ILLINOIS NATURAL HISTORY SURVEY

TECHNICAL REPORT

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, 2006 – March 31, 2007

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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 2006. 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 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 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 2006 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. 27 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 2006 were age-3 (62%) and age-4 (25%). The 1998 year-class (age-8) showed a decline in abundance from previous years, comprising only 4% of the catch.

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 2006 were age-4 (51%) and age-3 (26%).
2. The sex of 83% of the fish collected could not be determined without opening the body cavity.

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

1. Diver surveys for egg skeins were conducted during May and June 2006 at the US Steel intake line. Skeins were found during only one survey (June 15) when 11 skeins were detected.
2. Catches of larval yellow perch in nearshore waters were poor like they have been for more than a decade. Peak larval yellow perch density (9.4/100 m^3) in our samples occurred on June 13.

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

1. Only 56 pelagic, age-0 yellow perch were collected in offshore samples during 2006. Average offshore densities ranged from 0 to a peak of 0.33/100 m^3; densities were typically higher in surface water samples compared to samples taken at depth within the epilimnion. Pelagic age-0 yellow perch lengths ranged from less than 10 mm in early July to greater than 40 mm in early August.
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 2006.

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 288 fish/100,000m^2.
2. Mean June-July zooplankton density in 2006 was 18.9/L. Total zooplankton densities peaked on June 22 and remained relatively high through mid-July. Crustacean zooplankton density remained low through June and peaked on July 24.
3. Mean annual benthic invertebrate density for a site north of Waukegan Harbor was 3,916 ± 2433/m^2 (SD) in 2006. The most common taxa were ostracods, chironomids, Oligochaetes, and mollusks.

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

1. Both gears collected yellow perch and those collected in the bottom trawl were exclusively age-0 (100%), while 22% of the 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 = 5.045 + 9.777 [log (Trawl CPUE)].

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

1. Stomachs of 244 age-0 yellow perch collected by bottom trawls were examined in 2006. 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 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, 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. 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 ideally 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, and especially factors that determine year-class strength (Clapp and Dettmers 2004). 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 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. 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. 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

<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; Figure 1). Typically anal spine collection begins in May corresponding with the presence of yellow perch in angler catches, but during 2006 spine collection did not commence until June 15 due to lack of personnel support. As a result, spine collection during 2006 was down almost 50% from previous years. Spines were collected weekly through August 15, except during July when yellow perch harvest was closed. 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 2006.

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 95% ethanol.

Sagittal otoliths were removed from a subset of up to 40 larval perch for each sampling date from nearshore sites (Wiremill, North of Waukegan Harbor, and Dead River). Daily rings were counted on each otolith during two independent readings. If the two readings differed by more than 10% of the youngest age, then independent readings were conducted until a consensus was made.

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 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. 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 that these fish may have been moving back inshore (Redman et al. 2006). Thus, our sampling efforts at the three mile station during 2006 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 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 within the epilimnion 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. Age analysis followed the protocol set forth in job 101.3. Larval perch collected at all three offshore stations were grouped together for analysis of hatching distribution.

Replicate zooplankton samples were collected within the epilimnion at depths corresponding to larval fish sampling using a 0.5m diameter, 73-µm, closing zooplankton net. Zooplankton samples were taken at the beginning of each larval fish trawl transect. Water temperature and DO profiles were taken using a YSI meter. 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 July 31 through October 17, 2006. 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 age and stomach contents. Age analysis followed the protocol set forth in job 101.3. Larval perch collected at nearshore sites were grouped together for analysis of hatching distribution.

Zooplankton in 2006 was generally sampled weekly from June 7 through August 21 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. Dettmers et al. (2003) conducted paired zooplankton samples using the 73-µm and 153-µm mesh nets to determine whether the switch in sampling gear influenced zooplankton densities. Based on these comparisons they determined that the density of crustacean zooplankton was lower in the 153-µm mesh net. Thus, conversion factors were calculated and used to correct zooplankton densities from years when the 153-µm mesh net was used (1988-1990) to allow direct comparison of data across years (Dettmers at el. 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 through September. 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
<u>Objective:</u> 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 for 2-3 hours (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 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 1,000m^2 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 and 2006 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 2006 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 investigated three biological and 14 environmental variables using regression analysis and model selection techniques (AIC, BIC) in an effort to identify parameters that significantly influence age-0 yellow perch recruitment success. We used annual age-0 ($\leq$ 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). The biological variables include alewife abundance lagged by one year and yellow perch abundance as estimated by IDNR spring gill net efforts. We are also currently working with staff at the Milwaukee Metropolitan Sewerage District (MMSD) to get chlorophyll concentration (mg/m^3) collected at an offshore site northeast of the Milwaukee Harbor during summer months (June, July, and August) between 1987 and 2006. Fourteen environmental variables were generated based on weather data collected by the National Data Buoy Center at weather station 45007 - S MICHIGAN 43NM (East Southeast of Milwaukee, WI) or 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, hatching and larval movements between nearshore and offshore waters, as well as yellow perch thermal requirements and food availability. 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 change in temperature ($\Delta T = {}^{o}C/day$)), and 2) variables related to wind patterns, which were associated with wind speed, direction (on/offshore winds) and prevalence. Surface water temperatures as well as wind speed and direction were averaged for each day and then further calculations were performed to generate values that represent either warm versus cold or stable versus unstable years. Cumulative degree days for a given year were calculated as a sum of average daily temperatures during specified months (May-August). Cumulative degree days above a threshold for a given year were calculated as a sum of average daily temperatures that exceeded 13.5°C, which is the minimum bound for growth in yellow perch (LeCren 1958). Since larval perch are transported great distances offshore from nearshore spawning grounds (Dettmers et al. 2005), we generated degree day variables that reflect the period larval perch typically occupied nearshore and offshore waters throughout summer. Based on INHS egg skein surveys and nearshore larval fish sampling since 1996, yellow perch typically inhabit nearshore waters in either egg or larval form between May 1 and June 23. Thus, nearshore temperatures monitored by the Zion Water Plant were used to calculate degree days for this time period. Offshore water temperatures from the data buoy were used to calculate degree days between June 24 and August 5 as this time period reflects when larval perch were found three to fifteen miles offshore during INHS sampling efforts since 2002. Significant continuous winds during months May through August for a given year were calculated as the total number of two consecutive days when average daily wind speed was greater than 6 miles per hour (mph). Winds blowing between 30-135° were defined as offshore winds and onshore winds were defined as winds blowing between 225-330°.

Data analysis will begin once we receive chlorophyll data collected by MMSD for all study years. All variables that do not satisfy normality assumptions will be $\log_{10}$ transformed (thus far: age-0 CPUE and days of offshore wind). As preliminary analysis, we will perform bivariate regressions of age-0 CPUE against single predictors. We will then examine interaction plots between our recruitment indicator (age-0 CPUE) and each independent variable to identify those that correlate best with recruitment over the 20 year study period. Using the results of this analysis and our biological knowledge of the system we will reduce our parameter list to the variables that best represent factors we believe are likely to influence yellow perch recruitment. We will then use multiple regression analysis along with various model selection criterions (r^2, Cp, BIC, AIC) to assess a suite of models and rank them according to their explanatory power with respect to yellow perch recruitment.

Based on our knowledge of the fishery, the following working hypothesis were 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 have been tagged since 2004. However to date, 27 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 2006 (Figure 2). Age-3 individuals (2003 year-class) dominated the adult yellow perch population, comprising 62% of the catch (N = 102). Age-4 individuals (2002 year-class) were the next most abundant age group, making up 25% of the catch. The 1998 year-class (age-8) showed a decline in abundance from previous years, comprising only 4% of the catch. The presence of relatively high 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 = 110) was skewed towards males (F:M = 1:4.5). However, the sex of 10.0% 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. These fish were recorded as unknown and thus the sex ratio could be higher than reported.

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.

Angler-caught yellow perch subsampled from our creel survey in 2006 (N = 167) ranged in age from 2 to 8 years, but 51% were age-4 (2002 year-class). Age-3 fish (2003 year-class) were the next largest group accounting for 26% of the fish collected. The 1998 year-class (age-8) only accounted for 14% of angler-caught yellow perch during 2006 (Figure 3). Overall, catches of females and males appeared to be similar with females comprising 7% and males comprising 10% of the total subsample. However, the sex of the remaining fish (84%) 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
<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.

Divers conducted surveys for yellow perch egg skeins during May and June 2006 at the US Steel intake line, the location of this survey since 1996 (Table 1). However, divers only detected egg skeins on June 15 when a total of 11 skeins were counted. This equates to an overall mean of 1.1 egg skeins per 100 m^2 transect (Figure 4), which is a 66% decline from our 2005 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 2006 compared to catch rates reported before 1994 (Figure 5). Average daily densities of larval yellow perch between June 7 and July 24, 2006 ranged from 0.0 to 9.4 fish/100 m^3. The peak larval yellow perch density in

2006 occurred on June 13. Based on otolith analysis, larval yellow perch began hatching in the nearshore environment during the last week of May and continued until the end of June during 2006. Peak hatch of yellow perch in the nearshore pelagic environment occurred during the first week of June (Figure 6a). Growth of yellow perch in the nearshore environment averaged 0.11 mm*day^{-1}. Yellow perch quickly disappeared from the nearshore environment after hatching; few individuals were captured in the nearshore pelagic environment past 6 days of age (Figure 7a). The decline of older larvae in the nearshore pelagic area overlapped with the appearance of older individuals in the offshore pelagic environment (Figure 7b).

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 13 and August 21, 2006 (N = 36). A total of 56 age-0 yellow perch were collected in offshore samples: 43 from the surface and 13 at depth within the epilimnion. Mean volume of water sampled was 2,913 m^3 at surface (N = 18) and 1,660 m^3 at depth within epilimnion (N = 18). Annual CPUE of age-0 perch was 0.07/100 m^3, which is a huge decline from our 2004 and 2005 estimates of 9.8 and 31.5/100 m^3. Average offshore densities of age-0 yellow perch throughout the epilimnion ranged from 0 to a peak of 0.47/100 m^3, which occurred at the fifteen mile station on July 13 (Figure 8). Alewife (*Alosa pseudoharengus*) was the most abundant species collected in surface samples and they comprised over 80% of the catch. Burbot (*Lota lota*) dominated the catch from samples taken at depth within the epilimnion (> 50%).

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. The decline of older individuals in nearshore waters overlapped with the appearance of older age-classes in offshore pelagic waters; most of these fish arrived offshore approximately 16 days after hatch (Figure 7). Growth rates of yellow perch increased in the offshore environment and averaged 0.48 mm*day^{-1} compared to an average of 0.11 mm*day^{-1} detected in nearshore waters. Hatching distribution of yellow perch in the offshore pelagic environment was different from the nearshore pelagic environment (Figure 6b). Both early and late hatched cohorts were more likely to survive to the offshore pelagic environment than individuals that hatched during the first week of June (nearshore pelagic peak hatching period). Few individuals older than 60 days were captured in the offshore pelagic environment during 2006, suggesting that yellow perch spent approximately 45 days in offshore waters (Figure 7b).

