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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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Bernard Pientka, Brian D. S. Graeb, and John M. Dettmers

Center for Aquatic Ecology, Illinois Natural History Survey

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to
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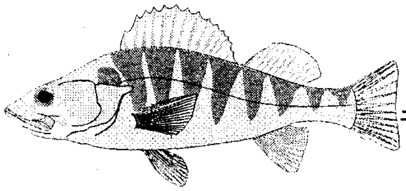

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April 1, 2001 – March 31, 2002

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Division of Fisheries, Illinois Department of Natural Resources
in fulfillment of the reporting requirements of
Federal Aid Project

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This study is conducted under a memorandum of understanding between the Illinois Department of Natural Resources and the Board of Trustees of the University of Illinois. The actual research is performed by the Illinois Natural History Survey, a division of the Illinois Department of Natural Resources. The project is supported through Federal Aid in Sport Fish Restoration by the U.S. Fish and Wildlife Service, the Illinois Department of Natural Resources, and the Illinois Natural History Survey. The form, content, and data interpretation are the responsibility of the University of Illinois and the Illinois Natural History Survey, and not the Illinois Department of Natural Resources.

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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 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 2001 sampling.

1. No yellow perch were tagged during 2001 but 92 were recaptured. The majority of recaptures in 2001 were from fish tagged in1998 and 1999. The average distance from tagging location to recapture location was 22.2 km (standard deviation (SD) = 36.5 km) and the maximum distance was 184.6 km. The average number of days between tagging and recapture was 1053.2 (SD=398.4); the maximum number of days was 2004 (~5.5 yrs).

2. The average total length of yellow perch collected in our spring fyke netting was 212.9 mm (N = 2,651, SD = 46.5 mm). The female:male ratio of the yellow perch collected in our fyke nets was 1:6.77 or 10.3%. The proportion of female yellow perch in 2001 was the highest seen in many years, primarily due to the appearance of the 1998 year-class.

3. The majority of yellow perch collected in fyke nets during 2001 were age 3 (81.4%).

4. Yellow perch egg skeins were counted south of Waukegan Harbor at the abandoned Waukegan wiremill (US Steel) intake line during 2001 on May 22, 25, 30 and June 7. On May 22, eggs were newly fertilized but on May 30, all stages of egg development were found. On June 7 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 95% for 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 2001 compared to sampling conducted prior to 1994. Peak larval yellow perch density in our samples occurred on June 7 (42.5 larval yellow perch•$100m^{-3}$).

6. In 2001, our daytime bottom trawling sampled approximately 213,140 m^2 and collected 62 age-0 yellow perch. Stomachs of 29 age-0 yellow perch were examined; amphipods were the major prey item.

7. No larval fish were found in the adult alewife stomachs (N=147) sampled in 2001. Of alewife stomachs examined, 144 contained food items.

8. Collection of zooplankton samples coincided with larval yellow perch sampling during 2001. The 2001 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.

9. We conducted laboratory experiments during the summer of 2001 that quantified the effects of zooplankton taxa on larval yellow perch growth, survival and prey selection. Our results demonstrate that zooplankton taxa influence the growth, survival and prey selection of larval yellow perch. Small larvae (<12 mm) positively selected copepods (both adult forms and nauplii) and experienced the highest growth while feeding on these taxa as compared to cladocerans and rotifers. As larvae grew >12mm, they selected cladocerans along with adult copepods but avoided copepod nauplii. Larvae >12mm also experienced better growth and survival while feeding on cladocerans and adult copepods as compared to copepod nauplii. The similarities in growth and survival while feeding on cladocerans and adult copepods for larvae >12mm can be partly explained by their foraging efficiencies. The high capture efficiency and low handling time of cladocerans balances out the low capture efficiency and low handling time for copepods, resulting in similar foraging costs between these two taxa.

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. 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 (Dettmers et al., *in review*). 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 2001 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. 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 2001, 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 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

On each sampling date in 2001, scuba divers swam two 100-m 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 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 2001, a 2 x 1 m neuston net was towed at the surface at night, every week or two weeks between May 22 and July 23. Two areas (north and south of Waukegan Harbor) were selected for the neuston tows. Within each area a single tows were performed at 5 and 10-m (bottom depth). 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 1,444 m^3. Larval fish were counted in the laboratory and identified to genus, or species when possible.

Age-0 Yellow Perch Sampling

Bottom trawling for age-0 yellow perch was conducted approximately weekly at four depth stations (3, 5, 7.5 and 10 m) from August 7 through October 23, 2001. All sampling occurred north of Waukegan Harbor, at a speed of approximately 2 $m \bullet sec^{-1}$. 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 mm and frozen for later examination of stomach contents; age-0 yellow perch were measured post-preservation.

Alewife Predation on Yellow Perch Larvae

In 2001, 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 min. 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 were measured to the nearest mm TL. Specimens were dissected to determine sex and maturity, and the entire digestive tract 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.

Zooplankton Sampling

Zooplankton was generally sampled weekly from May 22 to September 10 and on the same nights as larval fish collections (June-July) in 2001. 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, 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.

Data Integration

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 1). These loggers recorded temperature every hour at two depths: 4 and 10 meters. Egg assessment also occurred at this location (wiremill). Larval yellow perch and zooplankton densities were the means from all of our sampling sites near Waukegan Harbor.

Age-0 Yellow Perch Diet

Age-0 yellow perch collected by bottom trawl in 2001 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.

Invertebrate Sampling

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.

Larval Yellow Perch Growth Experiment

We conducted experiments on 4 size-classes of yellow perch: newly-hatched larvae (5-7 mm), small larvae (7-12 mm), medium larvae (12-16 mm) and large larvae (>16 mm). These size classes allowed us to account for important ontogenetic changes that occurred during their early life history, such as first feeding and swim bladder inflation. Previous observations showed that, due to logistical constraints at various fish sizes, the best approach to ensure an accurate description of the important ontogenetic changes in growth and survival was to conduct a series of independent experiments for each size class of larvae.

Yellow perch egg skeins collected from Lake Michigan during late May and early June 2001 were hatched and larvae reared in the lab. All experiments were conducted in controlled laboratory conditions with a 12h light:dark cycle and water temperatures of 18.9 ± 0.1 °C (mean ± 1 S.E.). Zooplankton used in our experiments were either collected from the field or cultured on site. Rotifers were cultured separately. To establish zooplankton treatments, we separated cladocerans, adult copepods and copepod nauplii using sieves.

Growth and Survival

To determine the effect of zooplankton taxon on larval yellow perch growth and survival, we conducted experiments using the following treatments replicated five times: cladocerans, adult copepods, copepod nauplii, rotifers and a foodless control. Common taxa in these groups included: *Brachionus* spp. (rotifers), *Ceriodaphnia* spp. and *Bosmina* spp. (cladocerans), and cyclopoid and calanoid copepods (both adult and nauplii). Average lengths for zooplankton taxa were: (mean mm ± 1 S.E.) cladocera (0.55, 0.02), copepoda (0.98, 0.02), copepod nauplii (0.18, 0.004), and rotifer (0.21, 0.01). Rotifers were excluded from experiments with small, medium, and large larvae because they were never observed in the diets of larvae during our selection experiments. We included rotifers as a treatment for newly hatched larvae because rotifers have been observed in the diets of small larval yellow perch in the field (Whiteside et al. 1985). Thus, with five replicates per treatment, 25 aquaria (our experimental unit) were used for the newly hatched size class, and 20 aquaria for the small, medium, and large size classes.

Yellow perch from each size class (n=150-200 newly-hatched larvae, n=75 small larvae, n=5 medium larvae and n=1 large larvae) were held in 38 - L aquaria with randomly assigned zooplankton taxa treatments. The number of larvae used in each replicate changed based on the size class involved (smaller larvae had higher mortality, requiring more larvae per replicate) and availability (normal mortality resulted in fewer fish available at larger size classes). Treatment densities of zooplankton were maintained at ≥ 75 individuals / L which we felt was ad libitum for larval yellow perch based on the asymptote of a functional response for walleye larvae consuming zooplankton (Johnston and Mathias 1994). Treatment densities were estimated every one to three days using a PVC tube sampler with an inner diameter of 47 mm. If densities in the replicate were below 75/L, zooplankton were added volumetrically.

To ensure that newly-hatched larvae experienced their first feeding during the experiment, we divided 6 fertilized egg skeins into approximately equal portions of 175 eggs and allowed them to hatch in randomly assigned aquaria. Upon hatching, aquaria were inoculated with zooplankton treatments. The experiment started 2 days post hatch to allow for partial (but not complete) yolk sac absorption (prior observations showed that newly-hatched larvae began exogenous feeding shortly before the yolk sac was completely absorbed). Initial sizes were determined by either sacrificing larvae at two days post-hatch (newly-hatched larvae only) or by sub-sampling 50 individuals at the start of each experiment. Up to five larvae were sacrificed daily to determine growth in experiments with newly- hatched and small larvae because these size classes generally experienced high mortality. Thus, experiment duration for these size classes was determined by survival. We defined the endpoint of these experiments as the day before all but one of the treatments experienced 100 % mortality. For example, the duration of the experiment with newly-hatched larvae was 6 days because all treatments, except copepod nauplii, reached 100 % mortality on day 7. Otherwise, experiment duration was 10 days. Although this eliminated some treatments from our survival analysis, we felt it was best to allow mortality to occur and focus on collecting growth data from larvae in the treatments that did survive. ANOVA was used to analyze average growth, and Tukey's multiple comparisons test was used to separate treatment means.

Survival of yellow perch larvae was measured concomitantly with growth. Larvae were counted every morning two h after the start of the light period using a small narrow-beam flashlight. The number of days to reach 100 % mortality in a given treatment was used to determine experiment duration. Life tables and survival functions were calculated for each size class and treatment combination. Wilcoxon chi-square tests was used to analyze survival functions, and the covariance matrix from the Wilcoxon statistics were used to calculate z-scores for each pairwise comparison (Fox 1993).

Prey Selection

Yellow perch larvae were starved for at least 12 h and then introduced into 38-L glass aquaria that were inoculated with equal densities (50/L) of cladocerans, adult copepods, copepod nauplii, and rotifers (only for newly hatched larvae). Larvae were allowed to feed for one h, euthanized, and preserved in 95% ethanol. Rotifers were excluded from experiments on small, medium and large larvae because they were always avoided during a pilot study (Graeb, unpublished data). Equal prey densities were chosen to give each individual yellow perch equal opportunity (by number) to consume a given prey item. We conducted a total of 10 feeding trials for newly hatched larvae, 72 trials for small larvae, 8 trials for medium larvae, and 17 trials for large larvae. The number of replicate trials varied across size classes based on availability of appropriately sized yellow perch. In general, more trials were conducted on smaller larvae to overcome the high occurrence of empty stomachs we observed in larvae <12 mm. Digestive tracts were later removed and the prey items enumerated and measured using a dissecting scope and digitizing tablet.

