths were removed and preserved for future analysis. 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.

Job 104.3: Laboratory experiments investigating the effects of food on larval and YOY yellow perch recruitment success

To test whether significant performance differences occur between yellow perch larvae with and without inflated swim bladders, we experimentally compared their growth and foraging performance. Differences in these performance measures indicate the behavioral mechanisms that lead to differential mortality between yellow perch larvae with and without inflated swim bladders.

Growth

Seven fertilized ribbons of yellow perch eggs were obtained from Lake Michigan by scuba divers on June 2, 2002. Egg ribbons were immediately placed in plastic mesh baskets and suspended in flow through raceways with ambient temperature lake water (11°C). The following day, sub-samples of egg ribbons (three from each ribbon) were separated and placed in small plastic mesh baskets floating in 38L aquaria (three replicates per female). The water in the aquaria, initially at ambient temperature (11°C), was gradually raised to room temperature 22°C (at the rate 2°C/day) to shorten incubation time. After hatching and yolk sack absorption yellow perch larvae were fed *ad libitum* with a combination of natural zooplankton obtained from Lake Michigan and newly hatched *Artemia* nauplii. Two weeks after hatching, fish were counted and swim bladder inflation was determined. We measured total length of ten individuals with and without swim bladders from each aquarium and averaged by female. Daily growth rate of larvae with and without swim bladders was calculated based on the initial length (measurements taken on representative subsamples just before first feeding) and the length of larvae after 12 days of feeding for offspring of each female. To compare the effect of female on growth rate of larvae with and without swim bladders and on swim bladder inflation rate, we used ANOVA; Tukey's Honestly Significant Difference test separated treatment means.

Remaining yellow perch eggs were incubated and hatched in one common raceway; larvae were fed and grown on natural zooplankton supplemented with *Artemia* nauplii. From this pool we randomly selected yellow perch with and without swim bladders and subsequently used them in a series of experiments designed to compare their foraging performance. Because yellow perch, like other percids, is a physoclistous fish, there is only a narrow window of opportunity in its ontogeny that allows for the initial swim bladder inflation. From our preliminary observations, the initial swim bladder inflation in yellow perch larvae occurs between 5.5 and 8 mm TL. For the purposes of our experiment we considered two yellow perch size classes: small, 8 to 12 mm total length (TL) and large, 12 to 16 mm TL. We assumed that if the swim bladder had not been inflated by 8 mm TL, yellow perch larvae would not inflate it due to pneumatic duct closure. The two size classes were selected to decrease individual variation associated with larvae size in our comparisons.

Foraging - prey selection and capture efficiency

To assess the foraging efficiency of yellow perch with and without inflated swim bladders, ten individuals from both size classes (total 40 fish) were placed in 38L aquaria (one per aquarium, N=10) and acclimated for at least 12 h prior to the experiment. Once acclimated, yellow perch were offered an assemblage of zooplankton at the density of 150/L consisting of equal densities (50/L) of cladocerans (*Bosmina* and *Ceriodaphnia*), adult copepods, and copepod nauplii. Zooplankton were either cultured on site or obtained from Lake Michigan as needed. Zooplankton density and assemblage was established by separating adult copepods from nauplii using 153 μm mesh sieves and adjusting volumes in zooplankton containers, while cladocerans came from pure cultures.

Yellow perch larvae were allowed to feed for 30 min., euthanized, and preserved in 95% ethanol. Equal prey densities were chosen to give each yellow perch equal opportunity by number to consume a given prey item. Digestive tracts were later removed for enumeration of prey items using a dissecting microscope.

Prey selectivity was estimated by calculating Chesson's coefficient of selectivity (α):

$$\alpha = \frac{r_i/n_i}{\sum_{j=2}^{m} r_j/n_j}$$

where r_i is the number of food type i in the predator diet, n_i is the number of food type i in the environment, and m is the number of prey types available. The expected value of random feeding is a function of the number of food items: $1/m$. The index varies between 0 and 1 with values above $1/m$ indicating preference and those below $1/m$ indicating avoidance. Mean selection coefficients for each size class were compared against random feeding to determine prey selectivity.

In a separate experiment, we investigated capture efficiency of yellow perch with and without inflated swim bladders from both size classes, while foraging on two major prey types; cladocerans (*Bosmina* and *Ceriodaphnia*) and adult copepods. We conducted a series of behavioral observations in 10-L aquaria where we placed a single yellow perch and offered it a combination of 10 cladocerans and 10 copepods. Zooplankton were selected by hand under the dissecting microscope with a pipette to ensure proper count. We counted all successful and unsuccessful attacks on both prey types during 15-min foraging sessions. Capture efficiency was quantified as the number of strikes per capture. Two-way (larva size * prey taxa) ANOVA was used to test for the effects of swim bladder presence and size class of yellow perch.

Job 104.4: Quantify seasonal benthic invertebrate density and composition

SCUBA divers collected benthic invertebrates at a depth of 7.5 m at each site using a 7.5-cm (3-in) diameter core sampler. Four replicate samples from the top 7.5 cm (3 in) of the soft substrate were collected and preserved in 95% ethanol (Fullerton et al. 1998). In the lab, samples were sieved through a 500µm mesh net to remove sand. Organisms were sorted from the remaining sediment debris. Organisms were identified to the lowest practicable level, typically to genus; total length (mm) and head capsule width were measured (mm) for each individual. All taxa were enumerated and total density estimates were calculated.

RESULTS

Study 101. Expand and improve annual assessments of the yellow perch spawning population in southwestern Lake Michigan

Job 101.1: Supplemental index gill netting

No supplemental index gillnetting was performed in 2002 because the commercial gill net fisherman (J. Camalick) went out of business.

Job 101.2: Yellow perch aging

The yellow perch subsampled from our fyke nets (N=388) ranged in age from 3 and 17 years but 77.6% were age-4 (Figure 2). Age-14 was the next largest group but it accounted for only 5.7% of the fish subsampled. Mean length of adult yellow perch captured in fyke nets during

2002 was 221.1 mm (N = 985; SD = 39.8 mm) and increase from 2001 (Figure 3). The sex ratio of the perch collected (N = 985) was skewed toward males, with the percent females being 3.8% (Table 1). Compared to earlier fyke netting in 1994-1999 by INHS, the percent female in 2002 was slightly higher but compared to more recent sampling 2000 and 2001 the percent female in 2002 was lower (Table 1). Mean length-at-age for male and female yellow perch varied greatly (Table 2), most likely a result of the age-4 fish dominating the sample. For example of the 353 males aged, 76.77% were age-4.

Job 101.3: Tagging yellow perch

No yellow perch were tagged in 2002 by the INHS (Table 3). Less than half of the tag returns in 2002 (42.1%) were from anglers, with the remainder (57.9%) coming from agencies (LMBS, IDNR, Wisconsin DNR, Michigan DNR, and Ball State University). Of the fish recaptured in 2002, the majority was tagged in 1999 (Table 4). The average distance from tagging location to recapture location was 13 km (standard deviation (SD) = 45.1km) and the maximum distance was 265.8 km. In the terms of site fidelity, 22 of the 38 recaptures were at the site of initial tagging. The average number of days between tagging and recapture was 1446 (SD=468); with the maximum number of days being 2355 (~6.45 yrs).

<u>Study 102</u>. Sampling for eggs, larvae, and older YOY of yellow perch

Job 102.1: Diel larval fish sampling

Yellow perch larvae were captured in low abundance relative to sampling before 1994 (Figure 4). Average daily densities of larval yellow perch between June 5 and July 31, 2002 ranged from 0 to 48.9 fish/100m^3, compared to densities of over 100 fish/100m^3 prior to 1994 (Marsden et al. 1993a, and unpub. data). The peak larval yellow perch density in 2002 occurred on June 17, when average daily density was 48.9 fish/100m^3 (SE=40.8). Larval yellow perch densities between 1994 and 2002 were very similar but at much lower levels than those of the late 1980s.

Job 102.2: Yellow perch egg sampling

Divers found yellow perch egg skeins in 2002 during May and June. 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 greater than 90% viable.

Job 102.3: Young-of-the-year sampling

In 2002, our daytime bottom trawling sampled approximately 240,786 m^2 and collected 368 age-0 yellow perch. The CPE of age-0 yellow perch for daytime bottom trawls was 152.8 fish/100,000m^2. Compared to sampling in recent years (1994-2001), age-0 CPE levels in 2002 exceeded all years (Figure 5). A large portion (306) of the age-0 yellow perch collected in 2002 came from a singe day (August 7). On this day (August 7), the majority of the age-0 yellow perch caught came from our shallow trawl sites (3 and 5m), a pattern similar to our catch in 1998. There was some yearly difference in the seasonal timing of the catch. In 2002, the majority of the catch came early in August but in other years (2001, 1998) most of the catch occurred in late September or early October. Alewives were the dominant species sampled in the bottom trawls during 2002 (Figure 6). Spottail shiners were next most abundant but at a much lower level than alewives.

Study 103. Identification of the potential role alewife predation plays to determine yellow perch year-class strength

Job 103.1 and Job 103.2: Estimate alewife abundance and alewife diet analysis

Alewife CPE for gillnets (N=11) averaged 9.37 fish/hour with a standard deviation of 10.17. Alewife CPE for our bottom trawls (N=2) was 4.71/1,000m^2 with a standard deviation of 2.86.

Stomach and intestinal tract contents of 150 adult alewives were examined from samples collected in 2002. Of the alewives examined, 117 contained diet items (46 bottom trawl and 71 gillnets). No larval fish were found in the stomach of alewife collected in 2002 (Table 6). *Bythotrephes cederstroemi* tail spines were often found as a compacted mass wedged into the stomach. In 2002, *Bythotrephes cederstroemi* tail spines were found in 18.02% of the alewife. Alewife collected with gillnets had more *Bythotrephes cederstroemi* tail spines than those collected in bottom trawls (Table 6).

Study 104. Effects of food availability on larval and early juvenile yellow perch survival and growth

Job 104.1: Quantify seasonal zooplankton availability and archived zooplankton samples

The mean June-July zooplankton density in 2002 was 13.1/L, which is much lower than 1988 level (54/L) for the same period. In comparison to recent years (2000 and 2001), mean June-July zooplankton densities in 2002 were slightly higher (Figure 7). Expanding this comparison to earlier years (1996-1999), zooplankton densities in 2002 were lower.