Densities of pelagic, age-0 yellow perch at the nine and fifteen mile station peaked in mid-July, declined in late July, and reached zero by mid-August (Figure 8). Densities at the three mile station peaked during the first two weeks of August after which no perch were detected at this station. Densities of pelagic age-0 yellow perch were typically higher in samples taken at the surface than in samples taken at depth within the epilimnion (Figure 9). Only 13 age-0 yellow perch were detected at depth within the epilimnion and all of these individuals were collected at the fifteen mile station on July 13. 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. Age-0 yellow perch lengths ranged from less than 4 mm in early June to greater than 32 mm in late July, and by late August the largest fish disappeared from our offshore samples. The disappearance of 30-40 mm perch from offshore samples during mid-August corresponds well to the appearance of similar sized demersal age-0 perch in nearshore bottom trawl samples (Figure 10). Several of the perch caught during the first two weeks of August were detected in surface waters of three mile station and were greater than 30 mm TL (size detected in early bottom trawl samples), suggesting that these fish were moving inshore.

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 2006. At the three mile station, calanoid and cyclopoid copepods, daphnia, and bosmina all peaked within the epilimnion during early August (Figure 11a). Cyclopoid copepods and bosmina dominated the zooplankton assemblage at the 3 mile station during the first week of August (3.3/L and 2.8/L, respectively), but these taxa were rare at this station during the remaining sampling period. Densities of cyclopoid copepods and bosmina remained very low within the epilimnion at both the nine and fifteen mile stations during 2006 (Figure 11b and c). Calanoid copepods peaked at the nine mile station during mid-July and remained low throughout the rest of the sampling period. Densities of daphnia at the nine miles station remained low throughout much of July and August and then peaked on August 21. Both calanoid copepods and daphnia peaked on July 26 at the fifteen mile station and remained low throughout the month of August.

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

Daytime bottom trawling efforts during 2006 sampled approximately 159,632 m^2 and collected 460 yellow perch estimated to be age-0 based on length. 2006 annual CPUE of age-0 yellow perch was 288 fish/100,000 m^2. Age-0 CPUE in 2006 was much lower than that detected in 2005 and most similar to catches during 2004 (Figure 12). Individual age-0 yellow perch were collected from July 31 through October 17, but CPUE peaked during mid-September. Yellow perch as young as 47 days appeared in the nearshore benthic environment and peak abundance occurred at 65 days old (Figure 7c). The cohort that hatched during the first week of June and was the most abundant in the nearshore pelagic environment also contributed the highest percentage of individuals in the nearshore benthic environment (Figure 6c). Growth rates in the nearshore benthic area for juvenile yellow perch averaged 0.52 mm*day^{-1} with later hatched cohorts experiencing faster growth rates.

During 2006 alewife had the highest overall CPUE in bottom trawl samples (926 fish/100,000 m^2). Yellow perch was the next most abundance species, but CPUE was more than 3 times lower than that of alewife. Rainbow smelt (*Osmerus mordax*) was also common with a CPUE of 189 fish/100,000 m^2. Spottail shiner (*Notropis hudsonius*) and round goby (*Neogobius melanostomus*) were also caught, but in much smaller numbers. Additionally, three bloater (*Coregonus hoyi*) and one sculpin (*Cottus* spp.) were also collected during our bottom trawling efforts.

Mean June-July zooplankton density in 2006 was 18.9/L, which is a 5% decrease from our 2005 estimate (Figure 13). In 2006, zooplankton densities varied significantly throughout the sampling period. Densities of both total and crustacean zooplankton were low during early June (Figure 14). Density of total zooplankton peaked on June 22, declined drastically by June 28, and then peaked again on July 5. One explanation for the sharp peak in total zooplankton detected on June 22 was the sudden presence of significant numbers of veligers; they made up over 92% of individuals collected on that date. Crustacean zooplankton density remained low through June, peaked on July 24 (11.0/L), and then declined slightly in early August and remained around 5.0/L through August. Copepod nauplii and adult calanoid copepods dominated the zooplankton assemblage throughout much of the month of June (Figure 15). Adult calanoid copepods made up less than 6% of the zooplankton assemblage after early July, but copepod nauplii accounted for 9-30% of weekly zooplankton densities during this same period. Rotifers were the single most prominent taxa during the first week of June, but densities declined until the first week of July when they accounted for over 80% of the zooplankton assemblage. Bosmina densities remained low through June and then peaked on August 8 when they accounted for over 31% of zooplankton. Daphnia were rare during 2006; they were only detected on July 24 at a density of 1.5/L. Other cladocerans (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 3,916 ± 2,433/m^2 (SD) in 2006, which is much higher than that detected in 2004, but similar to densities seen during 2005. Similar to 2005, such high densities of benthic invertebrates during 2006 can be partly explained by extremely high abundances of ostracods. Monthly densities of benthic invertebrates were lowest in June (2,533 ± 1,048/m^2) and highest during both July (5,036 ± 3,673/m^2) and August (5,000 ± 2,595/m^2). Zebra mussels made up very little (<1%) of the nearshore benthic invertebrate community throughout the sampling period. The most abundant species in June and July samples were ostracods and chironomids (Figure 16). These taxa made up over 78% of all individuals collected during both months. During August and September, ostracods were most abundant (46-49%), followed by chrionomids, and mollusks. During August, individuals of Pelecypoda were the most abundant mollusks followed by individuals of Valvatidae. Mollusks of Pelecypoda and Sphaeriidae each comprised about 50% of the mollusks found in benthic substrate during 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
<u>Objective:</u> 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 a bottom trawl were used to sample fish at the same location on five occasions from late August to mid-October during 2006. Total catch in the trawl from these dates was 212 individuals and 50% (105) of these fish were yellow perch. Additionally, all yellow perch collected in the trawl on these dates were determined to be age-0, based on length. We caught a total of 803 individuals in our small mesh gill nets and 49% (396) of these fish were yellow perch. Age-0 yellow perch comprised approximately 44% (349 fish) of the total catch from small mesh gill nets during 2006. Alewife, rainbow smelt, round goby, and spottail shiner were also collected in both the trawl and small mesh gill nets. Additionally, one bloater was collected in small mesh gill nets.

We were able to compare CPUE of age-0 yellow perch using a bottom trawl and small mesh gill nets on 9 different occasions between late August and mid-October during 2005 and

2006. Based on these assessments, CPUE of age-0 yellow perch from gill nets was positively correlated to log transformed CPUE from our bottom trawl ($r = 0.67$, $P = 0.003$). The regression equation Gill net CPUE = 5.045 + 9.777 [log (Trawl CPUE)] was highly significant ($P = 0.003$), and hopefully with continued effort will we be able to strengthen the relationship ($r^2 = 0.45$; Figure 17).

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 244 age-0 yellow perch from 8 sampling dates between July 31 and October 17, 2006 were examined. Overall age-0 yellow perch primarily consumed zooplankton (96%) and smaller quantities of benthic invertebrates. Over 65% of the zooplankton consumed by age-0 fish were copepods. An apparent shift from zooplankton to benthic invertebrate prey was detected during the assessment period. More specifically, zooplankton dominated the diet of age-0 fish through September after which benthic invertebrates, mainly amphipods, were primarily consumed (Figure 18). One exception was in late August when 30% of their diet consisted of chironomids, which was the highest consumption of this taxa detected. While copepods made up over 50% of the diet during mid-August, cladocerans (mainly Bosmina) comprised most of the diet during late August. During the first two weeks of September, age-0 yellow perch consumed copepods (mainly calanoids) almost exclusively (98-99%) and then consumed a larger portion of cladocerans during late September. Cladocerans comprised 61% of their diet during the last week of September and most of these prey were Daphnia (>75%). Then in October, amphipoda dominated age-0 yellow perch diets and smaller quantities of copepods and chironomids were consumed.

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 appears to have an effect on yellow perch recruitment success expressed as age-0 fall CPUE in nearshore waters of southwestern Lake Michigan. Cumulative degree days above a threshold of 13.5°C correlated positively with age-0 yellow perch CPUE in the fall ($r^2 = 0.25$; $P = 0.02$). We are in the process of updating our investigation of abiotic and environmental variables using multiple regression analysis and model selection criterion to determine their relative importance in predicting age-0 yellow perch recruitment success over a period of 20 years, 1987-2006.

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 2006 fyke net sampling collected only 146 yellow perch at three sites: Waukegan wiremill (US Steel), North Lake Forest, and Fort Sheridan. Annual spring CPUE of adult yellow perch has continually declined since 2000, and reached an all time low during 2006 with less than 15 perch caught per net night. This is a 94% decline from catch rates in 2000 when CPUE averaged 213 yellow perch per net night. Twenty-seven 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. Similar to 2005, the majority of yellow perch collected in fyke nets during 2006 were age-3 and age-4. Fish from the 2003 year-class dominated the catch, and fish from the 2002 year-class were also present in measurable numbers. Catch rates of the 1998 year-class declined with an 89% decrease from our 2005 estimate. Similar results were detected from fish collected during the 2006 creel survey in Waukegan and Montrose Harbors, IL. However, the largest group of fish was represented by the 2002 year-class, followed by the 2003 and 1998 year-classes. This is the second consecutive year that the 2002 year-class has dominated the sampled sport harvest; this year-class made up over 60% of our subsample during 2005 (Redman et al. 2006) and over 50% during 2006. Fish from these young year-classes (2002-2003) may be extremely important for future spawning events 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 over harvest and reduced recruitment events.

Continual decline in spawning activity at historical sites has not only been detected in our spring fyke net assessment, but also in our annual egg skein surveys. The density of yellow perch egg skeins collected at the US Steel intake line, south of Waukegan Harbor, in 2006 declined 66% from the 2005 estimate. This is the fourth consecutive year of reduced egg deposition at this site, and the first instance when egg skeins were only detected during one diver survey. One possible explanation for this decline is that the spawning potential of the younger 2001-2003 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. Fecundity of yellow perch from Lake Michigan is known to increase with age (Brazo et al. 1975) and length (Lauer et al. 2005). Furthermore, there is evidence that larvae produced by younger spawners can experience higher mortality rates than larvae from older individuals, there by potentially leading to gross over estimates of egg production when population age structure is not taken into account (O'Farrell and Botsford 2006). Thus, this continual decline of spawning activity raises concerns about the reproductive potential of the yellow perch population during a shift towards younger individuals.

Densities of newly-hatched larval yellow perch were much lower during 1994-2006 compared to densities observed before 1994. Densities peaked at 9.4 fish/100 m^3 in 2006, compared to peaks of over 100 fish/100 m^3 prior to 1994 (Marsden and Robillard 2004). Nearshore larval catches in 2006 were most similar to catch rates reported in 2003 and 2004. The density of larval yellow perch peaked in nearshore waters on June 13 followed by a steady decline. Pelagic, age-0 yellow perch density peaked on July 13 at stations nine and fifteen miles offshore, which suggests these fish moved from nearshore to offshore waters during this time period. Age analysis suggested that age-0 yellow perch spent only about one week in nearshore waters and arrived well offshore (9 to 15 miles from shore) about 16 days after hatch. The severe decline of larval yellow perch in nearshore and offshore waters of Illinois indicate that a reduction in adult females and reduced food availability may be negatively impacting yellow perch recruitment.

