University of Illinois
Institute of Natural Resource Sustainability
William Shilts, Executive Director

ILLINOIS NATURAL HISTORY SURVEY
Brian D. Anderson Director
1816 South Oak Street
Champaign, IL 61820-6964
217-333-6830

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

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

Prepared for:
Division of Fisheries, Illinois Department of Natural Resources
in fulfillment of the reporting requirements of
Federal Aid Project F-123 R-15

INHS Technical Report 2009(27)
Date of issue: September 2009

ILLINOIS NATURAL HISTORY SURVEY

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, 2008 – June 30, 2009

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

University of Illinois
Institute of Natural Resource Sustainability
Illinois Natural History Survey

submitted to
Division of Fisheries, Illinois Department of Natural Resources
in fulfillment of the reporting requirements of
Federal Aid Project F-123-R15

________________________	________________________
Sergiusz Czesny,	Michael Douglas,
Principal Investigator	Associate Director of Research
Illinois Natural History Survey	Illinois Natural History Survey

September 2009

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

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

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, and identify factors likely to have limited yellow perch recruitment since 1989. We sampled adult yellow perch during the spring to assess reproductive potential and determine 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. Age-0 yellow perch were sampled at multiple depths and distances from shore with neuston nets, a mid-water Tucker trawl, small mesh 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 2008 sampling associated with our study objectives.

<u>Study 101.</u> 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

Job 101.1 Improve annual assessments of the yellow perch spawning population

1. Annual mean CPUE (fish/net night) was 25 ± 21 yellow perch (SD) from gill netting efforts at Waukegan and North Lake Forest, IL. Age-6 (2002 year class) and age-5 (2003 year class) fish dominated the catch. The 1998 year class (age-10) made up 13% of the catch.
2. Fecundity ranged from 1,525 to 117,410 eggs. Mean fecundity by age was highest for age-9 (82,376 ± 24,362 eggs, SD), and age-7 fish (70,543 ± 11,583 eggs). Based on AIC analysis, ovary weight and maternal age were the most influential variables on fecundity.

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

1. During 2008, both boat and pedestrian catches were dominated by age-5 (2003 year class) and age-6 (2002 year class) fish.

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

1. Divers only found 1 egg skein during surveys at the US Steel intake line during 2-19 June, 2008. Overall mean density of egg skeins was less than 1 egg skein per 100m^2.
2. Overall, catches of larval yellow perch in nearshore waters were relatively poor like they have been for more than a decade. Mean weekly density of larval yellow perch peaked on 18 June, 2008 at 8.6 ind./100 m^3.

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

1. Due to low sample size in day and night comparisons we were unable to describe the diel vertical distribution of age-0 yellow perch and zooplankton during 2008.

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 90 ind./100,000 m^2.
2. Mean June-July total zooplankton density in 2008 was 9.2 ind./L. Weekly mean crustacean zooplankton densities remained low (< 6 ind./L) during June and July, and peaked around 7.5 ind./L on two occasions: 12 August and 8 September.
3. Mean annual benthic invertebrate density north of Waukegan Harbor was 2,579 ± 1,744 ind./m^2 (SD) in 2008. The most common taxa were mollusks, ostracods, Oligochaetes, and chironomids.

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. Twelve paired comparisons between a bottom trawl and gill net were conducted at the same location between 5 August and 9 October, 2008. Only 19 yellow perch, all of which were age-0, were collected in the trawl during these sampling occasions, while 53 age-0 perch were collected in gill nets. 93% 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 log Gill net CPUE = 0.621 + 0.486 [log (Trawl CPUE)], $r^2 = 0.17$, $P = 0.009$.

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

1. Stomachs of 86 age-0 yellow perch collected by bottom trawls were examined in 2008. Yellow perch of this age consumed primarily zooplankton and smaller quantities of benthic invertebrates.

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

1. Little variation in yellow perch recruitment was explained after fitting the Ricker stock-recruit model to age-0 yellow perch CPUE data from 1987-2007. Poor recruitment occurred across a wide range of spawning stock biomass.
2. Chlorophyll concentration was the most influential variable on yellow perch recruitment of the four external variables examined. It appeared in all of the eight top-ranked models and had the highest Akaike variable weight across all models ($w_i = 0.99$).

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 lake-wide 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). 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). Age-0 CPUE from trawling assessments during 2005 was the highest recorded in Illinois waters since 1988 (Redman et al. 2006). Unfortunately, based on our assessments of the spawning population and age-composition of angler-caught fish, the 2005 year class has not contributed significantly (<20%) to the fishery to this date (Redman et al. 2008, and current results from F-123 R-15). Thus, there continues to be concern about the survival and growth of yellow perch in Lake Michigan and sustainability of the population.

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 lake-wide management.

METHODS

<u>Study 101.</u> 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

Job 101.1: Improve annual assessments of the yellow perch spawning population
<u>Objective:</u> Monitor the age and size structure of the spawning population and evaluate yellow perch reproductive potential.

We collected adult yellow perch between 30 April and 2 June at Waukegan and North Lake Forest, IL. We deployed monofilament gill nets consisting of 100-ft panels of 2.0, 2.5, 3.0, and 3.5-in stretch mesh. Gill nets were set in 10, 15, and 20 m of water and fished for 24 hours. Yellow perch were processed in the laboratory to allow analysis of the size and age structure of the spawning population. Ovaries were also removed from 89 mature females collected between 30 April and 28 May, 2008. All eggs were weighed before a 1.0 g subsample of eggs was counted. We estimated fecundity of each female by multiplying the number of eggs within a 1.0 g subsample times the total weight of eggs taken from the ovary.

We investigated the influence of maternal traits on fecundity of yellow perch using multiple regression and an information theoretic approach. This analysis was based on fecundity estimates from 92 females collected during 2007 and 2008. We considered regression models with all possible combinations of the following variables: age, total length (TL), somatic weight, and ovary weight. A total of 15 models were fit and Akaike's information criterion corrected for small sample size (AIC_c) was calculated for each model (Burnham and Anderson 1998). Use of AIC_c allows for identification of multiple competing models that may explain variation in data equally (Burnham and Anderson 1998; Whittingham et al. 2006). Models were assessed based on the difference between AIC_c of each model and the model with the lowest AIC_c (Δ_i), and Akaike weights, which are the normalized relative likelihoods of the *i*th model being the best model in the set of models examined (Burnham and Anderson 1998). Akaike variable weights, w_i, were also assessed to determine the most influential external variables for each recruitment index.

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 lake-wide catch-age model in its final stages of development. Improved parameters for the age and sex composition of the fishery will provide more accurate estimates of the fishable yellow perch population in southwestern Lake Michigan.

We collected anal spines from yellow perch caught by anglers using the boat ramp at Waukegan Harbor between 21 April and 5 May, 2008. Anal spines were also collected from fish at two known yellow perch angling areas (Waukegan and Montrose Harbors, IL) between 1 May and 15 August, except for July when yellow perch harvest is closed. Spines were collected from up to 25 yellow perch during each weekly sampling occasion. 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 2008.

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.

Weekly SCUBA surveys were conducted between 2-19 June to count egg skeins along replicate 100-m long transects in 10 m of water along the abandoned US Steel intake line south of Waukegan Harbor. 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-µm mesh netting. 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 at four index stations outside Waukegan Harbor on 3 occasions between 10-23 June. 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 vertical distribution and describe diel movement patterns of pelagic age-0 yellow perch and their zooplankton prey in offshore waters of Lake Michigan.

Sampling for pelagic age-0 yellow perch and zooplankton was conducted at one station 9 miles offshore of Waukegan, IL. This station has a depth of approximately 70 m and fish and zooplankton were sampled from the surface to a depth of 27 m. The 9 mile site was chosen because relatively high larval yellow perch CPUE consisting of a wide range of lengths were observed here during previous segments of Job 101.4. Sampling was confined to a maximum depth of 27 m. To determine the vertical distribution of larval yellow perch, the water column was divided into five discrete depth bins. The first of these was the surface, which we define as the top 2 m of the water column. Pelagic, age-0 fish were collected at the surface (0-2 m) using a 1-m x 2-m fixed frame floating neuston net equipped with 1000-µm mesh. The four remaining depth bins were 6 m wide starting at 3 meters below the surface to a depth of 27 m. Each 6 m depth bin was sampled with a multi-net, opening/closing 1-m x 1.4-m mid-water Tucker trawl for 36 minutes. Both nets on the mid-water trawl were equipped with 1000-µm nitrex nets. Fish were preserved in the field and sorted according to species, enumerated, and measured in the laboratory. The goal for 2008 was to conduct day and night sampling on 6 occasions. Unfortunately we were only able to sample on two occasions: 24 June and 1 July, 2008. Both day and night sampling were conducted on 24 June. However, on 1 July only day sampling was conducted and sampling ceased after this due to vessel disablement.

Replicate zooplankton samples were collected at depths corresponding to larval fish sampling using a 0.5 m diameter, 64-µm, closing zooplankton net. Zooplankton samples were taken at the beginning of each larval fish trawl transect. 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.

Light intensity profiles and water temperatures were also were taken at the depths corresponding to larval fish and zooplankton samples. Light intensity was measured using a Biospherical Sciences BIC model which measures 3 discrete wavebands of UV light (320, 380, 395 nm) and PAR (400-700 nm). Mean light intensity and the range of light intensities for each depth bin were recorded. Water temperature was recorded during each larval fish tow using a remote mini-logger which was attached to the mid-water tucker trawl.

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 1 August through 14 October, 2008. All sampling occurred north of Waukegan Harbor, at a speed of approximately 2 m/sec. An area of approximately 4,460 m^2 of the lake bottom was sampled for each 0.9-km (0.5 nautical miles) transect. All fish collected during a trawl were counted and TL was measured to the nearest 1 mm for up to 30 individuals per species of fish. Additionally, up to 30 yellow perch were kept and frozen for later examination of stomach contents.

In 2008, zooplankton was sampled weekly between 10 June and 13 October in 10 m of water at two historical sites near Waukegan Harbor, IL. Sampling occurred on the same nights as larval fish collections during June-July. A 64-µm 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. Two replicates were collected 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 64-µm and 153-µm 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-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. 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 during August and 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
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. 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. Twelve paired comparisons between a bottom trawl and gill net were conducted at the same location between 5 August and 9 October, 2008. 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 m^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. For statistical analysis, CPUE of age-0 yellow perch for both gear types from 2008 were combined with 29 paired comparisons conducted during 2005-2007.

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 2008 were frozen for stomach analysis. Prior to dissection, TL (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 two biotic (larval yellow perch prey availability and pre-spawn maternal prey availability) and abiotic factors (wind-induced transport and spring-summer water temperatures) on yellow perch recruitment in southwestern Lake Michigan during 1987-2007. An index of recruitment was based on catch-per-unit-effort (CPUE) of age-0 yellow perch from bottom trawling conducted for Job 101.5 during 1987-2007. CPUE for each trawl was calculated as the number of age-0 yellow perch caught divided by the total area of lake bottom sampled by the trawl. Annual yellow perch recruitment index was expressed as mean CPUE (fish/100 000 m^2) of all trawls completed during August-October of each year.

Calculation of External Variables

An index of spawning stock biomass was based on gill net catches of yellow perch near Chicago and Lake Bluff, Illinois during 1987-2007. Monofilament gill nets were deployed annually between late May and early June for 24 hrs in 7.3-18.3 m of water. During 1987-1992, nets consisted of 15.0 m of 38 mm mesh, 45.7 m of 51 mm mesh, and 91.5 m of 64 and 76 mm mesh. In later years, 15.0 m of 25 mm mesh (1991) and 91.5 m of 89 mm mesh (1993) were added and used in all subsequent years. Female yellow perch spawners were rarely collected in 25 mm mesh; typically males and immature females were collected in this mesh. All fish were identified and counted and a subsample (n = 25) of yellow perch from each mesh size were processed to determine TL, weight (g), sex, and maturity. This biological data was used to estimate sex, maturity, and length distribution of all yellow perch collected in each mesh size. Then, subsampled yellow perch were grouped into 20 mm TL size classes and average weight of female yellow perch was calculated for each size class in a given year. Sex, maturity, weight, and length estimations were extrapolated for unprocessed yellow perch based on these estimations. Annual spawning stock biomass was expressed as mean biomass CPUE (g/30.5 m) from all gill net sets in a given year.