Zooplankton density also varied seasonally within 2002 (Figure 8). During late May and early June densities were low; by July, densities increased. This peak in early July was followed by a decline in mid July followed by another peak at the end of July. Copepod nauplii dominated the nearshore zooplankton assemblages during May and June (Figure 9). Nauplii decreased during late June and were replaced by Calanoid and Cyclopoid copepods. Other cladocerans (e.g., *Polyphemus*, *Ceriodaphnia*, *Leptodora*, *Diaphanosoma*, *Chydoridae*) that were commonly found in samples during 1988-1990 are rarely observed in samples collected since 1996.

Job 104.2: Implications of YOY yellow perch diet and growth to recruitment

Stomachs of 117 individuals from seven sampling dates were examined in 2002 (Table 7). Cladocera and Copepoda species dominated the diets on early sample dates but the dominance shifted to amphipods and chironomids later in the season (Figure 10). On most of the sampling dates *Bosmina* species were the most abundant diet item found (Table 7). Spines from predatory exotic zooplankton were found in a small percentage of the diets on two dates (August 7 and 8). On August 7, 11.9% of the diets examined contained spines but on August 8 this decreased to 3.1%. No spines were found in samples from later dates.

Job 104.3: Laboratory experiments investigating the effects of food on larval and YOY yellow perch recruitment success.

Yellow perch larvae that inflated their swim bladders grew significantly faster than those larvae that failed to inflate their swim bladders, during the initial 2 weeks after hatching ($F_{1,20}$ = 354.09, P < 0.0001) (Figure 11A). Average daily growth rate of all fish with swim bladders was 0.42 ± 0.01 mm/day vs. 0.23 ± 0.01 mm/day for fish without swim bladders. Both maternal traits and the swim bladder presence had significant effects on the growth rate of yellow perch larvae ($F_{6,28}$ = 3.27, P=0.015 and $F_{1,28}$ = 241.51, P<0.0001). Moreover, interaction between these two variables was also significant ($F_{6,28}$ = 3.28, P =0.014). We also found the rate of swim bladder inflation varying considerably among the offspring of individual females ($F_{6,98}$ = 31.54, P<0.0001) (Figure 11B).

Small yellow perch larvae positively selected adult copepods, regardless of swim bladder presence (Figure 12). Selection for cladocerans depended on swim bladder presence; fish with inflated swim bladders avoided this prey type, whereas individuals without swim bladders demonstrated neutral selection. Yellow perch from the large size class demonstrated an inverse selection pattern. Fish with swim bladders positively selected adult copepods and neutrally selected cladocerans, whereas fish without swim bladders strongly preferred cladocerans but negatively selected adult copepods (Figure 12). All fish tested, regardless of their size or swim bladder inflation status, avoided copepod nauplii.

Swim bladder presence affected yellow perch capture efficiency. Yellow perch with inflated swim bladders always captured prey more efficiently than individuals without inflated swim bladders from the same size class when foraging on a common prey type ($F_{1,25}$ = 50.77, P < 0.0001) (Figure 13). Further, fish from the same size class and with the same swim bladder status always captured cladocerans more efficiently than copepods ($F_{1,25}$ = 12.05, P = 0.0019). However, there was no significant effect of yellow perch size class on capture efficiency ($F_{1,25}$ = 0.08, P=0.775).

Job 104.4: Quantify seasonal benthic invertebrate density and composition

Total invertebrate density for a site north of Waukegan Harbor was highest (1.14 #/cm^2) on our second sampling date (Figure 14). The decrease from the peak on the second sampling date occurred in all species except amphipods, which peaked on the third sampling date (Figure 15).

CONCLUSIONS

The 2002 sampling with fyke nets collected 985 yellow perch at three sites: Waukegan wiremill (US Steel), North Lake Forest, and Fort Sheridan. The female:male sex ratio of the yellow perch collected was the third highest observed in the past seven years. Most dramatic was the large decrease from 2001. In 2002, the majority of yellow perch collected in fyke nets came from the 1998 year-class. In contrast, the 1988 and 1989 year-classes accounted for the majority of the catch from 1994 through 2000. For optimal conditions of population stability, the greatest proportion of fish sampled should be smaller and younger, which has occurred in 2002. Even with this shift towards younger individuals, the population likely is unstable because individuals are from a single year class. Our index of recruitment indicates barely detectable year classes from 1999 and 2000; a small but measurable year class may have resulted from the 2001 spawning. The

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

Yellow perch egg skeins collected at the US Steel intake line, south of Waukegan Harbor, were >90% 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 2002, 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.

In comparison to the past several years (1994-2001), the 2002 CPE for YOY yellow perch collected in bottom trawls exceed all years and was double the CPE of 1998. The relatively high CPE in 1998 developed into a comparatively strong year class as seen by its dominance in our 2002 fyke netting. This suggests that a spike in CPE of age-0 yellow perch may be a reasonable indicator of recruitment success. Thus, in a few years the 2002 year class may appear in our fyke net assessment. Compared to sampling in the late 1980s (1987 and 1988), current age-0 yellow perch CPEs are extremely low. So even though the 1998 and 2002 year classes are measurable, their levels are nowhere near that of the late 1980s and as such probably are not sufficiently strong to support extensive fishing pressure. 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.

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 2002. 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 1996-2002. There does appear to be some consistency in years 1996-1999, where mean densities were around 25-30/L. Zooplankton densities in 2002 were about half the levels found in year 1996-1999 but were higher than 2000 and 2001 levels. Copepod nauplii dominated the nearshore zooplankton assemblage from May to July, however *Bosmina* and rotifers became increasingly abundant and dominated samples during July through September of 2002. 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 southwestern 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 resulting in changes in the already confusing factors that affect yellow perch year-class strength.

Our findings from laboratory experiments indicate clearly that the presence of inflated swim bladders in larval yellow perch greatly enhanced their growth and foraging success. As such, intrinsic factors (foraging skills) that determine growth and survival of larval perch depend strongly on the presence of an inflated swim bladder. Thus, such developmental malformation, if present in larval and juvenile fish under natural environmental conditions, can cause disproportionately higher mortality.

There are many factors influencing yellow perch recruitment in Lake Michigan. In many situations, these factors are linked together. Integration of our sampling data helps to better understand how factors and their linkages influence yellow perch recruitment. In an attempt to understand how multiple factors influence yellow perch recruitment, we plotted data from our various sampling methods with water temperatures. Water temperatures were taken from temperature data loggers placed at the abandoned Waukegan wiremill water intake line (Figure 12). These loggers recorded temperature every hour at two depths: 4 and 10 m. Egg assessment also occurred at this location. Larval yellow perch and zooplankton densities were the means from all of our sampling sites near Waukegan Harbor. Eggs first appeared when water temperatures approached 9°C but the number of skeins remained low until the water warmed to around 11 °C (Figure 15). The number of egg skeins quickly reached a peak of 28 per 100m on June 10. As the number of egg skeins reached a peak, the density of larval yellow perch started to increase (Figure 15). By the time larval density peaked on June 17, egg skein density was almost zero. Two weeks after the peak in larval density, zooplankton density also peaked. During this two week period, water temperature showed an interesting pattern of decreasing. The decrease in temperature may actually be beneficial to the larval yellow perch because at lower temperatures it takes longer for mortality from starvation to occur (Jonas and Wahl 1998). Continued analysis of future integrated data will greatly add to our understanding of yellow perch recruitment in Southern Lake Michigan.

In summary, the fishable yellow perch population in 2002 was dominated by a single year-class hatched in 1998. The continued poor recruitment from 1999 to 2000 and possibly 2001 means that the fishery will continue to rely extensively on the 1998 year class for at least the next two years. YOY sampling indicated that recruitment in 2002 may be similar to that seen in 1998. If the 2002 year-class follows the same growth patterns as the 1998 year-class it is likely to not appear in the fishery until 2004 and by 2005 should be the dominant year-class. Although the potential of another measurable year-class exists, our results clearly demonstrate that recruitment is highly variable and low when compared to recruitment during the 1980s. Under this generally unfavorable recruitment environment, it is important to conserve the adult stock to the greatest degree possible so that the spawning stock can take full advantage of beneficial recruitment conditions when they occur. Given the current population characteristics, continued management for limited harvest seems appropriate to protect the future of the Lake Michigan yellow perch population.

ACKNOWLEDGMENTS

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TABLES

Table 1. Total number of adult yellow perch and percentage of female yellow perch captured in fyke nets by LMBS, 1994-2002.

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
2001	2,651	10.3
2002	985	3.8

Table 2. Mean length-at-age, standard deviation (STD) of length, and number of fish in each age class for yellow perch subsampled during fyke netting in 2002.

	Female			Males		
Age	Length (mm)	STD	Number	Length (mm)	STD	Number
1	---	---	---	---	---	---
2	---	---	---	---	---	---
3	183.0	---	1	173.5	2.1	2
4	251.7	34.6	30	199.2	19.8	271
5	311.0	---	1	251.3	34.5	4
6	331.0	---	1	281.0	9.9	2
7	---	---	---	284.8	14.1	13
8	---	---	---	280.3	18.8	3
9	---	---	---	307.0	4.2	2
10	---	---	---	---	---	---
11	---	---	---	299.7	11.6	7
12	---	---	---	284.6	22.3	5
13	290.0	---	1	285.7	15.1	15
14	303.0	---	1	280.7	13.5	21
15	---	---	---	261.0	3.0	3
16	---	---	---	276.5	4.9	2
17	---	---	---	289.0	12.8	3

Table 3. Location and number of yellow perch tagged, 1996-2001. No yellow perch were tagged in 2001 or 2002.

