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Yellow Perch Population Assessment in Southwestern Lake Michigan, Including Evaluation of Sampling Techniques

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Center for Aquatic Ecology

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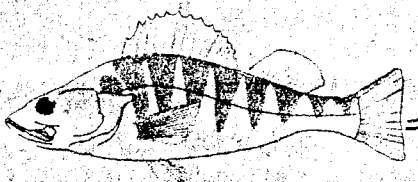

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Yellow Perch Population Assessment in Southwestern Lake Michigan, Including Evaluation of Sampling Techniques

April 1, 1995 - March 31, 1996

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES	3
EXECUTIVE SUMMARY	4
INTRODUCTION	6
METHODS	7
Sampling gear	
Supplemental index gill netting	
Calibration of data from fyke netting and gill netting	
Validation of index station locations	
Yellow perch population structure	
Diel larval perch and plankton sampling	
Harbor sampling for larval perch	
Young-of-the-year sampling	
Genetic stock identification	
RESULTS	13
Sampling gear	
Supplemental index gill netting	
Calibration of data from fyke netting and gill netting	
Validation of index station locations	
Yellow perch population structure	
Diel larval perch and plankton sampling	
Harbor sampling for larval perch	
Young-of-the-year sampling	
Genetic stock identification	
CONCLUSIONS	16
ACKNOWLEDGMENTS	18
REFERENCES	18
FIGURES	19-23

LIST OF TABLES AND FIGURES

Tables

1. Length and mesh size of panels used in IDNR yellow perch spawning assessment gill nets. 7
2. Summary of yellow perch collected from seven locations around Lake Michigan for gene 10
3. Enzyme systems and loci screened for polymorphism in yellow perch. 12
4. Sex ratio of yellow perch captured with fyke nets and gill nets on 13 and 14 June, 1995, in Lake Michigan, near Lake Bluff. 13
5. Allelic frequencies of polymorphic loci in populations of Lake Michigan yellow perch. 15
6. Frequency of banding patterns A and B detected by digesting the ATPase-6 gene with the restriction endonuclease *HAE III* for four Lake Michigan populations. 16

Figures

1. Age-frequency distributions of yellow perch captured with two types of sampling gear on 13 and 14 June, 1995, in Lake Michigan, near Lake Bluff. 19
2. Numbers of yellow perch captured in fyke nets at the Illinois Department of Natural Resources Lake Bluff index station and at three distances (1.5, 3, and 4.5 nautical miles) north and south of that index station between 22 May and 22 June, 1995. Error bars represent one standard deviation above and below the mean. 20
3. Age-frequency distribution of 834 yellow perch captured with fyke nets between 22 May and 22 June, 1995, in Lake Michigan, near Lake Bluff. 21
4. Length distribution of yellow perch captured in INHS fyke nets (n=9,696) between 22 May and 22 June, 1995, in Lake Michigan, near Lake Bluff. 21
5. Catch per unit effort (fish•100m^{-3}) of alewife larvae collected north of Waukegan Harbor at depths of 0, 2, 4, 6, and 8 m between 12 June and 13 July, 1995. Secchi depth is indicated by the vertical dashed line. 22-3

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 Illinois Natural History Survey (INHS) monitoring programs, investigate the diel vertical migration of larval yellow perch, monitor population densities of young-of-the-year yellow perch, and determine whether genetically discrete stocks of yellow perch exist in Lake Michigan. We added a supplemental index station to the two IDNR index stations traditionally used in Illinois waters. Catch data obtained from fyke nets and gill nets at one index station were compared so that catch per unit effort (CPUE) estimates between the two types of gear used in INHS and IDNR studies could be calibrated. 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 perch and their prey were investigated, young-of-the-year perch were sampled with a bottom trawl, and the genetic structure of yellow perch populations in Lake Michigan was explored using molecular genetic techniques.

The results of this project will enable fish managers to develop effective management strategies for this important sport and commercially fished species. New information on specific areas where yellow perch spawning occurs will strengthen IDNR spawning assessments. Larval perch sampling will expand our understanding of the early life history of yellow perch in terms of larval fish movements, feeding behaviors, and survival. Early life history data will eventually lead to an understanding of factors that affect juvenile survival and future year-class strength. Stock structure data from yellow perch populations in Lake Michigan will allow more effective management of stocks which are believed to overlap jurisdictional boundaries.

The following conclusions are drawn from the second year of the project. These conclusions must be regarded as preliminary, particularly as some of the objectives depend upon a time-series of data over three years, and it must be noted that these data only represent one year.

1. Fyke nets generally catch more yellow perch than gill nets and were more representative of the length-structure of the yellow perch population when both gears were fished for the same length of time. Gill nets captured more females than fyke nets. Age-compositions of yellow perch captured in both gear types were similar.

2. Results from the spawning concentration data suggest that the IDNR Lake Bluff index station is not the focus of spawning in the Lake Bluff area. During the 1995 spawning season, yellow perch appeared equally distributed along the entire nine miles of shoreline sampled.

3. The greatest proportion of yellow perch collected in fyke nets were 7 year-olds (1988 year-class); the average length of all sampled fish was 211 mm. The stretched measure of INHS fyke nets is designed to capture fish 150 mm and greater. Under optimal conditions of population stability, the greatest proportion of fish captured would have been smaller and younger.

4. Vertical sampling data indicated that alewife larvae were approximately equally distributed throughout the water column at night and nearly equally distributed at all depths greater than 2 m during the day. The depth at which alewife larvae are present during the day appears to be influenced both by the depth of the thermocline and degree of water clarity.

5. The near absence of larval yellow perch in Waukegan harbor and presence of larvae just outside the harbor may indicate that spawning does not occur in the commercial basin of the harbor. Waukegan harbor is susceptible to heavy boat traffic and is the northern Illinois port for large shipping vessels. The turbulence caused by these vessels along with the lack of suitable spawning structure may limit yellow perch spawning in this harbor.

6. We captured nine young-of-the-year yellow perch in forty-five 10-minute bottom trawls. Approximately 204,000 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 be recruited to the subadult population.

7. Genetic analysis of yellow perch from Lake Michigan using protein electrophoresis, RFLP analysis of mtDNA, and RAPD analysis of nuclear DNA revealed very few polymorphisms. RFLP analysis of mtDNA using digestion of the ATPase-6 gene with the restriction endonuclease *Hae III* revealed the most variability; however, there were not sufficient frequency differences among populations to identify distinct genetic groups in Lake Michigan.