An index of pre-spawn yellow perch maternal prey abundance was based on spring gill net by-catch of alewife (*Alosa pseudoharengus*) in 38 mm mesh of the gill net configuration mentioned above. We expressed the index of pre-spawn yellow perch maternal prey abundance as mean annual CPUE of alewife lagged by one year, because the majority of energy for ovarian development in yellow perch is allocated during the fall preceding spawning.

Calculation of prey availability for newly hatched larval yellow perch was difficult because a continuous series of observations on nearshore zooplankton density was unavailable (Dettmers et al. 2003). Instead, we used chlorophyll concentration (mg/m^3) measurements collected at a nearshore site 5.6 km south of Milwaukee, Wisconsin (M. Welling, personal communication, 2007), because this data extended over the entire study period. The larval yellow perch prey index was calculated as mean annual chlorophyll concentration from samples collected between June and August during 1987-2007.

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 was used as an index of spring-summer water temperatures that yellow perch were exposed to during their first summer. Based on diver surveys for egg skeins and nearshore larval fish sampling near Waukegan, Illinois during 1996-2006, yellow perch typically inhabit nearshore waters during embryonic and larval life stages between 1 May and 23 June (R. A. 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 24 June and 5 August, the time period when age-0 yellow perch are typically found at least 5 km offshore (S. Miehls, unpublished data; M. J. Weber, unpublished data). We then generated the water temperature index by summing nearshore and offshore cumulative degree days from the above mentioned time periods and locations for a given year.

Hourly wind data from NOAA weather station 45007 was used to calculate an index of wind-induced wind-induced transport of larval yellow perch. We used wind speed and direction for 1-31 July, because this is when most offshore movement of larval yellow perch occurs. This index was calculated as the total number of occurrences of at least two consecutive hours when wind speed was greater than 10 km/hr and wind direction was from 225-330°.

Statistical Analysis

A Ricker stock-recruitment model was constructed and fit to the recruitment index by first transforming it into a linear model,

$$In\left(\frac{R}{S}\right) = In(\alpha) - \beta S$$

The Ricker stock-recruitment model was used because visual inspection of age-0 yellow perch abundance plotted as a function of spawner stock biomass suggested some degree of density-dependent negative feedback on yellow perch recruitment. After the linearized Ricker model was fit we incorporated the multiplicative effects of external variables,

$$In\left(\frac{R}{S}\right) = In(\alpha) - \beta S + \sum_i \beta i X i$$

where X_i = external variable *i*, β_i = parameter with dimensions 1/ X_i, and *i* ranged from 1 to the number of external variables included in the model. We considered regression models with all possible combinations of the four external variables. Thus, including the basic Ricker stock-recruitment model, 16 models were fitted. Akaike's information criterion corrected for small sample size (AIC_c) was calculated for each model and Akaike variable weights, w_i, were assessed to determine the most influential external variables for each recruitment index.

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. 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

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 yellow perch reproductive potential.

Total effort during 2008 was 14 net nights during which 356 yellow perch were collected. 54% of these fish were females and their mean length was 292 ± 43 mm TL (SD). Average length of males collected was 232 ± 29 mm TL. Annual mean CPUE (fish/net night) was 25 ± 21 yellow perch. No significant differences were detected when mean CPUE was compared between the Waukegan and North Lake Forest sampling sites ($p > 0.50$) or among the 10, 15 and 20m depth stations ($p > 0.10$; Figure 1) using a Repeated Measures ANOVA. Both sampling sites (Waukegan and North Lake Forest) are characterized by rock/cobble substrate and have been classified as suitable habitat for yellow perch spawning (Creque et al. 2009). Thus, similar CPUE at these sites was expected. While mean CPUE of yellow perch at North Lake Forest increased with depth, these differences were not statistically significant. We will continue this sampling scheme in an effort to better understand movement of perch prior to spawning and to determine if yellow perch are spawning in deeper water than previously reported.

We aged 329 yellow perch using otoliths. Fish ranged in age from 3 to 12 years old. Age-6 (2002 year class) fish dominated our subsample followed by age-5 fish (2003 year class); these year classes comprised 64% of the subsample (Figure 2). Age-10 (1998 year class) fish also made up 13% of the subsample and most of these fish were females (67%). Unfortunately, few fish from the 2005 year class, a year class that was expected to contribute significantly to the adult population, were represented in our subsample.

In 2008, ovaries were taken from 85 females that ranged in length from 178 to 367 mm TL and ranged in age from 3 to 12 years. Estimated fecundity varied from 1,525 to 117,410 eggs. Max fecundity was produced by a five year old fish, while an age-6 fish had the lowest fecundity. Mean fecundity was highest for age-9 (82,376 ± 24,362 eggs, SD) and age-7 fish (70,543 ± 11,583 eggs). Based on AIC analysis, fecundity of yellow perch is influenced by multiple maternal traits such as age, somatic weight, ovary weight and total length. Four models should be considered for predicting fecundity (Table 1). The top two ranked models provide a good fit to the data (Figure 3) and both of these models explain 91% of the variation in $\log_{10}$ fecundity. The most influential variables on fecundity were ovary weight (w_i = 1.0), which appeared in the top eight models, and maternal age (w_i = 0.664).

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

Objective: Estimate age composition and, if possible, sex composition of angler-caught fish to better parameterize a lake-wide catch-age model in its final stages of development.

Anal spines were collected from 115 yellow perch harvested by boat anglers using the launch ramp at Waukegan Harbor, IL between 21 April and 5 May, 2008. Additionally, anal spines were collected from 138 yellow perch at two known pedestrian angling areas (Waukegan and Montrose Harbors, IL) during 5-30 June. Neither harbor was sampled during August due to reports of poor yellow perch harvest from LMBS creel clerks during this sampling month. Female yellow perch dominated the subsample collected from boat anglers at Waukegan Harbor (61% of boat harvest) and most of these females were age 5 and 6 (Figure 4a). Boat and pedestrian catches were dominated by the 2002 (age-6) and 2003 (age-5) year classes (Figure 4b). Age-4 fish (2004 year class) were the next most abundant age group, accounting for 18% of the boat and pedestrian subsample. Age-3 fish (2005 year class) also comprised about 8% of harvested fish and most of these fish were caught by pedestrian anglers in June.

Mean age of yellow perch harvested by boat anglers using Waukegan launch ramp (6.5 ± 2.0 years, SD) was significantly greater than that of yellow perch harvested by pedestrian anglers at Waukegan and Montrose Harbors (5.0 ± 1.7 years; t-value = 5.27, $P < 0.0001$). Similarly, mean length of yellow perch harvested by boat anglers (293 ± 38 mm TL) was significantly greater than that of yellow perch harvested by pedestrian anglers (255 ± 44 mm TL; t-value = 6.75, $P < 0.0001$). These differences in mean age and length are likely due to the fact that the majority of age-8+ fish were caught by boat anglers (Figure 4b).

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 2-19 June, 2008 at the US Steel intake line, the location of this survey since 1996 (Table 2). Divers found 1 egg skein on June 11 and embryos were fully formed and hatching. This equates to an overall mean of less than 1 skein per 100 m^2 transect (Figure 5). This skein was lodged among rocks within the cobble substrate.

Yellow perch larvae were captured in low abundance during 2008 (4.7 ind./100 m^3) compared to annual mean densities reported before 1994 (36 - 138 ind./100m^3; Figure 6). Average daily densities of larval yellow perch between 10 and 23 June, 2008 ranged from 1.0 to 8.6 ind./100 m^3. Average daily density of larval yellow perch peaked on June 18, 2008. We also caught larval alewife, burbot *(Lota lota)*, Cyprinids and Catostomids throughout the sampling period, but in low densities (< 1.0 ind./100 m^3).

Job 101.4: Sample pelagic age-0 yellow perch and their food resources in offshore waters
Objective: Determine the vertical distribution and describe diel movement patterns of pelagic age-0 yellow perch and their zooplankton prey in offshore waters of Lake Michigan.

A total of 726 pelagic, age-0 fish and thirty zooplankton samples were collected during three offshore trips. Burbot was the most abundant fish (44% of total catch) followed by bloater (*Coregonus hoyi*, 26%), yellow perch (25%) and sculpin (*Cottus* spp., 6%). Calanoid copepods and copepod nauplii dominated the zooplankton assemblage. No statistical analysis was conducted with our 2008 offshore larval fish or zooplankton data sets due to low sample size as a result of vessel malfunctions.

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 targeting age-0 yellow perch during 2008 covered approximately 185,532 m^2 between 5 August and 14 October, 2008. Approximately, 149 yellow perch estimated to be age-0 based on length were caught during this period. Thus, 2008 annual mean CPUE of age-0 yellow perch was 90 ind./100,000 m^2 (Figure 7). Individual age-0 yellow perch were collected from 12 August through 13 October, but mean daily CPUE peaked during October. As observed in previous years, several other fish species were collected in the trawl during 2008. Rainbow smelt (*Osmerus mordax*) had the highest annual mean CPUE (2784 ind./100,000 m^2). Most (~ 1,200 ind.) of the rainbow smelt collected were in larval form and were caught on 27 August, 2008. Alewife, round goby (*Neogobius melanostomus*), and spottail shiner (*Notropis hudsonius*) were the next most abundant species with annual CPUEs of 862, 774, and 331 inds/100,000 m^2. Nine spine stickleback (*Pungitius pungitius*), bloater, Johnny darter (*Etheostoma nigrum*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*) and Centrarchids were also caught, but in much smaller numbers.

Mean June-July zooplankton density in 2008 was 9.2 ind./L. This is the fourth consecutive year of declining zooplankton density and represents a 79% decrease in nearshore density since 2004 (Figure 8). Mean June-July crustacean zooplankton density was only 2.8 ind/L in 2008 and dominant taxa were adult calanoid copepods or copepod nauplii. Mean density of both total and crustacean zooplankton fluctuated on a weekly basis between June and October. Multiple peaks in total zooplankton density were detected on June 10, September 8, and September 26 and ranged from 14.8-18.8 ind./L (Figure 9). Veligers comprised over 60% of the individuals collected on a weekly basis during June and over 80% of that collected on September 26. Rotifer density increased throughout June and peaked on August 12 at 9.5 ind./L. Mean weekly crustacean zooplankton density peaked around 7.5 ind./L on two occasions: August 12 and September 8 (Figure 9). Calanoid copepods and copepod nauplii dominated the zooplankton assemblage during June (Figure 10). In August calanoid copepod density declined and copepod nauplii and bosmina dominated the zooplankton assemblage through the month of October. Densities of cyclopoid copepods and daphnia were less than was < 1.0 ind./L between June and October. Other cladocerans (e.g. *Polyphemus*, *Ceriodaphnia*, *Leptodora*, *Diaphanosoma*, *Chydoridae*) that were commonly found in samples during 1988-1990 remain either rare or absent in samples collected since 1996.

Mean annual benthic invertebrate density north of Waukegan Harbor was 2,579 ± 1,744 ind./m^2 (SD) in 2008. Monthly density of benthic invertebrates was 2,238 ± 1,639 ind./m^2 during August and 2,921 ± 2,023 ind./m^2 during September. The most abundant taxa in August and September samples were ostracods and mollusks followed by chironomids and Oligochaetes (Figure 11). No amphipods were collected in August and density was relatively low in September (28.8 ind./m^2, <1% of individuals). Individuals of Pelecypoda comprised over 70% of mollusks collected and relatively few Dressenids were collected. Freshwater snails, particularly Valvatidae, also made up 10-20 % of mollusks collected. Other insects and nematods were also found, 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.