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 4. Recapture source and year of recapture for yellow perch tagged by INHS during 1996-2002. No yellow perch were tagged in 2001 or 2002. Agency recaptures include yellow perch recaptured by LMBS, IDNR, Wisconsin DNR, Michigan DNR, Ball State University, and 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	0	0	0
2001						
	agency	6	7	12	12	3
	sport	3	12	12	22	3
	commercial	0	0	0	0	0
2002						
	agency	4	6	3	6	2
	sport	2	0	3	10	1
	commercial	0	0	0	0	0

Table 5. Summary of 2002 egg survey 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 14	7-9	20	0		
May 22	7-9	20	3	>90	a
May 29	7-9	22.8	1	>90	a
May 30	7-9	200	15	>90	a
June 6	7-9	160	37	>90	a, b
June 10	7-9	240	68	>90	a, b, c, d
June 12	7-9	240	42	>90	a, b, c, d
June 17	7-9	240	4	>90	d

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

Table 6. Percent occurrence by number of prey items in adult alewife stomachs containing food and sampled in 2002. Alewives were sampled during the hatch of yellow perch larvae using either graded-mesh gillnets set for 30 minutes after dusk or bottom trawl outside Waukegan Harbor.

Species	Combined gillnet and trawl 150 examined, 117 with items	Gillnet 104 examined, 71 with items	Trawl 46 examined all with items
amphipods	4.50	7.04	0.00
B. cederstroemi	18.02	21.13	10.87
chironomid larvae	25.23	33.80	8.70
cladocerans	9.91	1.41	21.74
copepods	57.66	26.76	97.83
D. polymorpha	2.70	1.41	4.35
Hydracarina spp.	0.90	1.41	0.00
larval fish	0.00	0.00	0.00
ostracoda	0.00	0.00	0.00
terrestrial insects	33.33	52.11	0.00

Table 7. Diets of YOY yellow perch collected in 2002 with bottom trawls north of Waukegan, IL.

	YOY yellow perch			Diet Information			
Date	Mean TL (mm)	STD	Sample Size	Species	Numbers Found	Mean Length (mm)	STD Length
8/07	41.7	5.6	42	*Alona*	250	0.50	0.09
				Amphipod	4	0.78	---
				Bosmina sp.	2650	0.39	0.07
				Chironomid larvae	104	3.36	1.62
				Chironomid pupae	145	3.90	1.47
				Chydoridae sp	30	0.69	0.20
				Copepod - Calanoid	374	1.16	0.39
				Copepod – Cyclopoid	429	0.85	0.25
				Copepod – Harpactoid	463	0.57	0.11
				Copepod – Unknown	203	---	---
				D. polymorpha	39	0.20	0.03
				Hydracarina	3	0.41	0.11
				Polyphemus	223	0.93	0.21
8/08	42.2	4.7	65	*Alona*	429	0.51	0.08
				Amphipod	8	---	---
				Bosmina sp.	6334	0.39	0.06
				Chironomid larvae	239	3.84	1.40
				Chironomid pupae	37	3.74	0.72
				Chydoridae sp	167	0.46	0.06
				Copepod - Calanoid	4447	0.93	0.28
				Copepod – Cyclopoid	290	0.77	0.16
				Copepod – Harpactoid	146	0.56	0.11
				Copepod – Unknown	922	---	---
				D. polymorpha	22	0.24	0.05
				Hydracarina	3	0.32	0.05
				Polyphemus	57	0.99	0.17
				Tricoptera	2	2.68	0.11
8/20	74	19.3	4	Amphipod	2	---	---
				Bosmina sp.	1	---	---
				Chironomid larvae	8	7.57	2.60
				Chironomid pupae	1	---	---
				Copepod – Unknown	2	---	---
8/26	45	---	1	*Alona*	13	0.48	0.05
				Chironomid larvae	11	5.45	2.92
				Chironomid pupae	1	3.25	---
				Copepod – Calanoid	30	0.99	0.08
				Copepod – Cyclopoid	3	0.71	0.10
				Copepod – Harpactoid	2	0.51	0.01
				Copepod – Unknown	28	---	---

Table 7. Continued - Diets of YOY yellow perch collected in 2002 with bottom trawls north of Waukegan, IL. (STD=Standard deviation, TL=total length).

	YOY yellow perch			Diet Information			
Date	Mean TL (mm)	STD	Sample Size	Species	Numbers found	Mean length (mm)	STD length
9/12	63.7	3.8	3	Amphipod	4	5.82	1.53
				Annelid	4	---	---
				Bosmina sp.	52	0.40	0.08
				Chironomid larvae	5	5.64	0.56
				Chironomid pupae	2	7.13	2.59
				Chydoridae sp	3	2.09	0.45
				Copepod - Calanoid	5	1.15	0.24
				Copepod – Cyclopoid	3	0.78	0.26
				Copepod – Harpactoid	4	0.71	0.08
				Copepod – Unknown	4	---	---
				Sididae	21	---	---
9/25	74	---	1	Amphipod	1	---	---
				Chironomid larvae	1	---	---
				Chironomid pupae	1	---	---
10/15	63	---	1	Amphipod	1	---	---

Figures

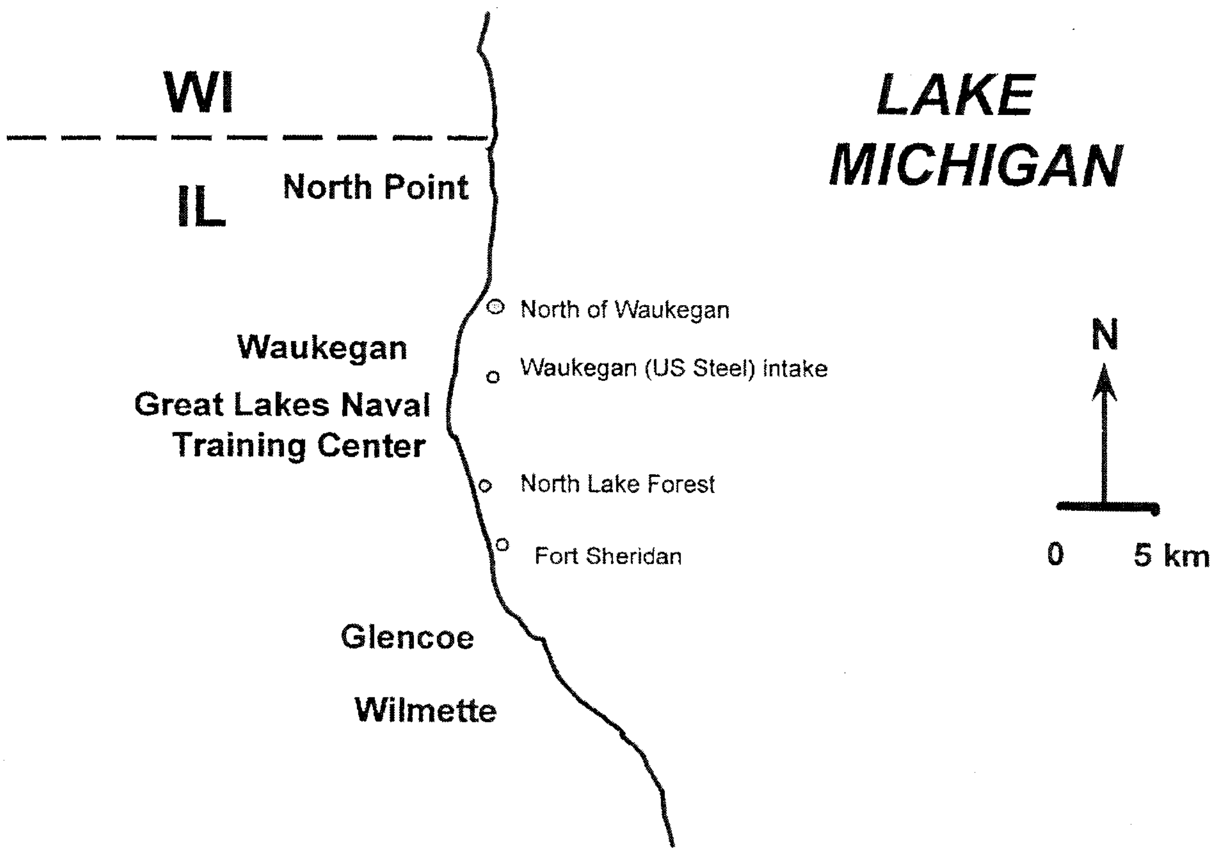

Figure 1. Yellow perch sampling sites in Lake Michigan during 2002.

