

**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**

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Rebecca A. Redman, Sergiusz J. Czesny, John M. Dettmers, and Daniel Zapf

Division of Ecology & Conservation Science, Illinois Natural History Survey

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Sergiusz Czesny, PI
Division of Ecology &
Conservation Science

Michael Douglas, Director
Division of Ecology &
Conservation Science

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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 densities of age-0 yellow perch cohort, and identify some of the factors likely to have limited yellow perch recruitment since 1989. We sampled adult yellow perch during the spring to assess the reproductive potential and age and size structure of the spawning population. Anal spines were collected from yellow perch at two known angling sites and analyzed to determine the angler-caught age distribution in 2007. Age-0 yellow perch were sampled at multiple depths and distances from shore with neuston nets, a mid-water 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 continued to evaluate factors that might regulate yellow perch year-class strength.

The results of this project will enable fish managers to develop effective management strategies for this important native sport fish. 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 2007 sampling associated with our study objectives.

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

Job 101.1 Improve annual assessments of the yellow perch spawning population

1. Age-2 thru age-5 fish each made up about 20% of yellow perch collected in fyke nets during spring 2007. The 1998 year class (age-9) comprised only 13% of the catch.
2. A majority of yellow perch collected in gill nets were age-5 (45%). Age-9 fish made up 25% of our catch and age-4 fish comprised 19% of the catch.

Job 101.2 Develop angler harvested age distribution and, if possible, sex distribution

1. The majority of angler harvested yellow perch from our creel survey in 2007 were age-5 (38%) and age-4 (33%).
2. The sex of 88% of the fish collected could not be determined due to lack of angler approval to open the body cavity.

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

1. Divers only found 4 egg skeins during surveys at the US Steel intake line between 29 May and 26 June 2007. Overall mean density of egg skeins was less than 1 egg skein per 100m².

2. Overall, catches of larval yellow perch in nearshore waters were relatively poor like they have been for more than a decade. However, mean weekly density of larval yellow perch peaked on June 13, 2007 at 15.1 ind./100 m³ and was the highest mean weekly density reported in several years.

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

1. Only 36 pelagic, age-0 yellow perch were collected in offshore samples during 2007. Average offshore densities ranged from 0 to a peak of 0.30 ind./100 m³; densities were typically higher in surface water samples compared to samples within the epilimnion.
2. In general, calanoid copepods and daphnia dominated the crustacean zooplankton assemblage in the epilimnion, while densities of cyclopoid copepods and bosmina remained very low in offshore waters during 2007.

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

1. CPUE of age-0 yellow perch north of Waukegan Harbor was 28 ind./100,000 m².
2. Mean June-July total zooplankton density in 2007 was 11.6 ind./L. Crustacean zooplankton densities remained low (< 7 ind./L) during June and July and then peaked around 13 ind./L on August 7 and September 19.
3. Mean annual benthic invertebrate density for a site north of Waukegan Harbor was 4,214 ± 6,338 ind./m² (SD) in 2007. The most common taxa were mollusks, chironomids, ostracods, and Oligochaetes.

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

1. A subset of our bottom trawling effort was used to compare the effectiveness of this gear and small mesh gill nets to catch age-0 yellow perch north of Waukegan Harbor, IL. Six paired comparisons between a bottom trawl and gill net were conducted at the same location between August 17 and October 3, 2007. Only 7 yellow perch, 6 of which were age-0, were collected in the trawl during these sampling occasions, while 95 age-0 perch were collected in gill nets. 41% of yellow perch collected in gill nets were age-1 or older based on length.
2. The relationship between CPUE of age-0 yellow perch from bottom trawling and small mesh gill nets was best described by the equation Gill net CPUE = 4.567 + 4.420 [log (Trawl CPUE)], r² = 0.36, P = 0.0004.

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

1. Stomachs of 56 age-0 yellow perch collected by bottom trawls were examined in 2007. Yellow perch of this age consumed primarily zooplankton and benthic invertebrates.

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

1. Based on regression analysis and Akaike's information criterion, an index of offshore transport, spring-summer water temperatures, spawning stock abundance, and an index of larval yellow perch prey availability explained 76% of the variation in annual fall CPUE of age-0 yellow perch near Waukegan, IL during 1987-2006. Examination of studentized residuals for the global model showed that the recruitment estimate from 2005 was an influential outlier (st. res. = 3.22).
2. The index of larval yellow perch prey availability was the most influential variable on yellow perch recruitment of the five variables examined. This variable appeared in 9 of the 10 top-ranked models and had the highest Akaike variable weight ($w_i = 0.96$).

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 nearshore 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 (Marsden and Robillard 2004). Few or no young-of-the-year (YOY) yellow perch were found in lakewide sampling efforts during 1994-1997 (Hess 1998), but significantly greater survival of the 1998 year class occurred. The 1998 year class dominated Lake Michigan Biological Station (LMBS) spring adult assessments between 2000 and 2004 (Creque et al. 2004). During this period, LMBS trawling efforts detected moderate year-class strength during 2002 and 2004 (Creque et al. 2004, Redman et al. 2005). Fortunately in 2005, the age structure of yellow perch began to shift towards younger fish so that 52% of the catch was age-3 (2002 year class) and the 1998 year class (age-7) only contributed 37% of the catch (Redman et al. 2006). In addition, age-0 CPUE from trawling assessments during 2005 was the highest recorded in Illinois waters since 1988. Hopefully, these and future year classes will help replace the declining 1998 year class and shift the population to a more stable condition.

To protect yellow perch stocks, fisheries managers should set harvest targets in accordance with fluctuating population sizes. However, the ability to successfully set these harvest targets for yellow perch is hampered by insufficient information about population size, natural mortality, movements, reproductive potential, and especially factors that determine year-class strength (Clapp and Dettmers 2004). The continued decline of the yellow perch population due to reduced survival of larvae to the age-0 stage has prompted researchers to narrow the focus of investigation to spawning behavior and success along with age-0 interactions and survival. Reproductive potential influences the ability of the population to respond to external forces such as overfishing or environmental fluctuations. Thus, accurate estimates of fecundity and knowledge of how reproductive potential varies over the life of yellow perch in Lake Michigan are crucial to the preservation of this species. Fecundity (Brazo et al. 1975) and egg quality (Heyer et al. 2001) have been shown to increase with age in yellow perch. Additionally, marine larvae produced by younger spawners have been shown to experience higher mortality than larvae produced by older, more experienced spawners (O'Farrell and Botsford 2006). Thus, estimates of reproductive potential based on biomass estimates alone risk oversimplifying and overestimating reproductive output. 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. Larval yellow perch in Lake Michigan 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 our 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. 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. *Daphnia retrocurva* dominated the daphnid community in nearshore waters of southern Lake Michigan during 1972–1984, but huge declines in abundance occurred following the invasion of *Bythotrephes cederstroemi* in 1986 (Madenjian et al. 2002, Barbiero and Tuchman 2004). Declines in several other cladoceran species, such as *Eubosmina coregoni*, *Daphnia pulicaria*, and *Leptodora kindti*, have also been attributed to the invasion of this predatory cladoceran (Makarewicz et al. 1995, Barbiero and Tuchman 2004). Additionally, we evaluated in earlier studies 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. Thus, the status and composition of the zooplankton community in both nearshore and offshore waters of Lake Michigan greatly impacts the recruitment success of yellow perch.

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

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

Job 101.1: Improve annual assessments of the yellow perch spawning population

Objective: Monitor the age and size structure of the spawning population and evaluate the reproductive potential.

We collected adult yellow perch between May 29 and June 12 at three sites (Waukegan, Lake Forest, Fort Sheridan; Figure 1) using both fyke and gill nets. We deployed 4 x 6-ft double-ended fyke nets with a 100-ft leader between two double-throated pots and monofilament gill nets consisting of 100-ft panels of 2.0, 2.5, 3.0, and 3.5-in stretch mesh. Fyke nets were set along the 5-m depth contour line, parallel to shore, and were fished on 4 occasions for approximately 24 hours. Gill nets were set between 5-10 m of water on 3 occasions and fished for 24 hours. We kept subsamples of yellow perch from both gears and processed them in the laboratory to allow analysis of the size and age structure of the spawning population. Ovaries were also removed from mature females collected between May 21-23, 2007. All eggs were weighed before a 1.0 g subsample of eggs was counted. We estimated fecundity of a female by multiplying the number of eggs within a 1.0 g subsample times the total weight of eggs taken from the ovary.

Job 101.2: Develop angler harvested 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.

We collected anal spines from up to 25 fish at two known yellow perch angling areas (Waukegan and Montrose Harbors, IL; Figure 1). Spines were collected weekly between May 1 and August 15, except during July when yellow perch harvest was closed. The sex of each angler-caught yellow perch was also determined by either external or internal inspection. Anal spines were aged in the laboratory to determine the angler-caught age composition of yellow perch in 2007.

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.

We counted egg skeins 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). In an effort to avoid recounting egg skeins during subsequent diver surveys all egg skeins were collected and transported shoreward at least 100 m of the survey transect. Viability and development of egg skeins was determined by taking a subsample of each egg skein back to the laboratory and assessing eggs under a microscope. Newly-hatched larval perch were sampled using a 2-m x 1-m neuston net with 500- μ m 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 preserved in the field with 95% ethanol and sorted according to species, enumerated, and measured in the laboratory.

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 between 3 and 15 miles offshore.

Pelagic age-0 yellow perch and zooplankton were sampled at three stations between 3 and 15 miles offshore of 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. Sampling was conducted weekly, weather permitting, during July and August at the nine and fifteen mile stations and during August at the three mile station. Past sampling efforts have shown that densities of pelagic age-0 perch drastically decline offshore during late July and yellow perch have rarely been detected in offshore waters after mid-August (Redman et al. 2005). However during 2005, a few perch were detected three miles from shore after the typical disappearance of fish from offshore waters, indicating these fish may have been moving back towards shore (Redman et al. 2006). Thus, our sampling efforts at the three mile station during 2006 and 2007 were focused on the time period when perch might be detected moving back inshore.

At each station, fish and zooplankton samples were taken within the epilimnion along with water column temperature 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 within the epilimnion using a multi-net, opening/closing 1-m x 1.4-m mid-water Tucker trawl, both equipped with 1000- μ m nitex mesh nets. Nets were switched to 1800- μ m nitex mesh as fish size increased to reduce gear avoidance. Fish were preserved in the field and sorted according to species, enumerated, and measured in the laboratory.

Replicate zooplankton samples were collected within the epilimnion at depths corresponding to larval fish sampling using a 0.5 m diameter, 64- μ m, closing zooplankton net.

Zooplankton samples were taken at the beginning of each larval fish trawl transect. Mean volume of water filtered in each vertical lift was 2.0 m³. Water temperatures were recorded at depths corresponding to larval fish and zooplankton sampling using a YSI meter (Sonde 6600). 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 weekly, weather permitting, at four depth stations (3, 5, 7.5 and 10 m) from August 1 through October 9, 2007. All sampling occurred north of Waukegan Harbor, at a speed of approximately 2 m/sec (Figure 1). An area of approximately 4,460 m² of the lake bottom was sampled for each 0.9-km (0.5 nautical miles) transect. All fish collected were counted and total length was measured to the nearest 1 mm for a subsample (30 individuals per species) of fish. Age-0 yellow perch were counted and frozen for later examination of stomach contents.

Zooplankton in 2007 was generally sampled weekly from May 30 through October 9 on the same nights as larval fish collections during June-July. A 64- μ m mesh, 0.5-m diameter plankton net was towed vertically from 0.5 m off the bottom to the surface at 10 m depth sites. Mean volume of water filtered in each vertical lift was 1.8 m³. 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- μ m mesh net at depths ranging from 8-10 m. Dettmers et al. (2003) conducted paired zooplankton samples using the 64- μ m and 153- μ m mesh nets to determine whether the switch in sampling gear influenced zooplankton densities. Based on these comparisons it was determined that the density of crustacean zooplankton was lower in the 153- μ m mesh net. Thus, conversion factors were calculated and used to correct zooplankton densities from years when the 153- μ m mesh net was used (1988-1990) to allow direct comparison of data across years (Dettmers et al. 2003). 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). Samples were collected once a month from June thru September. In the lab, samples were sieved through a 363- μ m 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 gill nets are as effective as a bottom trawl 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 for 2-4 hours (Figure 1). A subset of the bottom trawling for Job 101.5 was used for this gear comparison; 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-ft 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 sets 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. CPUE of age-0 yellow perch from bottom trawling was calculated as number of age-0 perch per 1,000 m² and CPUE from small mesh gill nets was represented as the number of age-0 perch caught per hour. Simple linear regression analysis was used to investigate the relationship between CPUE of age-0 fish for each gear type in an effort to establish a method for comparing data from these two sampling techniques. CPUE of age-0 perch from bottom trawling efforts was log transformed to comply with normality assumptions. CPUE of age-0 yellow perch for both gear types from 2005, 2006, and 2007 sampling efforts were used in the analysis to increase the number of observations.

