ILLINOIS NATURAL HISTORY SURVEY

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

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Center for Aquatic Ecology

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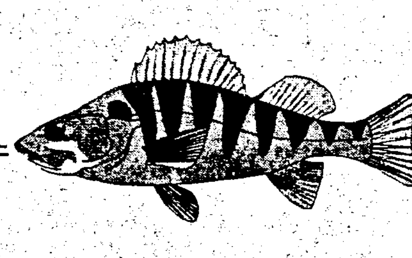

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Yellow Perch Population Assessment in Southwestern Lake Michigan, Including Evaluation of Sampling Techniques and the Identification of Factors that Determine Yellow Perch Year-Class Strength

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EXECUTIVE SUMMARY

The objectives of this study are to expand the Illinois Department of Natural Resources (IDNR) annual yellow perch stock assessment data, compare catches from IDNR and Lake Michigan Biological Station (LMBS) monitoring programs, investigate the diel vertical migration of larval yellow perch, monitor population densities of young-of-the-year yellow perch, and identify some of the factors likely to have limited yellow perch recruitment in the past nine years. We added a supplemental index station to the two IDNR index stations traditionally used in Illinois waters. The location of the IDNR Lake Bluff index station was assessed with respect to the annual yellow perch spawning concentrations to determine whether movements of spawning aggregations affect relative abundance estimates. Effective sampling techniques for larval yellow perch and their prey were investigated, young-of-the-year yellow perch were sampled with a bottom trawl, and programs to monitor yellow perch egg mass densities, post-larval yellow perch abundance, and the effect of adult alewife predation on yellow perch larvae were developed.

The results of this project will enable fish managers to develop effective management strategies for this important sport and previously commercially fished species. New information on specific areas where yellow perch spawning occurs will strengthen IDNR spawning assessments. 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.

The following conclusions are drawn from the fourth year of the project, second year in some cases. These conclusions represent one year of data and cannot stand alone, particularly as some of the objectives depend upon a time-series of data.

1. Similar numbers of yellow perch were captured in fyke nets and gill nets at all four depths (paired *t* test, $p \geq 0.05$). More yellow perch were captured in the 2.5-in mesh than in any other mesh size for all four gill nets. There were no significant differences (Kolmogorov-Smirnov 2-sample test, $p \geq 0.05$) between the age compositions of yellow perch captured with fyke nets and gill nets. More female yellow perch were captured in gill nets than fyke nets at the two intermediate depths; overall, females represented only 1% of the yellow perch captured using fyke nets as compared to 2.3% for gill nets.

2. Results from sampling sites with either cobble, sand, or mixed cobble and sand substrate types near the IDNR Lake Bluff index station suggest that yellow perch congregate in cobble substrate areas. The IDNR index station is located north of the focus of spawning in the Lake Bluff area and during the 1997 spawning season, mean catches of yellow perch were significantly higher at two sites located 2.78 km south (North Lake Forest) and 8.33 km south (Fort Sheridan) of the Lake Bluff index site (ANOVA, $p<0.05$; post-hoc Tukey). The relatively high degree of variability in catches at all six sites indicates that the yellow perch move in and out of these areas throughout the spawning period.

3. Tagged yellow perch were usually recaptured at the site at which they were tagged (66% of recaptures); we recaptured 4% (338 of 8,482) of the fish tagged during the spawning season (30 May - 31 July). These results suggest some long-term residence during the spawning period. Little effort was expended to catch fish outside the nine mile sample area during most of the tagging period because both the sport and commercial fisheries were closed during June. Thirty-seven percent of the yellow perch that were at liberty for one year (i.e., tagged in 1996) were also captured at the site at which they were tagged. Between 01 July and 31 December, sport anglers recaptured 62 yellow perch that we tagged during 1997 (0.07%).

4. The average length of all measured yellow perch was 239 mm (SD = 27 mm) for males, and 324 mm (SD = 41 mm) for females. Males constituted 96.4% of all measured yellow perch (N=10,054); females and unknowns comprised 0.8% and 2.8%, respectively. The male:female sex ratio of the yellow perch subsampled for age analysis was 170:1 (N = 681). The skewness of the sex ratio is likely a function of the sampling gear, because male yellow perch tend to congregate in fyke nets, and size-selective harvest by sport anglers and commercial fishermen; female yellow perch tend to grow faster and to larger sizes than male yellow perch in Lake Michigan. The proportion of female yellow perch in our samples has continued to decline each year since 1990 and may indicate problems with reproductive potential.

6. The majority of yellow perch collected in fyke nets during 1997 were age-9 (31%, 1988 year-class); yellow perch older than age-6 comprised 88% of the total catch. The distribution of ages for male yellow perch was approximately normally distributed and indicates instability in the population structure, because age-composition plots should ideally be skewed toward younger age-groups. The paucity of yellow perch less than age-8 in our samples reflects poor recruitment over the past nine years.

7. Virtually no yellow perch larvae were captured using ichthyoplankton nets compared to pre-1994 sampling, however larval yellow perch were captured on each night during the sampling period (10 June - 23 July, 11 nights sampled). Peak larval yellow perch density in our samples occurred on 17 June (10.25 larval yellow perch•$100m^{-3}$). A decline in the yearly abundance of yellow perch larvae after 1993 (S. Robillard, unpub. data) may indicate reproductive failure, failure of eggs to successfully hatch, or large-scale post-hatch mortality.

8. Relatively few larval fish were successfully sampled using the Miller samplers; usually a maximum of one fish per transect was collected. Predominant species were rainbow smelt and alewife. It appears that Miller samplers are not effective sampling devices for Lake Michigan because fish densities are relatively low compared to inland systems where Miller samplers have been effectively used. We recommend discontinuing using Miller samplers to sample yellow perch larvae as part of this project.

9. We captured 10 young-of-the-year yellow perch with a bottom trawl; approximately 239,500 m^2 of the lake bottom was sampled. The paucity of young-of-the-year yellow perch may indicate a failure of larval fish to recruit to the sub-adult population.

10. Larval fish were found in few adult alewife stomachs (16 of 355) and none could be positively identified as yellow perch larvae. Larval yellow perch abundance samples collected concurrently with alewife collections indicated that the density of yellow perch larvae at the sample sites was similarly low. Additional years of data or innovative experimental approaches will be required to look at the effect of alewife predation on yellow perch recruitment under conditions of higher prey (i.e., larval yellow perch) densities to effectively estimate the recruitment foregone to alewife predation.

11. Zooplankton samples collected coincident with larval yellow perch samples are still under analysis.

12. Yellow perch egg masses were located south of Waukegan Harbor at the abandoned US Steel intake line during June, 1997. Peak density was 25.7 egg masses•$100m^{-2}$ on 18 June. No egg masses were found prior to 09 June or after 18 June. Egg viability was estimated to be 95% for sampled egg masses returned immediately to the laboratory and viewed under a dissecting microscope.

13. Light traps deployed to sample post-larval stage yellow perch were successful in sampling non-target larval fish species (i.e., cyprinids and alewife) and unsuccessful in sampling larval yellow perch; macro-zooplankton were also successfully captured. Under conditions of low densities, the light trap is not an effective sampling device for larval fish species in Lake Michigan and we recommend discontinuing its use to sample post-larval stage yellow perch as part of this project.

INTRODUCTION

Yellow perch (*Perca flavescens*) is an important commercial and sport fish throughout much of its range in North America. Its schooling behavior promotes sizable captures in commercial gears such as trap nets and gill nets, and the tendency of yellow perch to congregate near shore in the spring makes this species accessible to shore anglers. The majority of yellow perch harvested in North America are taken from the Great Lakes; yellow perch provide the most important sport fisheries in the four states bordering Lake Michigan, and until 1997 supported large-scale commercial fisheries in three of those states.