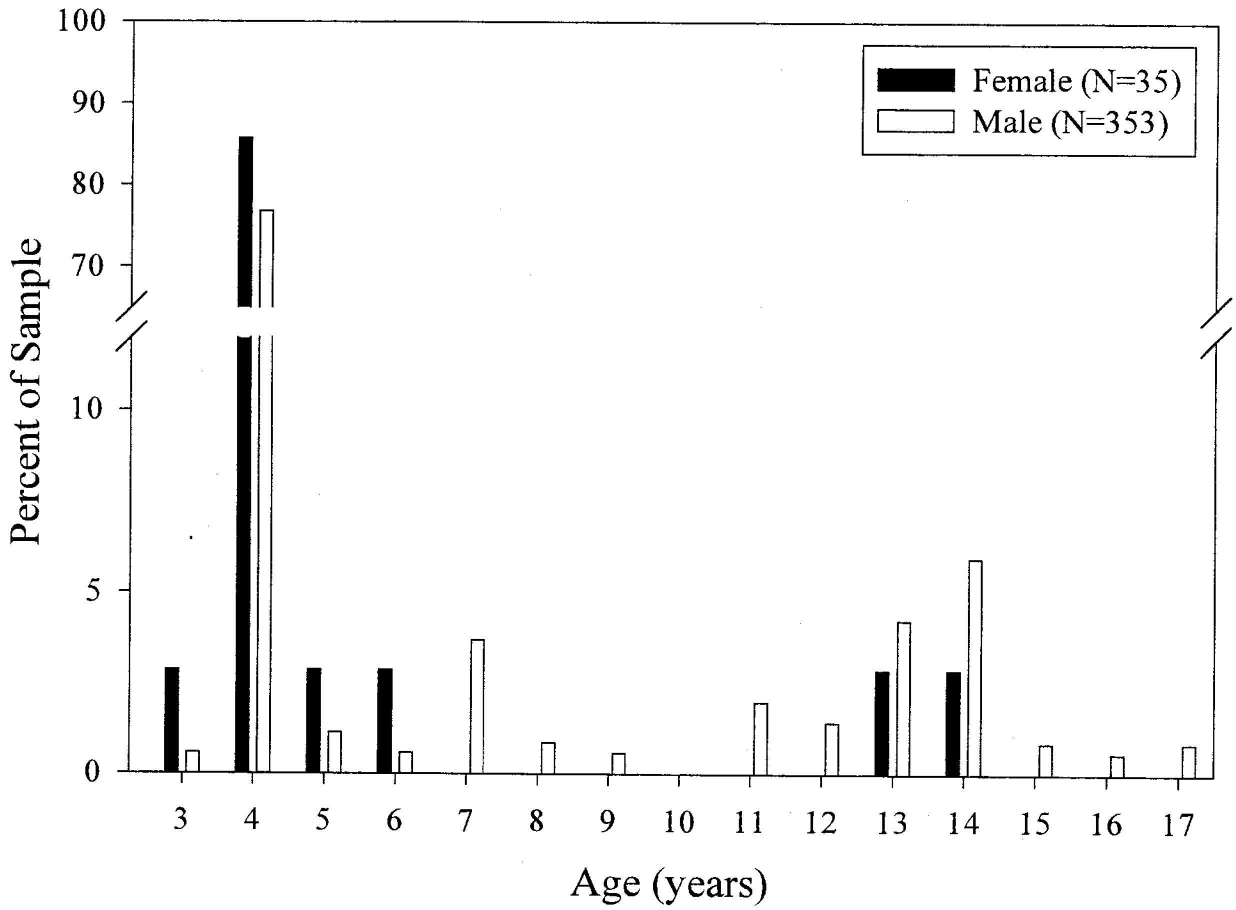

Figure 2. Age-distribution of adult yellow perch sampled in 2002 using fyke nets at Waukegan wiremill, North Lake Forest, and Fort Sheridan, IL.

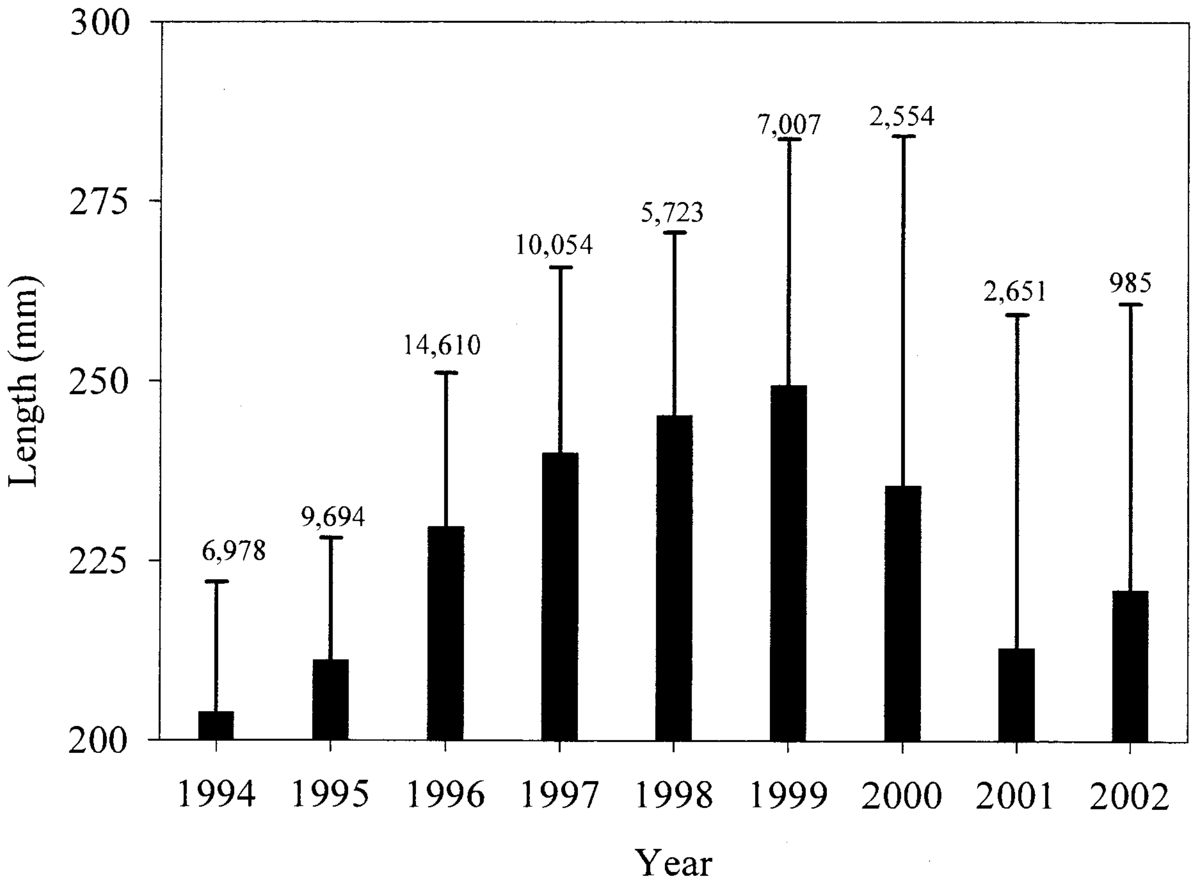

Figure 3. Mean length and standard deviation of adult yellow perch sampled using fyke nets near Lake Bluff, IL, 1994 – 2002. Sample size listed above bar.

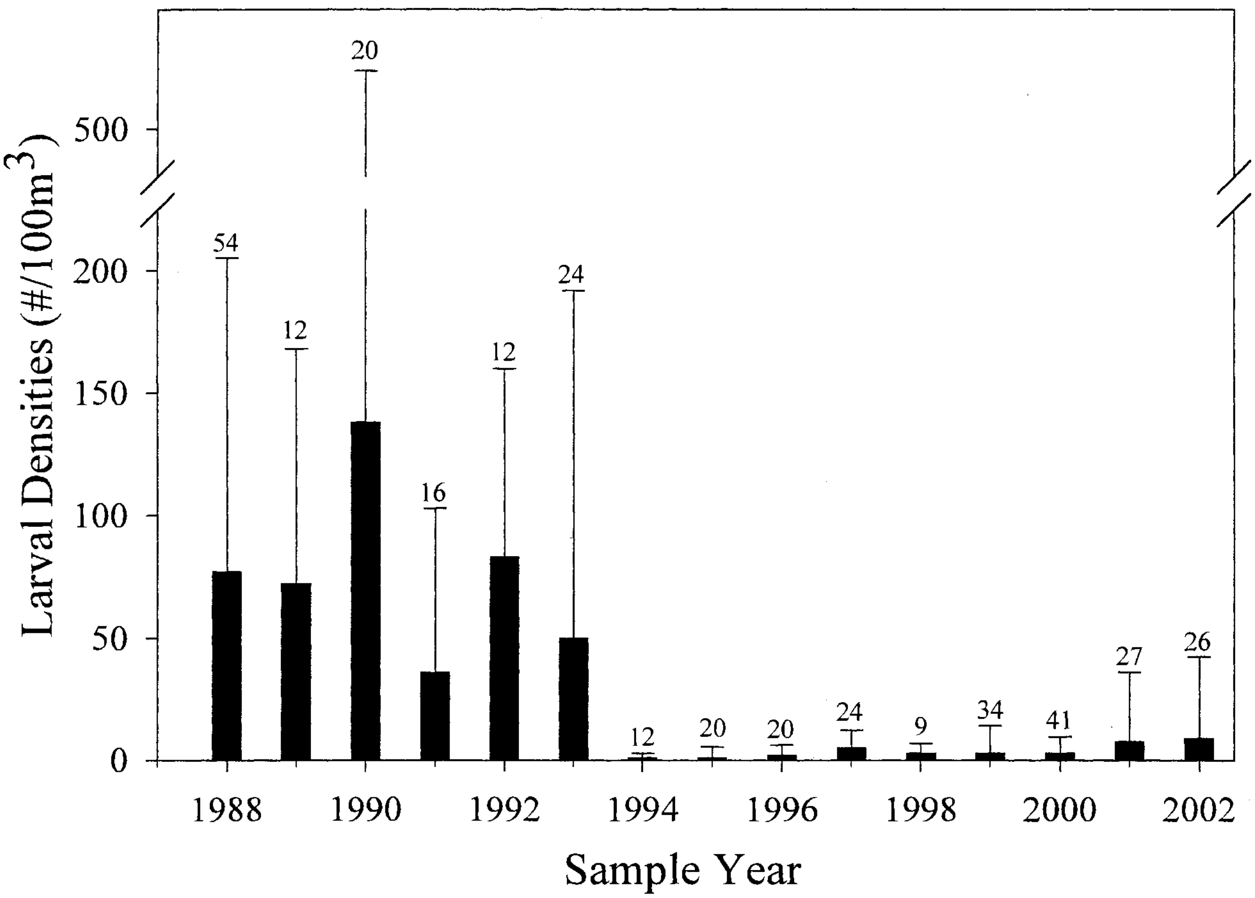

Figure 4. Density of yellow perch larvae (+ standard deviation) sampled near Waukegan Harbor, IL, 1988 to 2002. Number of sampling tows done each year is listed above error bar.

