

COMPARISON OF THE YELLOW PERCH, Perca flavescens (Mitchell),  
POPULATIONS IN HENDERSON LAKE AND SAVANNE LAKE, ONTARIO

by

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A thesis submitted to the Department of Biology in partial  
fulfillment of the requirements for the  
Degree of Master of Science

Lakehead University  
Thunder Bay, Ontario

December, 1984

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## ABSTRACT

Yellow perch (Perca flavescens) in Henderson Lake exhibit stunted growth and poor condition at all ages. In addition, they have lower fecundity, longer life span, slower maturation rate, and greater survival compared to perch in Savanne Lake.

Gillnet catch-per-unit-effort (CPUE) indicated that abundance of recruited perch was comparable between lakes, but that fish are at least 5 years of age before they are recruited to this gear in Henderson Lake. Gillnet CPUE identified diurnal activity periods for perch and walleye (Stizostedion vitreum vitreum) in both lakes, but the evening offshore movements and morning onshore movements by perch in Henderson Lake were more pronounced and prolonged. Sampling in littoral areas with bag seines prove that perch and walleye closely associate at dawn and dusk in Savanne Lake, but do not associate at any time in Henderson Lake. Young perch are the dominant littoral species in Savanne Lake, but share dominance with unutilized mimic shiners (Notropis volucellus) and blacknose shiners (Notropis heterolepis) in Henderson Lake.

No relationship between spring water temperature or precipitation and year-class strength of Savanne young-of-the-year (YOY) walleye and perch year-classes could be demonstrated. Strong YOY walleye year-classes did not occur in the same years as strong YOY perch year-classes in Savanne Lake. However, weaker YOY walleye year-classes were produced in those years when YOY perch grew faster.

Seasonal and annual changes in forage abundance determined the frequency of prey items found in Savanne and Henderson perch stomachs. Intraspecific diet overlap and cannibalism was greater in Henderson



perch than in Savanne perch. The incidence of cannibalism was a function of the availability of alternate prey in both lakes. Predation by walleye, northern pike (Esox lucius), and perch on same prey (ninespine sticklebacks Pungitius pungitius, perch, and mayfly nymphs) is frequent in Henderson Lake, but interspecific segregation of prey utilization occurs in Savanne Lake.

Values for mean age to maturity of male and female perch as determined by the proposed Probit Method were more comparable to empirical values than those determined by the Abrosov, Modified Abrosov, and Lysack methods.

Apparent differences between the two populations in behavior and biological characteristics are attributed to: lower predation levels on Henderson perch; differences in the physical structure of the two lakes. Mutual predation on the forage base in Henderson Lake at both an intraspecific and interspecific level helps to amplify these differences. The effect of physical characteristics, especially water transparency and macrophyte growth on predator-prey interactions is also examined.

## ACKNOWLEDGMENTS

I thank my supervisor Dr. Walter Momot for his support, constructive criticisms, patient editing and sense of humour.

Drs. Peter Colby and Murray Lankester, your critical review of this manuscript is greatly appreciated.

I thank Dr. Peter Colby and Dominic Baccante of the Walleye Research Unit, OMNR, Thunder Bay for the use of their Savanne Lake research facility. Your generous support in the field and during the final preparation of the thesis made life at the end of the Henderson road that much easier.

It takes two to tango --- no, set a gillnet, so I especially thank the technicians who suffered through midnight sampling sessions and my overzealousness for the almighty "N": Wendy Carrington, Barb Lovie, David Orr, Chris Nunan and Kit Kovacs.

Don Lough and his assistant of the Science Workshop at Lakehead University braved a weekend trek to Henderson Lake to build the best designer chipboard cabin on crown land. Don also constructed top-notch customized lab and field equipment whenever necessary.

I thank my friends and fellow graduate students for their support, peer pressure and fun-loving attitude during the often trying times of my graduate career. My sanity is intact thanks to you --- I think?!!

A special note of appreciation to Kim for his support and comic relief. You can finally have your shoulder back!

I thank Leslie Morgan for doing an excellent job of preparing the figures; and Joan Pineda for typing the Appendices.

I thank Phil Ryan and the Lac Des Milles Lacs Fisheries Assessment Unit, Thunder Bay, Ontario for allowing me to use their computing facilities to produce the final drafts of this manuscript.

Believe it or not Mom and Dad, I really think I'm finished. Thanks for your endless support and love.

Lastly, I thank my confidante and partner, Ludvik, for your support and patience during the final and hectic stages of thesis preparation.

Financial support was provided by:

1981 - Provincial Lottery Fund through the Fisheries Research Branch, OMNR, Maple, Ontario.

1981-2 - Department of Fisheries and Oceans Subvention Fund to Dr. Walter T. Momot, Lakehead University, Thunder Bay, Ontario.

1981-2 - Walleye Research Unit, OMNR, Thunder Bay, Ontario.

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## INTRODUCTION

Yellow perch (Perca flavescens) are normally not an important commercial or sportfish in northwestern Ontario, but they do serve as important forage for more economically valuable species such as walleye (Stizostedion vitreum vitreum) and northern pike (Esox lucius). However in the two study lakes, Henderson and Savanne, trophic relationships between yellow perch and their top predators differ. Juvenile perch (60-110 mm) serve as the primary forage of both walleye and northern pike in Savanne Lake (Sandhu 1979; Mosindy 1980). Whereas, in Henderson Lake, ninespine sticklebacks (Pungitius pungitius) provided the main forage for walleye and northern pike in 1978, 1980, and 1981. Following the unpredicted collapse of the Henderson ninespine stickleback population in 1982, both walleye and northern pike switched to perch as their dominant forage (Nunan 1982; Reid pers. comm.). The effects of predation may be manifested by differences in growth, activity, and abundance of perch. I, therefore studied how these differential predation levels affect perch population characteristics.

Past and present research on these lakes measured the responses of the walleye populations to exploitative stress. Exploitation of the Henderson walleye population from 1981 to 1983 involved the removal of biomass at a rate of 4 to 5 times the annual production, while implementation of a modified slot-size management scheme on Savanne walleyes has occurred since 1980 (Colby pers. comm.). The effect of exploitative stress on the two walleye populations and the extent and direction of changes in the perch populations is best understood by examining the role of prey utilization in inter- and intraspecific

competition. I, therefore, undertook a comparative study of yellow perch in these two lakes. I described the biological characteristics of these two populations, specifically age and growth, abundance, fecundity, maturity, and feeding behavior. As well, I examined the relative influence of food selection, behavior, and environmental structural complexity in limiting the range of interactions observable within these percid communities. The essential background information on population characteristics of the two perch populations provided by this study will assist others to determine the effects of walleye exploitation on lower trophic levels.

## STUDY AREAS

Henderson Lake and Savanne Lake are located approximately 135 kilometers northwest of Thunder Bay, Ontario (Fig. 1). They have been designated as provincial fish sanctuaries since 1969, for the purpose of research on the experimental management of their walleye populations.

Major physical and chemical characteristics of these lakes listed in Table 1, show that both lakes have comparable mean depths and pH. In addition, they are homothermous with maximum summer water temperatures reaching 24 to 26 C. The lakes differ in Morphoedaphic Index (MEI), water colour, and basin morphometry. The latter two characteristics affect, to some degree, the habitat complexity of a water body. Savanne Lake's area is approximately 2.5 times that of Henderson Lake (Table 1). Using the MEI we can categorize these lakes as slightly eutrophic (Adams and Olver 1977), with Savanne Lake having the greater production potential. Savanne Lake's stained brown colour indicates a relatively high dissolved organic content resulting in low transparency (Secchi readings of 0.5 to 1.5 m). In contrast, the clear to green colour of Henderson Lake indicates lower dissolved organic content and greater light transmission (Secchi readings of 1.5 to 2.0 m) (Wetzel 1975). As a result, submerged and emergent macrophytes are more abundant in Henderson Lake.

Basin morphometry of Henderson Lake differs substantially from that of Savanne Lake (Fig. 2). The basin in Savanne Lake is more uniform and oriented north to south. It has gradually sloping west, south, and north shores and a steeply sloping east shore. In contrast, a string of islands in Henderson Lake divides the lake into two basins oriented

Figure 1. Map showing the locations of Henderson and Savanne lakes,  
Ontario.

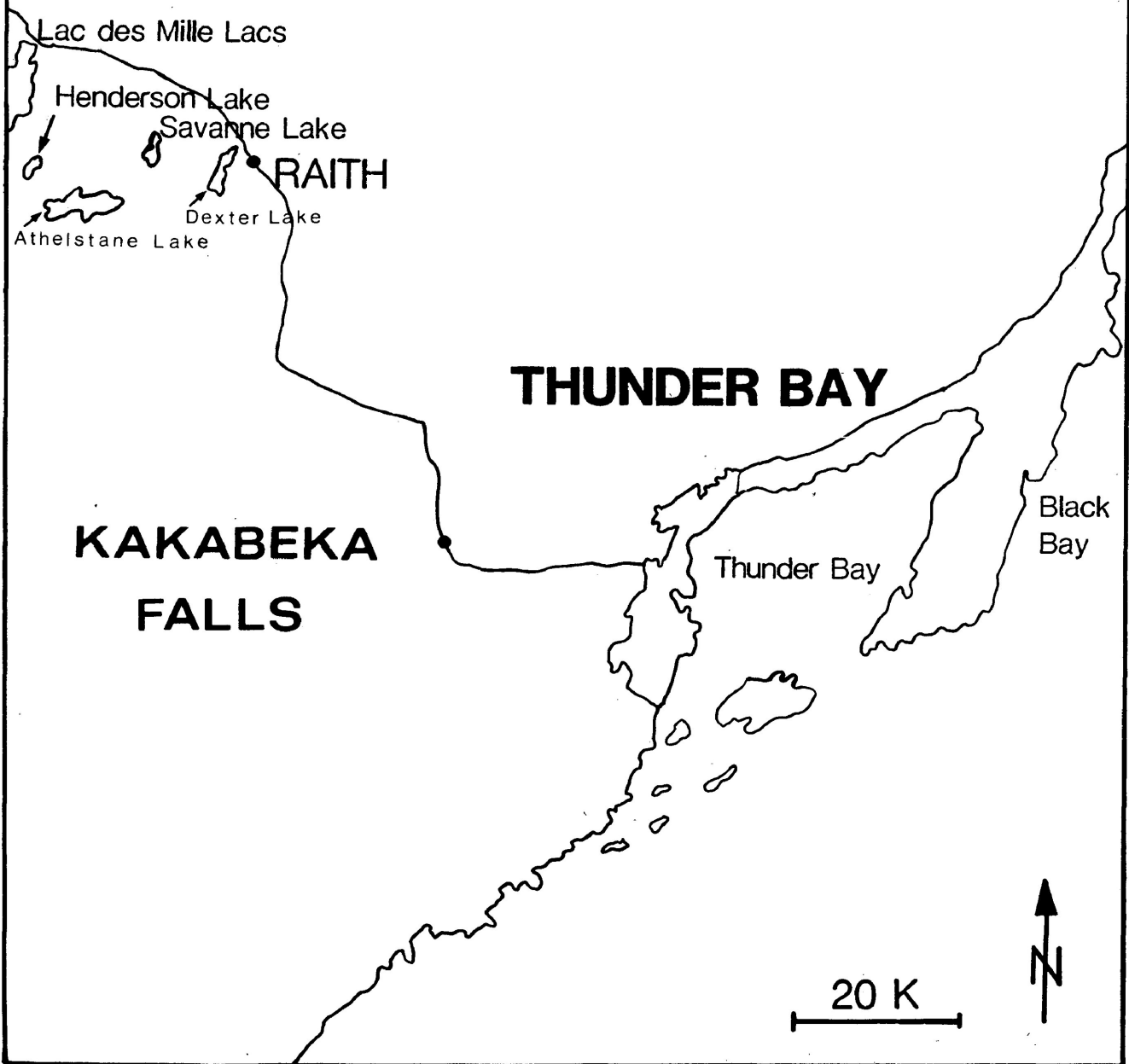
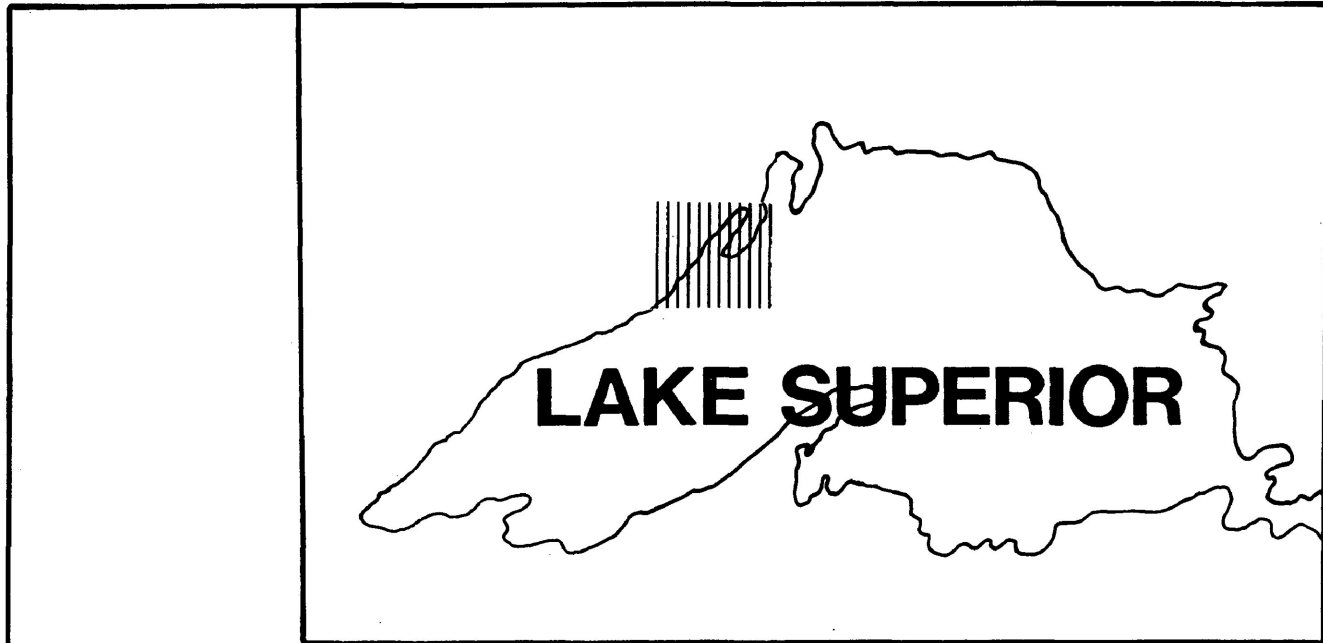




Table 1. Major physical and chemical characteristics of Henderson and Savanne lakes, Ontario.