Lake Michigan yellow perch have undergone severe fluctuations in abundance in the past few decades. The population in the southern basin increased dramatically in the 1980s (McComish 1986), and the sport and commercial fisheries expanded accordingly. In Illinois waters alone, the estimated annual catch by sport fishermen doubled between 1979 and 1993, from 600,000 to 1.2 million fish (Muench 1981, Brofka and Marsden 1993). Between 1979 and 1989, the commercial harvest in Illinois tripled, in Wisconsin (excluding Green Bay) it increased six-fold, and in Indiana the harvest increased by over an order of magnitude (Baumgartner et al. 1990, Brazo 1990, Hess 1990). However, a federally-funded study recently completed by the Lake Michigan Biological Station (Marsden et al. 1993) indicated that the 1993 yellow perch fishery was primarily supported by a strong year-class spawned in 1988, and that no strong year-class had been produced since then. Few or no young-of-the-year (YOY) yellow perch were found in lakewide sampling efforts during 1994 through 1997 (Hess 1998). Consequently, the yellow perch population is aging - the population as a whole was composed of larger and older individuals in 1996 than in 1986 (Robillard et al. 1997).

The ability to manage yellow perch is hampered by insufficient information about population size, stock structure, movements, and factors that affect population growth. Evaluation of the best techniques and locations to collect assessment data is necessary to maximize information access. Other federally funded research by the Lake Michigan Biological Station (LMBS) determined that Lake Michigan yellow perch populations are too large and too mobile for single agency mark-and-recapture studies to be viable (Marsden et al. *in review*). Annual assessment data of spring spawning populations at index stations, however, combined with assessment of year-class strength may permit evaluation of the population's relative abundance. These data have been obtained in the past by the Illinois Department of Natural Resources (IDNR) at two gill net index stations, and by LMBS at two sites using fyke nets. Several inadequacies in these data exist, however: (1) there is no index station near the southern border of the Illinois shoreline; (2) data from gill nets and fyke nets are not comparable without direct comparison at the same sites during the same time period; (3) it is unknown where spawning concentrations of yellow perch occur, or how stable such locations (if they exist) are from year to year. If foci of spawning concentrations move from year to year, then data from localized index stations may reflect this movement rather than any real information about population size.

To protect yellow perch stocks, fisheries managers should ideally set harvest targets in accordance with fluctuating population sizes. Assessment of larval and YOY yellow perch populations may permit prediction of future year-class strength. However, the variances on larval yellow perch abundance data and YOY catches are 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.

The continued decline of the yellow perch population due to reduced recruitment of larvae to the YOY stage has prompted researchers to narrow the focus of investigation to pre-YOY interactions and survival. The effect of alewife predation on yellow perch larvae will be investigated. Development of an annual index for yellow perch egg production will provide an index of reproductive potential and success. Comparing zooplankton species composition and abundance data from samples collected prior to the establishment of zebra mussels and recently collected samples will provide valuable information on the availability of food for emergent yellow perch larvae, and lend an understanding to the effects of alewife predation on yellow perch larvae in the presence of alternate food sources.

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

METHODS

Sampling gear

Adult yellow perch were collected using fyke nets (LMBS) and graded-mesh gill nets (IDNR). We used 1.2 x 1.8-m doubled-ended fyke nets with a 30.5-m leader between two double-throated pots. Fyke net mesh was 38-mm stretched measure. Assessment gill nets were composed of five panels (Table 1).

Table 1. Length and mesh size of panels used in IDNR yellow perch spawning assessment gill nets.

Panel	Length (m)	Mesh size (mm)
1	15.2	25.4
2	30.5	38
3	30.5	51
4	91.4	63
5	91.4	76

All plankton sampling was conducted using 0.5-m diameter nets with a 5:1 scope. Abundance sampling for yellow perch larvae was performed with a 363-μm mesh net; zooplankton samples were collected using a 72-μm mesh net.

A Miller sampler with a 10-cm diameter opening and 1000-µm mesh netting was used to sample post-larval stage yellow perch. Light traps were also deployed to sample post-larval stage yellow perch and light trap contents were rinsed through a 153-µm mesh net.

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 YOY yellow perch.

Supplemental Index Gill Netting
IDNR sampled a transect outside Calumet Harbor to monitor spawning yellow perch. All sampling at the Calumet Harbor index station was conducted by J. Camalick, with IDNR and LMBS personnel on board his boat. Gill nets were set at depths of 7.2, 10.8, 14.6 and 18.3 m on 29 May and fished for approximately 24 h. All fish in all nets were counted. Subsamples of 25 yellow perch were collected from each gill net panel. If the total catch for any panel was less than 25, all yellow perch in that panel were subsampled. Subsampled yellow perch were weighed to the nearest 10 g, measured to the nearest 5 mm, and dissected to determine reproductive status; ages were estimated from sagittal otoliths.

Calibration of Data from Fyke Netting and Gill Netting
One IDNR assessment gill net and one LMBS fyke net were set end to end, parallel to shore, at depths of 7.2 and 10.8 m on 04 June, and at 14.6 and 16.8 m on 05 June, at the IDNR Lake Bluff index station. All nets were fished for approximately 24 h.

A subsample of 50 yellow perch was collected from each fyke net. All other yellow perch were counted, measured to the nearest 1 mm TL and externally examined to determine reproductive status (i.e., ripe, green, or spent). All fish, except the subsampled yellow perch, were released.

All fish captured in gill nets were counted. Subsamples of 25 yellow perch were collected from each gill net panel. If the total catch for any panel was less than 25, all yellow perch in that panel were subsampled. Subsampled yellow perch were weighed to the nearest 10 g, measured to the nearest 5 mm, and dissected to determine reproductive status; ages were estimated from sagittal otoliths.

Catches of yellow perch at each depth were compared by paired t test; age-frequency distributions of yellow perch captured in fyke nets and gill nets were compared by Kolmogorov-Smirnov 2-sample test (SAS ver. 6.12).

Validation of Index Station Locations
Fyke nets were set near the IDNR Lake Bluff index station at six sites with either cobble, sand, or mixed cobble and sand substrates. All sampling sites were located within 8.33 km of the index station (Figure 1). Nets were set along the 5-m depth contour line, usually parallel to shore, and fished for approximately 24 h. Six sampling units of two sites with cobble substrate and one site with sand were completed; i.e., 6 sets of 3 nets per day. Catch data were analyzed using ANOVA (SAS ver. 6.12) with substrate type and date as the independent factors and yellow perch catch as the dependent factor. Tukey's test was used post-hoc for pairwise comparisons.

Subsamples of 25 yellow perch from each fyke net were collected (681 total) for dissection to determine sex, maturity, and age. The remaining yellow perch were tagged (~1,000 maximum per net) using individually numbered Floy tags, measured for total length, and externally examined to determine sex and reproductive status. All other fish captured in each fyke net were counted and non-target species were recorded. All fish, except the subsampled yellow perch, were released. The North Lake Forest, South Lake Forest, and Fort Sheridan sites were also sampled on 31 July to recapture tagged yellow perch; no yellow perch were subsampled or tagged from these nets.

Yellow Perch Population Structure

Biological data (i.e., length, weight, sex, and maturity) were obtained from all subsampled yellow perch, and the ages of the yellow perch were estimated from sagittal otoliths (Robillard and Marsden 1996).