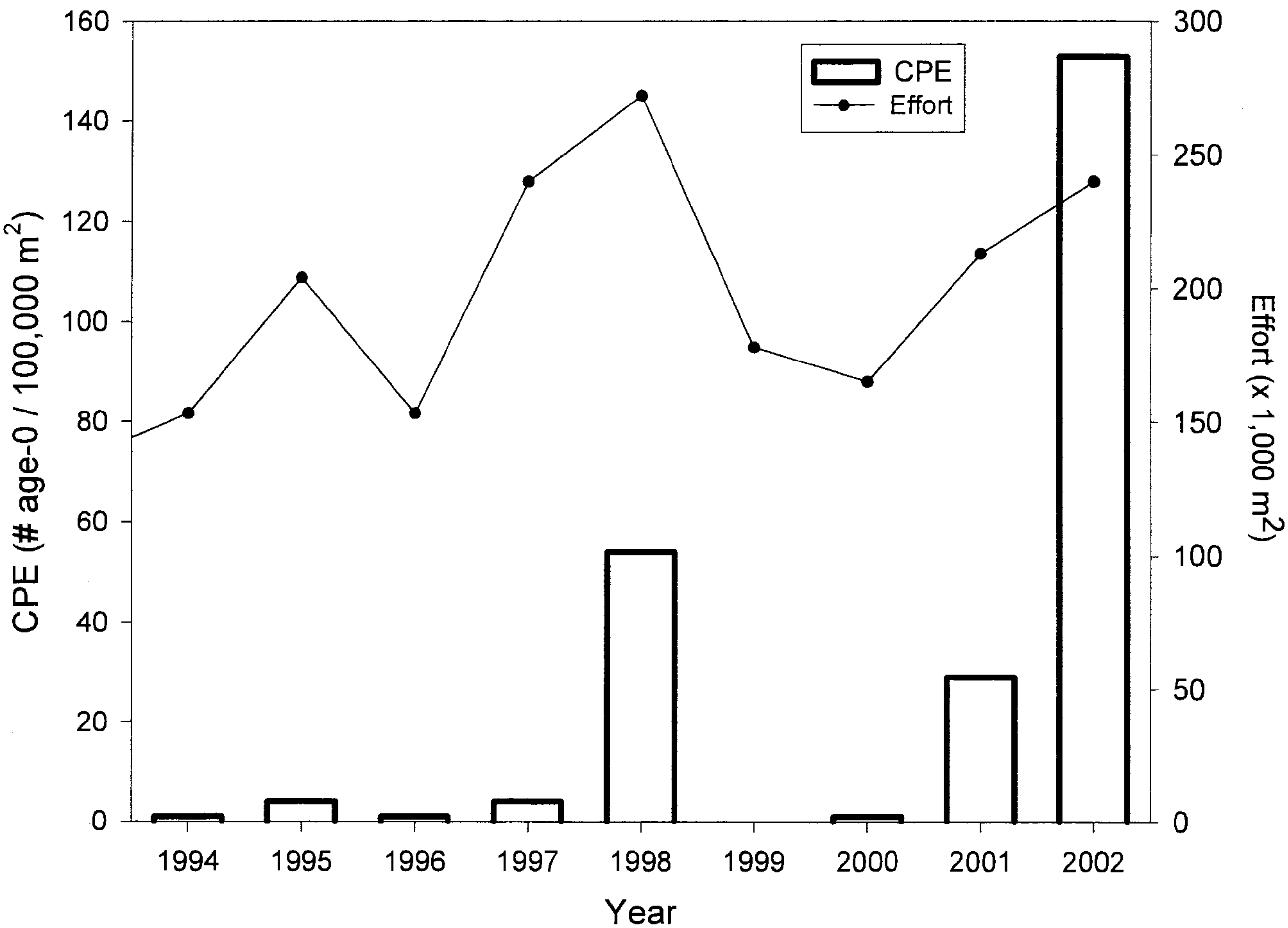

Figure 5. Relative abundance of age-0 yellow perch caught in daytime bottom trawls north of Waukegan Harbor, IL, 1994 to 2002.

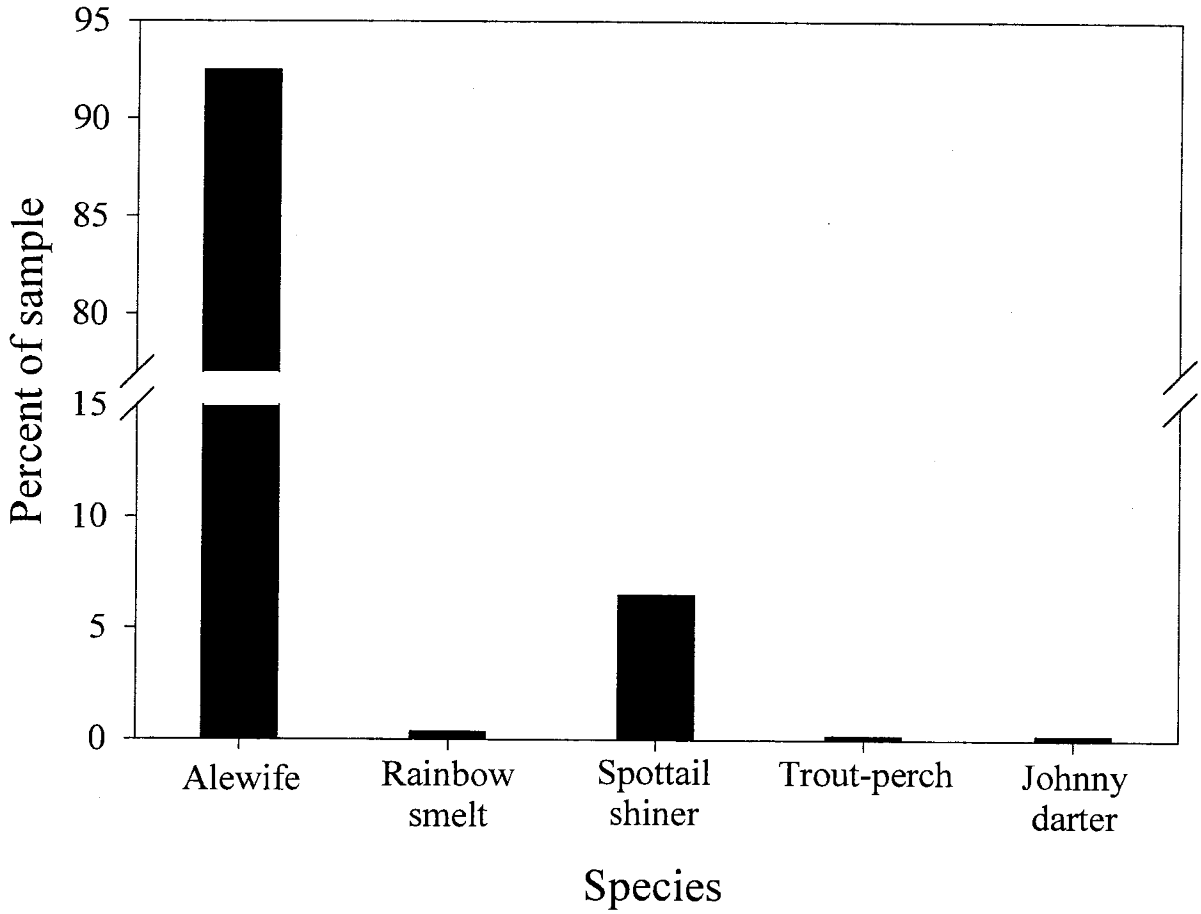

Figure 6. Percent composition of non-target species sampled during daytime bottom trawls north of Waukegan Harbor, IL, 2002.

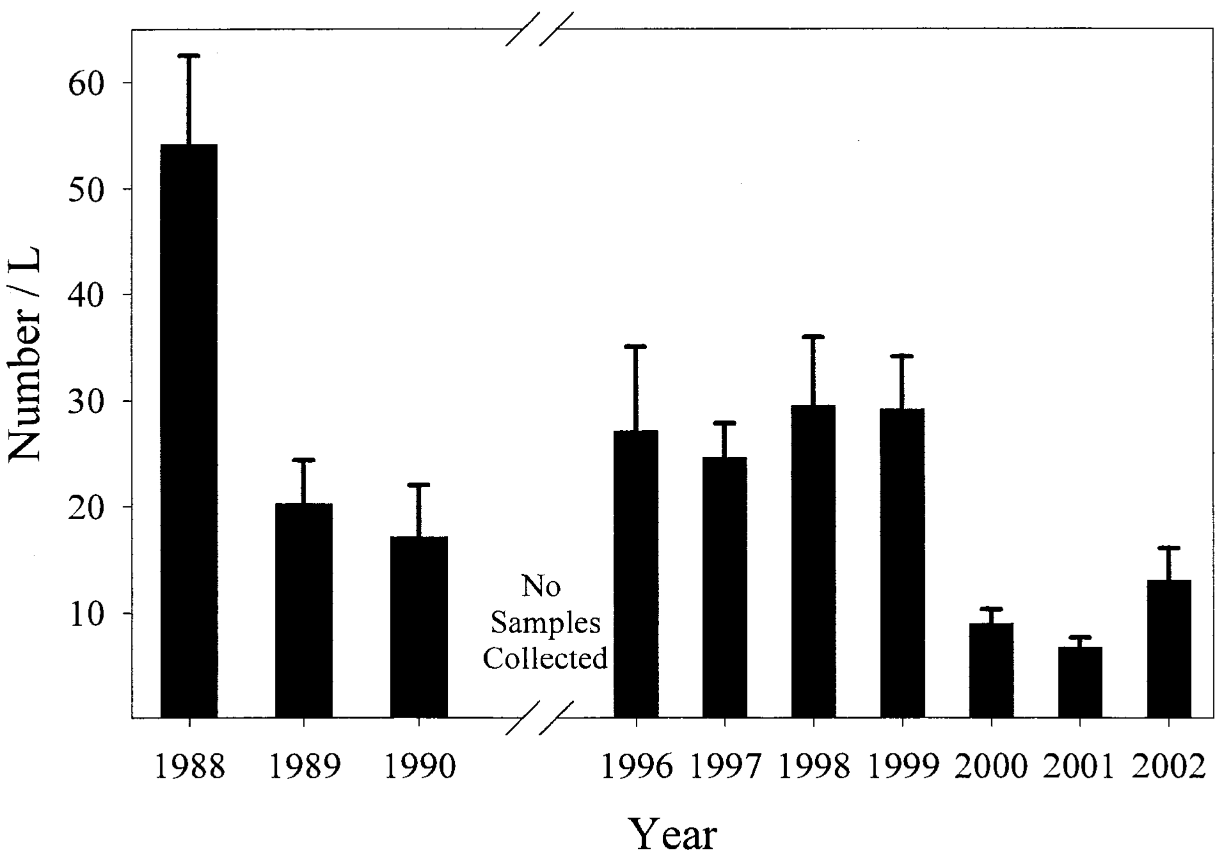

Figure 7. Mean density of zooplankton (+ 1 SE) present in Illinois waters of Lake Michigan near Waukegan during June through July for years 1988 – 1990 and 1996 – 2002.