Characteristic	Savanne <sup>a</sup>	Henderson <sup>b</sup>
Latitude	48° 49'	48° 49'
Longitude	90° 06'	90° 18'
Area (ha)	364.29	150.90
Shoreline (km)	14.8	6.7
Maximum Depth (m)	4.3	5.25
Mean Depth (m)	2.57	2.50
Secchi (m) <sup>c</sup>	0.5 - 1.5	1.5 - 2.0
Temperature Profile	homothermous	homothermous
	<u>12 July 1980</u>	<u>14 July 1980</u>
pH <sup>d</sup>	7.4	7.5
Total Dissolved Solids (mg/l)	29 - 55	41.0
Hardness CaCO <sub>3</sub> (mg/l)	24	20.0
MEI (metric)	11.3 - 21.4	16.4
Turbidity (F.T.U.) <sup>e</sup>	0.40	0.75
Conductivity (umhos/cm)	36 - 47	49.0

<sup>a</sup> Taken from Ontario Ministry of Natural Resources (1982).

<sup>b</sup> Taken from Nunan (1982).

<sup>c</sup> This study (1981, 1982).

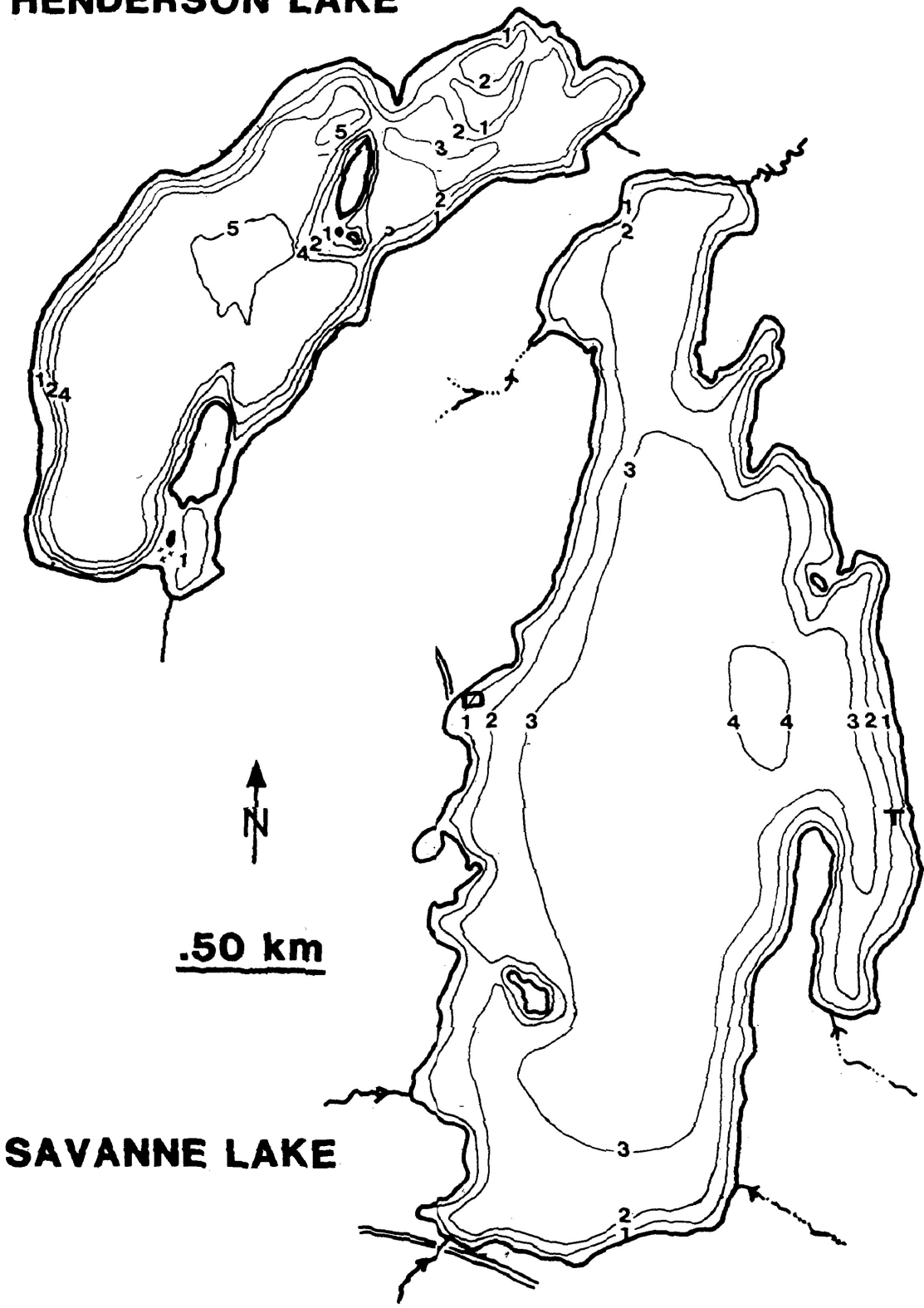
<sup>d</sup> Preserved sample.

<sup>d</sup> Measurement taken March 31, 1977.

<sup>e</sup> F.T.U. are Formazine Turbidity Units.

Figure 2. Depth contour maps of Henderson and Savanne lakes, Ontario.  
( T and D indicate thermograph locations in Savanne Lake)

# HENDERSON LAKE



.50 km

# SAVANNE LAKE

towards the northeast. The larger southern basin has a steep shoreline with a maximum depth of 5 m. On the other hand, the shallow north basin encloses a large central mudflat that usually becomes exposed during midsummer when the water level is low. Dense growths of submergent and emergent vegetation cover most of this shallow basin. The intense macrophyte production and more complex basin morphometry both contribute to the greater habitat complexity of Henderson Lake.

Both lakes support percid communities composed primarily of walleye, northern pike, yellow perch, white sucker (Catostomus commersoni), and burbot (Lota lota) (Table 2). However they differ with regard to potential forage species which are often associated with these five basic percid community components. Savanne Lake contains the pelagic cisco (Coregonus artedii) and trout-perch (Percopsis omiscomaycus), both of which are considered a basic but not essential component (Ryder and Kerr 1978). In contrast, Henderson Lake contains ninespine sticklebacks which have declined drastically since their large observed abundance in 1981 (this study). The main difference between the two lakes is that large schools of mimic (Notropis volucellus) and blacknose shiners (Notropis heterolepis) are associated with young perch in Henderson Lake but only blacknose shiners have been found incidentally in seine catches in Savanne Lake.

Table 2. Fish species found in Henderson and Savanne lakes, Ontario.

	Species	Henderson	Savanne
Walleye	<u>Stizostedion vitreum vitreum</u>	+	+
Northern Pike	<u>Esox lucius</u>	+	+
Yellow Perch	<u>Perca flavescens</u>	+	+
Burbot	<u>Lota lota</u>	+	+
White Sucker	<u>Catostomus commersoni</u>	+	+
Trout-perch	<u>Percopsis omiscomaycus</u>	-	+
Cisco	<u>Coregonus artedii</u>	-	+
Ninespine Stickleback	<u>Pungitius pungitius</u>	+	-
Mimic Shiner	<u>Notropis volucellus</u>	+	-
Blacknose Shiner	<u>Notropis heterolepis</u>	+	+
Johnny Darter	<u>Etheostoma nigrum</u>	-	+
Iowa Darter	<u>Etheostoma exile</u>	+	+

+ Present

- Absent

## MATERIALS AND METHODS

### 1. RELATIVE ABUNDANCE

#### 1.1 Index Gillnetting

I used experimental, Swedish-type, green, monofilament gillnets to measure the relative abundance of yellow perch. Each net was 61 m (200 ft) long and 2.4 m (8 ft) wide and consisted of four 15.2 m (50 ft) long panels of 25.4, 38.1, 50.8, 63.5 mm stretched mesh. In 1982, I removed the 63.5 mm mesh panel since perch were not vulnerable to this mesh and replaced it with a 19.1 mm mesh panel so I could sample younger age classes.

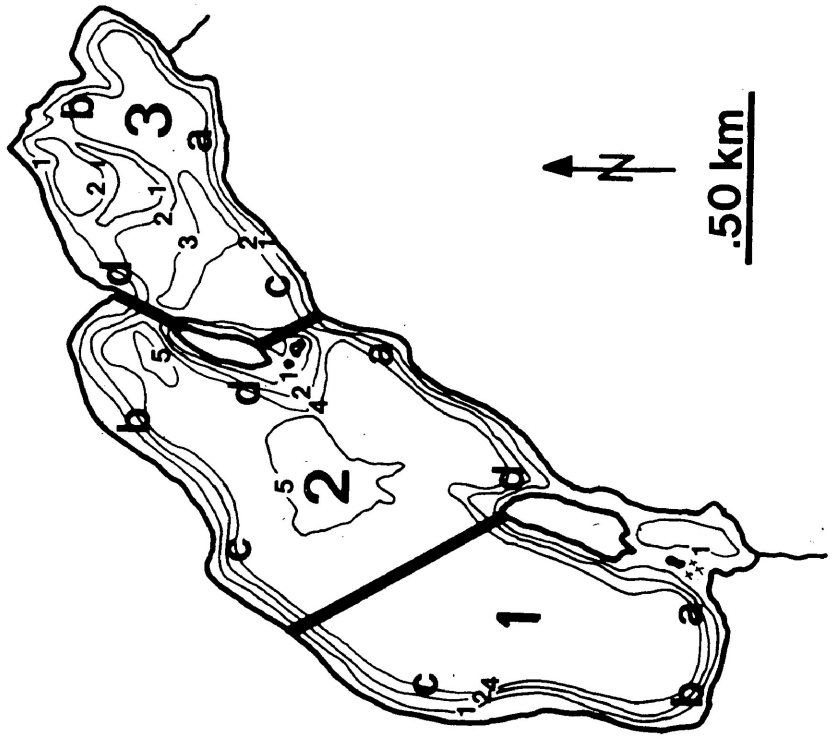
Each lake was divided into three areas consisting of four sampling locations (a,b,c,d) within each area (Figs. 3a and 4a). A sample consisted of three nets, one fished in each area. Net sets were alternated between locations during successive samples. Nets were set perpendicular to gradually sloping shores. Hubert and Sandheinrich (1983) reported catch-per-unit-effort (CPUE) to be influenced by both temperature and depth in stratified lakes. Since these lakes are homothermous, only depth was thought to influence the activity and CPUE of perch.

In 1981, monthly samples (July, August) consisted of 4-hour sets conducted at: dawn (0400-0800 hr), midday (1200-1600 hr), and dusk (2000-2400 hr) for a total of 36 sets per lake. Hasler and Bardach (1949), Emery (1973), Carlander and Cleary (1949), and Keast and Welsh (1968) all report that activity of yellow perch peaks at dawn and dusk. Therefore, dawn and dusk sets should be the most reliable for determining a relative abundance index based on CPUE.

Figure 3. Depth contour maps of Henderson Lake showing gillnet and beach seine sampling locations.