Twelve paired comparisons between a bottom trawl and gill net were conducted at the same location between 5 August and 9 October, 2008. A total of 19 yellow perch, all of which were age-0, were collected in the trawl. Mean CPE of age-0 yellow perch in the bottom trawl was <1 ind./1,000m^2). We caught 810 yellow perch in small mesh gill nets; 6.5% of which were age-0 yellow perch. Mean CPUE of age-0 yellow perch in small mesh gill nets was about 3 fish per hour.

Forty-one paired comparisons between a bottom trawl and small mesh gill net were conducted between late August and mid-October during 2005-2008. Based on these assessments, log transformed CPE of age-0 yellow perch from gill nets was positively correlated to log transformed CPE from the bottom trawl ($r = 0.41$, $P < 0.01$). The best regression equation was log (Gill net CPE) = 0.486 + 0.621 [log (Trawl CPE)] ($r^2 = 0.17$, $P = 0.009$, Figure 12). The frequency with which yellow perch have been absent in our sampling events has increased during the 2005-2008 period. During 2007 and 2008, yellow perch were absent from most of the bottom trawl samples. More specifically, no yellow perch were collected in 74% of 2007-2008 sampling occasions (N = 23); which is up from about 40% of sampling occasions in 2005-2006 (N = 18). On 6 of these occasions during 2007-2008 no yellow perch were collected in small mesh gill nets fished at the same location as the bottom trawl. It is possible that environmental variables such as water temperature and clarity are affecting our catch rates in both gear types. Further investigation of the influence of such factors will proceed as we continue to compare the efficiency of these gears for targeting age-0 yellow perch.

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 86 age-0 yellow perch from 7 sampling dates between 12 August and 13 October, 2008 were examined. Two of the stomachs examined did not contain any identifiable prey organisms, so age-0 perch diet composition was based on 84 age-0 yellow perch stomachs. Length of yellow perch used for diet analysis ranged from 35-80 mm TL and mean length was 58 ± 11 mm TL (SD). Similar to trends seen in past years, age-0 yellow perch primarily consumed zooplankton (96%) and smaller quantities of benthic invertebrates. Additionally, a fish (no id. possible) was found in the stomach of a 78 mm TL yellow perch collected on 12 August. Similar to 2007, the majority of zooplankton consumed by age-0 yellow perch were cladocerans (70% of zooplankton consumed). Cladocerans, primarily Chydoridae and Bosmina, dominated the diet of most age-0 yellow perch collected during August and early September, with the exception of three individuals collected on 27 August that primarily consumed copepods. Copepods dominated diet from mid-September through mid-October. Very few amphipods were detected in the diet of age-0 yellow perch until 9 October when they comprised 25% of the diet. Chironomids made up less than 10% of the diet throughout the sampling period, but consumption peaked on 13 October, 2008.

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.

The regression of $In\left(\frac{R}{S}\right)$ on S produced the following fit

$$In\left(\frac{R}{S}\right) = In(0.11) - 3.7x10^{-6}S$$

where S = mean spawner biomass CPUE (g/30.5 m of net), and explained less than 1% of the variation in $\log_e$ recruits per spawner (F = 0.02 with df = 20 and P = 0.89, r^2 = 0.001). Recruitment of yellow perch was still highly variable after accounting for the effect of spawning stock biomass.

Based on AIC analysis, four models explain variation well in $\log_e$ recruit per spawner (Table 3). The model with the lowest AIC_c included chlorophyll concentration and explained 44% of variation in $In\left(\frac{R}{S}\right)$. The second-ranked model included chlorophyll concentration and spring-summer water temperatures and explained 50% of variation in $In\left(\frac{R}{S}\right)$. The third-ranked model included chlorophyll concentration, spring-summer water temperatures, and wind-induced transport index and explained 55% of variation in $\log_e$ recruits per spawner. The fourth-ranked model included chlorophyll concentration and wind-induced transport index and explained 46%

of variation in $In\left(\frac{R}{S}\right)$. Comparison of Akaike weights for the four top-ranked models suggested that the top three-ranked models are superior to the fourth-ranked model (Table 3).

Of the four variables examined, chlorophyll concentration was most influential on yellow perch recruitment near Waukegan, Illinois. This variable appeared in all of the eight top-ranked models (Table 3) and had the highest Akaike variable weight across all models (w_i = 0.99). Yellow perch recruitment was positively related to chlorophyll concentration and spring-summer water temperatures and negatively related to the wind-induced transport index.

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

To improve our annual assessments of the yellow perch spawning population we targeted fish in deeper waters (10-20m) with gill nets. 356 yellow perch were collected in gill nets and mean CPUE was 25 fish per net night. The 2002 and 2003 year classes dominated the catch, while 1998 year class contributed over 10% of the catch. It was disappointing that few fish (<3%) from the 2005 year class were represented in our sample after contributing 20% of the catch in 2007 at an age when fish are often not fully recruited to this gear. In 2008, ovaries were taken from 85 females that ranged in length from 178 to 367 mm TL and ranged in age from 3 to 12 years. Fecundity ranged from 1,525 to 117,410 eggs per female. Variability in fecundity of yellow perch was explained by maternal traits such as age, somatic weight, ovary weight and total length. The most influential maternal traits on fecundity were ovary weight and maternal age. Based on these results, ovary weight may be a sufficient surrogate for egg counts for estimating fecundity of yellow perch. Additionally, estimates of reproductive potential should account for age composition of spawners rather than spawner biomass alone.

To determine age structure of yellow perch caught by boat anglers, anal spines were collected from over 100 fish at the Waukegan launch ramp between mid-April and early May. According to Brofka and Czesny (2009), angler success for yellow perch increased for launched boat anglers from 2007 to 2008 and about 51% of the 54,300 yellow perch harvested by boat anglers in 2008 were landed by anglers using the Waukegan launch ramp. The majority of fish caught by boat anglers were age-5 and age-6 females, which may continue to be very important for future spawning events. Thus, the launched boat fishery in Waukegan is contributing significantly to yellow perch harvest in Illinois and our results suggest this harvest is skewed towards larger females. Collection of spines from pedestrian anglers did not commence in Waukegan and Montrose harbors until early June, and most of these fish were caught in Montrose harbor during 2008. Sport anglers (boat and pedestrian combined) primarily harvested yellow perch from the 2002 and 2003 year classes. This is the fourth consecutive year that the 2002 year class has contributed significantly to the sport harvest; this year class made up about 40-60% of fish subsampled from our nets during 2005-2007. Fish from these year classes (2002-

2003) may be extremely important for future spawning and should be protected.

Continual decline in spawning activity at historical sites has been detected in both spring adult 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 2008 declined again from previous estimates. This is the sixth 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, there by 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.

2008 Year class

Annual densities of newly-hatched yellow perch larvae were much lower during 1994-2008 compared to densities observed before 1994. Average daily densities of larval yellow perch in nearshore waters peaked at 8.6 ind./100 m^3 in 2008 and is very low compared to daily peaks of over 100 ind./100 m^3 prior to 1994 (Marsden and Robillard 2004). Similar to previous years, the density of newly-hatched larval yellow perch peaked in nearshore waters during mid-June.

2008 CPUE of age-0 yellow perch collected in bottom trawls was much lower than that detected during 2004-2006, and slightly higher than that reported during 2007. 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 2005-2008 (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 will hopefully 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 no where near that of the late 1980s; as such, they probably are not sufficiently strong to support extensive fishing pressure.

We were able conduct 41 paired comparisons of the effectiveness of a bottom trawl and small mesh gill net in estimating relative abundance of demersal age-0 yellow between late August and mid-October during 2005-2008. A positive correlation was detected in CPE of age-0 perch between the two gears and the following regression equation was calculated:

log (Gill net CPE) = 0.486 + 0.621 [log (Trawl CPE)] ($r^2 = 0.17$, $P = 0.009$). However, more comparisons are needed before definitive conclusions can be drawn as to the comparable efficiency of these gears. Absence of yellow perch in both gear types has increased over the sampling period (2005-2008) and environmental variables such as water temperature and clarity are likely increasing avoidance of both the bottom trawl and gill net. Investigation of the influence of such factors may prove informative in future segments of F123-R. 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 1996-2008 (Dettmers et al. 2003, Redman et al. 2008). 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

Yellow perch recruitment was highly variable after accounting for the effect of spawning stock biomass; poor recruitment events occurred over a wide range of spawning stock biomass values. Wilberg et al. (2005) also found a weak relationship between recruitment and spawning stock biomass for yellow perch in Lake Michigan. A complex suite of factors influenced yellow perch recruitment during 1989-2007 as several multiple variable models should be considered for explaining variation in recruitment patterns. Of the four external variables examined, chlorophyll concentration was the most influential and yellow perch recruitment weakened as chlorophyll concentration declined. These results taken together with those of Madenjian et al. (2002) indicate that phytoplankton abundance in nearshore waters of Lake Michigan has been declining since 1970. A comparison of chlorophyll *a* concentration between the 1970s and 1998-2000 indicated at least 50% decline in nearshore waters of Lake Michigan (Madenjian et al. 2002). Our results concur with other studies (Dettmers et al. 2003; Marsden and Robillard 2004) that have suggested bottom-up effects are partly responsible for poor yellow perch recruitment in Lake Michigan. A manuscript was prepared from this analysis and is currently under review for publication in Canadian Journal of Fisheries and Aquatic Sciences.

Management Implications

In summary, the fishable yellow perch population in 2008 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 another year until the younger 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, April 01, 2008 – March 31, 2009

	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 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	$16,422	$16,422
Total Cost	$252,422	$252,422
Federal Share	$189,317	$189,317
State Share	$63,105	$63,105

REPORT OF EXPENDITURES, April 1, 2009 - June 30, 2009

	Proposed	Actual
Job 101.1A Improve annual assessments of the yellow perch spawning population: Spring spawning assesment	$29,700	$29,700
Job 101.2: Develop angler-caught age and sex distribution	$20,250	$20,250
Job 101.3: Sample pelagic age-0 yellow perch and their food resources in offshore waters	$13,155	$13,155
Total Cost	$63,105	$63,105
Federal Share	$47,329	$47,329
State Share	$15,776	$15,776

REPORT OF EXPENDITURES, April 1, 2008 - June 30, 2009

	Proposed	Actual
Total Cost	$315,527	$315,527
Federal Share	$236,646	$236,646
State Share	$ 78,881	$ 78,881

ACKNOWLEDGMENTS

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

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. A. 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.

Brofka, W. A. and S. J. Czesny. 2009. Survey of sport fishing in the Illinois portion of Lake Michigan. Annual report to the Illinois Department of Natural Resources. Illinois Natural History Survey Technical Report 09/15. 9pp.

Burnham, K.P. and D. R. Anderson. 1998. Model selection and multi-model inference: a practical information-theoretic approach. New York, New York: Springer-Verlag.

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.

Creque, S. M., K. M. Stainbrook, R. A. Redman, D. C. Glover, S. Czesny, D. Makauskas, and J. M. Dettmers. 2009. Linking yellow perch movements to nearshore bottom substrate. Great Lakes Fishery Commission 2008 Project Completion Report. 34pp.

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.

Heyer, C. J., T. J. Miller, F. P. Binkowski, E. M. Caldarone, and J. A. Rice. 2001. Maternal effects as a recruitment mechanism in Lake Michigan yellow perch (Perca flavescens). Canadian Journal of Fisheries and Aquatic Sciences 58:1477-1487.

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.

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.

