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Yellow Perch Population Assessment in Southwestern Lake Michigan

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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 (previous segments of F-123-R). During this period, LMBS trawling efforts detected moderate year class strength during 2002 and 2004. 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. Additionally, age-0 CPUE from trawling assessments during 2005 was the highest recorded in Illinois waters since 1988. During 2006-2008, the 2002 and 2003 year classes dominated LMBS spring adult assessments and sport harvest collections. Then, in 2009 LMBS adult catches (fishery independent and sport harvest) were dominated by the 2005 year class, while the 2002 and 2003 year classes also contributed significantly to the fishable population (Redman et al. 2010). Despite the presence of multiple year classes within the population, lake wide assessments show that current yellow perch abundance remains low, particularly in comparison to abundance observed in the late 1980s and early 1990s (Makauskas and Clapp 2010). Thus, there continues to be concern about the survival and growth of yellow perch and sustainability of the population in Lake Michigan.

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 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 pelagic and demersal age-0 yellow perch along with additional juvenile (age 1 and age 2) life stages may permit prediction of future year-class strength. However, variability of larval yellow perch abundance data and age-0 catches is very high, and much remains unknown about the early life history of yellow perch in large lakes. Particularly, how the hydrodynamics of Lake Michigan influence the advection of larval yellow perch from nearshore spawning sites to the offshore pelagic zone as well as eventual settlement into benthic nearshore nursery habitat. The ability to couple physical and biological data will not only enhance our understanding of pelagic age-0 fish feeding behavior and early life-stage movement and survival rates, but also contribute to our ability to monitor year-class strength relative to other years. 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 pelagic larval yellow perch drifting offshore, abundance of age-0 yellow perch returning to nearshore habitat in fall, and abundance and diet of age-1 and age-2 yellow perch, coupled with 20+ years of data collected on yellow perch in Illinois waters of Lake Michigan will help to identify critical bottlenecks that limit survival between early life stages and recruitment to the sport fishery.

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 1989–2009 were consistently lower than densities in the late 1980s, when yellow perch abundance and harvest were dramatically higher (Dettmers et al. 2003, Clapp and Dettmers 2004, Redman et al. 2010). 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 & RESULTS

<u>Study 101.</u> Yellow perch population assessment in southwestern Lake Michigan

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

<u>Objective:</u> Monitor the age and size structure of the spawning population on spawning grounds and evaluate reproductive potential.

Adult yellow perch were collected from 4-25 May, 2010 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 meters of water on 6 occasions and fished for approximately 24 hours. Total effort during the 2010 spring assessment was 26 net nights during which 474 yellow perch were caught.

Sixty-four percent of the yellow perch collected were females and their mean length was 255 ± 45 mm TL (SD). Average length of males was 230 ± 35 mm TL. Spring mean CPUE (fish/net night) was 18 ± 20 (SD) yellow perch. During 2010, no significant differences were detected when mean CPUE was compared between the Waukegan and North Lake Forest sampling sites ($p = 0.62$) or among the 10, 15 and 20m depth stations ($p = 0.23$; Figure 1) using a Repeated Measures ANOVA. In an effort to better understand the distribution of female and male yellow perch during the spawning season we compiled gender and total length data for yellow perch caught during 2008-2010 (N = 1,166 fish). To investigate whether the sex ratio and mean length of females changed throughout the spawning season we divided the 36 day sampling window (30 April-4 June) across years into three, 12 day periods: a) 30 April-11 May, b) 12-23 May, and c) 24 May-4 June; referred to as sample periods from this point forward. We then tested for a difference in sex ratio (Chi-square) and mean total length of females (Repeated Measures ANOVA) among the three sample periods and depth stations (10, 15 and 20m). In total, 616 females and 550 males were caught during 2008-2010. Our data did not show a tendency for the sex ratio to change among sample periods (2.16; df = 2; $p = 0.34$; Figure 2a). However, our data did show a gender bias among depth stations (29.3; df = 2; $p < 0.001$). There was a tendency for more females to be caught in deeper water and vice versa for males (Figure 2b). The sex ratio at the 10m depth station favored males (1:1.25), while the sex ratio at the 15 and 20m depth stations favored females (1.13:1 and 1.79:1, respectively) regardless of sample date. Mean TL of females differed among depth stations ($p = 0.01$), but not sample periods ($p = 0.42$). More specifically, mean TL of female yellow perch caught at the 15m depth station (278 ± 44 mm TL) was greater than that at the 10m depth station (265 ± 51 mm TL). A significant interaction between depth and sample period was also detected ($p <0.001$). More specifically, mean TL of females caught at the 10m depth station during the second sample period (12 -23 May) was significantly lower to that at the 20m station during the same survey period (Figure 3). Probably of less biological significance was significantly lower mean TL of females caught at the 10m station during 12-23 May compared to those caught at 15m station during 30 April-11 May. Our data show some evidence that female yellow perch are staying in deeper (≥ 15m) water throughout the spawning season and that those caught in shallower water (10m) tend to be smaller and presumably younger females.

We determined the age of 328 yellow perch using otoliths. Fish ranged in age from 3 to 12 years old. Age 5 fish (2005 year class) dominated our catch (Figure 4). Age 3 and 4 fish

(2006 and 2007 year classes) each contributed approximately 14% of the catch. Notably, about 80% (N= 152) of the fish within these dominate year classes (2005-2007) were females. Age 6 and 7 fish each contributed around 12% of the catch and the remaining older age classes each made up less than 10% of our catch. Mean TL of the 2005 year class was 245 ± 39 (SD) mm TL. Mean TL was 227 ± 28 mm TL for the 2006 year class and 211 ± 21 mm TL for the 2007 year class.

In 2010, ovaries were taken from 102 females that averaged 259 ± 41 (SD) mm in length and ranged in age from 3 to 12 years. Mean fecundity of yellow perch collected during 2010 was 44,834 ± 27,075 (SD) eggs. Based on analysis of fecundity estimates from 286 ovaries collected during 2007-2010, fecundity of yellow perch was influenced by multiple maternal traits such as total length, age, and ovary weight. Fecundity generally increased with age and size until about age 9 after which it either leveled off or declined (Figure 5). Based on AIC analysis, a single model was considered robust ($AIC_c \leq 2.0$; Table 1). The top ranked model provided a good fit to the data (Figure 6) and explained 92% of the variation in $\log_{10}$ fecundity. The most influential variables on fecundity were ovary weight (w_i = 1.0), maternal age (w_i = 1.0) and total length (w_i = 0.90).

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

Objective: Monitor the age, size and sex structure of the population during a period when male and female yellow perch are more evenly distributed.

We sampled for adult yellow perch between 9-28 September, 2010 at Waukegan, 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 meters of water on 3 occasions and fished for approximately 24 hours. Total effort during the 2010 fall assessment was 9 net nights during which only 16 yellow perch were caught; all fish were processed in the laboratory. Most of the yellow perch collected were females (N= 14). Average length of all fish was 275 ± 57 mm TL (SD). Fish ranged in age from 3 to 11 years old (Table 2).

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.

During 2010, we collected anal spines from 56 yellow perch harvested by launched anglers using Waukegan Harbor between 28 April-19 May. We also collected spines from 189 yellow perch harvested by pedestrian anglers at Waukegan and Montrose Harbors, IL during June and August. Ten spines were eliminated from age analysis due either to damage during the preparation process or <75% reader agreement (N = 235).

Yellow perch sampled from boat anglers ranged in age from 4-13 years old (Figure 7a). Unfortunately, gender data was not available for most (69%) of the yellow perch collected from the boat fishery. Age-5 fish dominated the sampled boat harvest (25%), followed by age 7 (21%) and age 8 fish (19%); these are the same year classes (2002, 2003 and 2005 year classes) that dominated the boat harvest in 2009. Yellow perch sampled from pedestrian anglers ranged in age from 2-12 years old (Figure 7b). Age 3, 4, and 5 fish made of 75% of the pedestrian fishery; each age class contributed 23-27%. When all data was combined (boat and pedestrian fisheries), age

3-5 fish each contributed 21-23% subsample and together comprised 65% of the sample harvest (Figure 5c).

Similar to that detected during 2008 and 2009, mean age of yellow perch harvested by boat anglers using Waukegan launch ramp (7.3 ± 2.3 years, SD) was significantly greater than that of yellow perch harvested by pedestrian anglers at Waukegan and Montrose Harbors (4.6 ± 1.8 years; t-value = 7.67, $P < 0.0001$). Additionally, mean length of yellow perch harvested by boat anglers (293.2 ± 43 mm TL) was significantly greater than that of yellow perch harvested by pedestrian anglers (248 ± 39 mm TL; t-value = 6.96, $P < 0.0001$).

Job 101.3: Sample pelagic age-0 yellow perch and their food resources in offshore waters
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.

Pelagic age-0 yellow perch and zooplankton were collected at fixed stations about 9 miles offshore of Waukegan, IL on four occasions between 1-30 July, 2010. 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. 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 2 to 38 m of water. This portion of the water column was separated into 6 depth strata (2-8, 8-14, 14-20, 20-26, 26-32, and 32-38 m) and each of these depth bins was sampled for 30 minutes. Both nets on the mid-water trawl were equipped with 1000-µm nitex mesh nets. Each depth strata was sampled for zooplankton using replicate vertical hauls of a 0.5 diameter plankton net (64-µm mesh) equipped with an opening/closing mechanism. A total of 25 larval fish and zooplankton samples were collected. However, our fish sampling at depth (2-38 m) was compromised by malfunctions with the opening and closing mechanism on the mid-water tucker trawl. Since that time, we have worked with the manufacturer to replace malfunctioning components on the tucker trawl. We did collect a total of 297 larval fish. However, we are not able to determine the vertical distribution of these fish due the gear malfunctions. Fish and zooplankton were preserved in the field and sorted to species, enumerated, and measured in the laboratory. Light intensity and water temperature were also determined at depths corresponding with larval fish and zooplankton sampling. In the lab, fish were identified to species and total length was measured. Zooplankton samples were processed by examining up to three 5-ml subsamples taken from adjusted volumes that provided a count of at least 20 individuals of the most dominant taxa. Zooplankton were enumerated, identified to the lowest taxon possible and measured.

Job 101.4: 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.