The 2006 CPUE for age-0 yellow perch collected in bottom trawls was much lower than that detected during 2005, and most similar to catches in 2004. Previously, relatively high CPUE 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 (Redman et al, 2006) and dominated creel survey collections during 2006. These results suggest that a spike in 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 in our fyke net 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 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, mediated by increased water clarity observed in the past eight years.

In light of these concerns, we compared the effectiveness of our bottom trawl and small mesh gill nets in estimating relative abundance of demersal age-0 yellow perch. We were able to make comparisons between these gears on nine occasions between late August and mid-October during 2005 and 2006. 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 = 5.045 + 9.777[log (Trawl CPUE)] ($r^2 = 0.45$, $P = 0.003$). However, more comparisons are needed before we can make definitive conclusions as to the comparable efficiency of these two gears. 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.

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 1996-2006 (Dettmers et al. 2003, Redman et al. 2006). 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 with the establishment of this exotic cladoceran in offshore waters of Lake Michigan. The establishment of zebra mussels throughout nearshore waters of Lake Michigan was another major change in the Lake Michigan ecosystem between the late 1980s and the late 1990s. Zebra mussels have drastically reduced phyto- and zooplankton 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 explore the role played by food availability in the recruitment success of yellow perch

In summary, the fishable yellow perch population in 2006 was dominated by the 2002 and 2003 year-classes. Our sport harvest data suggests that anglers are already primarily harvesting fish from these year-classes. 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 or two 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, 2006-2007

	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

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REFERENCES

Barbiero, R. P. and M. L. Tuchman. 2004. Changes in the crustacean communities of Lakes Michigan, Huron, and Erie following the invasion of the predatory cladoceran *Bythotrephes longimanus*. Canadian Journal of Fisheries and Aquatic Sciences 61:2111-2125.

Brazo, D. C., P. I. Tack, and C. R. Liston. 1975. Age, growth, and fecundity of yellow perch, *Perca flavescens,* in Lake Michigan near Ludington, Michigan. Transactions of the American Fisheries Society 1975(4):726-730.

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

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

Clapp, D. F., and J. M. Dettmers. 2004. Yellow perch research and management in Lake Michigan: evaluating progress in a collaborative effort, 1997-2001. Fisheries 29(11):11-19.

Czesny, S. J., B. D. S. Graeb, and J. M. Dettmers. 2005. Ecological consequences of swim bladder noninflation for larval yellow perch. Transactions of the American Fisheries Society 134:1011-1020.

Creque, S. M., S. J. Czesny, D. C. Glover, and J. M. Dettmers. 2004. Yellow perch population assessment in southwestern Lake Michigan, including the identification of factors that determine yellow perch year-class strength. Annual report to the Illinois Department of Natural Resources. Illinois Natural History Survey Technical Report 04/04. 35 pp.

Dettmers, J. M., M. J. Raffenberg, and A. K. Weis. 2003. Exploring zooplankton changes in southern Lake Michigan: implications for yellow perch recruitment. Journal of Great Lakes Research 29:355-364.

Dettmers, J. M., A. S. McNaught, D. M. Mason, D. J. Jude, and J. Janssen. 2004. Mechanisms affecting recruitment of yellow perch in Lake Michigan. Final report to the Great Lakes Fishery Trust. Illinois Natural History Survey Technical Report 04/12. 34 pp.

Dettmers, J. M., J. Janssen, B. Pientka, R. S. Fulford, and D.J. Jude. 2005. Evidence across multiple scales for offshore transport of yellow perch (*Perca flavescens*) larvae in Lake Michigan. Canadian Journal of Fisheries and Aquatic Sciences 62:2683-2693.

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

Graeb, B. D. S., J. M. Dettmers, D. H. Wahl, and C. E. Cáceres. 2004. Fish size and prey availability affect growth, survival, prey selection, and foraging behavior of larval yellow perch. Transactions of the American Fisheries Society 133:504-514.

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

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

Janssen, J., and M. A. Luebke. 2004. Preference for rocky habitat by age-0 yellow perch and alewives. Journal of Great Lakes Research 30(1):93-99.

Lauer, T. E., S. M. Shroyer, J. M. Kilpatrick, T. S. McComish, and P. J. Allen. 2005. Yellow perch length-fecundity and length-egg size relationships in Indiana waters of Lake Michigan. North American Journal of Fisheries Management 25:791-796.

Leach, J. H. 1993. Impacts of the zebra mussel (*Dreissena polymorpha*) on water quality and fish spawning reefs in western Lake Erie. In: T. F. Nalepa and D. Schloesser, eds. Zebra mussels: biology, impacts, and control. Lewis Publishers, Boca Raton, FL.

LeCren, E. D. 1958. Observations on the growth of perch (*Perca flavescens* L.) over twenty-two years with special reference to the effects of temperature and changes in population density. Journal of Animal Ecology 27:287-334.

Marsden, J. E., and S. R. Robillard. 2004. Decline of yellow perch in southwestern Lake Michigan, 1987-1997. North American Journal of Fisheries Management 24(3):952-966.

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

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

O'Farrell, M. R., and L. W. Botsford. 2006. The fisheries management implications of maternal-age-dependent larval survival. Canadian Journal of Fisheries and Aquatic Sciences 63:2249-2258.

Redman, R. A., S. M. Creque, S. J. Czesny, D. C. Glover, S. Miehls, and J. M. Dettmers. 2005. Yellow perch population assessment in southwestern Lake Michigan, including evaluation of sampling techniques and identification of factors that determine yellow perch year-class strength. Annual report to the Illinois Department of Natural Resources. Illinois Natural History Survey Technical Report 05/09. 38 pp.

Redman, R. A., S. J. Czesny, D. C. Glover, S. M. Miehls, and J. M. Dettmers. 2006. Yellow perch population assessment in southwestern Lake Michigan, including evaluation of sampling techniques and identification of factors that determine yellow perch year-class strength. Annual report to the Illinois Department of Natural Resources. Illinois Natural History Survey Technical Report 06/05. 45 pp.

Stewart, T. W., J. G. Miner, and R. L. Lowe. 1998. Quantifying mechanisms for zebra mussel effects on benthic macroinvertebrates: organic matter production and shell-generated habitat. Journal of the North American Benthological Society 17:81-94.

Wilson, K. A., E. T. Howell, and D. A. Jackson. 2006. Replacement of zebra mussels by quagga mussels in the Canadian nearshore of Lake Ontario: the importance of substrate, round goby abundance, and upwelling frequency. Journal of Great Lakes Research 32:11-28.

TABLE

Table 1. Summary of 2006 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 22	7-9	200	0	--	--
May 30	7-8	200	0	--	--
June 1	7-9	200	0	--	--
June 15	7-9	200	11	40%	c & d
June 29	7-9	200	0	--	--

FIGURES

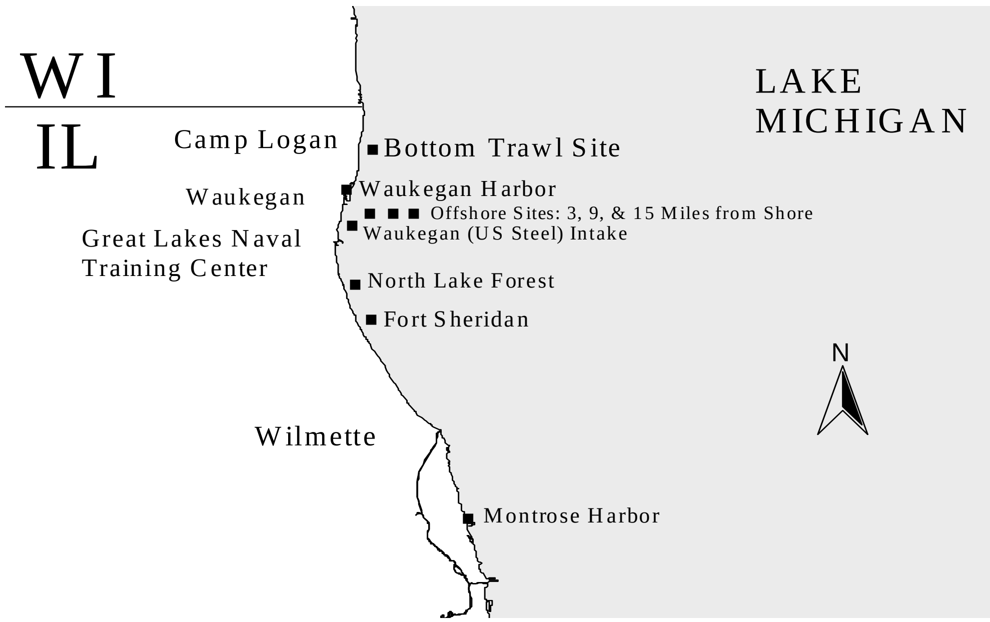

Figure 1. Sampling sites in Lake Michigan during 2006.

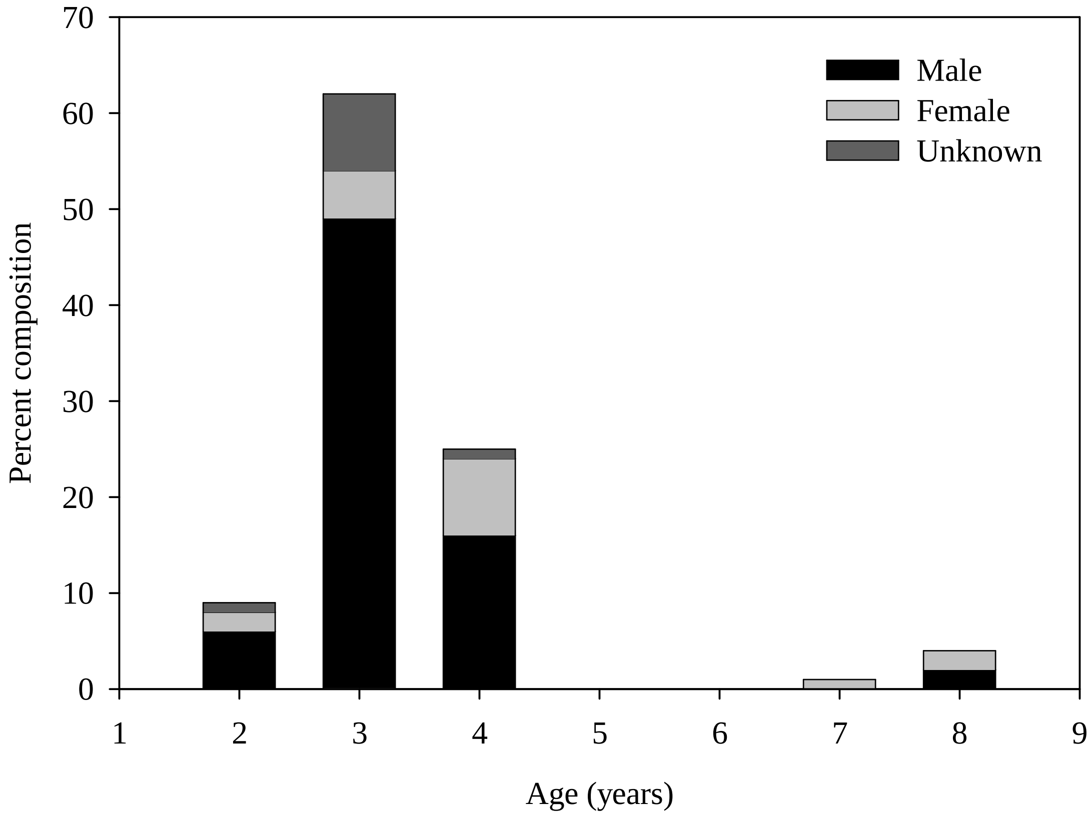

Figure 2. Age composition of adult yellow perch collected between Waukegan and Fort Sheridan, IL during the spring of 2006.

