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Yellow Perch Population Assessment in Southwestern Lake Michigan, Including Evaluation of Sampling Techniques and Identification of the factors that Determine Yellow Perch Year-Class Strength

F-123-R-12

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Center for Aquatic Ecology, Illinois Natural History Survey

Annual Report
to
Division of Fisheries
Illinois Department of Natural Resources

Illinois Natural History Survey
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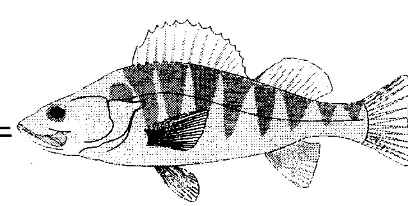
June 2006



Aquatic Ecology Technical Report 2006/05

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

April 1, 2005 – March 31, 2006

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

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June 2006

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 (*Perca flavescens*) 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 sampled for marked adult yellow perch to monitor their movement during spawning and estimate tag-loss rates. Determining the rate of tag loss is required for precise estimates of local spawning population sizes and mortality for past and future tagging studies. We also collected a subsample of adults to assess the age and size structure of the yellow perch population. Anal spines from yellow perch at two known angling sites were collected and analyzed to determine the angler-caught age distribution in 2005. Age-0 yellow perch were sampled at varying depths and distances from shore with neuston nets, a tucker trawl, gill nets, and a bottom trawl. We compared the use of gill nets and bottom trawling for sampling demersal age-0 yellow perch. We also monitored yellow perch egg skein densities, post-larval yellow perch abundance, age-0 yellow perch diets, and factors regulating year-class strength of yellow perch.

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. We highlight below some of the important results from 2005 sampling associated with our study objectives.

<u>Study 101.</u> Investigate adult mortality, age structure, and factors affecting success of yellow perch during their first year of life

Job 101.1 Recapture tagged yellow perch

1. 26 fish tagged in 2004 and 40 tagged in 2003 have been recaptured to date. The tag shedding rate for fish tagged in 2003 was 0.08; three fish tagged in 2003 have been reported with a single tag.
2. The majority of yellow perch collected in fyke nets during spring 2005 were age-3 (52%). The 1998 year-class (age-7) showed a decline in abundance from previous years, comprising only 37% of the catch.
3. Adult female yellow perch made up 6.8% of all fish caught, the highest proportion of females reported since 2001.

Job 101.2 Develop angler-caught age distribution and, if possible, sex distribution

1. The majority of angler-caught yellow perch from our creel survey in 2005 were age-3 (68.3%).
2. Catch rates of males and females appeared to be similar with each sex comprising about 28% of the total subsample; however, the sex of 44% of the fish collected was too difficult to distinguish.

Job 101.3 Quantify index of spawning activity and relative abundance of newly-hatched larvae at nearshore index sites

1. Divers found egg skeins during May and June 2005 at the US Steel intake line. About 3.3 egg skeins per 100 m^2 transect were observed, a 43% decline from our 2004 estimate.
2. Although fewer yellow perch larvae were captured using neuston nets in 2005 compared to sampling conducted prior to 1994, larval catches were higher in 2005 than those reported in 2003 or 2004. Peak larval yellow perch density (11.8/100 m^3) in our samples occurred on June 20.

Job101.4 Sample pelagic age-0 yellow perch and their food resources in offshore waters

1. 2,239 age-0 yellow perch were collected in offshore samples: 1,166 from the surface, 860 from the epilimnion, and 213 from the metalimnion. Average offshore densities ranged from 0 to a peak of 7.0/100 m^3; densities were typically higher in surface water samples compared to epilimnion and metalimnion samples. Age-0 yellow perch lengths ranged from less than 4 mm in early June to greater than 32 mm in late July.
2. In general, zooplankton densities were greater in the metalimnion than the epilimnion. Calanoid copepods and daphnia dominated the crustacean zooplankton assemblage in both strata, while densities of cyclopoid copepods and bosmina remained very low in offshore waters during 2005.

Job 101.5 Sample demersal age-0 yellow perch and their food resources in nearshore waters

1. CPE of age-0 yellow perch north of Waukegan Harbor was 1,387 fish/100,000 m^2.
2. Mean June-July zooplankton density in 2005 was 23.7/L. Densities remained low through June; both total and crustacean zooplankton densities were high in mid-July, but crustacean zooplankton did not peak until mid-September.
3. Mean annual benthic invertebrate density for a site north of Waukegan Harbor was 4,303 ± 956 /m^2 (SE) in 2005. The most common taxa were ostracods, chironomids, zebra mussels, and Oligochaetes.

Job 101.6 Compare two gear types for sampling demersal age-0 yellow perch

1. Gill nets and bottom trawling were compared on four occasions from late August to mid-October 2005. Both gears collected yellow perch, and were more productive when fished in 5 meters of water. However, yellow perch collected in the bottom trawl were almost exclusively age-0 (96%), while many of those collected in gill nets were age-1 or older based on length (32%).

Job 101.7 Evaluate diet and growth of age-0 yellow perch

1. Stomachs of 473 age-0 yellow perch collected by bottom trawls were examined in 2005. Yellow perch of this age consumed primarily zooplankton and benthic invertebrates.

Job 101.8 Explore factors regulating year-class strength of yellow perch

1. Annual variation in water temperature appears to have an effect on yellow perch recruitment success expressed as age-0 fall CPUE in nearshore waters of southwestern Lake Michigan. Variables associated with water temperature during the year (warming rate and cumulative degree days) correlate positively with age-0 yellow perch CPUE in the fall.
2. A combination of biological and physical variables is still being analyzed to determine their relative importance in predicting age-0 yellow perch recruitment.

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 (Brazo 1990, Hess 1990). However, the yellow perch fishery in Illinois waters during the early and mid 1990's was primarily supported by a strong year-class spawned in 1988, and no strong year-class had been produced since then (Marsden and Robillard 2004). 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 has been the dominant year-class in the population for several years (Creque et al. 2004). However, this year-class is approaching an age of 8 and will continually decline in abundance. Fortunately, for the first time in several years two new year-classes have appeared in LMBS adult yellow perch assessments. In 2004, yellow perch from the 2001 and 2002 year-classes were collected in measurable numbers during fyke net sampling and the creel survey (Redman et al. 2005). Hopefully, these and future year-classes will help replace the declining 1998 year-class and shift the population to a more stable condition.

The ability to manage yellow perch is hampered by insufficient information about population size, natural mortality, movements, and factors that determine year-class strength (Clapp and Dettmers 2004). Evaluation of the best techniques and locations to collect assessment data is necessary to maximize information access. However, annual assessment of spring spawning populations through tag recaptures at index stations combined with assessments of year-class strength may permit evaluation of the relative abundance of the population. Historically, these data have been obtained by the Illinois Department of Natural Resources (IDNR) at two gill net index stations, and by LMBS at multiple sites using fyke nets.

To protect yellow perch stocks, fisheries managers should ideally set harvest targets in accordance with fluctuating population sizes. 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. Assessment of larval and age-0 yellow perch populations may permit prediction of future year-class strength. However, variability of larval yellow perch abundance data and age-0 catches is 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. Recent research has shown that larval yellow perch are advected away from their nearshore spawning sites and into the offshore pelagic zone shortly after hatch (Dettmers et al. 2004 and 2005). Characterizing the mechanisms influencing ontogenetic diet and habitat shifts will contribute to basic understanding of the offshore pelagic stage of age-0 yellow perch in Lake Michigan. Annual assessment of egg mass numbers, newly hatched larvae, older pelagic larval perch drifting offshore, food resources, and the number of age-0 yellow perch returning to nearshore habitat in fall, coupled with analysis of the 10+ years of data already collected on yellow perch in Illinois waters, will help to identify which critical bottlenecks determine year-class strength of yellow perch.

Concurrent with the decline in larval fish recruitment, zooplankton density in southern Lake Michigan has been consistently lower, and the assemblage structure has shifted. Specifically, nearshore densities of zooplankton in southern Lake Michigan during 1989–2004 were consistently lower than 1988 densities, the last year of strong yellow perch recruitment (Dettmers et al. 2003, Clapp and Dettmers 2004, Creque et al. 2004). Furthermore, zooplankton taxonomic composition in June 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 the shift in southern Lake Michigan's zooplankton assemblage influenced growth and survival of larval yellow perch using laboratory experiments (Graeb et al. 2004). One observation made during these experiments was that some yellow perch larvae failed to inflate their swim bladder (Czesny et al. 2005). Swim bladder inflation is usually associated with the nutritional state of fish larvae and can affect survival of these fish to later life stages.

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

METHODS

<u>Study 101.</u> Investigate adult mortality, age structure, and factors affecting success of yellow perch during their first year of life

Job 101.1: Recapture tagged yellow perch
<u>Objective:</u> Estimate tag-loss rates of double-tagged yellow perch and monitor the movement of spawning yellow perch in Illinois waters of Lake Michigan.

We deployed 4 x 6-ft double-ended fyke nets with a 100-ft leader between the two double-throated pots to collect adult yellow perch. All nets were set along the 5-m depth contour line, parallel to shore; nets were fished for approximately 24 hours. Fyke nets were set at three primary sites (Waukegan, North Lake Forest, Fort Sheridan; Figure 1).

Job 101.2: Develop angler-caught age distribution and, if possible, sex distribution
<u>Objective:</u> Estimate age composition and, if possible, sex composition of angler-caught fish to better parameterize a lakewide catch-age model in its final stages of development.

We collected anal spines from 10-25 fish at two known yellow perch angling areas (Waukegan and Montrose Harbors, IL) each week, depending on the presence of yellow perch in angler catches, between May 1 and August 15, except for July when yellow perch harvest was closed (Figure 1). The sex of each fish was also visually determined, when possible. Anal spines were aged in the laboratory to determine the angler-caught age composition of yellow perch in 2005.

Job 101.3: Quantify index of spawning activity and relative abundance of newly-hatched larvae at nearshore index sites
<u>Objective:</u> Monitor the relative abundance of perch eggs at transects located along the abandoned US Steel intake line south of Waukegan Harbor, and determine the relative abundance of newly hatched larval yellow perch in southwestern Lake Michigan.

We counted egg masses along replicate 100-m long transects in 10 m of water along the abandoned US Steel intake line south of Waukegan Harbor using SCUBA divers (Figure 1). Viability of egg masses was determined by taking a subsample back to the laboratory and estimating percent viability. Newly-hatched larval perch were sampled using a 2-m x 1-m neuston net with 500-µm mesh netting for two weeks after hatching. The neuston net was towed for ten minutes at the surface. Replicate samples were taken at night at least 30 min after sunset. We sampled weekly, weather permitting, at four index stations outside Waukegan Harbor. All larvae were immediately preserved in 70% ethanol.

Job 101.4: Sample pelagic age-0 yellow perch and their food resources in offshore waters
Objective: Determine the relative abundance of pelagic age-0 yellow perch and their zooplankton prey within the epilimnion along a transect between 3 and 15 miles offshore.

Pelagic age-0 yellow perch and zooplankton were sampled weekly, weather permitting, at three stations along a 12-mile-long transect near Waukegan, IL (Figure 1). Stations were located 3, 9, and 15 miles from shore, and had water depths of 30, 70, and 100 meters, respectively. At each station, separate fish and zooplankton samples were taken within the epilimnion and metalimnion, along with water column temperature and DO profiles. Sample locations correspond with historical study sites of the Lake Michigan Biological Station, and thus allow for comparison of data across years. Sampling was only conducted at night and began 30 minutes after sunset, continuing until dawn.

Pelagic, age-0 fish were collected at the surface using a 1-m x 2-m fixed frame floating neuston net, and at depth using a multi-net, opening/closing 1-m x 1.4-m mid-water Tucker trawl, both equipped with 1000-µm nitex mesh nets. Nets were switched to 1800-µm nitex mesh as fish size increased to reduce gear avoidance. Fish were preserved in the field and were sorted according to species, enumerated, and measured in the laboratory. Mean lengths were taken for a random subset of 50 individuals for each species. Each fish was measured to the nearest 0.1 mm. A subset of ten individuals from each sample was also later taken for aging and diet analysis.

Replicate zooplankton samples were collected at depths corresponding to larval fish sampling depths using a 0.5m diameter, 73-µm, closing zooplankton net. Zooplankton samples were taken at both the start and end points of each larval fish trawl. Water temperature and DO profiles were taken using a YSI data sonde. Zooplankton were preserved in the field and returned to the lab for identification, enumeration, and measurement. Copepods were classified as calanoid, cyclopoid, harpacticoid or nauplii, whereas cladocerans were identified to genus. Other taxa were identified to genus when possible. 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 101.5: Sample demersal age-0 yellow perch and their food resources in nearshore waters
Objective: Determine the relative abundance of demersal age-0 yellow perch and the availability of their macroinvertebrate and zooplankton prey.