# HENDERSON LAKE

## Gillnet Locations



## Seine Locations

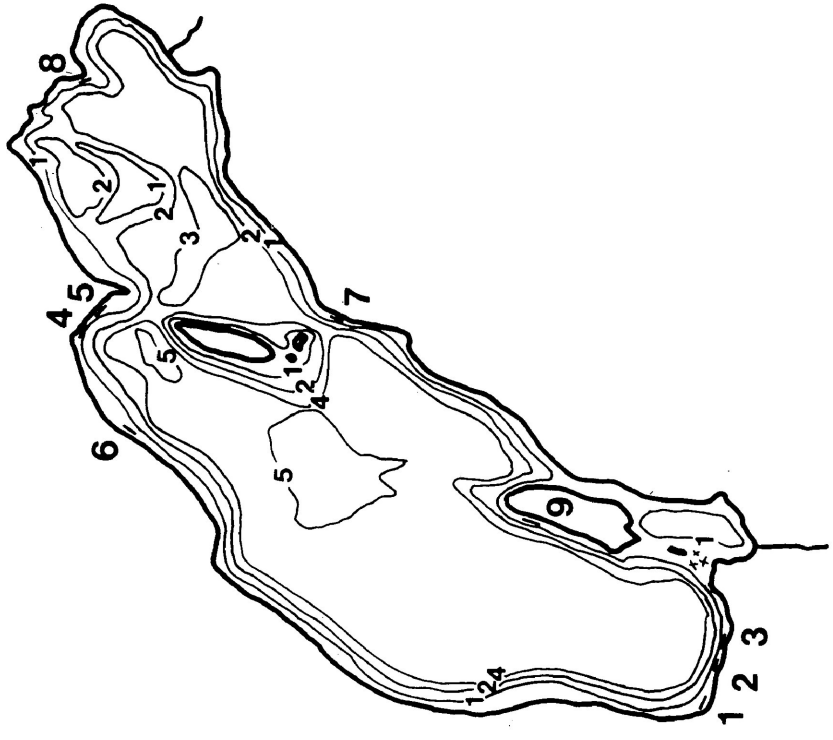
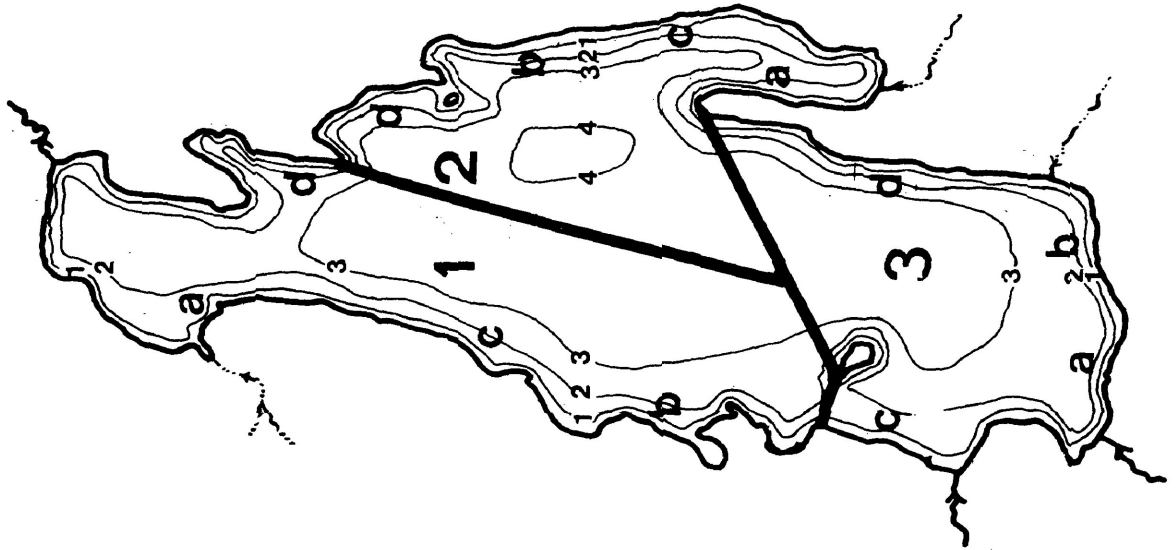


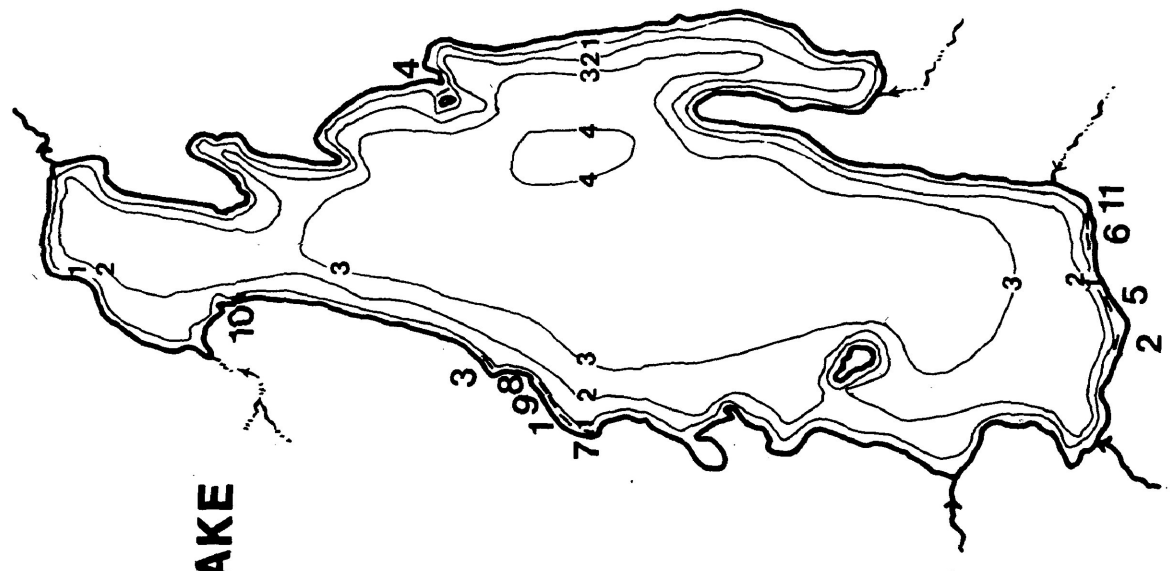


Figure 4. Depth contour maps of Savanne Lake showing gillnet and beach seine sampling locations.

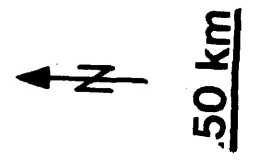
**Gillnet Locations**



**Seine Locations**



**SAVANNE LAKE**



In 1982, monthly sampling (June-August), consisted of successive 3-hour sets during a 24 hour period, for a total of 76 sets per lake. The 24 hour sampling period was deployed over a two week period each month. Sampling was standardized by location and time of day so comparisons could be made between months and sampling times.

Total length of fish was measured to the nearest millimeter. Perch and other small fish species were weighed individually to the nearest 1.0 g with an Ohaus Triple Beam Balance. Walleye, northern pike, and white suckers were weighed with a Chantillon (nearest 25 g) or Pesola spring balance (nearest 50 g).

Seasonal and temporal variations in CPUE of perch effectively recruited to the gear were assessed with Kruskal-Wallis Analysis of Variance (ANOVA) (Daniel 1978). Note that age of effective recruitment distinctly differs from age of vulnerability. The former is the first most abundant age class in the catch whereas the latter is the first age class following the age of effective recruitment (Ricker 1975).

## 1.2 Relative Abundance of Young-of-the-Year (YOY) Yellow Perch and Other Potential Forage Fish Species

Number per hectare seined served both as an index of strength of hatch of YOY perch and as a measure of the relative abundance of small fish species. Seining locations are shown in Figures 3b and 4b.

### 1.2.1 Savanne Lake

The seining locations on Savanne Lake have been used by the Walleye Research Unit, OMNR since 1972, to monitor abundance of YOY walleye and yellow perch. The eleven stations are sampled from midday to late afternoon on calm, usually sunny days. These conditions appear to be

ideal for inshore movements of young perch and walleye in Savanne Lake (Colby pers. comm.). All the locations have a sand substrate except location 4, the smooth, sloping northeast side of a small island (Fig. 4b). The sequence for sampling the stations was determined using a random numbers table. An 18.3 m (60 ft) long, 1.8 m (6 ft) wide bag seine with 3.2 mm square mesh bag and 6.5 mm square mesh wings was laid out parallel to shore, at a distance of 30.5 m (100 ft) and hauled in from shore. The area seined at each location was standardized at 15.2 m (50 ft) by 30.5 m (100 ft), or 0.047 hectares.

#### 1.2.2 Henderson Lake

In 1981, locations 1,2,4,6,7,8 were used and in 1982 and 1983 locations 3,5,9 were added (Fig. 3b). Locations 1,2,3,4,5 are sand beaches, 7 and 8 have gravel-cobble substrates, and 6 and 9 have sand-silt substrates with some submergent vegetation.

The 1981 seining schedule ascertained the time of day during which maximum numbers of young perch moved inshore. All locations were sampled at dawn (0500-0800 hrs), midday (1100-1600 hrs), dusk (2000-2200 hrs), and night (2400-0300) in June, July, and August, 1981. A 9.1 m (30 ft) long, 1.2 m (4 ft.) wide bag seine with 3.2 mm square mesh bag and 6.5 mm square mesh wings layed out parallel to shore, at a distance of 9.1 m (30 ft) was hauled in by walking directly towards shore. The area sampled was 9.1 m (30 ft) by 7.6 m (25 ft.), or 0.007 hectares. Large numbers of YOY perch were captured at all sampling times (Table 3). Therefore all seining was done from midday to late afternoon.

In 1982 and 1983, an 18.2 m (60 ft) long , 1.2 m (4 ft) wide bag seine with 3.2 mm square mesh bag and 6.5 mm square mesh wings was used. The deployment and hauling of the net utilized the same method described

Table 3. YOY Yellow perch abundance (mean number per hectare seined) in Henderson Lake, Ontario at four different times of day, 1981.

Date		Time of day (hrs)			
		0500-0800	1100-1600	2000-2200	2400-0300
May	23		0		
June	6		0		
June	23			0	
June	26	407	13590	0	168
July	13-24		34788	60413	
July	25-29	32228	31438		34884
August	12		10145		
August	24-25	2584	5647	11102	6298

for Savanne Lake, sampling an area of 0.047 hectares.

### 1.2.3 Sampling and Analysis

All species were counted and perch and walleye were recorded as YOY, 1+, or older. Subsamples of YOY perch were measured to the nearest millimeter and weighed to the nearest 0.1 g on each sampling day. Seasonal growth rates were determined by regression of total length against time. Annual YOY abundance (calculated as mean #/hectare seined), was ranked relative to the year of maximum mean abundance. YOY abundance was then compared to variables such as YOY seasonal growth rate, and YOY walleye abundance, and growing degree days (GDD) above 15 C in May and June. YOY perch survival and abundance has been correlated with the degree of warming following spawning (Smith 1977). A baseline temperature of 15 C was selected because the preferred temperature of young perch ranges between 13 and 29 C (Tarby 1973). Also, Hokanson (1977) reported feeding and survival of percid larvae was possible above 10 C and optimal above 20 C, thus 15 C was chosen as a mid-point between these survival thresholds.

## 2. AGE AND GROWTH

Despite the widespread use of scales for aging, other boney structures have proven more accurate, especially for unexploited populations (Erickson 1979; LeCren 1947). Annuli were very difficult to identify from the scales of both perch populations. The same is true of walleye and pike scales from Henderson Lake (Nunan 1982).

Age determinations were made from the left opercular bone and the fourth dorsal spine. Opercular bones were either soaked briefly in heated water to remove excess tissue or soaked in water until the tissue

decayed. They were then allowed to air dry until the annuli could be examined using reflected light against a black background under a dissecting scope at 6 to 50 times magnification. Annuli were distinguished as the border between narrow transparent winter and broad, opaque, summer growth zones. Several criteria distinguish between false and true annuli. Some appear as incomplete lines across the width of the opercular bone, while others termed growth checks occur as thin transparent bands in the middle of an opaque, summer growth zone.

Dorsal spines were prepared by: removing the skin, dipping in xylene, imbedding in Lepage's 5 Minute Epoxy, and then cutting into sections (approximately 0.06 mm) with a Slow-Speed Isomet Saw (Campbell and Babaluk 1979). The sections were mounted on glass slides using Permunt medium and viewed under a compound scope. Transmitted light distinguished the annuli as narrow, white rings between dark summer growth zones. False annuli appeared as very thin incomplete rings.

## 2.1 Backcalculations

Male and female yellow perch were subsampled for age and growth determinations. Since aging samples were collected from the end of May to mid-June, that year's annulus had not yet formed in most of the samples, so the edge of the opercular bone was taken as the annulus. Beckman (1943) reported that annulus formation in yellow perch in northern Michigan occurred in late June at temperatures of 11.1 to 14.4 C. For samples collected after annulus formation, growth was calculated to the last annulus.

The distance to each annulus was measured from the focus of the opercular bone along a line perpendicular to the anterior edge of the bone with an ocular micrometer to the nearest 0.01 mm (LeCren 1947)

(Fig. 5).

Significant linear relationships occurred for opercular bone length (X) related to total fish length (Y) for both sexes, in both populations, in 1981 and 1982 (Appendix 1). Total fish length at each annulus was calculated using the equation:

$$LA = C + [(OLA/OL)(TL-C)], \quad (1)$$

where:

TL = total fish length at sampling (mm),  
 LA = unknown fish length at formation of annulus A,  
 OLA = length of opercular bone to annulus A (mm),  
 OL = total length of opercular bone at sampling (mm), and  
 C = correction factor for length of fish at the time of bone formation.

The length-frequency distributions of samples from male and female perch used for backcalculations are shown in Appendix 2.

The relationship between opercular bone length and total fish length was fitted using least squares regression. Growth differences between sexes and between years were determined by Analysis of Covariance (ANCOV) (Snedecor and Cochran 1967).