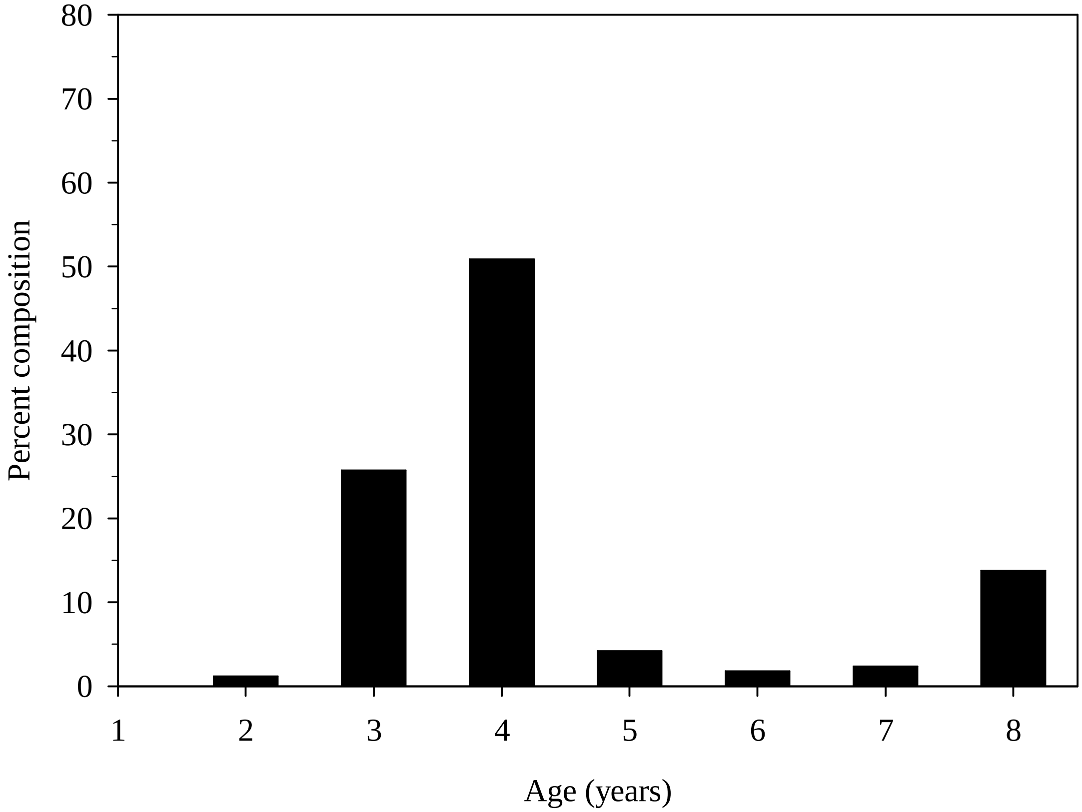

Figure 3. Age composition of adult yellow perch caught by anglers during 2006 at Waukegan and Montrose Harbors, IL.

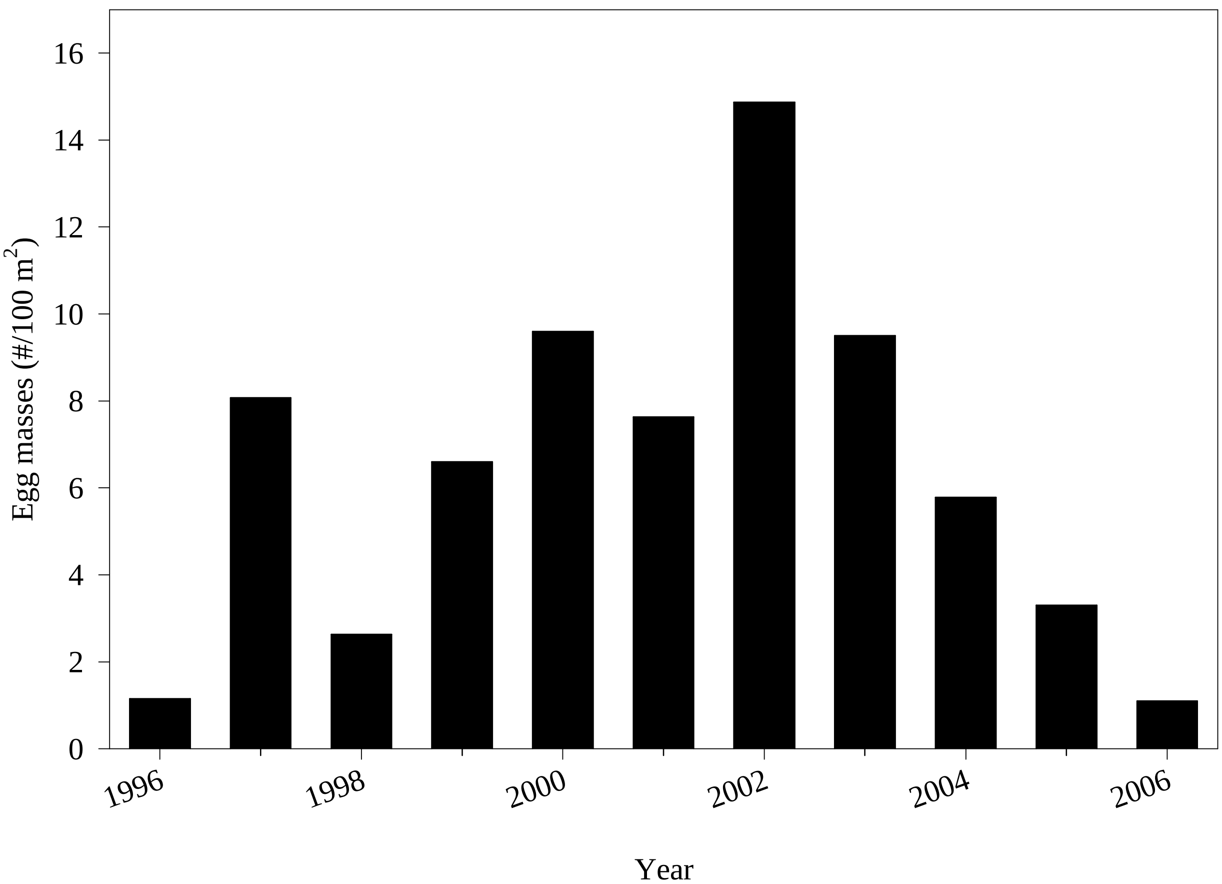

Figure 4. Annual patterns of yellow perch egg production at the US Steel intake for years 1996-2006.

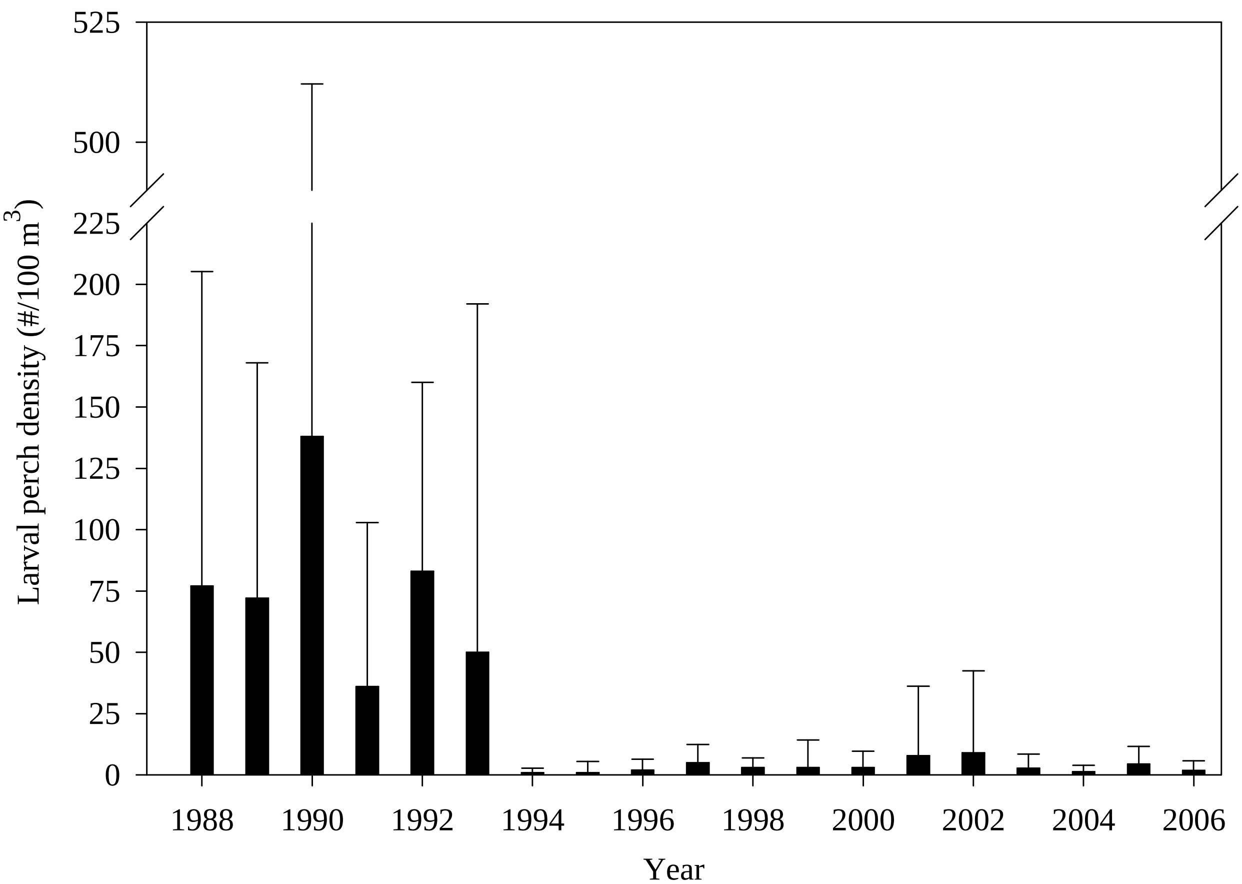

Figure 5. Seasonal mean density of larval yellow perch (+ 1SD) sampled at two sites near Waukegan Harbor, IL, 1988-2006.