Madenjian, C. P., G. L. Fahnenstiel, T. H. Johengen, T. F. Nalepa, H. A. Vanderploeg, G. W. Fleischer, P. J. Schneeberger, D. M. Benjamin, E. B. Smith, J. R. Bence, E. S. Rutherford, D. S. Lavis, D. M. Robertson, D. J. Jude, M. P. Ebener. 2002. Dynamics of the Lake Michigan food web, 1970-2000. Canadian Journal of Fish and Aquatic Sciences 59:736-753.

Makarewicz, J. C., P. Bertram, T. Lewis, and E. H. Brown, Jr. 1995. A decade of predatory control of zooplankton species composition of Lake Michigan. Journal of Great Lakes Research 21:620-640.

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.
Nielsen, E., O. Bagge, and B. R. MacKenzie. 1998. Wind-induced transport of plaice (*Pleuronectes platessa*) early life-history stages in the Skagerrak-Kattegat. Journal of Sea Research 39:11-28.

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.

Redman, R. A., S. J. Czesny, M. J. Weber, and J. M. Dettmers. 2007. 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 07/35. 45 pp.

Redman, R. A., S. J. Czesny, J. M. Dettmers, and D. Zapf. 2008. 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 08/19. 49 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.
Sundby, S., and P. Fossum. 1990. Feeding conditions of Arcto-norwegian cod larvae compared with the Rothschild-Osborn theory on small scale turbulence and plankton encounter rates. Journal of Plankton Research 12:1153-1162.
Truemper, H. A., and T. E. Lauer. 2005. Gape limitation and piscine prey size-selection by yellow perch in the extreme southern area of Lake Michigan, with emphasis on two exotic prey items. Journal of Fish Biology 66:135-149.
Whiteside, M. C., C. M. Swindoll, and W. L. Doolittle. 1985. Factors affecting the early life history of yellow perch, *Perca flavescens*. Environmental Biology of Fishes 12:47-56.
Whittingham, M. J., P. A Stephens, R. B. Bradbury, and R. P. Freckleton. 2006. Why do we still use stepwise modelling in ecology and behaviour? Journal of Animal Ecology 75:1182-1189.
Wilberg, M. J., J. R. Bence, B. T. Eggold, D. Makauskas, and D. F. Clapp. 2005. Yellow perch dynamics in southwestern Lake Michigan during 1986-2002. North American Journal of Fisheries Management 25:1130-1152.

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.

TABLES

Table 1. Regression models of yellow perch fecundity on maternal traits including total length (TL), somatic weight (SW), age (A), and ovary weight (OW). All variables were $\log_{10}$ transformed. Models were ranked by Akaike's information criterion corrected for small sample size (AIC_c).

Model rank	Model	AIC_c	Δ_i	Akaike weight
1	A + OW	-414.1	0	0.251
2	A + SW + OW	-413.8	0.27305	0.219
3	OW	-413.4	0.76941	0.171
4	TL + A + OW	-412.6	1.54018	0.116
5	TL + A + SW + OW	-411.8	2.34430	0.078
6	TL +L OW	-411.7	2.44804	0.074
7	SW + OW	-411.4	2.74635	0.064
8	TL + SW + OW	-409.7	4.42248	0.028
9	TL + A + SW	-284.3	129.805	2E-29
10	A + SW	-283.0	131.124	8E-30
11	TL + SW	-277.5	136.659	5E-31
12	SW	-272.0	142.131	3E-32
13	TL + A	-243.9	170.257	3E-38
14	TL	-241.9	172.201	1E-38
15	A	-205.4	208.756	1E-46

Table 2. Summary of 2008 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
June 2	6-8	200	0	--	--
June 11	6-8	200	1	unknown	d
June 19	6-8	200	0	--	--

Table 3. Results from fitting stock-recruit regression models of age-0 yellow perch CPUE to estimates of spawner biomass (S) and all combinations of external variables: CHL = chlorophyll concentration, DD = spring-summer water temperature, OT = wind-induced transport index and ALE = spring alewife abundance. Models were ranked by Akaike's information criterion (AIC_c).

Model Rank	Model	AIC_c	Δ_i	Akaike weight
1	S + CHL	-57.789	0	0.270
2	S + CHL + DD	-57.742	0.047	0.264
3	S + CHL + DD + OT	-57.282	0.507	0.210
4	S + CHL + OT	-56.042	1.747	0.113
5	S + CHL + DD + ALE	-54.306	3.483	0.047
6	S + CHL + ALE	-54.295	3.494	0.047
7	S + CHL + DD + OT + ALE	-52.762	5.027	0.022
8	S + CHL + OT + ALE	-52.322	5.468	0.018
9	S + DD + OT	-49.208	8.581	0.004
10	S + DD	-48.300	9.489	0.002
11	S	-46.400	11.389	0.001
12	S + OT	-45.644	12.145	0.001
13	S + DD + ALE	-45.311	12.478	0.001
14	S + DD + OT + ALE	-45.251	12.539	0.001
15	S + ALE	-43.380	14.409	<0.001
16	S + OT + ALE	-42.744	15.045	<0.001

FIGURES

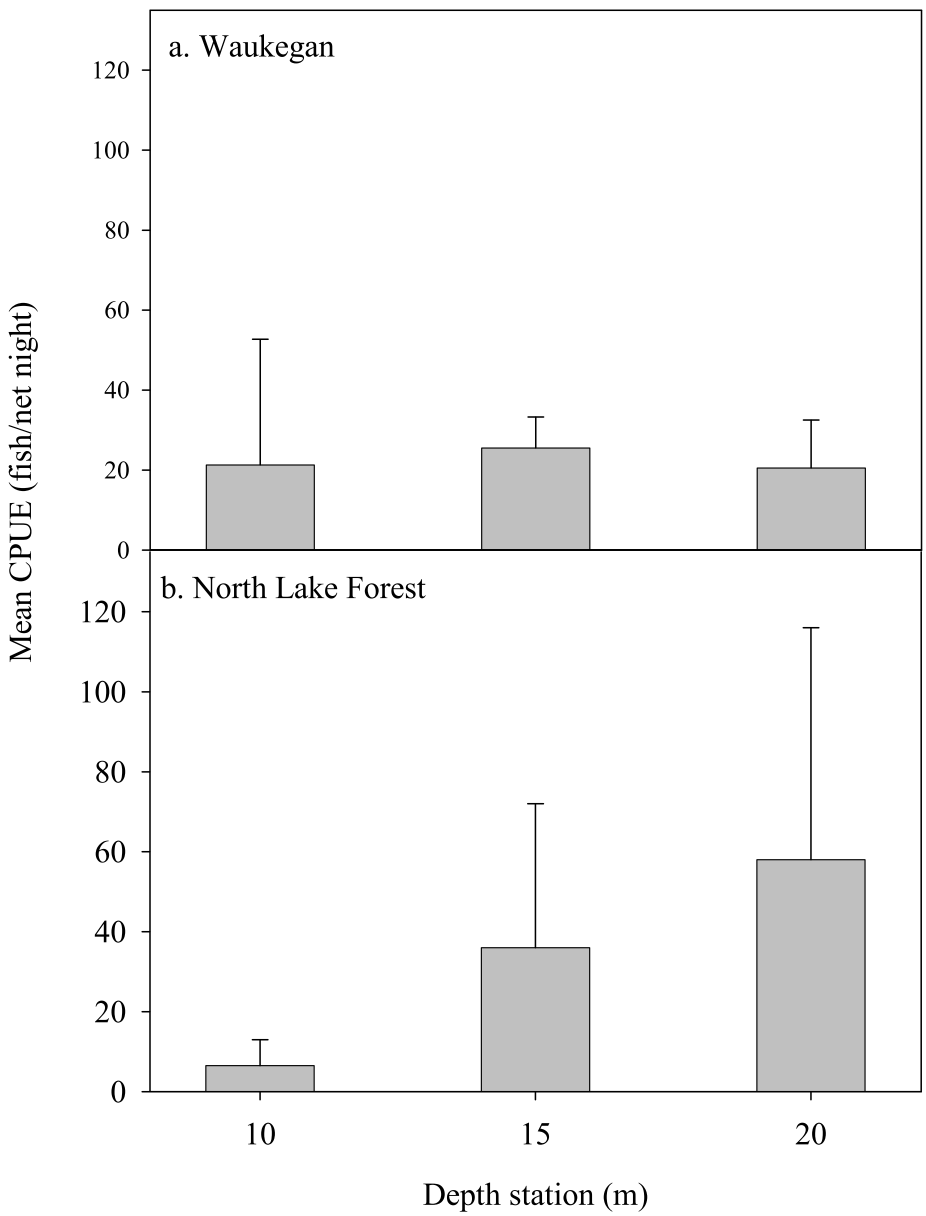

Figure 1. Mean CPUE (fish/net night) + 1 SD of yellow perch collected in gill nets at a) Waukegan and b) North Lake Forest, Illinois in 10, 15, and 20 meters of water during 2008.

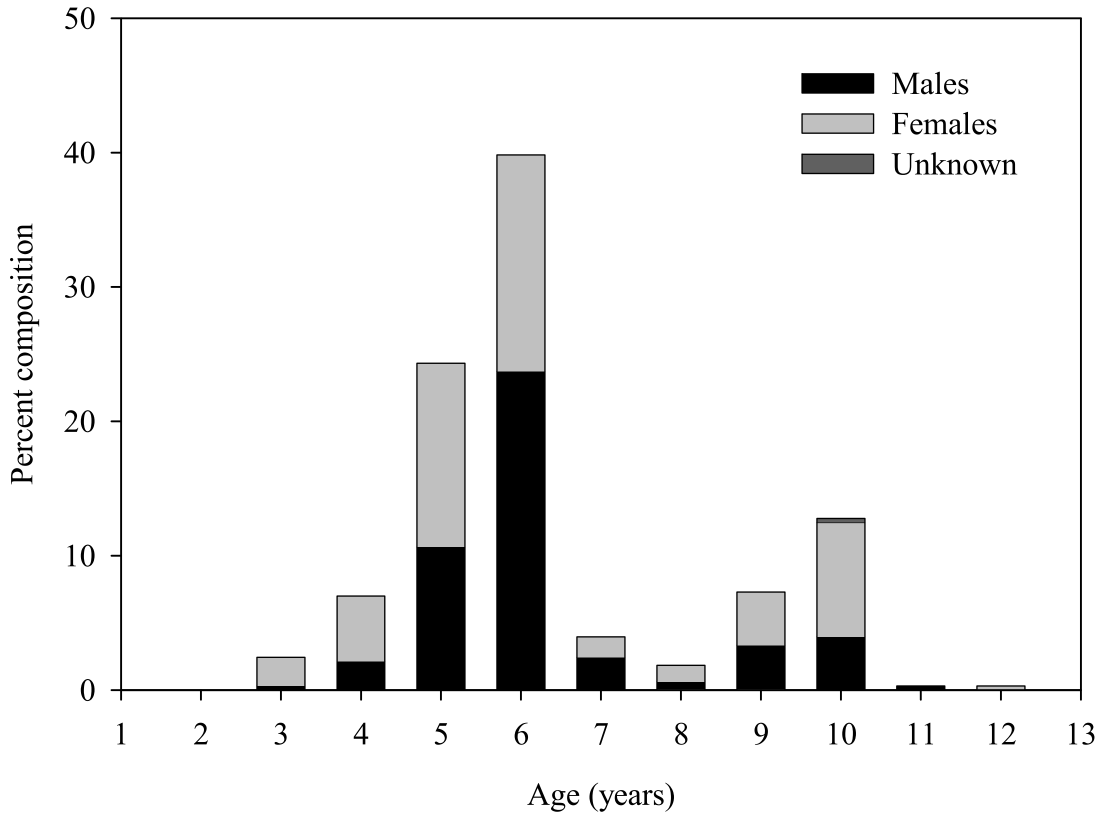

Figure 2. Age and gender composition of adult yellow perch collected using gill nets at Waukegan and North Lake Forest, IL during the spring of 2008.