Diel Larval Yellow Perch and Plankton Sampling

Abundance estimates

Samples were collected near Waukegan Harbor (Figure 2) on 11 nights between 10 June and 23 July. A plankton net, suspended below the surface of the water with a bow-mounted frame, was pushed through the water at a speed of approximately 2 $m \cdot sec^{-1}$. One 5-m and one 10-m (bottom depth) transect was sampled ~2.8 km both north and south of the harbor entrance. A calibrated General Oceanics™ standard flowmeter mounted in the mouth of the net was used to determine the volume of lake water sampled; each 0.93-km surface push sampled approximately 160 m^3 of water. Larval fish were extracted from ichthyoplankton samples in the laboratory and identified to genus, species when possible. Ostracods were extracted and enumerated.

Vertical movement

Larval and post-larval stage yellow perch were sampled using two Miller high-speed samplers fished simultaneously at depths of 0, 1, 2, 3, and 4 m during the day and at night on two occasions, 24 July and 06 August. Approximately 36 m^3 of water was sampled in each 4.63-km transect, along the 5-m (bottom depth) contour line. Samples were also collected during the day on 31 July.

Young-of-the-Year Sampling

Trawling for YOY yellow perch was conducted approximately weekly (13 times) between 04 August and 06 October, at four depth stations between 3 and 10 m. All sampling occurred north of Waukegan Harbor, at a speed of approximately 2 $m \cdot sec^{-1}$. Each 0.93-km transect sampled approximately 4459 m^2 of the lake bottom. YOY yellow perch and non-target species were recorded.

Alewife Predation on Yellow Perch Larvae

Adult alewife were sampled using a gill net suspended 0.5 m below the surface of the water for approximately 30 min on six of the same nights, between 10 June and 26 June, as larval yellow perch abundance sampling occurred. Samples were usually collected at either one 10-m (bottom depth) and one 5-m site, or at the two 10-m larval yellow perch sampling sites. The gill net was composed of three panels with stretched measures of 25.4, 38, and 44 mm. Each panel was 30.5 m in length; i.e., total length of the net was 91.5 m.

All alewife were measured to the nearest 1 mm TL. Specimens were dissected to determine sex and maturity; the entire digestive tract was preserved in 95% ethanol until examination. In the laboratory, stomach contents were quantified and intact larval fish were identified to lowest possible taxon.

Zooplankton Sampling
Zooplankton samples were collected on the same nights as larval fish samples between 17 June and 23 July (5 nights). Replicate, vertical-lift samples were collected at the two 10-m (bottom depth) larval yellow perch sampling sites. A Kahlisco flowmeter mounted inside the mouth of the net was used to monitor the volume of water sampled. Each vertical lift sampled approximately 1.9 m^3 of water.

In the laboratory, zooplankton were grouped into seven broad taxa: cladocerans (Daphnia and Bosminids), cyclopoid copepodites, calanoid copepodites, copepod nauplii, *Macrothrididae* spp., *Chydoridae* spp., and *Sididae* spp. Other rare taxa in the samples were noted. Up to twenty individuals of each taxon (except nauplii) were measured using an image analysis program (Optimas ver. 3.0).

Egg and Post-larval Yellow Perch Sampling
Yellow perch egg masses were counted by scuba divers along the abandoned US Steel water intake line, located approximately 1.86 km south of Waukegan Harbor (Figure 2, Table 2); divers usually explored an area approximately 4 m wide along the intake. Eggs were subsampled from each egg mass and transported back to the laboratory where the percentage of viable eggs was estimated using a dissecting microscope.

Table 2. Summary of egg census dives.

Date	Transect length (m)	Depth (m)
20 May	105	5.5 - 7
09 June	33	8
10 June	105	6 - 8
18 June	105, 75	6 - 8
24 June	105, 105	4 - 8
26 June	105, 105	3 - 7

Post-yolk-sac yellow perch were sampled using light traps deployed at sunset on three nights during the sampling season. Traps were suspended 1 m below the surface of the water on a tethered line at a 3-m (bottom depth) site that was due east of the 5-m larval yellow perch sampling site, north of Waukegan Harbor. Four traps were fished for 5 h on 25 July and seven traps were fished overnight on 01 and 07 August. Contents of the traps were examined for the presence of larval fish and macrozooplankton.

RESULTS

Supplemental Index Gill Netting

A total of 477 yellow perch were captured in IDNR assessment gill nets at the Calumet Harbor index station.

Calibration of Data from Fyke Netting and Gill Netting

Similar numbers of yellow perch were captured in LMBS fyke nets and IDNR gill nets (paired *t* test, $p \geq 0.05$). Numbers of yellow perch captured in the 7.2, 10.8, 14.6 and 16.8 m (bottom depth) fyke nets were 329, 140, 276, and 186, respectively, compared to 304, 809, 467, and 177 yellow perch in the equivalent gill net sets. Since catches in each gill net panel were not equally represented in the subsampled fish, the ages were weighted accordingly. There were no significant differences between the age distributions of yellow perch captured with either fyke nets or gill nets (Kolmogorov-Smirnov, $p \geq 0.05$; Figure 3). Overall, females represented less than 1% of the yellow perch captured using fyke nets (Table 3).

Table 3. Percent female yellow perch captured (by mesh size) in IDNR gill nets and LMBS fyke nets, set at depths of 7.2 and 10.8 m on 04 June and at 14.6 and 16.8 m on 05 June, at the IDNR Lake Bluff index station.

	IDNR						LMBS
	mesh size (in)						
Depth (m)	1	1.5	2	2.5	3	all meshes	fyke net
7.2	0	6.6	0	0	9.1	1.3	0.6
10.8	0	0	0	0	12.7	1.0	0.8
14.6	**	0	0	3.9	31.0	4.3	0
16.8	0	0	0	3.8	45.5	5.1	0.6

** no fish

Validation of Index Station Locations

A total of 15,062 yellow perch were captured between 30 May and 31 July, 1997. More yellow perch were captured south of the IDNR Lake Bluff index site (Figure 4); catches at the North Lake Forest and Fort Sheridan sites (cobble substrate sites) were significantly greater than those at the other five sites with sand or mixed sand and cobble substrates (ANOVA, $p<0.05$; post-hoc Tukey).

A total of 8,482 yellow perch were tagged from the first nine net sets (Table 4), and 338 of those tagged yellow perch were recaptured by LMBS during the 1997 spawning season (Table 5). The majority of fish recaptured by us were at the site at which they were tagged (66%). Other state agencies (e.g., IDNR) and sport anglers returned 62 tags (Table 4) in the first six months after the season was reopened (i.e., July through December).

We also recaptured 278 yellow perch that were tagged during the 1996 spawning season; approximately one-third of those yellow perch were recaptured at the site at which they were tagged (Table 6). We also recaptured one yellow perch at the Fort Sheridan site that was tagged at the Waukegan wiremill site during 1991 (2223 days at liberty); at capture, the yellow perch was 14 km from the site at which it was tagged.

Table 4. Number of tagged yellow perch initially tagged and then recaptured by LMBS, other state agencies, and sport anglers at each tagging site between 31 May and 31 December, 1997 (minimum 24 h at liberty).

Site	# tagged yellow perch	LMBS recaptures	Other state agency and sport angler recaptures	% total recaptures
Kenosha, WI	5	0	1	20.00
Camp Logan	12	0	0	0
North Waukegan	33	0	0	0
North Chicago	99	4	1	5.05
Waukegan wiremill	1,571	95	21	7.38
North Lake Forest	4,075	158	22	4.42
South Lake Forest	551	16	6	3.99
Fort Sheridan	1,851	65	7	3.89
Chicago	285	0	4	1.40
All sites	8,482	338	62	4.72

Table 5. Number of tagged yellow perch recaptured by LMBS during the 1997 spawning season at each tagging site, and number and percent of recaptured fish tagged at that site (minimum 24 h at liberty).