INTRODUCTION

Yellow perch (*Perca flavescens*) are an important commercial and sport fish throughout much of their range in North America. Their schooling behavior promotes sizable captures in commercial gears such as trap nets and gill nets, and their tendency to congregate near shore in the spring makes them readily available to shore fishermen. Due to their excellent taste, their flesh is prized, and currently sells in Illinois for $10 to $12 per pound. 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 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 Illinois Natural History Survey (Marsden et al. 1993) indicated that the fishery in 1993 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 between 1990 and 1993. Consequently, the yellow perch population is aging - the population as a whole was composed of larger and older individuals in 1993 than it was in 1986.

The ability to manage yellow perch is hampered by insufficient information about population size, stock structure, movements, and factors which affect population growth. Evaluation of the best techniques and locations to collect assessment data is necessary to maximize information access. Recent federally funded research by the Illinois Natural History Survey (INHS) has shown that yellow perch populations are too large and too mobile for single agency mark-and-recapture studies to be viable. However, annual assessment data of spring spawning populations at index stations, combined with assessment of year-class strength, 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 the INHS at two sites using fyke nets. There are several inadequacies in these data, 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 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 quotas in accordance with fluctuating population sizes. Assessment of larval and young-of-the-year perch populations may permit prediction of future year-class strength. However, the variances on larval perch

abundance data and YOY catches are very high, and the diel and 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 survival rates, contributing to our ability to monitor year-class strength relative to other years.

To date, no information exists to clearly define whether the yellow perch population in Lake Michigan is composed of one or many stocks. Consequently, the fish are managed as a single, panmictic population; until recently, each state bordering Lake Michigan has managed its fishery independently, with little communication and coordination among the states. However, tagging and movement studies suggest that yellow perch may return to the same breeding area year after year, and thus may comprise discrete breeding populations (Marsden et al. 1993). Similar studies in other lakes suggest that yellow perch may form discrete stocks (e.g., Mansueti 1960, Nakashima and Leggett 1975, Kelso and Ward 1977). If multiple stocks exist in Lake Michigan, then management actions in one state or management subunit could have a disproportionate effect on other areas. For example, management regulations that permit heavy fishing during the spawning season in one state could result in depletion of those stocks if they spend the remainder of the year in another part of the lake.

The results of this project will strengthen management strategies for this important sport and commercial species. Evidence of discrete yellow perch stocks in Lake Michigan will allow more effective management of stocks which are believed to overlap jurisdictional boundaries. 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 toward ecosystem management.

METHODS

Sampling gear

Adult yellow perch were collected using fyke nets (INHS) and graded-mesh gill nets (IDNR). We used 1.2 x 1.8 m (4' x 6') doubled-ended fyke nets with a 30.5 m (100') leader between the two double-throated pots. Fyke net mesh was 38 mm (1.5") 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	Mesh size
1	15.2 m (50')	25.4 mm (1")
2	30.5 m (100')	38 mm (1.5")
3	30.5 m (100')	51 mm (2")
4	91.4 m (300')	63 mm (2.5")
5	91.4 m (300')	76 mm (3")

All plankton sampling was conducted using 363 μm mesh nets with a 5:1 scope. Abundance and harbor sampling was performed with a 0.5 m dia net; vertical distribution sampling was performed with a 0.3 m dia net.

A bottom trawl with a 4.9 m (16') head rope, 38 mm stretch mesh body, and 13 mm mesh cod end was used to sample young-of-the-year yellow perch.

Supplemental Index Gill Netting

The Illinois Department of Natural Resources 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 INHS personnel on board his boat. Gill nets were set at depths of 7.2 and 10.8 m (4 and 6 fathoms) on 30 May, 1995, and at 14.6 and 18.3 m (8 and 10 fa) on 31 May, 1995. All nets were fished for approximately 24 hrs. All fish in all nets were counted. Subsamples of 25 fish from each gill net panel were collected. Subsampled fish were weighed to the nearest 10 g, measured (total length) to the nearest 5 mm, and dissected to determine reproductive status. Ages were estimated from otoliths. If the total catch for any panel was less than 25, all fish in that panel were subsampled.

Calibration of Data from Fyke Netting and Gill Netting

One IDNR assessment gill net and one INHS fyke net were set end to end, parallel to shore, at depths of 7.2 and 10.8 m (4 and 6 fa) on 13 June, 1995, and at 14.6 and 16.8 m (8 and 10 fa) on 14 June, 1995, at the IDNR Lake Bluff index station. All nets were fished for approximately 24 hrs.

A subsample of 50 yellow perch was collected from each fyke net. All other fish captured in each fyke net were counted; a minimum of 400 yellow perch, when present, were measured to the nearest 1 mm (total length) and externally examined to determine reproductive status. All fish, except the subsampled fish, were released.

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

Age-frequency distributions and catches were compared by Peterson Chi-square (Zar 1984).

Validation of Index Station Locations

Fyke nets were set at the IDNR Lake Bluff index station and either 1.5, 3, or 4.5 nautical miles (nm) north and south of that index station. Nets were set along the 5 m depth contour line, usually parallel to shore. All nets were fished for approximately 24 hrs. Three sampling units (Lake Bluff +/- 1.5, 3, and 4.5 nm) were completed; i.e., 9 sets of 3 nets per day.

Subsamples of 25 yellow perch from each net were collected. All other fish captured in each fyke net were counted; a minimum of 400 yellow perch from each net, when present, were measured to the nearest 1 mm (total length) and externally examined to determine reproductive status. All fish, except the subsampled fish, were released.

Yellow Perch Population Structure

Biological data (i.e., length, weight, sex, and maturity) were obtained from all INHS subsampled yellow perch, and the ages of the fish were estimated from otoliths. Sagittal otoliths were extracted and stored in 95% ethanol for a minimum of 24 hours. Forceps were used to remove the membrane surrounding each otolith. Otoliths were manually broken through the nucleus, perpendicular to the anterior-posterior axis, using thumbnail pressure. Usually the posterior half was examined, but when the anterior half contained the entire nucleus, that half was ground on 400 grit sandpaper to expose the nucleus. The broken surface of each otolith was burned briefly in the flame of an alcohol lamp to enhance distinction between absorbtive and reflective zones. Each otolith was mounted in clay, charred surface up, on a numbered microscope slide. The charred surface was wetted with immersion oil before viewing under a dissecting microscope at 30-60X magnification.

The absorbtive zones that appeared as dark bands on broken surface of the otolith were counted as annuli. Otolith annuli were counted if they were conspicuous in the ventral field and if they were apparent somewhere in the dorsal field. Usually, the otolith margin was counted as an annulus, but when there appeared to be 'new' growth at the margin, a "+" was added to that fish's age.

Diel Larval Perch and Plankton Sampling

Abundance estimates

Samples were collected near Waukegan Harbor on six nights between 05 June and 28 June, 1995. The net was pushed at the surface with a bow-mounted frame at a speed of approximately 2 $m \cdot sec^{-1}$. One 5 m and one 10 m bottom depth transect was sampled ~1.5 nm 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 0.5 nm surface push sampled approximately 169 m^3 of water. Larval fish were extracted from plankton samples and identified to genus, species when possible. Ostracods were extracted and enumerated.