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 age-0 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 15 through October 12, 2005. All sampling occurred north of Waukegan Harbor, at a speed of approximately 2 m/sec (Figure 1). Approximately 4,460 m^2 of the lake bottom were sampled for each 0.9-km (0.5 nautical miles) transect. All fish collected were counted and total lengths were measured to the nearest 1mm on a subsample (30 individuals per species) of non-target fish. Age-0 yellow perch were counted and frozen for later examination of stomach contents.

Zooplankton in 2005 was generally sampled weekly from June 6 through September 27 on the same nights as larval fish collections during June-July. A 73-µm mesh, 0.5-m diameter plankton net was towed vertically from 0.5 m off the bottom to the surface at the 10 m depth sites. Mean volume of water filtered in each vertical lift was 1.9 m^3. Two replicates were collected after sunset at each site. Samples were immediately preserved in 10% sugar formalin. Earlier zooplankton samples (1988-1990) were collected with vertical tows of a 0.5-m diameter, 153-µm mesh net at depths ranging from 8-10 m. Lab processing of zooplankton followed the protocol set forth above in job 101.4.

SCUBA divers collected benthic invertebrates at a depth of 7.5 m at a site north of Waukegan Harbor using a 7.5-cm (3-in) diameter core sampler (Figure 1). 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 363 µm mesh net to remove sand. Organisms were sorted from the remaining sediment debris and identified to the lowest practicable level, typically to genus. Total length (mm) and head capsule width (where applicable) were measured for each individual. All taxa were enumerated and total density estimates were calculated by dividing the total number of organisms counted by the sample area.

Job 101.6: Compare two gear types for sampling demersal age-0 yellow perch
Objective: Determine whether small mesh gillnets are as effective as bottom trawling to estimate relative abundance of demersal age-0 yellow perch.

Demersal age-0 yellow perch were sampled on the same day and same location using 1) a 16-foot semi-balloon otter trawl over soft substrates between Camp Logan and Waukegan and 2) small-mesh gill nets set overnight (Figure 1). The trawl was towed for 0.9 km at each of four depths (3, 5, 7.5, and 10 m). Experimental small mesh gill nets consisting of 33-foot panels of 0.31, 0.50, 0.75, and 1.0-in stretch mesh were set at one of the two shallow depths and one of the two deeper depths trawled for comparisons. Depth of the shallow and deep gill net set chosen were randomly assigned for each outing. Captures of age-0 fish in gill nets were compared to fish in the bottom trawl by length and total number of fish per unit effort to establish a method for comparing data from these two sampling techniques.

Job 101.7: Evaluate diet and growth of age-0 yellow perch
Objective: Investigate whether growth of age-0 yellow perch is related to diet composition and food availability.

Yellow perch collected by bottom trawl in 2005 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, whereas benthic invertebrates were identified as an amphipod, chironomid, and all others to order.

Job 101.8: Explore factors regulating year-class strength of yellow perch
Objective: Examine the relative importance of biotic and abiotic factors toward determination of yellow perch year-class strength.

We are in the process of updating our investigation of two biological and 25 environmental variables using a Ricker stock recruit-model to determine their relative importance in predicting age-0 yellow perch recruitment success. Alewife abundance (as estimated by IDNR) and zebra mussel presence (0 or 1 index, where 0 represents years prior to 1992 and 1 represents years 1992 and after) are the two biological variables. Twenty five environmental variables are being generated based on weather data collected by the National Data Buoy Center. In this analysis we utilized information collected by two weather stations (Station SGNW3 - Sheboygan, WI and Station 45007 - S MICHIGAN 43NM East Southeast of Milwaukee, WI) and nearshore water temperatures monitored by the Zion Water Treatment Plant in Zion, IL.

Specific environmental variables were selected based on general biological relevance related to timing of yellow perch spawning, spawning areas, yellow perch thermal requirements, gradient of environmental stability, and food resources. Two groups of environmental variables were generated: 1) variables related to warming rate (cumulative degree days, degree days above thresholds, as well as average daily temperature increases ($\Delta T = {}^{o}C/day$), and 2) variables related to wind patterns, which were associated with wind speed (daily averages above 6, 8, 10 mph) and wind direction (frequency - total number of days with prevailing on/offshore winds and consistency - number of consecutive days of on/offshore winds). Wind speed and direction as well as surface water temperature nearshore and offshore in the southeastern Lake Michigan are being used to calculate indexes describing relative physical conditions in southwestern Lake Michigan for a given year.

Surface water temperatures are being averaged for each day and further calculations will be performed to generate values that represent relative warm versus cold years. Spring warming rate for each year will be expressed as an average daily temperature increase (the difference between mean surface water temperature on day X and day X+1) for May and June, the time period that coincides with yellow perch spawning and hatching in southwestern Lake Michigan. The faster water warms and reaches about 10-11 °C, the sooner perch spawn, and thus larvae have a potentially longer first year growing season. Cumulative degree days in May and June, July, August, and September for a given year will be calculated for each year as a sum of average daily temperatures in specified months and will be used as an indication of favorable (warm) and less favorable (cool) years for yellow perch growth.

We will then examine interaction plots between the recruitment indicator (age-0 yellow perch CPUE) and each variable to select those that correlated best with recruitment over a period of 19 years, 1987-2005.

A Ricker stock-recruit relationship will be employed in the analyses:

$$R = \alpha\, Pe(-\beta P)$$

Where:
R = number of recruits
P = size of parental stock
α = dimensionless parameter
β = parameter with dimensions of 1/P

Two working hypothesis have been formed: 1) yellow perch recruitment should benefit from warmer years, and 2) patterns of physical forces (wind, currents) that would transport larval yellow perch to favorable areas of the lake should positively affect recruitment.

Job 101.9: Data analysis and report preparation
Objective: Analyze data and prepare reports and manuscripts.

Data from the above jobs were processed, analyzed, and summarized. This annual report was prepared from the data.

RESULTS

Study 101. Investigate adult mortality, age structure, and factors affecting success of yellow perch during their first year of life

Job 101.1: Recapture tagged yellow perch
Objective: Estimate tag-loss rates of double-tagged yellow perch and monitor the movement of spawning yellow perch in Illinois waters of Lake Michigan.

No yellow perch were tagged in 2005. However to date, 26 fish tagged in 2004 and 40 tagged in 2003 have been recaptured. Only three fish (all tagged in 2003) have been reported with a single tag, which equates to a 0.08 tag shedding rate for fish tagged in 2003.

Yellow perch ranged in age from 2 to 8 years in 2005 (Figure 2). Age-3 individuals (2002 year-class) dominated the adult yellow perch population, comprising 52% of the catch (N = 514). Age-7 individuals (1998 year-class) were the next most abundant age group, making up 37% of the catch. The oldest individual recorded from 2005 samples was age-8. Age-4 individuals (2001 year-class) were also present in measurable numbers, comprising 7.5% of the catch. The presence of significant abundances of age-3 and age-4 fish suggests that these fish may help replace the declining 1998 year-class.

The sex ratio of yellow perch collected (N = 1,613) was skewed towards males (F:M = 1:94), but percent females was the highest reported since 2001 (Table 1). The sex of 30.0% of the yellow perch collected was too difficult to distinguish in the field because they were not expressing milt or eggs and had no other distinguishing sexual dimorphic characteristics such as a swollen belly. These fish were recorded as unknown and thus the sex ratio could be much higher than reported. For example, the sex ratio of subsampled yellow perch (N = 520) dissected in the laboratory was 20.0 % female.

Job 101.2: Develop angler-caught age distribution and, if possible, sex distribution
Objective: Estimate age composition and, if possible, sex composition of angler-caught fish to better parameterize a lakewide catch-age model in its final stages of development.

Angler-caught yellow perch subsampled from our creel survey in 2005 (N = 303) ranged in age from 2 to 8 years, but 68.3% were age-3 (2002 year-class). Age-7 fish (1998 year-class) were the next largest group accounting for 14.9% of the fish, followed by age-4 which accounted for 9.2% of the sampled sport harvest (Figure 3). Overall, catches of males and females were similar with each sex comprising about 28% of the total subsample; the sex of the remaining fish (44%) was too difficult to distinguish in the field. The sex of these fish was recorded as unknown, and thus the proportion of females caught could be much higher than reported for all ages.

Job 101.3: Quantify index of spawning activity and relative abundance of newly-hatched larvae at nearshore index sites
Objective: Monitor the relative abundance of perch eggs at transects located along the abandoned US Steel intake line south of Waukegan Harbor and determine the relative abundance of newly hatched larval yellow perch in southwestern Lake Michigan.

Divers found egg skeins during May and June 2005 at the US Steel intake line, the location of this survey since 1996 (Table 2). All eggs were found on cobble or bedrock substrate, and were generally within a shallow cavity formed by the cobbles, lodged among rocks, or laid across the top of the cobble-covered water intake. We observed an overall mean of 3.3 egg skeins per 100 m^2 transect (Figure 4), which is a 43% decline from our 2004 estimate. During 2005, diving surveys started about 2 weeks later than in previous years due to severe weather conditions. Thus, divers may have missed peak spawning causing our index of spawning activity to be artificially low.

Yellow perch larvae were captured in low abundance during 2005 compared to catch rates reported before 1994. However, larval catches were higher in 2005 than those reported in 2003 or 2004 (Figure 5). Average daily densities of larval yellow perch between June 6 and July 19, 2005 ranged from 0.0 to 11.8 fish/100 m^3. The peak larval yellow perch density in 2005 occurred on June 20. An increase in the abundance of newly hatched larval perch may be the result of younger females (age-3 and age-4) entering the spawning stock.

Job 101.4: Sample pelagic age-0 yellow perch and their food resources in offshore waters
Objective: Determine the relative abundance of pelagic age-0 yellow perch and their zooplankton prey within the epilimnion along a transect between 3 and 15 miles offshore.

We collected pelagic age-0 yellow perch in offshore Illinois waters between July 7 and August 24, 2005 (N = 71). A total of 2,239 age-0 yellow perch were collected in offshore samples: 1,166 from the surface, 860 from the epilimnion, and 213 from the metalimnion. Mean volume of water sampled per stratum was 2,976, 2,042, and 3,876 m^3 for the surface (N = 24), epilimnion (N = 23), and metalimnion (N = 24), respectively. Annual CPE was 31.5/100 m^3, which is more than 3 times our 2004 estimate of 9.8/100 m^3. Average offshore densities of age-0 yellow perch throughout the water column ranged from 0 to a peak of 7.0/100 m^3, which occurred at both the three and nine mile stations on July 7 (Figure 6). As seen in previous years, newly hatched yellow perch larvae (4-6 mm) were collected at our nearshore site (1 mile offshore) for only the first several weeks of the sampling season. In general, yellow perch were collected at the three mile station during early summer. However, perch abundance at the three mile site during 2005 was higher than that detected in 2004. In 2005, densities at the nine and fifteen mile station peaked in mid-July, declined in late July, and reached zero by early August (Figure 6). Age-0 yellow perch lengths ranged from less than 4 mm in early June to greater than 32 mm in late July, and by early August the largest fish disappeared from our offshore samples. The disappearance of 30-40 mm perch from late July offshore samples corresponds well to the appearance of similar sized demersal age-0 perch in nearshore bottom trawl samples (Figure 7).

Densities of age-0 yellow perch were typically higher in surface samples than epilimnion and metalimnion samples; however, the use of different gear types does not allow for direct comparison between surface samples and lower stratum samples (Figure 8). In 2005, we detected a second peak of perch abundance (6.2/100 m^3) at the three mile station in the epilimnion on August 8 (Figure 8b). The appearance of perch three miles offshore in late summer is unlike the abundance pattern we observed in 2004 when age-0 yellow perch were not detected in the water column at the three mile station after mid-July.

Densities of cyclopoid copepods and bosmina remained very low at all offshore sites throughout the sampling period in both strata (Figures 9 and 10). At the three mile station, calanoid copepods and daphnia peaked in the epilimnion from mid- to late August (Figure 9a), and in the metalimnion during early August (Figure 10a). Calanoid copepods peaked during mid-June in both strata at the nine mile station. Daphnia peaked during early August in the metalimnion and during mid-June in the epilimnion at the nine mile station. Calanoid copepods remained at a relatively stable density from mid-June to late August in the metalimnion at the fifteen mile site (Figure 10c), but peaked during early June and then declined in the epilimnion (Figure 9c). Daphnia were most abundant in both strata during August at the fifteen mile station (Figures 9 and 10).

Wind and wave direction data, downloaded from the NOAA National Data Center website (http://www.ndbc.noaa.gov/station_history.php?station=45007), are also being analyzed as a possible mechanism for driving pelagic yellow perch back to the nearshore environment. These data are highly variable; however, we do see onshore wind events occurring before and during the appearance of age-0 yellow perch in nearshore waters as early as August (Figure 11).

Job 101.5: Sample demersal age-0 yellow perch and their food resources in nearshore waters
Objective: Determine the relative abundance of demersal age-0 yellow perch and the availability of their macroinvertebrate and zooplankton prey.