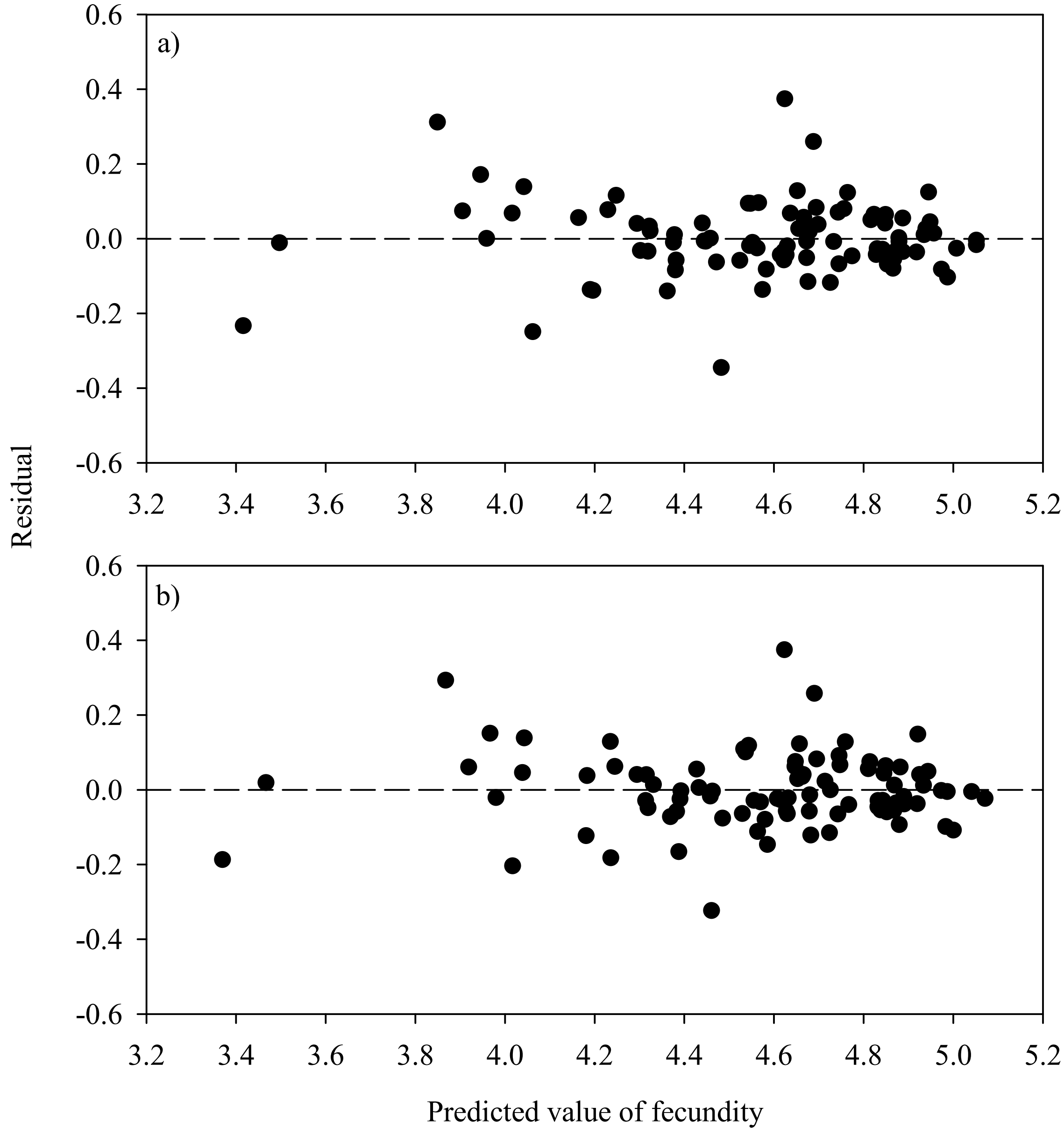

Figure 3. Residual values versus predicted fecundity for two top-ranked models: a) ovary weight and age and b) ovary weight, age and total length.

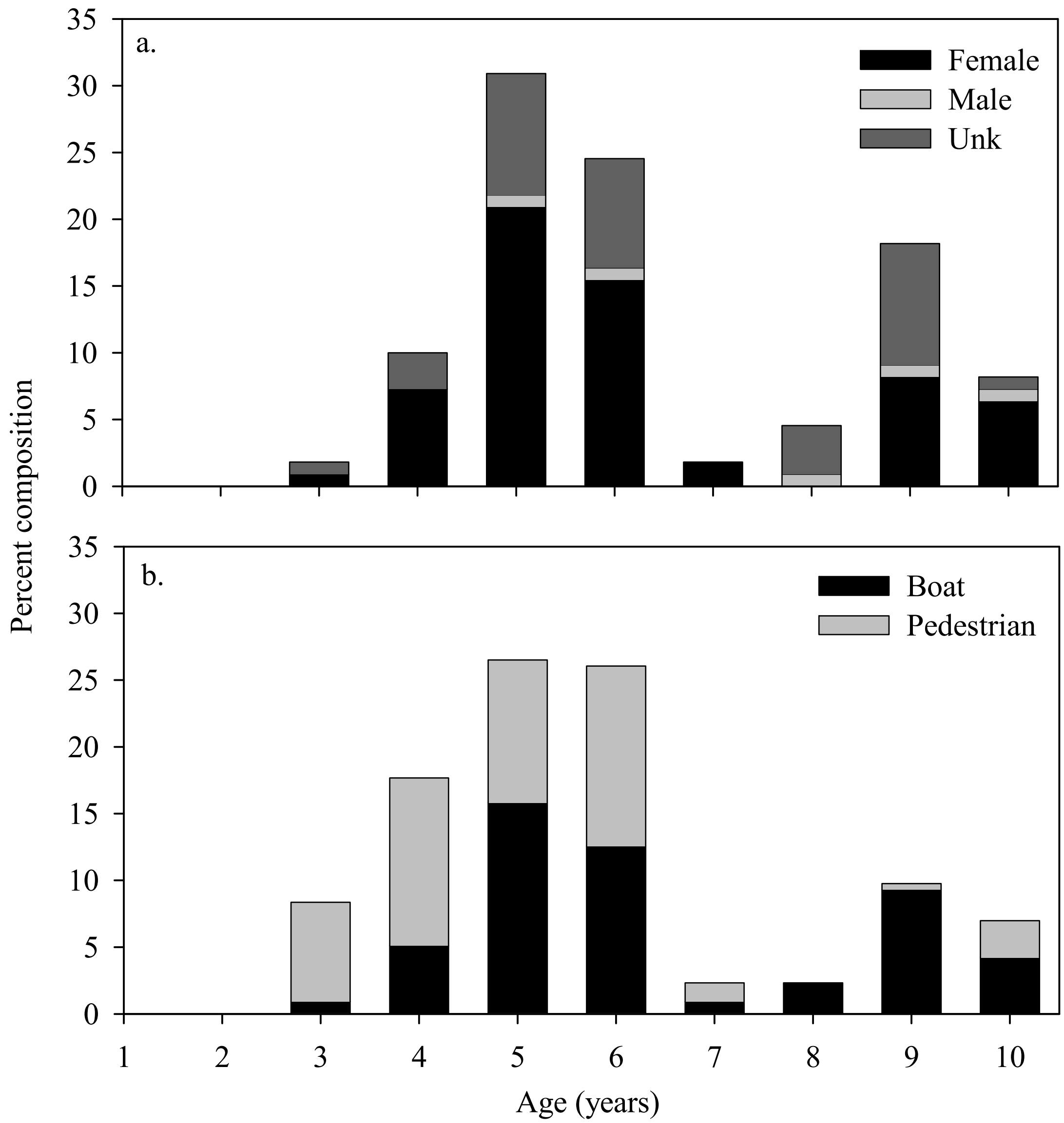

Figure 4. Age and gender composition of yellow perch harvested by a) boat anglers using the launch ramp at Waukegan Harbor and b) the age contribution of yellow perch caught by pedestrian anglers at Waukegan and Montrose Harbors and boat anglers at Waukegan Harbor during 2008.

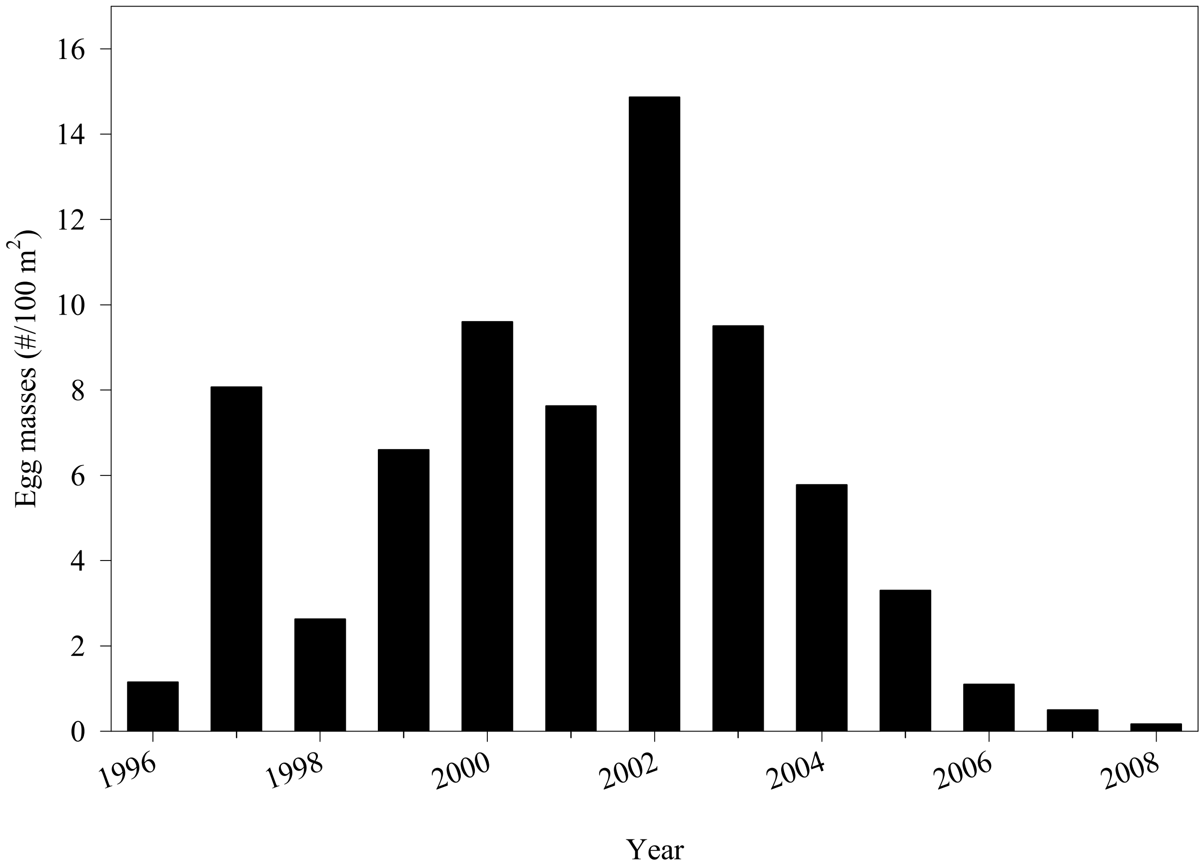

Figure 5. Annual patterns of yellow perch egg deposition at the US Steel intake for years 1996-2008.