Vertical movement

A plankton net was used to sample horizontal transects at the surface and at four water depths (2, 4, 6, and 8 m) just north of Waukegan Harbor, between 12 June and 13 July, 1995. The net was pushed at the surface with a bow-mounted frame or towed from the transom at depth at a speed of approximately 1 $m \cdot sec^{-1}$. Eight complete vertical strata samples were collected; i.e., three day samples with corresponding night samples and two day samples without night samples. A calibrated General Oceanics™ standard flowmeter mounted in the mouth of the net was used to determine the volume of lake water sampled. Each 0.2 nm push or tow sampled approximately 24 m^3 of water. Larval fish were extracted from plankton samples and identified to genus, species when possible. Ostracods were extracted and enumerated.

Harbor Sampling for Larval Perch

Plankton samples were collected in Waukegan Harbor on the same nights as the abundance sampling between 05 June and 28 June, 1995. The net was pushed at the surface with a bow-

mounted frame at a speed of ~1 m•sec^{-1}. A total of 12 samples were collected. Each 0.2 nm push sampled ~59 m^3 of water. Larval fish were extracted from plankton samples and identified to genus, species when possible. Ostracods were extracted and enumerated.

Young-of-the-Year Sampling

Trawling for young-of-the-year (YOY) yellow perch was conducted approximately weekly (10 times) between 10 August and 11 October, 1995, at various depths between 3 and 10 m at a speed of ~2 m•sec^{-1}. All sampling occurred north of Waukegan harbor. Each 0.5 nm transect sampled approximately 4519 m^2 of the lake bottom. YOY yellow perch and non-target species were recorded.

Genetic Stock Identification (Note: portions of this section were completed in previous segments of the project. An entire summary of the methods has been included here to improve clarity and understanding.)

Sample Collection

Adult yellow perch were collected during previous spawning seasons with various types of gear from 7 locations around Lake Michigan (Table 2). Samples of 45 to 50 perch were collected near Zion, IL, Bailey's Harbor, WI, and Green Bay, WI in 1993. The latter two samples were collected with the assistance of the Wisconsin Department of Natural Resources. In 1994, we collected approximately 50 perch from Ludington, MI, with the assistance of the Michigan Department of Natural Resources, and 50 from South Haven by angling and with the assistance of local charter fishermen. Approximately 20 fish were collected near Michigan City, IN by staff of Ball State University; due to low daily catches, no additional fish were sampled from this site. Personnel working with the Grand Traverse Bay Ottawa/Chippewa Indian fisheries acquired a sample of approximately 30 perch for us from Grand Traverse Bay. All specimens were frozen on dry ice immediately after collection; bodies of some fish (minus the liver) were removed to save storage space, as all the tissues used for analysis are in the head and liver. Samples were maintained on dry ice or in a deep freezer until transport to more permanent cold storage in Champaign, IL.

Table 2. Summary of yellow perch collected from seven locations around Lake Michigan for genetic analysis.

Site	n	Area of lake sampled
Zion, IL	~45	SW shore
Michigan City, IN	20	S shore
Grand Traverse Bay, MI	30	NE shore (adjacent bay)
Ludington, MI	50	E shore
South Haven, MI	50	SE shore
Bailey's Harbor, WI	~45	NW shore
Green Bay, WI	~45	NE shore (adjacent bay)

Protein electrophoresis

Standard vertical starch gel electrophoresis procedures were used to screen 43 loci for polymorphisms (Table 3). Yellow perch from Lake Michigan, Minnesota, and Wisconsin were combined for the screen to maximize the potential for finding polymorphisms. The Lake Michigan sample included perch from Bailey's Harbor, Zion, and Green Bay.

Fish from the Grand Traverse Bay population were examined using 3 loci found to be polymorphic in the Lake Michigan populations (GPI-A, GPI-B, and MDH-A), 5 loci found to be polymorphic in the Minnesota and Wisconsin populations (AK-1, GLYDH-1, LDH-B, MPI-1, and PGM-A), and 7 other loci that have shown polymorphisms in other species (CK-A, CK-B, CK-C, G2DH-2, IDH-B, LDH-A, and LDH-C).

RFLP analysis of mitochondrial DNA

An intensive restriction fragment length polymorphism (RFLP) analysis of mitochondrial DNA was conducted. We used southern blotting with hybridization using a non-specific American shad probe. Due to low amounts of isolated DNA or incompatibility of the non-specific probe we were not able to resolve bands for all populations. Therefore, we used a PCR technique to amplify specific regions or genes on the mitochondrial genome. Three genes (NADH subunit 3/4, NADH subunit 5/6, and ATPase 6) were amplified and digested with 9 restriction endonucleases (*aTaq I, BSTU I, Dde I, Dpn II, Hae III, Hinf I, Msp I, and Rsa I*) for the Bailey's Harbor, Zion, and Green Bay populations. We also examined the D-loop/12s region in the mitochondrial genome and digested product with the same 9 restriction endonucleases.

Our initial screen of four regions in the mitochondrial genome revealed polymorphism in the ATPase-6 gene with one restriction endonuclease (*Hae III*). The ATPase-6 gene was then amplified for 30 individuals from the Grand Traverse Bay population and digested with three restriction endonucleases (*Dde I, Hae III,* and *Hinf I*).

RAPD analysis of nuclear DNA

Whole genome DNA was isolated from small amounts of muscle and purified using a standard extraction procedure combining phenol and chloroform:isoamyl alcohol steps, followed by cold precipitation in 100% ethanol. The whole genomic DNA was then used as the template in a series of PCR reactions, each one using one of 20-30 different 10-base primers (each with a different random sequence, as sold by several companies). These DNA fragments were then separated electrophoretically using an agarose gel and stained using ethidium bromide. Twenty RAPD primers (L-Operon L series) were screened for polymorphism. Fifteen of the primers consistently amplified; the other five primers (L6, L13, L15, L17, and L19) did not amplify.

Table 3. Enzyme systems and loci screened for polymorphism in yellow perch.