A bottom trawl with a 4.9-m head rope, 38-mm stretch mesh body, and 13-mm mesh cod end was used to sample age-0 yellow perch north of Waukegan Harbor. Daytime bottom trawling for age-0 yellow perch was conducted weekly between 30 July-14 October, 2010 at four depth stations (3, 5, 7.5 and 10 m). Water temperature was also recorded at each depth station. 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 2010 was approximately 173,500 m^2 and 1,776 age-0 yellow perch were collected. Mean annual CPUE of age-0 yellow perch during 2010 was 966 fish/100,000m^2 (Figure 8). Ninety-eight percent of these yellow perch were collected in 3 meters of water on 30 July. On this date, mean total length of age-0 yellow perch was 41 ± 3 mm. Age-0 yellow perch caught in the bottom trawl during 2010 were quite small; monthly mean total length only increased to 61 mm over the course of the sampling period (Figure 9).

Thirty-two zooplankton samples were collected at two historical sites near Waukegan Harbor, IL between 30 July-14 October, 2010. Samples were immediately preserved in 10% sugar formalin. 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. In the lab, samples were processed by examining up to three 5-ml subsamples taken from adjusted volumes that provided a count of at least 20 individuals of the most dominant taxa. Zooplankton were enumerated, identified to the lowest taxon possible and measured. Mean June-July zooplankton density in 2010 was 8.0 ind./L, which continues to be below the minimum density (10/L) suggested for age-0 yellow perch foraging success (Bremigan et al. 2003); Figure 10). Mean June-July crustacean zooplankton density was only 5.8 ind./L in 2010 and dominant taxa were adult calanoid copepods and copepod nauplii. Mean monthly density of total zooplankton was relatively low during June, peaked in July, and declined to a minimum in September; densities showed a slight recovery during October (Figure 11). Mean monthly density of veligers was low during June (1.5 ind./L), increased to 26 ind./L in July, and then peaked at 124 ind./L in August (25% of individuals collected). Then, veliger density declined to about 8 ind./L in September and October. Mean monthly crustacean zooplankton density was low during June (7 ind./L), but increased to 37 ind./L during July and remained around 25 ind./L in August after which densities declined to less than 10 ind./L (Figure 11). Calanoid copepods and copepod nauplii dominated the crustacean zooplankton assemblage during June; with mean densities of 7 and 6 ind./L, respectively (Figure 12). During July, copepod nauplii and rotifers dominated the zooplankton assemblage with densities of 79 and 63 ind./L, respectively. Density of cyclopoid copepods was < 1.0 ind./L (< 2% of taxa) during June, but increased in July and peaked around 18 ind./L (<3% of taxa) during August. Density of bosmina was low (<5 ind./L) throughout much of the sampling period with the exception of July and August when densities were 7 and 17 ind./L, respectively. Harpacticoid copepods were also collected throughout the sample period, but in much smaller densities (<1 ind./L). 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.

Benthic invertebrates were collected monthly August through October in 7.5 meters of water at a site north of Waukegan Harbor. When possible, SCUBA divers collected benthic invertebrates 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. When weather conditions did not allow collection by divers benthic invertebrates were sampled using a petite ponar grab with 232-cm^2 sampling area. During each sampling event, two replicate ponar grabs were collected and preserved in 95% ethanol. During 2010, August samples were collected by SCUBA divers, while September and October samples were collected using a ponar grab. In the lab, all samples were sieved through a 363-µm mesh net to remove sand. Organisms were then sorted from the remaining sediment debris and identified to the lowest taxon possible, 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. Based on benthic core collections, the most abundant taxa in substrate near Waukegan during August were ostracods followed by nematods, chironomids and mollusks (Figure 13a). Individuals of Sphaeriidae made up 78% of mollusks collected during August. Notably, Diporeia were detected in the substrate near Waukegan during August; mean density was 28 ind./cm^2. Oligochaetes, insects, and hydra were also found, but in much smaller abundances (collectively <15% of total density). Based on ponar grabs, mollusks dominated the benthic invertebrate community near Waukegan during September and October (88-94%, respectively; Figure 13b). Almost all of these mollusks were identified as quagga mussels; members of Sphaeriidae and Valvatidae were also collected, but in much smaller quantities. Chironomids, nematods and Oligochaetes were also collected in relatively small quantities during September and October.

We examined the stomachs of 73 age-0 yellow perch collected on nine occasions between 30 July-14 October, 2010; all but one stomach contained identifiable prey organisms. Length of yellow perch used for diet analysis ranged from 34-78 mm TL and mean length was 50 ± 10 mm TL (SD). Overall, age-0 yellow perch primarily consumed zooplankton (95%) and smaller quantities of benthic invertebrates which is consistent to trends seen in past years. The majority of zooplankton consumed by age-0 yellow perch were copepods (94% of zooplankton consumed). Diets of age-0 yellow perch shifted from 97% copepods (primarily cyclopoids) in late July to varying amounts of chironomids and cladocerans, and much smaller quantities of copepods during August through October (Figure 14). Cladocerans, primarily Chydoridae and Daphnia, contributed 38-69% of the diet during August through October. No amphipods were detected in the diets of age-0 yellow perch collected in 2010.

Job 101.5: Sample juvenile (age-0 through age-2) yellow perch in nearshore waters
Objective: Collect age-0 yellow perch in nearshore waters in a manner consistent with guidelines developed by the Yellow Perch Task Group's lakewide age-0 yellow perch assessment. Monitor the abundance and diet of juvenile yellow perch.

To fulfill our commitment to the Yellow Perch Task Group's lakewide age-0 yellow perch assessment, we sampled yellow perch with 10-m gill net panels of 6, 8, 10, and 12 mm stretch mesh on seven occasions between 30 July-30 August, 2010. We continued to sample juvenile yellow perch during the fall and were able to sample on one occasion in September and two occasions in October. Nets were fished for approximately four hours in 3-10 meters of water at historical sites near Waukegan Harbor, IL. All fish collected in these assessments were processed in the laboratory for size and diet information. Total effort during late July/August 2010 was 68.1 hours during which we caught 148 yellow perch. Most (69%) of these fish were caught in 3-5 meters of water on 23 August. Total effort during September and October was 36 hours during which we captured 221 yellow perch and 260 fish from other species (mainly alewife, spottail shiner and rainbow smelt). CPUE (No. fish/hr) of yellow perch in small mesh gill nets was high on 30 July when a total of 65 fish were caught in 5-7.5 meters of water north of Waukegan Harbor. CPUE of yellow perch in August and September was less than 4 fish/hr and then increased to 8 fish/hr during October (Figure 15). Yellow perch collected in small mesh gill nets during 2010 ranged from 50-221 mm TL. Mean length of yellow perch caught in 6 and 8 mm mesh panels was 63 ± 17 (SD) and 91 ± 40 mm TL, respectively (Figure 16). Mean length of yellow perch caught in 10 and 12 mm panels was 118 ± 40 and 133 ± 36 mm TL, respectively.

We examined the stomachs of 45 juvenile yellow perch collected on seven occasions between August 12^{th} and September 27^{th}, 2010; all but one stomach contained identifiable prey organisms. Length of yellow perch used for diet analysis ranged from 51-131 mm TL and mean length was 79 ± 26 mm TL (SD). Fish were divided into three size classes for diet description: 1) < 80 mm, 2) 80-110 mm, and 3) > 110 mm TL. A diet shift was apparent across size classes with smaller yellow perch primarily consuming zooplankton and larger yellow perch consuming mostly benthic invertebrates and some fish. Yellow perch < 80 mm TL primarily consumed zooplankton with cladocerans and copepods each comprising about 44% of their diet (Figure 17). Yellow perch 80-110 mm and > 110 mm TL consumed primarily chironomids (98 and 63%, respectively) along with smaller quantities of zooplankton. We also had one account of cannibalism; a 130 mm fish consumed another yellow perch that was about 42 mm long. No amphipods were detected in the diets of juvenile yellow perch collected in 2010.

Job 101.6: Data analysis and report preparation

Objective: Analyze data and prepare reports, manuscripts and presentations.

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

CONCLUSIONS

Spawning stock

To improve our annual assessments of the yellow perch population we targeted fish in deeper waters (10-20m) with gill nets during both spring and fall. Four hundred and ninety yellow perch were collected in gill nets during 2010 and 97% of these were caught during the spring. Mean CPUE during the spring was 18 fish per net night and 2 fish per net night during the fall. In general, yellow perch seemed to be evenly distributed within 10-20 meters of water during the spring as no differences were detected in CPUE among depth stations (10, 15, and 20m), which is similar to that detected in 2008 and 2009. However, analysis of data from 2008-2010 revealed that a significantly larger proportion of the yellow perch caught in 15 meters of water were females. These results suggest that females may be depositing eggs in deeper water and may partly explain why divers could no longer find egg skeins on the Waukegan Wiremill intake pipe during the mid-2000s (previous segments of F-123-R). These results bring up questions about whether spawner success has changed as well as how hatching success and larval survival may be affected by deeper egg deposition. Williamson et al. (1997) found that yellow perch egg deposition was deeper in a lake with high-damaging solar ultraviolet radiation (UVR), which is associated with low dissolved organic carbon and high water clarity. The establishment and expansion of Dreissenid mussels has been linked to significant increases in water clarity in Lakes Ontario and Huron (Dobiesz and Lester 2009), which would also imply lower levels of dissolved organic carbon and higher levels of UVR within these lakes. We have observed increased water clarity at our historical yellow perch spawning sites, thus it is possible that Dreissenids are indirectly affecting the spawning behavior of yellow perch in Lake Michigan through increased levels of UVR. However, at this point in time, it remains unclear how this change in behavior effects overall reproductive success and survival of progeny.

The 2005 year class dominated our catch during the spring and was followed by the 2006, 2007, 2004 and 2003 year-classes. This is the second consecutive year when the 2005 year class was well represented in our adult assessment after being the most abundant group of age-0 yellow perch detected in our trawl survey since 1988. Based on very low CPUE during the fall, it seems that yellow perch were not utilizing the nearshore zone near Waukegan, IL as they did during the fall of 2009. Although few yellow perch were caught, the sex ratio during September 2010 was highly skewed towards females (14 of the 16 fish caught). Wisconsin Department of Natural Resources reported an increase in the percent of female yellow perch collected during their winter assessment since 2007. More specifically, female yellow perch made up 50% of the catch in 2007 and this increased to 70% by 2010 which surpasses that detected in the late 1980s and early 2000s (Makauskas and Clapp 2010). Lakewide CPUEs show a long-term decline in the abundance of adult yellow perch and current abundance remains well below levels detected in the late 1980s and early 1990s (Makauskas and Clapp 2010).

In 2010, ovaries were taken from 102 females that ranged in length from 188-334 mm TL and ranged in age from 3 to 12 years. Fecundity ranged from 9,763 to 122,041 eggs per female. The most influential maternal traits on fecundity were ovary weight, maternal age and total length. Based on these results, ovary weight may be a sufficient surrogate for egg counts when estimating fecundity of yellow perch. However, more samples are needed to develop a defendable relationship between these two parameters. Our data set does support the contention thatestimates of reproductive potential should account for age composition of spawners rather than spawner biomass alone.