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 2007 were frozen for stomach analysis. Prior to dissection, total length (mm) and weight (g) were recorded. 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 evaluated the importance of three biological (spawning stock abundance, pre-spawn adult perch prey availability, and larval yellow perch prey availability) and two environmental factors (offshore transport index and spring-summer water temperatures) on yellow perch recruitment in Lake Michigan. We used annual age-0 (≤ 80 mm TL) yellow perch CPUE from fall bottom trawling efforts in Illinois waters north of Waukegan Harbor as an indicator of recruitment success for years 1987 to 2006 (see collection methods from Job 101.5). Spawning stock abundance and spring alewife (*Alosa pseudoharengus*) abundance were based on annual catches of adult yellow perch and alewife from IDNR gill net assessments conducted during

1986-2006. Yellow perch spawning stock abundance was calculated as total CPUE (fish/30.5m/night) from all mesh sizes fished in a given year. To calculate an index of pre-spawn yellow perch prey abundance for a year class hatched during year i we used alewife CPUE (fish/30.5m/night) from 38mm mesh panels in year $i-1$. Yellow perch in Lake Michigan consume large quantities of alewife (Truemper and Lauer 2005). Thus, it is possible that spring alewife abundance could be a reliable indicator of yellow perch females' condition for spawning that year and have a greater impact on yellow perch recruitment than an index of alewife predation on larval yellow perch. Calculation of prey availability for newly hatched larval yellow perch was difficult because a complete series of observations on nearshore zooplankton density was unavailable (Dettmers et al. 2003). Instead, we used a data series of chlorophyll concentration (mg/m^3) measured from surface water collections at a nearshore site 5.6 km south of Milwaukee, Wisconsin (M. Welling, personal communication, 2007). For details on sampling methodology refer to MMSD (2001). The larval yellow perch prey index was calculated as mean chlorophyll concentration from samples collected from June-August in a given year during 1987-2006.

To calculate an index of spring-summer water temperatures that yellow perch were exposed to during their first summer in the lake, we used a combination of average daily nearshore and offshore water temperatures based on timing of yellow perch spawning, hatching, and larval movements between nearshore and offshore waters. Based on diver surveys for egg skeins and nearshore larval fish sampling near Waukegan, Illinois during 1996-2006, yellow perch typically inhabit nearshore waters in either embryonic or larval form between May 1 and June 23 (Dettmers et al. 2005, R. Redman, unpublished data). Thus, nearshore temperatures monitored by Zion Water Plant, Illinois were used to calculate cumulative degree days for this time period. Offshore water temperatures from the National Ocean and Atmospheric Administration (NOAA) weather station 45007 (80 km ESE of Milwaukee, WI) were used to calculate cumulative degree days between June 24 and August 5, the time period when age-0 yellow perch are typically found at least 5km offshore (Dettmers et al. 2005, Miehl, unpublished data, Weber, unpublished data). We then generated the water temperature index by summing nearshore and offshore cumulative degree days from the above mentioned time periods for a given year.

Hourly wind data from NOAA weather station 45007 was used to calculate an index of wind-induced offshore transport of larval yellow perch. We used wind speed and direction during July, because this is when most offshore movement of larval yellow perch occurs (Dettmers et al. 2005). This index was calculated as the total number of at least two consecutive hours when wind speed was greater than 10 km/hr and wind direction was from 225-330°. Wind speeds above 10 km/hr are associated with surface water movement and creation of upwelling and downwelling events in large lakes (Alto and Newsome 1993).

We analyzed variation in yellow perch recruitment with respect to variables discussed above using multiple regression analysis along with an information-theoretic approach based on Akaike's information criterion [(AIC), Burnham and Anderson 1998]. An information theoretic approach allows for identification of multiple competing models that may explain variation in data equally well instead of relying on one "best" model (Burnham and Anderson 1998; Whittingham et al. 2006). All possible models were assessed based on second-order AIC values (AIC_c , corrected for small sample size), Δ_i ($AIC_i - AIC_{\min}$, where AIC_{\min} is the smallest AIC_c value among the models), and w_i (relative weight of support for a given model; Burnham and

Anderson 1998). All possible model combinations were run (31 models), but only the top ten models are presented. Akaike variable weights (w_i) were also assessed to determine the most influential explanatory variables. All variables were \log_{10} transformed prior to statistical analysis to satisfy normality assumptions.

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: Improve annual assessments of the yellow perch spawning population

Objective: Monitor the age and size structure of the spawning population and evaluate the reproductive potential.

Relatively few adult yellow perch ($N = 167$) were collected in our fyke nets (5-6 m of water) between May 29 and June 12, 2007. Based on results from previous segments of this project, CPUE has been declining annually since 2001; CPUE for 2007 was only 14 fish per net night. Females comprised 44% of total catch which was the highest percentage recorded in at least a decade. Mean length of fish collected in fyke nets was 210 ± 46 (SD) mm TL and length ranged from 130-339 mm TL. We aged 160 fish from fyke net catches during 2007 using otoliths. Fish ranged in age from 2 to 10 years old. Age-2 thru age-5 (2005-2002 year class) together comprised 85% of the subsample (Figure 2a). Age-9 fish (1998 year class) made up only about 12% of the subsample.

We also sampled for yellow perch using gill nets (10-15 m of water) near Waukegan, IL during May 21-29, 2007. CPUE was 44 fish per net night. Male yellow perch made up 62% of the catch, whereas females made up 37% of the subsample ($N = 220$). The remaining fish (1%) were not mature. Mean length of fish collected in gill nets was 257 ± 37 (SD) mm TL and length ranged from 149-361 mm TL. We aged 215 fish from gill net catches during 2007 using otoliths. Fish ranged in age from 3 to 9 years old. Age-5 (2002 year class) fish dominated our subsample (45%; Figure 2b). Age-9 (1998 year class) and age-4 (2003 year class) were the next largest age groups and comprised 25% and 19% of the subsample, respectively. In 2007, ovaries were taken from 13 females that ranged in length from 149 to 284 mm TL and ranged in age from 3 to 5 years. Estimated fecundity for these females varied from 11,329 to 61,078 eggs. Mean fecundity was $19,383 \pm 6,964$ (SD) eggs for age-3 females ($N = 4$), $31,724 \pm 4,742$ eggs for age-4 females ($N = 4$), and $38,467 \pm 16,350$ eggs for age-5 females ($N = 5$).

Job 101.2: Develop angler harvested 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.

We collected and aged anal spines from 233 yellow perch harvested by anglers at Waukegan and Montrose Harbors, IL. During 2007, boat and shore anglers were interviewed at Waukegan Harbor. Thirty yellow perch were sampled from the boat fishery during 7-18 May, 2007; all remaining fish (N = 203) were sampled from shore anglers during 2007. Similar to results from 2005 and 2006, fish from 2002 (age-5) and 2003 (age-4) year classes dominated our subsample (38% and 33%, respectively). Age-3 fish (2004 year class) were the next most abundant age group, accounting for 12% of our subsample. Age-9 (1998 year class) and age-2 (2005 year class) fish each accounted for about 6% of the sampled sport harvest (Figure 3). Mean length of fish caught by anglers was 259 ± 38 (SD) mm TL and length ranged from 135-370 mm TL. Approximately 50% of the sampled sport harvest consisted of fish between 240-279 mm TL. Mean length of females (N=15) was 288 ± 38 (SD) mm TL and 249 ± 28 (SD) mm TL for males (N = 13). Sex determination of the majority of fish (N = 205) was not possible. 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 conducted surveys for yellow perch egg skeins between May 1 and June 26, 2007 at the US Steel intake line, the location of this survey since 1996 (Table 1). Divers detected egg skeins on May 29 and June 11 and a total of 4 skeins were counted. This equates to an overall mean of 0.5 egg skeins per 100 m² transect (Figure 4), which is a 55% decline from our 2006 estimate. 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.

Yellow perch larvae were captured in low abundance during 2007 (2.3 ind./100 m³) compared to seasonal mean densities reported before 1994 (36 - 138 ind./100m³; Figure 5). Average daily densities of larval yellow perch between May 30 and July 30, 2007 ranged from 0.0 to 15.1 ind./100 m³. Average daily density of larval yellow perch peaked on June 13, 2007 and was the highest daily density reported in several years. We also caught larval Cyprinids, alewife and burbot (*Lota lota*) throughout the sampling period, but in low densities.

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 sampled for pelagic age-0 yellow perch in offshore Illinois waters between July 11 and August 7, 2007 (N = 20). A total of 36 age-0 yellow perch were collected in offshore samples: 31 from the surface and 5 at depth within the epilimnion. Mean volume of water

sampled was 2,999 m³ at surface (N = 10) and 3,207 m³ at depth within epilimnion (N = 10). Annual CPUE of age-0 perch during 2007 (0.06 ind./100 m³) was most similar to that in 2006, and declined from our 2004 and 2005 estimates of 9.8 and 31.5 ind./100 m³. This decline may reflect lower densities of larval yellow perch during 2006-2007, but it may also be an artifact of a truncated sampling period during these years. During 2004 and 2005 sampling efforts were conducted weekly during late June through August 30, whereas during 2006 and 2007 sampling was reduced to early July through early August in an effort to target yellow perch moving nearshore.

As seen in previous years, larval yellow perch were collected at our nearshore site (1 mile offshore) for only the first several weeks of the sampling season (Figure 6). Densities of pelagic, age-0 yellow perch nine and fifteen miles offshore peaked on July 24, and then declined and reached zero by early-August (Figure 6). No yellow perch were detected three miles offshore in late July and early August during 2007. As seen in the past, densities of pelagic age-0 yellow perch were higher in samples taken at the surface than in samples taken at depth within the epilimnion (Figure 7). Only 5 age-0 yellow perch were detected at depth within the epilimnion and all of these individuals were collected nine miles offshore during July. Unfortunately, the use of different gear types does not allow for direct comparison between samples taken at the surface and those taken at depth within the epilimnion. We also caught pelagic age-0 alewife, burbot, bloater (*Coregonus hoyi*), and Cyprinids. Alewife was the most abundant species collected in surface water samples (0.88 ind./100m³), followed by burbot (0.41 ind./100m³), bloater (0.38 ind./100m³), and yellow perch (0.11 ind./100m³). Although similar densities of burbot were caught at the surface and at depth within the epilimnion (0.30 ind./100m³), burbot dominated species composition of samples taken within the epilimnion.

Age-0 yellow perch lengths ranged from less than 5 mm in nearshore waters during late May to greater than 34 mm in offshore waters during late July and early August. The disappearance of 30-40 mm perch from offshore samples during mid-August corresponds well with the appearance of similar sized demersal age-0 perch in nearshore bottom trawl samples (Figure 8). Unlike in 2006 when several age-0 yellow perch greater than 30 mm TL (size detected in early bottom trawl samples) were caught during early August in surface waters three miles offshore, no perch were caught three miles offshore during 2007. Thus, the mechanism and exact timing of their movement back to the nearshore demersal habitat remains elusive.

In general, calanoid copepods and daphnia dominated the crustacean zooplankton assemblage within the epilimnion, while densities of cyclopoid copepods and bosmina were low in offshore waters during 2007. Densities of cyclopoid and calanoid copepods, bosmina, and daphnia were low (< 2.0 ind./L) within the epilimnion three miles offshore during late July and early August. Nine and fifteen miles offshore, calanoid and cyclopoid copepods, daphnia, and bosmina all peaked within the epilimnion during early July (Figure 9a and b). However, peak densities of daphnia and calanoid copepods were much higher than peak densities of bosmina and cyclopoid copepods. Densities of calanoid copepods and daphnia declined throughout July and reached densities less than 2.0 ind./L by early August.

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.

Daytime bottom trawling efforts during 2007 covered approximately 198,426 m² between August 1 and October 9, 2007. Only 56 yellow perch estimated to be age-0 based on length were caught during this period. Thus, 2007 annual CPUE of age-0 yellow perch was 28 ind./100,000 m². Age-0 CPUE in 2007 was much lower than that detected in 2005 and 2006 and was most similar to catches during 2001 (Figure 10). Individual age-0 yellow perch were collected from August 1 through October 9, but mean daily CPUE peaked during mid-August. During 2007, alewife had the highest overall CPUE in bottom trawl samples (69 ind./100,000 m²). Round goby (*Neogobius melanostomus*) and yellow perch were the next most abundant species, but CPUE of these species was about 2.5 times lower than that of alewife. Spottail shiner (*Notropis hudsonius*) were also caught, but in much smaller numbers. Additionally, one rainbow smelt (*Osmerus mordax*) and one smallmouth bass (*Micropterus dolomieu*) were also collected.