Enzyme number	Enzyme name	Locus	Tissue analyzed	Buffer system	M/P
2.6.1.1	Aspartate amino transferase	mAAT	Liver	TC	M
		AAT-A	Muscle	TC	M
		AAT-B	Liver	TC	M
4.2.1.3	Aconitate hydratase	AH	Liver	TC	M
3.5.4.4	Adenosine deaminase	ADA	Liver	EBT	M
2.7.4.3	Adenylate kinase	AK-1	Muscle	TC	P
4.1.2.13	Fructose bisphosphate aldolase	FBALD	Eye	TC	M
2.7.3.2	Creatine kinase	CK-A	Muscle	TC	M
		CK-B	Eye	TC	M
		CK-C	Eye	TC	M
3.1.1.-	Esterase	EST-1	Liver	EBT	M
		EST-2	Liver	EBT	M
3.1.3.11	Fructose bisphosphatase	FBP	Muscle	TC	M
4.2.1.2	Fumarate hydratase	FH	Liver	TC	M
1.2.1.12	Glyceraldehyde-3-phosphate dehydrogenase	GAPDH	Muscle/Eye	TC	M
1.1.1.29	Glycerate dehydrogenase	GLYDH-1	Liver	TC	P
		GLYDH-2	Liver	TC	M
1.1.1.8	Glycerol-3-phosphate dehydrogenase	G3PDH	Liver	TC	M
2.7.1.2	Glucose kinase	GK	Liver	TC	M
5.3.1.9	Glucose phosphate isomerase	GPI-A	Muscle	TC	P
		GPI-B	Muscle	TC	P
1.1.1.42	Isocitrate dehydrogenase	IDHP-A	Muscle	TC	M
		IDHP-B	Liver	TC	M
1.1.1.27	Lactate dehydrogenase	LDH-A	Eye	TC	M
		LDH-B	Eye	TC	P
		LDH-C	Eye	TC	M
1.1.1.40	Malic enzyme (NADP+)	MEP-1	Muscle	EBT	M
		MEP-2	Muscle	EBT	M
1.1.1.37	Malate dehydrogenase	mMDH	Muscle	TC	M
		MDH-A	Muscle	TC	P
		MDH-B	Muscle	TC	M
5.3.1.8	Mannose phosphate isomerase	MPI-1	Liver	RID	P
--------	Peptidase (leu-tyro)	LT-1	Liver	RID	M
		LT-2	Liver	RID	M
5.4.2.2	Phosphoglucomutase	PGM-A	Liver	TC	P
1.1.1.44	Phosphogluconate dehydrogenase	PGDH-1	Liver	TC	M
		PGDH-2	Liver	TC	M
2.7.1.40	Pyruvate kinase	PK	Liver	TC	M
1.15.1.1	Superoxide dismutase	SOD-1	Liver	TC	M
		SOD-2	Liver	TC	M
1.1.1.14	Sorbitol dehydrogenase	SDH	Liver	TC	M
5.3.1.1	Triose-phosphate isomerase	TPI-1	Eye	TC	M
		TPI-2	Eye	TC	M
1.2.3.2	Xanthine dehydrogenase	XDH	Liver	EBT	M

RESULTS

Supplemental Index Gill Netting

A total of 432 yellow perch were captured in IDNR assessment gill nets at the Calumet Harbor index site.

Calibration of Data from Fyke Netting and Gill Netting

Greater numbers of yellow perch were usually captured with fyke nets than gill nets. The numbers of yellow perch captured in the 7.2 , 10.8, 14.6 and 16.8 m depth fyke nets were 226, 10, 141, and 139, respectively, compared to 107, 64, 119, and 127 yellow perch in the equivalent gill net sets. More yellow perch were captured in the 2" mesh panel than in any other panel in all four gill nets; no fish were captured in any of the 1" mesh panels. Since catches in each gill net panel were not equally represented in the subsampled fish, the ages were weighted accordingly. Chi-square tests revealed no significant differences ($P>0.05$) between the age distributions of fyke net and gill net captured yellow perch (Figure 1). More females were captured in gill nets compared to fyke nets (Table 4); all fyke net captured fish were males.

Table 4. Sex ratio (male : female) of subsampled yellow perch captured with gill nets and fyke nets on 13 and 14 June, 1995, in Lake Michigan, near Lake Bluff.

mesh size	gill net (n=173)	fyke net (n=161)
25.4 mm (1")	-	-
38 mm (1.5")	4 : 0	-
51 mm (2")	100 : 0	-
63 mm (2.5")	53 : 12	-
76 mm (3")	0 : 4	-
total	157 : 16	161 : 0

Validation of Index Station Locations

A total of 11,107 yellow perch were captured in the nine net sets over the spawning season. Yellow perch appeared to be equally distributed between the seven index sites (Figure 2). Variability in catches was greatest at the southernmost site. These data may indicate that concentrations of perch move throughout the spawning season; data from all three years of this project will likely clarify these movements.

Nontarget species captured in the fyke nets included 276 alewife (*Alosa pseudoharengus*), 18 longnose sucker (*Catostomus catostomus*), 12 white sucker (*Catostomus comersoni*), 12 lake chub (*Couesius plumbeus*), 1 rock bass (*Ambloplites rupestris*), and 1 slimy sculpin (*Cottus*

cognatus). Nontarget species were captured in 25 of the 27 nets. Of the remaining two nets, one contained the smallest catch of yellow perch (21 perch).

Yellow Perch Population Structure

The average length of all of the measured adult perch was 211 mm (SD = 17, n = 9696). The length distribution of perch captured in our fyke nets was nearly centered around the mean (Figure 4). Males comprised 95.5% of all measured fish; females and unknowns comprised 0.2% and 4.3%, respectively.

The 1988 year-class (age-7) made up the greatest proportion (30%) of the 834 subsampled fish captured with fyke nets (Figure 3). Three 1981 year-class (age-14) and two 1980 year-class (age-15) yellow perch were collected in the subsampled fish. Over 69% of the subsampled fish were age-7 or older.

The smallest subsampled perch (133 mm, 28.11 g) was a 2 year old ripe male; the largest perch (331 mm, 530.36 g) was a 7 year old spent female. Subsampled fish dissections revealed a 59:1 male to female ratio.

Diel Larval Perch and Plankton Sampling

Relatively few yellow perch larvae were captured with the 0.5 m plankton nets, deployed at the surface at night, compared to previous years (Marsden et al. 1993). Virtually no larval yellow perch were captured after 13 June, with the exception of a single larva on 19 June and three larvae on 22 June. Average catch per unit effort (CPUE) of larval perch between 09 June and 02 July ranged between 0 and 5.9 fish•100m^{-3}, compared to CPUEs of over 100 fish•100m^{-3} in previous years (Marsden et al. 1993). Reduced abundances of alewife larvae were also noted. The abundance of ostracods, a zooplanktor, which has been relatively constant over all sampling periods since 1992 (unpublished data) declined by more than two orders of magnitude.

The 0.3 m net vertical movement sampling data indicated that alewife larvae were approximately equally distributed throughout the water column at night and nearly equally distributed at all depths greater than 2 m during the day. The depth of alewife larvae during the day appears to be influenced both by the depth of the thermocline and degree of water clarity (Figure 5). On those days when the Secchi depth was greater than the bottom depth (10 m), the larvae appeared to be concentrated at greater depths.