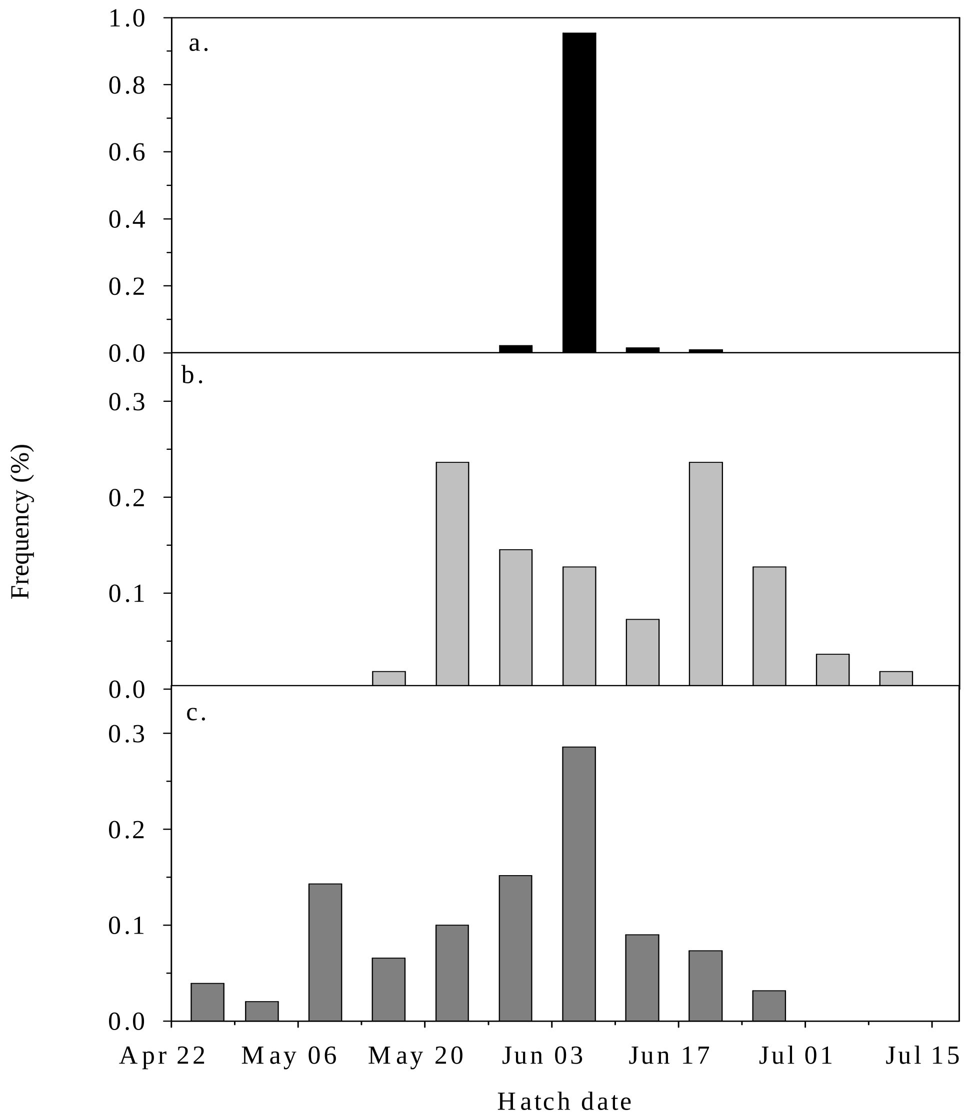

Figure 6. Hatching distributions of yellow perch captured at a) nearshore pelagic, b) offshore pelagic, and c) nearshore benthic environments in 2006 near Waukegan, IL.

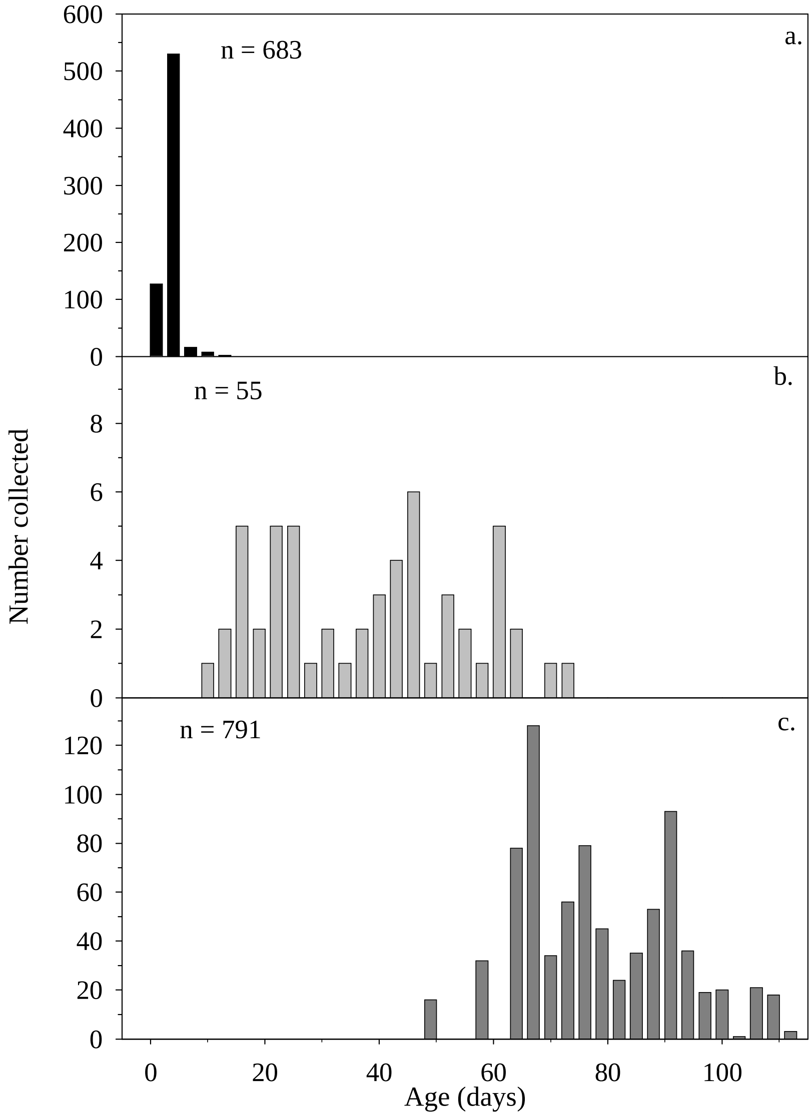

Figure 7. Age-frequency histogram of yellow perch collected at a) nearshore pelagic, b) offshore pelagic, and c) nearshore benthic locations in 2006 near Waukegan, IL. Yellow perch are grouped into 3-day age classes. Number of yellow perch collected (n) for each location is provided.

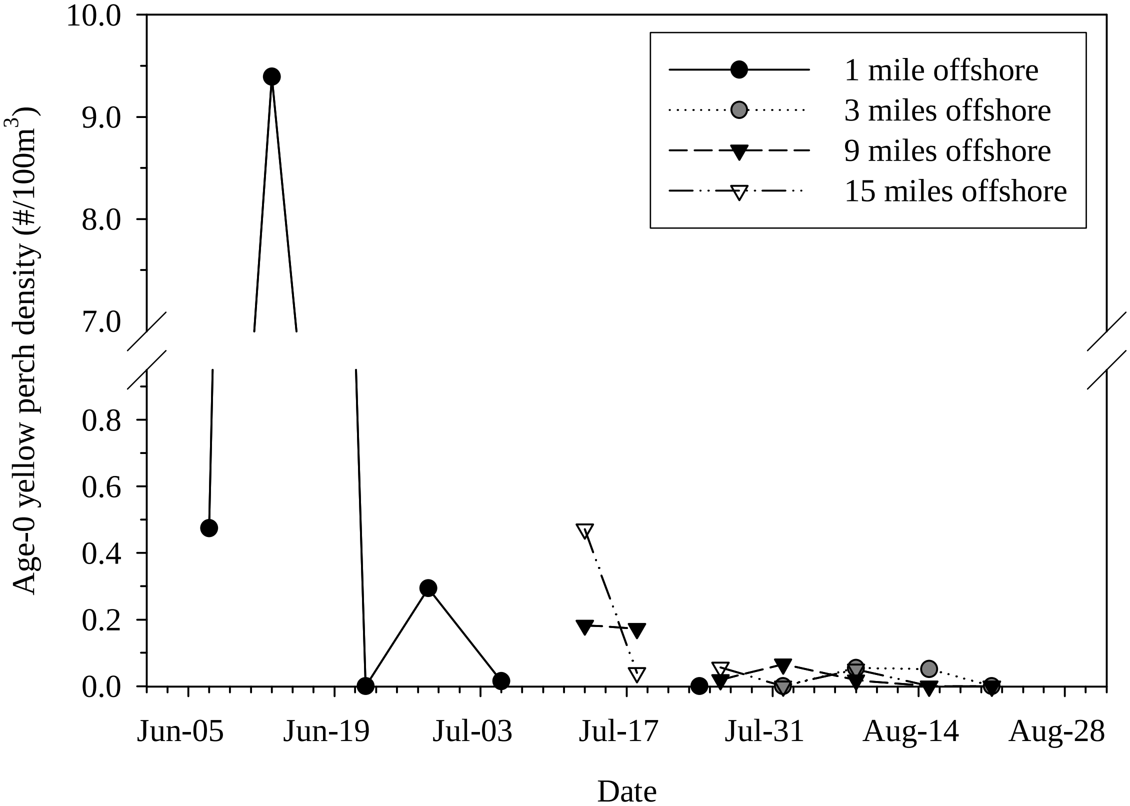

Figure 8. Mean densities of pelagic age-0 yellow perch at all sampling depths along a 15 mile transect north of Waukegan, IL during 2006. The site one mile offshore is in close proximity to nearshore spawning sites and is included for reference.