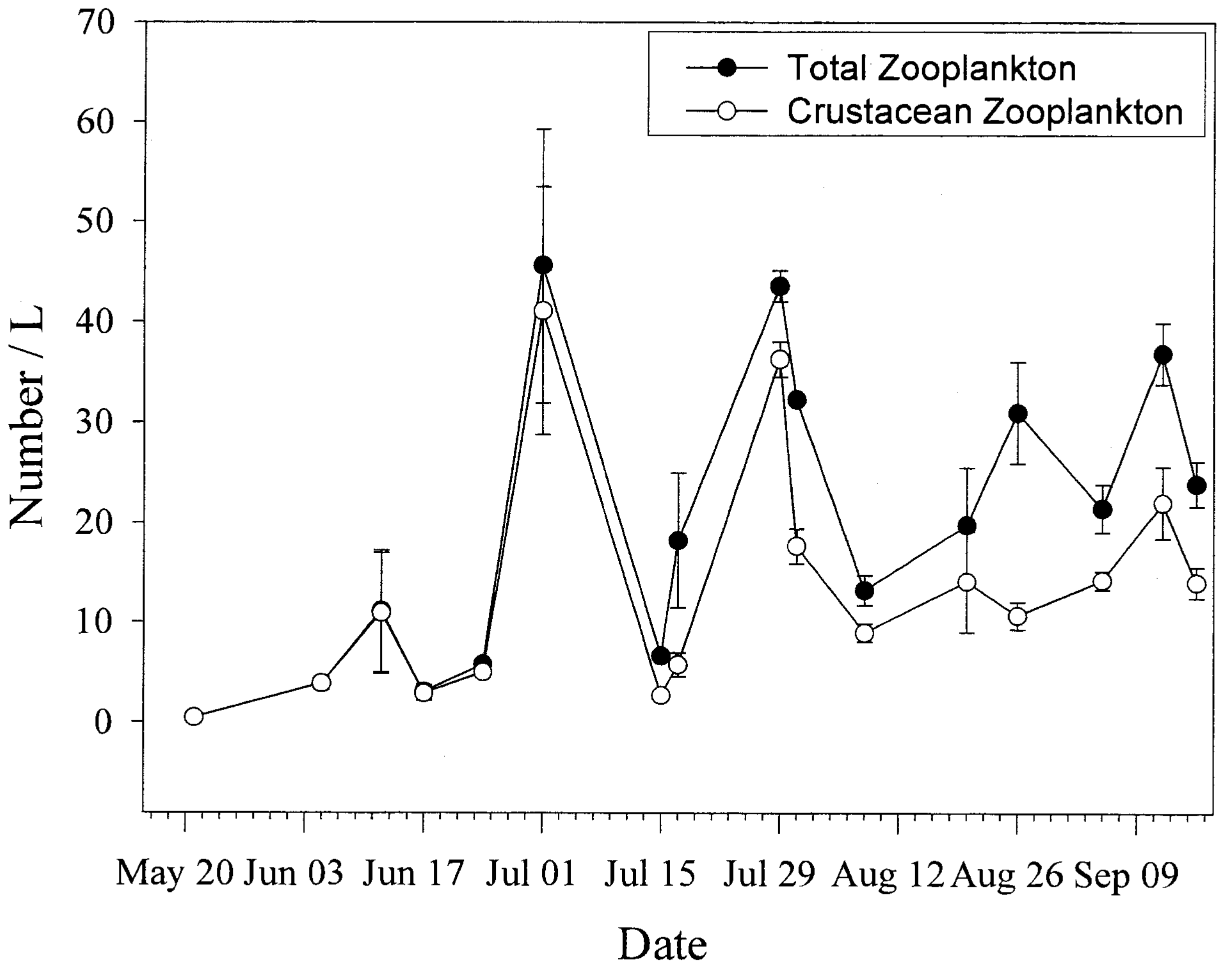

Figure 8. Mean density by date of zooplankton (± 1 SE) present in nearshore Illinois waters of Lake Michigan around Waukegan during May – September 2002. Closed circles (●) represent total zooplankton, whereas open circles (○) represent crustacean zooplankton only.

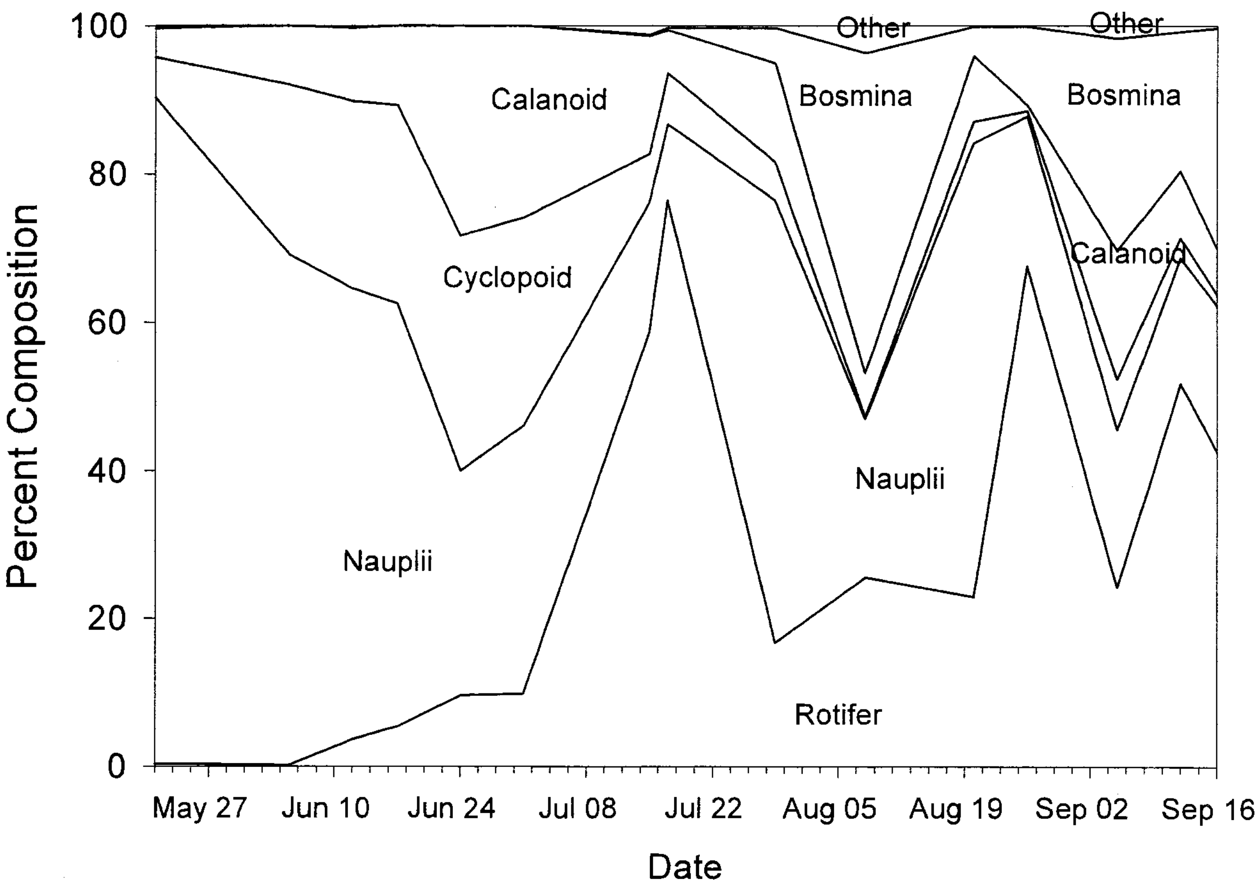

Figure 9. Percent composition of zooplankton found in nearshore Illinois waters of Lake Michigan near Waukegan during May through September 2002.

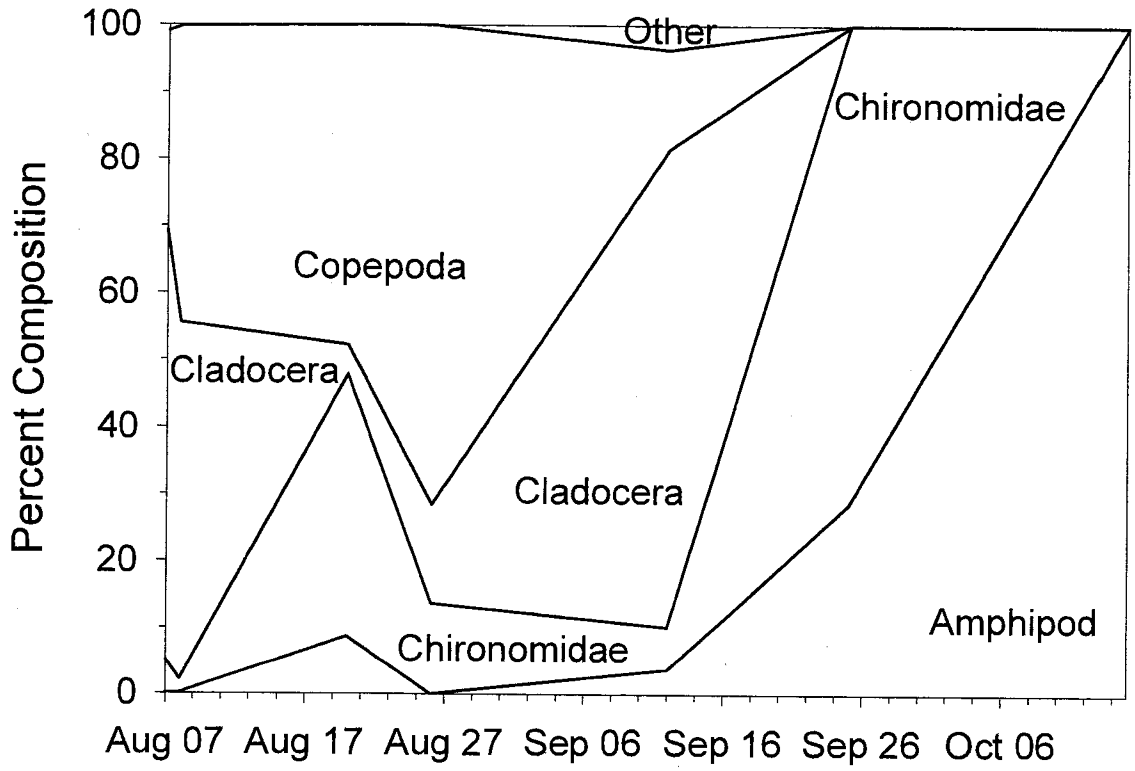

Figure 10. Percent composition by numbers of items found in the diets of age-0 yellow perch collected with bottom trawls north of Waukegan Harbor, IL between August 7 and October 15, 2002.