Harbor Sampling for Larval Perch

Five yellow perch larvae were captured in 12 surface pushes (709 m^3 total sampled) inside Waukegan Harbor. No perch larvae were captured in the harbor after 13 June; this date coincided with the absence of perch larvae in surface pushes conducted outside the harbor. The greatest proportion of larval fish captured in the harbor were alewife (50%). Other species of larval fish captured in Waukegan Harbor included: miscellaneous cyprinids (44%), three-spine stickleback (*Gasterosteus aculeatus*) 4%, and rainbow smelt (*Osmerus mordax*), unknown and unidentified (<2%).

Young-of-the-Year Sampling

Nine YOY yellow perch were captured in forty-five 10-minute bottom trawls, yielding a CPUE of 0.044 (fish•1000m^{-2}) for the year. The most abundant fish species captured were rainbow smelt 37.7%, alewife 27.9%, nine-spine stickleback (*Pungitius pungitius*) 24%, and spottail shiner (*Notropus hudsonius*) 6.9%. One or more boater chub (*Coregonus hoyi*), burbot (*Lota lota*), brown trout (*Salmo trutta*), Johnny darter (*Etheostoma nigrum*), longnosed dace (*Rhinichthys cataractae*), sculpin (*Cottus* spp.), three-spine stickleback, and adult yellow perch were also captured, and cumulatively represented < 4% of the total catch.

Genetic Stock Identification (Note: the results presented here are a final summary of the research results of two segments of this project.)

Protein electrophoresis

Protein eletrophoresis for 30 individuals from each of three Lake Michigan populations (Bailey's Harbor, Zion, and Green Bay) revealed that 2 of the 43 loci examined were polymorphic (Table 5). The Grand Traverse population contained only one heterozygote (GPI-A). None of the Lake Michigan populations had polymorphic loci that were above the 95% criterion.

Table 5. Allelic frequencies of polymorphic loci in populations of Lake Michigan yellow perch.

Locus	Allele Mobilities	Bailey's Harbor, MI	Zion, IL	Grand Traverse Bay, MI	Green Bay, WI
GPI-A	86	0.000	0.017		0.000
	100	1.000	0.983		1.000
GPI-B	100	1.000	1.000	0.983	1.000
	90	0.000	0.000	0.017	0.000
MDH-A	71	0.000	0.017		0.000
	100	1.000	0.983		1.000

RFLP analysis of mitochondrial DNA

The restriction endonuclease *HAE III* was the only enzyme to reveal polymorphism in the ATPase-6 gene with two distinct banding patterns. Frequency of the banding patterns for all four populations is shown in Table 6.

Table 6. Frequency of banding patterns A and B detected by digesting the ATPase-6 gene with the restriction endonuclease *Hae III* for four Lake Michigan populations.

Population	Banding Pattern A	Banding Pattern B
Bailey's Harbor	0.933	0.067
Grand Traverse Bay	0.767	0.233
Green Bay	1.000	0.000
Zion	0.800	0.200

RAPD analysis of nuclear DNA

Analysis of 15 primers from the Operon "L" series produced 3 polymorphic fragments from a total of 88 fragments.

CONCLUSIONS

These preliminary conclusions have been drawn from the second of three years of sampling, and should therefore be used with caution.

Fyke nets generally capture more yellow perch and the fish are more representative of the length-structure of the population than gill nets fished for the same length of time. Age-distributions of yellow perch captured in both types of assessment gear are similar; thus, both types of gear are equally useful for describing the year-class structure of the population. Sampling using fyke nets is more efficient (more fish, less size selective, easier to process) and causes less mortality than gill nets. However, the IDNR is restricted to sample using gill nets because of the limitations of the sampling vessel employed.

Spawning yellow perch appeared equally distributed along the entire nine miles of shoreline sampled around the IDNR Lake Bluff index station. The high variability in catches at each of the sampling sites implies that the fish move frequently during the spawning period, rather than spawning in one limited area. Therefore, sampling at the index station may reflect the daily movements of spawning fish rather than the abundance of fish in the Lake Bluff area.

The greatest proportion (30%) of yellow perch collected with fyke nets in 1995 were 7 year-olds (1988 year-class); the average length of all measured fish was 211 mm. The stretched measure of INHS 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 1995 sampling. These results 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.

Vertical sampling data indicated that alewife larvae are approximately equally distributed throughout the water column at night and nearly equally distributed at all depths greater than 2 m during the day. This is contrary to the common belief that larvae migrate vertically in the water column to avoid predators and to maximize food availability and are concentrated at the surface at night. The depth which larval alewives occupy during the day appears to be influenced both by the depth of the thermocline and degree of water clarity. On those days when the Secchi depth was greater than the bottom depth (10 m), the larvae appeared to be concentrated at greater depths than when the Secchi depth was not the bottom.

Recent work by Savitz et al. (1990) in several Chicago harbors indicated that after an early spring plankton bloom, harbor waters are essentially empty of larval fish food. Nevertheless, we found numerous larval fish species in Waukegan Harbor as late as 28 June. Chicago's harbors were largely constructed on wetlands which served as the nursery grounds of larval yellow perch. The near absence of yellow perch larvae in Waukegan Harbor and presence of larvae just outside the harbor may indicate that spawning does not occur in the commercial (north) basin of the harbor. Waukegan Harbor is susceptible to heavy boat traffic and is the northern Illinois port for large shipping vessels. The turbulence caused by these vessels along with the lack of structure may limit yellow perch spawning in this harbor. Future work on this project will include comparison of zooplankton densities inside and outside the harbor, and comparison of recent samples collected outside the harbor with those from years when yellow perch were not in decline.

Nine young-of-the-year yellow perch were captured in forty-five 10-minute bottom trawls. Approximately 204,000 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 be recruited to the subadult 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. The increased water clarity is a consequence of reduced plankton populations. Water clarity may also affect juvenile yellow perch survival by increasing their susceptibility to predation by visual feeders such as alewife.

Genetic analysis of Lake Michigan yellow perch using protein electrophoresis, RFLP analysis of mtDNA, and RAPD analysis of nuclear DNA revealed very few polymorphisms. RFLP analysis of mtDNA using digestion of the ATPase-6 gene with the restriction endonuclease *Hae III* revealed the most variability; however, there were not sufficient frequency differences among populations to identify distinct genetic groups in Lake Michigan. In order to determine whether genetically distinct populations are present, we will need to use another technique such as microsatellite analysis. This technique requires development of a specific primer for yellow perch or another closely related percid species. Such a primer is currently being developed for walleye at the University of Minnesota. With such a primer, we could analyze an additional region of the yellow perch genome in an effort to detect variation which could be used to identify genetic stocks in Lake Michigan.