Mean June-July zooplankton density in 2007 was 11.6 ind./L. This is a 39% decrease from our 2006 estimate and the third consecutive year of declining zooplankton densities (Figure 11). Densities of both total and crustacean zooplankton were relatively low during June and increased during July (Figure 12). Density of total zooplankton peaked on July 17, declined drastically by August 1, and then peaked again on September 24. Rotifers made up 63% of individuals collected on July 17 and veligers comprised almost 80% of the individuals collected on September 24. Crustacean zooplankton density remained low through June and then increased slightly in July. Densities peaked on August 7 (13.2 ind./L), declined slightly through early September, peaked again on September 19 and remained between 5.0 - 11.6 ind./L through early October. Copepod nauplii and adult calanoid copepods dominated the zooplankton assemblage throughout much of June, September and October (Figure 13). Adult calanoid copepods made up less than 16% of the zooplankton assemblage during July and August, but copepod nauplii accounted for 8-60% of weekly zooplankton densities during this same period. *Bosmina* densities remained low through June, then increased during July and peaked on August 17 when they accounted for 65% of zooplankton. Densities of cyclopoid copepods ranged from 0.05 – 4.09 ind./L and did not comprise more than 10% of the zooplankton assemblage between June and October. *Daphnia* were rare during 2007. Densities of *daphnia* were less than 1.0 ind./L until October 3 when density peaked at 20.6 ind./L and *daphnia* comprised 43% of zooplankton. Other cladocerans (e.g. *Polyphemus*, *Ceriodaphnia*, *Leptodora*, *Diaphanosoma*, *Chydoridae*) that were commonly found in samples during 1988-1990 have been rarely observed in samples collected since 1996.

Mean annual benthic invertebrate density north of Waukegan Harbor was 4,214 ± 6,338 ind./m² (SD) in 2007, which is much higher than that detected in 2004, but similar to densities seen during 2005 and 2006. Monthly densities of benthic invertebrates were lowest in July (748 ± 192 ind./m²), moderate in June (1,295 ± 133 ind./m²) and August (2,785 ± 1936 ind./m²) and then peaked during September (12,030 ± 9,248 ind./m²). Peak densities of benthic invertebrates during September can be partly explained by extremely high abundances of mollusks, primarily Pelecypoda (65 % of September invertebrate density). Zebra mussels (*Dreissena polymorpha*) were most abundant in September (475 ind./m²), but made up little (<5%) of the nearshore benthic invertebrate community throughout most of the sampling period. The most abundant taxa in June and July samples were ostracods, chironomids, and mollusks (Figure 14). These taxa combined made up around 90% of all individuals collected during both months. During August, ostracods were most abundant (56%), followed by chironomids, and mollusks. During September, mollusks dominated the benthic invertebrate community north of Waukegan Harbor

and individuals of Pelecypoda made up 90% of mollusks collected in September. Other insects, nematods, amphipods, and Oligochaetes were also found throughout the summer, but in much smaller abundances.

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

Objective: Determine whether small mesh gill nets are as effective as a bottom trawl to estimate relative abundance of demersal age-0 yellow perch.

Six paired comparisons between a bottom trawl and gill net were conducted at the same location between August 17 and October 3, 2007. Total catch in the trawl from these comparisons was 127 individuals, but less than 5% of these fish were yellow perch. A total of 6 yellow perch (<2 ind./1,000m²) collected in the trawl were determined to be age-0, based on length. We caught a total of 382 individuals in the small mesh gill net and 42% (161) of these fish were yellow perch. Age-0 yellow perch comprised approximately 25% (95) of the total catch from small mesh gill nets during 2007. Annual CPUE of age-0 yellow perch was about 4 fish per hour. Alewife dominated both bottom trawl (24 ind./1,000 m²) and gill net catches (52 ind./hr) and round goby and spottail shiner were also collected in smaller abundances. Additionally, two rainbow smelt were collected in the gill net.

Twenty-eight paired comparisons between a bottom trawl and small mesh gill net were conducted between late August and mid-October during 2005-2007. Based on these assessments, CPUE of age-0 yellow perch from gill nets was positively correlated to log transformed CPUE from our bottom trawl ($r = 0.62$, $P < 0.001$). The regression equation Gill net CPUE = $4.567 + 4.420 [\log (\text{Trawl CPUE})]$ was highly significant ($P = 0.0004$), and hopefully with continued effort we will be able to strengthen this relationship ($r^2 = 0.36$; Figure 15).

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 56 age-0 yellow perch from 8 sampling dates between August 1 and October 9, 2007 were examined. Four of the stomachs examined did not contain any identifiable prey organisms, so age-0 perch diet composition is based on 52 age-0 yellow perch stomachs. Similar to trends seen in past years, age-0 yellow perch primarily consumed zooplankton (91%) and smaller quantities of benthic invertebrates. Unlike 2006, over 74% of the zooplankton consumed by age-0 yellow perch were cladocerans. Cladocerans, primarily Chydoridae, dominated the diet of age-0 yellow perch in early August and Bosmina were primarily consumed in early September. In past years, zooplankton, primarily copepods, have dominated the diet of age-0 perch through September after which primarily amphipods have been consumed. During 2007, no clear diet shift from zooplankton to benthic invertebrates was detected; consumption of zooplankton and benthic invertebrates fluctuated throughout the sampling period (Figure 16). The 2007 year class consumed very few amphipods during August-October and chironomids were primarily consumed during August and in early October chironomids made up almost 50% of yellow perch diet. Copepods made up less than 12% of the diet throughout much of August and September and then during the last week of September age-0 perch consumed copepods, mainly calanoids, almost exclusively (98%).

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.

Based on bottom trawling near Waukegan, IL yellow perch recruitment peaked at almost 7,000 ind./1,000 m² in 1988, and then drastically declined to near zero levels between 1989 and 2001 (Figure 10). Recruitment levels showed a recovery between 2002 and 2006, and in 2005 the highest abundance of age-0 yellow perch was detected since the late 1980's. Upon examination of studentized residuals for the global model, we determined 2005 to be an influential outlier (st. res. = 3.22). We examined modeling results using data from all study years and excluding data from 2005; however, rankings for the top ten candidate models were similar between analyses (Table 2). The top-ranked model for yellow perch recruitment based on bottom trawling near Waukegan, IL included the offshore transport index, spring-summer water temperatures, spawning stock abundance, and larval yellow perch prey index. Regression coefficients for these variables were significantly different from zero regardless of whether observations from 2005 were included; thus all four variables influenced yellow perch recruitment (OT: $P < 0.01$; DD: $P < 0.01$; S: $P < 0.05$; CHL: $P < 0.01$). The top-ranked model explained 76% of the variation in yellow perch recruitment when observations from 2005 were excluded from the analysis. The variation in recruitment explained by this model dropped to 60% when observations from 2005 were included in the analysis. The top-ranked model fit observed trends in recruitment well during 1987-2006, but underestimated peak yellow perch recruitment observed in 2005 (Figure 17). The second-ranked model included all independent variables in the best model except spawning stock abundance, and provided moderate support ($\Delta_i = 2.19$). However, Akaike weights for the two top-ranked models indicate there is low probability that the second-ranked model is actually better than the top-ranked model (Table 2). The larval yellow perch prey index was the most influential variable on yellow perch recruitment near Waukegan, IL of the five variables examined. This variable appeared in 9 of the 10 top-ranked models and had the highest Akaike variable weight ($w_i = 0.96$). Pre-spawn adult yellow perch prey abundance had the least influence on yellow perch recruitment ($w_i = 0.11$) among the predictors examined. Based on regression coefficients estimated for the top-ranked model and including observations from all years, yellow perch recruitment was positively related to larval prey availability and spring-summer water temperatures (CHL: $\beta = 2.60$; DD: $\beta = 11.64$) and negatively related to our offshore transport index and spawner abundance (OT: $\beta = -1.07$; S: $\beta = -1.34$).

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

Spawning stock

Our annual assessments of the yellow perch spawning population have shown a steady decline in abundance since 2000 at the Waukegan, North Lake Forest, and Fort Sheridan sites. CPUE of adult yellow perch reached an all time low during 2007 with less than 14 perch caught per net night. This is a 94% decline from catch rates in 2000 when CPUE averaged 213 yellow perch per net night. We caught the highest percentage of females (44%) reported in at least a decade during 2007 fyke net efforts. A general decline in adult yellow perch abundance (Makauskas and Clapp 2008) and an increase in proportion of females have been shown throughout much of Lake Michigan over the last decade (Makauskas and Clapp 2008; Lauer et al. 2008). Fish from 2002-2005 year classes each made up about 20% of the catch, and the 1998 year class comprised about 12% of the catch. It was promising to see the 2005 year class contributing 20% of the catch, since fish this young are often not fully recruited to this gear. In addition, for the first time in over a decade we have evidence that the Lake Michigan yellow perch population is being supported by several year classes.

To improve our annual assessments of the yellow perch spawning population we also targeted fish in deeper waters (10-15m) with gill nets. 220 yellow perch were collected in gill nets and CPUE was 44 fish per net night. The 2002 year class dominated the catch, while 1998 and 2003 year classes each comprised about 20% of the catch. In 2007, ovaries were taken from 13 females that ranged in length from 149 to 284 mm TL and ranged in age from 3 to 5 years. Fecundity ranged from 11,329 to 61,078 eggs per female; age-5 females produced on average approximately 20% more eggs than age-4 females and 50% more than age-3 females.

Sport anglers fishing in or around Waukegan and Montrose Harbors primarily harvested perch from the 2002 and 2003 year classes during 2007. This is the third consecutive year that the 2002 year class has dominated the sport harvest; this year class made up about 40-60% of fish subsampled from our nets during 2005-2007. Fish from these young year classes (2002-2003) may be extremely important for future spawning and should be protected. Furthermore, the continued decline of adult yellow perch detected at historical spawning grounds raises concerns that the population is still not recovering from past overharvest and recruitment failures.

Continual decline in spawning activity at historical sites has been detected in both spring fyke net assessments, and annual egg skein surveys. The density of yellow perch egg skeins collected at the US Steel intake line, south of Waukegan Harbor, in 2007 declined 55% from the 2006 estimate. This is the fifth consecutive year of reduced egg deposition at this site. One possible explanation for this decline is that the spawning potential of the younger 2001-2005 year classes is not high enough yet 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. Our fecundity results (mentioned previously) support other evidence provided by Brazo et al. (1975) of increased fecundity in older yellow perch from Lake Michigan. Furthermore, there is evidence that larvae produced by younger spawners can experience higher mortality rates than larvae from older individuals, thereby potentially leading to gross over estimates of recruitment based on egg

production when population age structure is not taken into account (O'Farrell and Botsford 2006). Thus, the continual decline of spawning activity (i.e. egg skein densities we observed) raises concerns about the reproductive potential of the yellow perch population during a shift towards younger individuals.

2008 Year class

Annual densities of newly-hatched yellow perch larvae were much lower during 1994-2007 compared to densities observed before 1994. Average daily densities of larval yellow perch in nearshore waters peaked at 15.1 ind./100 m³ in 2007. This peak daily density was still low compared to peaks of over 100 ind./100 m³ prior to 1994 (Marsden and Robillard 2004). However, it is the highest average daily density reported in recent years; higher than peak daily density of about 11.1 ind./100 m³ reported during 2005. Similar to previous years, the density of newly-hatched larval yellow perch peaked in nearshore waters during mid-June. Pelagic, age-0 yellow perch density peaked on July 24 at stations nine and fifteen miles offshore, which suggests these fish moved from nearshore to offshore waters during this time period.

2007 CPUE of age-0 yellow perch collected in bottom trawls was much lower than that detected during 2004-2006, and most similar to catches in 2001. Previously, relatively high CPUE in 1998 led to a comparatively strong year class as seen by its dominance in LMBS 2000-2004 fyke netting (Redman et al. 2005). A similar pattern occurred with the 2002 year class. These fish were caught in relatively high abundance at age-0 in 2002, and then dominated fyke net catches during 2005 and angler catches during 2005-2007 (Redman et al. 2006 and 2007). These results suggest that strong CPUE of age-0 yellow perch may be a reasonable indicator of recruitment success. Thus, because CPUE levels were higher during 2004-2006 than during 1998, within a few years the 2004, 2005, and 2006 year classes may appear more readily in our spring adult assessment as we saw with the 1998 and 2002 year classes. However, compared to sampling in the late 1980s (1987 and 1988) current age-0 yellow perch CPUEs are extremely low. So even though the 2002, 2004, 2005, and 2006 year-classes were measurable, their levels were nowhere near that of the late 1980s; as such, they probably are not sufficiently strong to support extensive fishing pressure.