Site	No. recaptures at site	No. recaptures tagged at site	% of recaptures tagged at site
North Waukegan	0	0	0
North Chicago	3	1	33.33
Waukegan wiremill	95	88	92.63
North Lake Forest	157	91	57.96
South Lake Forest	16	2	12.50
Fort Sheridan	101	40	39.60
All sites	338	222	65.68

Table 6. Number of yellow perch tagged in 1996 recaptured by LMBS during the 1997 spawning season, by site, and number and percent of recaptured fish tagged at that site.

Site	No. recaptures at site	No. recaptures tagged at site	% of recaptures tagged at site
North Chicago	0	0	0
North Lake Forest	201	71	35.32
South Lake Forest	19	1	5.26
Fort Sheridan	58	31	5.34
All sites	278	103	37.05

Nontarget species captured in the fyke nets included 371 alewife (*Alosa pseudoharengus*), 91 white sucker (*Catostomus comersoni*), 5 lake chub (*Couesius plumbeus*), 21 longnose sucker (*Catostomus catostomus*), 106 rock bass (*Ambloplites rupestris*), and 2 pumkinseed (*Lepomis gibbosus*). Nontarget species were captured in 12 of the 43 nets.

Yellow Perch Population Structure

The average length of all measured yellow perch was 239 mm (SD = 27 mm) for males (Figure 5), and 324 mm (SD = 41 mm) for females. Males constituted 96.4% of all measured yellow perch (N = 10,054); females and unknowns were 0.8 and 2.8%, respectively. The male:female sex ratio of subsampled fish was 170:1.

The 1988 year-class (age-9) made up the greatest portion (31%) of the subsampled fish captured with fyke nets (Figure 6); age-6 and older fish comprised 88% of the total catch. Twenty-six 1983 year-class (age-14) and three 1982 year-class (age-15) male yellow perch were collected in the subsampled fish. No age-5 fish (1992 year-class) were present in the subsample, suggesting minimal recruitment of the 1992 year-class to the population.

Diel Larval Yellow Perch and Plankton Sampling

Relatively few yellow perch larvae were captured using a 0.5-m ichthyoplankton net, deployed at the surface at night, compared to previous years (Marsden et al. 1993, Robillard et al. 1995, 1996), although larval yellow perch were collected each night between 10 June and 23 July. Average density of larval yellow perch between 09 June and 02 July ranged from 0.9 to 10.3 fish•$100m^{-3}$, compared to densities of over 100 fish•$100m^{-3}$ prior to 1994 (Marsden et al. 1993; Robillard et al. 1995). Abundances of alewife larvae were highest in the 23 July samples. The abundance of ostracods, a zooplankter which had been relatively constant over all sampling periods between 1990 and 1994 (unpublished data), was more than two orders of magnitude less than previously recorded abundances.

Relatively few larval fish were successfully sampled using the Miller samplers and no larval stage or post-larval stage yellow perch were captured. Usually a maximum of one fish per transect was collected; the predominant species were rainbow smelt (*Osmerus mordax*) and alewife.

Young-of-the-Year Sampling
Ten YOY yellow perch were captured in 53 0.93 km trawl transects, yielding an average density of 0.042 (fish•1000m^{-2}) for the year. The most abundant fish species captured included ninespine stickleback (*Pungitius pungitius*, 35.3%), alewife (24.0%), spottail shiner (*Notropis hudsonius*, 20.2%), and rainbow smelt (14.6%). Small numbers of threespine stickleback (*Gasterosteus aculeatus*, 2.4%) and trout-perch (*Percopsis omiscomaycus*, 1.4%) were also captured. One or more adult yellow perch, Johnny darter (*Etheostoma nigrum*), longnose dace (*Rhinichthys cataractae*), sculpin (*Cottus* spp.), smallmouth bass (*Micropterus dolomieui*), white sucker (*Catostomus commersoni*), and brook stickleback (*Culaea inconstans*) were also captured, and cumulatively represented 2% of the total catch.

Alewife Predation on Yellow Perch Larvae
Stomach and intestinal tract contents from 355 adult alewife were examined. Only 16 stomachs contained larval fish (4.5%, Table 7). A maximum of 2 larval fish were found in 2 alewives' stomachs. Most larval fish were digested to a point at which genus and species identification was difficult - none could be identified with any certainty as larval yellow perch. Fifty-six stomachs contained spiny water flea (*Bythotrophes cederstromi*) tail spines (mean = 51.2 spines per stomach); one stomach contained 444 spines. Fifty stomachs were completely empty (14.1%).

Table 7. Percent of adult alewife stomachs (N = 355) containing prey items. Alewife were sampled between 10 June and 26 June, 1997 using graded-mesh gill nets set for 30 min after dusk outside Waukegan Harbor.

Prey taxa	Percent of stomachs sampled
chironomid larvae	62.8
copepods	33.5
terrestrial insects	31.0
B. cederstromi	15.8
amphipods	7.9
cladocerans	5.4
larval fish	4.5
isopods	0.3

Zooplankton Sampling
Zooplankton samples were collected and analysis is in progress. Preliminary analysis of 1996 samples has begun. Total zooplankton density varied little between 11 and 30 July, although a slight increase in zooplankton numbers did occur (from 4 to 16/L) at the site ~2.8 km north of Waukegan Harbor (Figure 7). Zooplankton was composed primarily of cyclopoid and calanoid copepods, copepod nauplii, and *Bosmina* spp. (Figure 8). *Bosmina* did exhibit a trend of increasing numbers through time, but no other trends in the dynamics of individual zooplankton

taxa were visually apparent. Further detailed analysis of our archived and current zooplankton samples continues.

Egg and Post-larval Yellow Perch Sampling
Egg masses were found on the south side of the abandoned US Steel intake line, generally in crevices among the cobbles covering the intake line. SCUBA divers found 68 egg masses. No eggs were found on sand substrates north of the intake line, or prior to 09 June or after 18 June (divers surveyed a total of 210 m of the bottom on both 24 and 26 June).

Average viability of the eggs was 95% for the 56 egg masses examined. Eggs collected on 09 June were at all stages of development, from newly fertilized (i.e., not eyed, little movement of larvae) to fully developed and hatching; eggs collected on 18 June had developed eyes and all masses were in advanced stages of development.

CONCLUSIONS

These conclusions have been drawn from the fourth year of sampling; second for some portions of the study.

Similar numbers of yellow perch were captured in fyke nets and gill nets, and there was no significant difference between age distributions of yellow perch sampled with either fyke nets or gill nets. More females were captured in gill nets than fyke nets at two depths, however, females represented less than 1% of the yellow perch captured using fyke nets compared to 2.3% of the catch in gill nets. The difference in the sex ratio is likely due to size selective fishing by gill nets; most female yellow perch were captured in the 76-mm (3-in) mesh panel. Female yellow perch grow faster and to larger sizes than males (Becker 1983) and, as a consequence, are more likely to be captured in larger mesh sizes. In addition, fyke nets tend to concentrate male yellow perch because males are more likely to search for females and enter the net on the chance that a female may be inside.

Adult yellow perch catch data from six sampling sites around the IDNR Lake Bluff index station indicate that these fish tend to congregate in areas with cobble substrate rather than sand or mixed sand and cobble substrate sites. Mean catch was greatest at the North Lake Forest and Fort Sheridan sites, which are both cobble-substrates sites. Variability in catches at all sampling sites implies that male yellow perch move frequently during the spawning period, rather than spawning in one limited area. Therefore, limited sampling at a single index station (e.g., two days per year at the Lake Bluff index site) may only reflect the daily movements of spawning fish rather than the true abundance of fish in that area.