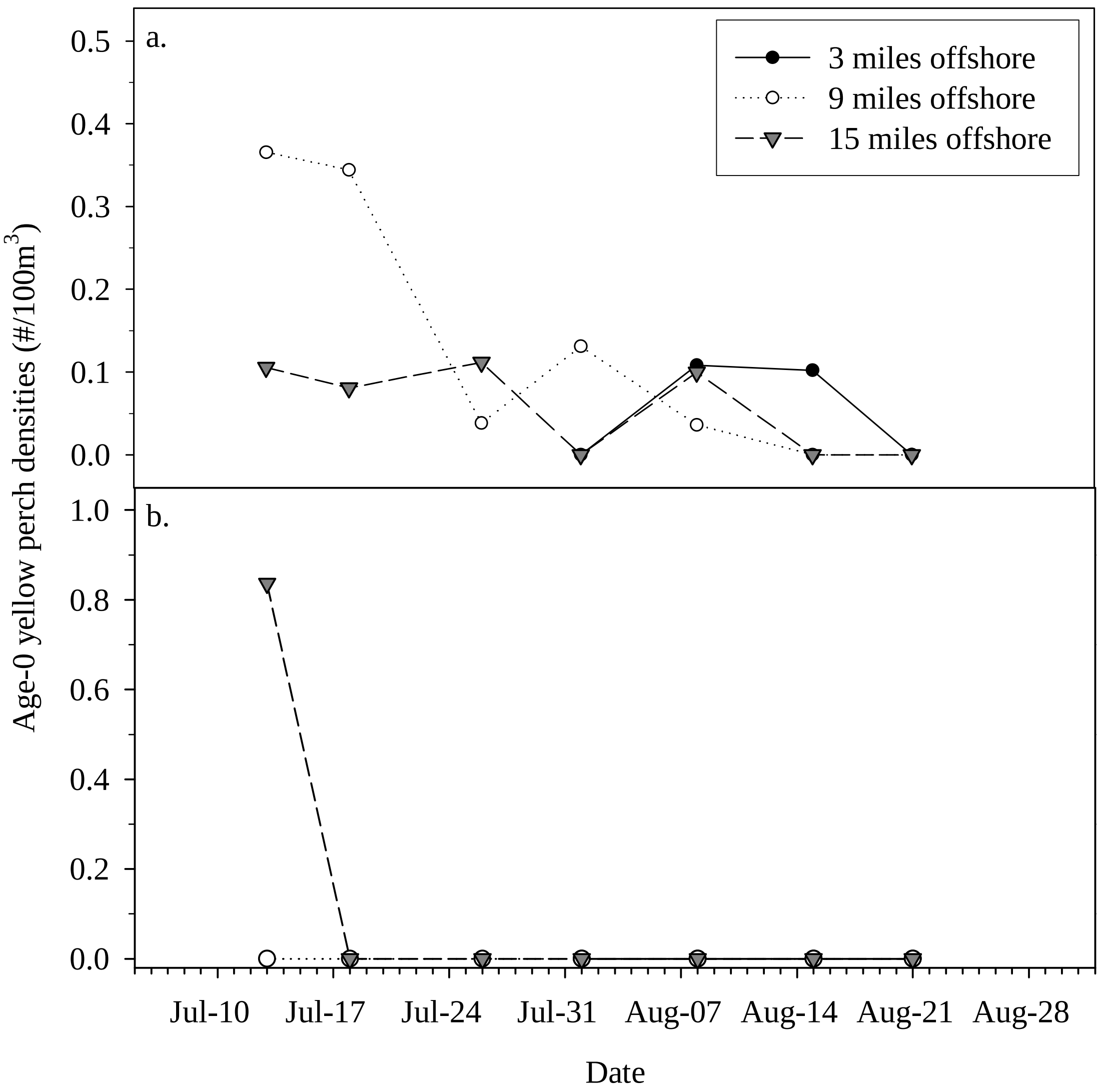

Figure 9. Relative abundance of pelagic age-0 yellow perch collected a) at the surface and b) at depth within the epilimnion along a 15 mile transect north of Waukegan, IL during 2006.

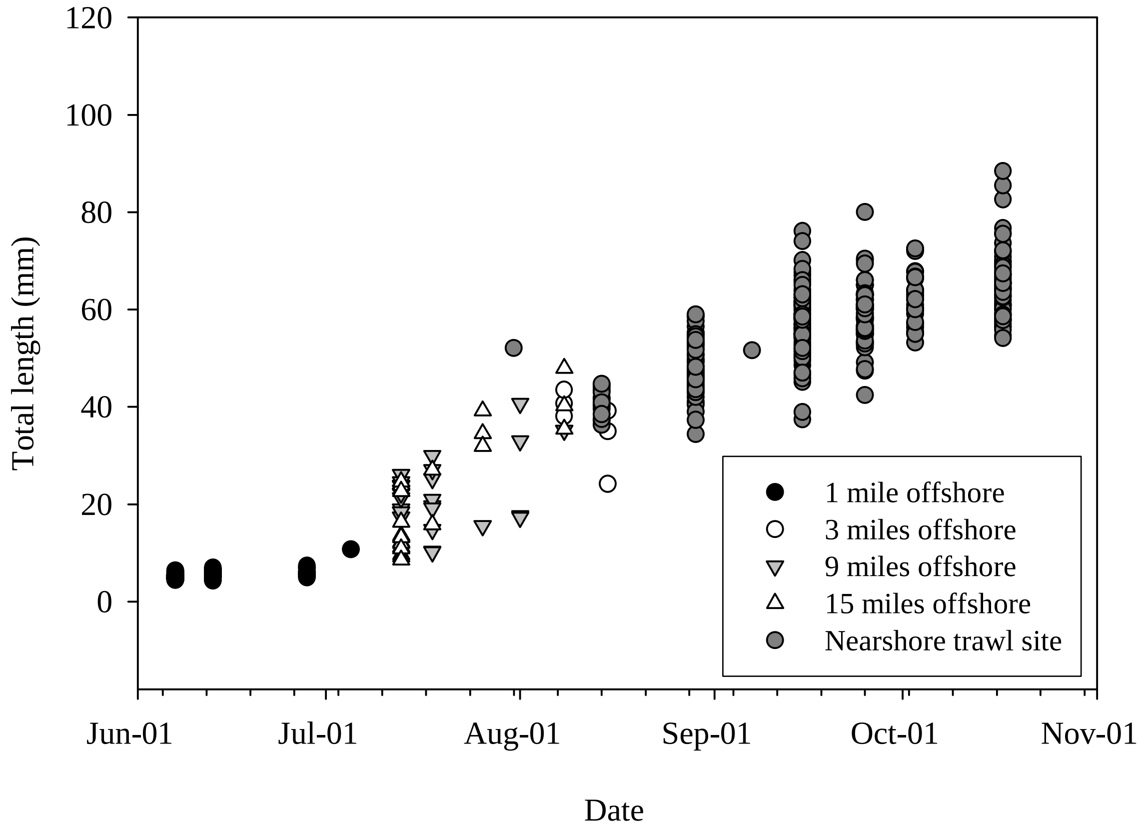

Figure 10. Length distribution of larval and age-0 yellow perch collected in nearshore and offshore waters north of Waukegan, IL during 2006.

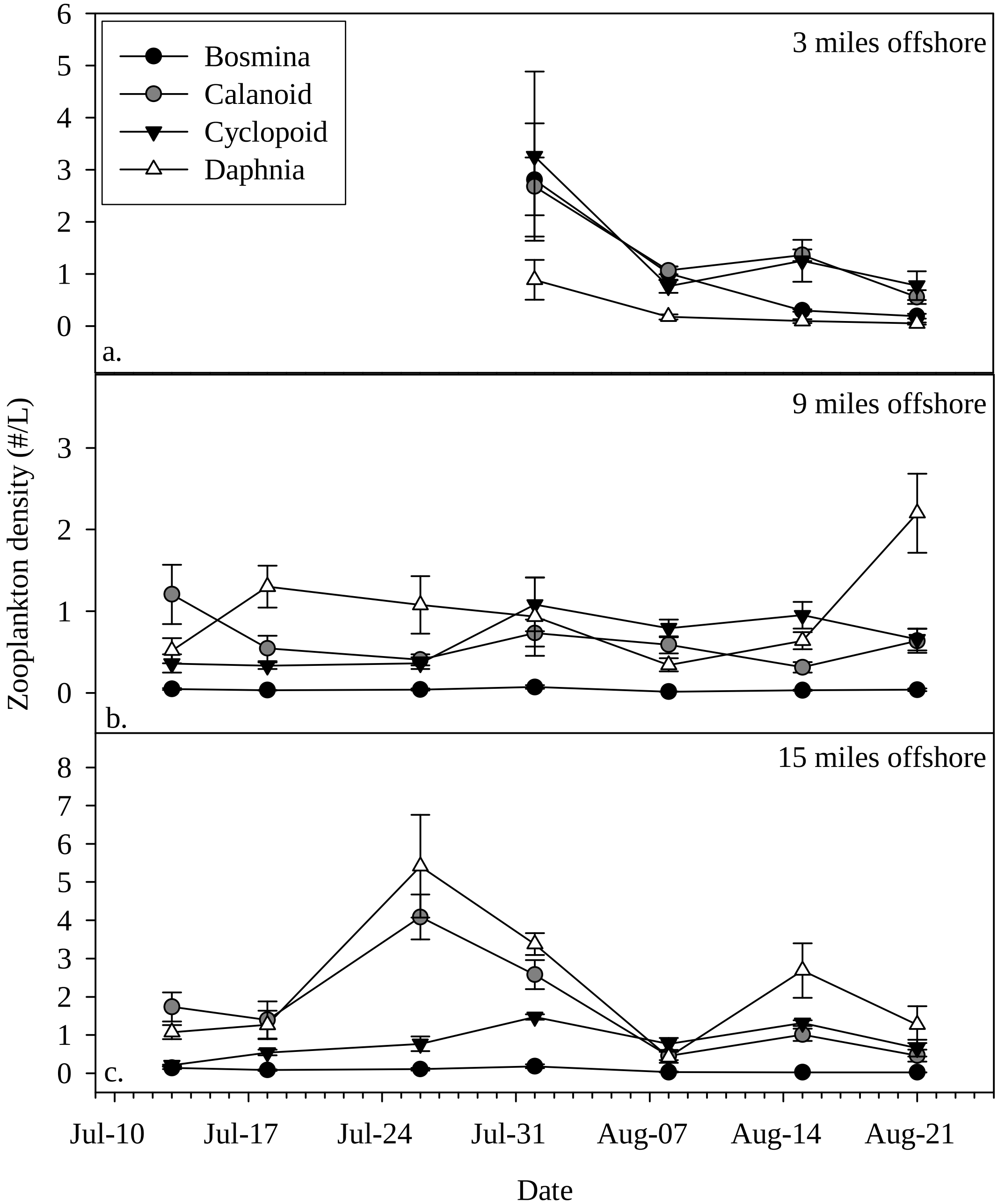

Figure 11. Relative abundance of common crustacean zooplankton collected within the epilimnion at sites a) 3 miles, b) 9 miles, and c) 15 miles offshore during 2006.

