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Yellow Perch Population Assessment in Southwestern Lake Michigan, Including Evaluation of Sampling Techniques
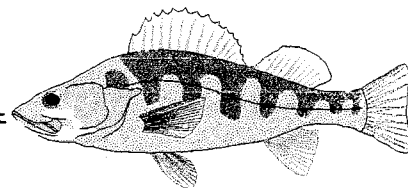
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Annual Report
to
Illinois Department of Conservation

Center for Aquatic Ecology

Steven R. Robillard, Todd Kassler, and J. Ellen Marsden

Illinois Natural History Survey
Lake Michigan Biological Station
400 17th Street
Zion, Illinois 60099

June 1995

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

April 1, 1994 - March 31, 1995
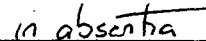
Steven R. Robillard, Todd Kassler, and J. Ellen Marsden

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Center for Aquatic Ecology, Illinois Natural History Survey
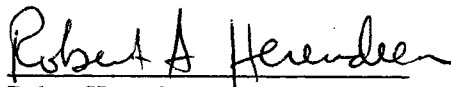
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J. Ellen Marsden
Principal Investigator
Center for Aquatic Ecology

_____
David P. Philipp
Principal Investigator
Center for Aquatic Ecology

_____
Robert Herendeen
Center Director
Center for Aquatic Ecology

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EXECUTIVE SUMMARY

The objectives of this study are to expand the Illinois Department of Conservation (IDOC) annual yellow perch stock assessment data, compare catches from IDOC and 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. In the first year of the project we added a supplemental index station to the two IDOC 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 gear types used in INHS and IDOC studies could be calibrated. The location of the IDOC 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 management strategies for this important sport and commercial species. New information on specific areas where yellow perch spawning occurs will strengthen IDOC spawning assessments. Larval perch sampling will expand our understanding of the early life history of yellow perch in terms of larval movements, feeding, and survival. Early life history data will eventually lead to an understanding of factors affecting juvenile 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 first year of the project and must be regarded as preliminary, particularly as some of the objectives depend upon a time-series of data over three years.

1. Fyke nets captured more fish than gill nets and were more representative of the length-structure of yellow perch when both gears were fished for the same length of time. Age distributions of yellow perch captured in both assessment gears were similar.

2. Preliminary results from the spawning concentration data suggest that the IDOC Lake Bluff index station is not the focus of spawning in the Lake Bluff area. The greatest percentage of yellow perch were captured south of the Lake Bluff index site.

3. The greatest proportion of yellow perch collected in fyke nets were 6 year-olds (1988 year-class); the average length was 202 mm. The stretched measure of these nets is designed to capture fish 150 mm and greater. Under optimal conditions of population stability, the greatest proportion of fish captured would be smaller and younger.

4. More larval fish were collected at or below the thermocline during the day and at the surface at night than at any other depth. This result suggests that larval alewife vertically migrate from the surface to greater depths during the day, and back to the surface at night. Presumably, the larvae migrate to avoid predators and to maximize food availability. Ostracods, an abundant zooplankter, were also numerous on the surface at night but virtually absent during the day; this result is consistent with other findings that suggest they are benthic during the day.