Recaptures of tagged yellow perch at the site at which they were tagged implies that some yellow perch do reside in spawning areas for more than 24 h. During the peak of spawning, information on movements outside of our study area was limited due to the absence of angler and commercial harvest during June. Total recapture rate was markedly higher (4.7%) for the first six months after the commencement of tagging compared to a previous LMBS tagging study (1.3% within 6 months of the start of tagging, Marsden et al. 1993) and may indicate that yellow perch are significantly less abundant in 1997 than they were in 1991.

The greatest portion (31%) of yellow perch collected with fyke nets in 1997 were age-9 (1988 year-class). Sixty-eight percent of the yellow perch we captured were within the 8 to 10 in harvest slot imposed by IDNR; the majority (99%) of those fish were males.

The stretched measure of LMBS fyke nets is designed to capture fish 150 mm and greater. This length is approximately the length that females reach by age-3 and males by age-4 in Lake Michigan (Becker 1983). Under optimal conditions of population stability, the greatest proportion of fish sampled would be smaller and younger than those captured during our sampling. Yellow perch age and length data from 1997 sampling confirm that, due to reduced juvenile survival in the past several years and limited recruitment of juvenile fish to the adult population, the average age and length of the yellow perch population in Lake Michigan is continuing to increase.

Larval yellow perch were nearly absent from samples collected during 1997. Abundances of yellow perch larvae during 1995 and 1996 were similarly low (Robillard et al. 1996; Robillard and Marsden 1997). The absence of larval yellow perch may indicate that the reduced abundance of adult female yellow perch is affecting the reproductive success of the population.

Relatively few larval fish were successfully sampled using the Miller samplers and usually a maximum of only one fish per transect was collected. Predominant species were rainbow smelt and alewife. There were no significant depth at time (i.e., day or night) for these two species from the limited data. It appears that Miller samplers are not effective sampling devices for Lake Michigan, since larval fish densities are relatively low compared to the inland waters where Miller samplers have been effectively used and we recommend discontinuing their use as part of this study.

Ten YOY yellow perch were captured in 53 0.93-km bottom trawls. Approximately 239,500 m^2 of the lake bottom was sampled. The paucity of YOY yellow perch may indicate a failure of larval fish to be recruited to the sub-adult population. Increased water clarity observed in the past four years, which is likely due to filtration by zebra mussels, may directly affect YOY catches by increasing avoidance of sampling gear. However, trawling at night, when visual gear avoidance should be reduced, did not increase catch rates in 1995 (Robillard et al. 1996). The increased water clarity is a consequence of reduced plankton populations that may indirectly limit available food for developing larval yellow perch. Water clarity may also affect juvenile yellow perch survival by increasing their susceptibility to predation by visual feeders such as alewife.

The effect of alewife predation on yellow perch larvae cannot be adequately addressed due to the near-absence of available larval yellow perch as prey. Relatively few alewife had larval fish as a component of stomach contents (5.4%) and none could be identified with certainty as larval yellow perch, so several years of effort at various densities of yellow perch larvae will be necessary to place any confidence on the percent of yellow perch recruitment lost to predation by alewife. Most likely the partially digested larval fish we found in alewife stomachs were cyprinids because the majority larval fish, with similar body forms to larval yellow perch, in the ichthyoplankton samples were cyprinids.

No conclusions can be drawn from the zooplankton sample data as analysis has not yet been completed.

Yellow perch egg masses collected at the US Steel intake line, south of Waukegan Harbor, were nearly 100% viable; the survival of these eggs to post-hatch stages, however was not investigated. The absence of emergent yellow perch larvae in the ichthyoplankton samples dictated that post-larval sampling be limited in effort and as a consequence, no post-larval stage yellow perch were collected.

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REFERENCES

Baumgartner, M., et al. 1990. Untitled report to the Great Lakes Fishery Commission. Lake Michigan Committee Meeting, March 1990.

Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press. 1078 pp.

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

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

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.

Marsden, J. E., W. A. Brofka, and W. H. Horns. ***In review***. Seasonal movements of yellow perch in Lake Michigan. *Trans. Am. Fish. Soc.*

Marsden, J. E., W. Brofka, D. Makauskas, and W. H. Horns. 1993. Yellow perch supply and life history. Final report to the Illinois Department of Conservation. Illinois Natural History Survey Technical Report 93/12. 46 pp.

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. 17p.

Robillard, S. R., T. Kassler, and J. E. Marsden. 1995. Yellow perch population assessment in southwestern Lake Michigan, including evaluation of sampling techniques. Annual report to the Illinois Department of Natural Resources. Illinois Natural History Survey Technical Report 95/9. 19 pp.

Robillard, S. R., T. Kassler, and J. E. Marsden. 1996. Yellow perch population assessment in southwestern Lake Michigan, including evaluation of sampling techniques. Annual report to the Illinois Department of Natural Resources. Illinois Natural History Survey Technical Report 96/7. 23 pp.

Robillard, S. R., and J. E. Marsden. 1996. Comparison of otolith and scale ages for yellow perch from Lake Michigan. J. Great Lakes Res. 22:429-435.

Robillard, S. R., and J. E. Marsden. 1997. Yellow perch population assessment in southwestern Lake Michigan, including evaluation of sampling techniques. Annual report to the Illinois Department of Natural Resources. Illinois Natural History Survey Technical Report 97/9. 21 pp.

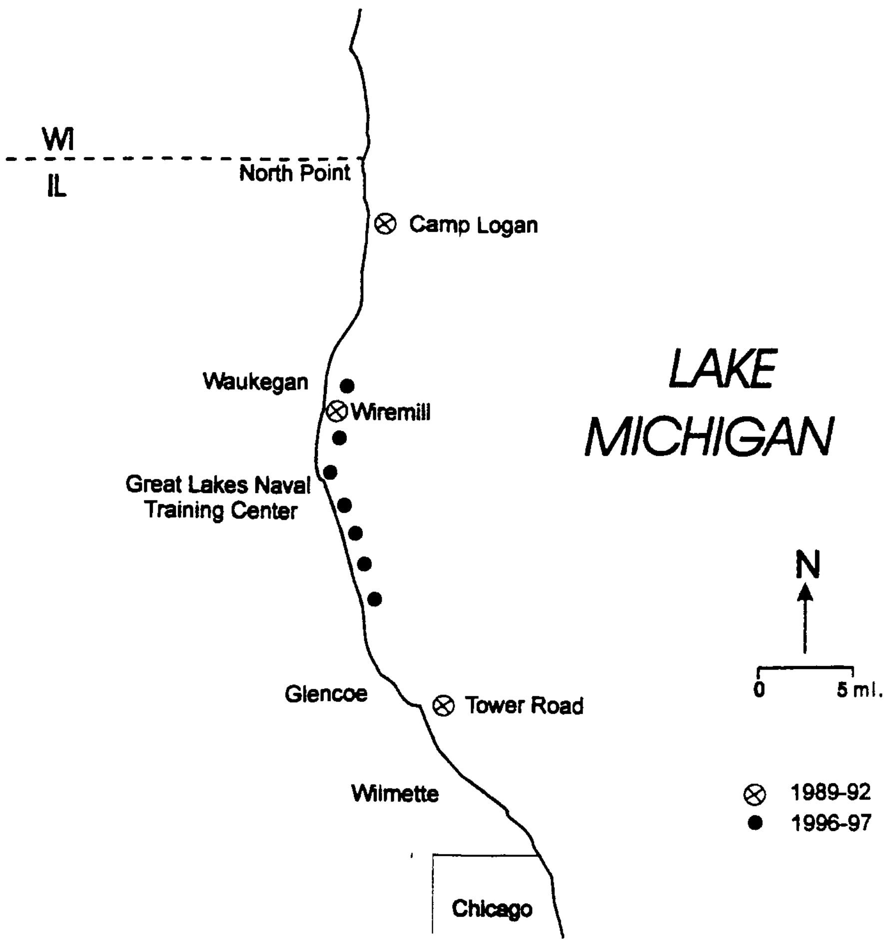

Figure 1. Index sites for adult yellow perch sampling.