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

$$\alpha = \frac{\mathbf{r_I / n_I}}{\sum_{j=2}^{m} \mathbf{r_j / n_j}}$$

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 (Chesson 1983). Selection coefficients were calculated for each fish, but mean values were pooled for trials that included more than one fish per aquarium. Mean selection coefficients for each size class were compared against random feeding (1/m) to determine prey selectivity.

Feeding Behavior

We quantified capture efficiency and handling time for medium and large larvae feeding on cladocerans and copepods. Attempts to observe smaller larvae and/or smaller prey items such as copepod nauplii were unsuccessful because we could not accurately discern successful captures. A single yellow perch was placed in a 4-L rectangular feeding arena with opaque sides. After an acclimation time of 1.5 h, 10 prey items (copepods or cladocerans) were introduced into the arena. Strikes, captures, and handling times were then observed for 30 min. Five replicate trials were conducted on each zooplankton taxon and size class combination resulting in 20 trials. Capture efficiency (the number of strikes per capture) was averaged for each trial. Handling time (the time required to begin active searching after a capture event) was recorded for the first capture event only to avoid interactions between handling times and gut fullness. Capture efficiency was analyzed with a 2-factor (larvae size and zooplankton taxa) ANOVA.

RESULTS

Movement Patterns of Adult Yellow Perch

No yellow perch were tagged in 2001 by the INHS (Table 1). Over half of the tag returns in 2001 (56.5%) were from anglers, with the remainder (43.5%) coming from agencies (LMBS, IDNR, Wisconsin DNR, Michigan DNR, Ball State University, and Beak Consultants Incorporated). The majority of recaptures in 2001 were from fish tagged in 1998 and 1999 (Table 2). The average distance from tagging location to recapture location was 22.2 km (standard deviation (SD) = 36.5 km) and the maximum distance was 184.6 km. The average number of days between tagging and recapture was 1053.2 (SD=398.4); the maximum number of days was 2004 (~5.5 yrs).

Yellow Perch Population Structure

The ages of yellow perch subsampled from our fyke nets (N=437) were between 2 and 16 but 81% were age-3 (Figure 2). Age 12 was the next largest group and it accounted for only 4.3% of the fish subsampled. Mean length of adult yellow perch captured in fyke nets during 2001 was 212.9 mm (N = 2,651; SD = 46.5 mm). When compared to mean lengths of yellow perch from 1994 to 2000, yellow perch mean length in 2001 (212.9mm), was one of the smallest (Figure 3). From 1994 to 1999, yellow perch mean length increased each year but in 2000, mean length started decrease. In 2001 mean length continued to decrease. The sex ratio of the perch collected (N = 2,651) was skewed toward males, with the female: male being 1:6.77 (Table 3). Compared to earlier fyke netting (1994-2000) by INHS, the 2001 female: male ratio is the greatest found. Mean length-at-age for male and female yellow perch varied greatly (Table 4). Much of this variation is because so few fish were not age-3. Of the 129 females that were aged, 89.1% were age-3, making any evaluation of length-at-age very difficult.

Yellow Perch Egg Sampling

Divers found yellow perch egg skeins in 2001 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 95% viable.

Larval and Post-larval Yellow Perch Sampling

Yellow perch larvae were captured in low abundance relative to sampling before 1994 (Figure 4). Average daily densities of larval yellow perch between May 22 and July 23, 2001 ranged from 0 to 42.5 fish•100m^{-3}, compared to densities of over 100 fish•100m^{-3} prior to 1994 (Marsden et al. 1993a, and unpub. data). The peak larval yellow perch density in 2001 occurred on June 7, when average daily density was 42.5 fish•100m^{-3} (SE=35.6, range: 1.7 to 148.9 fish•100m^{-3}). Larval yellow perch densities between 1994 and 2001 were very similar but at much lower levels than those of the late 1980s.

Age-0 Yellow Perch Sampling

In 2001, our daytime bottom trawling sampled approximately 213,140 m^2 and collected 62 age-0 yellow perch. The CPE of age-0 yellow perch for daytime bottom trawls was 29.1 fish•100,000m^{-2}. Compared to recent years (1994-2000), 2001 age-0 CPE levels were only exceeded by the relatively high CPE of 1998 (Figure 5). A large portion (47) of the age-0 yellow perch collected in 2001 came from a singe day (10/3/01). On this day (10/3), all the age-0 yellow perch were collected at our deeper trawls sites (7.5 and 10m) but on other sampling dates, age-0 yellow perch were collected at our shallower trawl sites (3 and 5m). Alewife was the dominant species sampled in the bottom trawls in 2001 (Figure 6). Spottail shiners were next most abundant but at a level much lower than alewives.

Alewife Predation on Yellow Perch Larvae

Stomach and intestinal tract contents of 139 adult alewives were examined from samples collected in 2001. Of the alewives examined, 136 contained diet items (89 bottom trawl and 47 gillnets). No larval fish were found in the 2001 alewife stomachs (Table 6). Additional alewife stomachs, which were collected in 2000 but not processed, were also examined. The total number of alewife stomachs examined from 2000 is 145. Of the 145 examined for 2000, 141 contained diet items (117 bottom trawl and 24 gillnets). Three items, which could be larval fish, were found in the 2000 alewife stomachs but no species identification was possible (Table 6). *Bythotrephes cederstroemi* tail spines were often found as a compacted mass wedged into the stomach. In 2001, *Bythotrephes cederstroemi* tail spines were found in 16.7% of the alewife stomachs but in 2000, they were found in 26.2% (Table 6). Alewife collected in gillnets had more *Bythotrephes cederstroemi* tail spines than those collected in bottom trawls (Table 6).

Zooplankton Sampling

The mean June-July zooplankton density in 2001 was 6.8 individuals per liter. In 1988, mean zooplankton density for the same period was 54 individuals per liter. In comparison to previous mean June-July zooplankton densities, the 2001 value was lowest (Figure 7). Zooplankton density varied seasonally (Figure 8). During early June densities were low but by July densities increased, largely due to the appearance of rotifers.

Copepod nauplii and calanoid copepodites dominated the nearshore zooplankton assemblages during May and June (Figure 9). By late June, rotifer composition increased to 40% of the species composition and continued at this level through late July (Figure 9). In late July rotifer composition decreased and *Bosmina* increased. Other cladocerans (e.g., *Polyphemus*, *Ceriodaphnia*, *Leptodora*, *Diaphanosoma*, *Chydoridae*) which were commonly found in samples during 1988-1990 have been rarely observed in samples collected since 1996.

Data Integration

Eggs first appeared when water temperatures approached 12°C but the number of skeins remained low, possibly due to a sudden drop in water temperature (Figure 10). After the water warmed again close to 12 °C (5/30/01) the number of egg skeins increased to over 14 per 100m. On that same date (5/30) neuston sampling collected larval yellow perch at low densities of 1 fish•100m^{-3} (Figure 10). This was the first date on which we found embryos in hatching condition (Table 5) and the larvae seen likely reflect egg deposited before May 25. On June 7 the number of egg skeins were still high but most embryos were ready to hatch. That evening we recorded the highest density of larval yellow perch (42.5 fish•100m$^{-3)}$ for the 2001 season. Zooplankton levels during the larval peak (6/7) were only 0.74 per liter (Figure 10). On July 2, the zooplankton peaked at 12.4/L but this occurred almost a month later than the larval yellow perch peak. Compared to mean June-July zooplankton density found in the late 1980s (Figure 7) the peak daily density in 2001 is not even half those historical means.

Age-0 Yellow Perch Diet

Stomachs of 29 individuals from seven sampling dates were examined in 2001 (Table 7). Copepods and chironomids dominated the diets on early sample dates but the dominance shifted to amphipods later in the season (Figure 11). On the early dates only, a limited number of age-0 perch were collected so the shifting may actually be a result of the small sample size. For dates on which multiple stomachs were examined (10/3 and 10/23), amphipods were the dominant item (Table 7).

Invertebrate Sampling

Total invertebrate density for a site north of Waukegan Harbor was highest at 1.98 •cm^{-2} (± 0.28 SE) on our first sampling date; densities decreased on each consecutive sample date (Figure 12). This pattern of decreasing densities was found for all species except amphipods, which peaked on the second sampling date (Figure 12).

Larval Yellow Perch Experiment

Growth and Survival

Zooplankton taxa influenced the growth of yellow perch larvae in all size classes. Newly-hatched larvae experienced greater growth ($F_{1,8} = 12.94$, P = <0.001) while feeding on copepod nauplii as compared to rotifers (Figure 13). Newly-hatched larvae in the control, cladoceran and adult copepod treatments did not survive the experiment duration, and had little or no growth. A slight shift occurred for the small size class of yellow perch larvae wherein copepod adults as well as copepod nauplii confer the best growth (Figure 1). Small sized larvae in the cladoceran and control treatments did not survive the experiment duration. The zooplankton taxa that conferred the best growth for larger 12 and 16 mm larvae shifted to cladocerans and adult copepods, whereas larvae had lower growth while feeding on copepod nauplii ($F_{2,9} = 10.72$, P = <0.001 and $F_{2,9} = 0.54$, P =0.61 for medium and large size classes respectively; Figure 13). For the largest size class of larvae we concluded that the copepod nauplii treatment had lower growth than larvae in the cladoceran and adult copepod treatments even though the relationship was not statistically significant. We felt that this lack of statistical significance was driven by the low sample size (n=1) of larvae in the copepod nauplii treatment surviving the experiment duration, and that the differences were biologically significant.