In 2005, our daytime bottom trawling sampled approximately 243,461 m^2 and collected 3,378 yellow perch estimated to be age-0 based on length. Over 63% of these fish were caught during two fishing episodes. The first episode occurred on July 29 when 1,127 age-0 yellow perch were caught in 3 meters of water. The second episode occurred on October 12 when 1,016 age-0 yellow perch were caught at a depth of 5 m. 2005 annual CPE of age-0 yellow perch was 1,387 fish/100,000 m^2; CPE excluding the fish on caught on July 29 and October 12 was 507 fish/100,000 m^2. Age-0 CPE in 2005 was high compared to that detected in the last ten years and is the highest reported since 1988 when age-0 CPE was 6,869 fish/100,000 m^2 (Figure 12). Individual age-0 yellow perch were collected from mid-July through early October. Yellow perch had the highest overall CPE in 2005 bottom trawls, primarily due to high catches in July and October. Alewife (*Alosa pseudoharengus*) was the next most abundant species, but CPE was approximately 4 times lower than that of yellow perch. Spottail shiners (*Notropis hudsonius*) were also common, but were caught at much lower densities than either yellow perch or alewife. We also caught an additional 1,244 yellow perch that were probably from the 2004 year-class or earlier based on lengths.

Mean June-July zooplankton density in 2005 was 23.7/L, which is a 47% decrease from our 2004 estimate (Figure 13). In 2005, zooplankton densities varied significantly throughout the sampling period. Densities of both total and crustacean zooplankton remained low during June, increased in mid-July, and then decreased significantly in early August (Figure 14). Crustacean zooplankton increased and peaked on August 9, decreased again, and then increased to a maximum density of 17.4/L on September 12. Copepod nauplii and adult calanoid copepods dominated the zooplankton assemblage from June to early August (Figure 15). Adult calanoid copepods made up less than 21% of the zooplankton assemblage after early August, but copepod nauplii accounted for 9-50% of zooplankton during this same period. Rotifers became the most prominent taxon in mid-August, but densities declined until mid-September when rotifers accounted for over 70% of zooplankton. Adult calanoid copepods were a dominant taxon during June 2004, but they only accounted for <1-8% of zooplankton in 2005. Bosmina and daphnia occurred throughout the sampling season, but bosmina were most common in mid- to late August, and daphnia were most common in September (Figure 15). Other cladeocerans (e.g. *Polyphemus*, *Ceriodaphnia*, *Leptodora*, *Diaphanosoma*, *Chydoridae*) that were commonly found in samples during 1988-1990 were rarely observed in samples collected since 1996.

Mean annual benthic invertebrate density north of Waukegan Harbor was 4,303 ± 956 /m^2 (SE) in 2005, which is much higher than that detected in 2004. Such high densities during 2005 can be partly explained by extremely high abundances of ostracods during August and September. Monthly densities were lowest in June (1,475 ± 96 /m^2) and highest in September (9,008 ± 2309 /m^2). The most abundant species in June and July samples were chironomids, *Diporeia*, Oligochaetes and ostracods. These taxa made up over 80% of all individuals collected during both months. During August and September, ostracods were most abundant (53-70%), followed by chrionomids, zebra mussels, and Oligochaetes. Other insects, amphipods, and mollusks were also found throughout the summer in smaller abundances.

Job 101.6: Compare two gear types for sampling demersal age-0 yellow perch
Objective: Determine whether small mesh gillnets are as effective as bottom trawling to estimate relative abundance of demersal age-0 yellow perch.

Small mesh gill nets and bottom trawling were used to sample fish at the same location on four occasions from late August to mid-October during 2005. Total catch in the trawl was 1,873 individuals and 93% (1,734) of these fish were yellow perch. Total catch in gill nets was 2,782 individuals and 46% (1,271) of these fish were yellow perch. Additionally, total catch of age-0 yellow perch, based on length, was approximately 1,050 (56% of total catch) in the trawl and 642 (23% of total catch) in gillnets.

At the 10 m site, only 17 yellow perch were collected in the trawl and based on length 11 of these fish were age-0. A round goby (*Neogobius melanostomus*) and a threespine stickleback (*Gasterosteus aculeatus*) were also collected in the trawl (Table 3). Gill nets set at the10 m site caught 299 yellow perch (75 fish/net night), and based on length 47% of these perch were age-0. Alewife, spottail shiner (*Osmerus mordax*), rainbow smelt, and a trout-perch (*Percopsis omiscomaycus*) were also collected in gill nets at the 10 m site (Table 3).

Catches for both gears were higher in 5 meters of water. 1,717 yellow perch (39 fish/100m^2) were collected in the trawl. Based on lengths, we believe that 59% of these fish were age-0. In addition, spottail shiner, rainbow smelt, alewife, Johnny darter (*Etheostoma nigrum*), bloater (*Coregonus hoyi*), and sculpin (*Cottus* spp.) were collected in the trawl (Table 3). In gill nets at the 5 m site, 972 yellow perch (243 fish/net night) were collected, and 52% of these perch were age-0 based on lengths. Spottail shiner, alewife, rainbow smelt, bloater, banded killifish, and a minnow were also collected in gill nets.

Mean total length of yellow perch caught during bottom trawling was 66 mm with a range of 43-135 mm. Mean total length of yellow perch collected in gill nets was 87 mm with a range of

51-319 mm. Only five of the fish measured from bottom trawling (N = 130) were longer than 80 mm, whereas 32% of the fish measured from gill nets (N = 473) were longer than 80 mm. While both gears caught age-0 yellow perch, small mesh gill nets collected larger and presumably older fish, while bottom trawling tended to select for smaller individuals.

Job 101.7: Evaluate diet and growth of age-0 yellow perch
Objective: Investigate whether growth of age-0 yellow perch is related to diet composition and food availability.

Stomachs of 473 age-0 yellow perch from 12 sampling dates between July 15 and October 12, 2005 were examined. Copepods dominated the diet of age-0 yellow perch through August (Figure 16). In September however, fish foraged mostly on cladocera and chironomids, which comprised nearly 90% of all prey species consumed. In early October, copepods, amphipoda, and other benthic invertebrates dominated age-0 yellow perch diets, and of the other invertebrates 96% of these were Bythotrephes spp.

Job 101.8: Explore factors regulating year-class strength of yellow perch
Objective: Examine the relative importance of biotic and abiotic factors toward determination of yellow perch year-class strength.

Annual variation in water temperature affected yellow perch recruitment success expressed as age-0 fall CPUE in nearshore waters of southwestern Lake Michigan. Variables associated with water temperature during the year (warming rate and cumulative degree days) correlated positively with age-0 yellow perch CPUE in the fall (Figure 17). We are in the process of updating our investigation of two biological and 25 environmental variables using a Ricker stock recruit-model to determine their relative importance in predicting age-0 yellow perch recruitment success over a period of 19 years, 1987-2005.

Job 101.9: Data analysis and report preparation
Objective: Analyze data and prepare reports and manuscripts.

Relevant data were analyzed, and the results were incorporated into this report.

CONCLUSIONS

The 2005 fyke net sampling collected 1,613 yellow perch at three sites: Waukegan wiremill (US Steel), North Lake Forest, and Fort Sheridan. Twenty-six of the 1,837 fish double tagged in 2004 were recaptured, and 40 tagged in 2003 have been recaptured. Annual tag shedding rate for fish tagged in 2003 equated to 0.08; three fish that were tagged in 2003 were reported with a single tag. Unlike the last several years, the majority of yellow perch collected in fyke nets during 2005 were from the 2002 year-class, and fish from the 2001 year-class were also present in measurable numbers. Catch rates of the 1998 year-class declined with a 47% decrease from our 2004 estimate. Similar results were detected from fish collected during the 2005 creel survey in Waukegan and Montrose Harbors, IL. The largest group of fish was represented by the 2002 year-class, followed by the 1998 and 2001 year-classes. Thus, the 2001 and 2002 year-classes may be critical in replacing the declining1998 year-class. However, even with this shift toward younger individuals, the population may remain unstable until multiple strong year-classes recruit into the fishery. As a result, the 1998 and 2001 year-classes may be extremely important for future spawning events and as such should be protected to the greatest extent possible.

The density of yellow perch egg skeins collected at the US Steel intake line, south of Waukegan Harbor, in 2005 declined 43% from the 2004 estimate. This is the third consecutive year of reduced egg deposition at this site. One explanation for this continued decline is as that the spawning potential of the younger 2001 and 2002 year-classes is not high enough to make up for the continual decline of 1998 year-class, which has been the primary source of new yellow perch generations for several years. However, larval perch catches in nearshore and offshore waters during 2005 were higher than those reported in the last couple years. Also, diving surveys during 2005 started about two weeks later than in previous years due to severe weather conditions. Thus, divers may have missed peak spawning causing our index of spawning activity to be artificially low. Regardless, these results raise concerns about the spawning potential of the yellow perch population during a shift towards younger individuals.

Larval yellow perch density was much lower during 1994-2005 compared to densities observed before 1994. Densities peaked at 11.8 fish/100 m^3 in 2005, compared to peaks of over 100 fish/100 m^3 prior to 1994 (Marsden and Robillard 2004). However, larval catches in 2005 were higher than those reported in 2003 and 2004. The density of larval yellow perch peaked in nearshore waters on June 20, followed by a steady decline. Age-0 yellow perch density peaked on July 7 at stations three and nine miles offshore, which suggests these fish moved from nearshore to offshore waters during this time period. The severe decline in larval yellow perch and an apparent habitat shift indicate that a reduction in adult females and reduced food availability may be negatively impacting yellow perch recruitment.

The mechanisms that drive pelagic age-0 yellow perch to shift habitats, and the reason this shift occurs later in Lake Michigan than other systems remains unclear. Age-0 yellow perch grow better while maintaining a zooplankton diet (Prout et al. 1990). Thus, we would expect yellow perch in Lake Michigan to remain offshore unless the offshore zooplankton population declined to a level insufficient to sustain these fish. Our preliminary data show a decline in offshore zooplankton late in the summer, which may coincide with this habitat shift. In all likelihood, this shift is not driven by one factor alone, but rather multiple factors such as ontogeny, food resources, and abiotic factors, like wind events, that may push fish back to nearshore areas.

The 2005 CPE for age-0 yellow perch collected in bottom trawls was much higher than seen in the last decade, and is the highest catch reported since 1988 when age-0 CPE was 6,869 fish/100,000 m^2. Previously, relatively high CPE in 1998 developed into a comparatively strong year-class as seen by its dominance in LMBS 2000-2004 fyke netting (Redman et al. 2005). We have detected a similar pattern with the 2002 year-class. These fish were caught in relatively high abundances as age-0 fish in 2002 and then dominated fyke net and creel survey collections during 2005. These results suggest that a spike in CPE of age-0 yellow perch may be a reasonable indicator of recruitment success. Thus, because CPE levels were higher in 2004 and 2005 than 1998, within a few years the 2004 and 2005 year-classes may appear in our fyke net assessment as we saw with the 1998 and 2002 year-classes. Compared to sampling in the late 1980s (1987 and 1988), current age-0 yellow perch CPEs are extremely low. So even though the 1998, 2002, 2004, and 2005 year classes are measurable, their levels are nowhere near that of the late 1980s; as such, they 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.

In light of these concerns of possible gear avoidance due to water clarity, we compared our bottom trawling to small mesh gill nets to see the effectiveness of each to estimate relative abundance of demersal age-0 yellow perch. We were able to make comparisons between these gears on four occasions between late August and mid-October during 2005. Varying units of effort made direct comparisons between the gears difficult, however some differences were observed in the proportions of yellow perch caught and their size range. At the 10 m site, 17 yellow perch were caught in the bottom trawl and 299 yellow perch were caught in small mesh gill nets. Catches for both gears were higher in 5 meters of water with 1,717 yellow perch collected in the bottom trawl (39 fish/100 m^2) and 972 perch collected in gill nets (243 fish/net night). Comparing lengths of yellow perch in each gear showed that a larger proportion of perch caught in the bottom trawl were age-0 fish (56%) compared to the proportion of age-0 yellow perch caught in small mesh gill nets (23%). Bottom trawling seemed to be more effective at targeting age-0 yellow perch than small mesh gill nets over sandy substrate in 2005. However, more comparisons are needed before we can make definitive conclusions as to the comparable efficiency of these two gears. In addition, analysis of habitat selection by demersal age-0 yellow perch in Lake Michigan has indicated that they prefer rocky substrate to sandy bottom. Janssen and Luebke (2004) reported that the catch rate of age-0 yellow perch in small mesh gill nets at rocky sites was about four times greater than at sandy sites in Wisconsin waters. Thus, small mesh gill nets set over rocky substrate may prove to be more accurate than bottom trawling for estimating the relative abundance of demersal age-0 yellow perch in southwestern Lake Michigan.