To determine the age structure of yellow perch caught by boat anglers, anal spines were collected from 56 fish at the Waukegan launch ramp between late April and mid-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 during 2010 were age 5, 7 and 8 which may continue to be very important for future spawning potential. Thus, the launched boat fishery in Waukegan is contributing significantly to yellow perch harvest in Illinois and results from previous segments of F-123R 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 2010. Pedestrian anglers primarily harvested age 3, 4 and 5 fish. Overall, sport anglers (boat and pedestrian combined) primarily harvested yellow perch from the 2005-2007 year-classes with 2003 and 2002 year classes also contributing to the harvest. This is the second consecutive year the 2005 year class has contributed significantly to the sport harvest and the sixth consecutive year that the 2002 year class has contributed significantly to the sport harvest. The 2002 year-class made up about 40-60% of fish subsampled from our nets during 2005-2009. Fish from these year classes (2002-2007) will be extremely important for future spawning and should be protected.

2010 Year class

CPUE of age-0 yellow perch collected in bottom trawls during 2010 was the highest recorded since 2005, but still much lower than that detected during the late 1980s. Previously, relatively high CPUE in 1998 led to a comparatively strong year class as seen by its dominance in LMBS 2000-2004 fyke netting (previous segments of F-123-R). A similar pattern occurred with the 2002 and 2005 year classes. Both of these year classes were caught in relatively high abundance at age-0 and were detected at significant levels in our adult assessments by age 4. The 2002 year class has contributed significantly to adult assessments and angler catches since 2006 (previous segments of F-123-R) and 2009 was the first year the 2005 year class dominated both our adult assessment and sport harvest collections. These results suggest that strong CPUE of age-0 yellow perch is a reasonable indicator of recruitment success. Thus, because CPUE levels were higher in 2010 compared to during 1998, within a few years hopefully the 2010 year class will appear more readily in our spring adult assessment as we saw with the 1998, 2002 and 2005 year classes. Despite all this, yellow perch year class strength remains very erratic from year to year and recent CPUEs are extremely low compared to sampling in the late 1980s (1987 and 1988). Therefore, although the 2002, 2004, 2005, and 2006 and 2009 year-classes were measurable, their levels were nowhere near that of the late 1980s; as such, they probably are not sufficiently strong to support extensive fishing pressure.

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 1996-2009 (Dettmers et al. 2003, previous segments of F-123-R). Zooplankton densities since 1996 have barely reached even half of the densities found during the late 1980s when multiple strong year classes 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) and quagga mussels during the early 2000s (Nelepa et al. 2009). 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). The presence of these invaders and other exotic species have had major impacts on the zooplankton and benthic invertebrate assemblages, and may result 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.

Management Implications

In summary, the fishable yellow perch population was supported by several consecutive year classes (2002-2007) with the 2005 year class being the dominate cohort. Our 2010 sport harvest data suggest that anglers primarily harvested fish from the 2005-2007 year classes. There is a need to protect all these year classes (2002-2007) so that they can reach their full reproductive potential. Although we continue to see evidence that the Lake Michigan yellow perch population is being supported by multiple year classes, poor recruitment during 1999-2001 and 2008-2009 and the continued trend of low abundance of adult yellow perch throughout Lake Michigan (Makauskas and Clapp 2010) raises concerns about the growth and survival of yellow perch. Our long-term data still clearly demonstrate that recruitment is highly variable and low when compared to recruitment during the 1980s. Thus, 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 advantage of beneficial recruitment conditions when they occur. Given the current population characteristics, management for limited harvest is necessary to protect the future of the Lake Michigan yellow perch population.

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TABLES

Table 1. Regression models of yellow perch fecundity on maternal traits ranked by Akaike's information criterion corrected for small sample size (AIC_c). Also shown for each model are the difference (Δ_i) between its AIC_c and AIC_c of the top-ranked model, Akaike weight and evidence ratio (w_1/w_j); models in bold text were deemed robust ($\Delta AIC_c < 2$). Variables are as follows: TL = total length (mm), AGE = age in years, GWT = total gonad weight (g).

List of variables	Adj R^2	Model P-value	AIC_c	Δ_i	Akaike weight
TL AGE GWT	0.92	<0.001	-1435.33	0	0.90
AGE GWT	0.92	<0.001	-1430.89	4.4	0.10
TL GWT	0.92	<0.001	-1419.73	15.6	<0.001
GWT	0.91	<0.001	-1387.66	47.7	<0.001
TL AGE	0.79	<0.001	-1149.49	286.0	<0.001
TL	0.79	<0.001	-1150.28	285.1	<0.001
AGE	0.36	<0.001	-825.81	609.5	<0.001

Table 2. Sample date and depth (m) of yellow perch collected during the 2010 fall assessment. Also shown are total length, sex, and age of each fish.

Sample date	Water depth (m)	TL (mm)	Sex	Age
Sept 9	15	316	F	8
Sept 9	20	311	F	6
Sept 9	20	313	F	6
Sept 13	20	193	M	-
Sept 13	20	306	F	7
Sept 13	20	232	M	6
Sept 13	20	301	F	8
Sept 13	20	181	M	5
Sept 28	15	273	F	5
Sept 28	15	254	F	3
Sept 28	15	205	F	3
Sept 28	15	192	F	5
Sept 28	20	313	F	-
Sept 28	20	344	F	8
Sept 28	20	329	F	7
Sept 28	20	333	F	11

FIGURES

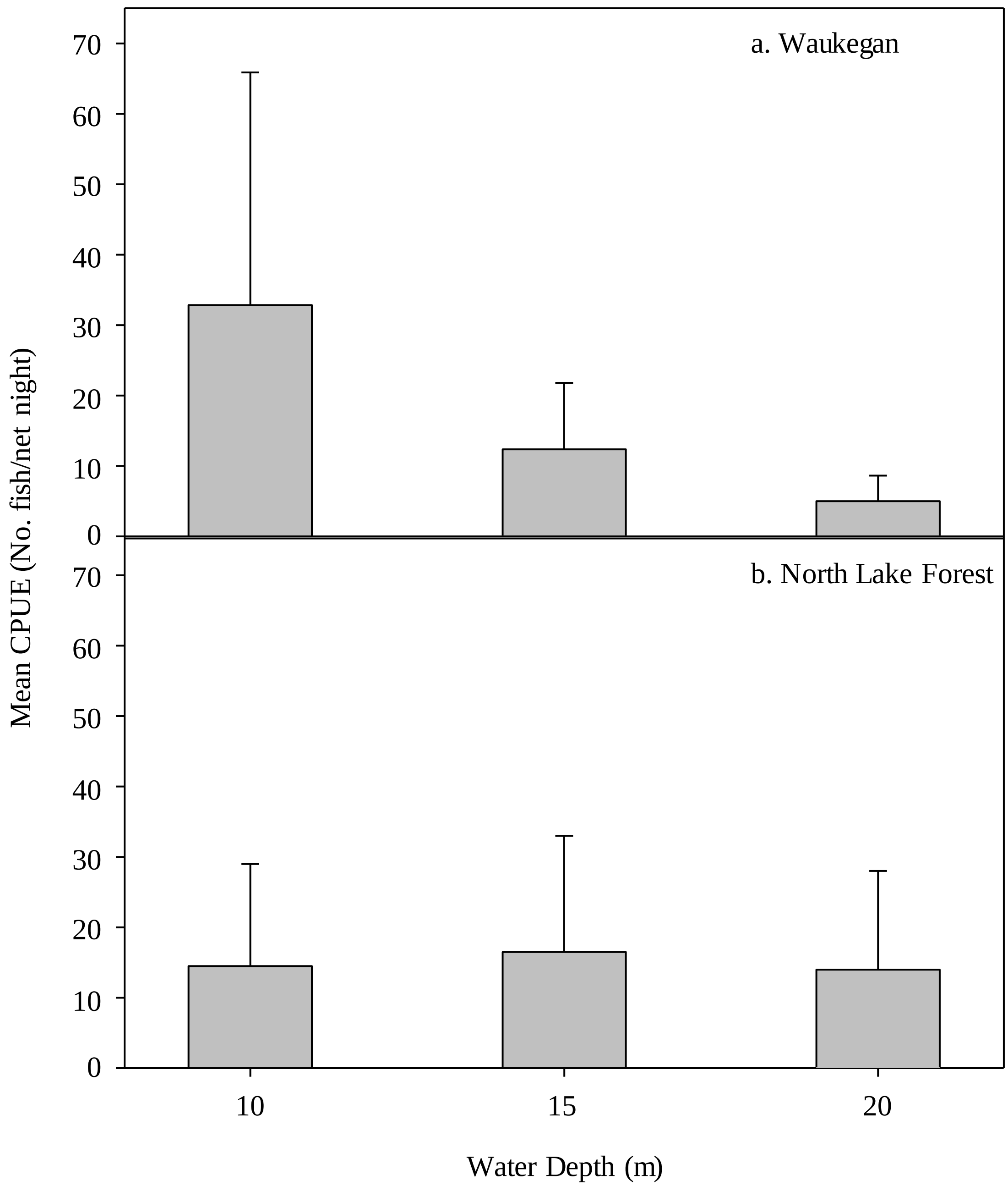

Figure 1. Mean CPUE (fish/net night) (+ 1 SD) of yellow perch collected in gill nets at a) Waukegan and b) North Lake Forest, Illinois in 10, 15, and 20 meters of water during 2010.