Zooplankton taxa influenced the survival of newly hatched larvae (Wilcoxon $\Pi^2 = 165.3$ df=4 p=<0.0001). However, the patterns of survival were dissimilar to patterns from the growth experiment. Newly hatched larvae in the cladoceran and copepod treatments did not survive the experiment duration (and were assumed to have lower growth), however, they had similar survival to larvae from the copepod nauplii treatment (the treatment with the highest growth; Table 8). Conversely, even though larvae in the rotifer treatment survived the experiment duration (yet, had poor growth), their pattern of survival was the same as larvae in the control treatment (Table 8). We expected similar survival curves for all treatments (except copepod nauplii) based on their realized or assumed poor growth. Zooplankton taxa also influenced the survival of small larvae (Wilcoxon $\Pi^2 = 78.5$ df=3 p=<0.0001), but the patterns were expected given the results from the growth experiments. Larvae in the copepod adult and nauplii treatments had similar survival (and the highest growth), and larvae in the cladoceran and control treatments had similar survival (and poor growth; Table 8). Similar to the growth results, medium and large size classes of larvae had similar survival while feeding on cladocerans and adult copepods (Wilcoxon Π^2 =68.83 df=3 p=<0.0001, and Wilcoxon Π^2 =14.8 df=3 p=0.002 for medium and large size classes respectively). Larvae in these size classes that fed on copepod nauplii survived either slightly better than (medium size class) or the same as (large size class) larvae in the control treatment (Table 8). Overall, the zooplankton taxa that confer the highest survival shifted during the early life history of yellow perch; initially, survival was best on copepods, both adult and nauplii, but then shifted to cladocerans and adult copepods

Prey Selection

Yellow perch larvae generally selected prey taxa that resulted in the best growth and survival. Newly hatched larvae positively selected copepod nauplii, but also selected adult copepods (Figure 14). Cladocerans and rotifers were never encountered in the diets of newly hatched larvae. Small larvae positively selected adult copepods, but negatively selected copepod nauplii even though growth and survival was similar between treatments. Cladocerans were also observed in the diets of small larvae, though they were negatively selected (Figure 14). Twelve and 16 mm larvae positively selected adult copepods, and had either, positive (12 mm) or neutral (16 mm) selection for cladocerans (Figure 14). Overall, adult copepods were selected across all sizes, and selection for copepod nauplii decreased whereas selection for cladocerans increased as larvae size increased.

Feeding Behavior

Capture efficiency was higher for cladocerans (87 % medium and 73% large) compared to copepods for both medium (58%) and large (59%) size classes ($F_{1,16}$ = 17.97, P<0.01). Handling time, however, was consistently high for cladocerans averaging 4.6 and 4.4 sec respectively for 12 and 16 mm size classes. Further, even though capture efficiency of copepods was lower than cladocerans, handling times averaged less than 1 s (and was 0 s n = 9 of 10 capture events). Thus, in terms of foraging costs, the high capture efficiency and high handling time of cladocerans compared to lower capture efficiency and low handling time of copepods indicate that these two prey items are similar in terms of energetic gains.

CONCLUSIONS

The 2001 sampling with fyke nets collected 2,651 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 highest observed in the past seven years. This shift in sex ratio may be related to a shift in age structure. In 2001, the majority of yellow perch collected in fyke nets (81.4%) 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 2001. Even with this shift towards younger individuals, the population likely is unstable because individuals are from a single year class. The 1998 year class may be extremely important for future spawning events and as such should be protected to the extent possible.

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 2001, 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 2001 was the second highest between 1994 and 2001. During that seven year period (1994-2001), only the 1998 CPE was higher. In comparison to the catch of age-0 yellow perch in 1998, the 2001 CPE was about half. The relatively high CPE in 1998 developed into a comparatively strong year class as seen by its dominance in our 2001 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 2001 year class may appear in our fyke net assessment. Compared to sampling in the late 1980s (1987 and 1988), current age-0 yellow perch CPE are extremely low. So even though the 1998 and 2001 year classes are measurable, their levels are nowhere near that of the late 1980s and as such may not be 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.

Results from the lab experiments were very beneficial to our understanding of larval yellow perch early life history and ontogenetic changes. Zooplankton taxa influenced growth for all size classes of larvae examined. The zooplankton taxa, that confer the highest survival shifted during the early life history of yellow perch. Initially, survival was best on copepods, both adult and nauplii. A shift then occurs to better survival when feeding on cladocerans and adult copepods. Similar to survival, prey selection showed that adult copepods were selected by all larval size classes. Selection for copepod nauplii decreased with increasing size and selection for cladocerans increased with larvae size. Capture efficiency for cladocerans was high but so was handling time. Copepods were captured with a lower efficiency but were easy to consume, resulting in a low handling time. Thus for larvae >12mm, growth was similar when feeding on copepods and cladocerans because overall energetic costs of feeding on these two different prey items were similar.

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 2001. 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 1996-2001. There does appear to be some consistency in years 1996-1999, where mean densities were around 25-30/L. Zooplankton densities in 2001 were the lowest found in all the years LMBS has sampled. 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 2001. 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.

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. We have demonstrated the linkage between temperature, egg deposits and the hatching of larvae. Continued analysis of future integrated data will greatly add to our understanding of yellow perch recruitment in Southern Lake Michigan.

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REFERENCES

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

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

Charlebois, P. M., M. J. Raffenberg, and J. M. Dettmers. 2001. First occurrence of *Cercopagis pengoi* in Lake Michigan. Journal of Great Lakes Research 27:258-261.

Chesson, J. 1983. The estimation and analyses of preferences and its relationship to foraging models. Ecology 70:1227-1235

Fox, G. A. 1993. Failure-time analysis: emergence, flowering, survivorship, and other waiting times. Pages 253-389 in S. M. Scheiner and J. Gurevitch, editors. Design and analysis of ecological experiments. Chapman and Hall, New York, NY.

Fullerton, A. H., G. A. Lamberti, D. M. Lodge, and M. B. Berg. 1998. Prey preferences of Eurasian ruffe and yellow perch: comparison of laboratory results with composition of the Great Lakes benthos. Journal of Great Lakes Research 24:319-328.

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

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

Johnston, T. A., and J. A. Mathias. 1994. Feeding ecology of walleye, *stizostedion vitreum*, larvae: Effects of body size, zooplankton abundance, and zooplankton community composition. Canadian Journal of Fisheries and Aquatic Sciences 51: 2077-2089.

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

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

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

Mayer, C. M., and D. H. Wahl. 1997. The relationship between prey selectivity and growth and survival in a larval fish. Canadian Journal of Fisheries and Aquatic Sciences 54:1504-1512.

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

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

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

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

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

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

Whiteside, M. C., C. M. Swindoll and W. L. Doolittle. 1985. Factors affecting the early life history of yellow perch, *Perca flavescens*. Environmental Biology 12:47-56.

TABLES

Table 1. Location and number of yellow perch tagged, 1996-2001. No yellow perch were tagged in 2001.

		Year				
Site	Location (lat./long.)	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 1996-2001. No yellow perch were tagged in 2001. 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

Table 3. Total number of adult yellow perch and percentage of female yellow perch captured in fyke nets by LMBS, 1994-2001.

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

Table 4. Mean length-at-age, standard error, and number of fish in each age class for yellow perch subsampled during fyke netting in 2001.

	Female			Males		
Age	Length (mm)	SE of Length	Number	Length (mm)	SE of Length	Number
1	---	---	---	---	---	---
2	---	---	---	162.5	1.5	2
3	229.8	3.0	115	187.3	1.9	239
4	276.0	27.6	5	223.3	15.7	8
5	339.5	6.5	2	255.3	33.4	3
6	322.0	5.6	3	273.0	7.5	8
7	---	---	---	292.0	---	1
8	---	---	---	285.0	27.0	2
9	354.0	---	1	---	---	---
10	---	---	---	279.0	5.9	6
11	342.0	---	1	275.0	6.7	3
12	282.0	---	1	271.4	3.9	18
13	254.0	---	1	270.9	4.1	14
14	---	---	---	255.0	---	1
15	---	---	---	---	---	---
16	---	---	---	258.0	---	1

Table 5. Summary of 2001 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 10	7-9	100	0		
May 16	7-9	100	0		
May 22	7-9	100	3	95	a
May 25	7-9	100	2	95 – 100	a, b
May 30	7-9	200	29	95 – 100	a, b, c, d
June 7	7-9	200	27	95 – 100	a, d

Developmental stages: [a] newly fertilized; [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 and sampled in 2000 and 2001. 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.

2001			
Species	Gillnet and Trawl 139 examined, 136 with items	Gillnet 50 examined, 47 with items	Trawl 89 examined all with items
amphipods	17.36	5.45	18.80
B. cederstroemi	16.67	21.82	10.26
chironomid larvae	59.03	34.55	56.41
cladocerans	24.31	12.73	23.93
copepods	75.69	76.36	57.26
D. polymorpha	3.47	1.82	3.42
Hydracarina spp.	7.64	1.82	8.55
larval fish	0.00	0.00	0.00
ostracoda	5.56	3.64	5.13
terrestrial insects	3.47	1.82	3.42

2000			
Species	Gillnet and trawl 145 examined, 141 with items	Gillnet 24 examined, all with items	Trawl 121 examined 117 with items
amphipods	21.28	8.33	23.93
B. cederstroemi	26.24	41.67	23.08
chironomid larvae	85.82	75.00	88.03
cladocerans	65.25	66.67	64.96
copepods	70.21	66.67	70.94
D. polymorpha	7.80	0.00	9.40
Hydracarina spp.	7.80	0.00	9.40
larval fish*	2.13	0.00	2.56
ostracoda	22.70	4.17	26.50
terrestrial insects	8.51	16.67	6.84

* larvae fish – three possible fish were found but no species identification was possible.

Table 7. Diets of yellow perch YOY collected in 2001 with bottom trawls north of Waukegan, IL.

Date	Size range(mm)	Larval perch	Species	Numbers found	Mean length (mm)	STD length
8/21	51.7	1	Amphipod	1	5.83	--
			Calanoid copepod	15	0.82	0.054
			Chironomid larvae	27	5.0	0.67
			Chironomid pupae	1	--	--
			Cyclopoid copepod	1	0.60	--
9/11	42.6	1	Alona	1	0.47	
			Bosmina	2	0.33	0.009
			Calanoid copepod	6	0.68	--
			Cyclopoid copepod	6	0.63	0.062
			Daphnia sp.	1	--	--
			Harpacticoid Copepod	1	0.35	--
9/17	57.7-68.3	2	Acanthocephalus	1	5.24	--
			Amphipod	2	--	--
			Calanoid copepod	27	0.87	0.047
			Chironomid larvae	10	5.77	2.495
			Copepod	4	--	--
			Cyclopoid copepod	1	--	--
			Harpacticoid Copepod	17	0.47	0.0921
10/3	61.4-89.5	19	Acanthocephalus	1	7.65	--
			Amphipod	596	5.15	1.086
			B. cederstroemi	10	--	--
			Calanoid copepod	3	0.78	0.0959
			Chironomid larvae	14	9.44	4.088
			Chironomid pupae	1	3.43	--
			Cyclopoid copepod	1	0.76	--
			Sphaeriidae	4	0.37	0.134
			D. polymorpha	4	0.57	0.149
10/11	83.5	1	Amphipod	11	4.79	0.977
			Sphaeriidae	2	0.38	0.0347
10/15	78.6	1	Amphipod	69	4.31	1.0490
10/23	68.8-83.4	4	Amphipod	113	4.58	1.481
			Chironomid larvae	1	12.89	--
			Isopod	1	2.83	--
			Sphaeriidae	2	0.61	0.0214

Table 8. Pairwise comparisons, Z-scores (calculated from the covariance matrix of the Wilcoxon statistics), critical z-values (adjusted to maintain an overall significance level of 0.05), and statistical grouping of survival curves of yellow perch larvae fed different zooplankton taxa. CLAD= cladoceran, CONT=control, COPE=copepod, NAUP=copepod nauplii, and ROTI= rotifer. Note: only statistically similar comparisons are shown; all pairwise comparisons not shown were statistically different.