Mean zooplankton densities were significantly higher during 1988 in comparison to 1989-1990 and 1996-2005 (Dettmers et al. 2003, Creque et al. 2004, Redman et al. 2005). There does appear to be some consistency in years 1996-1999, where mean densities were around 25-30/L. Mean zooplankton densities from 2001-2004 show a slight increasing trend, but 2005 zooplankton densities decreased from our 2004 estimate and were most similar to 2003. Zooplankton densities in the last four years, although positive from the perspective of food for early life stages of yellow perch, do not reach even half of the densities found during the late 1980s, when the last strong year-classes of yellow perch were produced. The potential relationship between zooplankton density and age-0 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. 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. 1993). Changes in nutrients, such as phosphorus, have also occurred within the lake. Copepod nauplii dominated the nearshore zooplankton assemblage from May to mid-June, however zebra mussel veligers became increasingly abundant and dominated samples during mid-June through August of 2003. 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 complex set of factors that affect yellow perch year-class strength. Alewife predation and competition for food resources may play a role in zooplankton assemblage changes. Temporal variation could explain some of the changes seen in taxonomic composition; however, mean densities differ too much from 1988 to be considered natural variation.

Annual variation in water temperature appeared to have an effect on yellow perch recruitment in nearshore waters of southwestern Lake Michigan. CPUE of age-0 yellow perch in the fall increased with both warming rate and cumulative degree days, suggesting higher recruitment success during warmer years. A combination of biological and physical variables is still being analyzed to determine their relative importance in predicting age-0 yellow perch recruitment based on data collected over a period of 19 years, 1987-2005.

In summary, the fishable yellow perch population in 2005 was dominated by the 2002 and 1998 year-classes. Anglers generally caught a similar age distribution of yellow perch, as compared to subsamples from our fyke nets. Fortunately for the first time in over a decade we have evidence that the Lake Michigan yellow perch population is being supported by more than one year-class. However, poor recruitment during 1999 to 2000 and likely 2003 means that the fishery will rely extensively on the 2002 and 1998 year-classes for at least the next couple years until 2004 and 2005 year-classes recruit into the fishery. Our results still 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.

REPORT OF EXPENDITURES, 2005-2006

	Proposed	Actual
Study 101. Investigate adult mortality, age structure, and factors affecting success of yellow perch during their first year of life		
Job 101.1 Recapture tagged yellow perch	$16,000	$16,000
Job 101.2: Develop angler-caught age distribution and, if possible, sex distribution	$25,000	$25,000
Job 101.3: Quantify index of spawning activity and relative abundance of newly-hatched larvae at nearshore sites	$26,000	$26,000
Job 101.4: Sample pelagic age-0 yellow perch and their food resources in offshore waters	$64,000	$64,000
Job 101.5: Sample demersal age-0 yellow perch and their food resources in nearshore waters	$51,000	$51,000
Job 101.6: Compare two gear types for sampling demersal age-0 yellow perch	$35,000	$35,000
Job 101.7: Evaluate diet and growth of age-0 yellow perch	$23,000	$23,000
Job 101.8: Explore factors regulating year-class strength of yellow perch	$50,000	$50,000
Job 101.9: Data analysis and report preparation	$12,680	$12,680
Total Cost	$302,680	$302,680
Federal Share	$227,010	$227,010
State Share	$75,670	$ 75,670

ACKNOWLEDGMENTS

We wish to thank the permanent and temporary staff of the Lake Michigan Biological Station who assisted with data collection, sample processing, and data entry for this project. We also thank M. Kneuer for her administrative support and assistance in the field.

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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, 1994-2005.

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	2,556	4.0
2001	2,651	10.3
2002	985	3.7
2003	3,271	3.0
2004	2,484	1.9
2005	1,613	6.8

Table 2. Summary of 2005 egg survey dives at US Steel intake over cobble substrate, including viability and developmental stages of egg skeins. Developmental stages are: a = newly fertilized, b = tail forming, c = eyed and developed, d = fully formed and hatching.

Date	Depth range (m)	Transect length (m^2)	No. YP egg skeins	Percent viable	Stage of development
May 25	7-9	200	15	--	--
May 31	7-9	200	15	100	c
June 7	7-9	200	3	--	--
June 13	7-9	200	0	--	--
June 21	7-9	200	0	--	--

Table 3. Total abundance and CPE of the species collected in bottom trawl and small mesh gill nets samples from late August to mid-October 2005 in a) 5 meters and b) 10 meters of water.

a) 5 meters

	Bottom Trawl		Small Mesh Gill Net	
Species	N	CPE (#/100m^2)	N	CPE (#/net night)
Perca flavescens	1,717	38.51	972	243.00
Notropis hudsonius	85	1.91	706	176.50
Osmerus mordax	37	0.83	22	5.50
Alosa pseudoharengus	11	0.25	311	77.75
Etheostoma nigrum	2	0.04	0	0
Coregonus hoyi	1	0.02	3	0.75
Cottus spp.	1	0.02	0	0
Fundulus diaphanus	0	0	2	0.50
Neogobius melanostomus	0	0	2	0.50
Cyprinidae	0	0	1	0.25

b) 10 meters

	Bottom Trawl		Small Mesh Gill Net	
Species	N	CPE (#/100m^2)	N	CPE (#/net night)
Alosa pseudoharengus	0	0	300	75.00
Perca flavescens	17	0.38	299	74.75
Notropis hudsonius	0	0	146	36.50
Osmerus mordax	0	0	19	4.75
Percopsis omiscomaycus	0	0	1	0.25
Gasterosteus aculeatus	1	0.03	0	0
Etheostoma nigrum	1	0.02	0	0

FIGURES

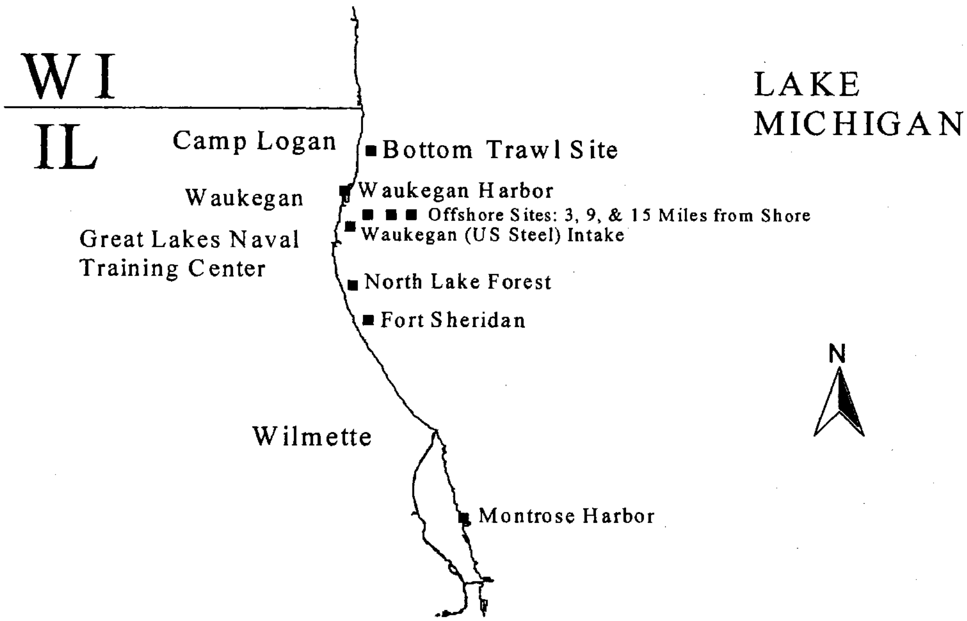

Figure 1. Sampling sites in Lake Michigan during 2005.

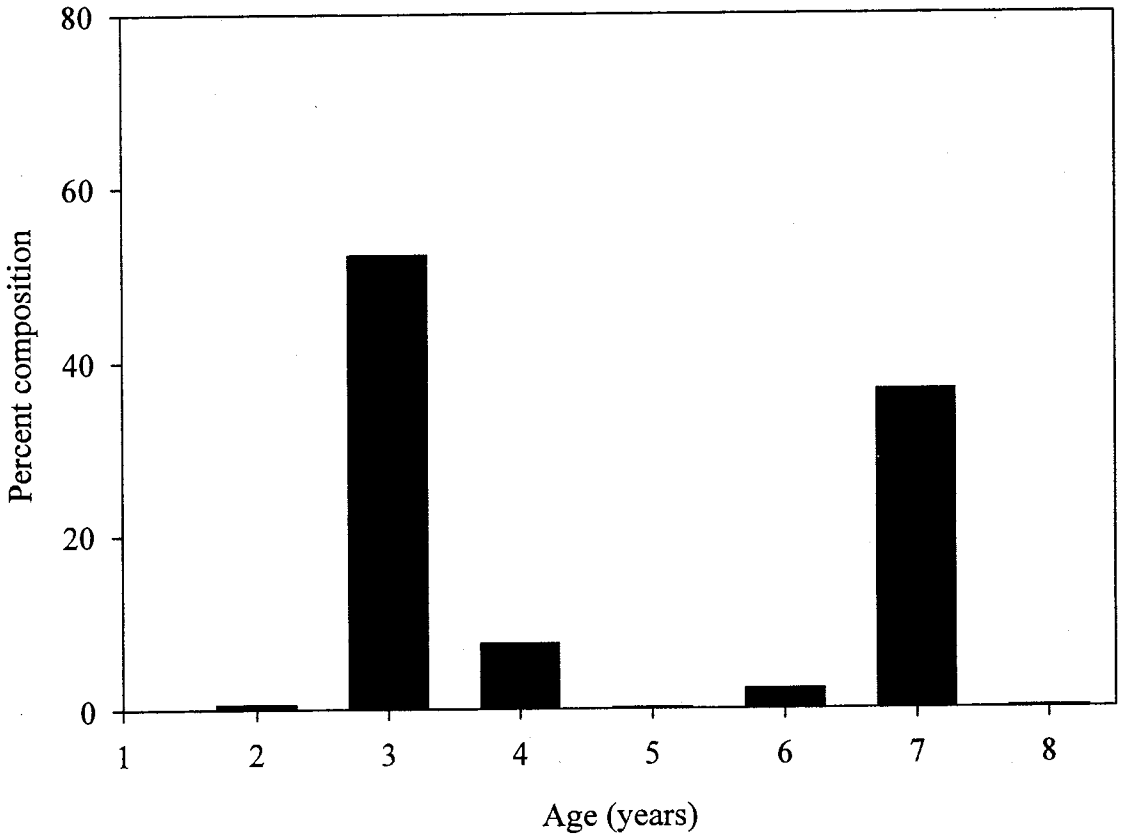

Figure 2. Age composition of adult yellow perch collected between Waukegan and Fort Sheridan, IL during the spring of 2005.

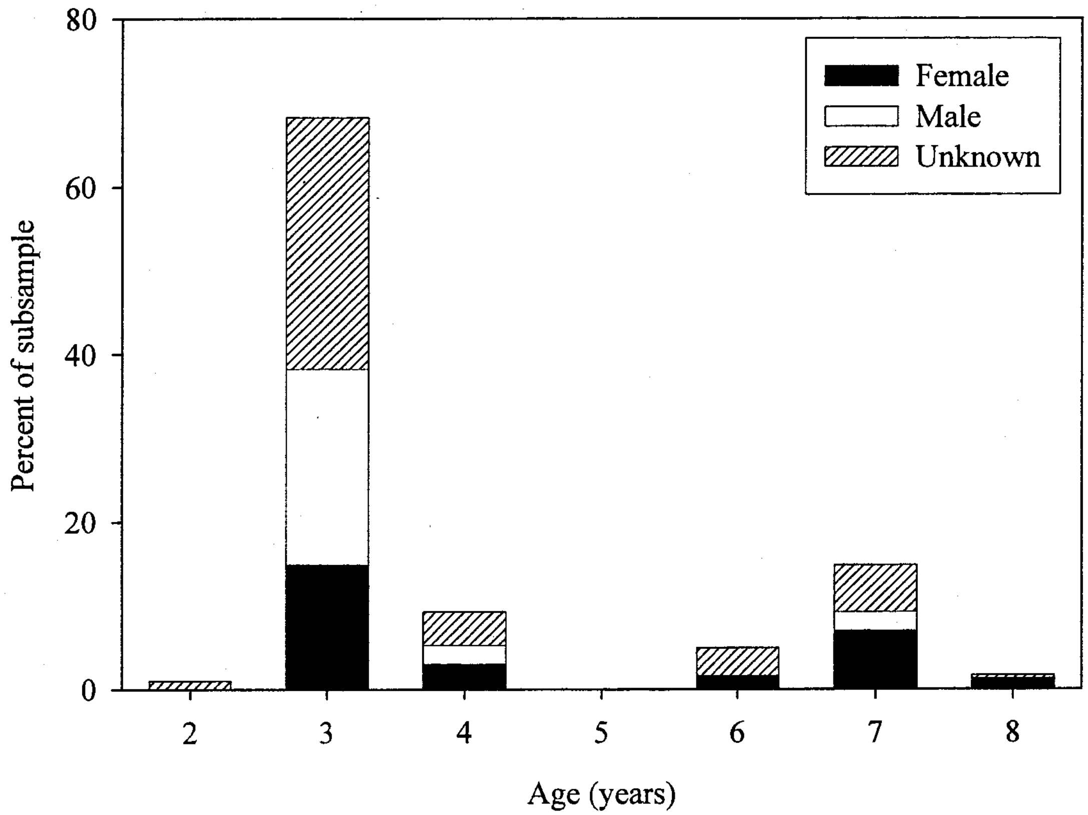

Figure 3. Age and sex composition of adult yellow perch caught by anglers in 2005 at Waukegan And Montrose Harbors, IL.