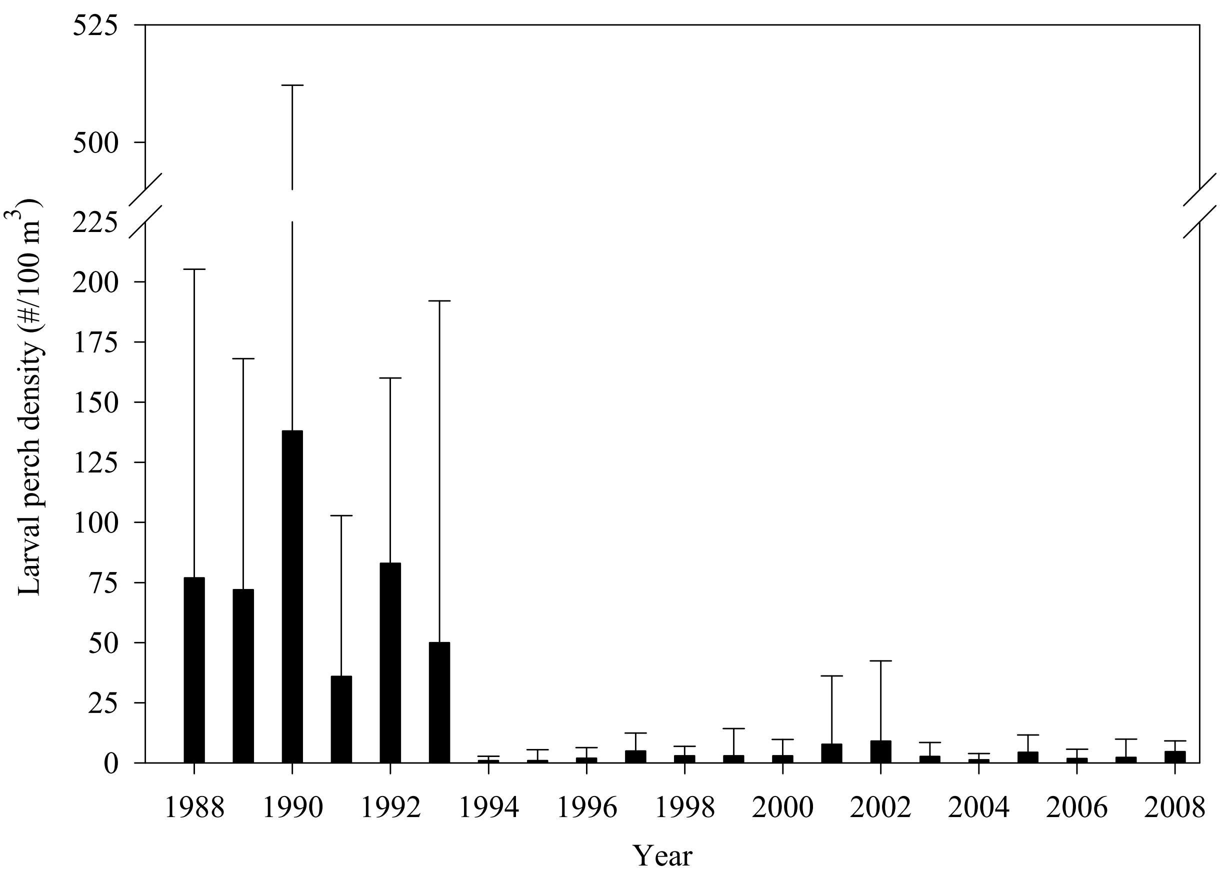

Figure 6. Seasonal mean density of larval yellow perch (+ 1 SD) sampled at two sites near Waukegan Harbor, IL, 1988-2008.

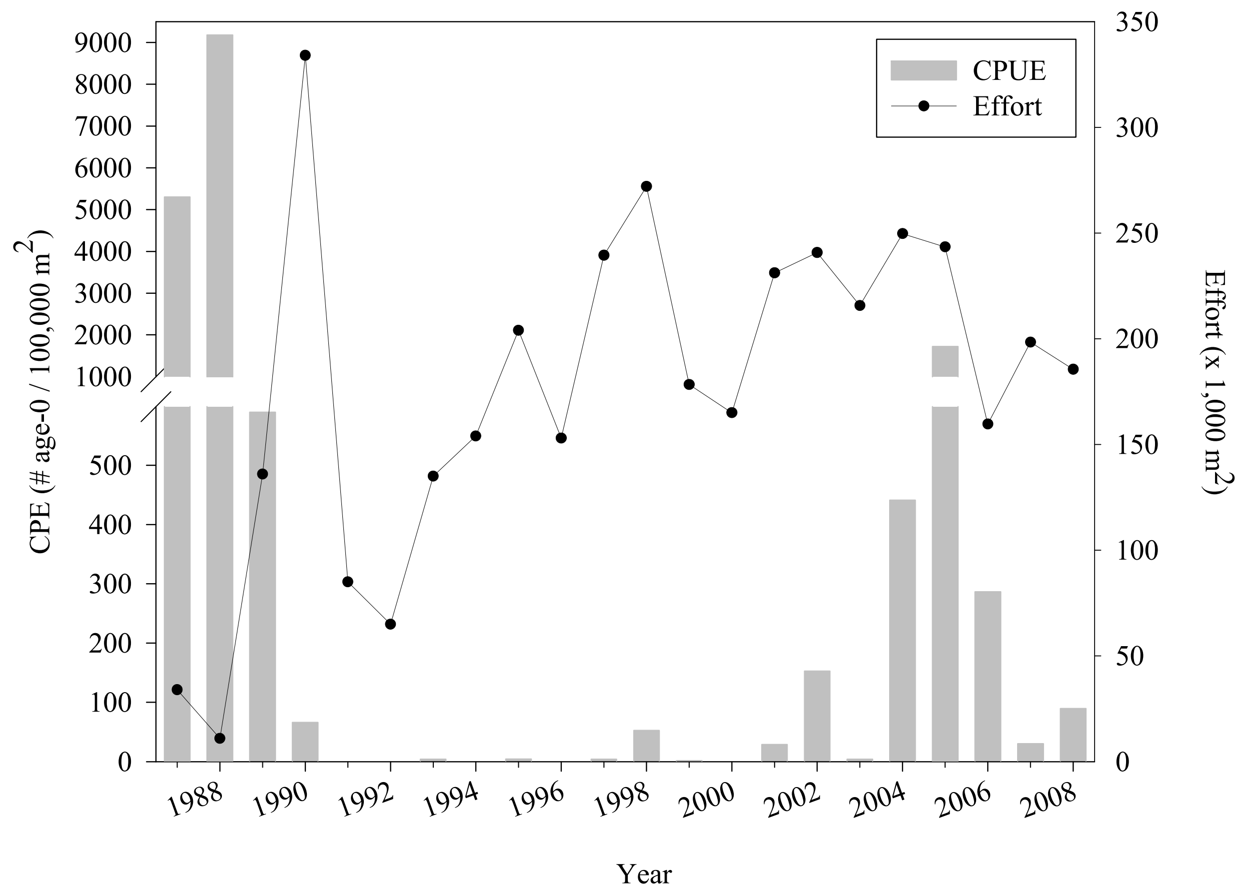

Figure 7. Relative abundance of age-0 yellow perch collected by daytime bottom trawls in 3 – 10 m of water north of Waukegan Harbor, IL, 1987-2008.

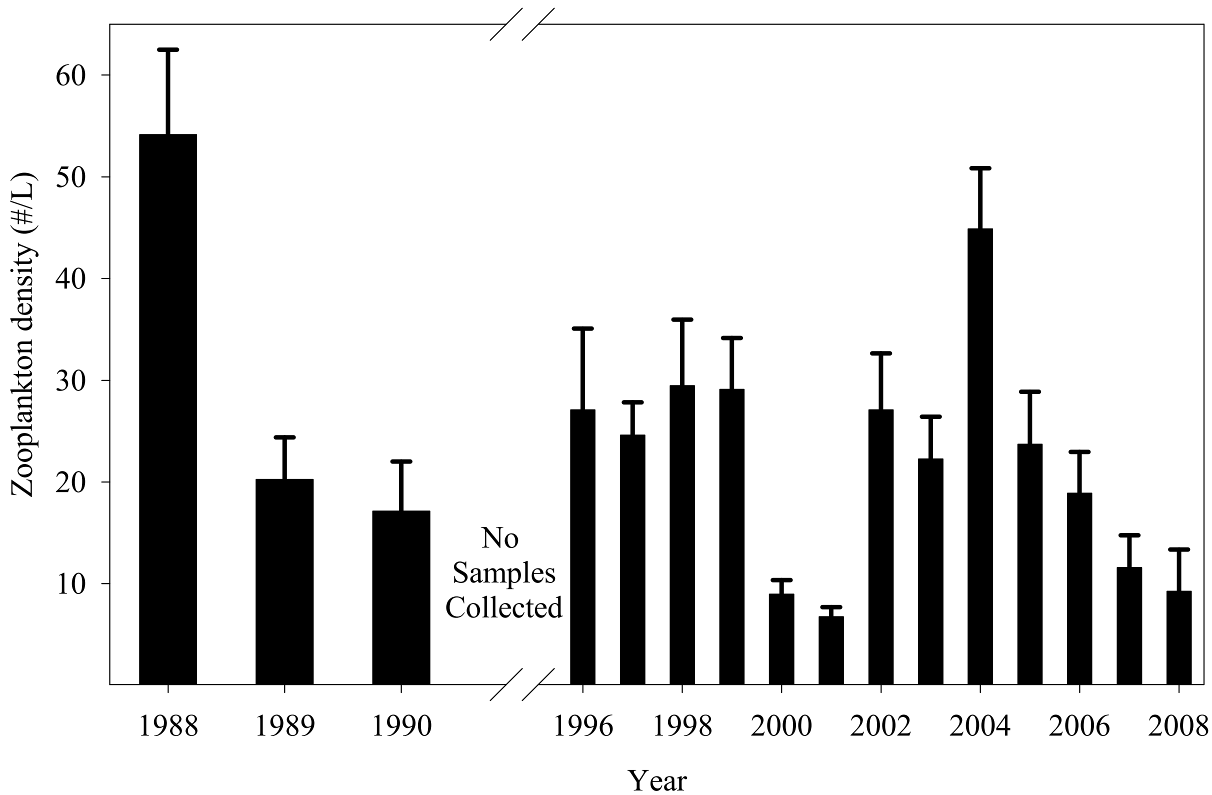

Figure 8. Mean density of zooplankton (+ 1 SE) present in Illinois waters of Lake Michigan near Waukegan during June-July for years 1988-2008.