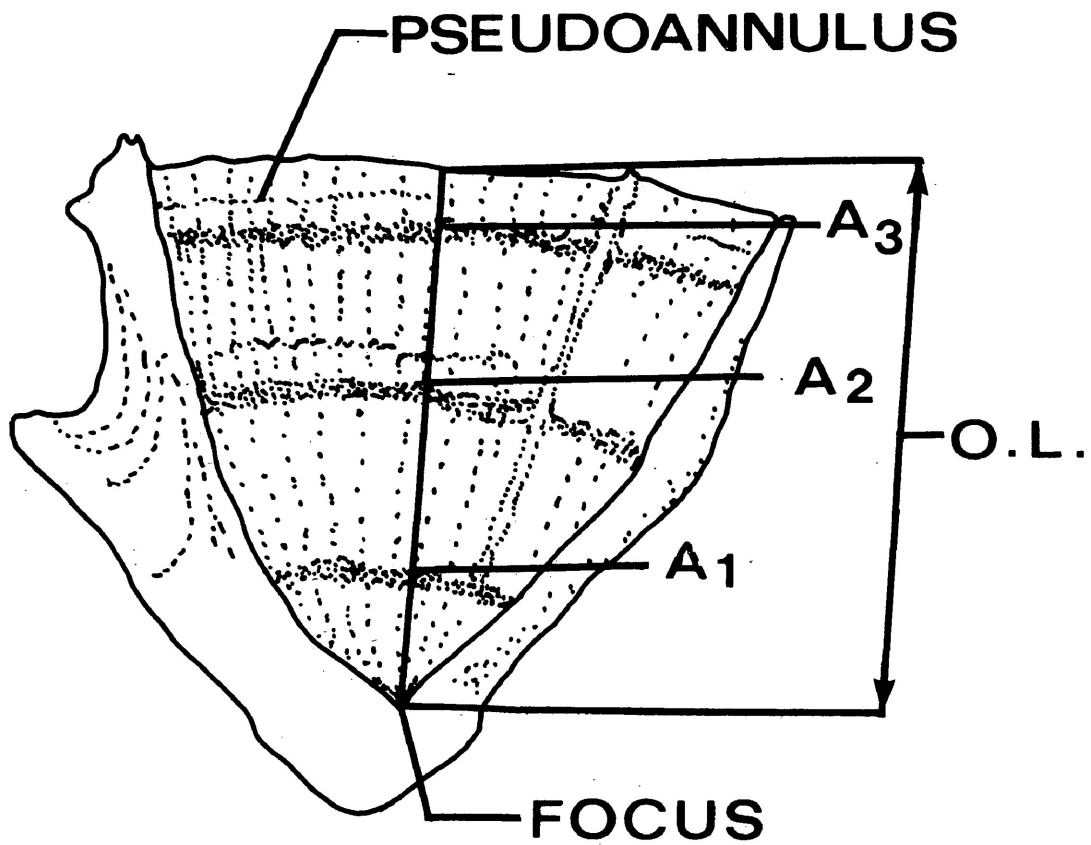
## 2.2 Age Verification

Ages determined from opercular bones were compared to those obtained from both dorsal spines and modal lengths associated with the length-frequency distribution of the total catch.

Opercular bone samples from both populations were also read by John Babaluk, a specialist in aging at the Federal Department of Fisheries and Oceans (DFO) in Winnipeg, Manitoba and by Dominic Baccante, Senior Research Technician for the Walleye Research Unit of OMNR in Thunder Bay, Ontario. No information on length or sex of the samples was given to the former. The aging results are listed in Appendix 3.



Figure 5. Diagram of an opercular bone showing true (A1,A2,A3) and false annuli, the focus, and the line of measurement used for backcalculating growth and aging yellow perch.



O.L. = TOTAL OPERCLE LENGTH

Because of small sample sizes, a nonparametric paired t-test (Wilcoxon Mann-Whitney Two Sample Test) was used to test for significant differences between readers (Daniel 1978). The results are shown in Table 4.

There was a significant difference between Babaluk and myself for the Henderson sample ( $Z = -4.015$ ,  $P < 0.01$ ; Table 4), but agreement with Baccante, although not significant ( $Z = -1.826$ ,  $P = 0.068$ ; Table 4), indicated that achieving accuracy in the aging of stunted populations may require information on growth.

The number of annuli found on opercular bones and the fourth dorsal spine was compared for samples taken from both populations (Appendix 4). Since there was a small sample size used for Henderson Lake (less than 30), the Wilcoxon Mann-Whitney Two Sample Test was used to test for differences between age determinations made from the two bone structures (Table 4). There was 91% agreement and no significant differences between the two bone structures from Savanne perch ( $Z = -1.014$ ,  $P = 0.310$ ; Table 4). However, there was only 29% agreement and a significant difference between Henderson samples ( $Z = -3.030$ ,  $P < 0.01$ ; Table 4). The Henderson samples came from older, stunted fish (greater than 5 years of age), for which age is assessed with less accuracy. Aging of Henderson Lake perch is far more difficult and inconsistent and fish can be accurately aged only up to age 8 to 10. However, relatively good agreement occurred between individual readers for Savanne Lake perch using criteria similar to those used for aging Henderson perch using opercular bones.

Table 4. Discrepancies in assessing age between: a) readers of yellow perch opercular bones; b) the number of annuli found on dorsal spines and opercular bones, assessed with Wilcoxon Mann-Whitney Two Sample Tests.

Lake	Comparison between:	N-pairs (N-ties)	Mean age	Z-score
Henderson	A	29 ( 8)	4.35	-4.015 **
	B		2.66	
	A	20 (16)	5.10	-1.826
	C		4.90	
	Opercular Bone	24 ( 7)	8.04	-3.030 **
	4th Dorsal Spine		7.08	
Savanne	A	22 (16)	2.73	-2.201
	B		3.14	
	Opercular Bone	79 (72)	3.95	-1.014
	4th Dorsal Spine		3.99	

\*\* Significant at  $P < 0.01$ .

A = Ritchie, B = Babaluk, C = Baccante.

### 3. AGE COMPOSITION

Samples used for determining the age structure of the two perch populations were taken using identical gear during the same season (May 5-June 14). All fish were measured for total length and a stratified subsample was taken for age and growth studies (Ketchen 1950). Up to 30 fish of both sexes were selected from each 1.0 cm length interval. Poorly represented length intervals were augmented by samples taken later in the field season. Age compositions of combined sexes were determined by estimating the proportion of ages in the stratified subsample. Two cm length intervals were used for the Savanne population to allow for seasonal growth, while the slower growth of the Henderson population required 1.0 cm length intervals.

The length-frequency distributions of the aged samples used for determining the age structures of both populations in 1981 and 1982 are shown in Appendix 5. These samples represented from 6.5 to 14.2% of the total catch.

### 4. GEAR SELECTIVITY

Gear selectivity can affect determinations of population structure. I therefore assessed the selectivity of the experimental gillnets used for this study by comparing the modal lengths from length-frequency distributions of perch sampled with gillnets and bag seines for both populations. In addition, a boatmounted electro-shocker was used only in Savanne Lake. The voltage and amperage used was 400-1000 VDC and 4.0-6.4 amps, respectively (Baccante unpub.). The mean, median, range, and standard deviation for total lengths of perch captured by the four gear types are shown in Appendix 6a.

## 5. LENGTH-WEIGHT RELATIONSHIPS AND CONDITION

Condition factor (K) can be used to compare two or more monospecific populations inhabiting environments that differ in terms of climate, food, and density (Weatherley 1972). Monthly (June-August), sex-specific, length-weight relationships were determined for both populations in 1981 and 1982. Natural logarithmic transformations of total length and total weight gave the best linear fit by least squares regression. Differences between months, sexes, and years were determined by ANCOV.

Fulton's Condition Factor satisfactorily compares differences related to sex and location if it is calculated for fish at approximately the same length and if fish from both populations are captured at the same time, with the same gear (Bagenal and Tesch 1978). Fulton's Condition Factor is calculated using the equation:

$$K = 100(TW/TL^3), \quad (2)$$

where:

TW = total weight in grams, and  
TL = total length in centimeters.

"K" was calculated for both sexes in each population sampled from July to mid-August, in 1981 and 1982. "K" was then averaged by age and at each 1.0 cm length interval.

Differences between sexes and within and between populations were determined by Wilcoxon Matched-Pairs Ranked-Sign Tests since the number of ages and length intervals was less than 30 for each test (Sokal and Rohlf 1981).

## 6. MATURITY

Perch captured in experimental gillnets and seines were examined for sex and gonad condition. During and shortly after spawning, fish were classified as mature based on the presence of eggs or milt. During the non-spawning period, males were classified mature if gonads were white and not string-like, while females were mature if gonads were opaque to pink in colour. Immature males and females had translucent gonads.

Samples of males and females used for total length at maturity calculations were taken from gillnet samples in May and at the end of August. These samples were combined assuming that little growth would occur from fall to the following spring.

Samples for age at maturity calculations were taken from May to June and from fecundity samples collected in September to October of 1981 and again in late summer of 1982 using gillnets.

Mean age of onset of sexual maturity was calculated using four methods: Abrosov (1969); Modified Abrosov (Lysack 1980); Lysack's Method (Lysack 1980); and the Probit Method (present study). The latter two methods were also used to determine mean length at onset of sexual maturity.

### 6.1 Abrosov Method:

$$Z = \frac{A_1K_1 + A_2K_2 + \dots + A_nK_n}{K_1 + K_2 + \dots + K_n} , \quad (3)$$

where:

Z = mean age of onset of sexual maturity,  
 A = age (completed years of life), and  
 K = percent of mature fish in the nth age class.

## 6.2 Modified Abrosov Method:

$$Z = \frac{A_1K_1 + A_2(K_2-K_2-1) + \dots + A_n(K_n-K_n-1)}{K_1 + (K_2-K_1) + \dots + (K_n-K_{n-1})}, \quad (4)$$

Symbols are as described for Equation (3).

## 6.3 Lysack's Method

The modified Abrosov method is especially biased when small sample sizes in any age group cause  $A_n(K_n-K_n-1)$  to be a negative value (Lysack pers. comm.). Lysack (1980), using a fitted curve, eliminates the problem provided there are sufficient data points available for a least squares regression. In addition, the resulting slope of the line i.e. the instantaneous rate of maturity, is more sensitive to annual changes even while "Z" remains relatively constant (Lysack pers. comm.).

A plot of percent of mature fish versus age or length interval yields a logistic curve:

$$Y = \frac{K}{1 + e^{-b(X-x_0)}}, \quad (5)$$

where:

Y = percent mature,  
 K = the asymptote of the curve which Lysack assumes is 100%,  
 x = inflection point,  
 b = slope (instantaneous rate of maturity), and  
 X = age.

A linear transformation of "Y" results by using:

$$Y = \text{Log}_e \left[ \left( \frac{K-Y}{Y} \right) + 1 \right]. \quad (6)$$

By regressing these transformed maturity percentages on age or length, the inflection point is then calculated by dividing the intercept by the slope of the line (Lysack 1980).



#### 6.4 Probit Method

Graphing the cumulative frequency distribution results in a sigmoid curve. Such cumulative sigmoid curves can be straightened by probit transformation (Fig. 6) (Sokal and Rohlf 1981). This is a common method used for determining median lethal doses (LD50), for bioassay studies (Sprague 1969). Probit analysis might be used to study animals in which maturation cannot be exactly dated but rather recorded as either occurring or not occurring in any one particular individual (Finney 1971).

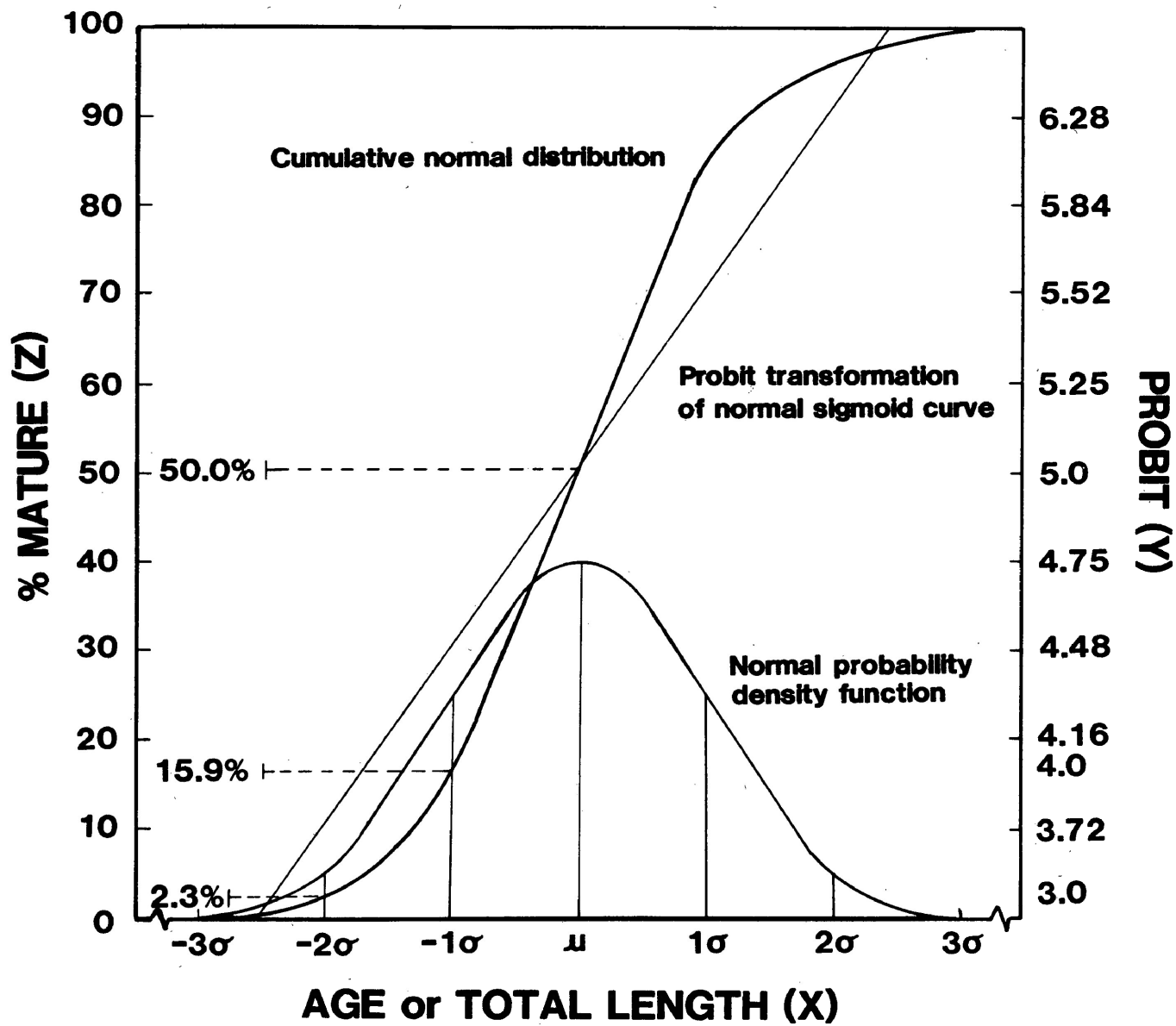
The symbol definitions are as follows:

X = independent variable (ie. age, length),  
 Z = the cumulative percent of mature individuals of each age,  
 Y = is the probit transformation of "Z",  
 $\mu$  = population mean, and  
 $\sigma$  = population standard deviation.