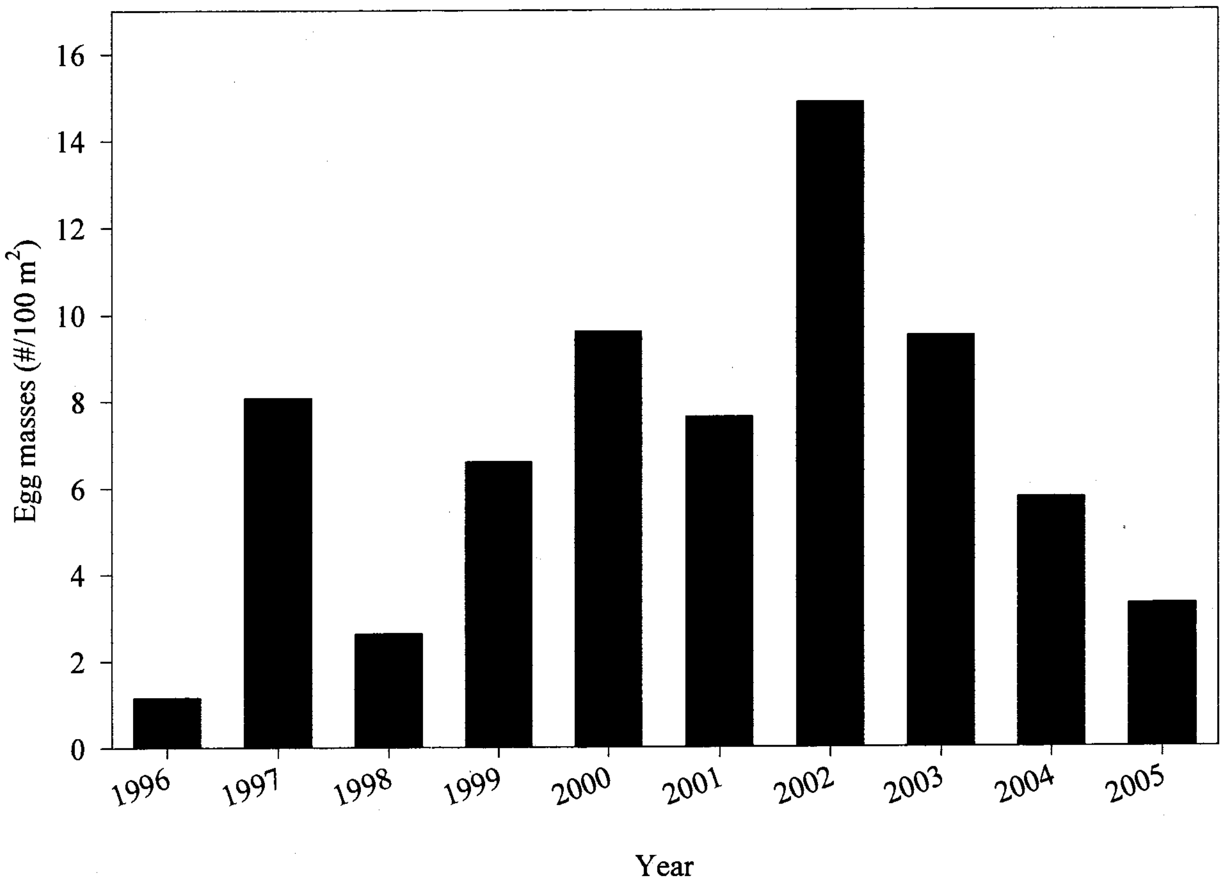

Figure 4. Annual patterns of yellow perch egg production at the US Steel intake for years 1996-2005.

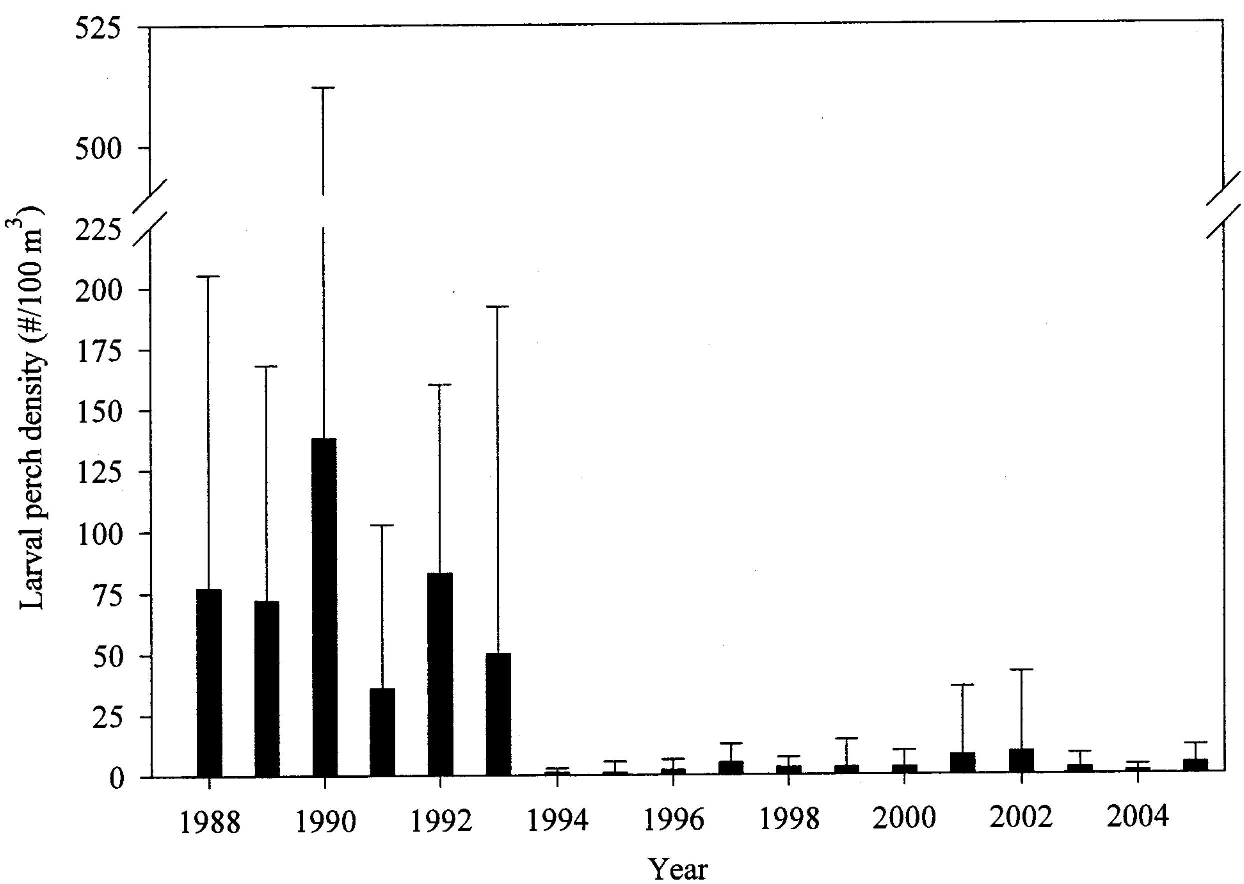

Figure 5. Seasonal mean density of larval yellow perch (+ standard deviation) sampled at two sites near Waukegan Harbor, IL, 1988-2005.

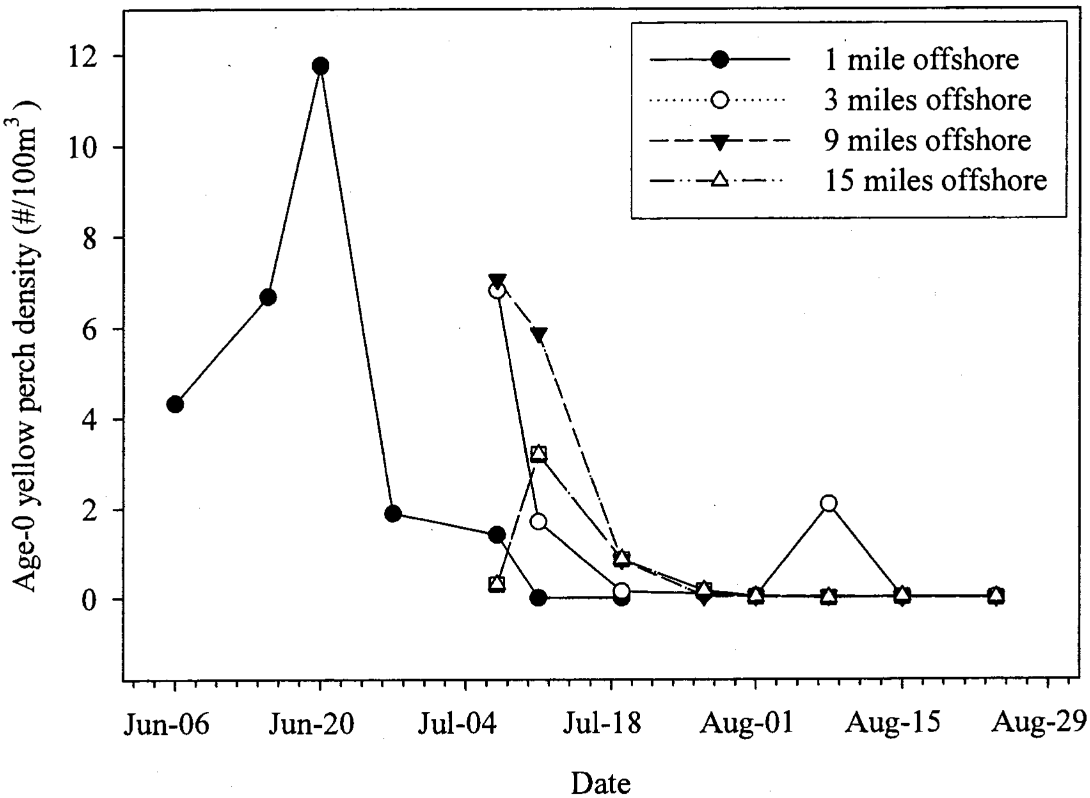

Figure 6. Mean densities of pelagic age-0 yellow perch at all sampling depths along a 15 mile transect north of Waukegan, IL during 2005. The site one mile offshore is in close proximity to nearshore spawning sites and is included for reference.

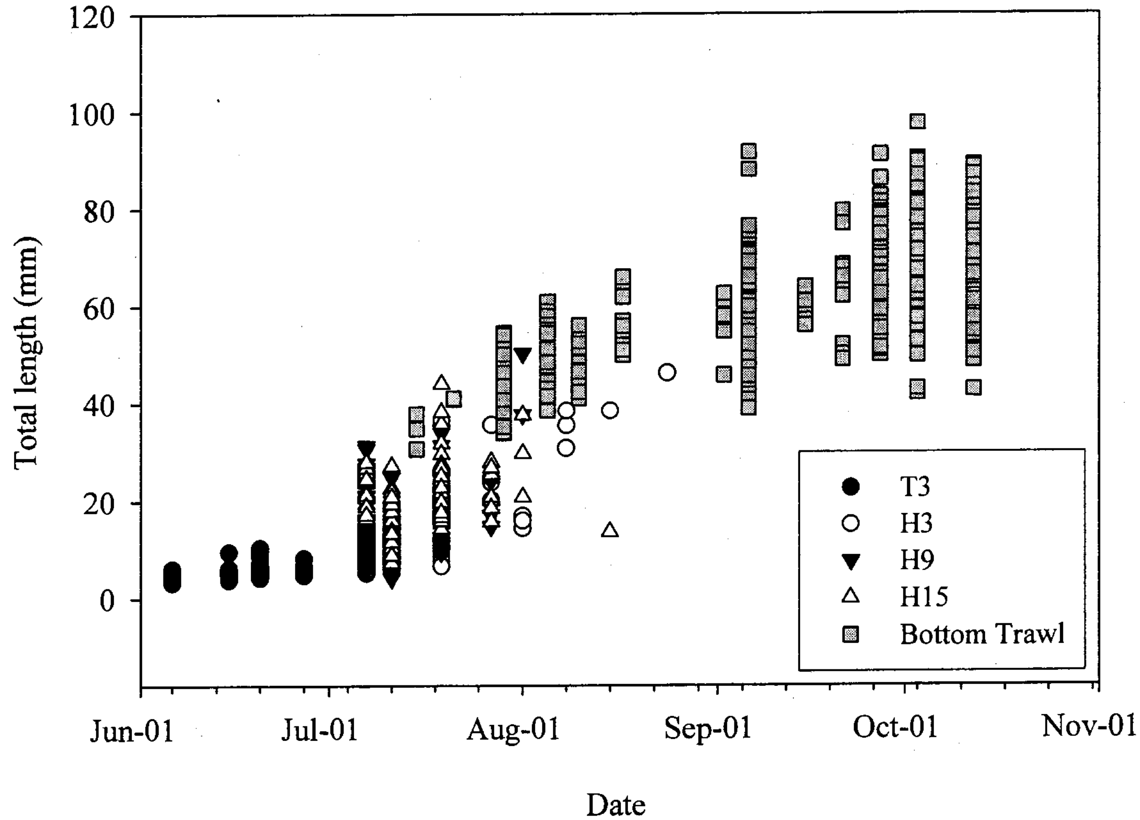

Figure 7. Length distribution of larval and age-0 yellow perch collected in nearshore and offshore waters north of Waukegan, IL during 2005.