Size Class	Pairwise Comparison	Z-score	Critical Z- value	Grouping
Newly-hatched	CLAD vs. COPE	1.58	2.57	A
	CLAD vs. NAUP	0.91	2.57	A
	CONT vs. ROTI	0.26	2.57	B
Small	COPE vs. NAUP	0.24	2.39	A
	CLAD vs. CONT	0.31	2.39	B
Medium	CLAD vs. COPE	1.19	2.39	A
Large	CLAD vs. COPE	0	2.39	A
	NAUP vs. CONT	0.25	2.39	B

Figures

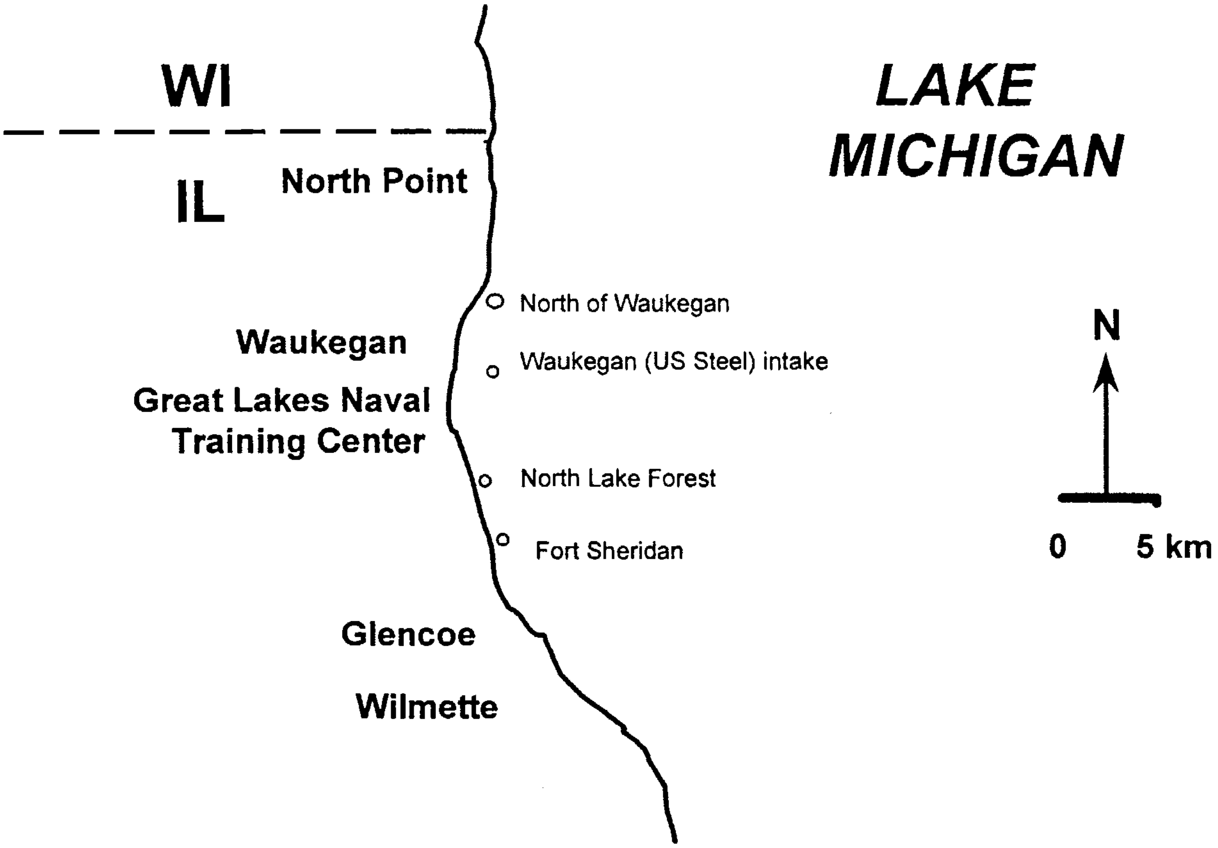

Figure 1. Yellow perch sampling sites in Lake Michigan during 2001.

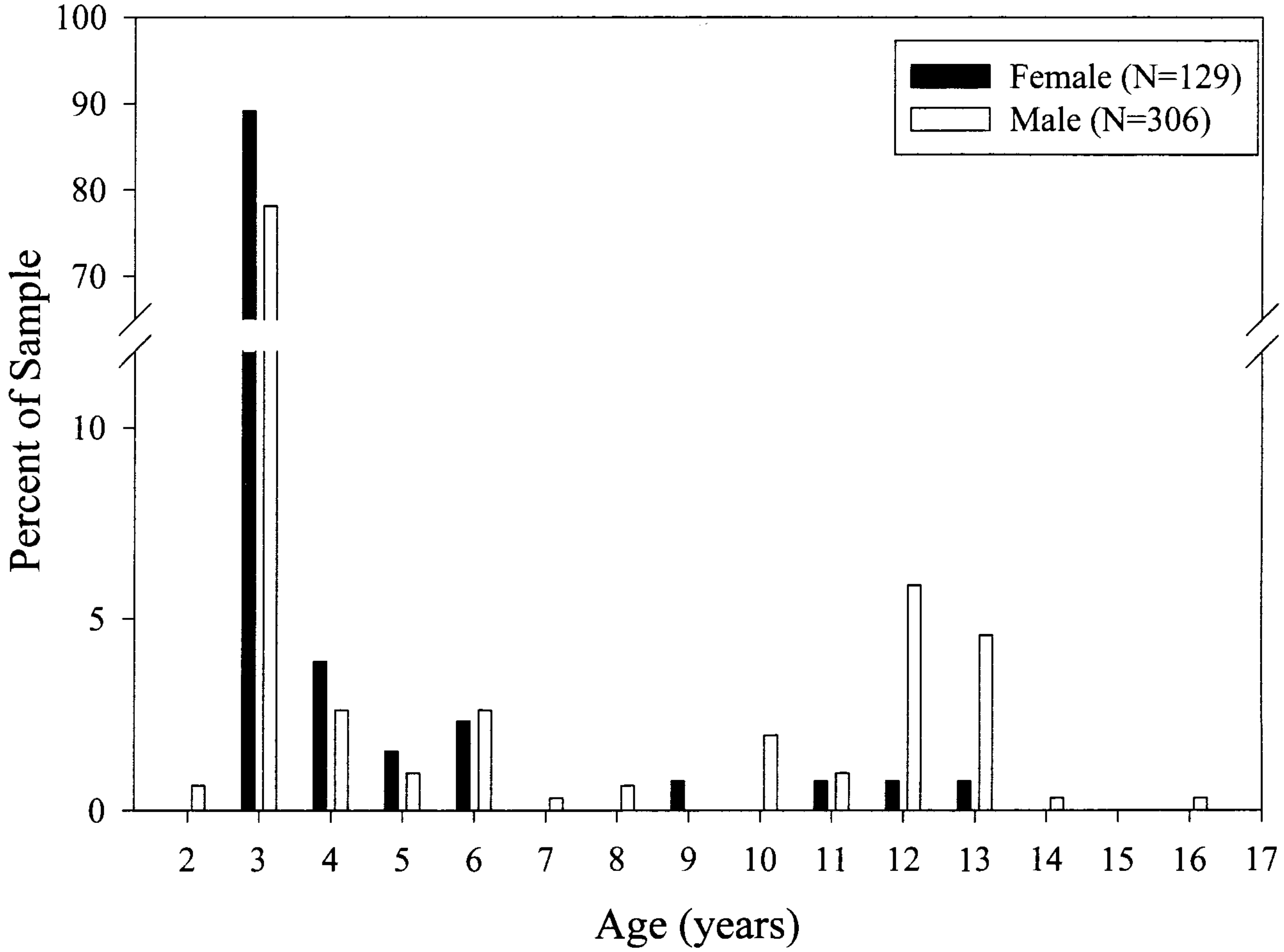

Figure 2. Age-distribution of adult yellow perch sampled in 2001 using fyke nets at Waukegan wiremill, North Lake Forest, and Fort Sheridan, IL.