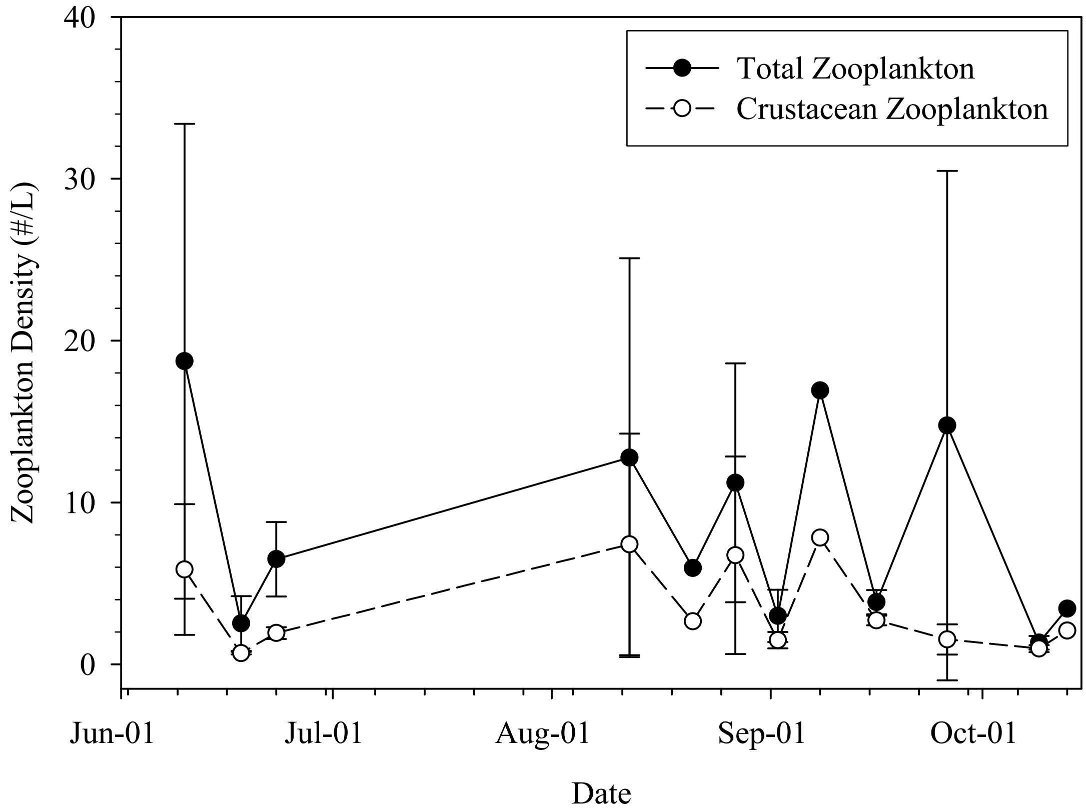

Figure 9. Relative abundance of zooplankton (± 1 SD) present in nearshore Illinois waters of Lake Michigan around Waukegan during June-October 2008. Closed circles (●) represent total zooplankton, whereas open circles (○) represent crustacean zooplankton.

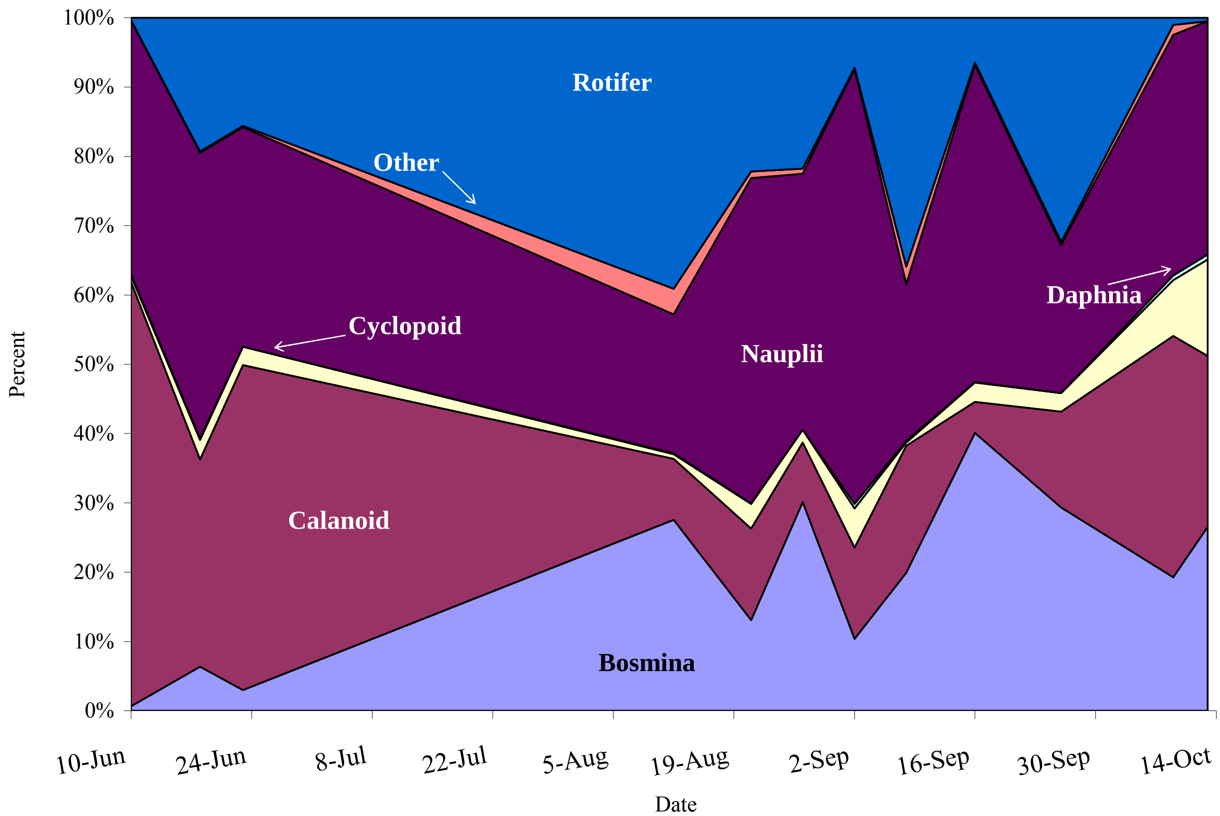

Figure 10. Percent composition of zooplankton found in nearshore Illinois waters of Lake Michigan near Waukegan between June and mid-October, 2008.

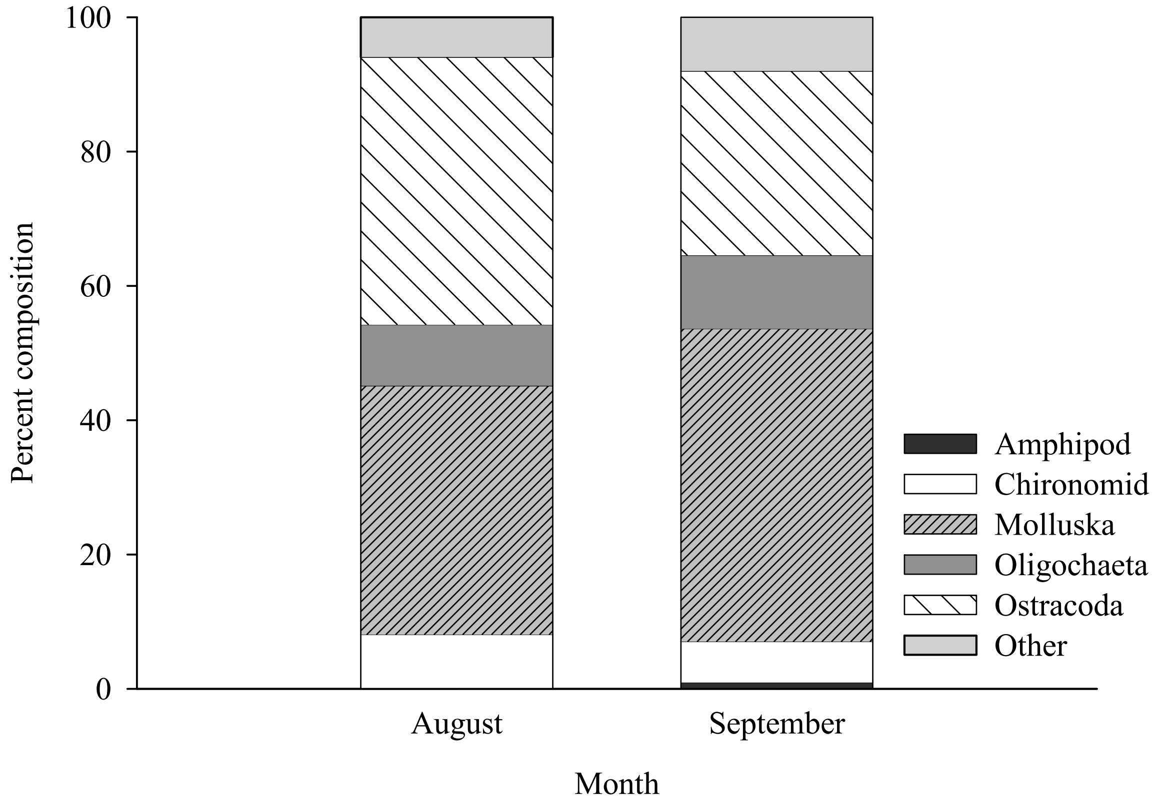

Figure 11. Percent composition of benthic invertebrates found in nearshore substrate of Lake Michigan north of Waukegan Harbor, IL during August and September 2008.

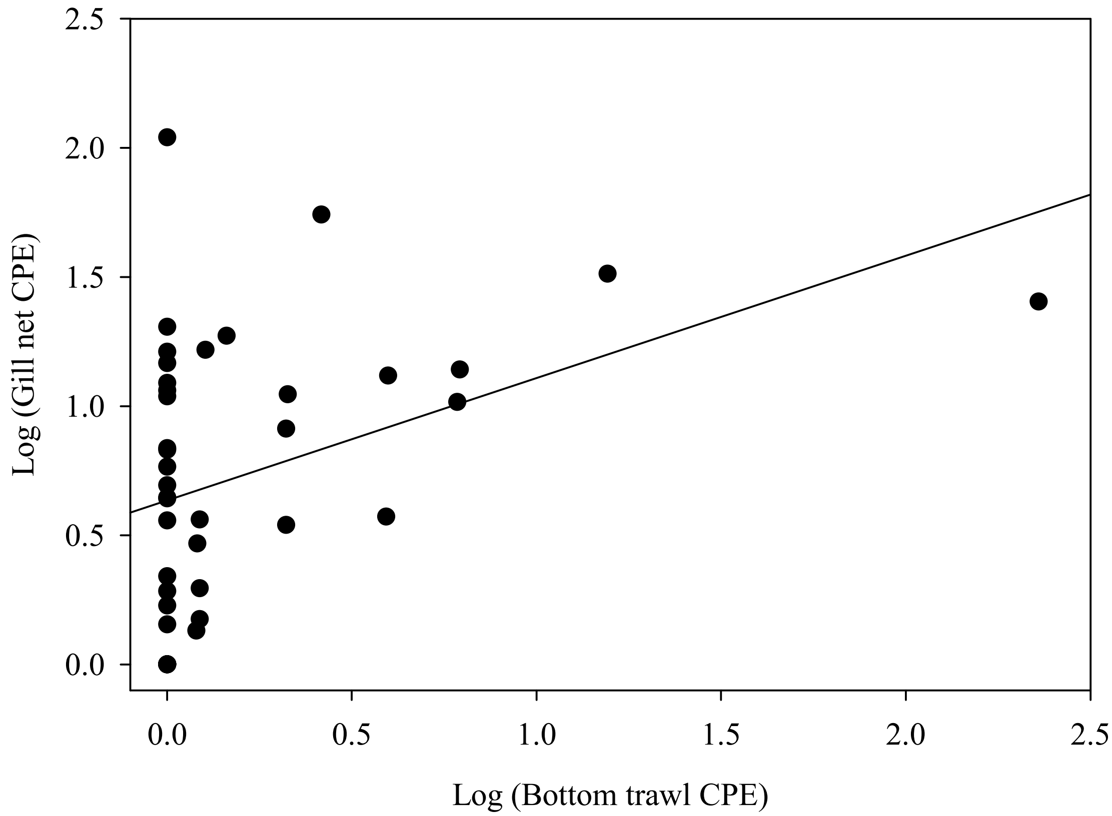

Figure 12. Relationship between age-0 yellow perch CPUE from small mesh gill netting and bottom trawling conducted north of Waukegan Harbor, IL during 2005-2008. The regression equation is log Gill net CPUE = 0.486 + 0.621 [log (Trawl CPUE)], $r^2 = 0.17$; $P = 0.009$.