"Z", is referred to as a Normal Equivalent Deviate (NED) by Finney (1971) and Sokal and Rohlf (1981). "Z" represents the area under a normal curve,  $x-\mu/\sigma$ . Probits are equal to these NED's (Z) which are then coded by the addition of 5.0 in order to avoid negative values for most deviates. Therefore a cumulative frequency of 50% would have a Probit value of 5.0, while a cumulative frequency of 16% would have a Probit value of 4.0 as shown in Figure 6. Tables for probit transformation of cumulative frequency percentages are available in Finney (1971).

Graphing cumulative frequency percentages against age or length on probability paper, or plotting probits against age or length on linear graph paper, results in a straight line fitted by least squares regression. From this, the age or length at which 50% of the fish are mature can be determined.

Figure 6. Relationship between the normal distribution, cumulative normal distribution, and probit transformation of the cumulative normal distribution.



The equation of the probit line is described by:

$$Y = \frac{x-\mu}{\sigma} + 5 = a + bX, \quad (7)$$

where:

$$a = 5 - \mu/\sigma \text{ and}$$

$$b = 1/\sigma.$$

An example using an age at maturity schedule for male perch from Henderson Lake is shown in Appendix 7.

## 7. FECUNDITY

Mature, female yellow perch were collected with monofilament gillnets and bag seines from September 29 to November 2 in 1981 and from August 24 to September 23 in 1982. Each fish was measured to the nearest 1.0 mm and weighed to the nearest 0.1 g. The ovary was excised and preserved in 10 percent formalin. Gravimetric methods are more accurate than volumetric methods for determining absolute fecundity (Wolfert 1969), so the gravimetric subsample method of Bagenal (1973) was used.

Each ovary was blotted dry, ovarian tissue removed, and then weighed to the nearest 0.01 g. Three subsamples taken from each ovary were each weighed to the nearest 0.01 g and the number of eggs counted. The weight of each subsample ranged from 5.0% to 100% of the ovary weight. All ova were counted and any differential development was considered negligible for this study.

Absolute fecundity was regressed against ovary weight, total weight, spawning age, and total length using the least squares method. ANCOV tested for differences between years for each population.

## 8. FEEDING ANALYSIS

Seasonal and size-specific dietary changes and differences in the diet composition between the two populations were monitored by the frequency of occurrence method.

Monthly (June-August) samples were obtained from gillnet sets used for the relative abundance index in 1981 and 1982. At least 10 fish were collected in each 1.0 cm total length interval over a range of 7.0-20.0 cm in Henderson Lake and 7.0-26.0 cm in Savanne Lake. Total length (1.0 mm) and total weight (0.1 g) were determined for each fish. To arrest digestion upon capture, either the whole fish or its digestive tract from the pyloric valve to the anus was preserved in 10% formalin. Regurgitated food items found in the esophagus and mouth were also included.

Only those food items found in the pyloric and cardiac portions were used for frequency of occurrence analysis. A subjective points system (Craig 1978) identifying amounts of food and state of digestion was employed as follows: 1 = full stomach, 2 = pyloric region full with some in the cardiac region, 3 = some food in both pyloric and cardiac regions, 4 = empty; 1 = recent ingestion, 2 = partially digested, 3 = old but identifiable, 4 = unidentifiable remains. Prey items were identified to at least order (Pennak 1978; Merritt and Cummins 1978). Perch were grouped into four size categories; < 91, 91-130, 131-200, and > 200 mm based on the similarity of diet composition.

## 9. WATER TEMPERATURE

A continuous recording thermograph measured daily water temperatures in Savanne Lake from ice-out to the end of the summer or freeze-up. In Henderson Lake, a thermograph was not available therefore temperature readings were taken with a thermometer during seine and gillnet sampling. Henderson daily water temperatures are comparable to Savanne temperatures (Appendix 8a). Therefore Savanne Lake thermograph records were used to calculate Growing Degree Days (GDD) > 15 C, for the 1972 to 1983 field seasons in May and June using the formula:

$$\text{GDD} > 15 \text{ C} = (\text{Mean daily water temperature} - 15).$$

Mean beach temperatures for Savanne Lake, 1981 - 1983 are shown in Appendix (8b). A malfunction of the thermograph in June of 1983 meant that daily temperatures were taken only during gillnet and seine sampling times. Therefore GDD could not be calculated IN 1983.

## 10. PRECIPITATION

Precipitation was accumulated for May to August, 1972 - 1983 from the Department of Transport Meteorological Observations (1972 - 1976) and the Environment Canada Atmospheric Environmental Service Monthly Records (1977 - 1983) for the Raith automatic meteorological station (TCPL 64) and is shown in Appendix (9). This station is located approximately 10 km east of Savanne Lake (Fig. 1).

## 11. STATISTICAL ANALYSIS

The Vax 11/780 computer equipped with the Statistical Package for the Social Sciences - SPSS (Nie et al 1975) was used for all statistical analysis. Criterion for significance was at  $P < 0.01$ .

## RESULTS

## 1. RELATIVE ABUNDANCE

1.1. Index Gillnetting

CPUE of perch recruited to experimental gillnets was used for assessing seasonal, temporal, and population differences. Age of effective recruitment was 5 years for Henderson perch and 2 years for Savanne perch (Fig. 16). Mean lengths at these ages based on an aged subsample are as follows:

Lake	Year	Age	Total length (cm)		
			Range	Mean	Length used for CPUE
Henderson	1981	5	9.3 - 11.6	10.0	≥ 10.0
Henderson	1982	5	9.0 - 12.5	10.5	≥ 10.0
Savanne	1981	2	8.2 - 13.9	11.4	≥ 11.0
Savanne	1982	2	8.4 - 13.7	11.0	≥ 11.0
Savanne	1981	5	17.2 - 25.1	20.6	≥ 20.0
Savanne	1982	5	17.7 - 25.5	20.0	≥ 20.0

Taken from Appendix (18b).

Since only Henderson perch at age 5 or older are recruited, the CPUE was compared to age 5 and older Savanne perch.

Index gillnetting effort in Henderson and Savanne lakes was as follows:

Lake	Year	Total captured	Number of sets	Total effort (hrs)	Set duration (hrs)
Henderson	1981	1,518	36	150.0	4
Henderson	1982	2,787	76	244.7	3
Savanne	1981	1,417	36	150.1	4
Savanne	1982	1,970	78	240.0	3

#### 1.1.1 Henderson Lake

No seasonal or temporal differences in CPUE were noted in 1981 (K-W ANOVA,  $P > 0.05$ ; Table 5). Consequently, all samples were combined to produce a mean CPUE of 6.7 with a range of 0.5 - 16.5 among 36 samples (Table 6; Appendix 10). However significant differences between sampling times occurred within each month in 1982 so samples could not be combined (K-W ANOVA,  $P < 0.01$ ; Table 5), but CPUE ranged from 0.0 - 26.1 among 76 samples (Appendix 10).

#### 1.1.2 Savanne Lake

No seasonal differences in CPUE within each sampling time occurred but a significant difference between times occurred in August, 1981 (K-W ANOVA,  $P < 0.01$ ; Table 5). As a result, samples could not be combined, but the range was 0.0 - 14.1 among 36 samples (Appendix 10).

There were no seasonal or temporal differences in CPUE of age 5+ perch, in 1981 (K-W ANOVA,  $.025 < P < 0.040$ ; Table 5). The mean CPUE was 0.22 with a range of 0.0 - 0.72 among 36 samples (Table 6; Appendix 10).

In 1982, there were significant differences between times within



Table 5. Seasonal and temporal differences in catch-per-unit-effort of: (A) yellow perch effectively recruited; (B) age 5 and older yellow perch effectively recruited to experimental gillnets in Henderson and Savanne lakes, Ontario, assessed by Kruskal-Wallis ANOVA. (2 df for each test).

Lake	Year	Group <sup>a</sup>	χ <sup>2</sup> - value		Number of sets		
			A	B			
Henderson	1981	I. July	5.956	5.956	9		
			1.082	1.082	27		
		II. 0400-0800	1.872	1.872	12		
			0.846	0.846	12		
			4.115	4.115	12		
Savanne	1981	I. July	4.356	2.936	9		
			11.210 **	2.080	27		
		II. 0400-0800	7.266	5.007	12		
			6.580	0.979	12		
			7.615	1.497	12		
Henderson	1982	I. June	11.297 **	11.297 **	25		
			13.827 **	13.827 **	24		
			16.306 **	16.306 **	27		
		II. 2400-0300	1.277	1.277	9		
			0.267	0.267	9		
			5.422	5.422	9		
			4.526	4.526	12		
			0.874	0.874	9		
			4.992	4.992	10		
			4.356	4.356	9		
			3.822	3.822	9		
		Savanne	1982	I. June	10.037 **	5.831	30
					14.640 **	16.224 **	24
					18.945 **	9.684 **	24
II. 2400-0300	0.091			2.000	9		
	0.291			0.125	9		
	5.956			5.620	9		
	3.290			2.540	9		
	3.154			0.341	12		
	7.615			6.980	12		
	2.489			1.130	9		
	3.317			2.000	9		

<sup>a</sup> Group refers to: I. Test for significant differences between times within months or II. Test for significant differences between months within sampling times.

\*\* Significant at P < 0.01.

Table 6. Mean catch-per-unit-effort for each month and sampling period for: A) yellow perch effectively recruited to gillnets in Henderson and Savanne lakes, Ontario, 1981 and 1982; B) yellow perch age 5+ in Savanne Lake, 1981 and 1982. (CPUE/number of sets, SE in brackets, < > indicate means calculated even though significant differences occurred).

A.(i) Henderson 1981 (age  $\geq 5$ ;  $\geq 10.0$  cm)

Month	Time			Mean
	0400-0800	1200-1600	2000-2400	
July	3.45/3 (1.69)	5.76/3 (0.61)	10.53/3 (0.52)	6.58 (1.17)
August	7.76/3 (1.83)	5.36/9 (0.86)	7.94/9 (1.41)	6.81 (0.82)
Mean	6.61 (1.48)	5.41 (0.65)	7.94 (1.15)	6.66 (0.67)

A.(ii) Savanne 1981 (age  $\geq 2$ ;  $\geq 11.0$  cm)

Month	Time			Mean
	0400-0800	1200-1600	2000-2400	
July	1.02/3 (0.35)	4.50/3 (1.54)	1.92/3 (0.61)	2.48 (0.71)
August	4.67/9 (1.03)	1.97/9 (0.49)	6.70/9 (1.20)	<4.45> (0.65)
Mean	3.76 (3.11)	2.60 (0.59)	5.51 (1.09)	<3.95> (0.54)

Table 6. Continued

A.(iii) Henderson 1982 (age  $\geq 5$ ;  $\geq 10.0$  cm)

Month	Time								Mean
	2400- 0300	0300- 0600	0600- 0900	0900- 1200	1200- 1500	1500- 1800	1800- 2100	2100- 2400	
June	0.70/3 (0.27)	8.86/3 (3.25)	4.22/3 (1.16)	1.75/3 (0.38)	3.10/3 (0.64)	2.13/4 (1.17)	2.86/3 (1.47)	5.12/3 (2.71)	<3.53> (0.69)
July	0.29/3 (0.18)	5.89/3 (2.63)	14.74/3 (3.22)	4.89/3 (1.39)	5.78/3 (2.48)	10.00/3 (2.72)	10.26/3 (2.42)	14.09/3 (6.45)	<8.24> (1.34)
August	0.33/3 (0.20)	7.06/3 (1.53)	4.84/3 (1.27)	6.28/6 (2.12)	3.33/3 (0.68)	2.83/3 (1.64)	14.06/3 (5.67)	1.78/3 (0.62)	<5.20> (1.04)
Mean	0.44 (0.13)	7.27 (1.36)	7.93 (2.03)	4.81 (1.38)	4.07 (0.88)	4.70 (1.56)	9.06 (2.46)	6.99 (2.74)	<5.01> (0.64)

A.(iv) Savanne 1982 (age  $\geq 2$ ;  $\geq 11.0$  cm)

Month	Time								Mean
	2400- 0300	0300- 0600	0600- 0900	0900- 1200	1200- 1500	1500- 1800	1800- 2100	2100- 2400	
June	0.73/3 (0.57)	2.26/3 (0.88)	2.34/3 (1.00)	2.78/3 (1.68)	2.32/6 (0.63)	2.00/6 (0.82)	6.37/3 (1.17)	2.56/3 (0.48)	<2.57> (0.39)
July	0.69/3 (0.21)	1.84/3 (0.95)	8.15/3 (1.20)	3.00/3 (1.16)	4.96/3 (1.44)	3.17/3 (0.35)	12.38/3 (3.60)	6.35/3 (3.04)	<5.07> (0.93)
August	0.73/3 (0.44)	2.26/3 (0.90)	12.66/3 (3.43)	8.73/3 (2.80)	4.48/3 (1.03)	6.38/3 (0.20)	8.22/3 (0.44)	0.89/3 (0.11)	<5.55> (0.96)
Mean	0.71 (0.22)	2.12 (0.46)	7.72 (1.85)	4.85 (1.40)	3.52 (0.61)	3.39 (0.67)	8.99 (1.42)	3.27 (1.20)	<4.25> (0.46)

Table 6. Continued.