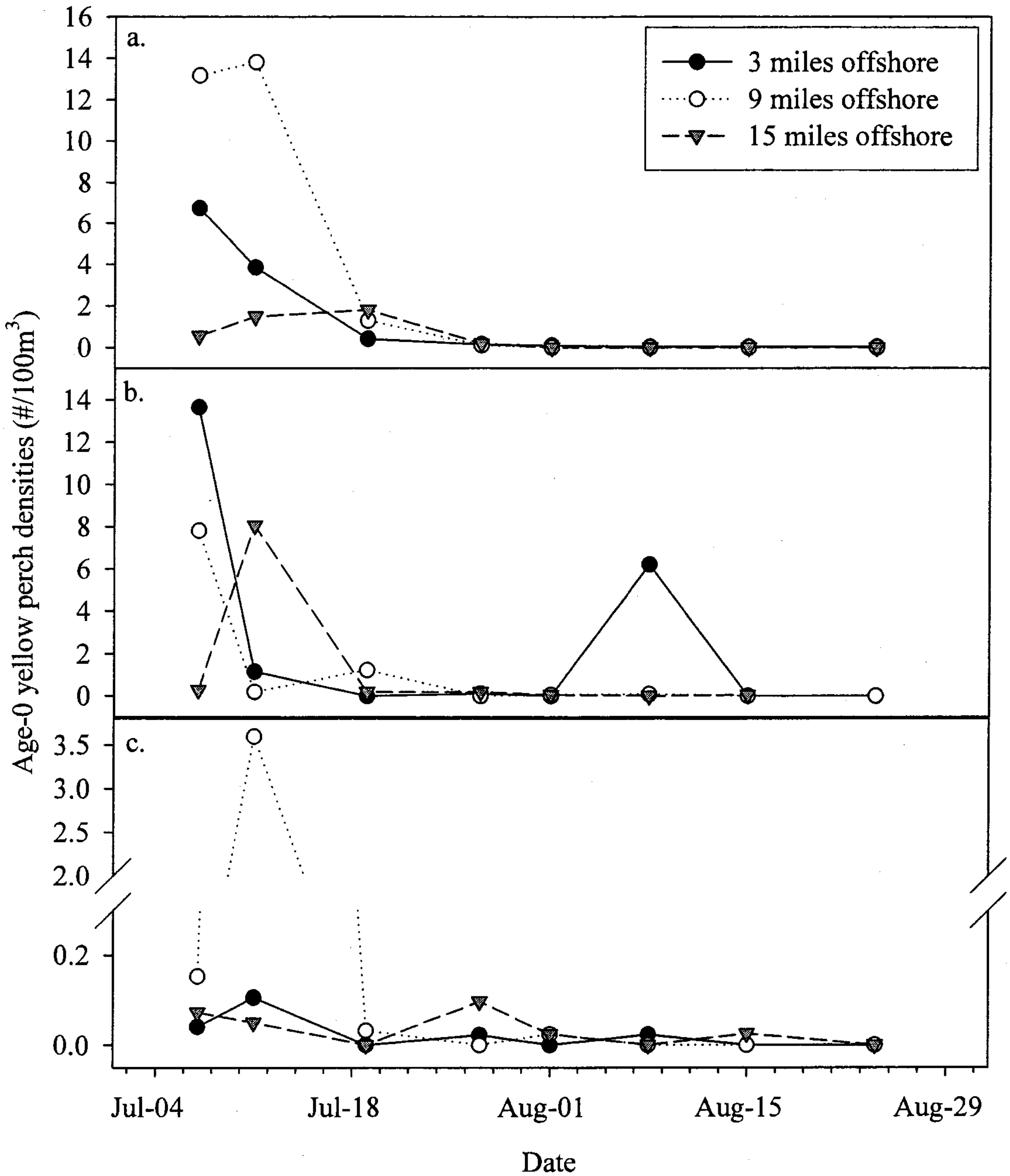

Figure 8. Relative abundance of pelagic age-0 yellow perch collected a) in the surface water, b) in the epilimnion, and c) in the metalimnion along a 15 mile transect north of Waukegan, IL during 2005.

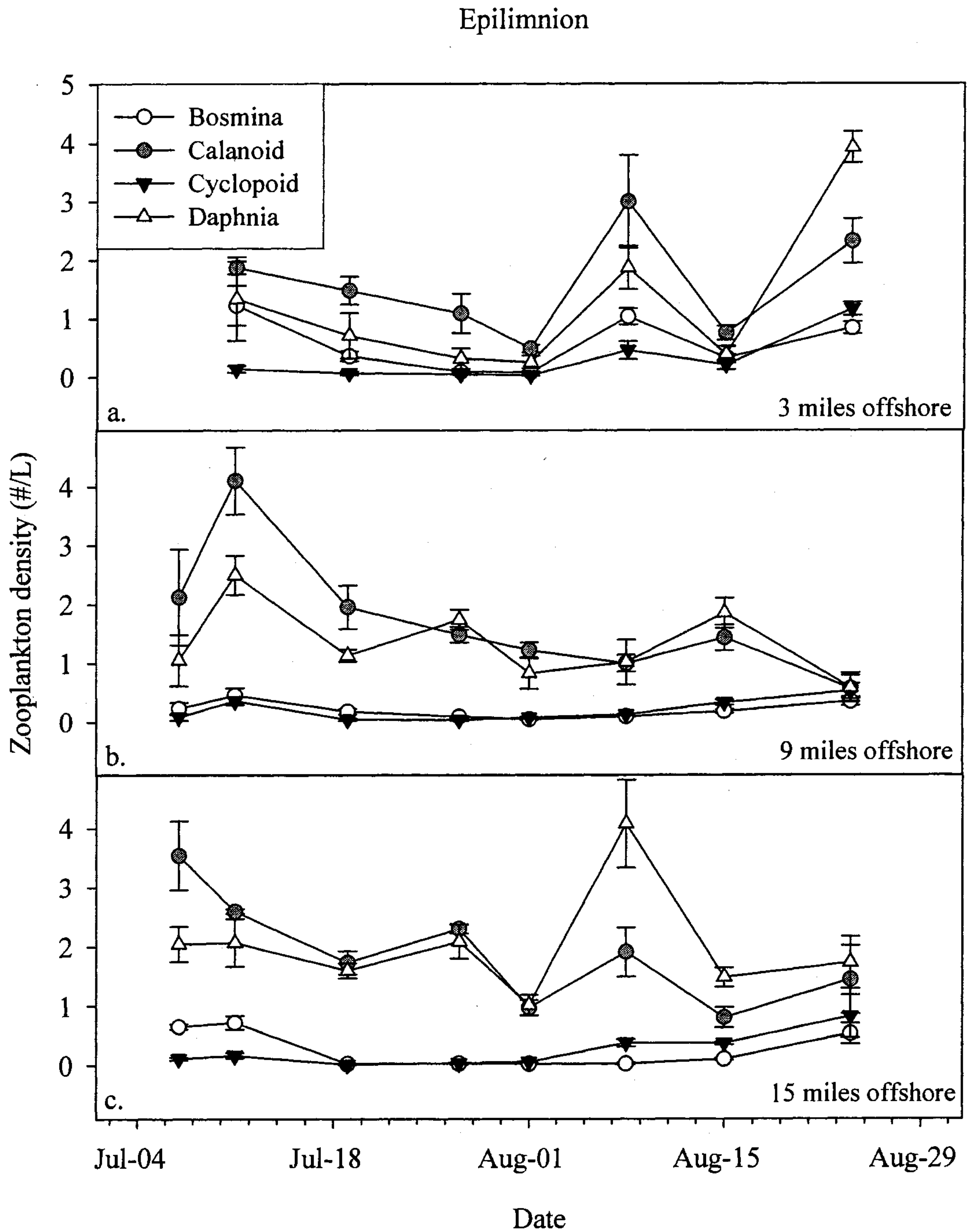

Figure 9. Relative abundance of common crustacean zooplankton collected in the epilimnion at sites a) 3 miles, b) 9 miles, and c) 15 miles offshore during 2005.

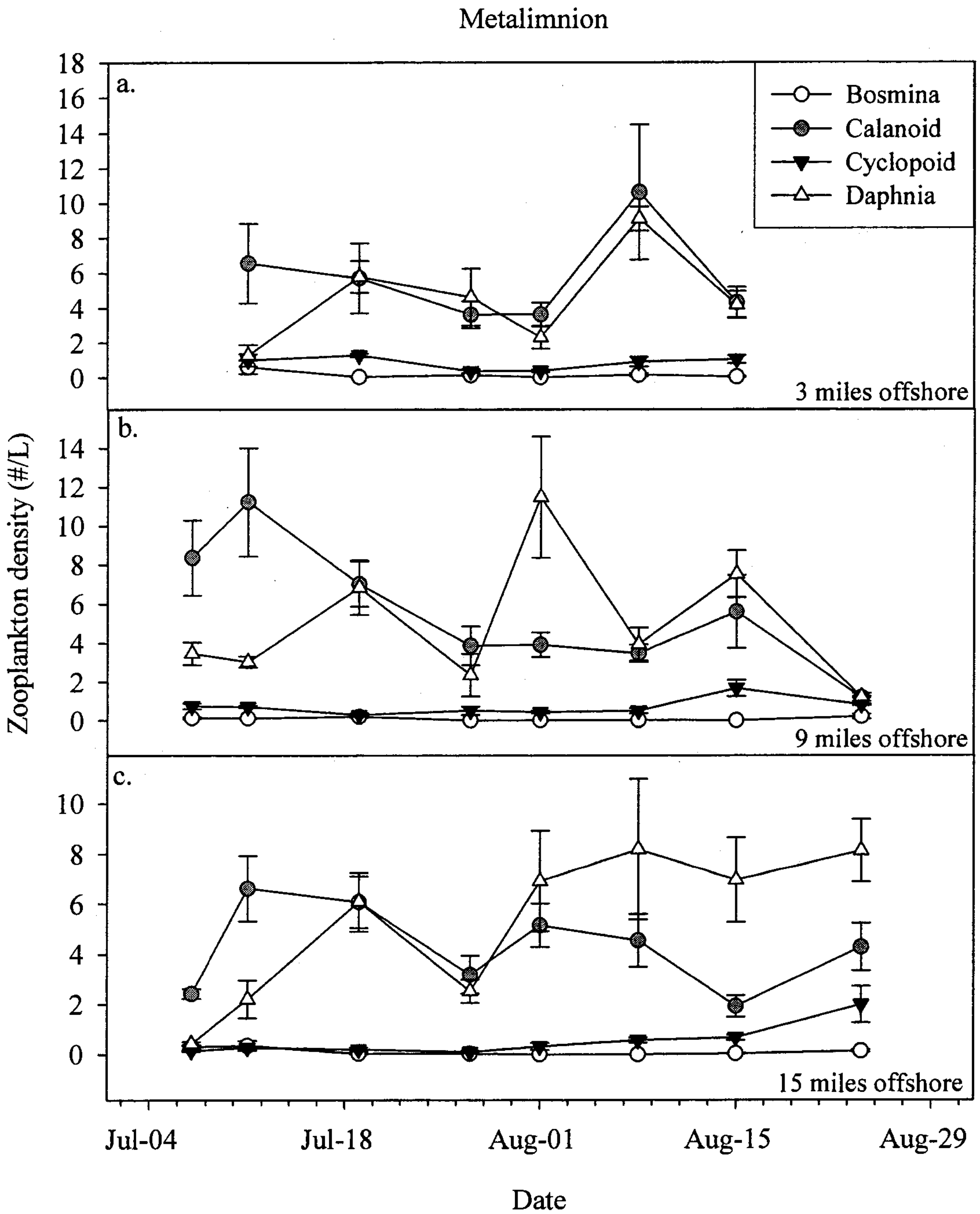

Figure 10. Relative abundance of common crustacean zooplankton collected in the metalimnion at sites a) 3 miles, b) 9 miles, and c) 15 miles offshore during 2005.