5. The 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 structure may limit yellow perch spawning in this harbor.

6. We captured one young-of-the-year yellow perch in thirty-four 10-minute bottom trawls. Approximately 154,000 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. Analysis of protein loci and mitochondrial and nuclear DNA revealed a small number of variable markers which could potentially be used to differentiate stocks in Lake Michigan. Additional work is needed to determine how many of these markers can be used reliably, and whether they provide sufficient variation to differentiate populations of yellow perch.
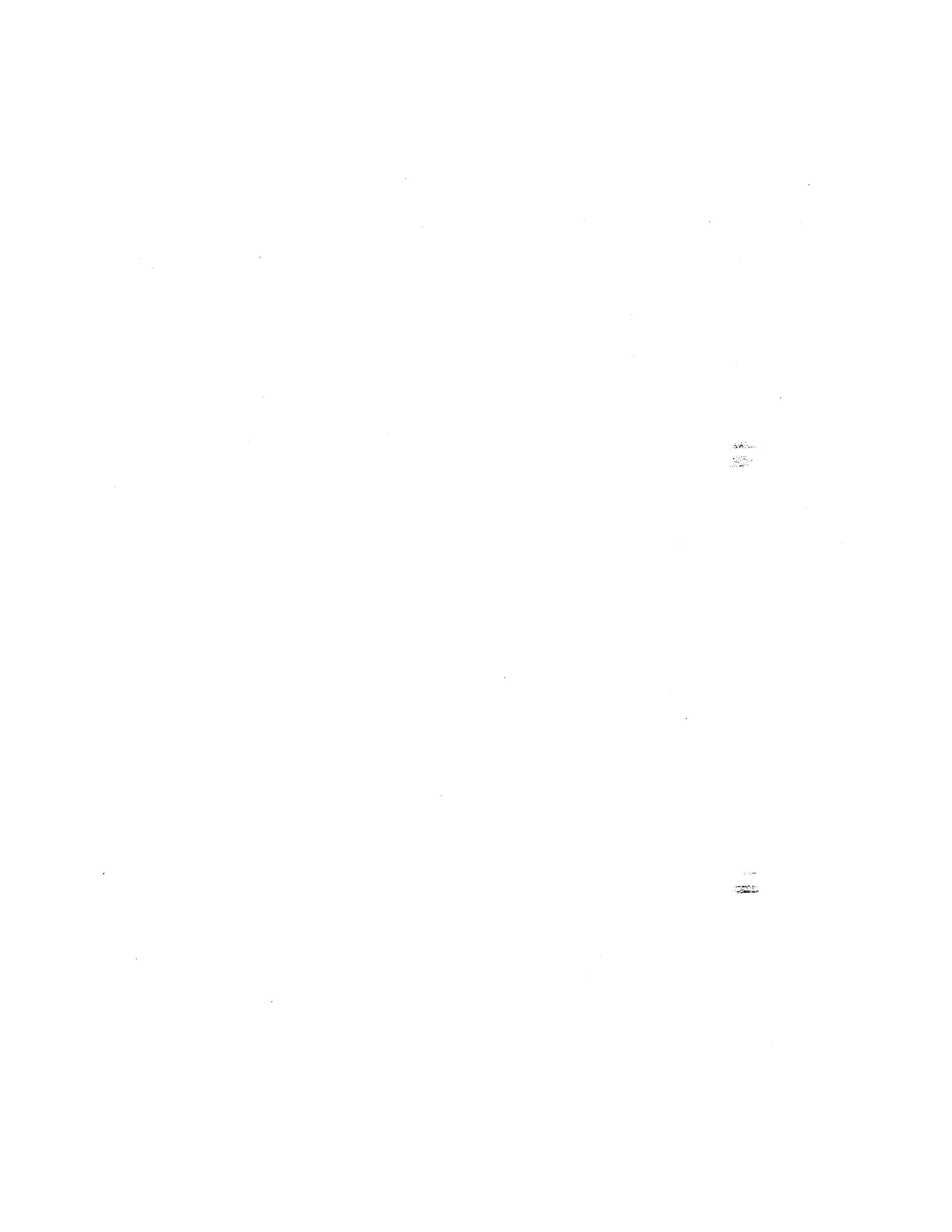
INTRODUCTION

Yellow perch (*Perca flavescens*) are an important commercial and sport fish throughout much of their range in North America. Their schooling behavior enhances 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. 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 commercial and sport fishery for the four states bordering Lake Michigan.

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 through 1993. Consequently, the yellow perch population is aging - the population as a whole is 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 Conservation (IDOC) 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-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 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.

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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

Yellow perch were collected using fyke nets deployed by INHS staff and graded-mesh gill nets deployed by IDOC. 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. All gill nets used for sampling were composed of five panels (Table 1).

Table 1. Length and mesh size of panels used in IDOC 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. Abundance sampling was performed with a 0.5 m dia net with a 5:1 scope. Vertical distribution and harbor sampling was performed with a 0.3 m dia net with a 5:1 scope.

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 Conservation added a transect outside Calumet Harbor to its index stations to monitor spawning yellow perch. All sampling at the Calumet Harbor index station was conducted by J. Camalick, with IDOC personnel on board his boat. Gill nets were set at depths of 7.2 and 12.8 m (4 and 7 fathoms) on 06 June and retrieved after 24 hrs, and at 14.6 and 18.3 m (8 and 10 fa) on 07 June and retrieved after 48 hrs. Gill nets set on 07 June could not be retrieved after the preferred 24 hr sampling period due to inclement weather. All fish in all nets were counted. A subsample of 25 fish from each gill net panel was weighed to the nearest 10 g, measured (total length) to the nearest 5 mm, dissected to determine reproductive status, and aged using 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 gill net and one fyke net were set end to end, parallel to shore, at depths of 7.2 and 10.8 m (4 and 6 fa) on 02 June, 1994, at the IDOC Lake Bluff index station. Nets were retrieved 24 hrs later. A subsample of 25 yellow perch was collected from the 7.2 m net; twenty-six yellow perch were subsampled from the other net. Subsampled fish were measured to the nearest 1 mm (total length), weighed to the nearest 0.01 g, dissected to determine reproductive status, and aged using otoliths. 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.