B.(i) Savanne 1981 (age  $\geq 5$ ;  $\geq 20.0$  cm).

Month	Time			Mean
	0400- 0800	1200- 1600	2000- 2400	
July	0.00/3 (0.00)	0.16/3 (0.08)	0.15/3 (0.08)	0.10 (0.04)
August	0.25/9 (0.07)	0.18/9 (0.08)	0.34/9 (0.08)	0.26 (0.04)
Mean	0.18 (0.06)	0.17 (0.06)	0.29 (0.07)	0.22 (0.04)

B.(ii) Savanne 1982 (age  $\geq 5$ ;  $\geq 20.0$  cm)

Month	Time								Mean
	2400- 0300	0300- 0600	0600- 0900	0900- 1200	1200- 1500	1500- 1800	1800- 2100	2100- 2400	
June	0.00/3 (0.00)	0.19/3 (0.19)	0.22/3 (0.11)	0.22/3 (0.22)	1.11/6 (0.07)	0.06/6 (0.06)	0.20/3 (0.10)	0.00/3 (0.00)	0.12 (0.04)
July	0.00/3 (0.00)	0.10/3 (0.10)	0.00/3 (0.00)	0.00/3 (0.00)	0.00/3 (0.00)	0.40/3 (0.06)	0.20/3 (0.10)	0.97/3 (0.10)	<0.10> (0.03)
August	0.10/3 (0.10)	0.08/3 (0.08)	0.97/3 (0.50)	0.66/3 (0.51)	0.33/3 (0.19)	0.22/3 (0.11)	0.66/3 (0.33)	0.00/3 (0.00)	<0.38> (0.11)
Mean	0.33 (0.03)	0.12 (0.07)	0.40 (0.21)	0.29 (0.19)	0.14 (0.06)	0.18 (0.06)	0.35 (0.13)	0.03 (0.03)	<0.19> (0.04)

each month for perch age 2+ (K-W ANOVA,  $P < 0.01$ ; Table 5). The range in CPUE was 0.0 - 17.6 among 78 samples (Table 6). There were no significant seasonal differences in CPUE within each sampling time (K-W ANOVA,  $0.030 < P < 0.939$ ; Table 5). There were significant differences between times in July and August for CPUE of age 5+ perch, in 1982 (K-W ANOVA,  $P < 0.01$ ; Table 5). The range in CPUE was 0.0 - 1.95 among 78 samples (Appendix 10).

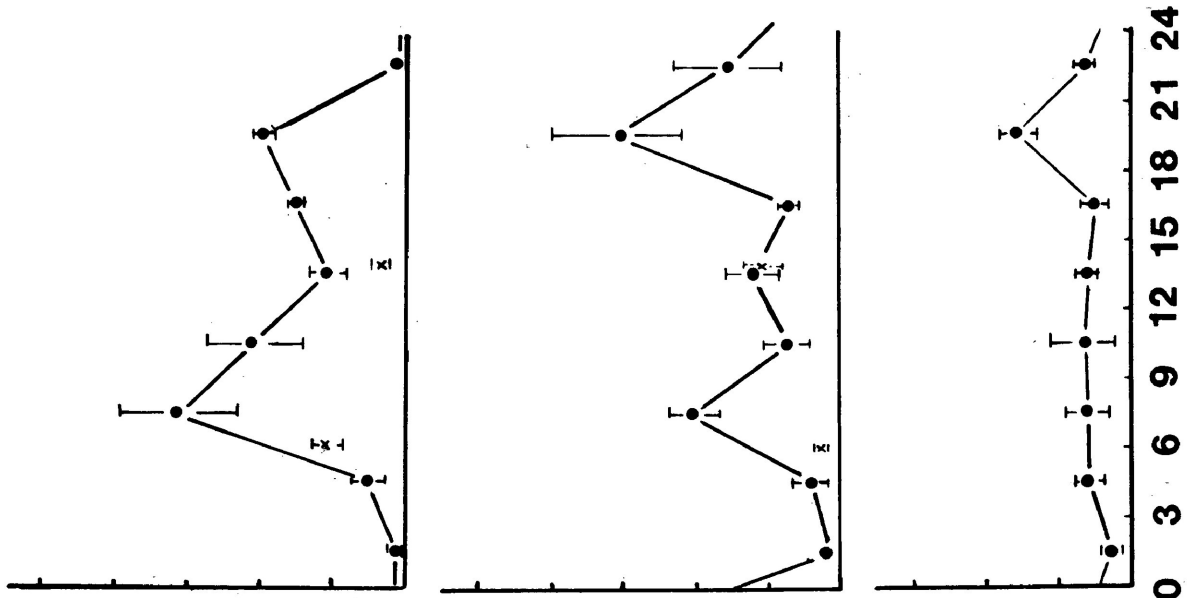
### 1.1.3 Population Comparisons

Temporal differences occurred in the CPUE of perch effectively recruited to gillnets. This meant that samples could not be combined to calculate an overall mean CPUE in 1982 for Henderson Lake or in 1981 and 1982 for Savanne Lake. However, valid mean CPUE's could be calculated for each sampling time for combined months.

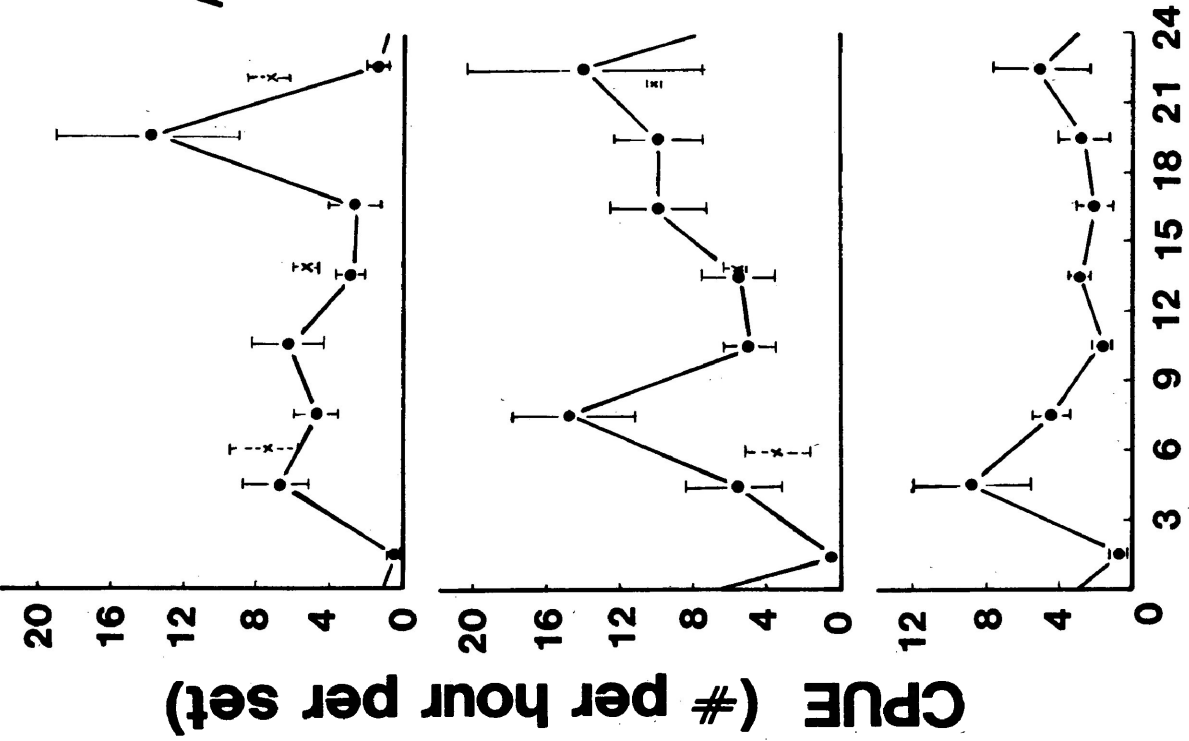
A diurnal activity pattern is shown for perch in both lakes, especially during July and August, 1982 (Fig. 7). Low numbers of perch were caught after nightfall, although considerable effort was expended. At night, perch were observed to remain motionless either on the bottom or amongst submergent vegetation in Henderson Lake. Low transparency in Savanne Lake prevented similar observations. Maximum mean CPUE occurred in the 0400 - 0800 hr and 2000 - 2400 hr sampling periods in 1981 and in the 0600-0900 hr and 1800 - 2100 hr sampling periods in 1982, in both lakes (Table 6). Dawn and dusk catches were 1.2 to 1.5 times and 2.0 to 2.2 times greater than midday catches in Henderson Lake in both 1981 and 1982. Similarly, at dawn and dusk, CPUE was 1.5 to 2.0 times and 2.2 to 2.6 times greater than at midday in Savanne Lake in both 1981 and 1982 (Table 6). CPUE's at peak activity periods provided the best indication of relative abundance for perch (Table 7). In 1981, perch were more

Figure 7. Seasonal and temporal variation in catch-per-unit-effort (#/set/hour  $\pm$  SE) of yellow perch effectively recruited to experimental monofilament gillnets in Henderson and Savanne lakes, Ontario, June to August, 1981 (  $\bar{X}$  ) and 1982 (  $\bar{I}$  ). (stretched mesh sizes: 25.4, 38.1, 50.8, 63.5 mm in 1981; 19.1, 25.4, 38.1, 50.8 mm in 1982)

# SAVANNE LAKE



# HENDERSON LAKE



CPUF (# per hour per set)

TIME OF DAY (hrs)

Table 7. Mean catch-per-unit-effort for peak activity sampling periods (June - August) for yellow perch age 5 and older and those effectively recruited to experimental gillnets in Henderson and Savanne lakes, Ontario, 1981 and 1982.

Lake	Year	CPUE Calculated for:	Mean CPUE	SE	Sampling time (hrs)
Henderson	1981	Vulnerable (Age $\geq$ 5)	7.94	1.15	2000 - 2400
			6.61	1.48	0400 - 0800
Savanne	1981	Vulnerable (Age $\geq$ 2)	5.51	1.09	2000 - 2400
			3.76	3.11	0400 - 0800
Savanne	1981	Age $\geq$ 5	0.29	0.07	2000 - 2400
			0.18	0.06	0400 - 0800
Henderson	1982	Vulnerable (Age $\geq$ 5)	9.06	2.46	1800 - 2100
			7.93	2.033	0600 - 0900
Savanne	1982	Vulnerable (Age $\geq$ 2)	8.99	1.42	1800 - 2100
			7.72	1.85	0600 - 0900
Savanne	1982	Age $\geq$ 5	0.35	0.13	1800 - 2100
			0.12	0.07	0600 - 0900



abundant in Henderson Lake than in Savanne at both dawn and dusk. Whereas, the relative abundance of vulnerable perch in the two lakes was comparable in 1982. Mean CPUE in 1982 was comparatively higher than in 1981 for both peak sampling periods (Table 7). Addition of a smaller mesh panel in 1982 may have increased recruitment of younger age classes. However, age 5+ perch were anywhere from 25.7 to 63.3 times more abundant in Henderson Lake, in 1981 and 1982 (Table 7).

During 1982 mean CPUE of walleye and perch for each sampling period (combined months) were compared (Fig. 8). Although intensive exploitation of walleye has reduced their numbers, diurnal activity of walleye was coincidental with that of perch. However, in Savanne Lake, maximum CPUE of walleye followed that of perch, from 2000 - 2400 hr. An early activity period was not apparent for walleye in Savanne Lake (Fig. 8).

## 1.2 Shore Seining

Maximum numbers of perch were caught in July and August, in both lakes when water temperatures were around 19 C (Appendix 8a). In 1981, YOY perch were 4 times as abundant in Henderson Lake, but by 1982 and in 1983, they were 4 and 50 times more abundant in Savanne Lake (Table 8).

### 1.2.1 Henderson Lake

Upon reaching total lengths of 13 - 37 mm, YOY perch became vulnerable to seine nets from mid- to late June, 1981 to 1983 (Appendix 11).

Perch consistently dominated the total catch of forage-sized fish species (measured as percent of total species composition) only in July and August of 1981, August of 1982, and June of 1983 (Fig. 9).

Table 8. Relative abundance, year-class strength, and growth rates of YOY yellow perch and walleye; GDD > 15 C and precipitation in Henderson Lake (1981 - 1983) and Savanne Lake (1972 - 1983), Ontario.