We were able to conduct 28 paired comparisons of the effectiveness of a bottom trawl and small mesh gill net in estimating relative abundance of demersal age-0 yellow perch between late August and mid-October during 2005-2007. A positive correlation was detected in CPUE of age-0 perch between the two gears and the following regression equation was calculated: Gill net CPUE = 4.567 + 4.420 [log (Trawl CPUE)] ($r^2 = 0.36$, $P = 0.0004$). However, more comparisons are needed before definitive conclusions can be drawn as to the comparable efficiency of these gears. Analysis of habitat selection by demersal age-0 yellow perch in Lake Michigan has indicated that they prefer rocky substrate over 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 more effective than bottom trawling for estimating the relative abundance of demersal age-0 yellow perch in southwestern Lake Michigan.

The forage base available to young yellow perch has changed in species composition and abundance over the last several decades, and many of these changes are linked to exotic species invasions. Mean zooplankton densities were significantly higher during 1988 in comparison to 1989-1990 and 1996-2007 (Dettmers et al. 2003, Redman et al. 2007). Zooplankton densities since 1996 have barely reached even half of the densities found during the late 1980s, when the last strong year classes of yellow perch were produced. These shifts within the zooplankton community may be related to the establishment of several recent invaders. The spiny water flea (*Bythotrephes longimanus*) was first detected in Lake Michigan during 1986 and was established in offshore waters lake wide by 1987 (Barbiero and Tuchman 2004). Barbiero and Tuchman (2004) attributed a dramatic reduction in several native cladoceran species to the establishment of this exotic cladoceran in offshore waters of Lake Michigan. Declines in once dominant benthic macroinvertebrate groups such as *Diporeia*, oligochaetes and sphaeriids in nearshore waters of Lake Michigan are attributed to bottom-up effects of decreased phosphorus loading during 1980-1987 and continued declines of *Diporeia* coinciding with the invasion of zebra mussels during the 1990s (Madenjian et al. 2002). The establishment of zebra mussels throughout nearshore waters of Lake Michigan has resulted in major changes in the Lake Michigan ecosystem since the early 1990s. Zebra mussels have drastically reduced phyto- and zooplankton levels and altered the abundance of benthic macroinvertebrates in other Great Lakes (Leach 1993; Stewart et al. 1998). Another dreissenid invader, the quagga mussel (*Dreissena bugensis*), thought to mainly occupy substrates in deep, cool waters recently replaced zebra mussels in nearshore waters of Lake Ontario (Wilson et al. 2006). We have already begun to detect large quantities of quagga mussels in nearshore areas of Lake Michigan (personal observation). The presence of this invader 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. A comparison of zooplankton density and yellow perch recruitment success in southern Lake Michigan between the late 1980s (good perch recruitment) and the late 1990s (poor perch recruitment) revealed that perch recruitment was positively related to zooplankton abundance in the month after yellow perch larvae hatched (Dettmers et al. 2003). It is likely that reduced zooplankton abundance in recent years is partly responsible for limiting successful recruitment and survival of young yellow perch. Thus, continued monitoring of nearshore zooplankton and benthic invertebrate densities is needed to further explore the role of food availability in yellow perch recruitment success.

Factors influencing year-class strength

Based on our modeling efforts, a suite of complex factors (larval yellow perch prey availability, spring-summer water temperatures, spawner abundance, offshore transport, and pre-spawn prey availability) affected yellow perch recruitment in southwestern Lake Michigan during 1987-2006. Larval yellow perch prey availability based on summer chlorophyll level was the most influential variable for yellow perch recruitment. Growth and survival of larval fishes is largely determined not only by adequate densities of zooplankton prey, but also appropriate size and taxonomic composition of the zooplankton community (Miller et al. 1990). Declines in mean size, density, and ultimately biomass of crustacean zooplankton in nearshore waters of Lake Michigan (Dettmers et al. 2003) coincided with drastic declines in the abundance of age-0 yellow perch throughout southwestern Lake Michigan during 1988-1998. The invasive zebra

mussel was first reported in Lake Michigan near Chicago in 1989, and had colonized all hard substrates within 7 km from shore between Waukegan, Illinois and Michigan City, Indiana by 1993 (Marsden et al. 1993). These benthic filtering bivalves have impacted zooplankton production in the Great Lakes by depressing algal biomass and primary production (Johannsson et al. 2000). All this taken with our findings indicates that bottom-up effects may have contributed to this prolonged period of poor yellow perch recruitment.

Offshore wind events that create surface current were thought to benefit pelagic larval yellow perch by transporting them to more favorable environments, such as areas with higher prey densities (Dettmers et al. 2005). However, we detected a negative relationship between number of at least two consecutive offshore wind hours (>10 km/hr) and yellow perch recruitment in Lake Michigan. Although it is widely recognized that turbulence (wind or tidal-induced) influences ingestion and ultimately survival rates of pelagic larval fish, it has been shown to effect fish in different ways. The plankton contact hypothesis (Rothschild and Osborn 1988) contends that encounter rates increase with small-scale turbulence thereby positively effecting ingestion and survival rates at low prey density conditions (Rothschild and Osborn 1988, Sundby and Fossum 1990, Nielsen et al. 1998). Other studies have implied that a dome-shaped relationship exists between turbulence intensity and larval capture success of planktonic prey (Cury and Roy 1989, MacKenzie et al. 1994). Wind induced turbulence is also thought to disrupt concentrated patches of planktonic prey thereby reducing encounter and survival rates of larval fish (Lasker 1975, Landry et al. 1995, Peterman and Bradford 1987). We are unable to speculate whether this type of relationship exists for age-0 yellow perch in Lake Michigan based on the results of this study. Synthesis from a review of field studies showed that no clear relationship exists between turbulent mixing and estimates of larval fish ingestion, growth, mortality, and fish recruitment across systems (MacKenzie 2000). Thus, further investigation of the effects of wind-induced turbulence on feeding and survival rates of larval yellow perch in Lake Michigan is needed.

Larval-stage dynamics, prey availability, and transport are typically more important determinates of recruitment in marine than freshwater fishes (Houde 1994). However, age-0 yellow perch in Lake Michigan exhibit large passive movements between nearshore and offshore environments due to exposure to the hydrodynamics (i.e. currents and winds) of a macroscopic system (Dettmers et al. 2005). Several studies have shown the pelagic phase for yellow perch in Lake Michigan is prolonged (Clapp and Dettmers 2004, Dettmers et al. 2005, Miehl, unpublished data) compared to counterparts in smaller, inland systems (Whiteside et al. 1985, Post et al. 1995). In inland systems, this shift typically occurs 2-7 weeks after hatching and is associated with lengths of 20-30 mm (Whiteside et al. 1985, Post et al. 1995). Yellow perch in Lake Michigan exhibit an extended pelagic phase ranging from 7 to 10 weeks (30-70 mm TL; Miehl, unpublished data). Early life pelagic stages of yellow perch are most vulnerable to irregular transport, wind and storm events and prey availability, mechanisms associated with recruitment of marine fishes (Houde 1994). Thus, our results imply that processes regulating recruitment of yellow perch in large and dynamic systems such as Lake Michigan are more similar to those influencing recruitment in marine environments.

In summary, the fishable yellow perch population in 2007 was dominated by the 2002 and

2003 year classes. Our sport harvest data suggests that anglers have been primarily harvesting fish from these year classes since 2006. There is a need to protect these fish so that they can reach their full reproductive potential. 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 means that the fishery will rely extensively on the 2002 and 2003 year classes for at least the next year until the 2004-2006 year classes recruit into the sport 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 remains important to conserve the adult stock to the greatest degree possible so that the spawning stock can reach full reproductive potential and their offspring 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, 2007-2008

	<u>Proposed</u>	<u>Actual</u>
Study 101. Investigate adult mortality, age structure, and factors affecting success of yellow perch during their first year of life		
Job 101.1 Improve annual assessments of the yellow perch spawning population	\$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	\$37,000	\$37,000
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	\$22,000	\$22,000
Job 101.8: Explore factors regulating year-class strength of yellow perch	\$11,000	\$11,000
Job 101.9: Data analysis and report preparation	\$15,658	\$15,658
Total Cost	\$251,658	\$251,658
Federal Share	\$188,743	\$188,743
State Share	\$62,915	\$ 62,915

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TABLES

Table 1. Summary of 2007 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 29	6-8	200	1	90%	b & c
June 11	7-8	200	3	100%	a, b, c, & d
June 20	7-9	200	0	--	--
June 26	7-9	200	0	--	--

Table 2. Ten highest ranked regression models based on Akaike's information criterion for yellow perch recruitment estimated from bottom trawling near Waukegan Harbor, Illinois during 1987-2006. Also included for each model is adjusted r^2 .

Model ^a	K ^b	AIC _c		Δ_i		w_i		r^2	
		A ^c	B ^c	A ^c	B ^c	A ^c	B ^c	A ^c	B ^c
OT DD S CHL	6	2.70	-6.63	0	0	0.49	0.65	0.60	0.76
OT DD CHL	5	4.89	-4.22	2.19	2.41	0.17	0.20	0.49	0.68
OT DD ALE S CHL	7	6.15	-2.31	3.46	4.32	0.09	0.08	0.60	0.75
DD CHL	4	7.20	-0.17	4.50	6.46	0.05	0.03	0.35	0.60
OT S CHL	5	7.55	0.13	4.86	6.76	0.05	0.02	0.41	0.65
DD S CHL	5	7.93	0.28	5.24	6.91	0.04	0.02	0.40	0.53
OT DD	4	8.02	3.55	5.32	10.18	0.04	0.00	0.32	0.51
OT CHL	4	8.56	3.62	5.86	12.25	0.03	0.00	0.31	0.44
OT DD ALE CHL	6	9.05	4.87	6.35	11.50	0.02	0.00	0.45	0.33
CHL	3	9.13	5.68	6.44	12.31	0.02	0.00	0.21	0.38

^a OT, offshore transport index; DD, spring-summer water temperatures; ALE, pre-spawn perch prey availability index; S, spawning stock abundance; CHL, larval prey availability index.

^b Parameter count includes intercept and variance.

^c A, years 1987-2006; B, years 1987-2004 and 2006.

FIGURES



Figure 1. Sampling sites in Lake Michigan during 2007.

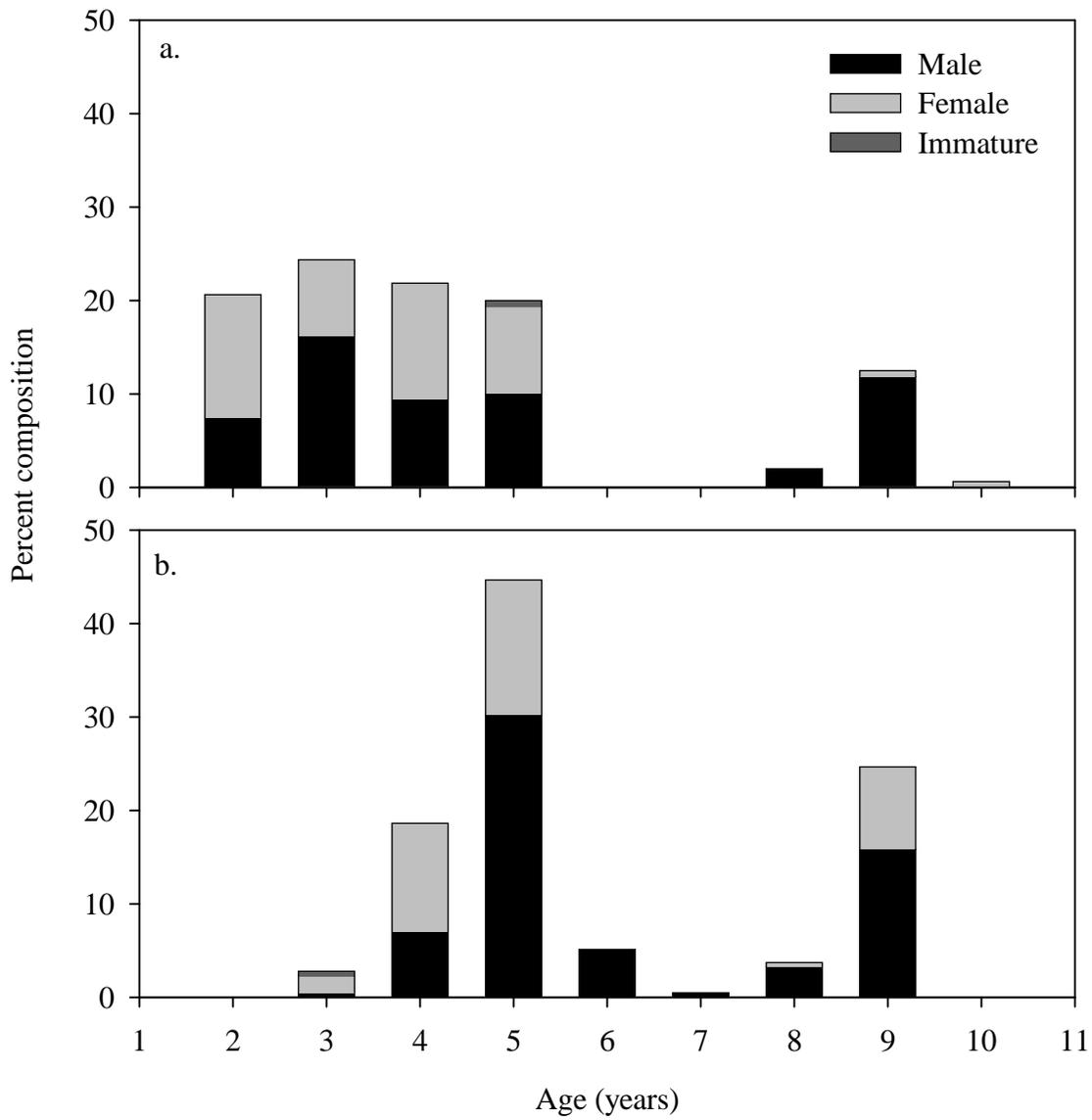


Figure 2. Age composition of adult yellow perch collected using a) fyke nets and b) gill nets between Waukegan and Fort Sheridan, IL during the spring of 2007.