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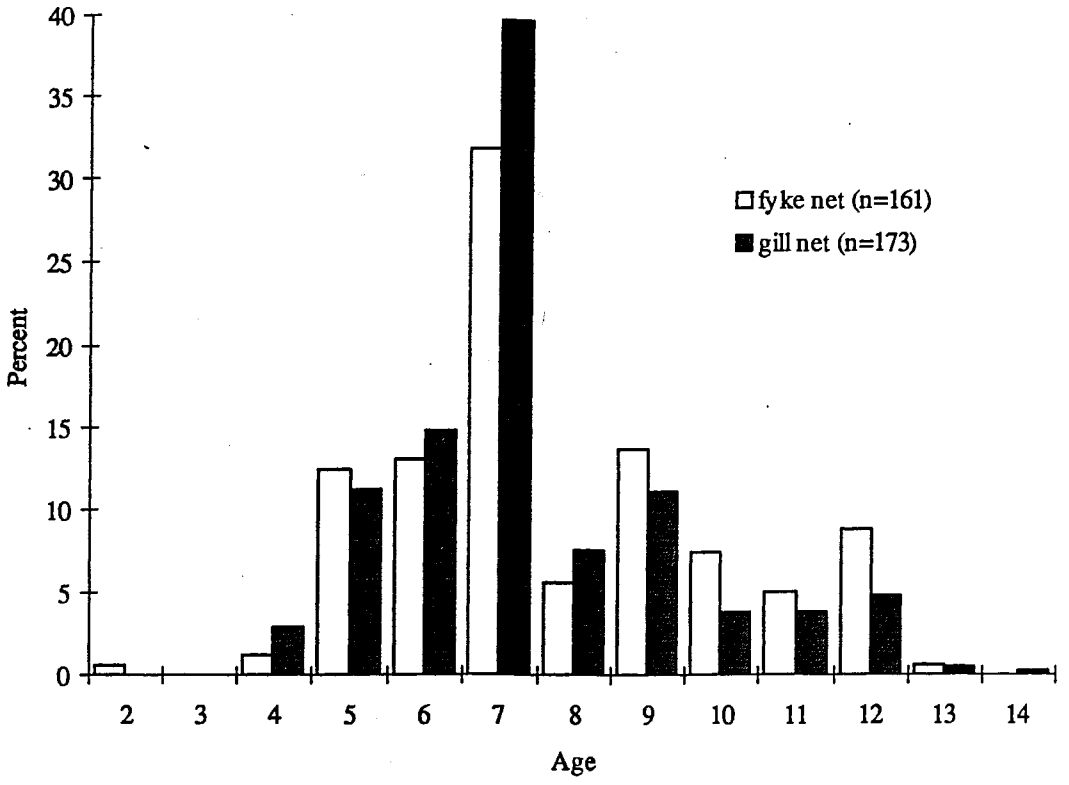

Figure 1. Age-frequency distributions of yellow perch captured with two types of sampling gear on 13 and 14 June, 1995, in Lake Michigan, near Lake Bluff.

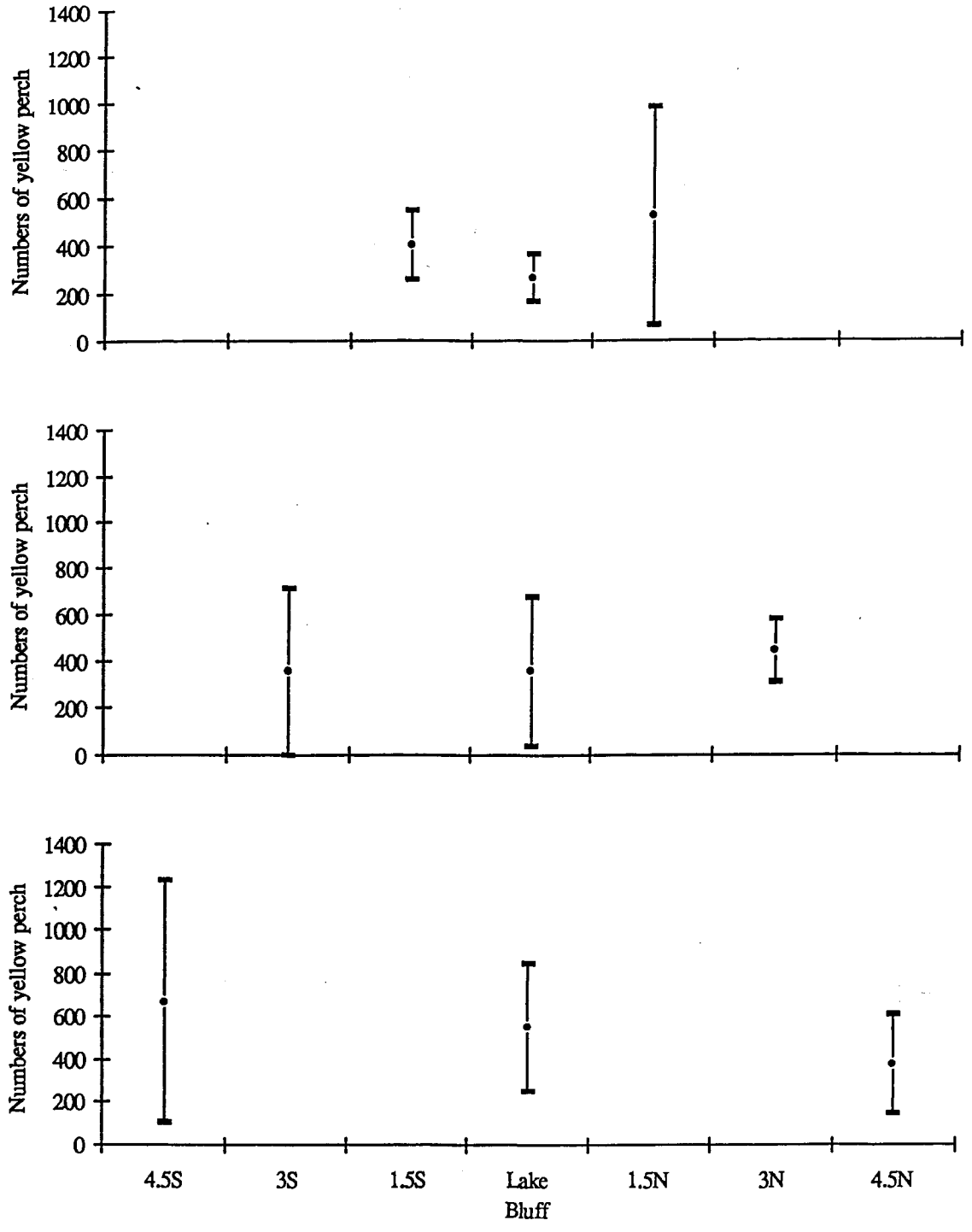

Figure 2. Numbers of yellow perch captured in fyke nets at the Illinois Department of Natural Resources Lake Bluff index station and at three distances (1.5, 3, and 4.5 nautical miles) north and south of that index station between 22 May and 22 June, 1995. Error bars represent one standard deviation above and below the mean.