Lake	Year	No. of seine hauls (Duration) <sup>a</sup>	Yellow perch				Walleye				GDD > 15 C				Precipitation (mm) <sup>d</sup>	
			Relative abundance (#/ha seined)		Relative year-class abundance <sup>b</sup>	Growth rate <sup>c</sup>	Relative abundance (#/ha seined)		Relative year-class abundance <sup>b</sup>	Growth rate <sup>c</sup>	My17-My31	My17-Ju31	My17-Ju31	My17-Ju31	My1-Ju30	My1-Ju30
			Range	Mean	abundance	rate	Range	Mean	abundance	rate	My31	My31	My31	My31	My31	My31
Savanne	1972	165 (Jy13-Au31)	168-2,796	1203	11.5	0.32	37-1,105	307	97.8	1.08	32.1	138.0	54.9	146.9		
	1973	242 (Jy 4-Au31)	10-2,583	835	8.0	NA	0-545	89	28.3	0.87	0.0	44.0	56.1	113.0		
	1974	225 (Jy 3-Au28)	333-3,580	1389	13.3	0.44	0-172	46	14.8	1.35	0.0	24.9	91.7	148.1		
	1975	286 (Jy 2-Au29)	108-3,024	1014	9.7	NA	0-474	32	10.2	1.24	37.8	132.3	53.6	147.1		
	1976	286 (Jy 2-Au30)	425-11,675	3360	32.1	0.47	24-598	112	35.7	1.17	3.0	92.8	5.8	138.4		
	1977	231 (Jy 2-Au31)	41-32,060	2993	28.6	0.47	0-706	74	23.5	1.23	43.6	120.6	105.1	209.7		
	1979	174 (Jy 4-Au28)	292-33,578	10480	100	0.69	7-243	103	32.9	1.12	25.8	88.5	77.1	184.5		
	1980	143 (Jy 3-Au26)	231-22,616	4318	41.2	0.48	8-662	166	53.0	0.94	0.0	20.2	45.0	96.6		
	1981	143 (Jy25-Au19)	349-18,922	4760	45.4	0.66	0-127	22	6.9	1.19	20.3	105.3	69.2	237.8		
	1982	77 (Jy 8-Au19)	2727-22,224	9511	90.8	0.56	0-772	314	100	1.75	25.3	80.6	74.3	138.1		
1983	55 (Jy14-Au18)	1129-10,678	6990	66.7	0.71	0-47	13	4.0	1.61	0.0	NA	49.7	157.4			
Henderson	1981	30 (My23-Au24)	5647-34,788	19122	100	0.22					20.3	105.3	69.2	237.8		
	1982	54 (Ju 6-Au24)	401-4,004	2175	11.4	0.53					25.3	80.6	74.3	138.1		
	1983	81 (Jull-Au16)	2-409	147	0.8	0.25					0.0	NA	49.7	157.4		

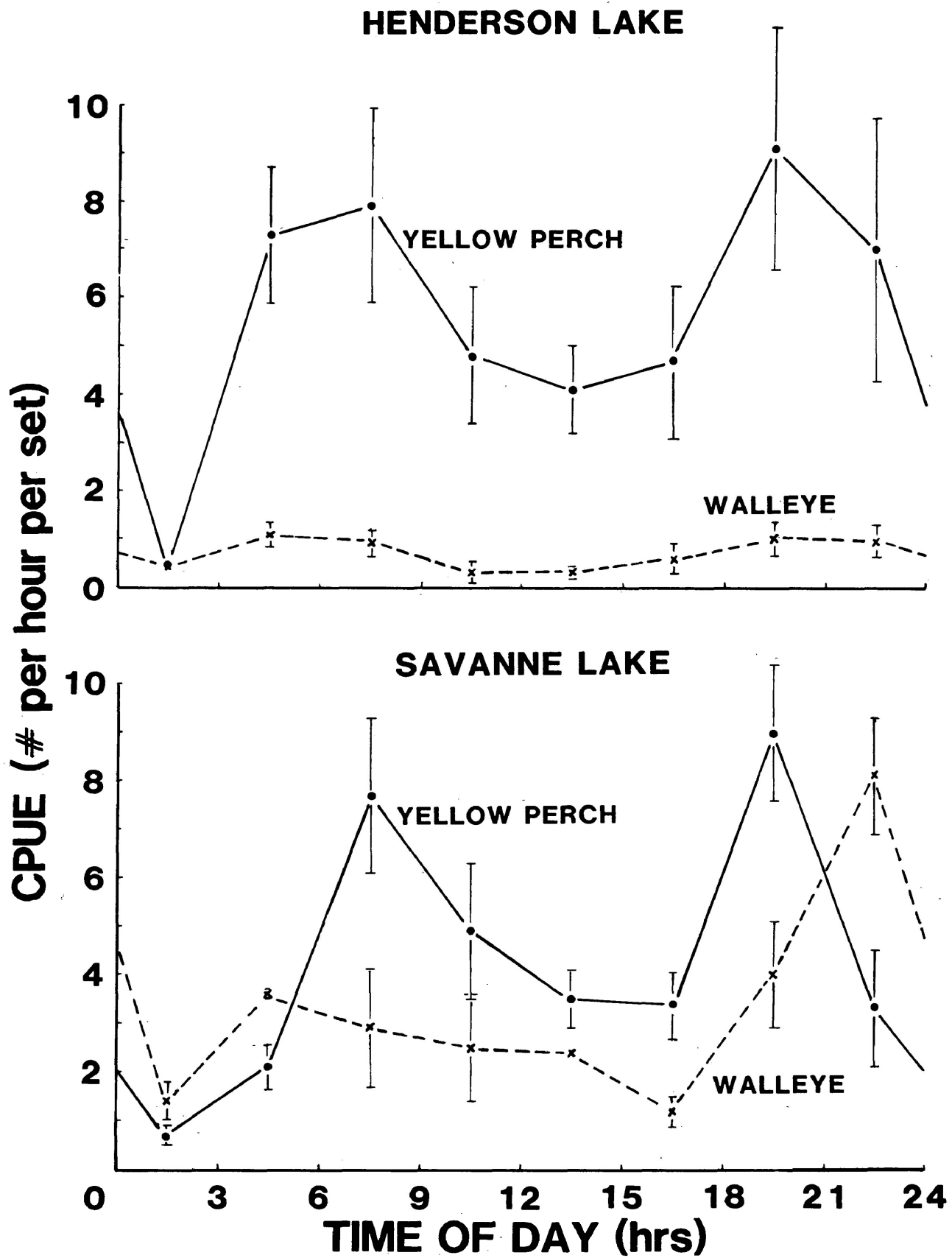
a My - May, Ju - June, Jy - July.

b Calculated as percent of year of maximum mean abundance (1979 for perch, 1982 for walleye).

c Growth rates determined by linear regression, see Appendix 12.

d From Meteorological Station at Raith, Ontario (Fig. 1).

Figure 8. Temporal variation in catch-per-unit-effort ( $\#/set/hour \pm SE$ ) of yellow perch (effectively recruited) and walleye in experimental, monofilament gillnets for the combined months of June, July, and August in Henderson and Savanne lakes, Ontario, 1982. (19.1, 25.4, 38.1, 50.8 mm stretched mesh)



Mimic and blacknose shiners dominated seine catches, especially in 1982 and 1983 when YOY perch abundance decreased (Fig. 9). Since 1981, YOY perch abundance drastically declined, resulting in a 9 fold reduction in 1982 and a 125 fold reduction in 1983 (Table 8).

Though small numbers of ninespine sticklebacks were caught in 1981 and 1982, this probably did not reflect the actual abundance since these fish are reported to remain demersal in deep areas of lakes making them less vulnerable to shore seining (Ryder and Kerr 1978). In 1981, aggregations of ninespine stickleback were often observed inshore at night over sandy substrate and in open water areas near large boulders. Ninespine sticklebacks became rare by 1982, having seriously declined since their observed high abundance in 1980 (Nunan 1982).

#### 1.2.2 Savanne Lake

YOY perch became vulnerable to seine nets by June 7 in 1981 (35 mm), and by July 1 in 1982 (19 - 28 mm) (Appendix 11).

YOY and 1+ perch proved more abundant than all other forage species combined in all months sampled, in 1981 to 1983 (Fig. 9). However, YOY perch abundance varied 12 fold relative to the strong 1979 year-class and mean abundance has been higher since 1975 (Table 8).

YOY and 1+ walleye, white suckers, burbot, northern pike, and Iowa darters occurred in relatively small numbers in 1981 and 1983, but larger numbers of YOY white suckers and burbot were captured in July and August of 1982 (Fig. 9).

Abundance and seasonal growth rates of YOY perch and walleye were not significantly correlated to temperature GDD > 15 C for May and May-June (Kendall's Rank Correlation,  $P > 0.01$ ; Table 9). The only significant positive correlation was between growth rate and mean

Figure 9. Comparison of percentage species composition (#/hectare seined) of beach seine catches in Henderson and Savanne lakes, Ontario, June to August, 1981 to 1983.

PERCENTAGE COMPOSITION IN SEINE HAULS

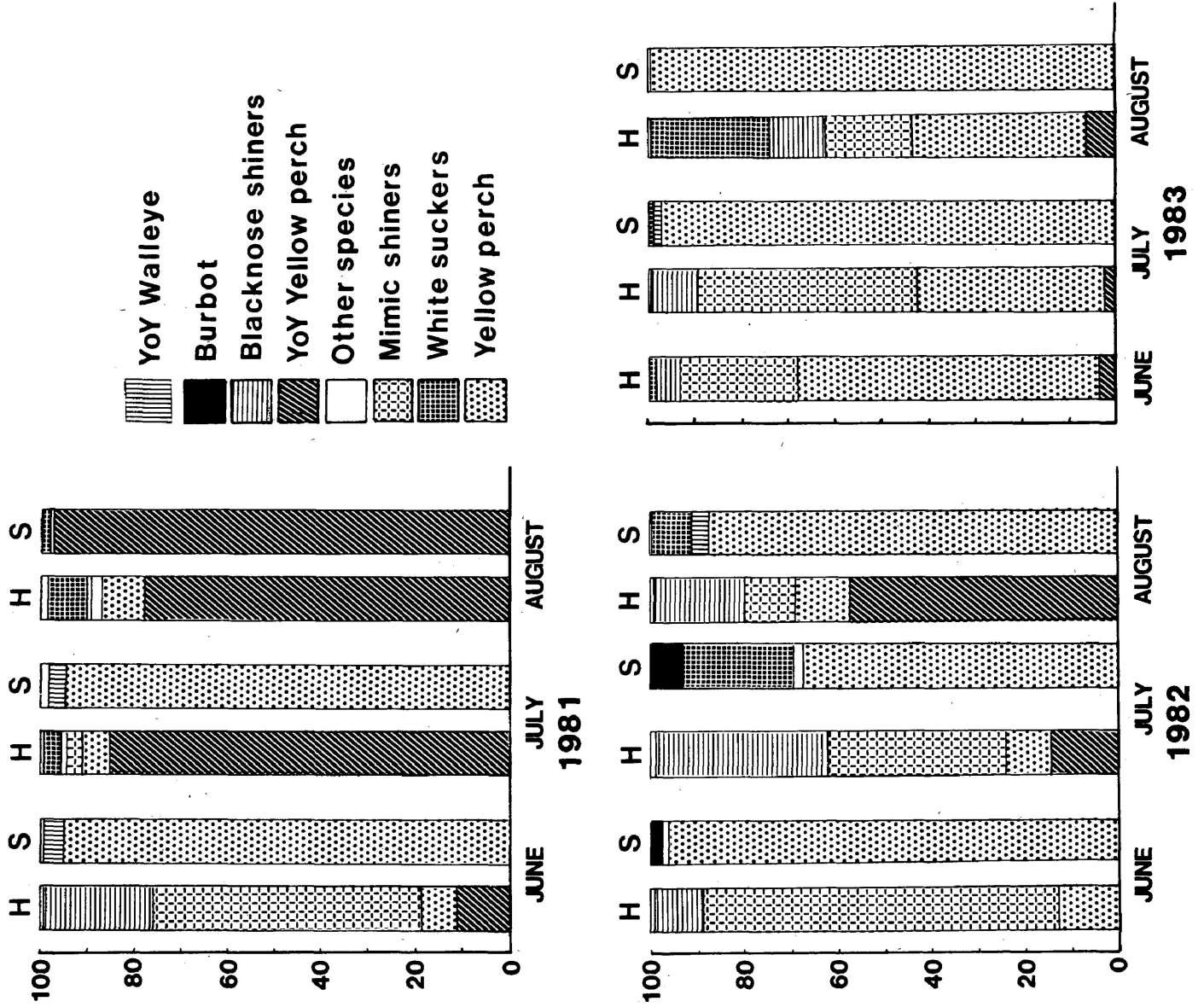


Table 9. Relationships between water temperature, precipitation, abundance<sup>a</sup>, and growth<sup>b</sup> for young-of-the-year walleye and yellow perch in Savanne Lake, Ontario, 1972-1983, using Kendall's Tau correlation coefficient.