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

A total of 51 fish captured in fyke nets and 111 fish caught in gill nets were aged. Age-frequency distributions were compared by Peterson Chi-square (Zar 1984).

Validation of Index Station Locations
Fyke nets were set at the IDOC Lake Bluff index station and either 1.5, 3, or 4.5 nautical miles (nm) north and south of that station. All nets were set along the 5 m depth contour line, usually parallel to shore. Three sampling units (Lake Bluff +/- 1.5, 3, and 4.5 nm) were completed; i.e., 9 net sets.

Subsamples of 25 yellow perch from each net were collected. Subsampled fish were measured to the nearest 1 mm (total length), weighed to the nearest 0.01 g, dissected to determine reproductive status, and aged using otoliths. 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.

Aging of Yellow Perch
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 the distinction between bands. Each otolith was mounted in clay, charred surface up, on a numbered microscope slide. The charred surface was wetted with immersion oil to enhance the annuli before viewing. One half of one otolith from each fish was viewed under a dissecting microscope at 30-60X magnification.

The dark bands produced as a result of charring the broken surface of the otolith were counted as annuli. Otolith annuli were counted when they were conspicuous in the ventral field and were apparent somewhere in the dorsal field. Spacing between annuli was assumed to be regular, i.e., the reader assumed that a year of little growth was not followed by a year of markedly increased growth. 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
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 20 June and 18 July, 1994. The net was either pushed at the surface with a bow-mounted frame or towed from the transom at depth at a speed of approximately 1 m•sec^{-1}. Four complete vertical strata samples (3 day, 1 night) were collected at the 10 m depth site, and two samples were collected at the 5 m depth site (1 day, 1 night). Sampled depths at the 5 m site were surface and 3 m. Each 0.25 nm push or tow sampled approximately 20 m^3 of water. Larval fish were extracted from plankton samples and identified to genus, species when possible. Ostracods were extracted and enumerated.

Abundance estimates
Samples were collected near Waukegan Harbor on three nights between 22 June and 30 June, 1994, with a bow-mounted plankton net at a speed of approximately 2 m•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. Each 0.5 nm surface push sampled approximately 162 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 days and nights as the vertical movement sampling between 15 June and 07 July, 1994. The net was pushed at the surface with a bow-mounted frame at night and towed obliquely through the water during the day at a speed of approximately 1 m•sec^{-1}. Four night samples (8 surface pushes) and two day samples (6 oblique tows) were collected. Each push and tow sampled approximately 16m^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 bi-weekly (8 times) between 08 August and 20 October, 1994, at various depths between 3 and 12 m at a speed of approximately 2 m•sec^{-1}, 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

Sample Collection

Adult yellow perch were collected during the spawning season with various gears 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. Twenty polymorphic loci were identified during the screen. To date we have examined perch from Bailey's Harbor, Zion, and Green Bay at these loci, and found only two of the loci (GPI-A and MDH-A) to be polymorphic in the perch from Zion; all loci were monomorphic in the Bailey's Harbor and Green Bay perch. These loci, plus additional loci found to be polymorphic in the Minnesota and Wisconsin populations, will be examined in the remaining Lake Michigan populations.

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	Muscle	TC	M
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-2-dehydrogenase	G2DH-1	Liver	TC	P
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	Isocitric dehydrogenase	IDH-A	Muscle	TC	M
		IDH-B	Muscle	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	Liver	RID	P
--------	Peptidase (leu-tyro)	LT-1	Liver	RID	M
		LT-2	Liver	RID	M
2.7.5.1	Phosphoglucomutase	PGM	Liver	TC	P
1.1.1.43	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-1	Liver	EBT	M

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) have been 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 same three populations used in screening allozyme loci. A total of 27 markers have been examined using three genes and digested with 9 restriction endonucleases. We also examined the D-loop/12s region in the mitochondrial genome and digested product with the same 9 restriction endonucleases.

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. To date, eleven out of 20 RAPD primers (L-Operon L series) have been screened for polymorphism (L1, L2, L4, L5, L8, L10, L11, L13, L15, L17, and L19).

RESULTS

Supplemental Index Gill Netting

A total of 224 yellow perch were captured in IDOC assessment gill nets at the Calumet Harbor index site.