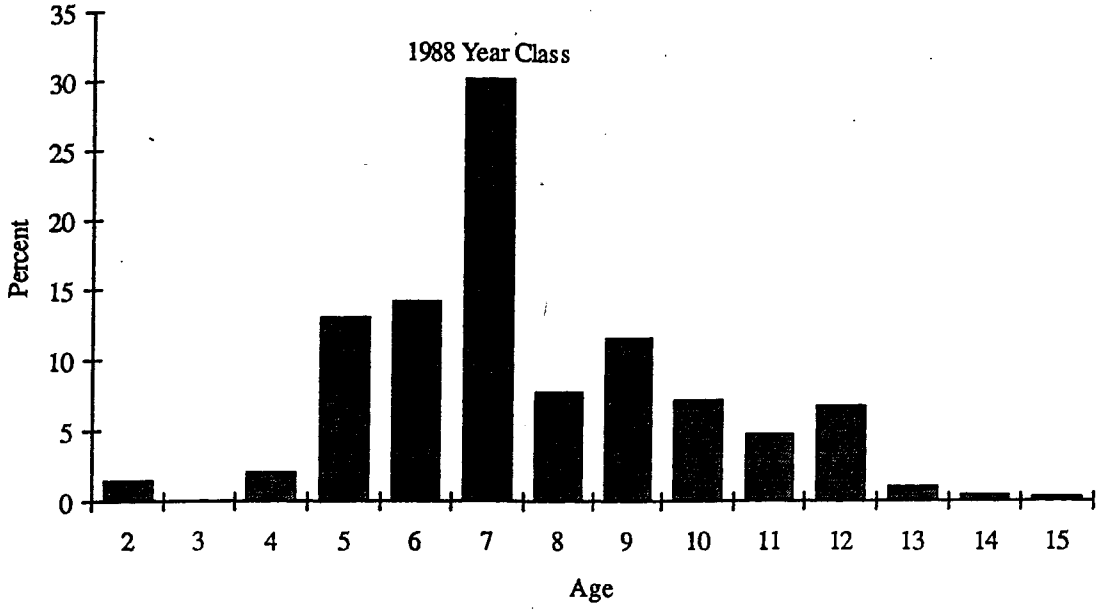

Figure 3. Age-frequency distribution of 834 yellow perch captured in INHS fyke nets between 22 May and 22 June, 1995, in Lake Michigan, near Lake Bluff.

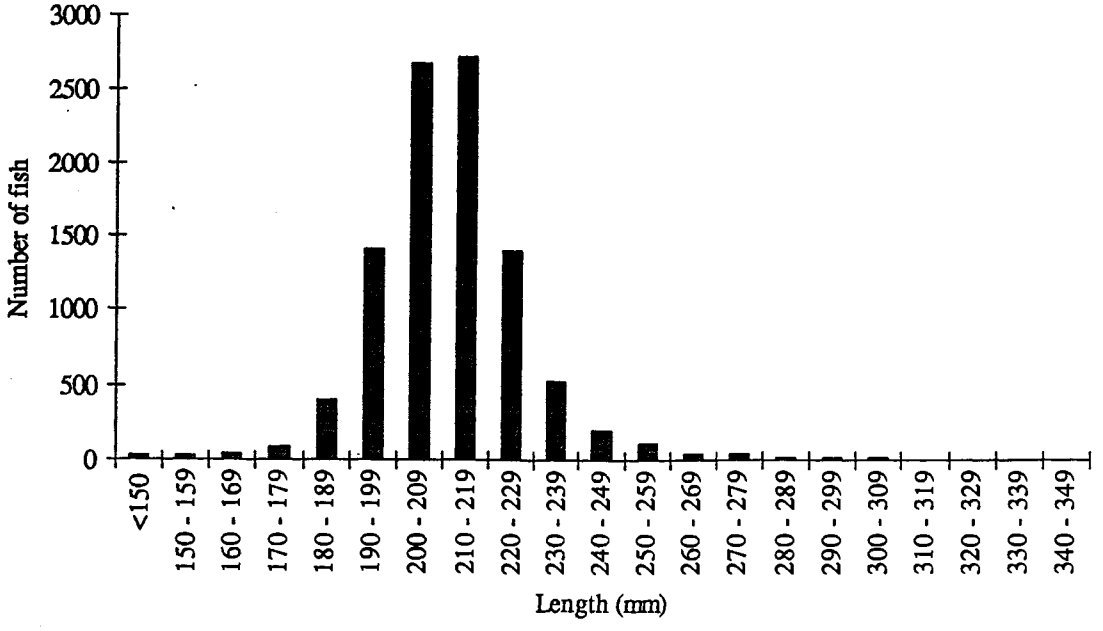

Figure 4. Length distribution of yellow perch captured in INHS fyke nets between 22 May and 22 June, 1995, in Lake Michigan, near Lake Bluff.