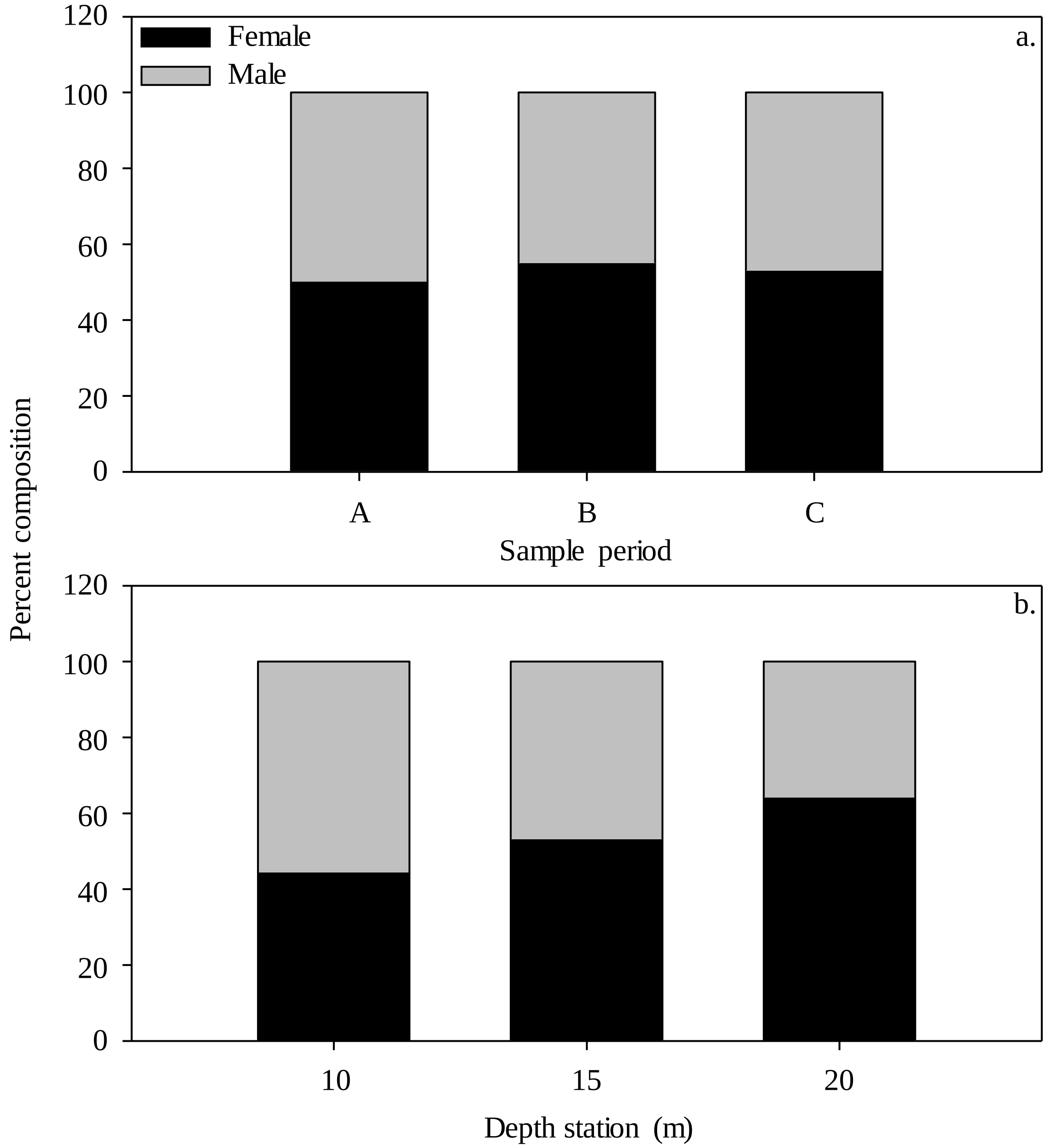

Figure 2. Gender composition of adult yellow perch collected in gill nets during the 2008-2010 spawning seasons a) during three sample periods (see text for explanation) and b) among three depth stations.

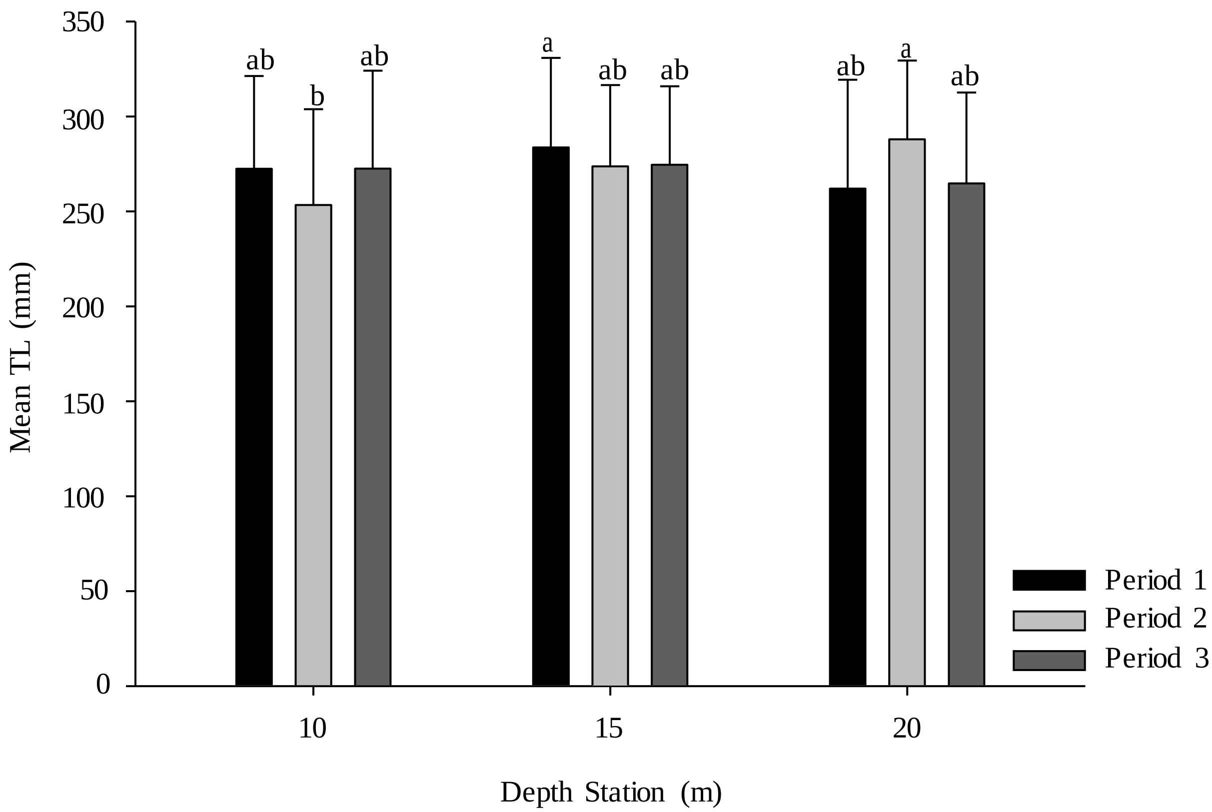

Figure 3. Mean total length (+ 1 SD) of female yellow perch collected in gill nets during the 2008-2010 spawning seasons among depth stations and sample periods.

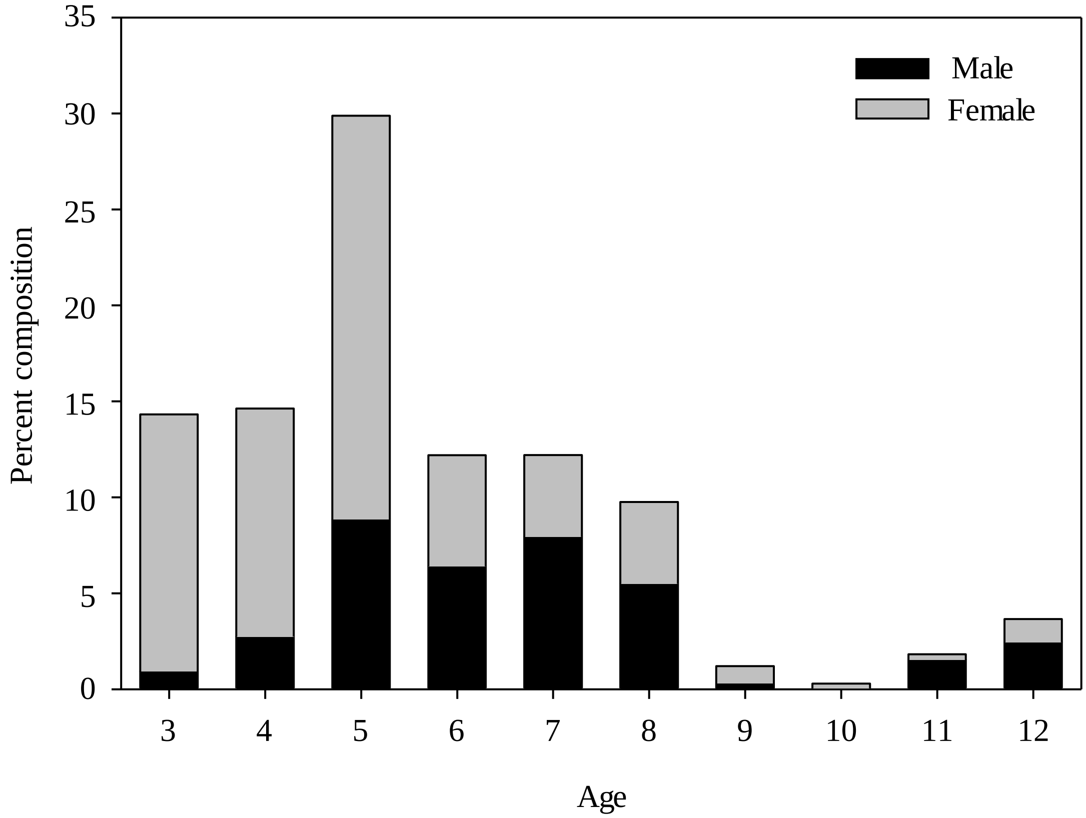

Figure 4. Age and gender composition of adult yellow perch collected using gill nets at Waukegan and North Lake Forest, IL during the spring of 2010.