Calibration of Data from Fyke Netting and Gill Netting

Greater numbers of yellow perch were captured with fyke nets than gill nets at both sites (7.2 and 10.8 m). The total number of yellow perch captured in gill nets was 247 and 132 for the 7.2 and 10.8 m nets, respectively, compared to 420 and 382 yellow perch in the equivalent fyke nets. More fish were captured in the 2" mesh panel than any other panel in both gill nets; no fish were captured in the 1" mesh (Table 4). Chi-square tests revealed no significant differences ($P<0.65$) between the age distributions of fyke net and gill net captured yellow perch (Figure 1).

Table 4. Length comparison of yellow perch captured with fyke nets and gill nets in Lake Michigan, near Lake Bluff, 03 June, 1994.

gill net	7.2 m depth			10.8 m depth		
mesh size (in)	mean length (mm)	SD	n	mean length (mm)	SD	n
1	-	-	0	-	-	0
1.5	177	12	10	176	17	8
2	204	10	25	201	8	25
2.5	233	19	13	241	18	14
3	263	44	5	283	15	10
fyke net	202	17	420	203	15	382

Validation of Index Station Locations

More fish were usually captured at the southern sampling sites than at the IDOC Lake Bluff index station or north of the Lake Bluff index station (Figure 2). However, the variability in catches across sampling days was also highest at the southern sites. These data may indicate that concentrations of perch move throughout the spawning season; data from the next two years of this project will likely clarify these movements.

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Aging of Yellow Perch
The 1988 year-class (age 6) made up the greatest percentage (34%) of the fish captured with fyke nets (Figure 3). Three fish from the 1980 year-class (age 14) were collected in the 715 subsampled fish.

Diel Larval Perch and Plankton Sampling
Relatively few yellow perch larvae were captured with the plankton nets compared to previous years (Marsden et al. 1993). Larval yellow perch constituted <1% of the total larval fish captured compared to 50-70% of total captures in previous years during the same sampling time period (15 June - 30 June). Consequently, alewife made up the greatest percentage of larval fish captured. Alewife abundance was also greater than for previous years during the sampling period (Marsden et al. 1993).

Alewife larvae were more abundant at the surface at night and at or below the thermocline during the day than at any other sampled depths (Figure 4).

Harbor Sampling for Larval Perch
No yellow perch were captured in 8 surface pushes and 6 oblique tows. One larval alewife was captured in each of three night samples; two larval alewife were captured in one night sample. Two alewife larvae were captured in one of the day samples. Several (11) miscellaneous cyprinid species were captured in night samples.

Young-of-the-Year Sampling
One YOY yellow perch was captured (05 October, 5 m depth) in 34 trawls, yielding a catch per unit effort (CPUE) of 0.007 (#fish/1000m^2) for the year. Young-of-the-year and adult rainbow smelt comprised 59% of the total trawl catch (spottail shiner 21.4%; alewife 18.6%; yellow perch, stickleback, sculpin, and unknown 1%).

Genetic stock identification
Protein electrophoresis
Protein eletrophoresis was completed for 30 individuals from each of three populations, Bailey's Harbor, Zion, and Green Bay. Only 2 of the 20 loci examined were polymorphic in Lake Michigan populations (Table 5). Seven of the 20 loci revealed low levels of polymorphism in populations from Minnesota and Wisconsin; GPI-A, MPI-1, and PGM-A were polymorphic at the 95% level, and G2DH-1, GPI-B, LDH-B, and MDH-A were polymorphic at the 99% level.

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

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

RFLP analysis of mitochondrial DNA
We have determined that 25 markers are monomorphic. Two additional markers using ATPase 6, digested with Dde I and Hae III, have shown variation, but we have not been able to resolve every fragment; as a result, they have not been scored. Additional work on optimizing the electrophoretic conditions should allow us to score those markers. We will also examine the D-loop/12s region in the mitochondrial genome and digest product with the same 9 restriction endonucleases.

RAPD analysis of nuclear DNA
Preliminary data suggest a total of 49 scorable bands using 7 of the 11 primers that were screened (L1, L2, L4, L5, L8, L10, and L11). Eight of the scorable bands indicate varying levels of polymorphism, however, no repeatability

estimates have been calculated. Additional primers will be screened before decisions are made on which polymorphic primers to use.

CONCLUSIONS

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

Fyke nets capture more fish 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 assessment gears are similar; thus, both gears 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, IDOC is restricted to sample using gill nets, due to the limitations of the vessel employed.