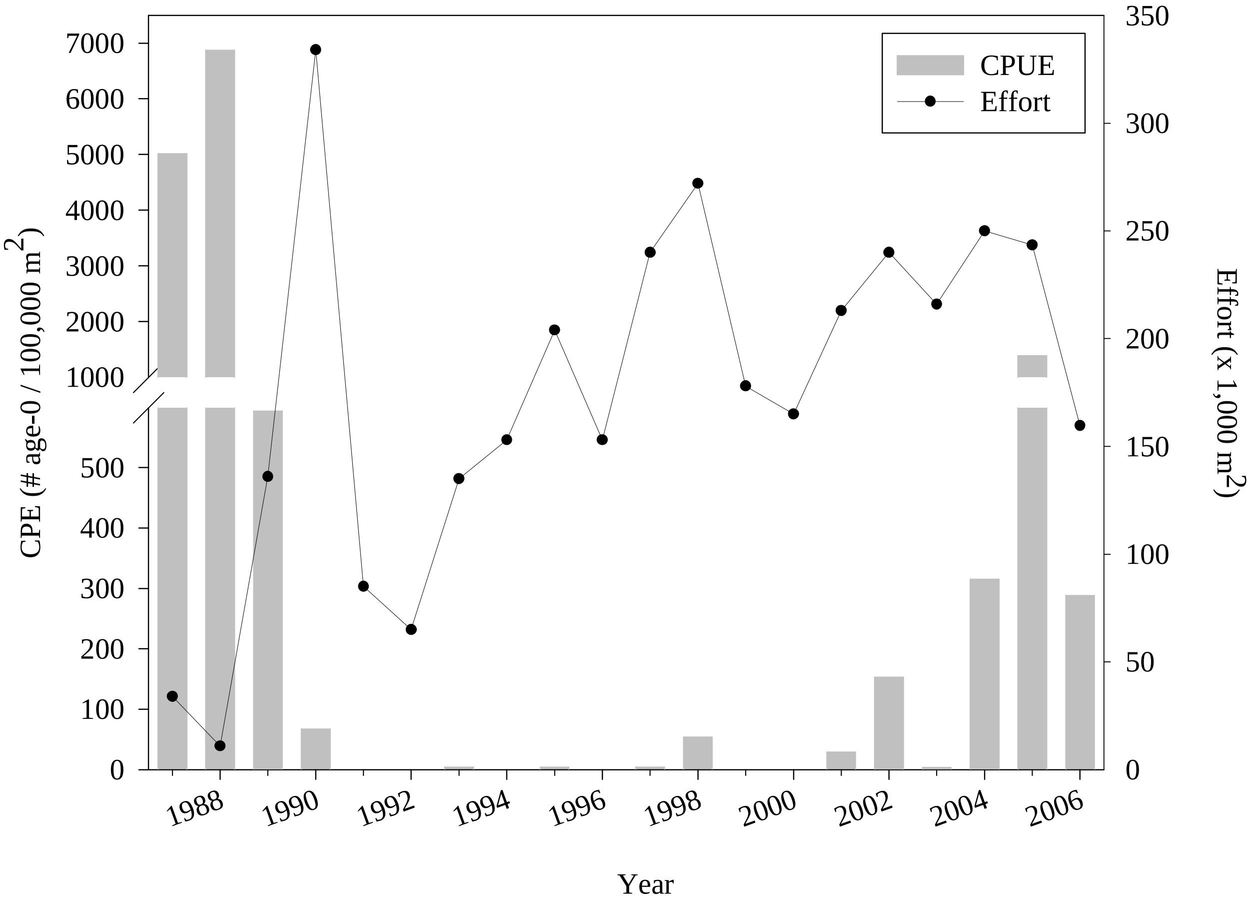

Figure 12. Relative abundance of age-0 yellow perch collected by daytime bottom trawls in 3 – 10 m of water north of Waukegan Harbor, IL, 1987-2006.

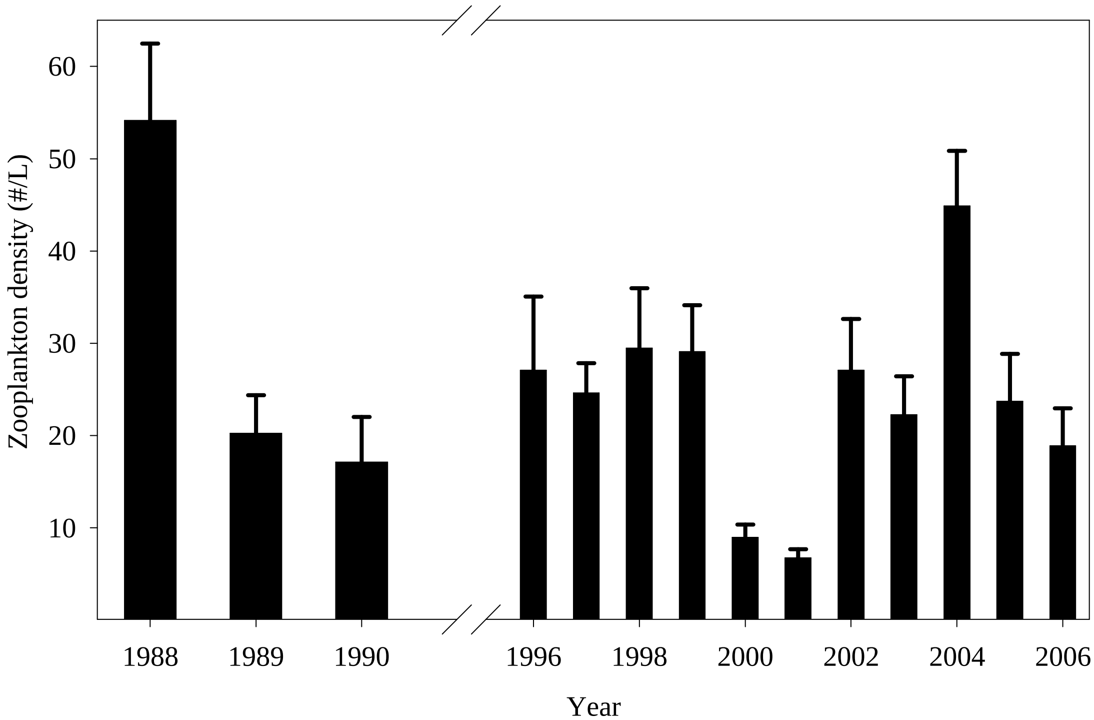

Figure 13. Mean density of zooplankton (+ 1 SE) present in Illinois waters of Lake Michigan near Waukegan during June-July for years 1988-2006.

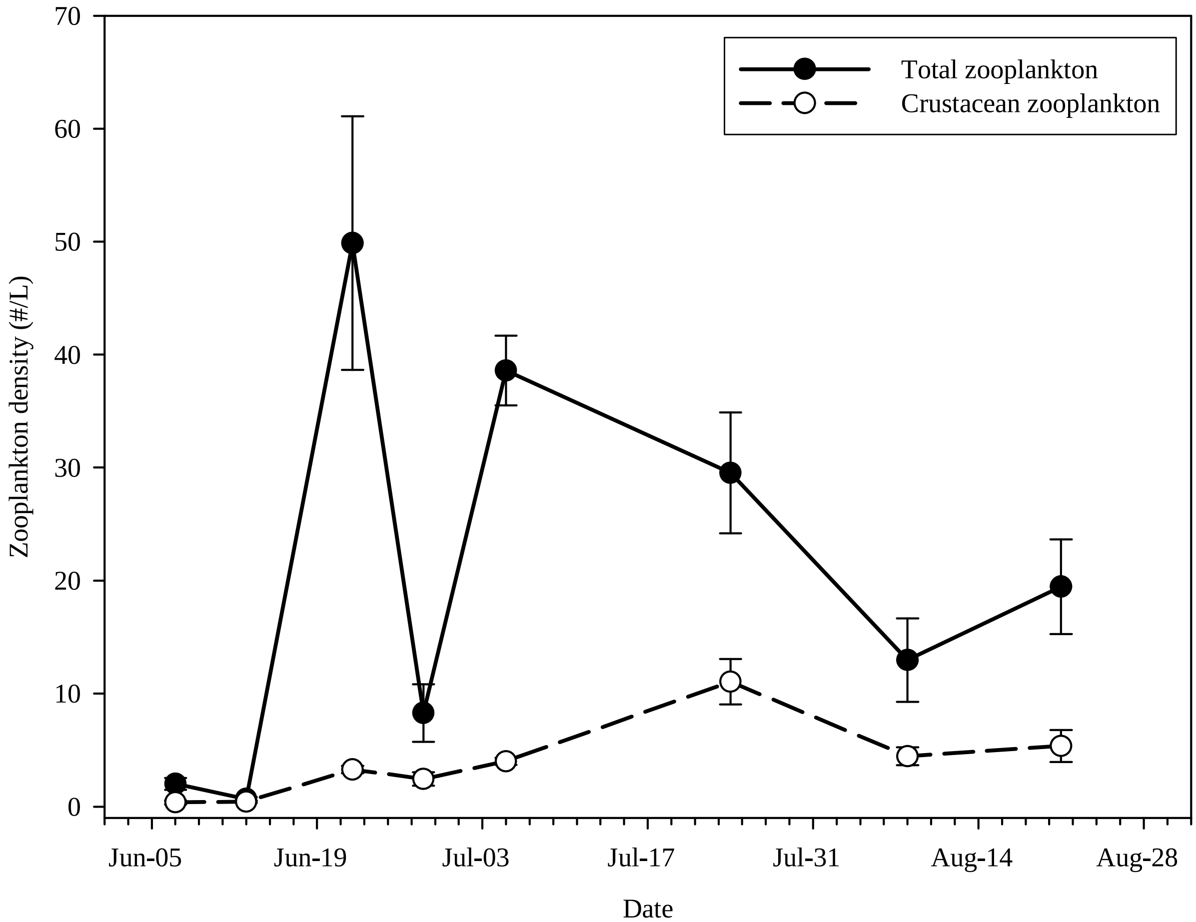

Figure 14. Relative abundance of zooplankton (± 1 SE) present in nearshore Illinois waters of Lake Michigan around Waukegan during June-August 2006. Closed circles (●) represent total zooplankton, whereas open circles (○) represent crustacean zooplankton.

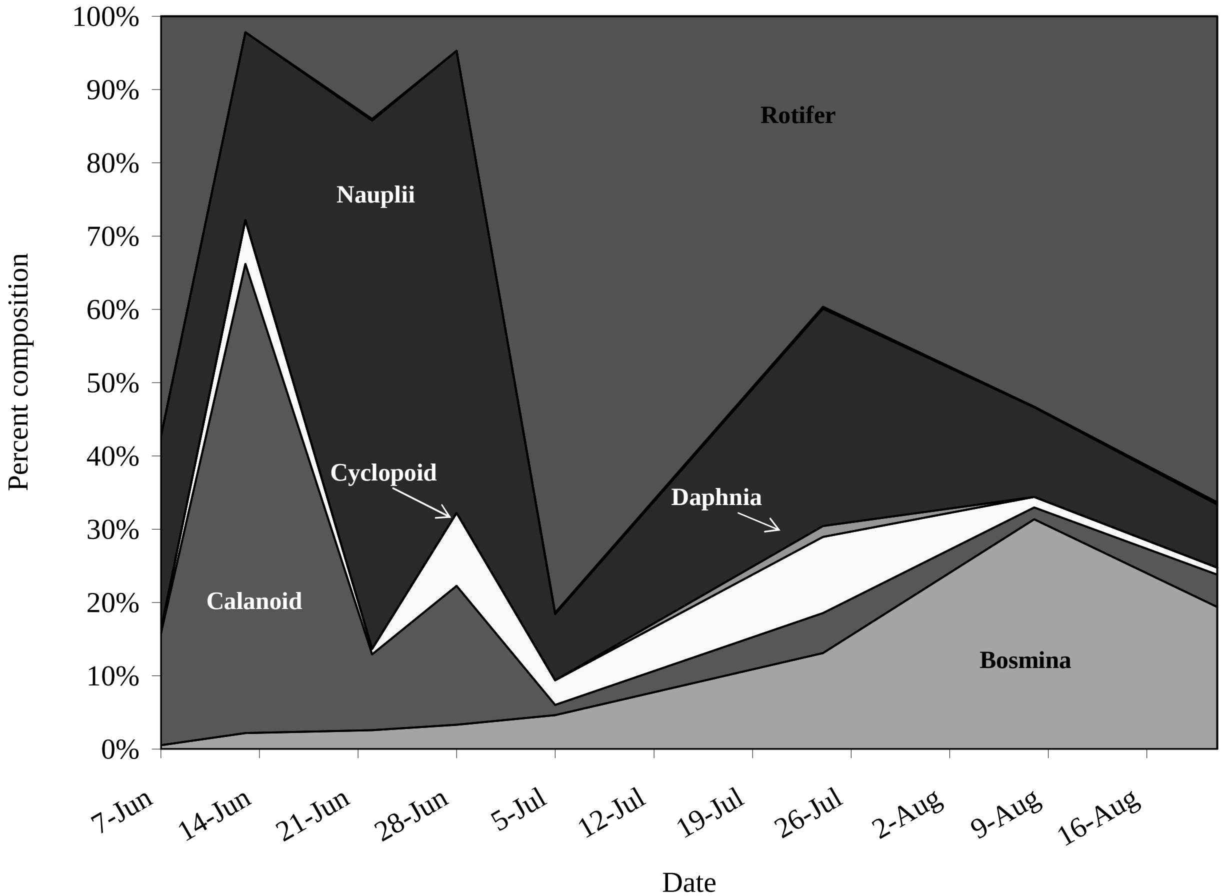

Figure 15. Percent composition of zooplankton found in nearshore Illinois waters of Lake Michigan near Waukegan during June-August 2006.