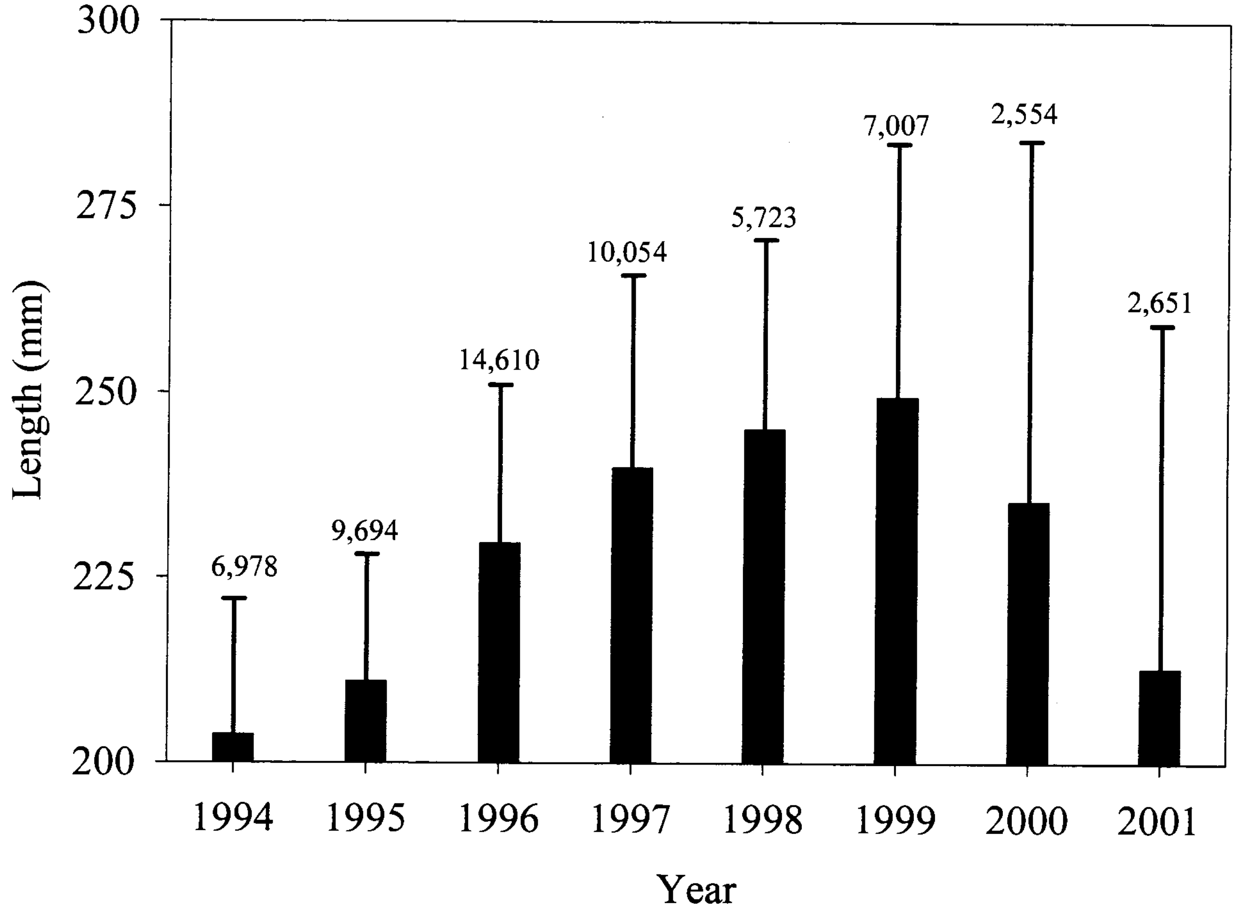

Figure 3. Mean length and standard deviation of adult yellow perch sampled using fyke nets near Lake Bluff, IL, 1994 – 2001. Sample size listed above bar.

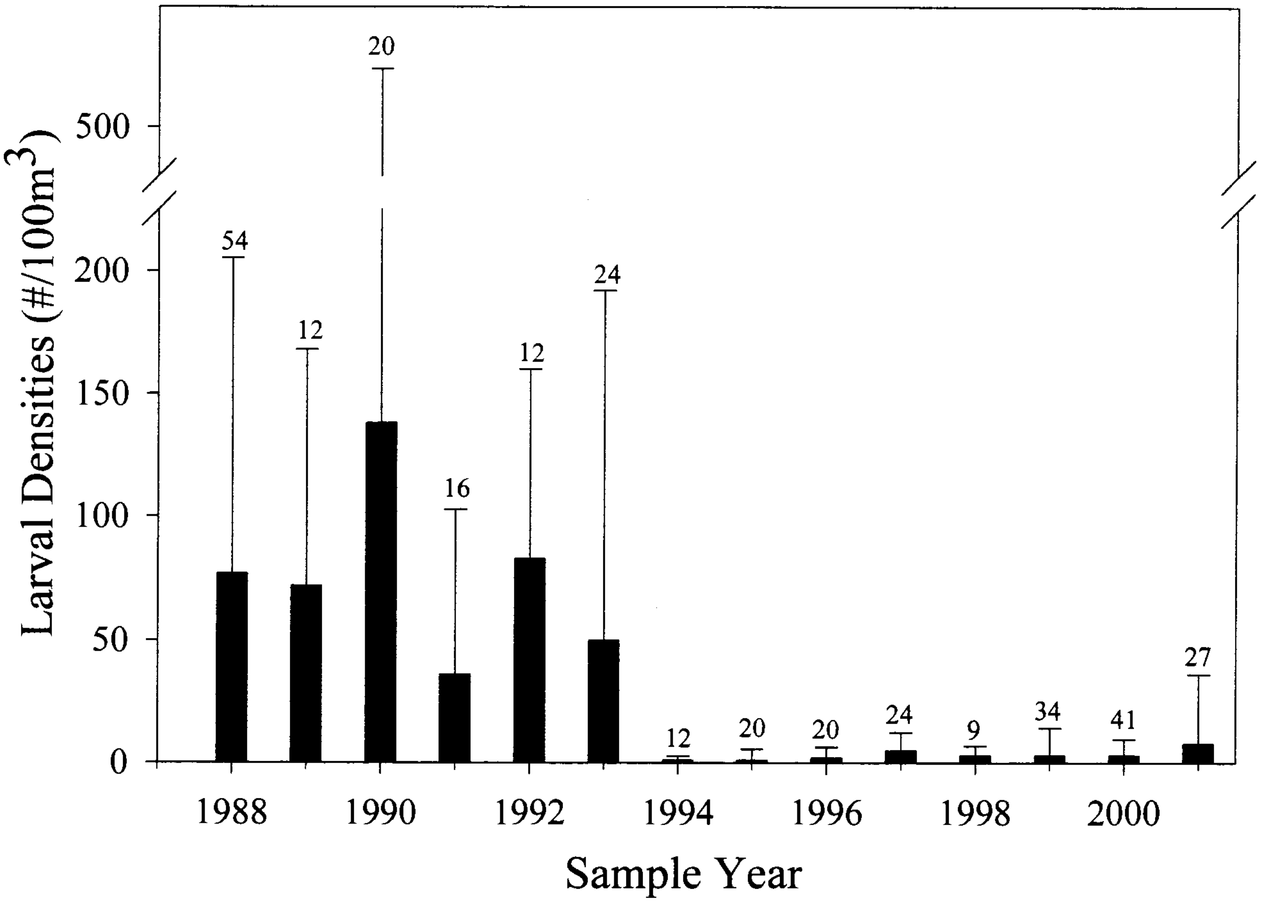

Figure 4. Density of yellow perch larvae (+ standard deviation) sampled near Waukegan Harbor, IL, 1988 to 2001. Number of sampling tows done each year is listed above error bar.

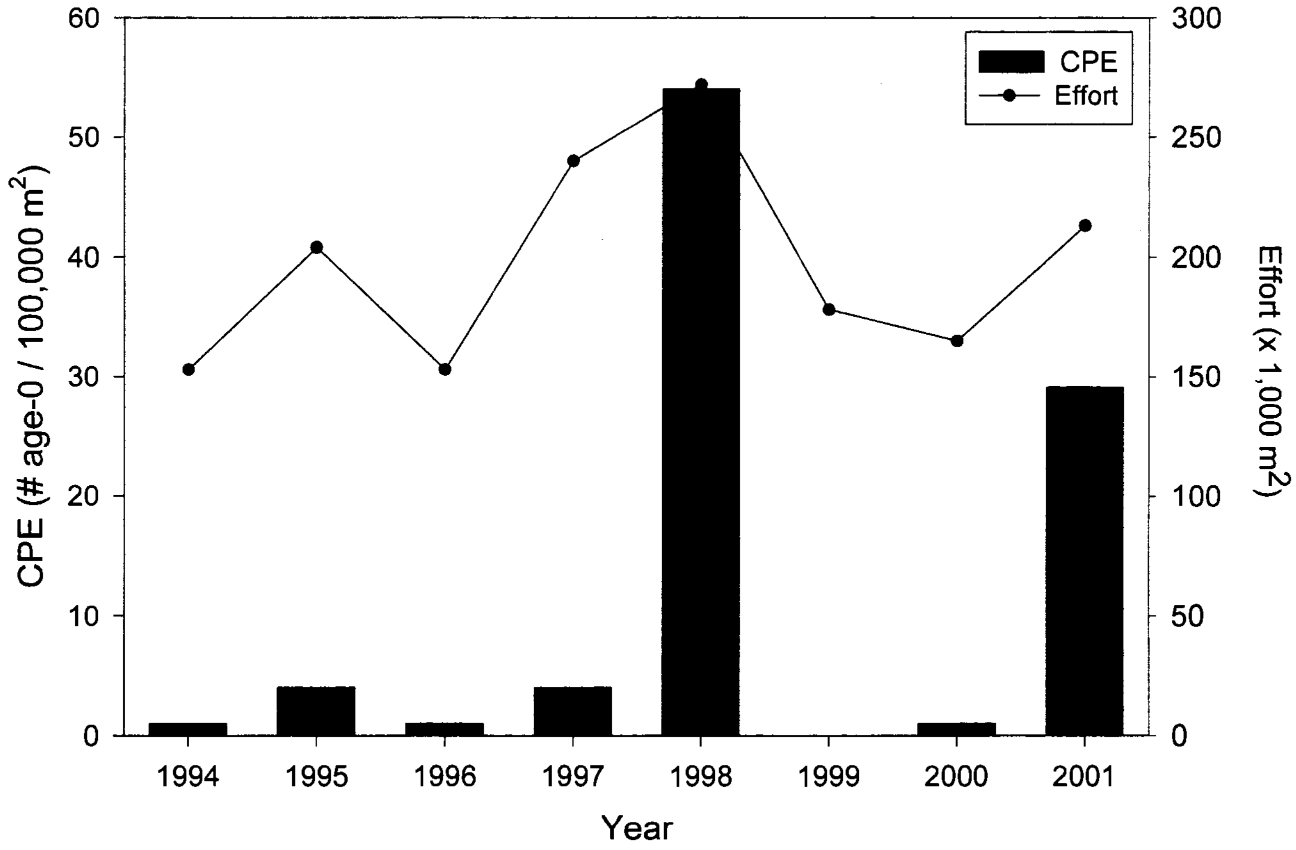

Figure 5. Relative abundance of age-0 yellow perch caught in daytime bottom trawls north of Waukegan Harbor, IL, 1994 to 2001.