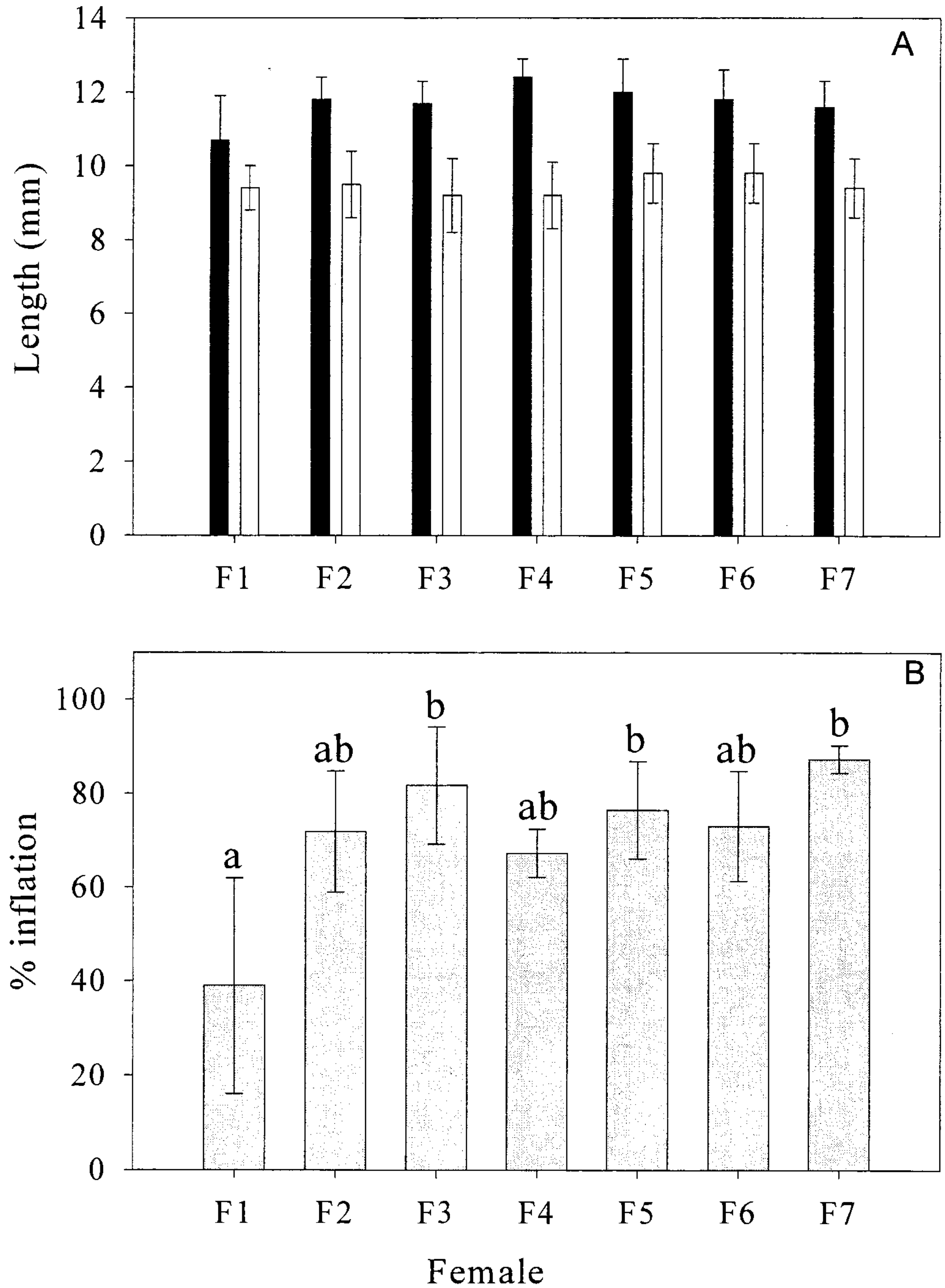

Figure 11. Total length (mean + SE) of larval yellow perch from 7 females with (black bars) and without (white bars) swim bladders two weeks after hatching (A). Percent (mean + SE) swim bladder inflation among yellow perch larvae from 7 females at the end of two weeks of growth (B).

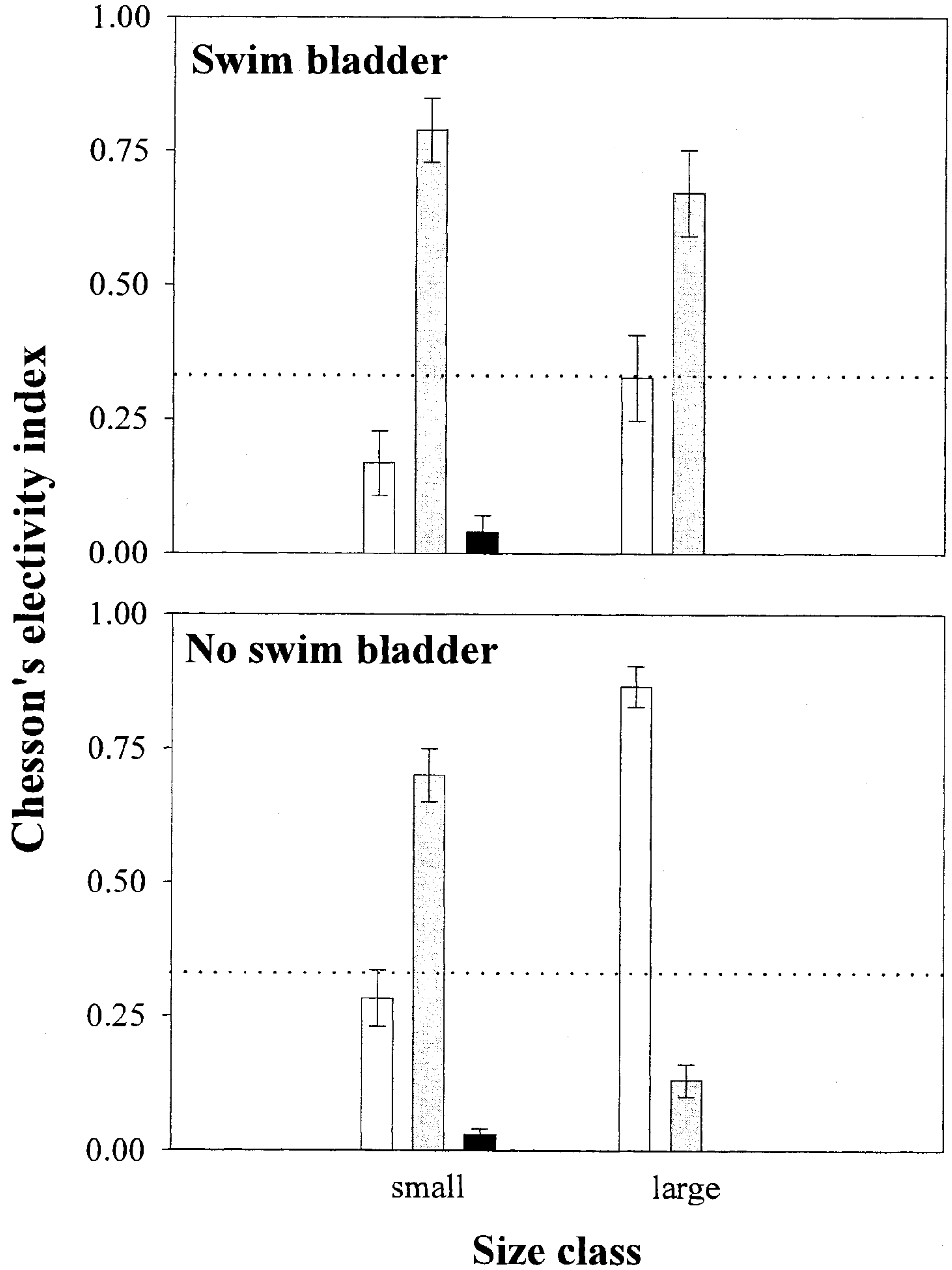

Figure 12. Chesson's electivity index for yellow perch with (top panel) and without (bottom panel) inflated swim bladders, foraging on cladocerans (white bars), adult copepods (gray bars), and copepod nauplii (black bars). Horizontal dotted line indicates neutral selection.