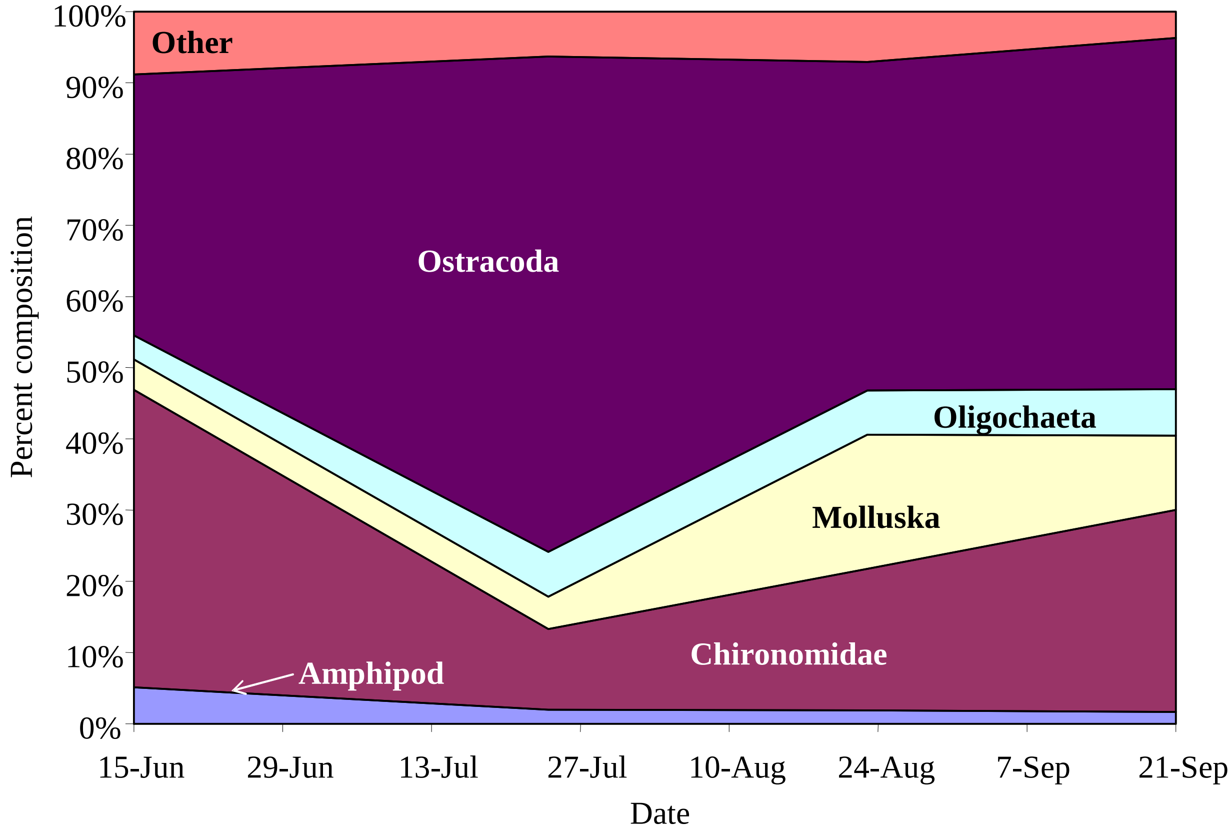

Figure 16. Percent composition of benthic invertebrates found in nearshore substrate of Lake Michigan north of Waukegan Harbor, IL between June 15 and September 21, 2006.

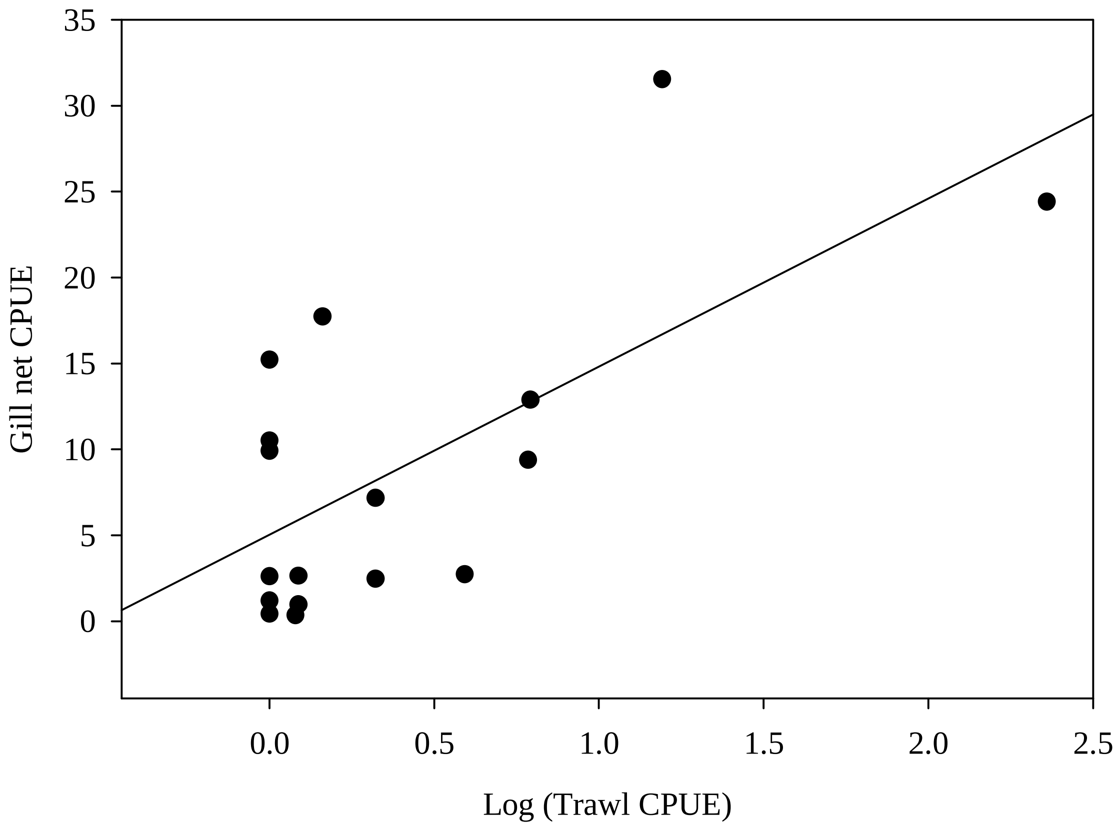

Figure 17. Relationship between age-0 yellow perch CPUE from small mesh gill netting and bottom trawling conducted north of Waukegan Harbor, IL during 2005 and 2006. The regression equation is Gill net CPUE = 5.045 + 9.777 [log (Trawl CPUE)], $r^2 = 0.45$; $P = 0.003$.

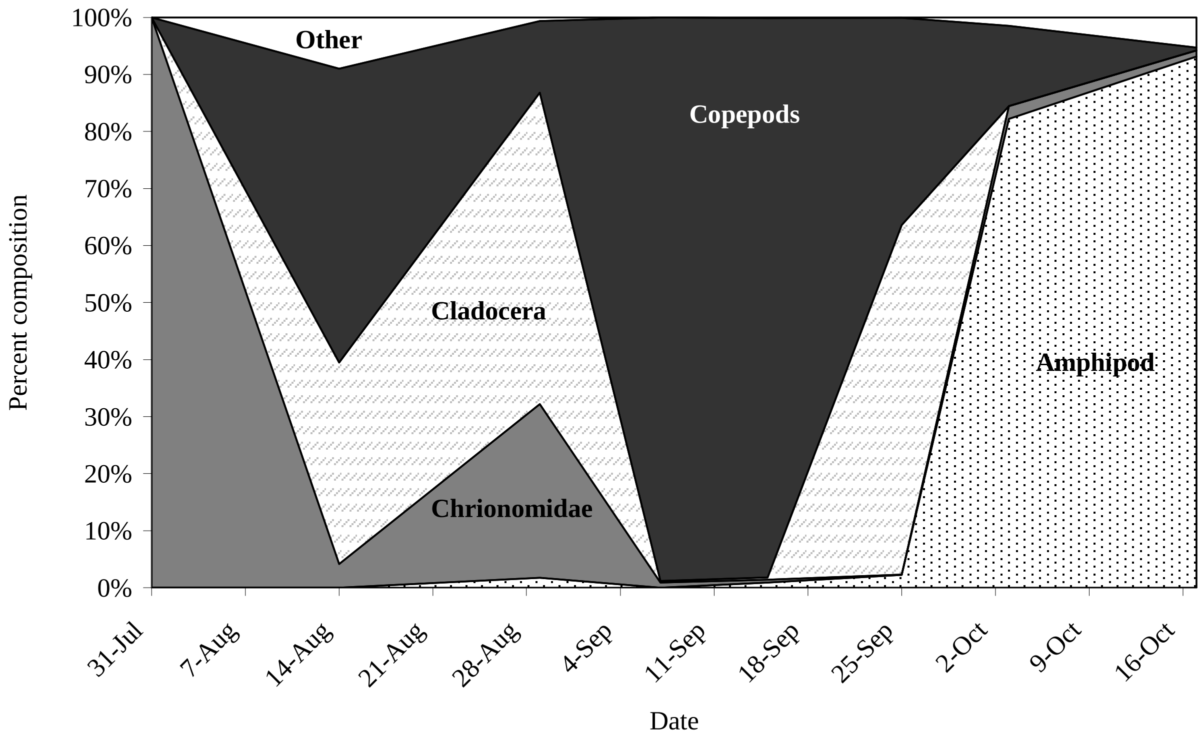

Figure 18. Percent composition by number of items found in the diets of age-0 yellow perch collected with bottom trawls north of Waukegan Harbor, IL between July 31 and October 17, 2006.