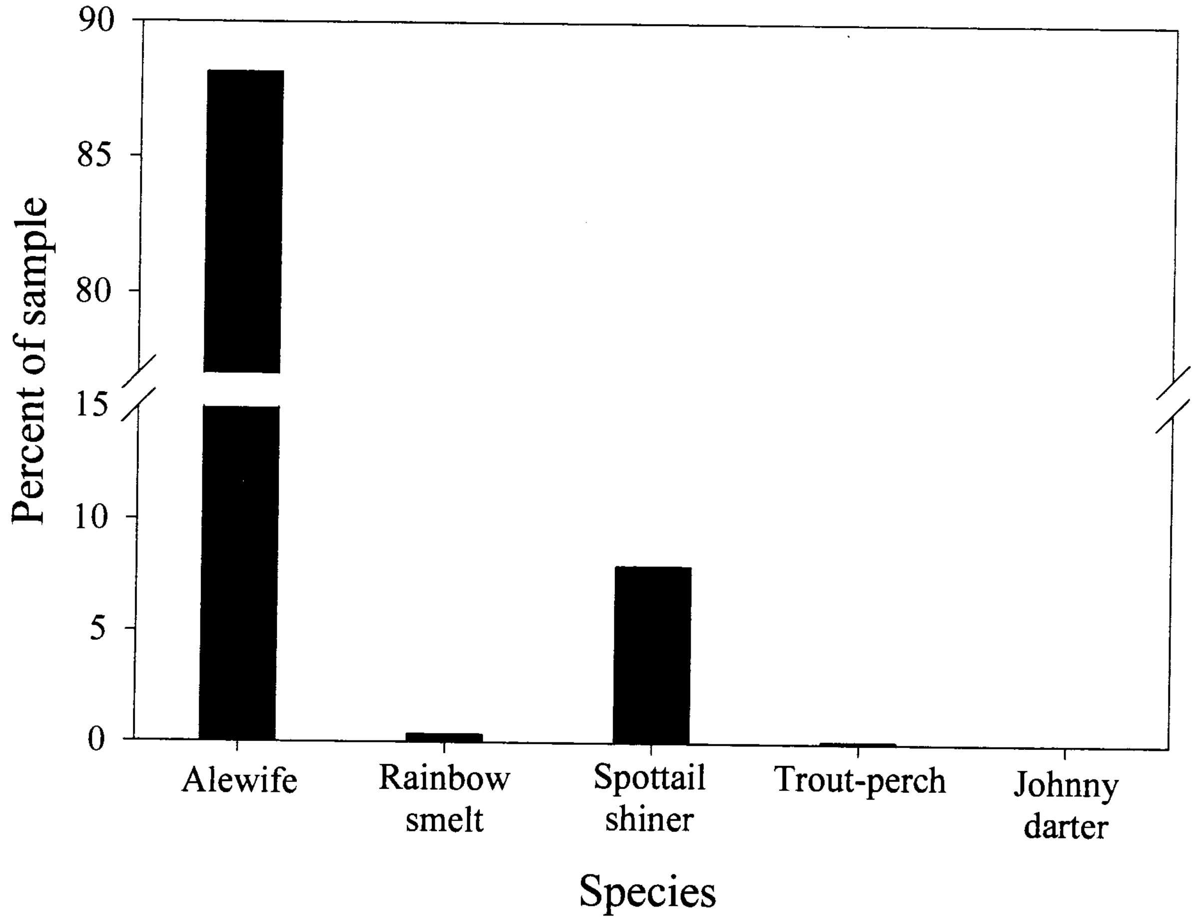

Figure 6. Percent composition of non-target species sampled during daytime bottom trawls north of Waukegan Harbor, IL, 2001.

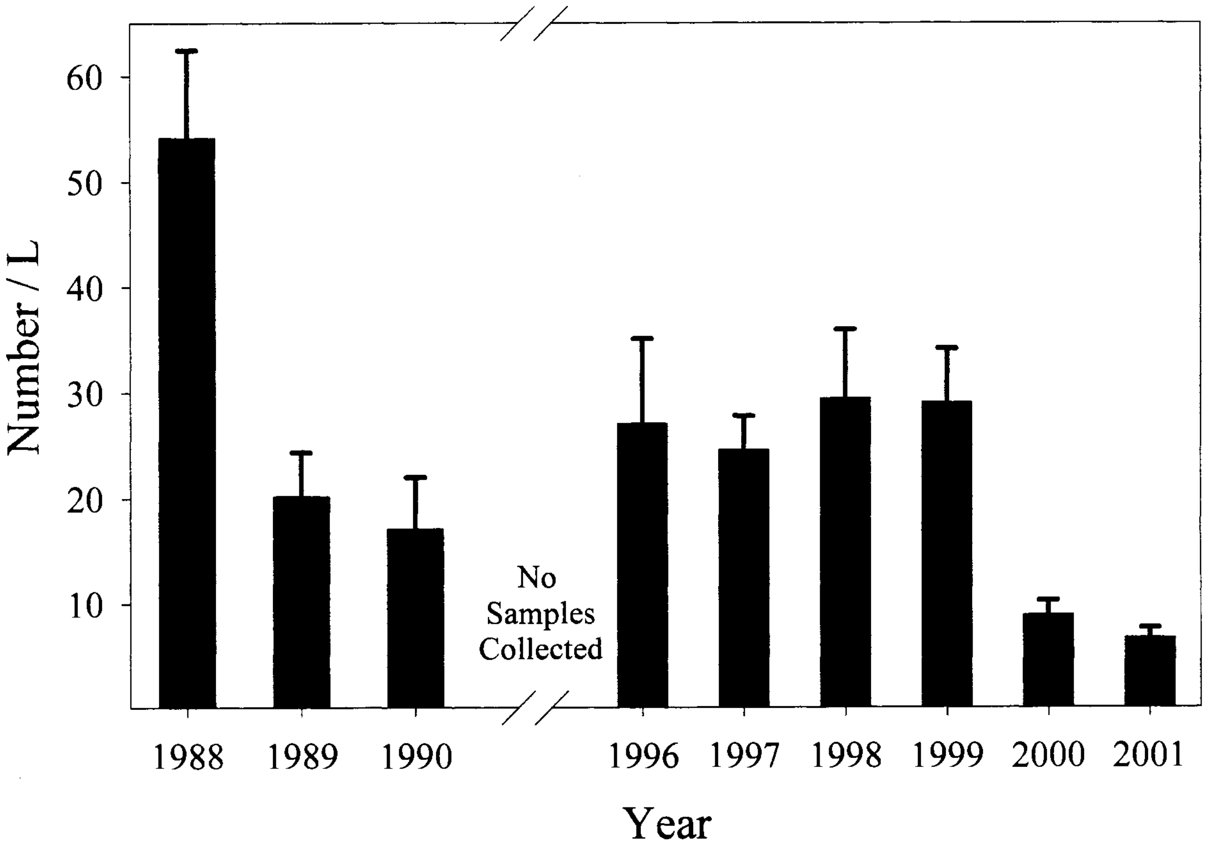

Figure 7. Mean density of zooplankton (+ 1 SE) present in Illinois waters of Lake Michigan near Waukegan during June through July 1988 – 1990 and 1996 – 2001.

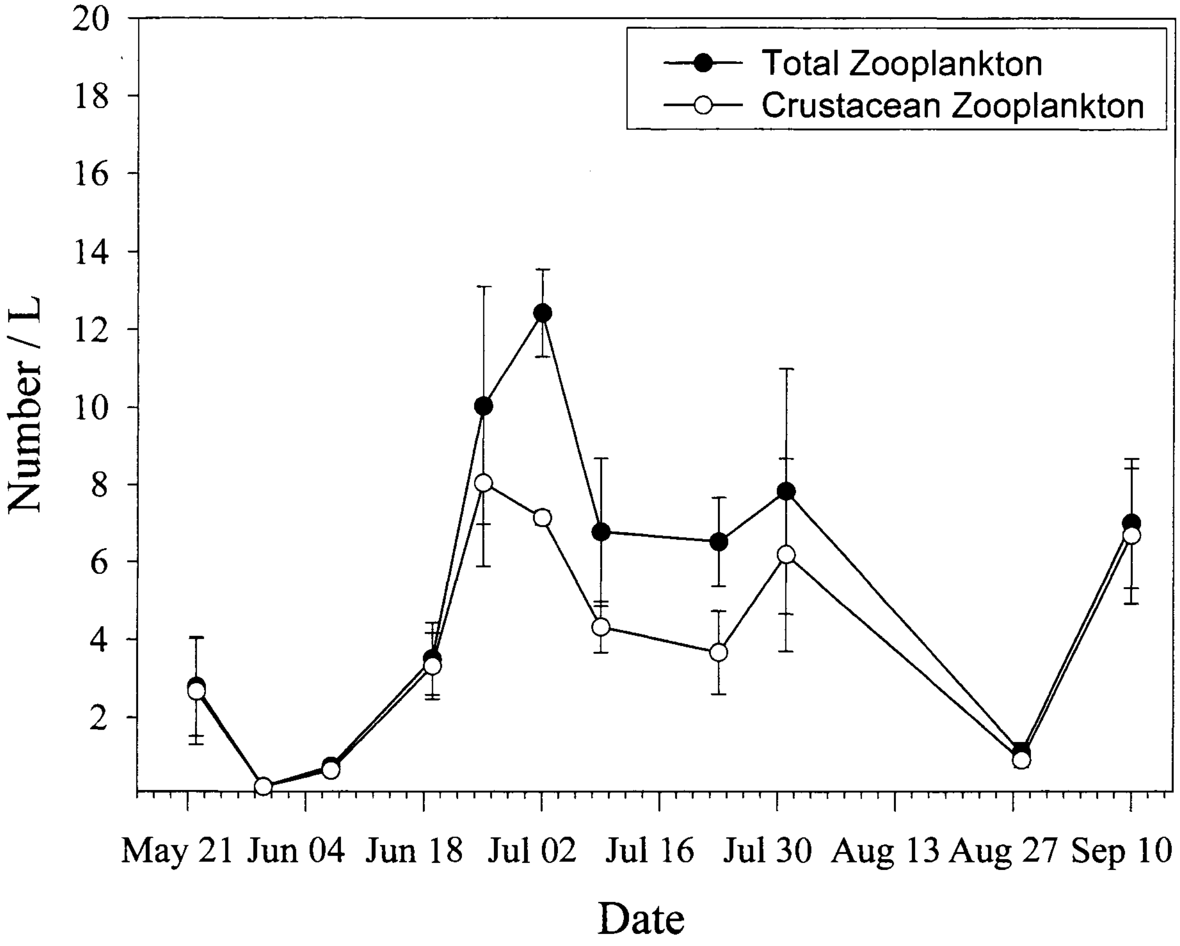

Figure 8. Mean density by date of zooplankton (± 1 SE) present in nearshore Illinois waters of Lake Michigan around Waukegan during May – September 2001. Closed circles represent total zooplankton, whereas open circles represent crustacean zooplankton only.