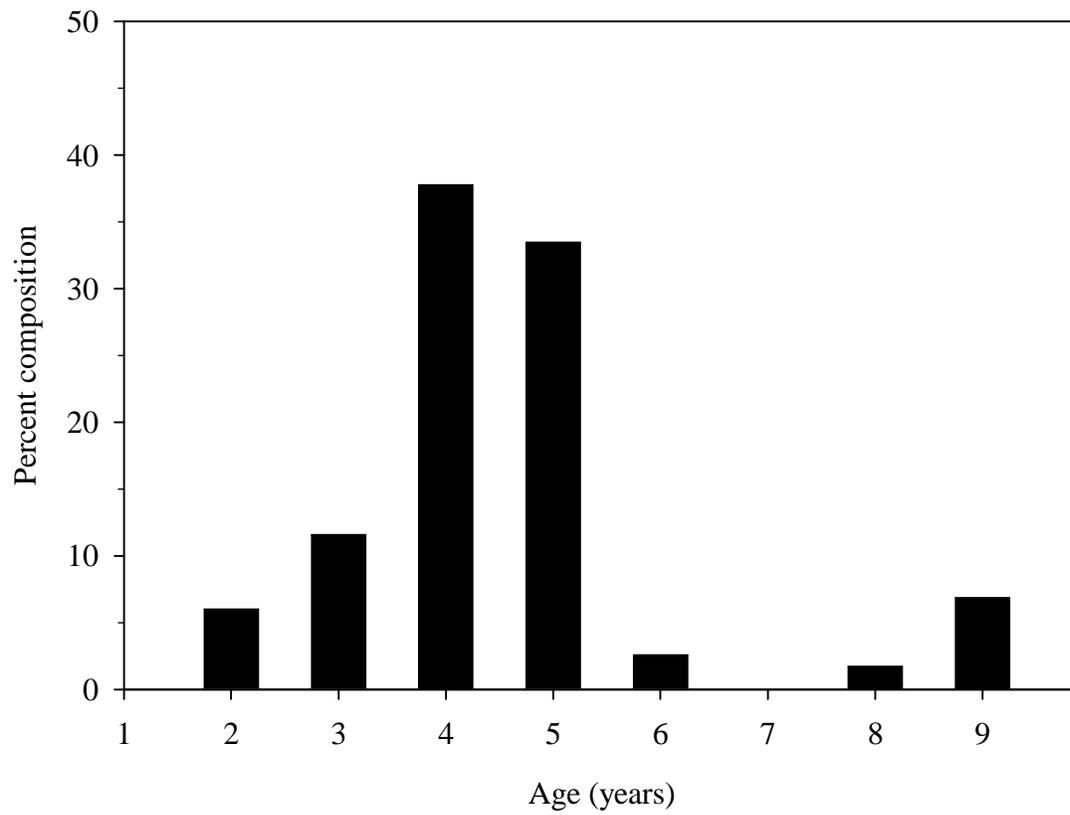


Figure 3. Age composition of adult yellow perch harvested by anglers during 2007 at Waukegan and Montrose Harbors, IL.

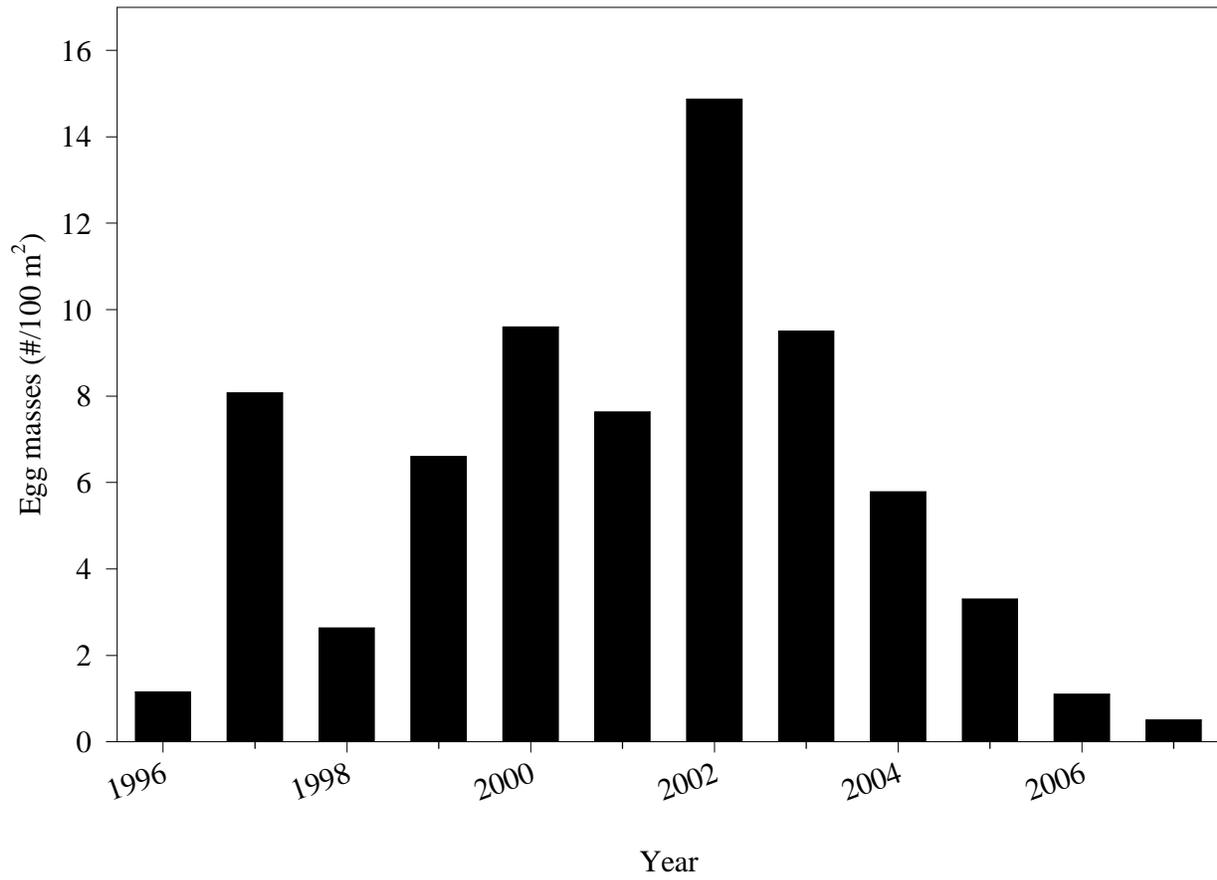


Figure 4. Annual patterns of yellow perch egg production at the US Steel intake for years 1996-2007.

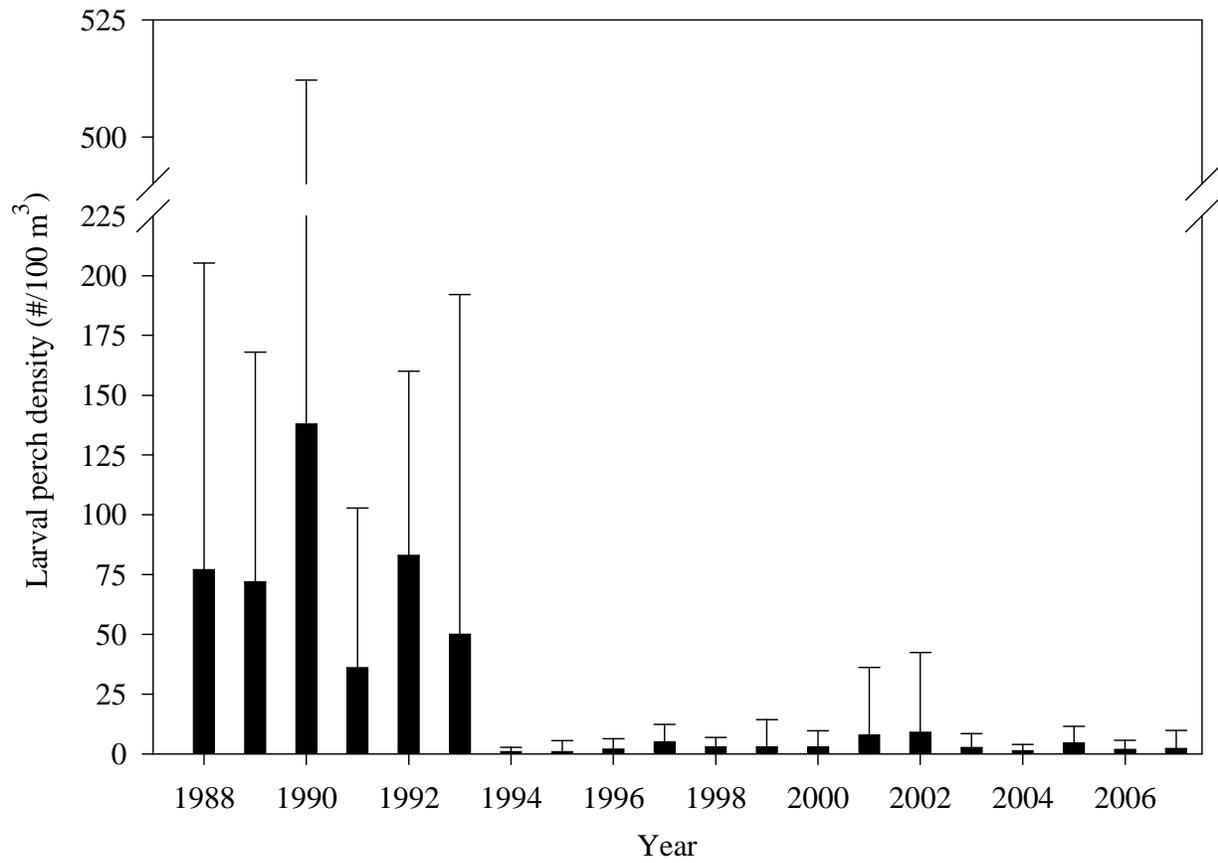


Figure 5. Seasonal mean density of larval yellow perch (+ 1 SD) sampled at two sites near Waukegan Harbor, IL, 1988-2007.