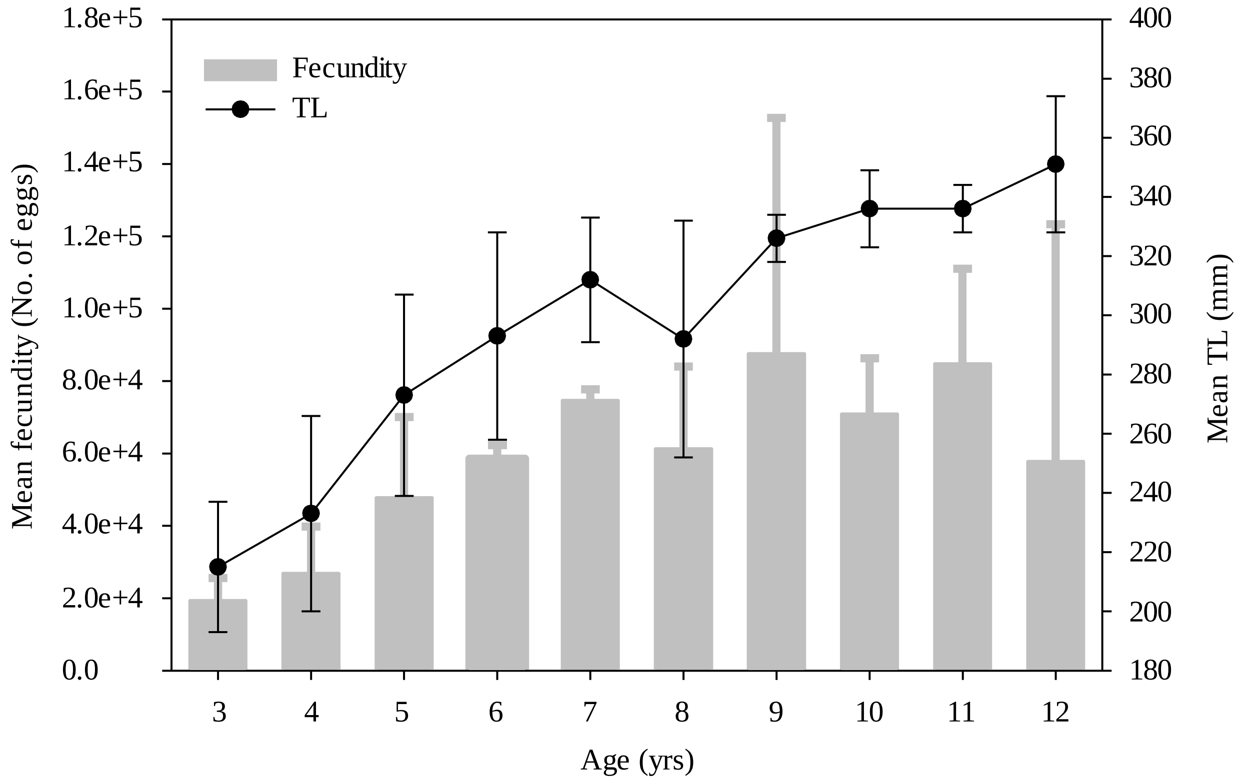

Figure 5. Mean fecundity (No. eggs) + 1 SD and TL (mm) of yellow perch age classes represented from gill net catches at Waukegan and North Lake Forest, IL during 2007-2010.

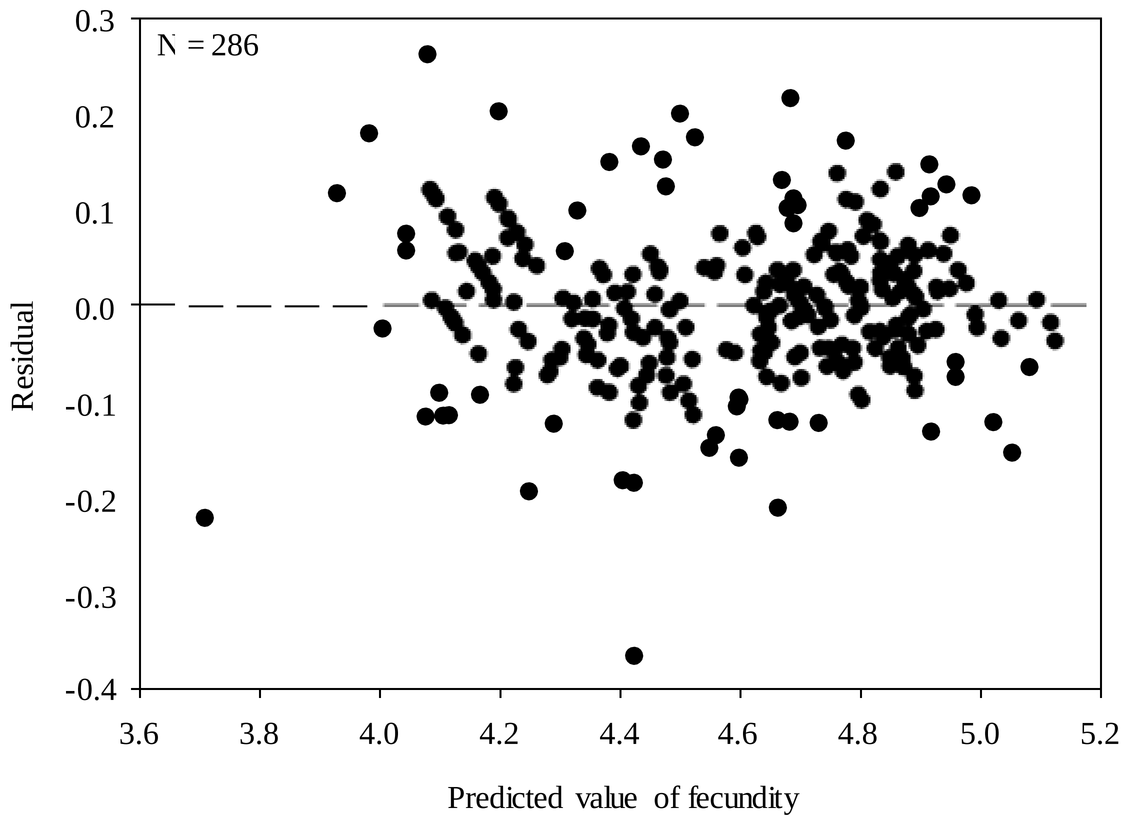

Figure 6. Residual values versus predicted fecundity for top-ranked model which included total length, maternal age and ovary weight.

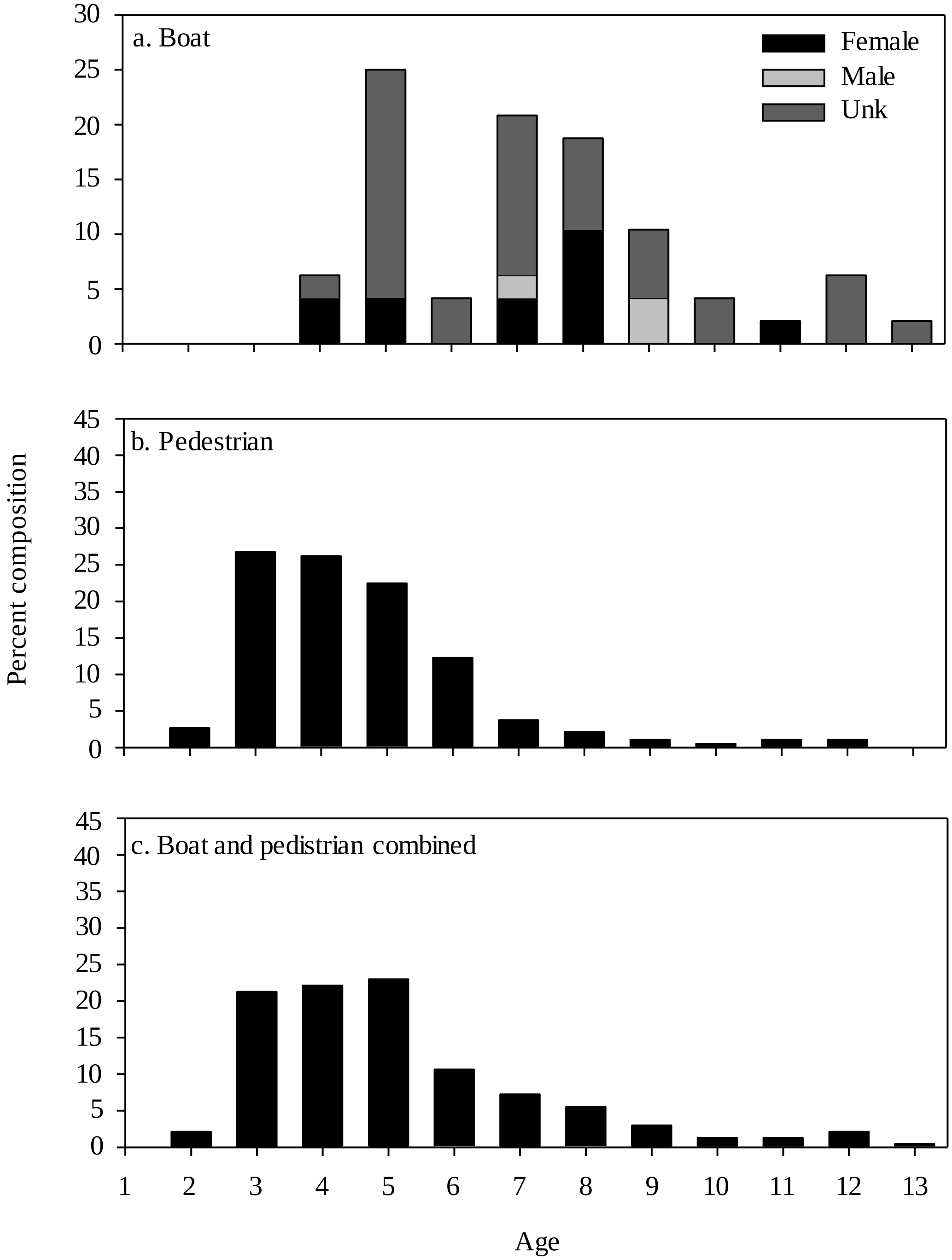

Figure 7. Age composition of yellow perch harvested by a) boat anglers using the launch ramp at Waukegan Harbor, b) pedestrian anglers at Waukegan and Montrose Harbors, and c) boat and pedestrian fisheries combined during 2010.