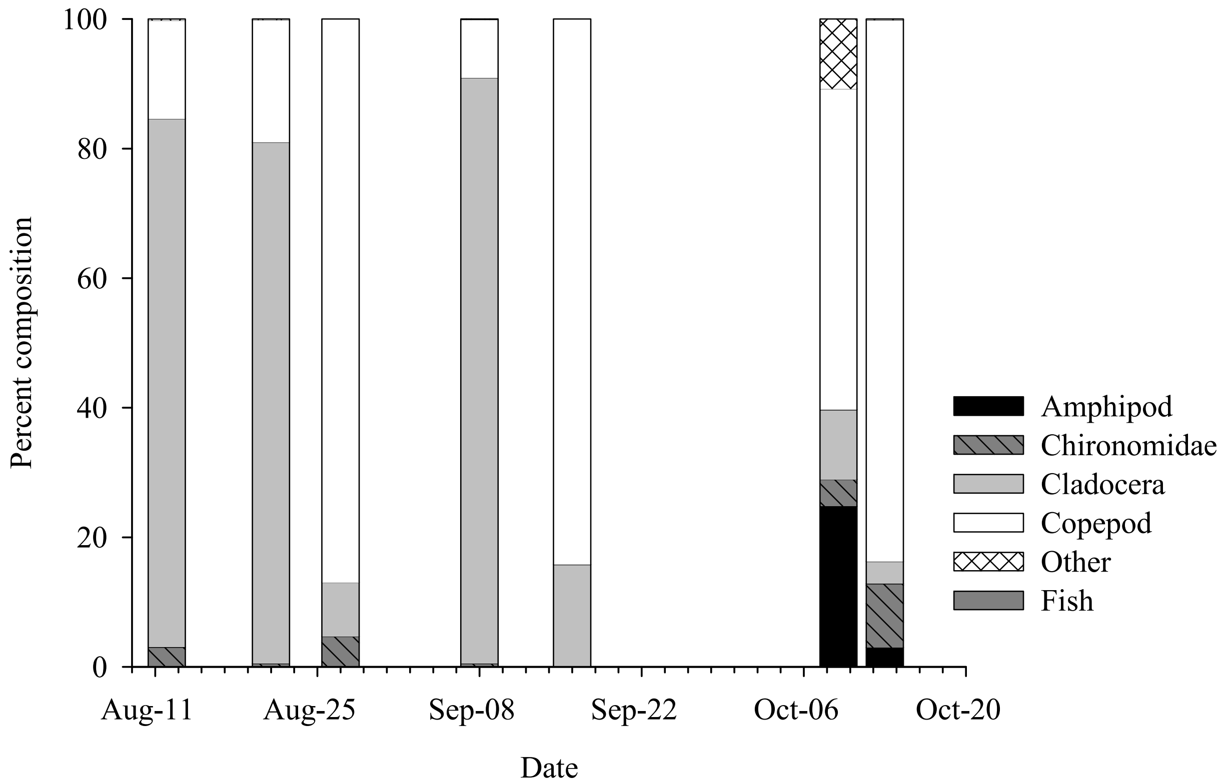

Figure 13. Percent composition by number of items found in the diet of age-0 yellow perch collected with a bottom trawl north of Waukegan Harbor, IL between 12 August and 13 October, 2008.

APPENDIX A – PROJECT F-123 R-15 PERFORMANCE REPORT

Project objective: 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.

SUMMARY FOR REPORTING PERIOD: April 1, 2008 – March 31, 2009

Study 101. 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.

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.

Progress: We collected adult yellow perch between 30 April and 2 June at Waukegan and Lake Forest, IL using gill nets. We deployed monofilament gill nets consisting of 100-ft panels of 2.0, 2.5, 3.0, and 3.5-in stretch mesh. Gill nets were set in 10, 15, and 20 m of water on 6 occasions and fished for approximately 24 hours. Total effort during 2008 was 14 net nights during which 356 yellow perch were collected. These fish were processed in the laboratory to allow analysis of the size and age structure of the spawning population. Ovaries were also removed from 89 mature females collected between 30 April and 28 May. All eggs were weighed before a 1.0 g subsample of eggs was counted. Fecundity of a female was estimated by multiplying the number of eggs in a 1.0 g subsample by the total weight of eggs taken from the ovary.

Planned Direct Costs:	$16,000
Direct Costs:	$16,000

Job 101.2: Develop angler-caught age distribution and, if possible, sex distribution
Objective: Estimate age composition and, if possible, sex composition of angler-caught fish to better parameterize a lakewide catch-age model in its final stages of development. Improved parameters for the age and sex composition of the fishery will provide more accurate estimates of the fishable yellow perch population in southwestern Lake Michigan.

Progress: We collected anal spines from 115 yellow perch caught by anglers using the boat ramp in Waukegan Harbor between 21 April and 5 May. Anal spines were also collected from 138 yellow perch at two known yellow perch pedestrian angling areas (Waukegan and Montrose Harbors, IL) during May and June. The sex of each fish was also determined by either external or internal inspection. Anal spines were cleaned and mounted in epoxy and then sectioned using a low speed saw. Then, anal spines were aged in the laboratory to determine the angler-caught age composition of yellow perch in 2008.

Planned Direct Costs: $25,000
Direct Costs: $25,000

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 yellow perch egg skeins at transects located along the abandoned US Steel water intake line south of Waukegan Harbor, and determine the relative abundance of newly hatched larval yellow perch in southwestern Lake Michigan.

Progress: Weekly SCUBA surveys were conducted between 2-19 June in 10 m of water along the selected transects south of Waukegan Harbor. 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. SCUBA divers found 1 egg skein on June 11 and embryos were fully formed and hatching. Newly-hatched larval perch were sampled using a 2-m x 1-m neuston net with 500-µm mesh netting. 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 at four index stations outside Waukegan Harbor on 3 occasions between 10-23 June. All larvae were preserved in the field with 95% ethanol and identified to species, enumerated and measured in the laboratory.

Planned Direct Costs: $26,000
Direct Costs: $26,000

Job 101.4: Sample pelagic age-0 yellow perch and their food resources in offshore waters

Objective: Determine the vertical distribution and describe diel movement patterns of pelagic age-0 yellow perch and their zooplankton prey in offshore waters of Lake Michigan.

Progress: Sampling for pelagic age-0 yellow perch and zooplankton was conducted 9 miles offshore east of Waukegan, IL on 24 June and 1 July. Both day and night sampling were conducted on 24 June. However, due to equipment malfunctions night sampling was not conducted on 1 July. A total of 15 larval fish samples were collected on these two dates. Pelagic, age-0 fish were collected at the surface (0-2 m) using a 1-m x 2-m fixed frame floating neuston net. A multi-net, opening/closing 1-m x 1.4-m mid-water Tucker trawl was used to sample pelagic, age-0 fish at the depth range of 3 to 27 m of water. This portion of the water column was separated into 4 depth ranges (3-9, 9-15, 15-21, and 21-27 m) and each of these depth bins was sampled for 36 minutes. Fish were preserved in the field and identified to species, enumerated, and measured in the laboratory. Thirty zooplankton samples were collected on 24 June and 1 July at depths corresponding to larval fish sampling using a 0.5 m diameter, 64-µm, closing zooplankton net. Zooplankton samples were taken at the beginning of each larval fish trawl transect. Water temperatures were recorded at depths corresponding to larval fish and zooplankton sampling. Zooplankton were preserved in the field and returned to the lab for identification, enumeration, and measurement.

Planned Direct Costs: $64,000

Direct Costs: $64,000

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.

Progress: 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 1 August through 14 October. An area of approximately 4,460 m^2 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. Total effort during 2008 was approximately 185,532 m^2 during which 149 age-0 yellow perch were collected. Forty-two zooplankton samples were collected at two historical sites near Waukegan Harbor, IL between 10 June and 13 October. Sampling occurred on the same nights as larval fish collections during June-July. 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. Four replicate samples from the top 7.5 cm (3 in) of the soft substrate were collected and preserved in 95% ethanol. During 2008, samples were collected once a month during August and 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.

Planned Direct Costs: $37,000
Direct Costs: $37,000

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.

Progress: 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. 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. Twelve paired comparisons between a bottom trawl and gill net were conducted at the same location between 5 August and 9 October, 2008. Captures of age-0 fish in gill nets will be 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 will be calculated as number of age-0 perch per 1,000 m^2 and CPUE from small mesh gill nets will be expressed 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.

Planned Direct Costs: $35,000
Direct Costs: $35,000

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.

Progress: One hundred and forty-eight yellow perch collected in a bottom trawl during 2008 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. Diet information for age-0 (≤ 80 mm TL) yellow perch was analyzed and summarized.

Planned Direct Costs: $22,000
Direct Costs: $22,000

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.

Progress: We evaluated the importance of two biotic (chlorophyll concentration and spring alewife abundance lagged by one year) and two abiotic factors (wind-induced transport index and spring-summer water temperatures) on yellow perch recruitment in southwestern Lake Michigan. Age-0 yellow perch abundance estimates based on sampling efforts from Job 101.5 were used as an index of recruitment. A basic Ricker stock-recruitment model for Lake Michigan yellow perch was fit to our recruitment index and then external variables were added to the model to determine if explanatory power could be improved. The results of this analysis were prepared into a manuscript which is currently under review for publication in Canadian Journal of Fisheries and Aquatic Sciences.

Planned Direct Costs: $11,000
Direct Costs: $11,000

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

Progress: Data from the above jobs were processed, analyzed and summarized. A final report was prepared from the data.

Planned Direct Costs: $16,422

Direct Costs: $16,422

SUMMARY FOR REPORTING PERIOD: April 1, 2009 – June 30, 2009

Be advised: Job titles and objectives listed for the extension period of the original project period have changed, so that Job 101.1 listed for the original project period (April 1, 2008 – March 31, 2009) differs from Job 101.1A listed below for the project extension period.

Job 101.1A: Improve annual assessments of the yellow perch spawning population
Objective: Monitor the age and size structure of yellow perch on spawning grounds and evaluate reproductive potential

Progress: We fished for adult yellow perch on 24 net nights at Waukegan and North Lake Forest, IL between 5 May and 5 June, 2009. We measured, weighed and removed otoliths from 537 yellow perch. Otoliths will be prepped for aging and assigned an age by three independent readers this winter.

Planned Direct Costs: $29,700
Direct Costs: $29,700

Job 101.2: Develop angler-caught age and sex distribution
Objective: Estimate age composition and, if possible, sex composition of angler-caught fish to better parameterize a lake-wide catch-age model in its final stages of development. Improved parameters for the age and sex composition of the fishery will provide more accurate estimates of the fishable yellow perch population in southwestern Lake Michigan.

Progress: Anal spines were collected from 100 yellow perch caught by anglers using the launch ramp in Waukegan, IL between 24 April and 11 May. During June we were able to collect spines from 68 yellow perch caught by pedestrian anglers fishing Waukegan and Montrose Harbors, IL. Spines will be prepped for aging and assigned an age by three independent readers this winter.

Planned Direct Costs: $20,250
Direct Costs: $20,250

Job 101.3: Sample pelagic age-0 yellow perch and their food resources in offshore water
Objective: Monitor the relative abundance of pelagic age-0 yellow perch and their zooplankton prey in offshore waters (≥ 3 miles from shore) of Lake Michigan.

Progress: We collected 14 larval fish and zooplankton samples in 1-27 meters of water approximately 9 miles from shore on June 24-25, 2009. Half of the samples were collected during day light (10:00 – 14:30) and the remaining samples were collected at night (22:14 – 02:09). We also monitored light intensity and water temperature at water depths corresponding to larval fish and zooplankton sampling.

Planned Direct Costs:	$13,155
Direct Costs:	$13,155

SUMMARY OF EXPENDITURES

Original Project Period: *April 1, 2008 – March 31, 2009*

Original Cost	$252,422
Federal Share	$189,317
State Share	$63,105

Extension of Original Project Period: *April 1, 2009 – June 30, 2009*

Amount of Change	$63,105
Federal Share:	$47,329
State Share:	$15,776

TOTAL EXPENDITURES: *April 1, 2008 - June 30, 2009*

Total Cost	$315,527
Federal Share:	$236,646
State Share:	$78,881