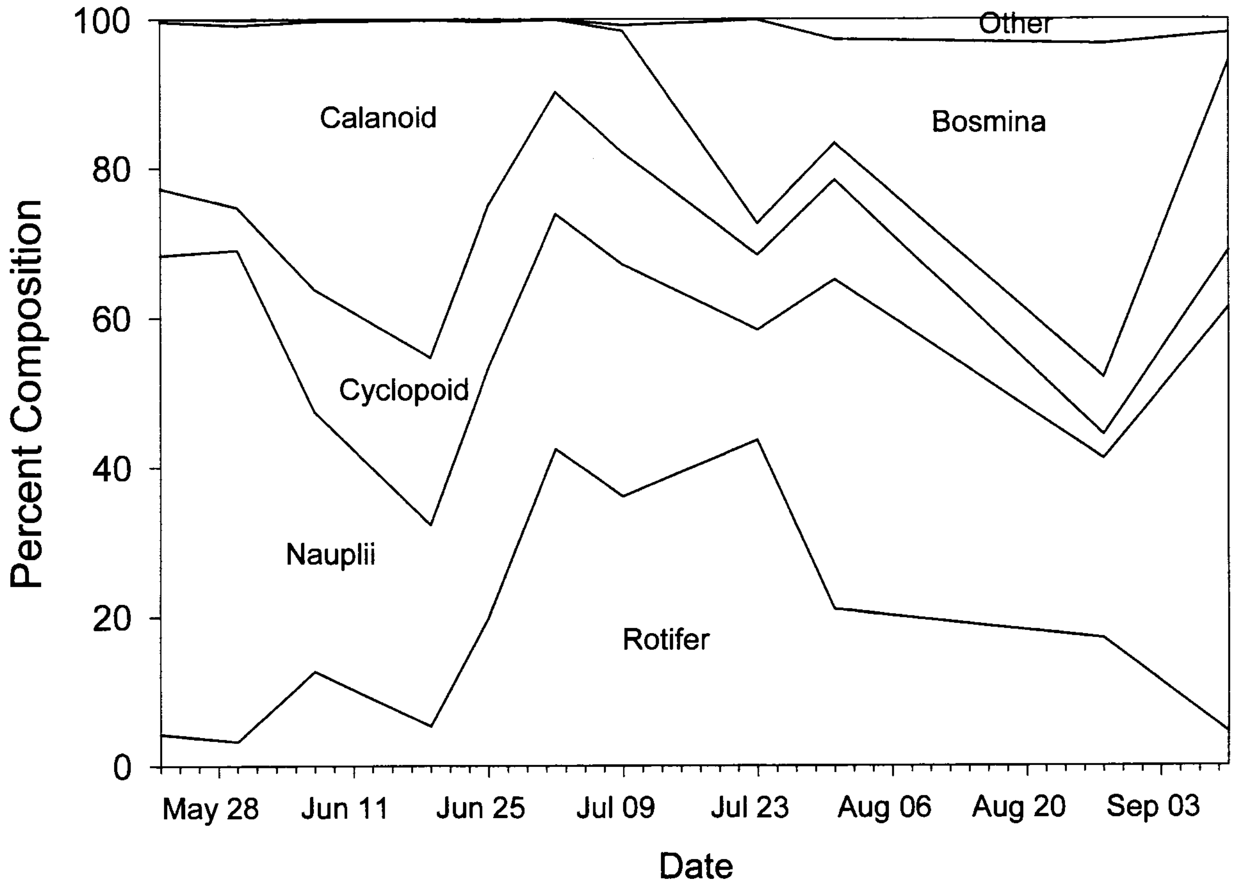

Figure 9. Percent composition of zooplankton found in nearshore Illinois waters of Lake Michigan near Waukegan during May through September 2001.

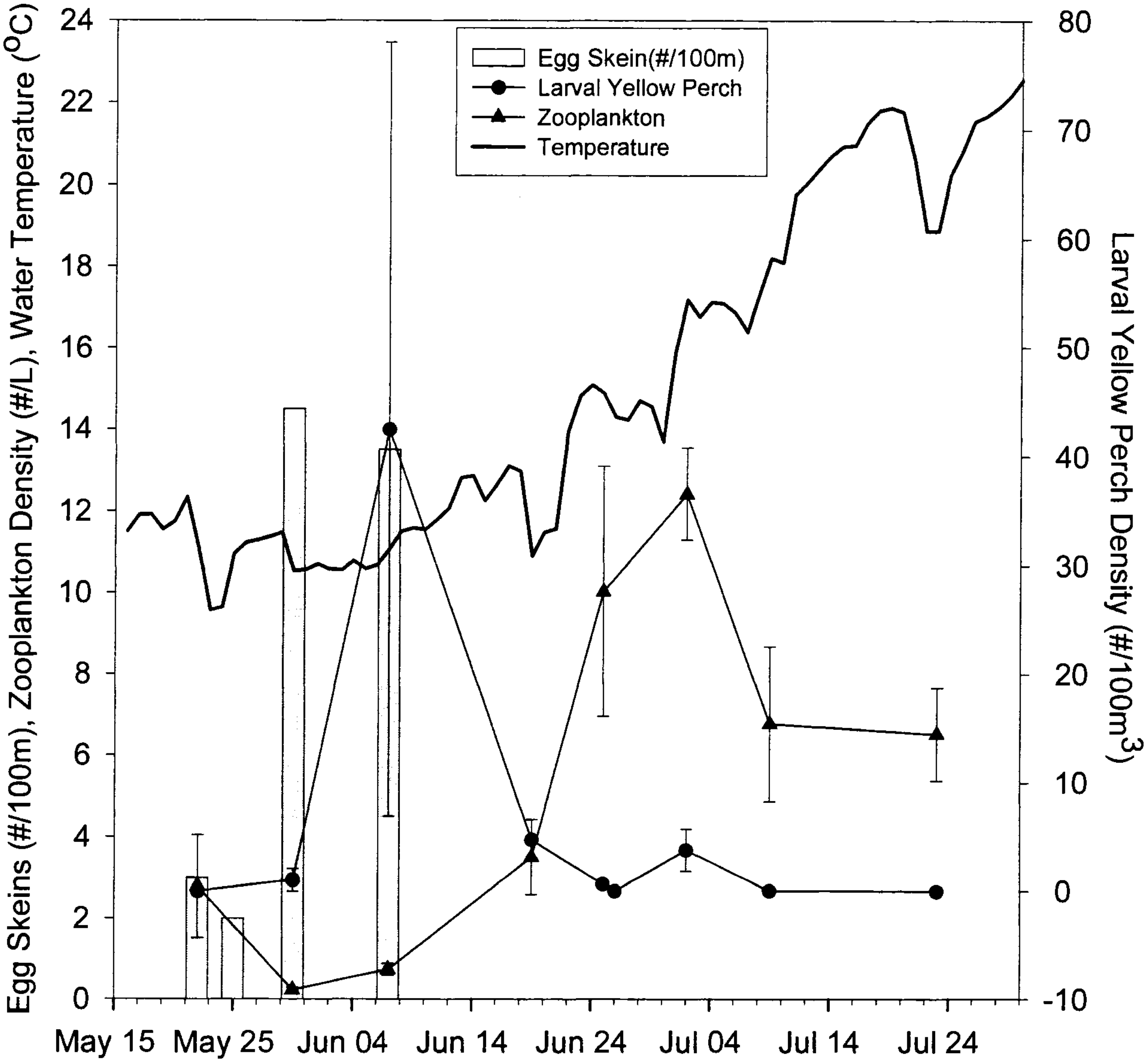

Figure 10. Seasonal patterns of yellow perch egg production (gray bars), larval yellow perch density (●), total zooplankton density ± 1 SE (▲) and water temperatures (solid line) for 2001 in Illinois waters of Lake Michigan near Waukegan Harbor.

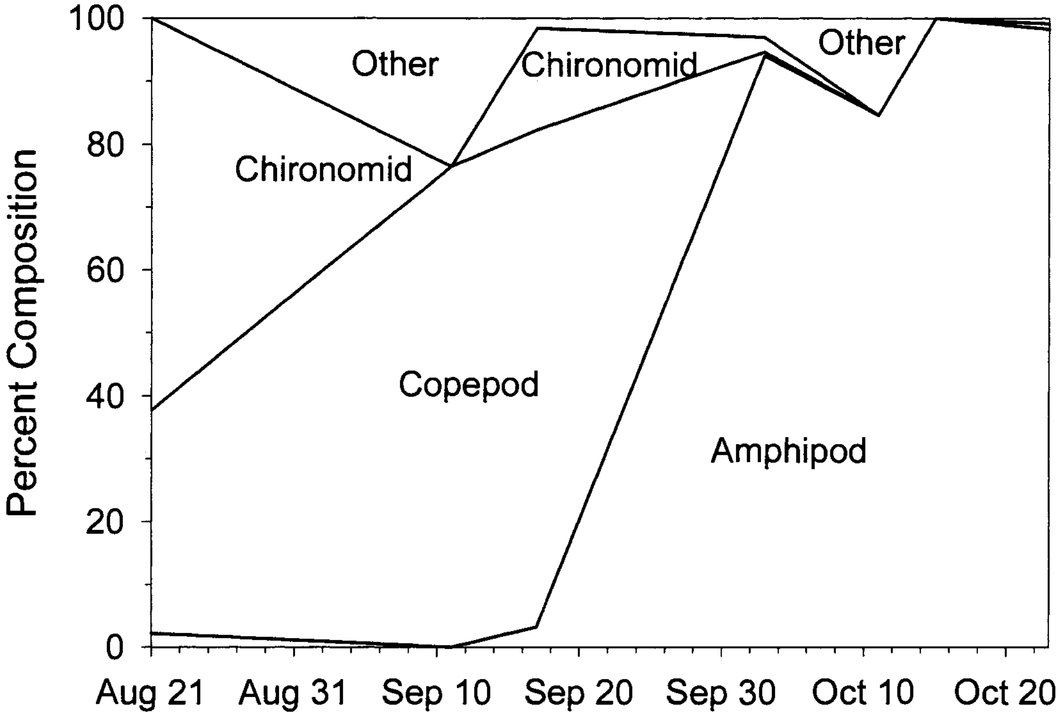

Figure 11. Percent composition of items found in the diets of age-0 yellow perch collected with bottom trawls north of Waukegan Harbor, IL between August 21 and October 23, 2001.