The IDOC Lake Bluff index station does not appear to be the focus of spawning in the Lake Bluff area. Overall, the greatest percentage of yellow perch were captured south of the Lake Bluff index site. The variability in catches implies that the fish move frequently during the spawning period, rather than spawning in one limited area.

The greatest proportion (34%) of yellow perch collected with fyke nets were 6 year-olds (1988 year-class); the average size was 202 mm. The stretched measure of these nets is designed to capture fish 150 mm and greater. Under optimal conditions of population stability, the greatest proportion of fish sampled would be smaller and younger than those captured during 1994 sampling. These results confirm that, due to reduced juvenile survival in the past several years, the average age and size of the yellow perch population in Lake Michigan is continuing to increase.

The greatest proportion of larval fish were collected at or below the thermocline during the day and at the surface at night. Presumably the larvae migrate vertically in the water column to avoid predators and to maximize food availability. However, temperature and energetics are also important - the water is very cold below the thermocline and long vertical migrations are energetically expensive. Ostracods were also more numerous on the surface at night and virtually absent during the day. Ostracods are a sizable component of juvenile yellow perch diets (Scott and Crossman 1973), so we expect that larvae would follow the diel migration of their prey.

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. Chicago's harbors were largely constructed on wetlands which served as nursery grounds of larval yellow perch. The 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 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 with those from years when yellow perch were not in decline.

A single young-of-the-year yellow perch was captured in thirty-four 10-minute bottom trawls. Approximately 154,000 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. 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 (Brandt 1987).

Previous attempts to find variable genetic characters in yellow perch have used only protein electrophoresis, and have not been successful (e.g., Leary and Booke 1982). We found two variable protein loci in a single sample from Lake Michigan; analysis of the remaining samples may reveal additional polymorphisms. We found a similar paucity of variability in mitochondrial DNA. To date we have found two potential mitochondrial DNA markers, but additional work is needed to enhance the resolution of bands. Work in the second segment of this project will focus on finding additional markers in the D-loop/12s region of the mitochondrial genome. Eight potential markers have been found in the nuclear DNA, but additional analysis is needed to determine how reliably they can be used.

ADDENDUM

During this segment of the project, we conducted a study to compare aging of yellow perch by the method used by IDOC (scales) with the method used by INHS (otoliths). The results of this study have been submitted to the Journal for Great Lakes Research as a manuscript by S. Robillard and J. E. Marsden entitled "Evaluation of the otolith and scale methods for aging yellow perch in Lake Michigan". Reprints of the paper will be sent to IDOC if and when it is published; a copy of the manuscript has been sent to the IDOC Lake Michigan Program.