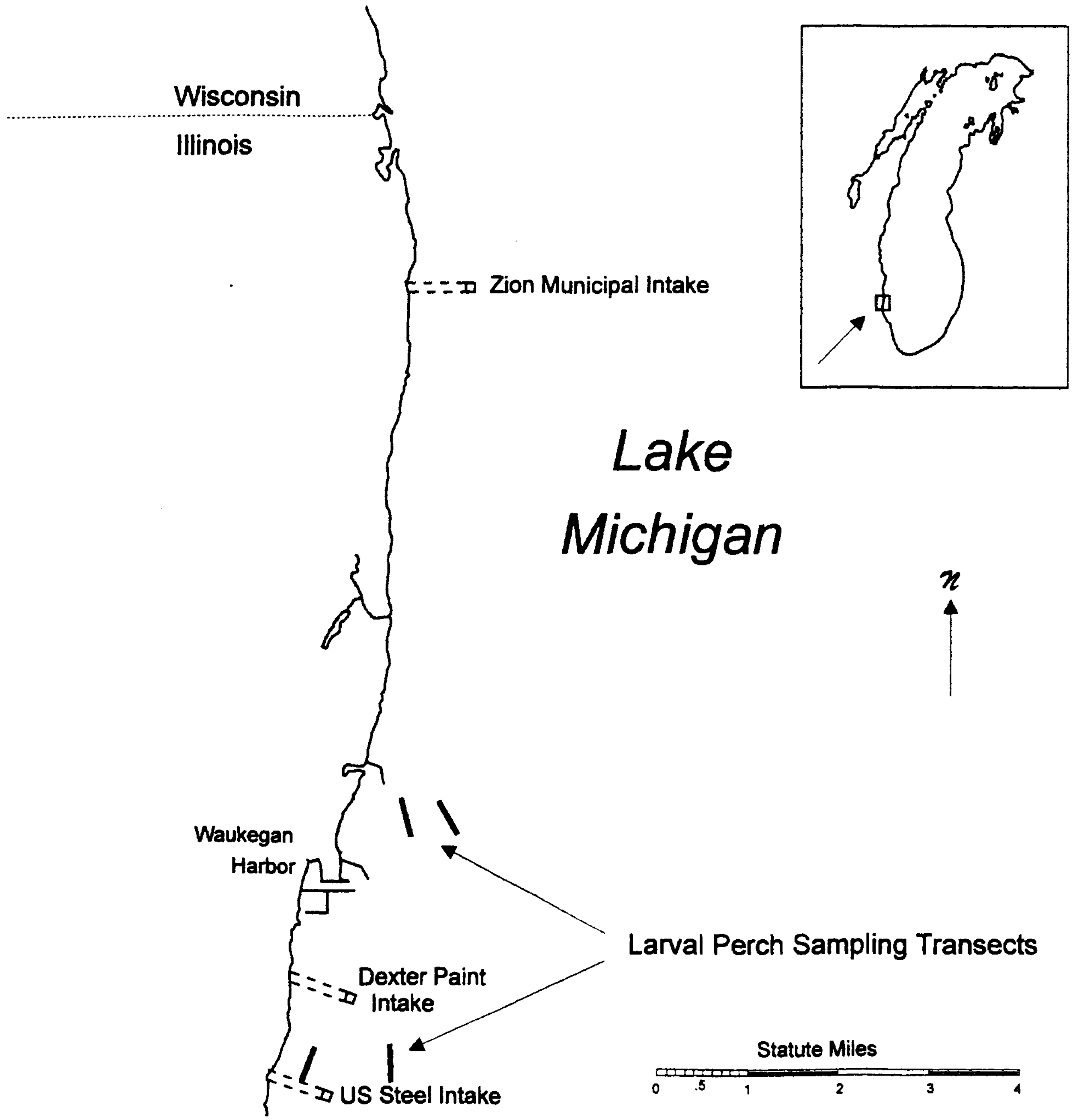

Figure 2. Index sites for yellow perch egg and larval perch sampling.

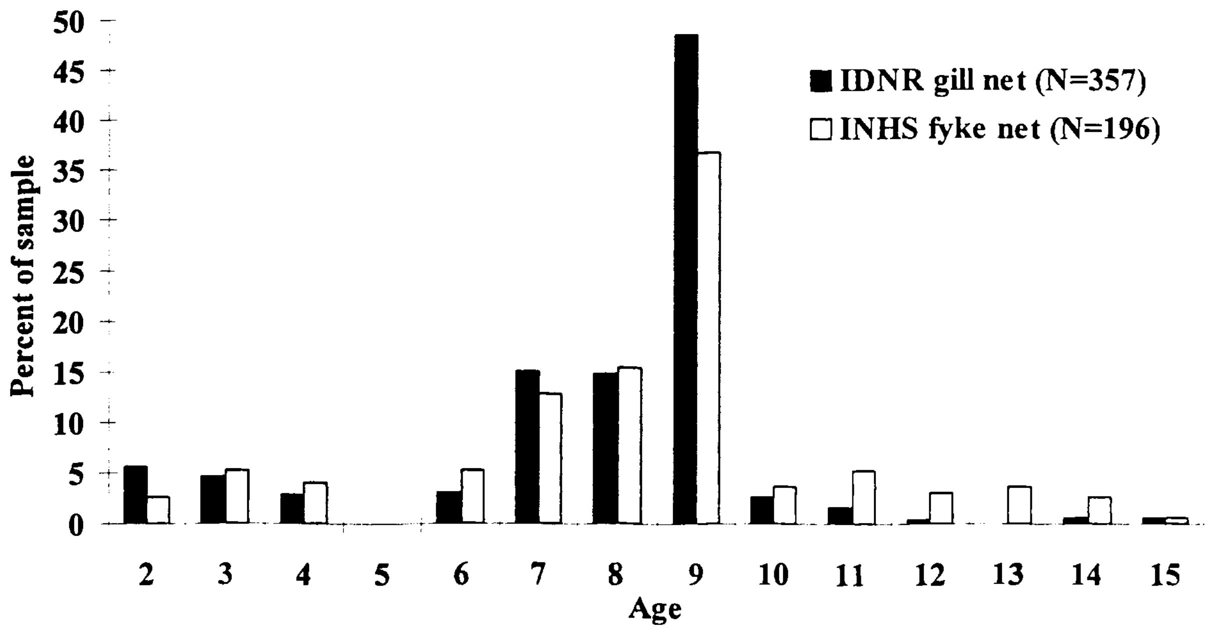

Figure 3. Age-frequency distribution of yellow perch captured in LMBS fyke nets and IDNR gill nets on 05 and 06 June, 1997 at the IDNR Lake Bluff index station.