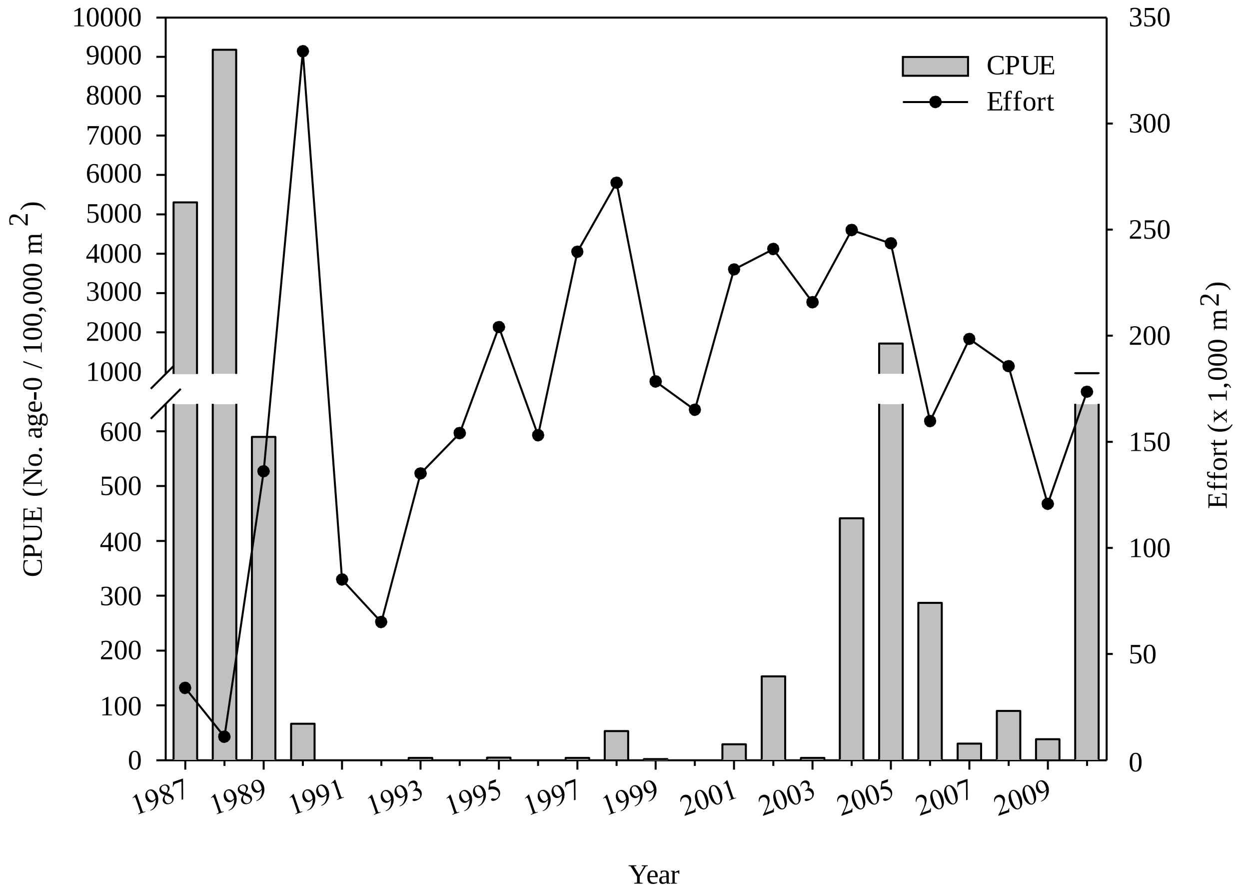

Figure 8. Relative abundance of age-0 yellow perch collected by daytime bottom trawls in 3 – 10m of water north of Waukegan Harbor, IL, 1987-2010.

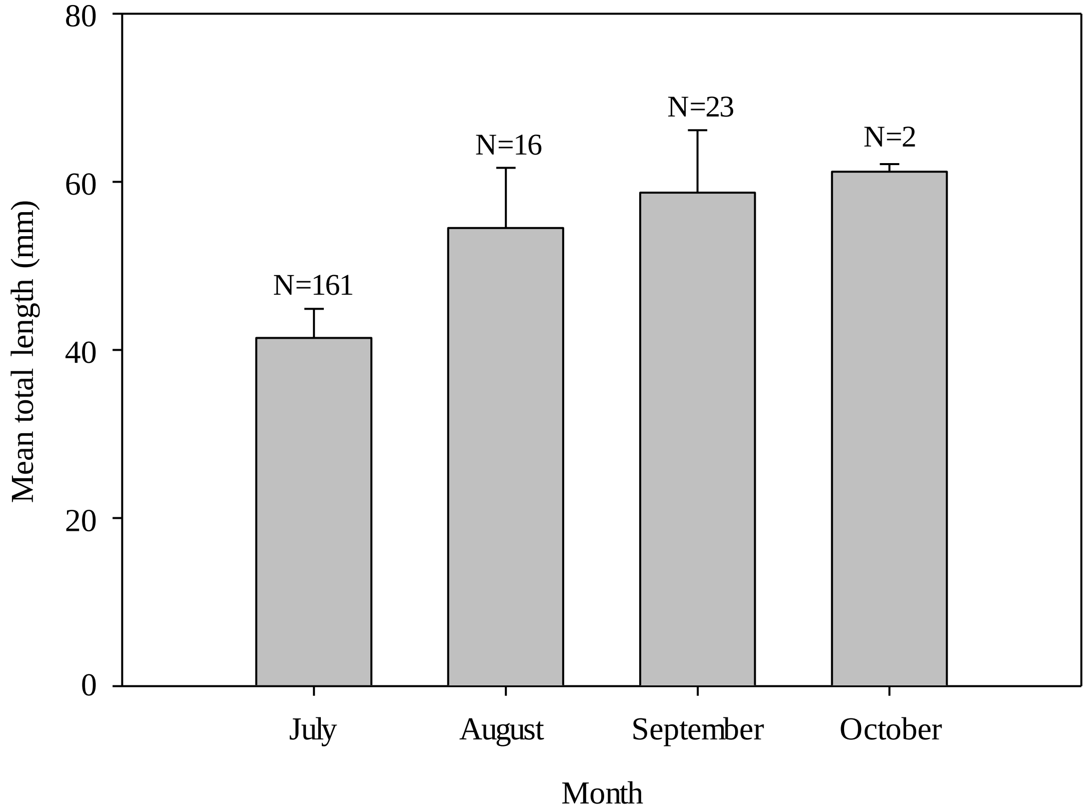

Figure 9. Monthly mean total length (+ 1 SD) of yellow perch collected in a bottom trawl north of Waukegan Harbor, IL during late July-October, 2010.

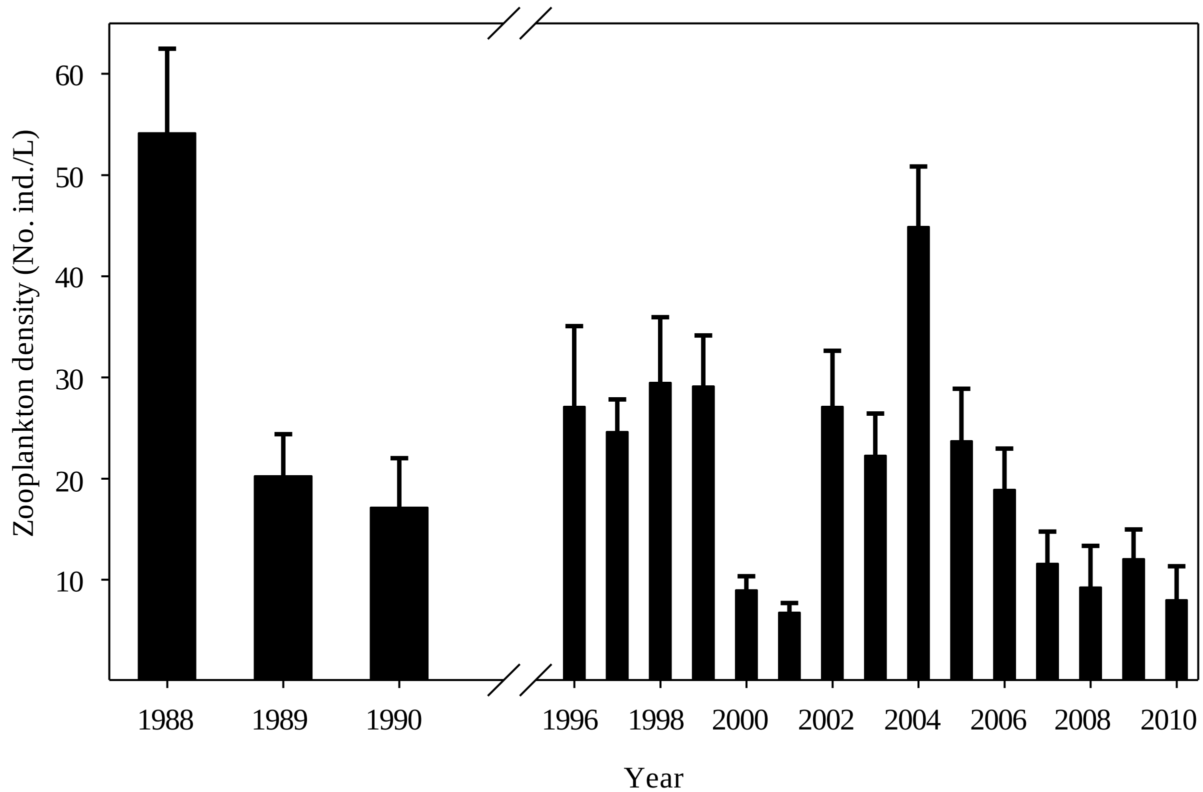

Figure 10. Mean density of zooplankton (+ 1 SE) present in Illinois waters of Lake Michigan near Waukegan during June-July for years 1988-2010.

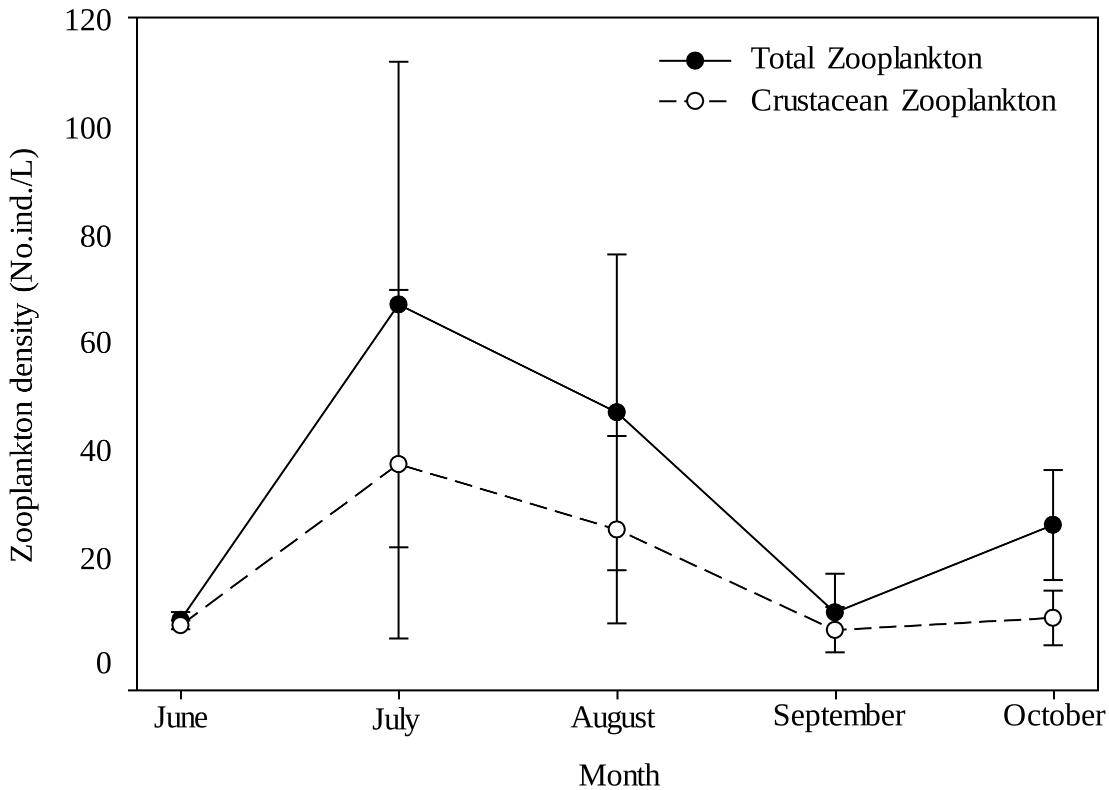

Figure 11. Mean monthly zooplankton density (± 1 SD) in nearshore Illinois waters of Lake Michigan near Waukegan during June-October 2010. Closed circles (●) represent total zooplankton, whereas open circles (○) represent crustacean zooplankton.