ACKNOWLEDGMENTS

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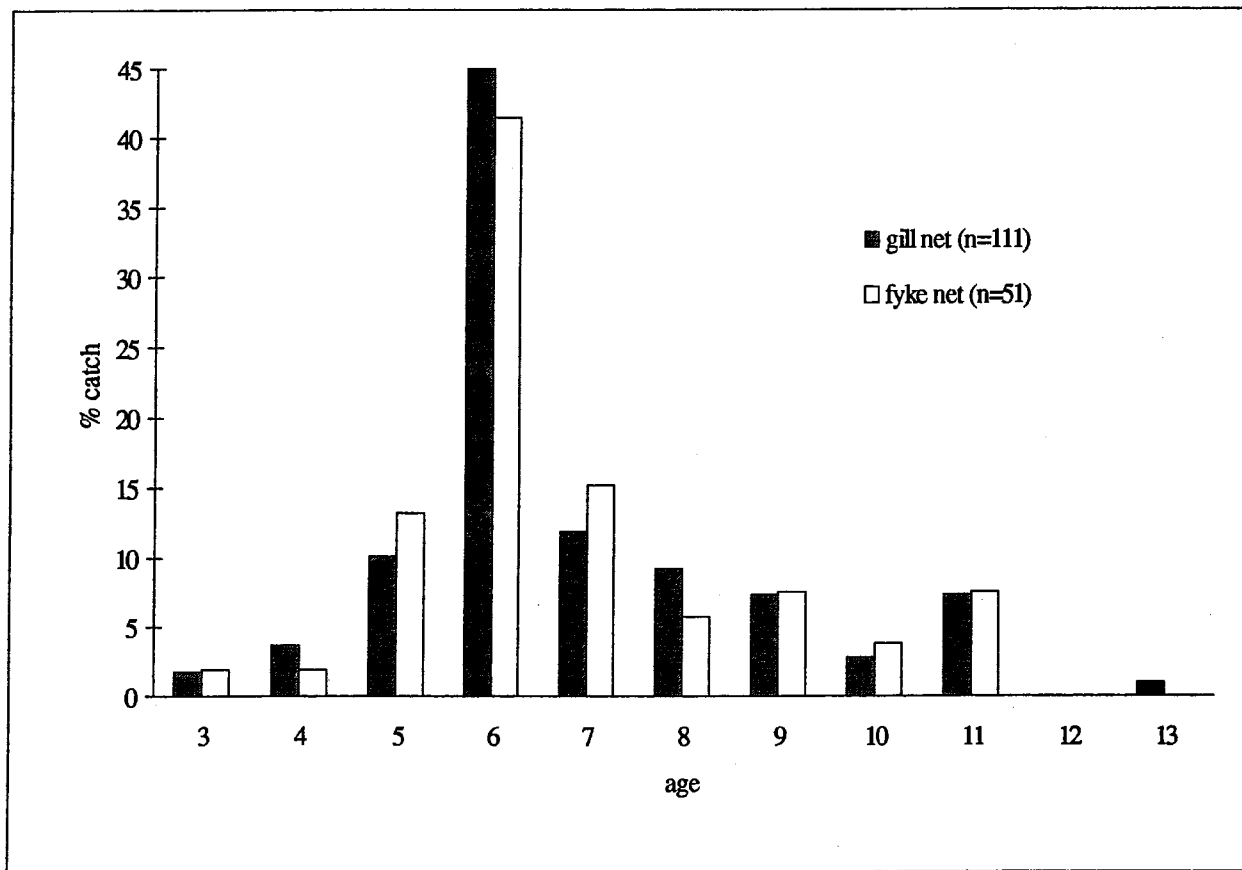Zar, J. H. 1984. Biostatistical Analysis, 2nd ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Figure 1. Age-frequency distributions of yellow perch captured with two types of sampling gear in Lake Michigan, near Lake Bluff, 03 June, 1994.
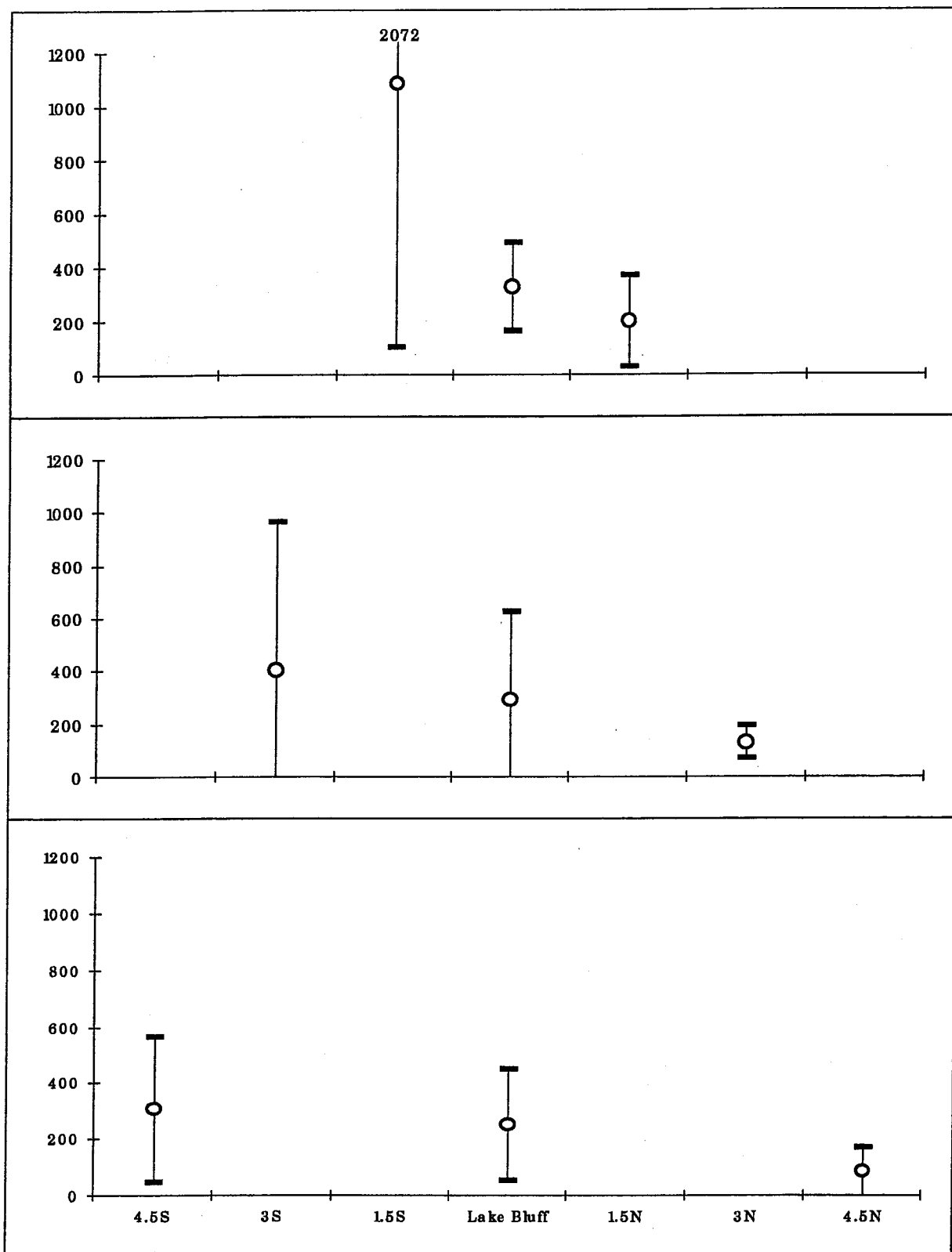