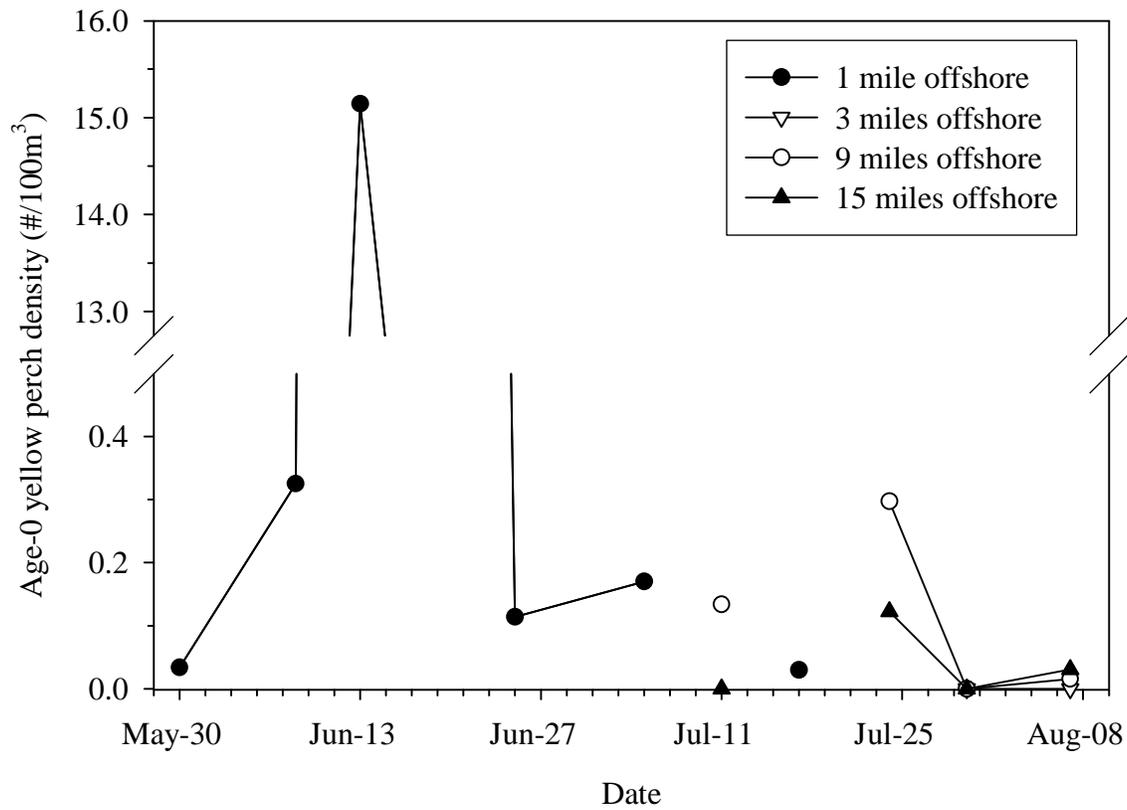


Figure 6. Mean densities of pelagic age-0 yellow perch at all sampling depths from stations between 1 and 15 miles offshore of Waukegan, IL during 2007. The site one mile offshore is in close proximity to nearshore spawning sites and is included for reference.

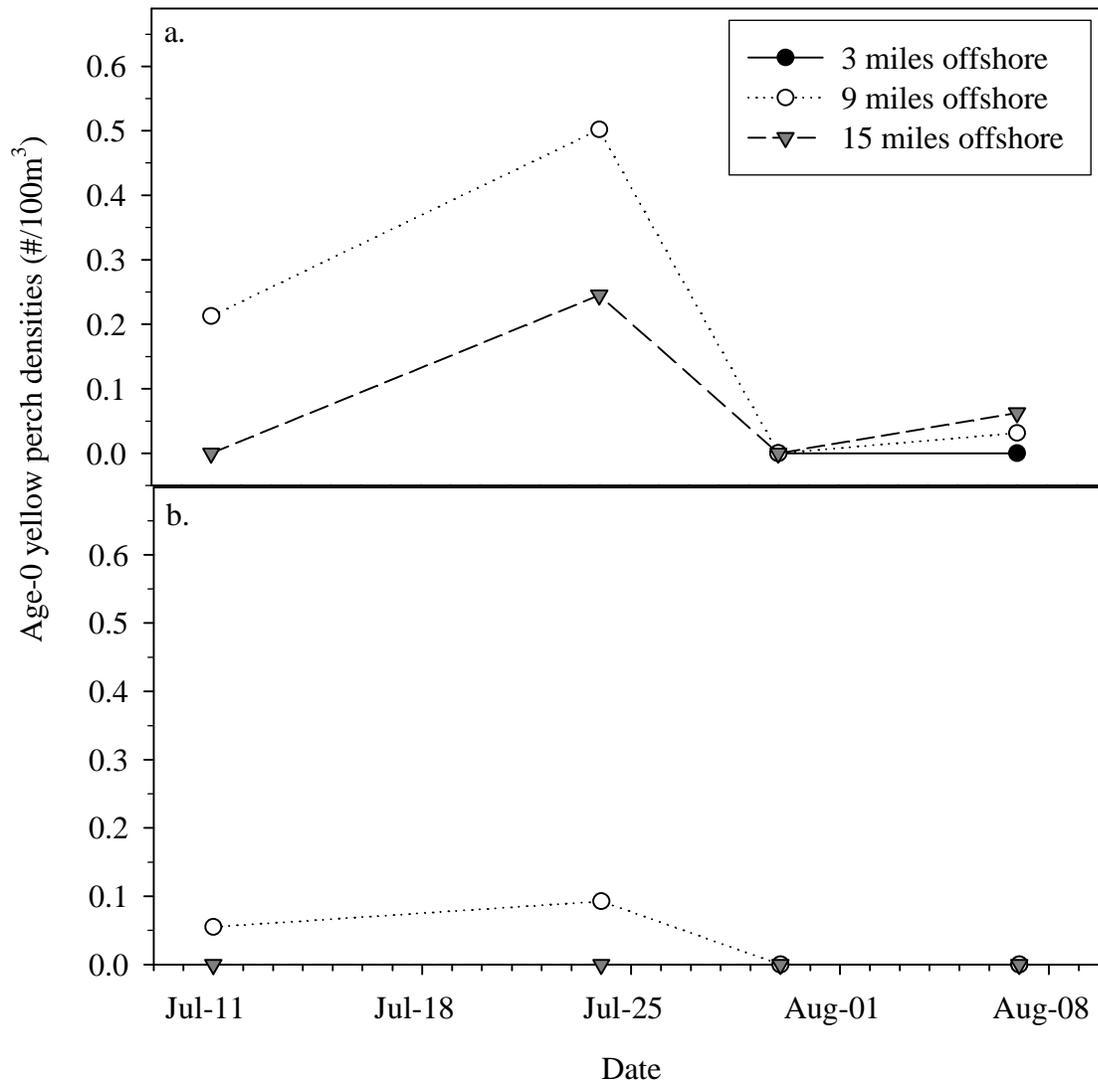


Figure 7. Relative abundance of pelagic age-0 yellow perch collected a) at the surface and b) at depth within the epilimnion from stations between 3 and 15 miles offshore of Waukegan, IL during 2007.

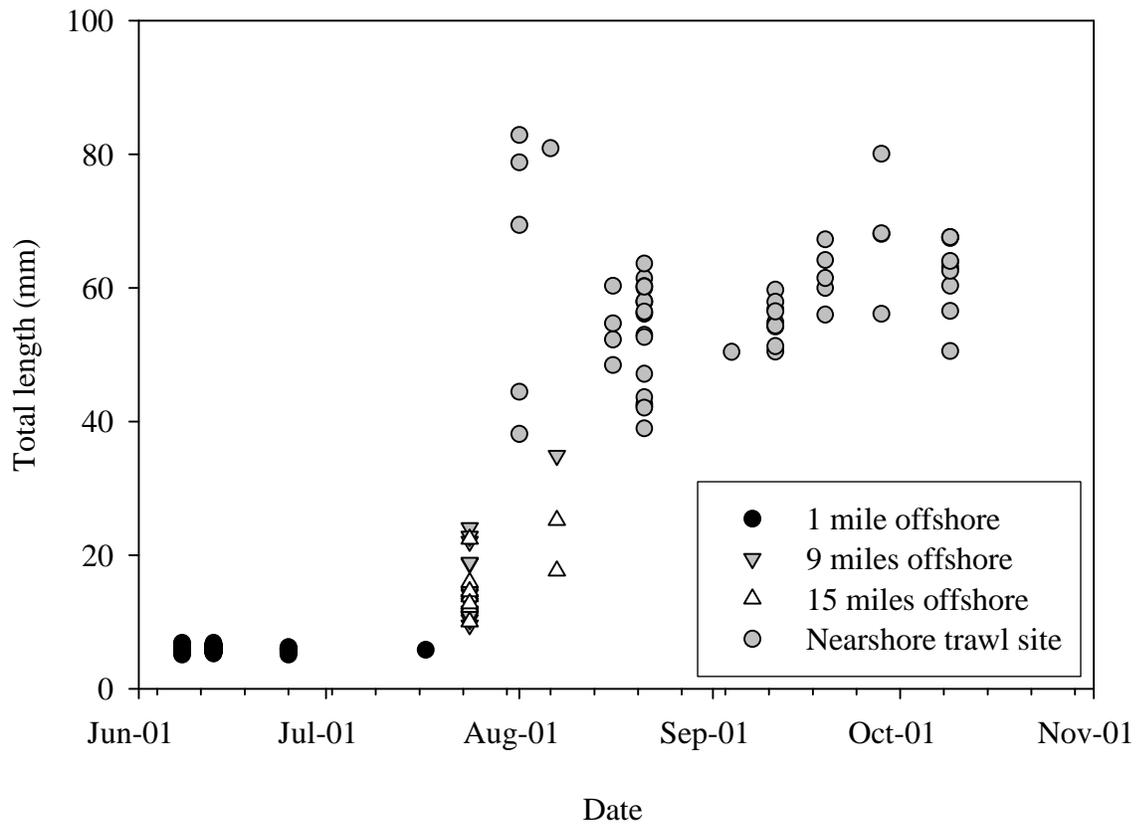


Figure 8. Length distribution of larval and age-0 yellow perch collected in nearshore and offshore waters north of Waukegan, IL during 2007.

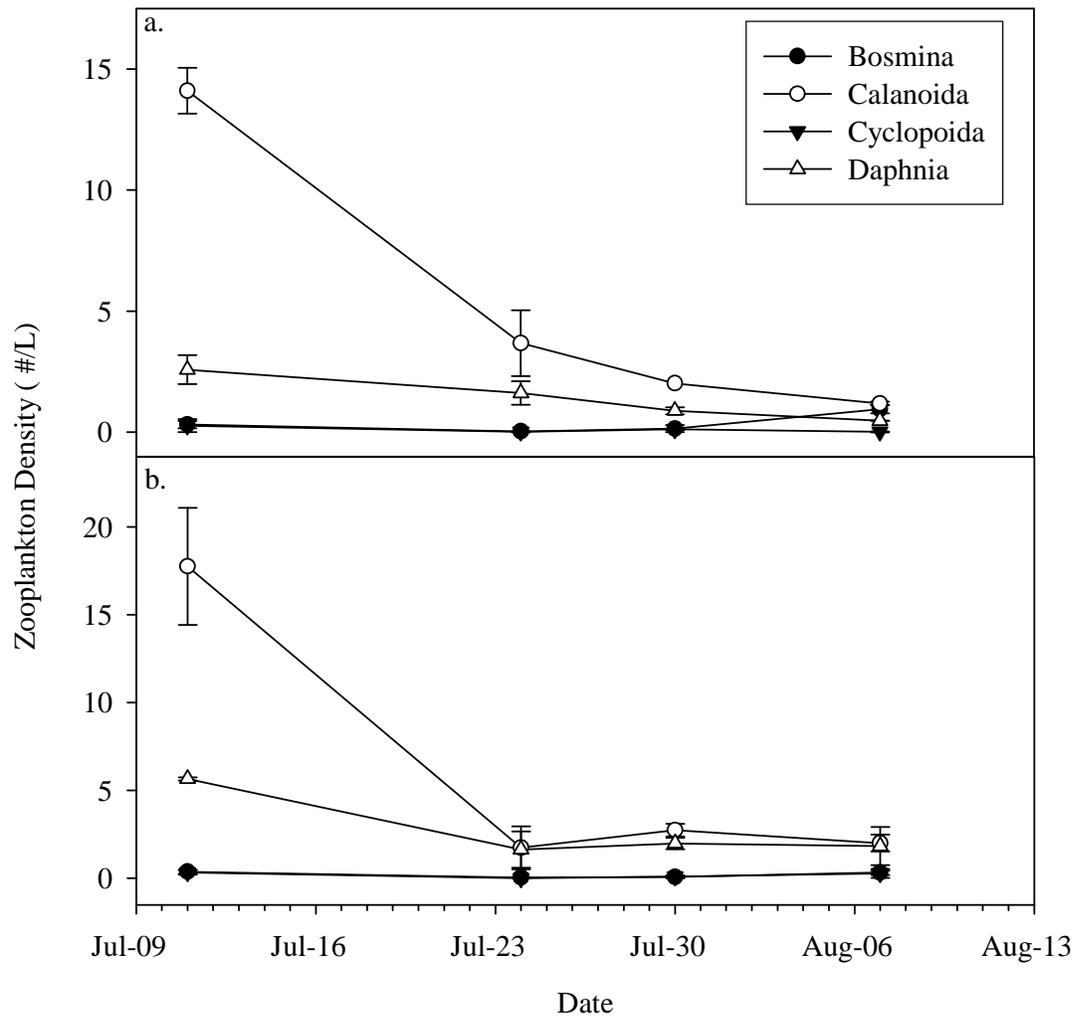


Figure 9. Relative abundance of common crustacean zooplankton collected within the epilimnion at sites a) 9 miles and b) 15 miles offshore during 2007.