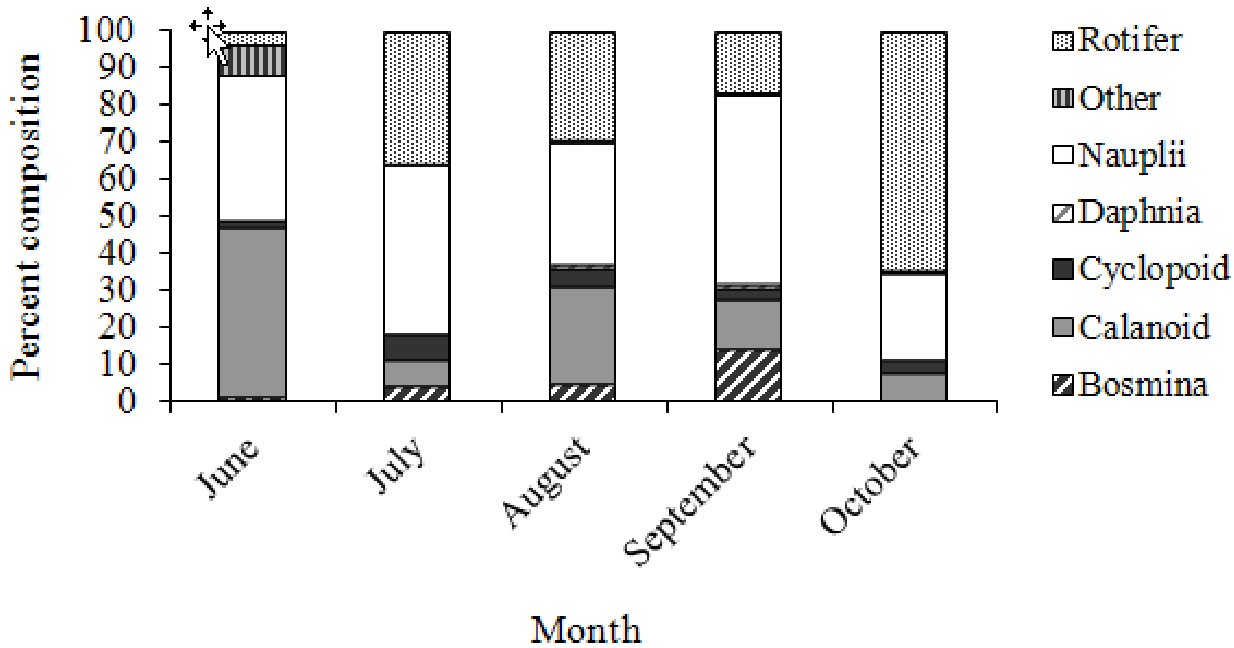

Figure 12. Monthly percent composition of zooplankton found in nearshore Illinois waters of Lake Michigan near Waukegan during June-October 2010.

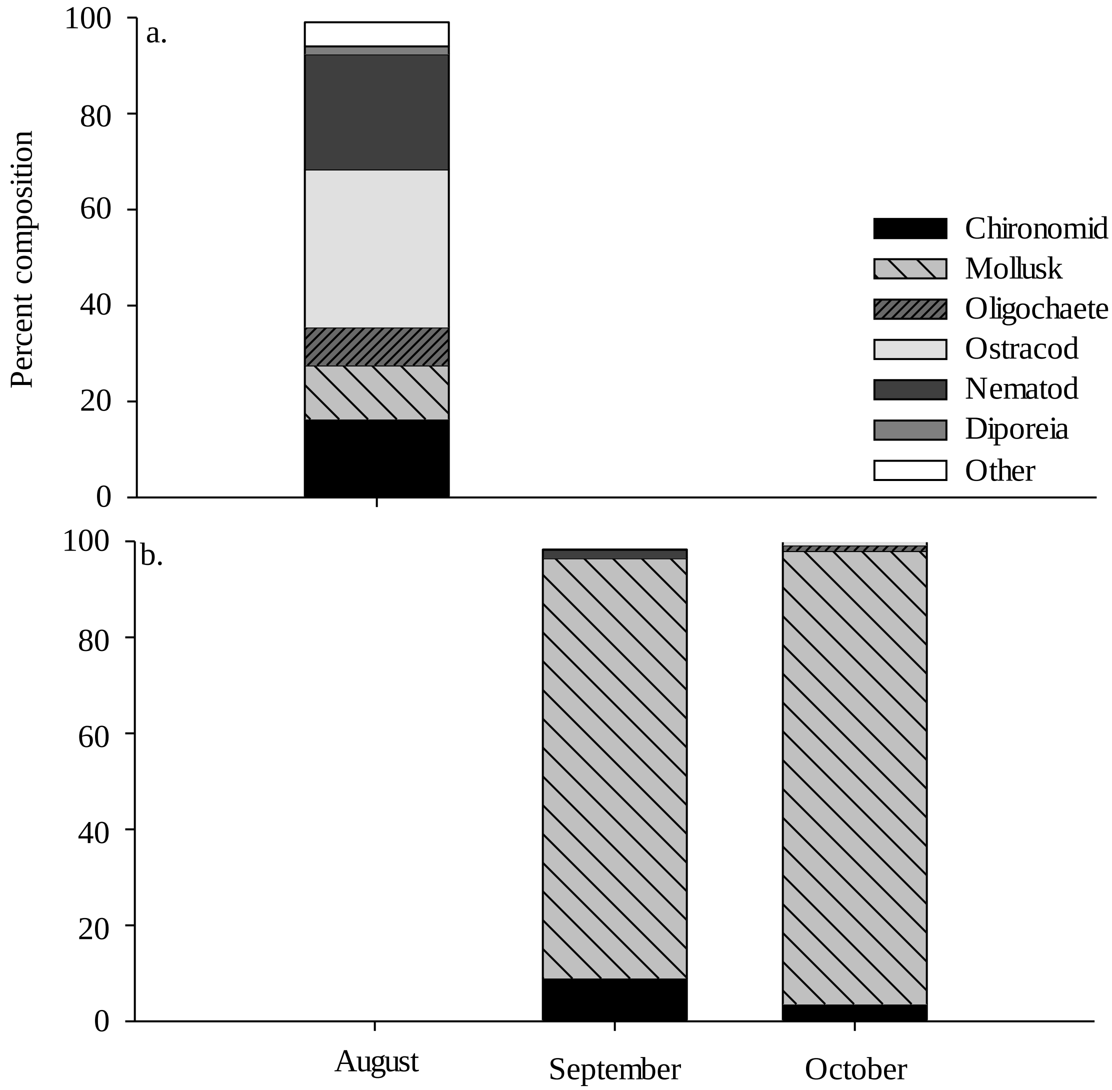

Figure 13. Percent composition of benthic invertebrates found in substrate of Lake Michigan near Waukegan using a) benthic core collection methods during August and b) a ponar grab during September and October 2010.

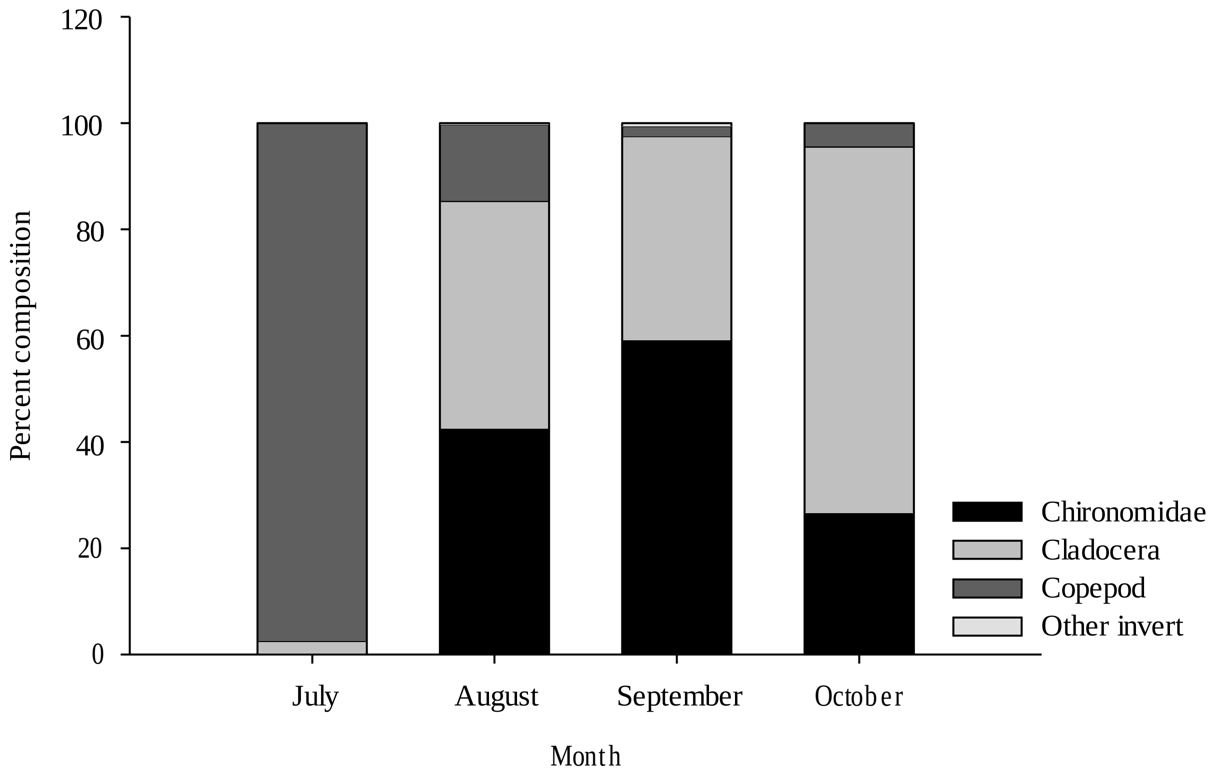

Figure 14. Diet composition of age-0 yellow perch collected in a bottom trawl north of Waukegan Harbor, IL during late July-October, 2010.