Figure 2. Numbers of yellow perch captured in fyke nets at the Lake Bluff index site and 1.5, 3, and 4.5 nautical miles north and south of Lake Bluff between 11 May and 28 June, 1994. Error bars represent one standard deviation above and below the mean.
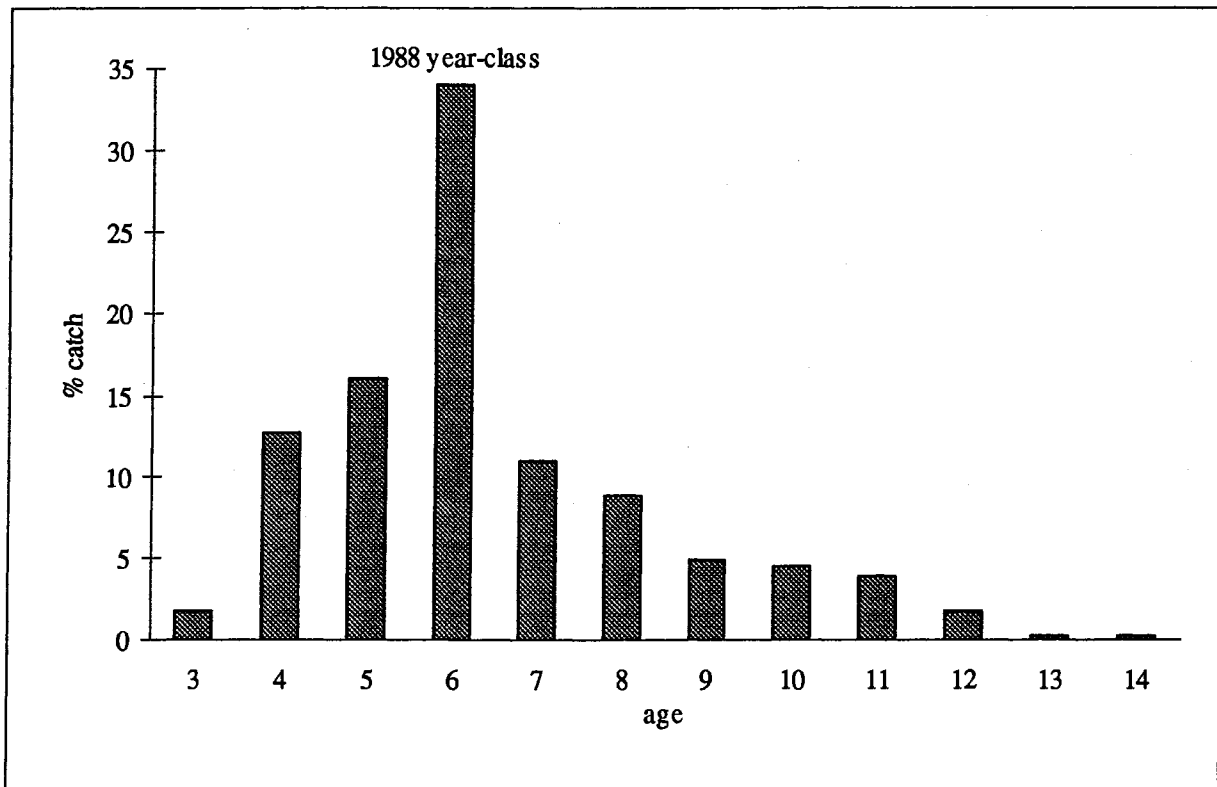
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Figure 3. Age-frequency distribution of 715 yellow perch captured in