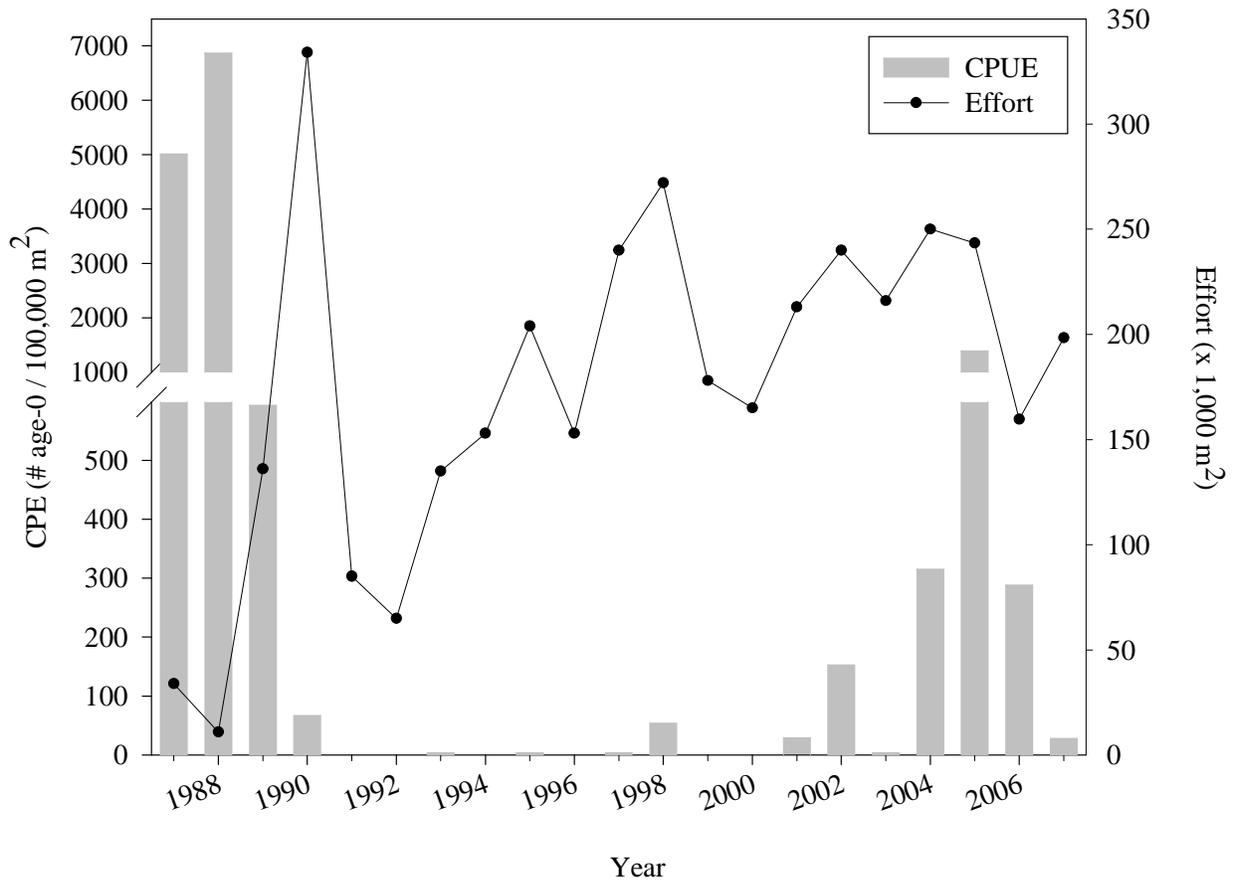


Figure 10. Relative abundance of age-0 yellow perch collected by daytime bottom trawls in 3 – 10 m of water north of Waukegan Harbor, IL, 1987-2007.

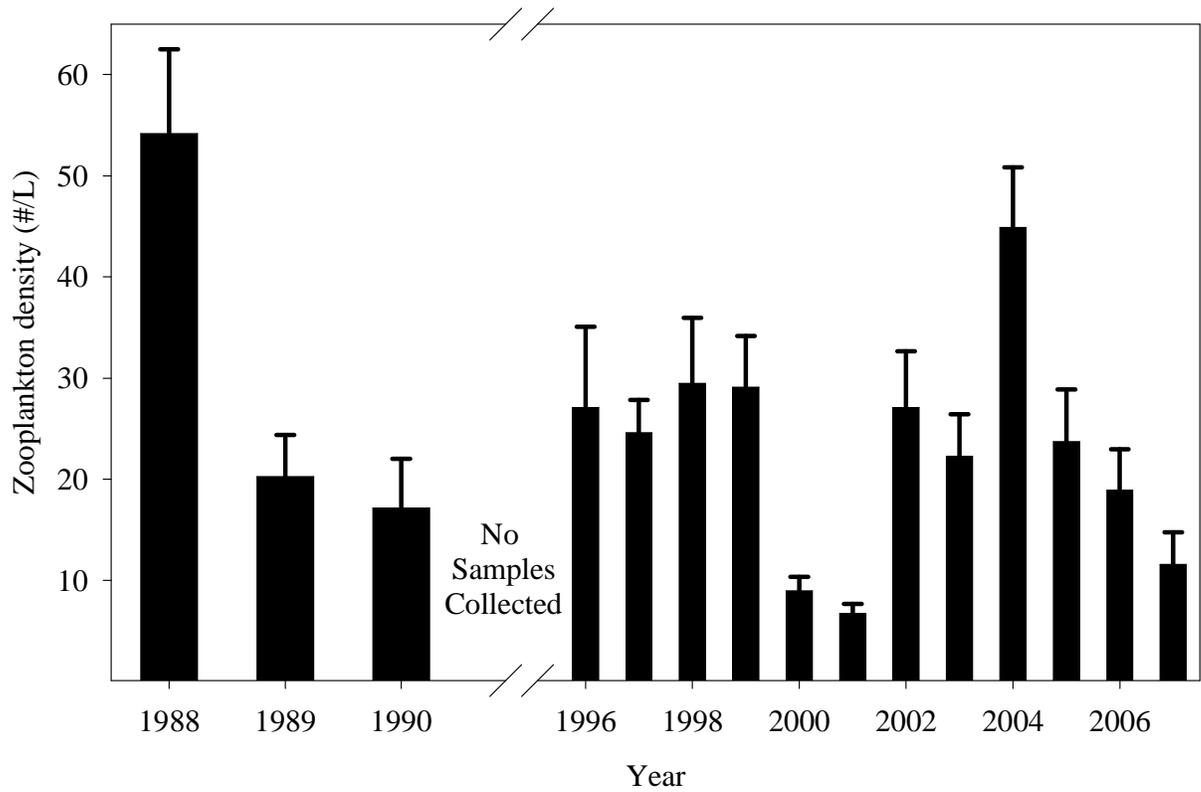


Figure 11. Mean density of zooplankton (+ 1 SE) present in Illinois waters of Lake Michigan near Waukegan during June-July for years 1988-2007.

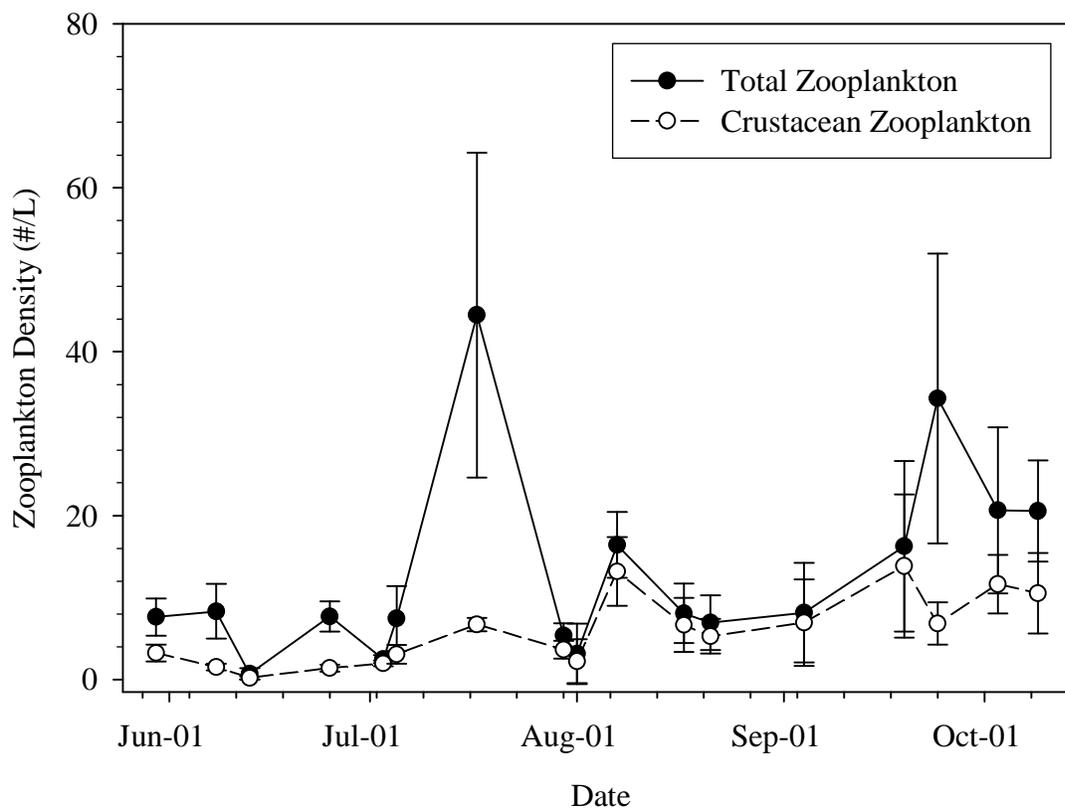


Figure 12. Relative abundance of zooplankton (± 1 SD) present in nearshore Illinois waters of Lake Michigan around Waukegan during June-October 2007. Closed circles (●) represent total zooplankton, whereas open circles (○) represent crustacean zooplankton.

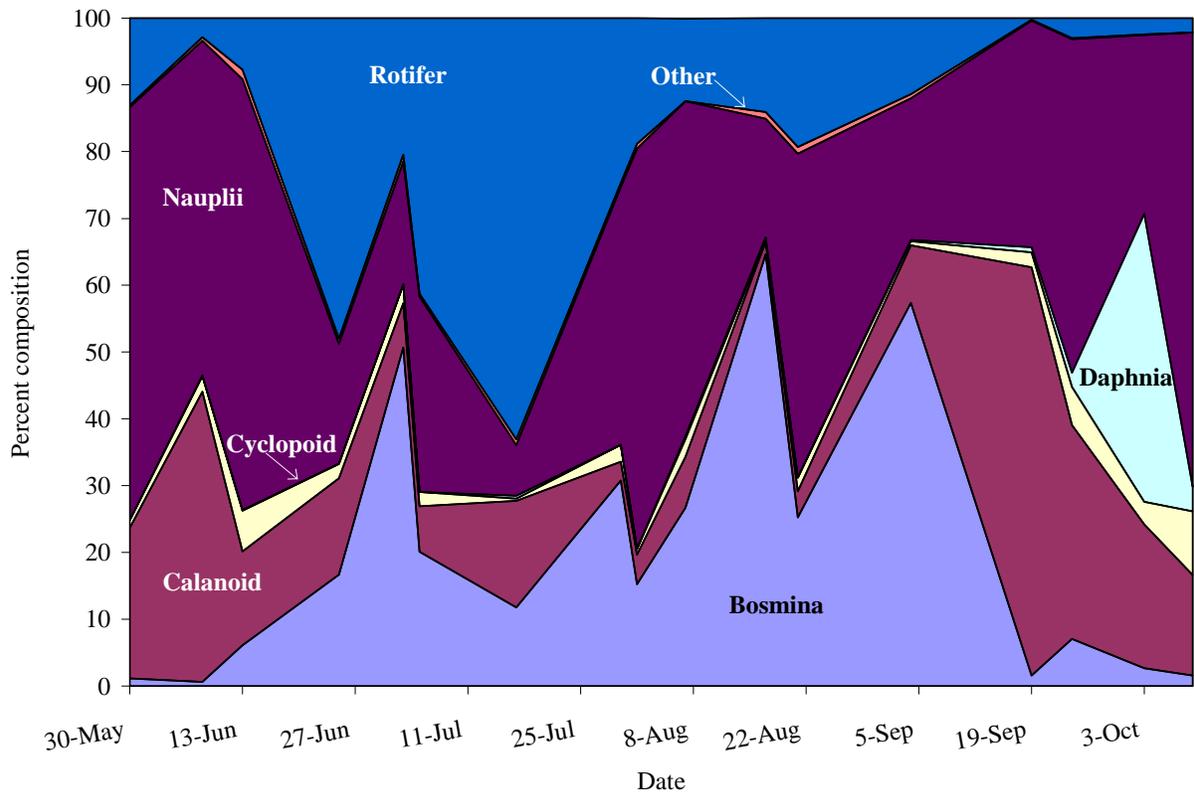


Figure 13. Percent composition of zooplankton found in nearshore Illinois waters of Lake Michigan near Waukegan between late May and early October, 2007.