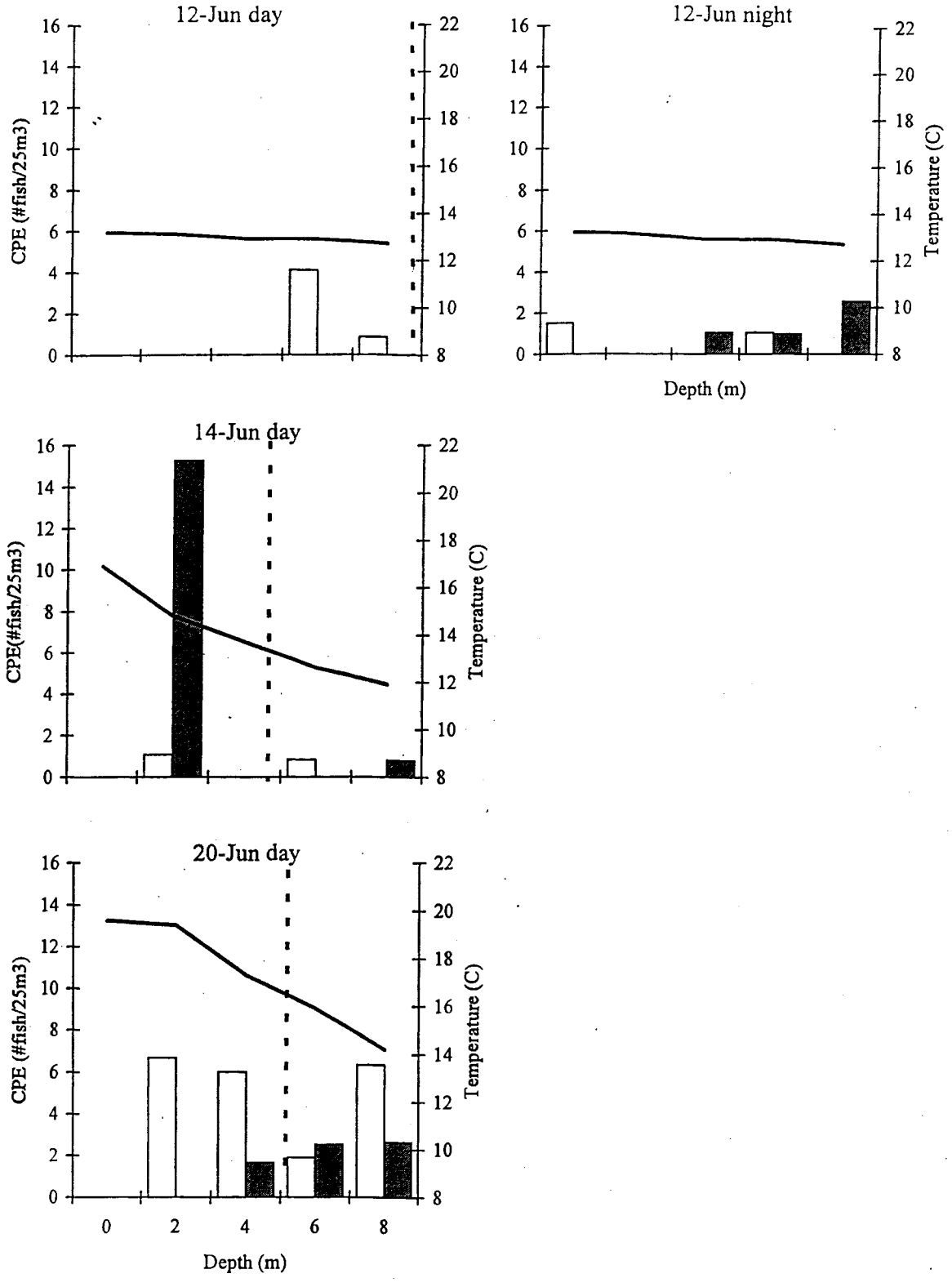

Figure 5a. Catch per unit effort (#fish/100m^3) of alewife larvae collected north of Waukegan Harbor at depths of 0, 2, 4, 6, and 8 m between 12 June and 13 July, 1995. Secchi depth is indicated by the vertical dashed line.

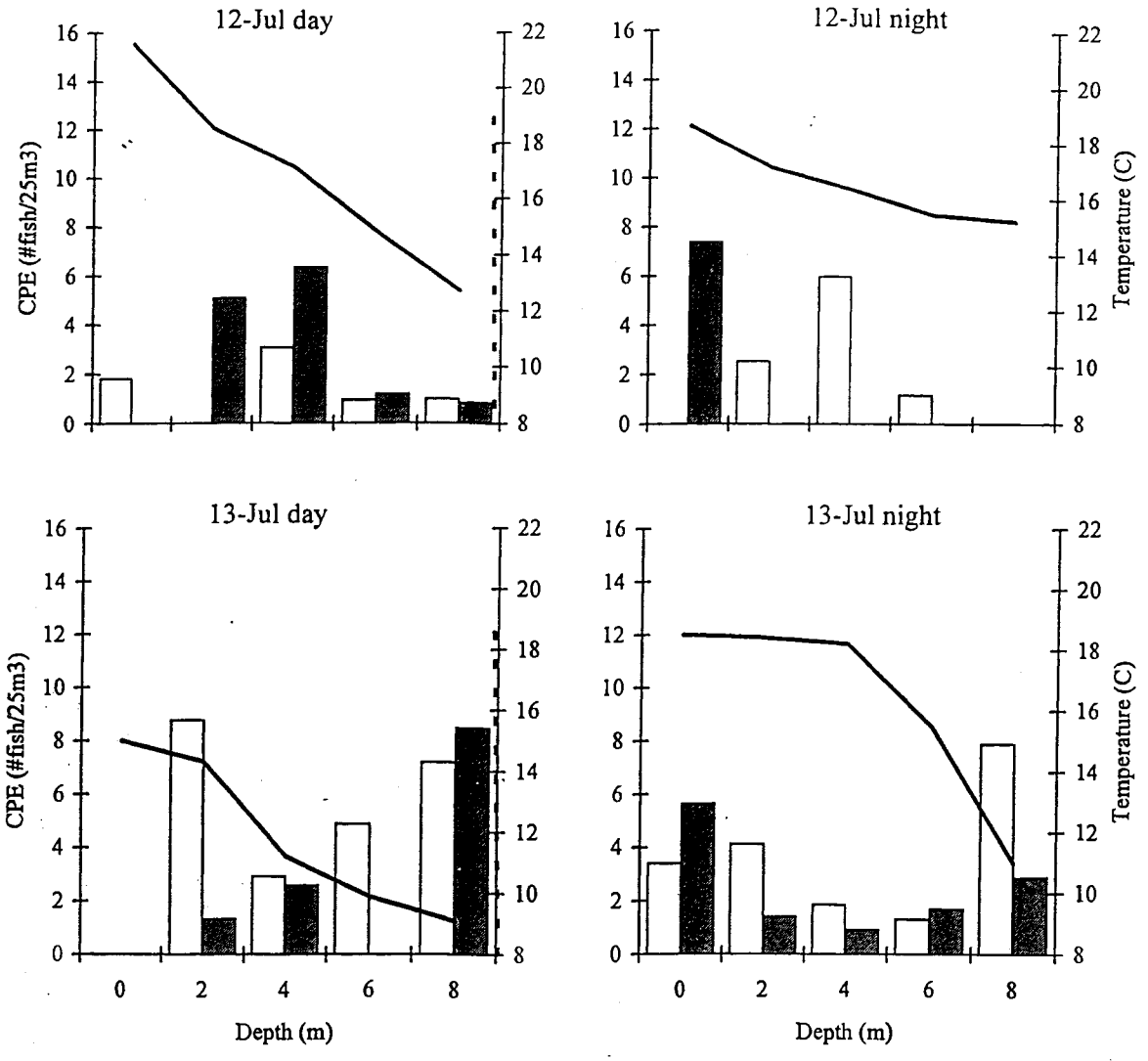

Figure 5b. Catch per unit effort (#fish/100m^3) of alewife larvae collected north of Waukegan Harbor at depths of 0, 2, 4, 6, and 8 m between 12 June and 13 July, 1995. Secchi depth is indicated by the vertical dashed line.