fyke nets between 11 May and 28 June, 1994, in Lake Michigan, near Lake Bluff.
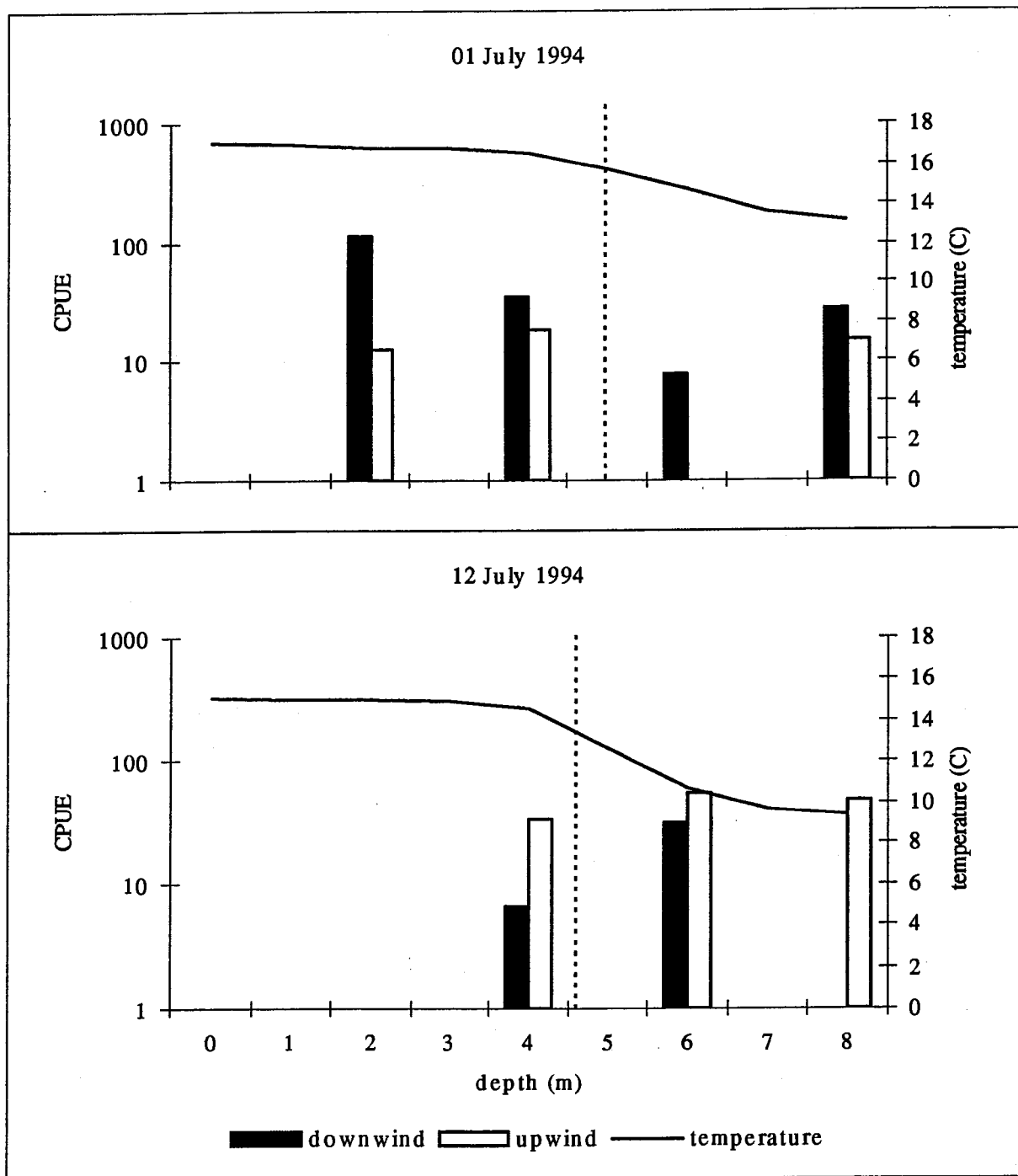
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Figure 4. Catch per unit effort (#fish/100m³) of alewife larvae collected at depths of 0, 2, 4, 6, and 8 m during the day. Secchi depth is indicated by the vertical dashed line.

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