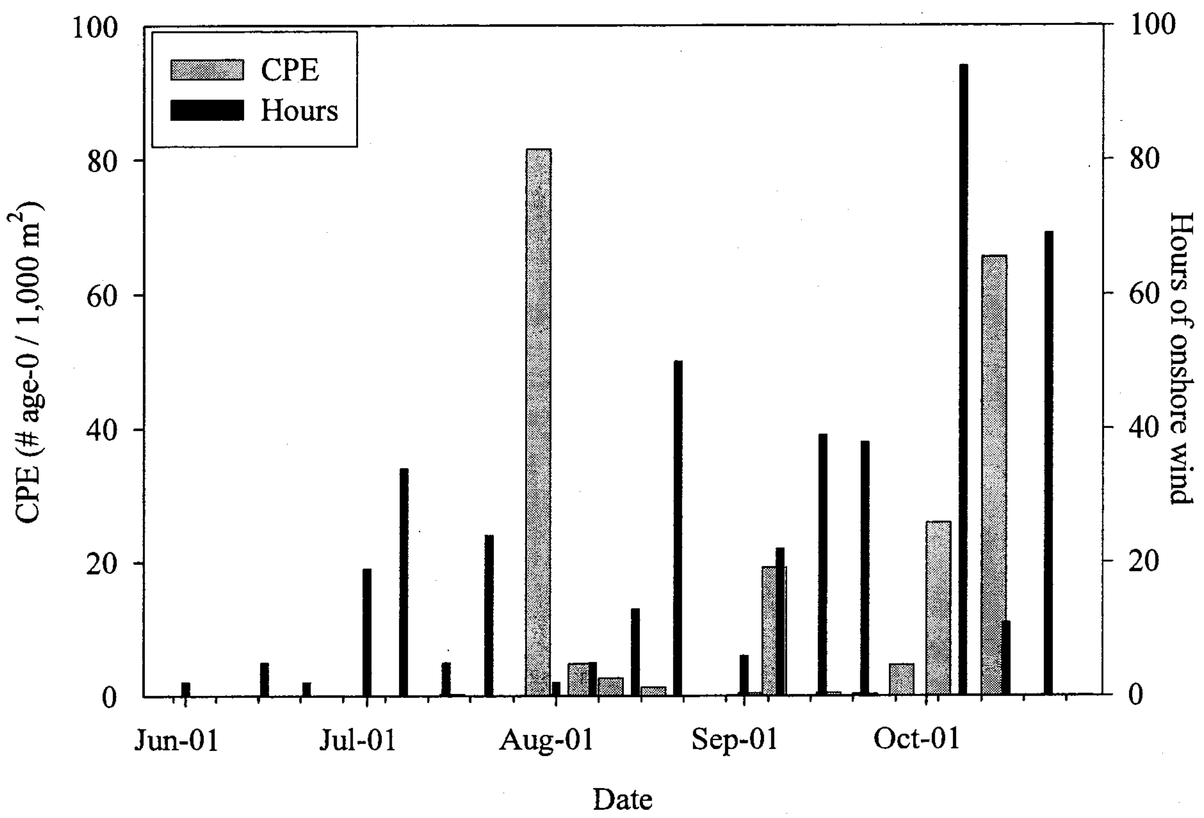

Figure 11. Age-0 yellow perch CPE in nearshore bottom trawl samples (gray bars, left y-axis) and hours per week of onshore wind (black bars, right y-axis) between 10 and 135 degrees with mean wind speed >5 knots during 2005. Bottom trawls were conducted near Waukegan, IL at water depths ranging from 5–10 m. Wind data was gathered from the mid-Lake Michigan weather buoy located in the southern basin.

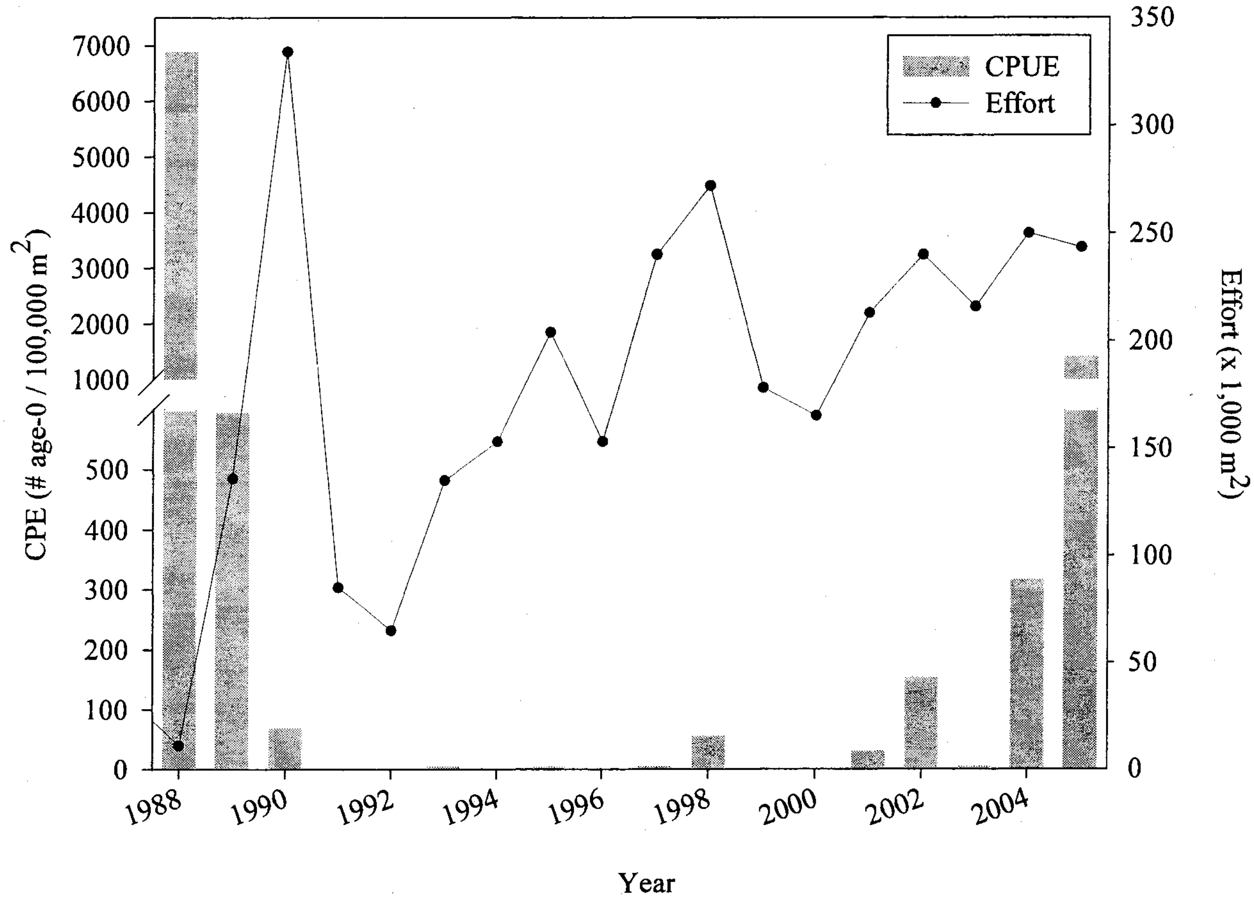

Figure 12. Relative abundance of age-0 yellow perch collected by daytime bottom trawls in 3 – 10 m of water north of Waukegan Harbor, IL, 1988-2005.

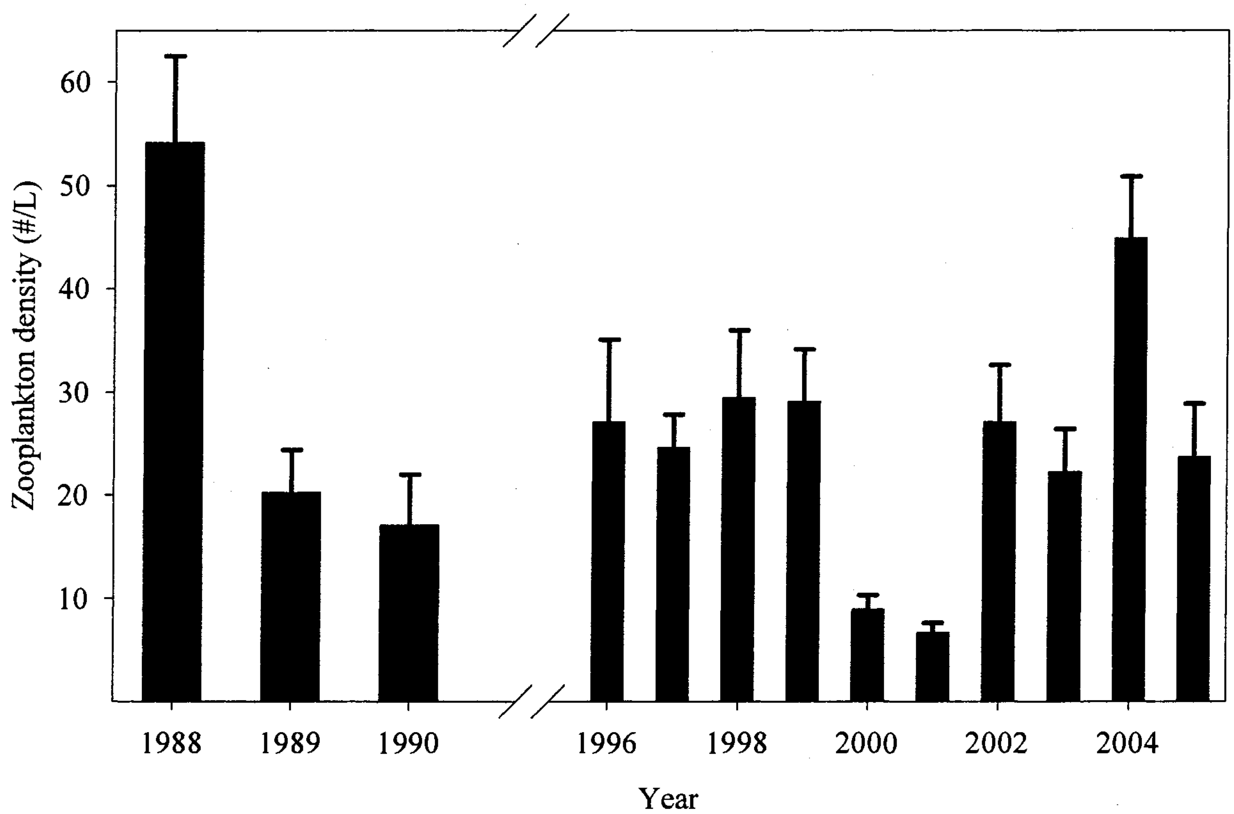

Figure 13. Mean density of zooplankton (+ 1 SE) present in Illinois waters of Lake Michigan near Waukegan during June-July for years 1988-2005.