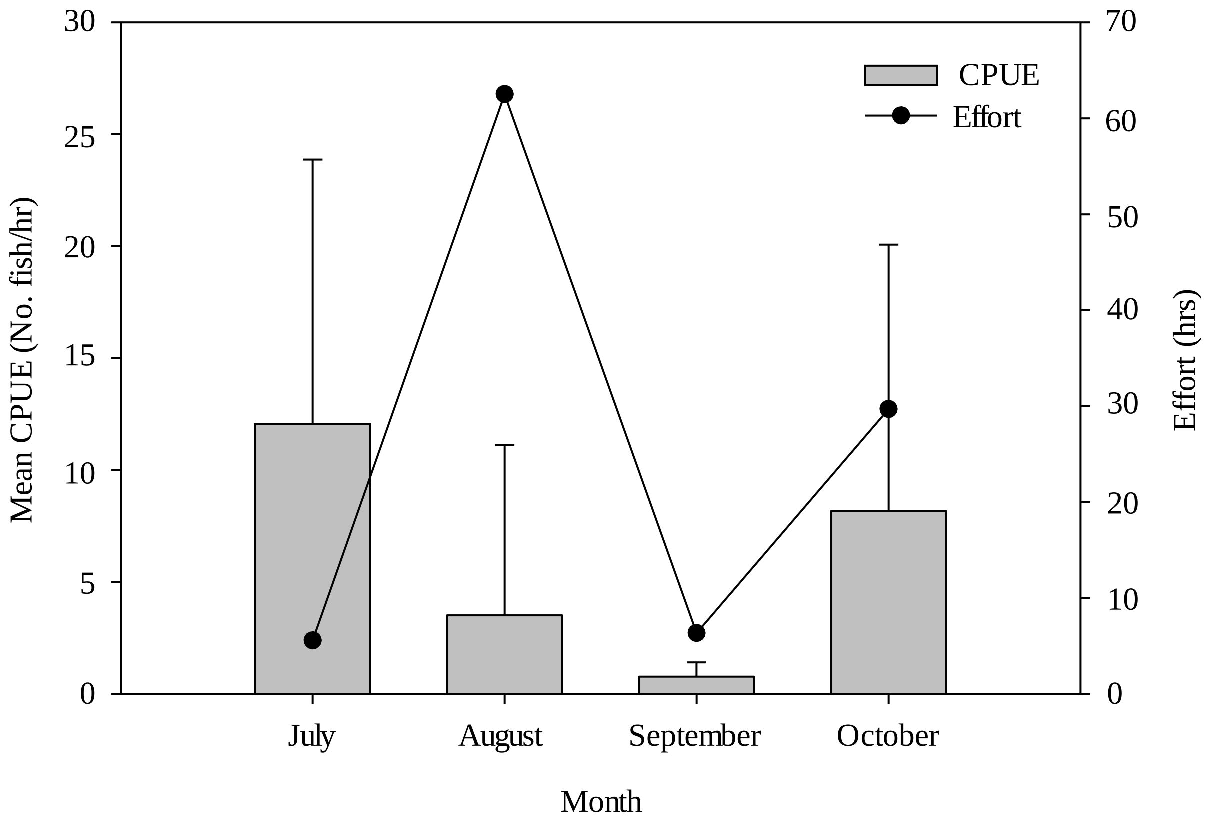

Figure 15. Mean monthly CPUE (+ 1 SD) of yellow perch collected in small mesh gill nets fished in 3-10 meters of water near Waukegan Harbor, IL during late July-October, 2010.

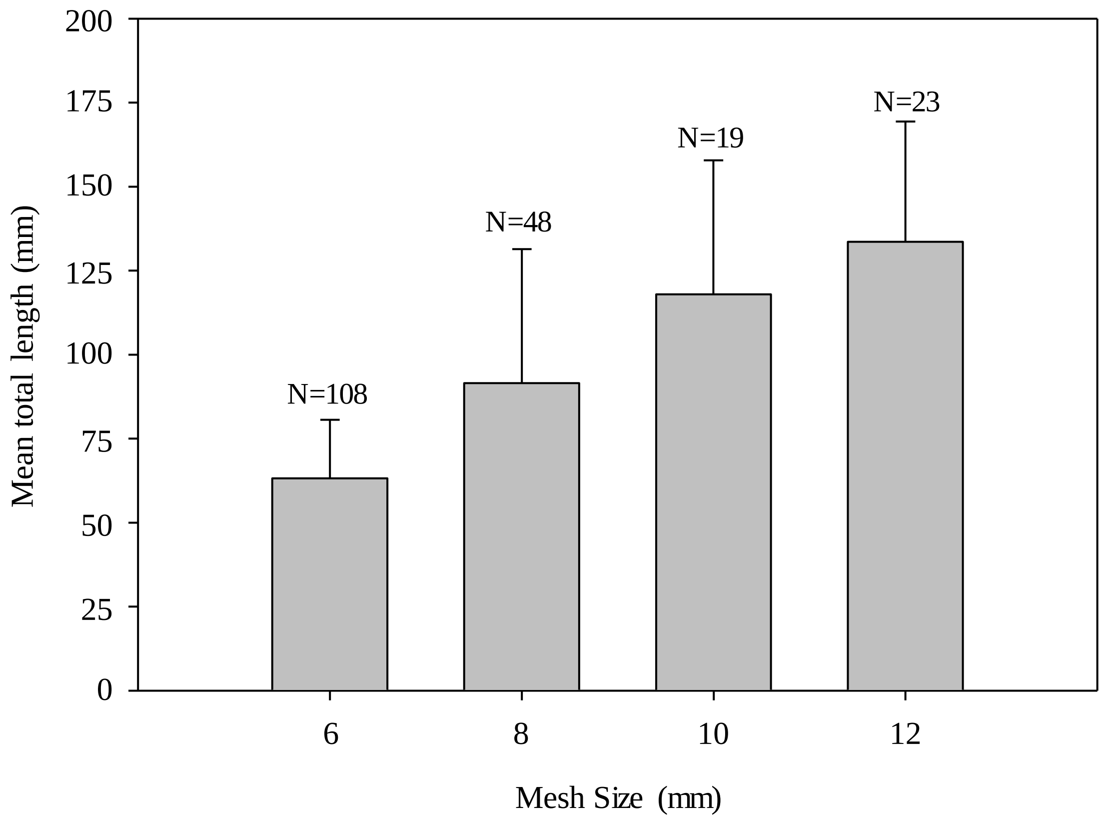

Figure 16. Mean total length (+1 SD) by mesh size of juvenile yellow perch collected in small mesh gill nets near Waukegan Harbor, IL during late July-October, 2010.

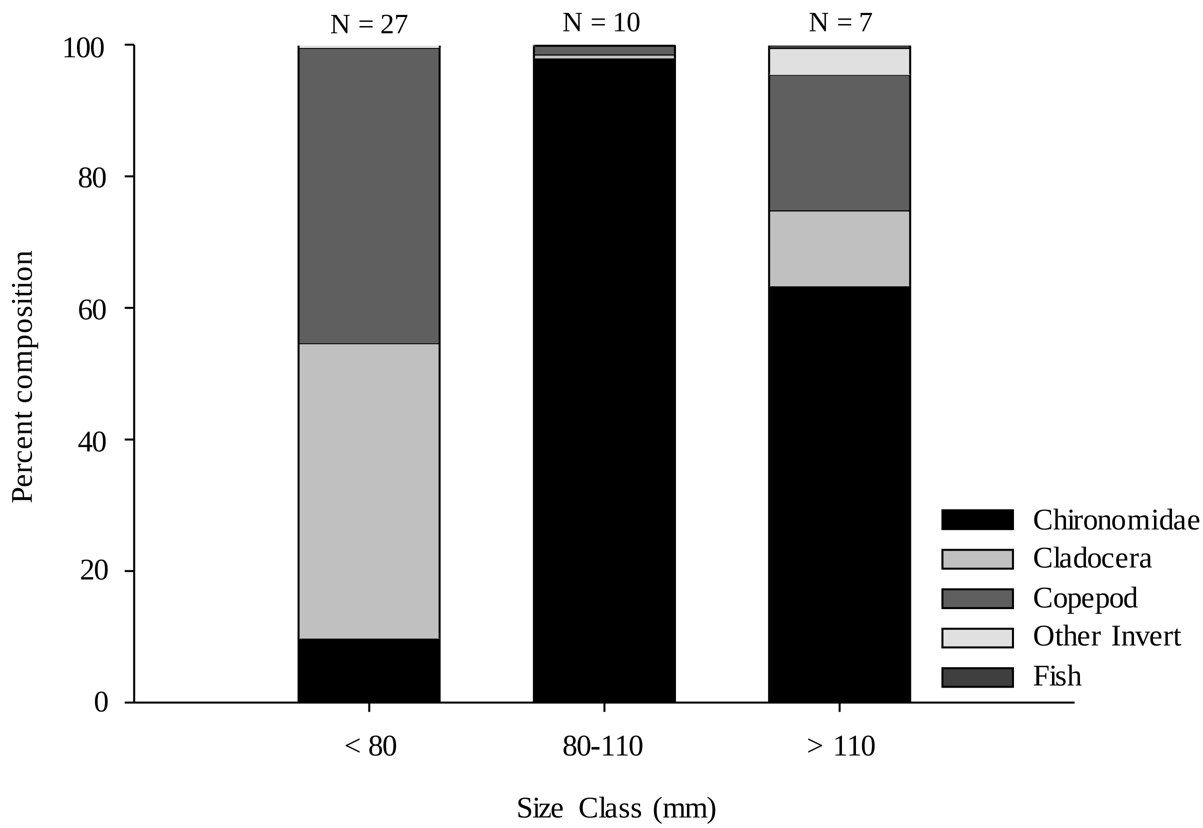

Figure 17. Diet composition of three size classes of juvenile yellow perch collected in small mesh gill nets near Waukegan Harbor, IL during late July-October, 2010. Size classes represented are 1) < 80 mm, 2) 80-110 mm, and 3) > 110 mm TL.