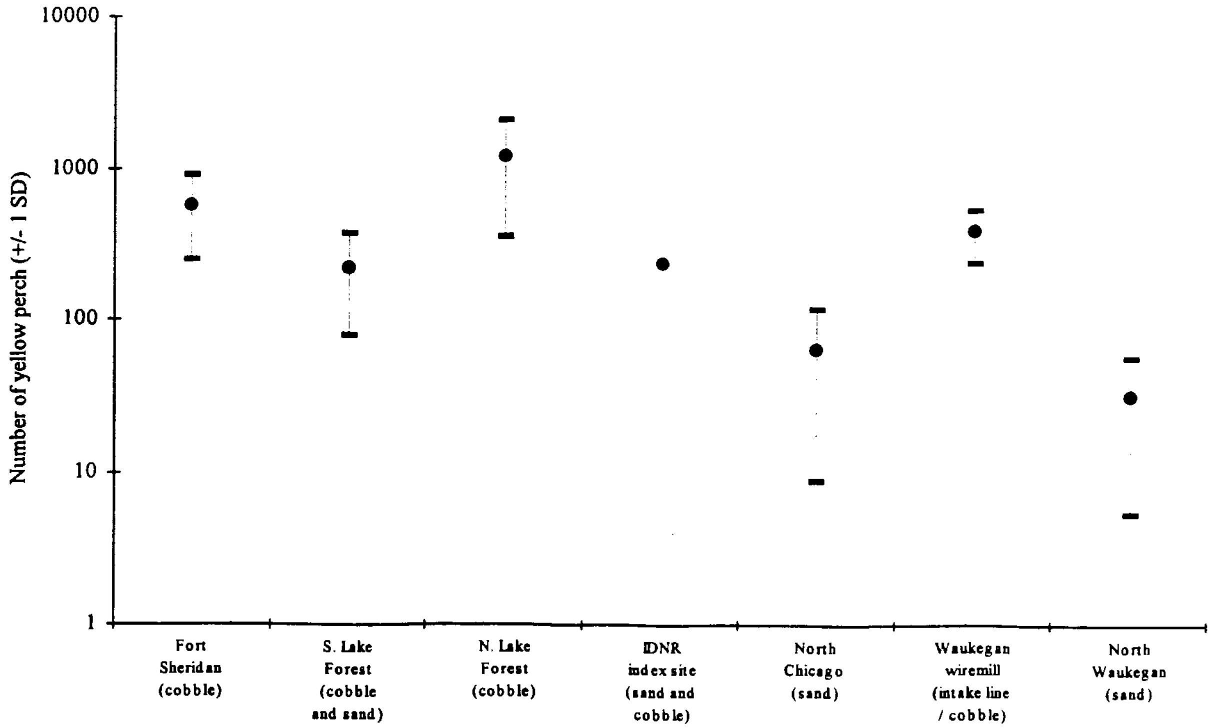

Figure 4. Number of yellow perch captured in fyke nets at the Illinois Department of Natural Resources Lake Bluff index station and at three sites with cobble substrate and three sites with predominantly sand substrate between 30 May and 03 July, 1997. Error bars represent one standard deviation above and below the mean.

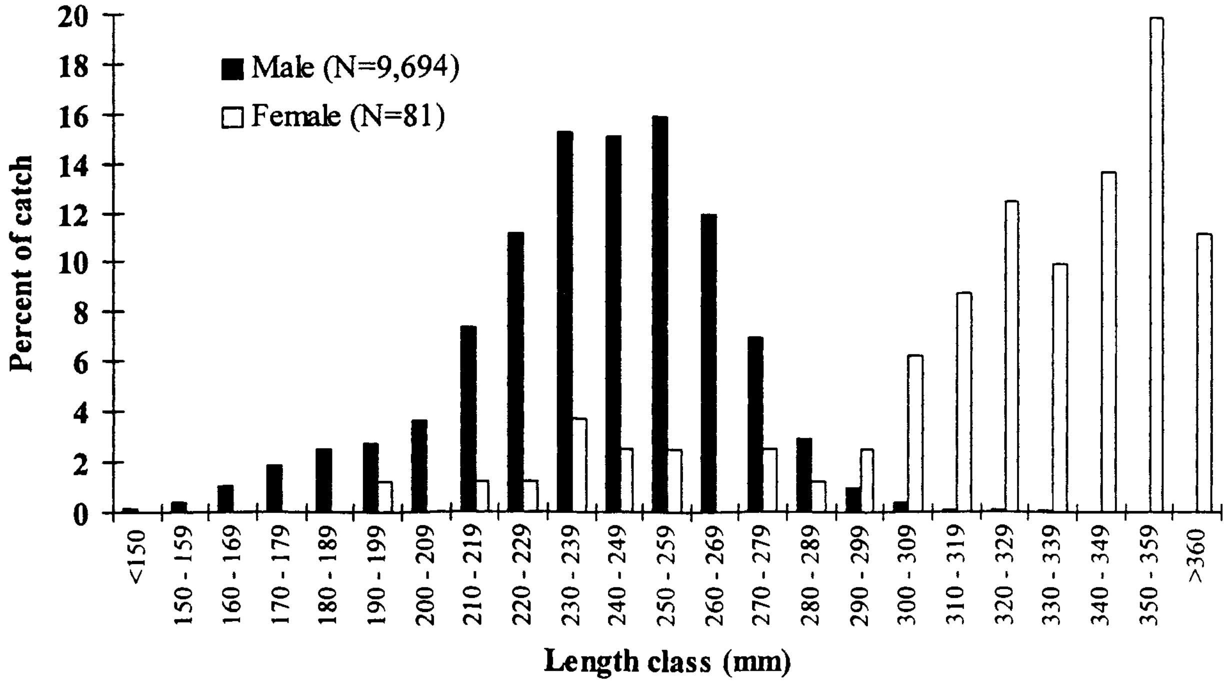

Figure 5. Percent of male and female yellow perch belonging to 10-mm size groups. All fish were captured in LMBS fyke nets between 30 May and 03 July, 1997 in Lake Michigan near Lake Bluff.

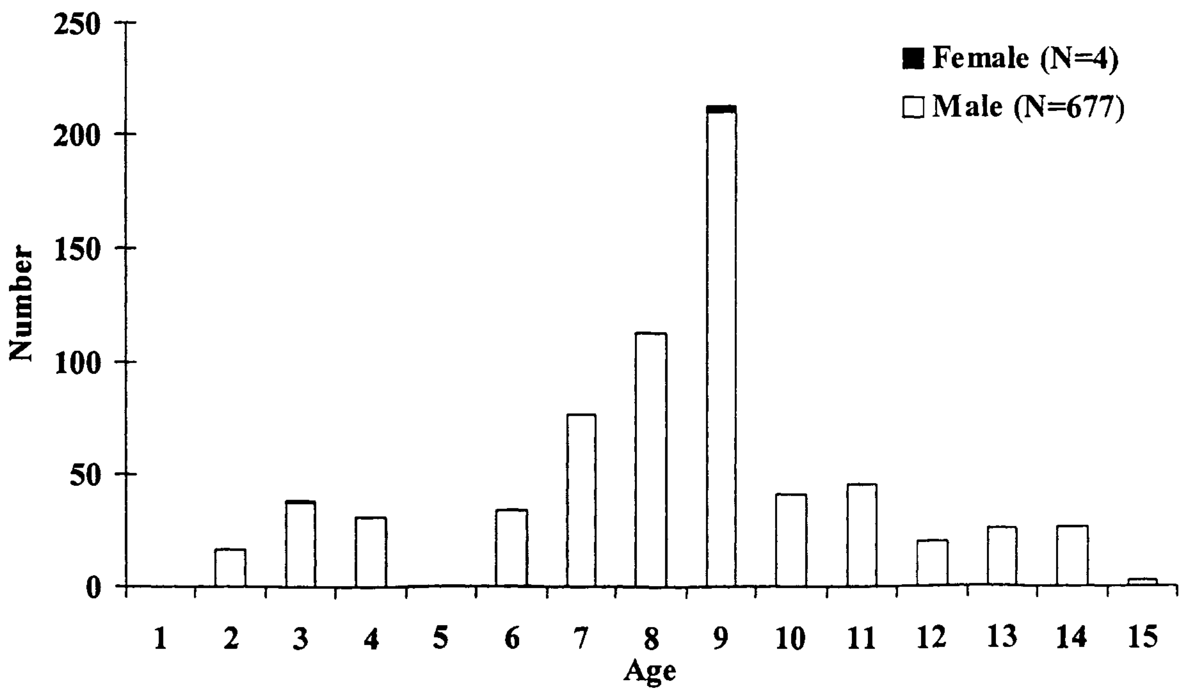

Figure 6. Age-frequency distribution of male and female yellow perch captured in LMBS fyke nets between 30 May and 03 July, 1997 in Lake Michigan near Lake Bluff.