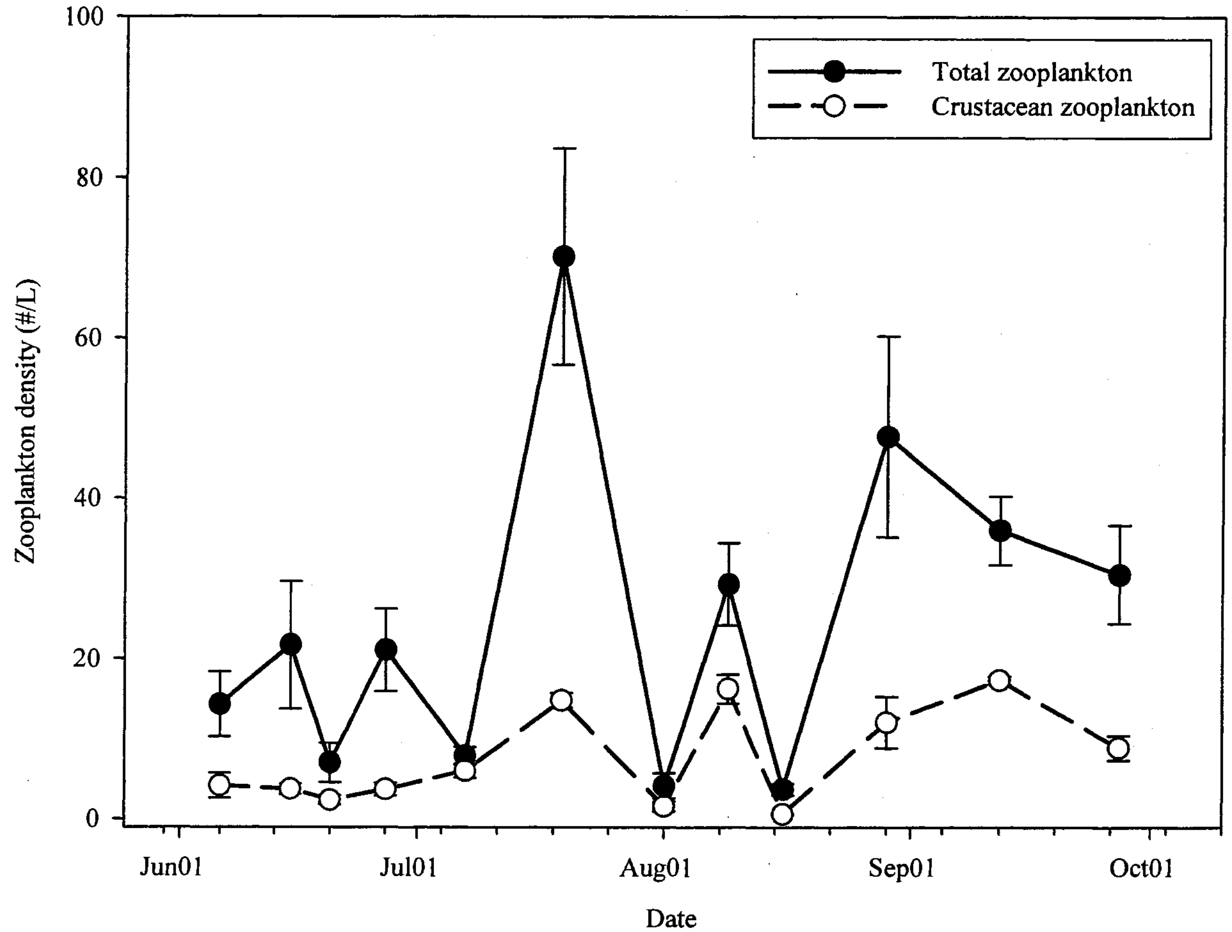

Figure 14. Mean density by date of zooplankton (± 1 SE) present in nearshore Illinois waters of Lake Michigan around Waukegan during June-September 2005. Closed circles (●) represent total zooplankton, whereas open circles (○) represent crustacean zooplankton.

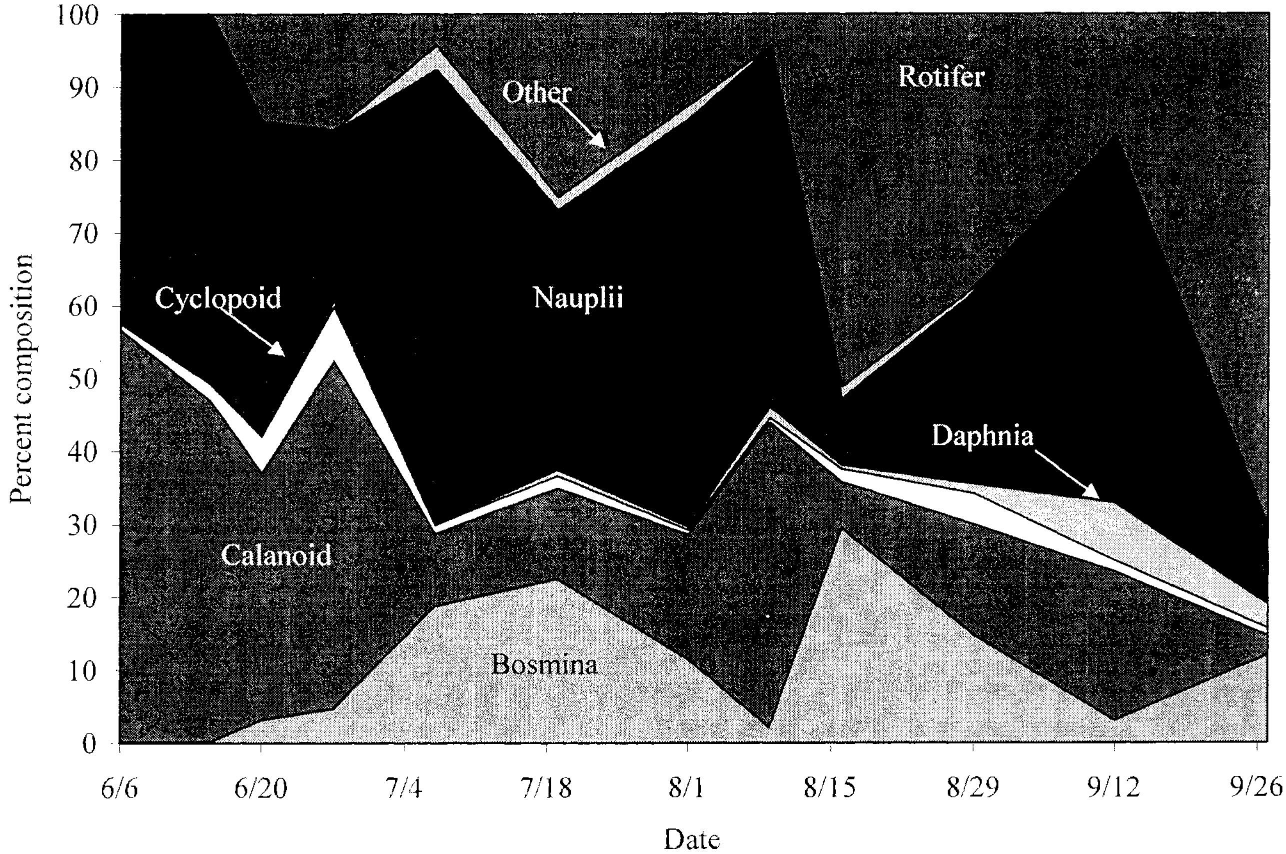

Figure 15. Percent composition of zooplankton found in nearshore Illinois waters of Lake Michigan near Waukegan during June-September 2005.

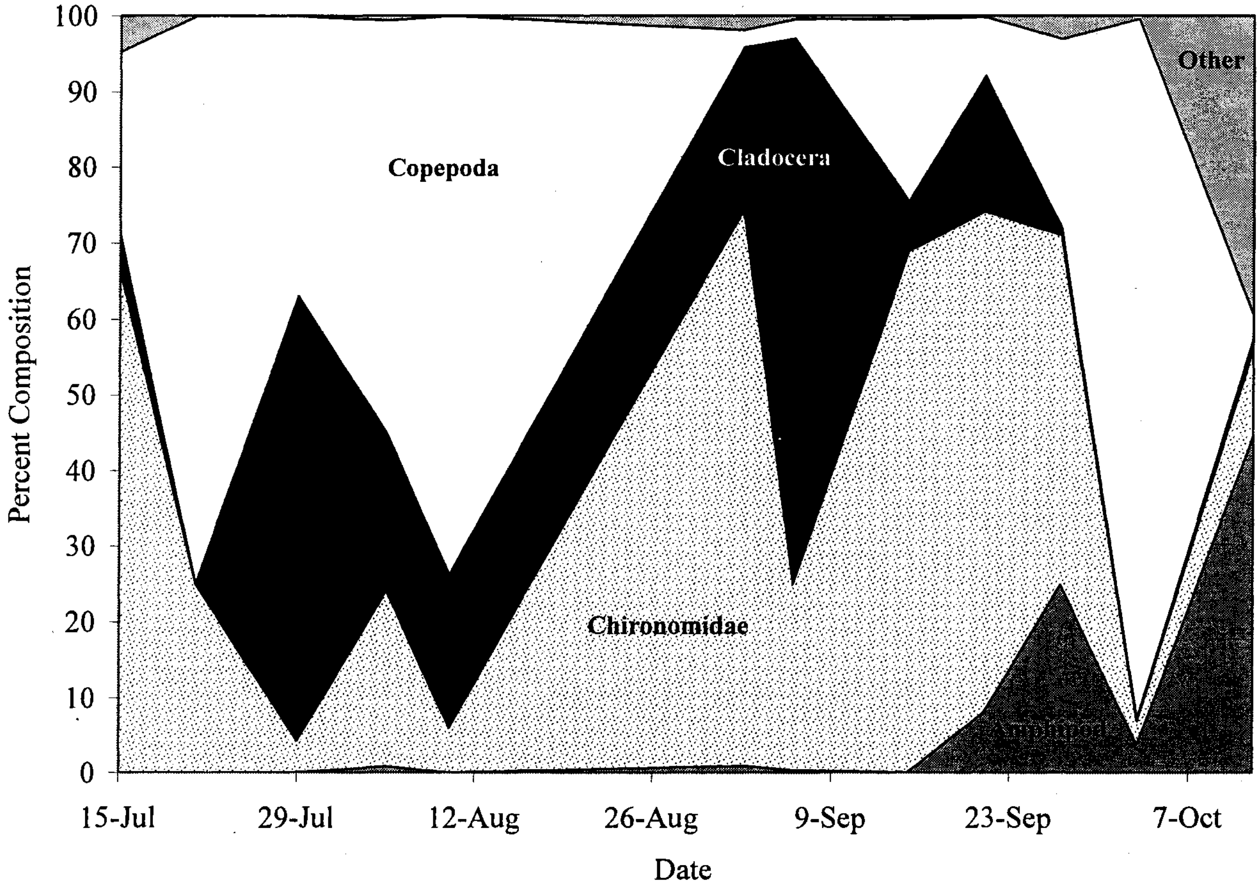

Figure 16. Percent composition by numbers of items found in the diets of age-0 yellow perch collected with bottom trawls north of Waukegan Harbor, IL between July 15 and October 12, 2005.

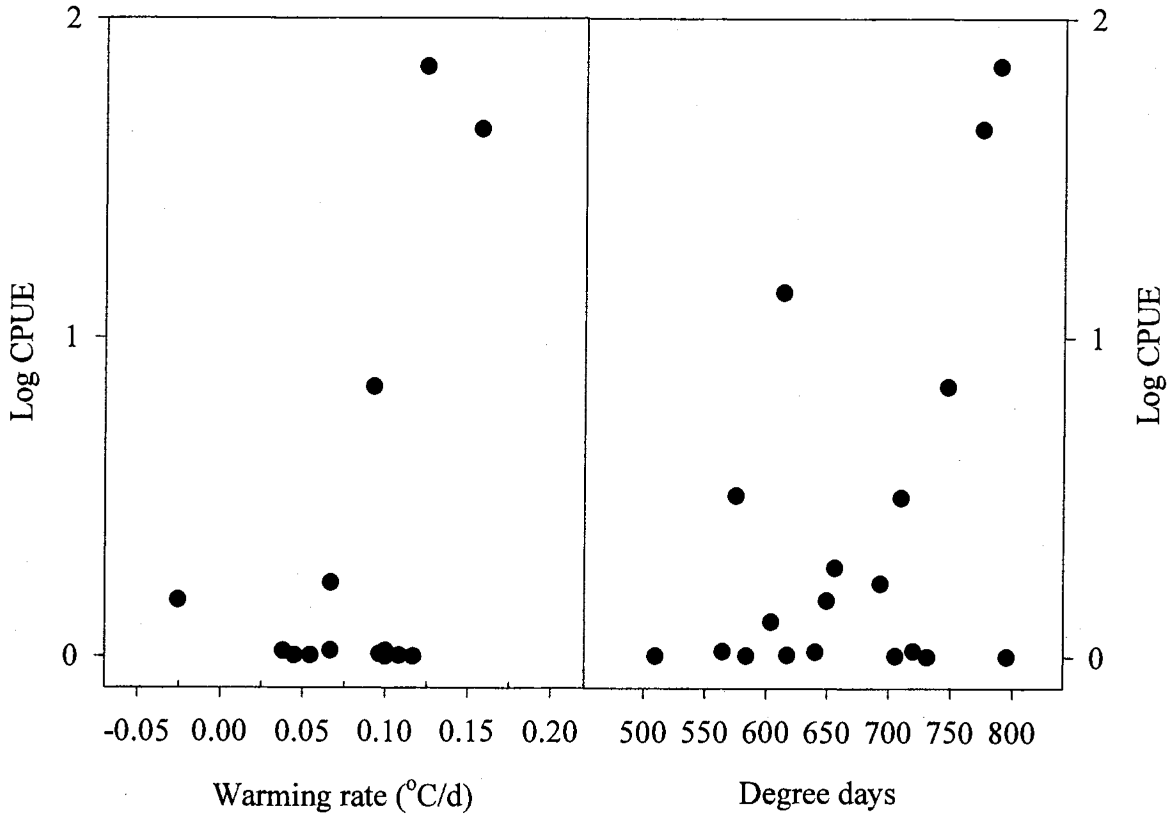

Figure 17. Relations between age-0 yellow perch CPUE in the fall and warming rate ($P = 0.03$, $r^2 = 0.25$) and cumulative degree days ($P = 0.04$, $r^2 = 0.23$) in southwestern Lake Michigan during May and June of 1987 – 2005.

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