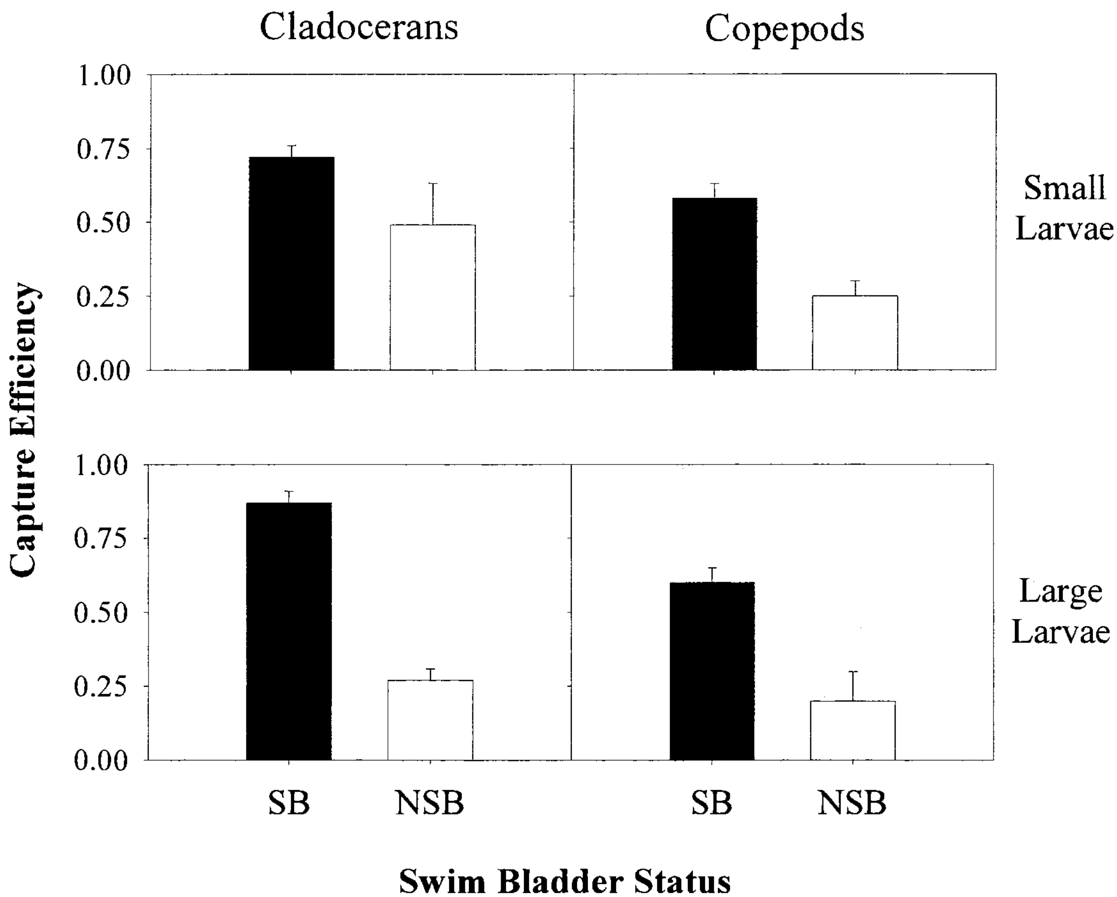

Figure 13. Capture efficiency of small (top) and large (bottom) yellow perch with (SB) and without (NSB) inflated swim bladders foraging on cladocerans (left) and copepods (right).

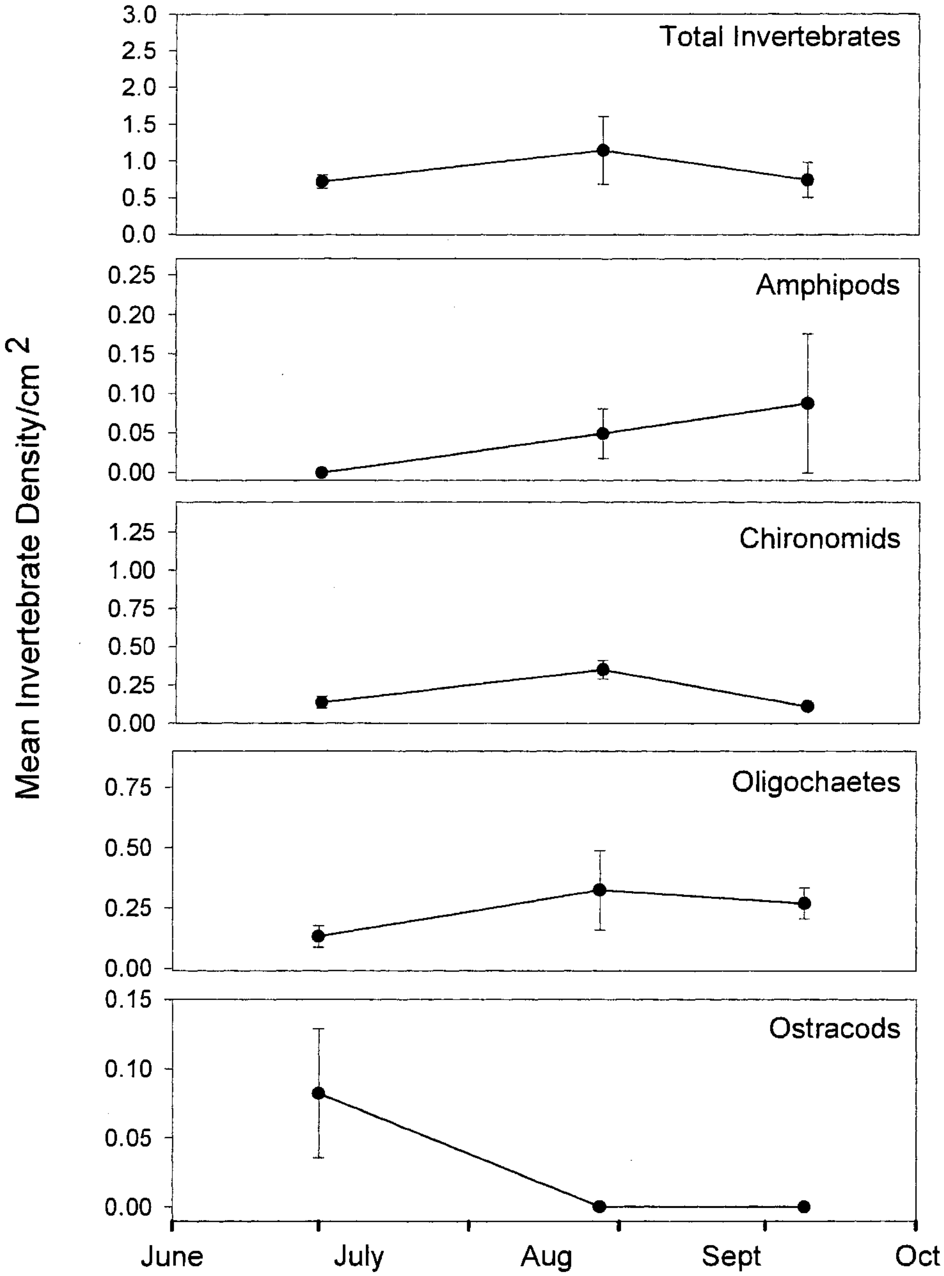

Figure 14. Mean density (+ 1 SE) of total invertebrates, amphipods, chironomids, oligochaetes and ostracods collected in 2002 using a 7.5-cm-diameter core sampler at monthly intervals. Samples were collected at a site north of Waukegan Harbor, IL. Note that y-axis scales vary considerably.

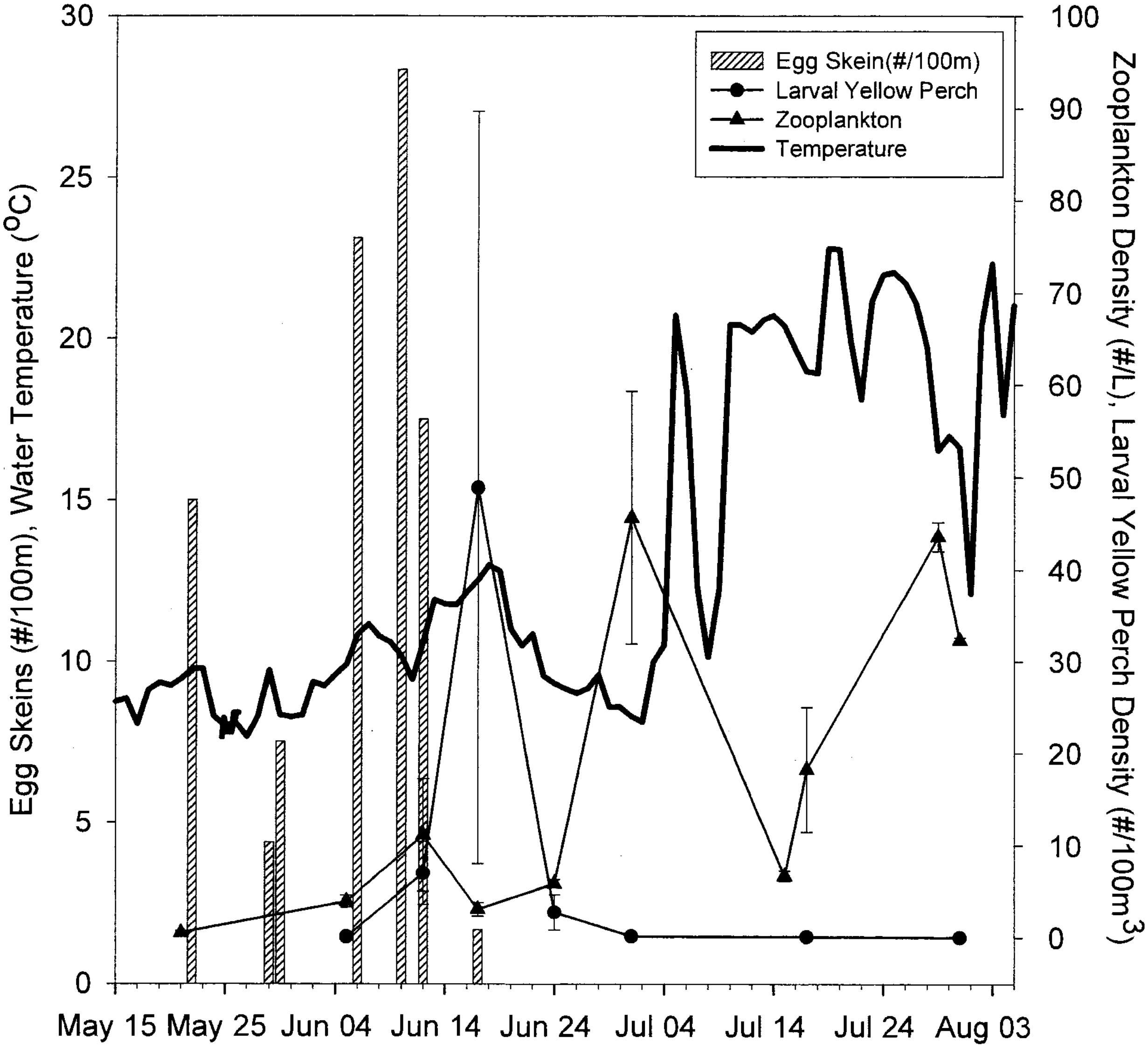

Figure 15. Seasonal patterns of yellow perch egg production (gray bars), larval yellow perch density (●), total zooplankton density ± 1 SE (▲) and water temperatures (solid line) for 2002 in Illinois waters of Lake Michigan near Waukegan Harbor.