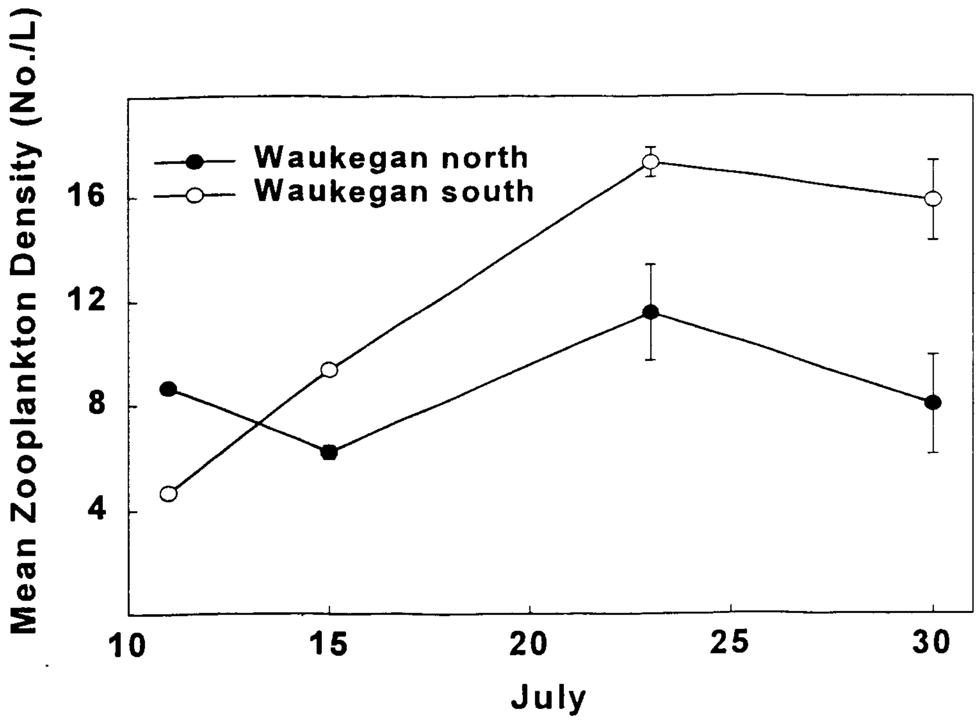

Figure 7. Mean density ± 1 SE of crustacean zooplankton collected at one site north and one site south of Waukegan Harbor during 10 July to 30 July 1996.

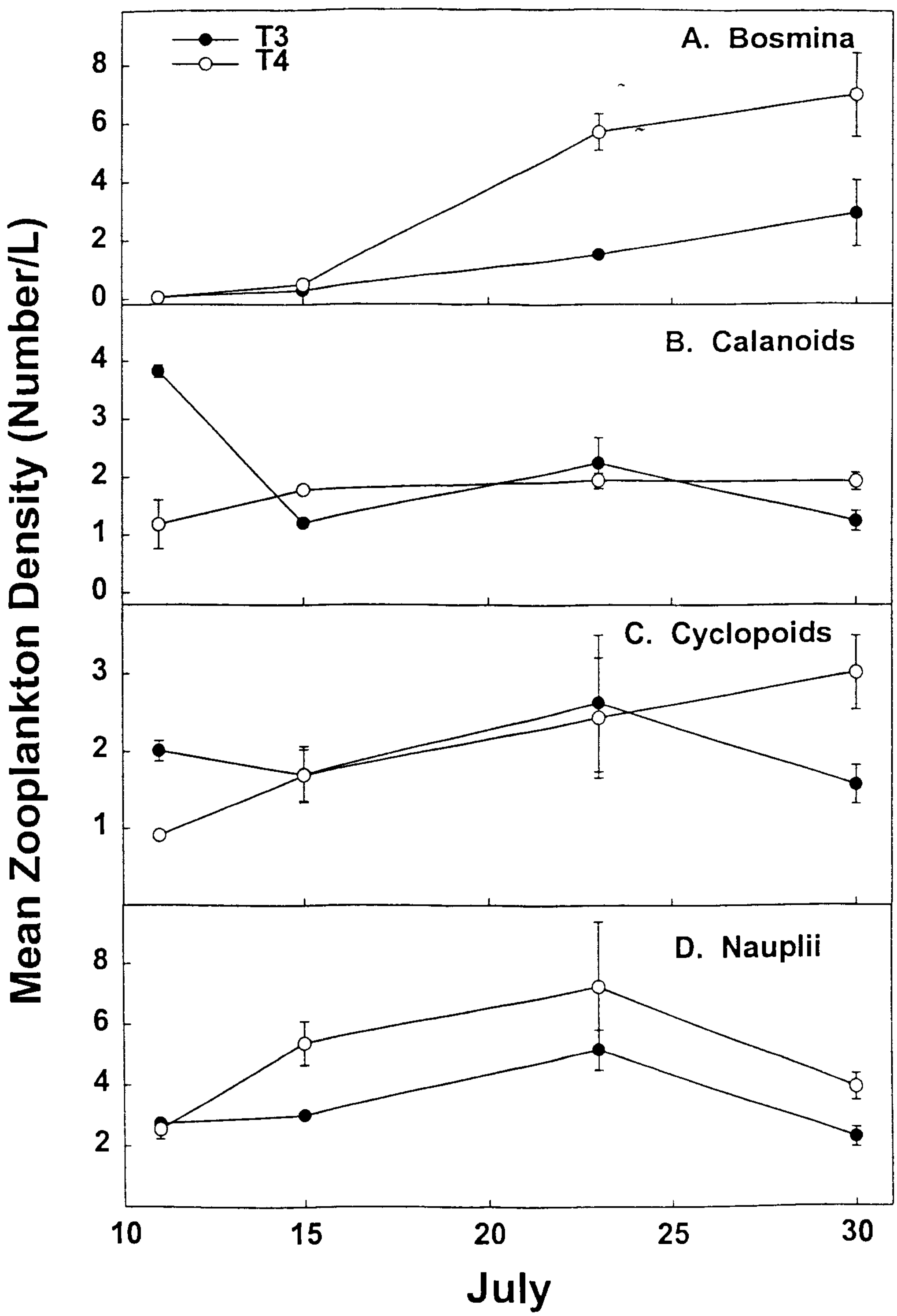

Figure 8. Mean density ± 1 SE of A) *Bosmina*, B) calanoid copepods, C) cyclopoid copepods, and D) copepod nauplii collected at one site north and one site south of Waukegan Harbor during 10 July to 30 July 1996.