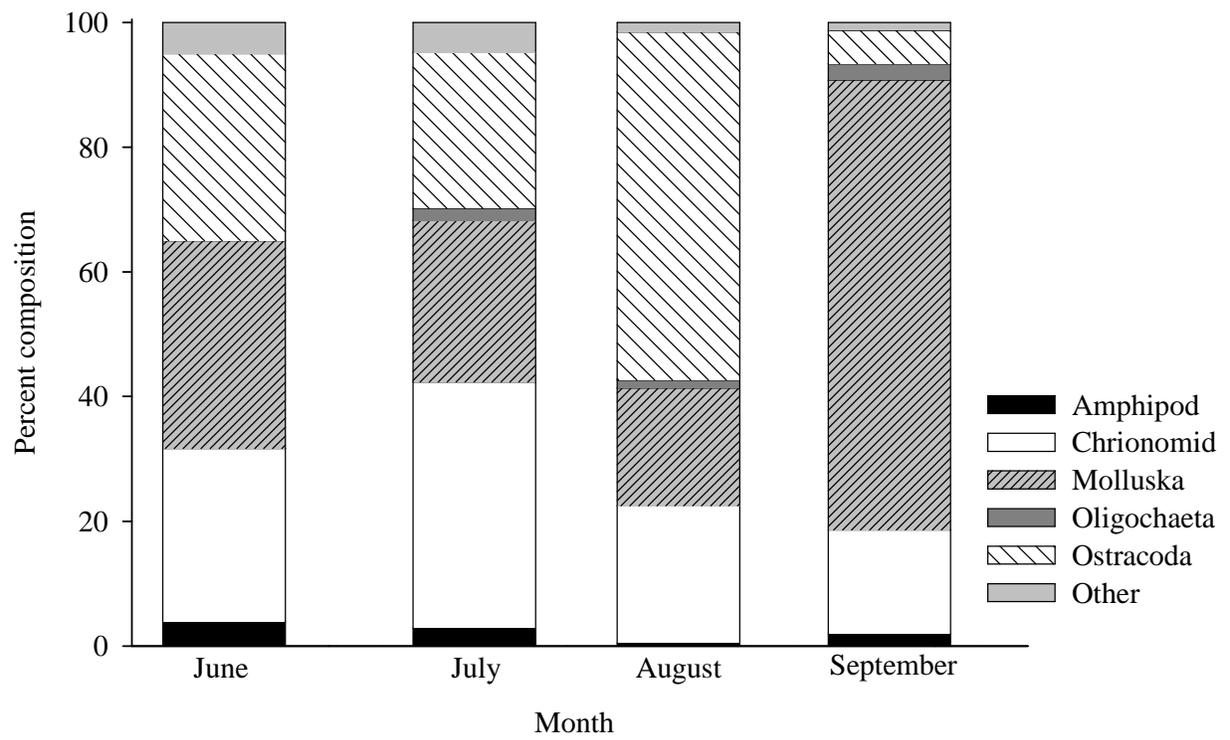


Figure 14. Percent composition of benthic invertebrates found in nearshore substrate of Lake Michigan north of Waukegan Harbor, IL during June through September 2007.

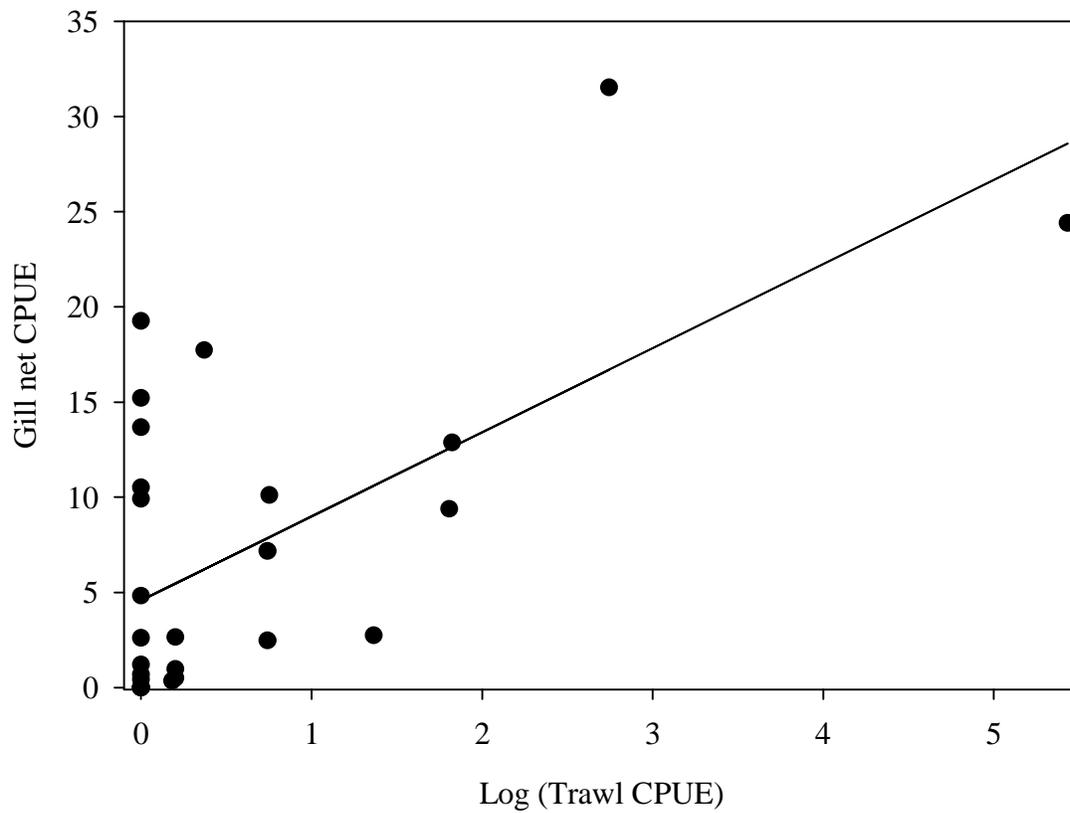


Figure 15. Relationship between age-0 yellow perch CPUE from small mesh gill netting and bottom trawling conducted north of Waukegan Harbor, IL during 2005-2007. The regression equation is Gill net CPUE = 4.567 + 4.420 [log (Trawl CPUE)], $r^2 = 0.36$; $P = 0.0004$.

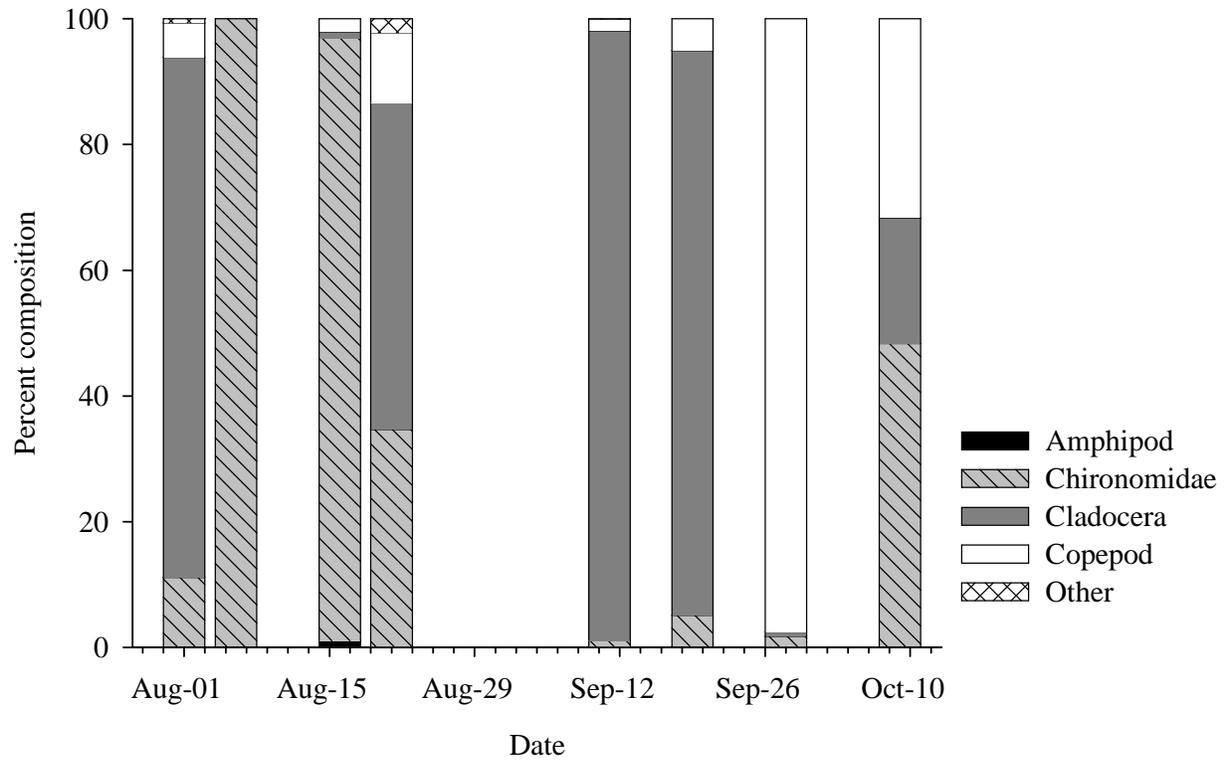


Figure 16. Percent composition by number of items found in the diet of age-0 yellow perch collected with bottom trawls north of Waukegan Harbor, IL between August 1 and October 9, 2007.

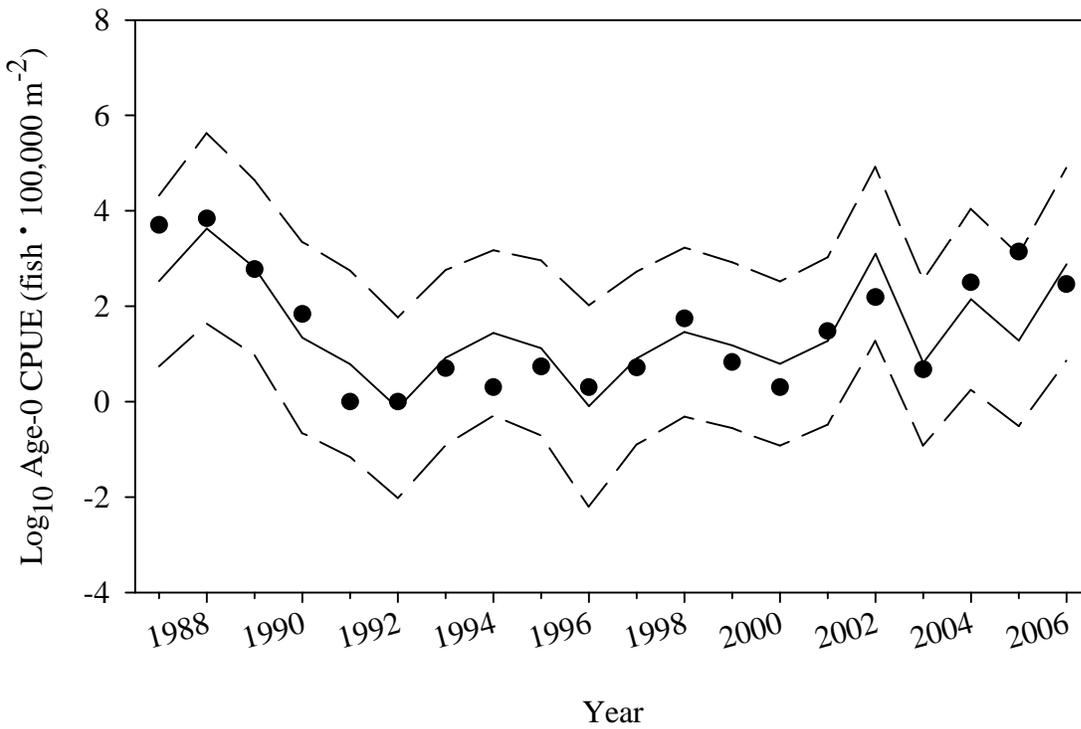


Figure 17. Yellow perch year-class abundance predictions (solid line; \pm 95% confidence intervals) from the top-ranked model (offshore transport index, spring-summer water temperatures, spawning stock abundance, and larval yellow perch prey index) versus observed year-class abundance (black circles) from fall bottom trawling efforts during 1987-2006 near Waukegan Harbor, Illinois.