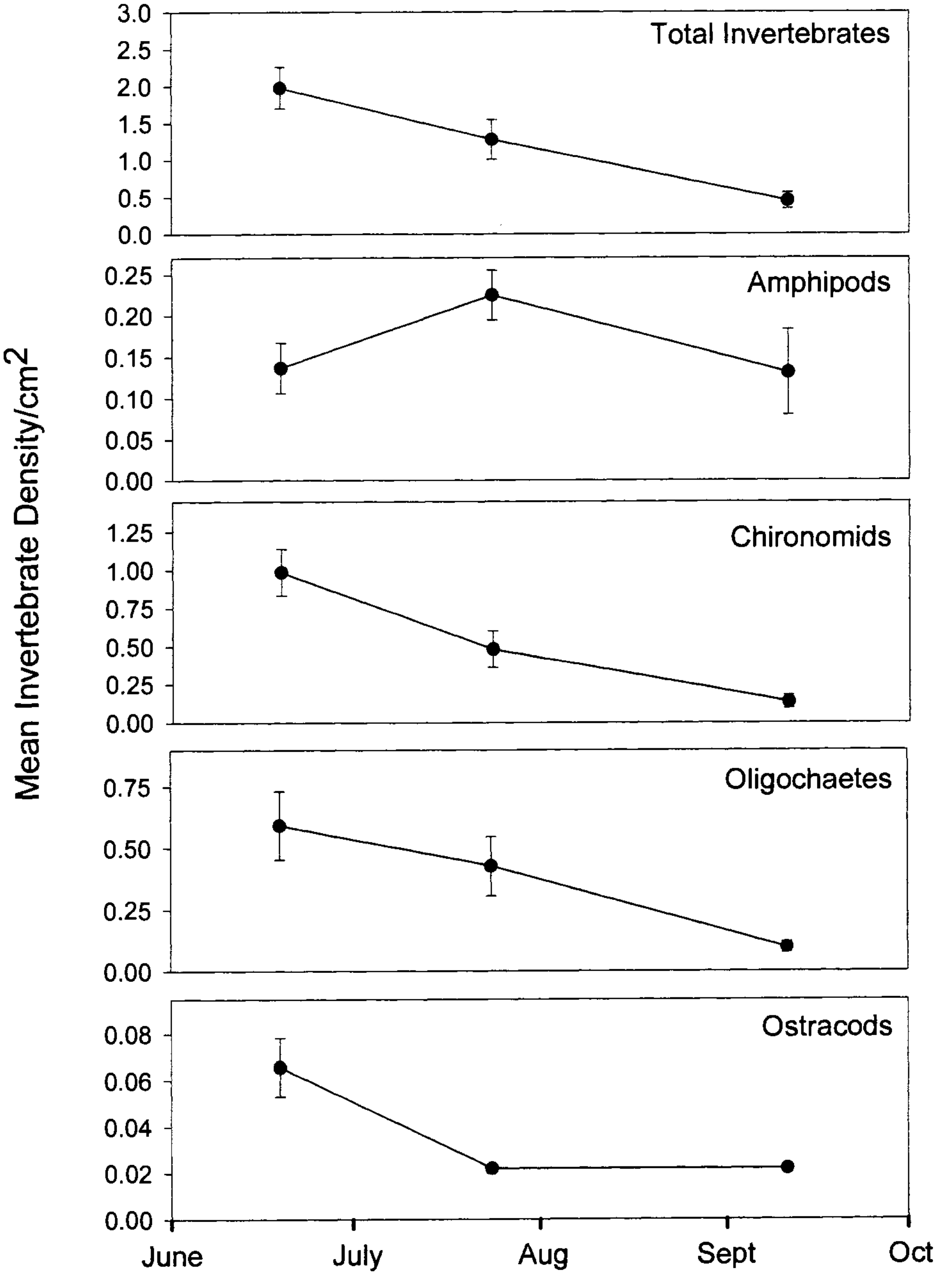

Figure 12. Mean density (± 1 SE) of total invertebrates, amphipods, chironomids, oligochaetes and ostracods collected in 2001 using a 7.5-cm-diameter core sampler at monthly intervals. Samples were collected at a site north of Waukegan Harbor, IL. Note that y-axis scales do vary considerably.

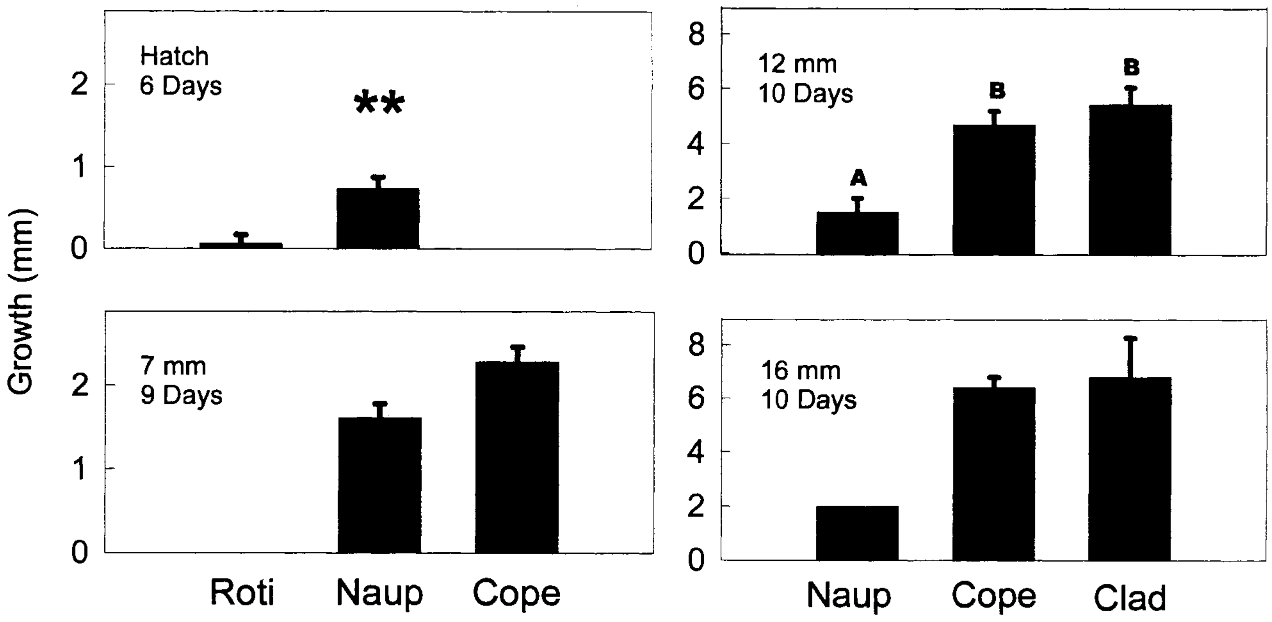

Figure 13. Growth in mm of post-hatch, 7 mm, 12 mm, and 16 mm size classes of yellow perch. Naup = copepod nauplii, Cope = adult copepods, and Clad = cladocerans. Experiment duration was 6 days for post-hatch larvae, 9 days for 7 mm larvae, and 10 days for 12 and 16 mm larvae. Rotifers (Roti) were not included in the 7 mm larvae experiment. Significant differences are denoted by ** (newly hatched larvae), and by letters for 12 and 16 mm larvae.

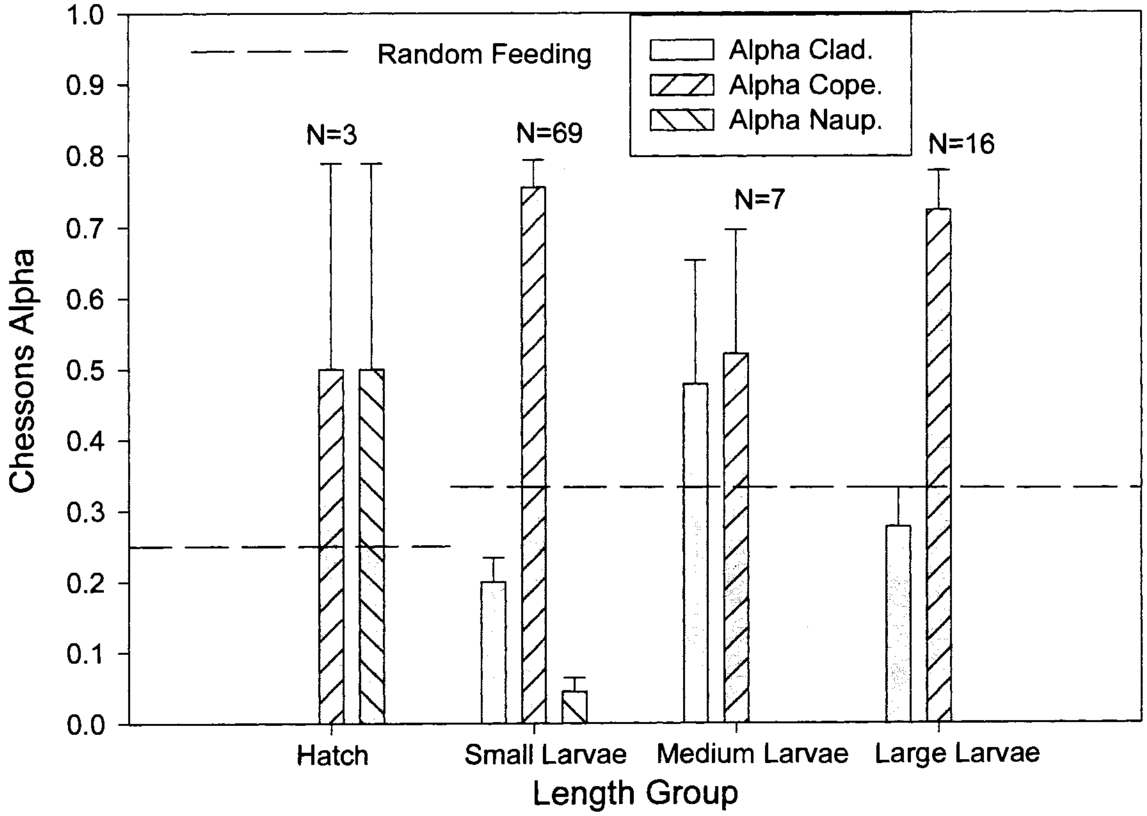

Figure 14. Prey selection of larval yellow perch. Mean values of Chesson's alpha above the random feeding (dashed) line indicate positive selection, mean values below the line indicate negative selection, and mean values near the line indicate neutral selection. Sample sizes (the number of larvae with items in the stomach) are noted for each size class.