Dependent variable	Kendall's Tau	P	N
Independent Variable			
GDD > 15 C (MAY 17 - MAY 31)			
YOY Perch Abundance	0.019	0.936	11
YOY Walleye Abundance	0.342	0.163	11
YOY Perch Year-class Abundance	0.019	0.936	11
YOY Walleye Year-class Abundance	0.342	0.163	11
YOY Perch Growth Rate	-0.413	0.147	9
YOY Walleye Growth Rate	0.221	0.366	11
GDD > 15 C (MAY 17 - JUN 30)			
YOY Perch Abundance	-0.200	0.421	10
YOY Walleye Abundance	0.067	0.788	10
YOY Perch Year-class Abundance	-0.200	0.421	10
YOY Walleye Year-class Abundance	0.067	0.788	10
YOY Perch Growth Rate	-0.416	0.161	8
YOY Walleye Growth Rate	0.156	0.531	10
Accumulated Precipitation (MAY)			
YOY Perch Abundance	0.127	0.586	11
YOY Walleye Abundance	0.200	0.392	10
YOY Perch Year-class Abundance	0.127	0.586	10
YOY Walleye Year-class Abundance	0.200	0.392	10
YOY Perch Growth Rate	-0.029	0.915	8
YOY Walleye Growth Rate	0.164	0.484	10
Accumulated Precipitation (MAY - JUN)			
YOY Perch Abundance	0.200	0.392	10
YOY Walleye Abundance	-0.455 ***	0.052	10
YOY Perch Year-class Abundance	0.200	0.392	10
YOY Walleye Year-class Abundance	-0.455 ***	0.052	10
YOY Perch Growth Rate	0.145	0.595	8
YOY Walleye Growth Rate	0.236	0.312	10



Table 9. Continued

Dependent variable	Kendall's Tau	P	N
Independent Variable			
YOY Perch Abundance			
YOY Walleye Abundance	0.091	0.790	11
YOY Perch Year-class Abundance	1.000 **	0.001	11
YOY Walleye Year-class Abundance	0.091	0.790	11
YOY Perch Growth Rate	0.912 **	0.001	9
YOY Walleye Growth Rate	0.386	0.312	11
YOY Perch Growth Rate			
YOY Walleye Abundance	-0.402 ***	0.284	9
YOY Walleye Year-class Abundance	-0.402	0.284	9
YOY Walleye Growth Rate	0.268	0.486	9
YOY Walleye Abundance			
YOY Walleye Year-class Abundance	1.000 **	0.001	11
YOY Walleye Growth Rate	-0.327	0.326	11

- <sup>a</sup> Mean YOY year-class abundance as a percentage of year of maximum abundance (1979 for perch; 1982 for walleye from Table 8).
- <sup>b</sup> Growth rates determined by linear regression (Appendix 12).
- \* Significant correlations at  $P < 0.05$ .
- \*\* Significant correlations at  $P < 0.01$ .
- \*\*\* Biological significance is discussed even though not statistically significant.

relative abundance of YOY perch ( $T = 0.783$ ,  $P = 0.004$ ; Table 9).

Though mean relative abundance of YOY walleye was negatively correlated to growth rate of YOY perch, this was not statistically significant ( $T = -0.435$ ,  $P = 0.110$ ; Table 9). The growth rate of YOY walleye was positively correlated with mean relative abundance of YOY perch but was not statistically significant ( $T = 0.309$ ,  $P = 0.186$ ; Table 9). There were no significant correlations between precipitation and abundance or growth of YOY walleye and perch (Table 9).

## 2. GROWTH OF YOUNG-OF-THE-YEAR YELLOW PERCH

Both perch populations displayed linear growth rates in their first growing season in all sampling years. This was shown by a series of regressions of total length and total weight versus time (Appendix 12). However, annual variations in growth rate in length occurred in both Henderson Lake (0.22 to 0.53 mm/day) and Savanne Lake (0.32 to 0.71 mm/day) (Table 10).

Growth rate in length and weight was greater for Savanne perch, 1981 to 1983 (Figs. 10 and 11). Condition for Savanne YOY perch was better from 1981 to 1983 as illustrated by the greater increase in weight per unit length of 0.047 - 0.067 g/mm compared to 0.035 - 0.041 g/mm in Henderson lake (Table 10).

Seventy to 100% of first year's growth occurred by late August in both lakes (Table 10). While first year growth increments varied from 62.3 to 75.9 mm for Savanne perch (1974-1981), they were somewhat less for Henderson perch (50.7 mm in 1981) (Table 10). Though length increased in 1979 for Savanne perch, this trend did not apply to growth in weight or condition (Table 10).

Table 10. YOY yellow perch growth rates and growth increments during their first growing season in Henderson Lake (1981 - 1983) and Savanne Lake (1972 - 1983), Ontario.

Lake	Year	No. of sampling days	Growth rates			Total length		TL at first annulus <sup>a</sup>
			mm/day	g/day	g/mm	(% TL at first annulus)	August 24	
Henderson	1981	7	0.22	.010	0.041	40 (78.9)	45 (88.8)	50.7
	1982	6	0.53	.019	0.034	46	52	
	1983	9	0.25	.009	0.035		32	
Savanne	1972	6	0.32	.104	0.357	51 (67.2-77.2)		
	1974	10	0.44	.022	0.049	50 (67.5-79.0)	52 (70.2-82.1)	66.1-75.9
	1976	8	0.47	.050	0.097	60 (86.2-94.8)	65 (87.7-100)	63.3-74.1
	1977	9	0.47	.038	0.078	62 (89.1-98.9)	63 (90.5-100)	62.7-69.6
	1979	9	0.69	.047	0.067	63 (86.9-100)	66 (91.0-100)	62.3-72.5
	1980	13	0.48	.035	0.071	56 (81.0-85.1)	59 (85.4-89.7)	65.8-69.1
	1981	5	0.66	.041	0.062	60 (82.2)		73.0
	1982	8	0.56	.027	0.047	52		
	1983	5	0.71	.049	0.067	59		

<sup>a</sup>From backcalculations, 1981 and 1982, Appendix (14).

Figure 10. Differences in growth in total length (mm) between young-of-the-year yellow perch in Henderson (H) and Savanne (S) lakes, Ontario, 1981 to 1983.

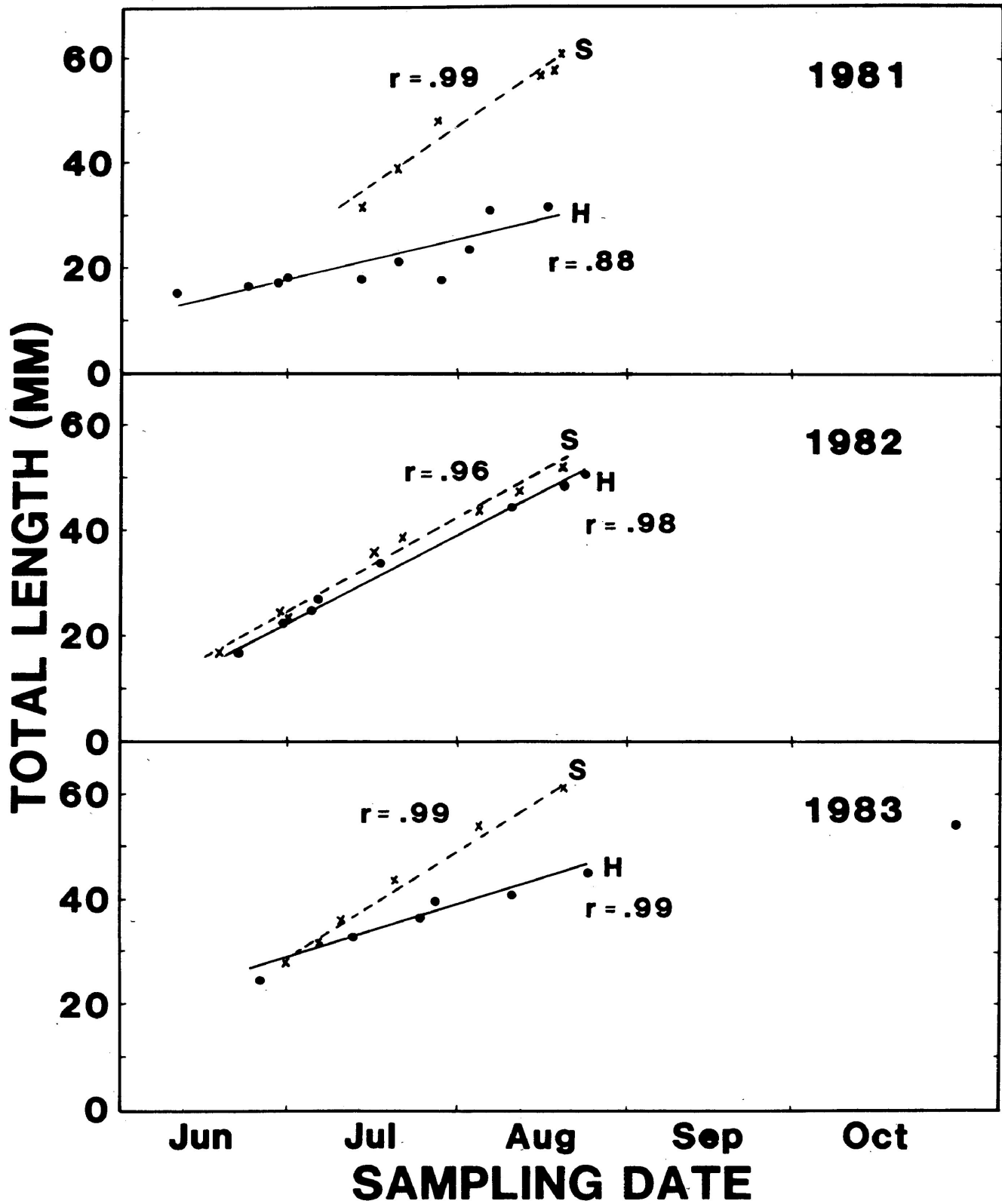
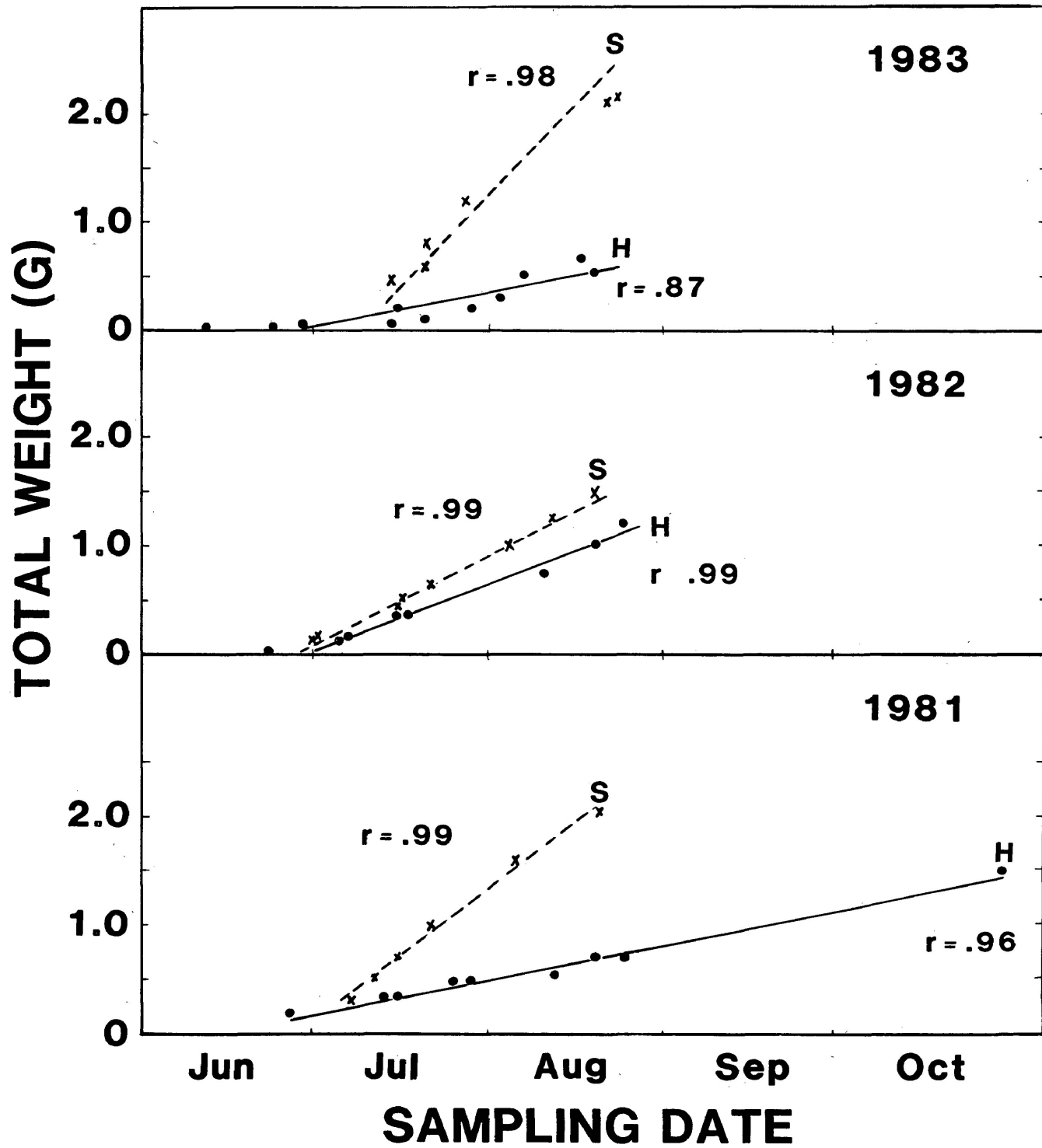


Figure 11. Differences in growth in total weight (g) between young-of-the-year yellow perch in Henderson (H) and Savanne (S) lakes, Ontario, 1981 to 1983.



### 3. AGE AND GROWTH

#### 3.1 Total Length - Opercular Bone Length Relationships

Opercular bone length (OL) was linearly related to total fish length (TL) for males, females, and combined sexes for both populations, in 1981 and 1982 (Appendix 1). Differences between male and female TL - OL relationships occurred for both populations in 1982, but not in 1981 as indicated by ANCOV (Appendix 13a). There were significant between year differences in TL - OL relationships for males and females in both populations (Appendix 13b). Therefore total length at each annulus was backcalculated for males, females, and combined sexes using the regression statistics shown in Appendix 1.

#### 3.2 Backcalculations

Mean length at each annulus was calculated for samples collected in both 1981 and 1982 for the 1973-1981 year-classes in Savanne Lake and 1964-1981 year-classes in Henderson Lake (Appendix 14a-d). There were no trends in calculated length at annulus across all year-classes in either population, rather growth patterns remained consistent among year-classes. Absence of Lee's phenomenon indicated that gillnets did not cause selective mortality. Because of small sample sizes for older individuals, mean calculated lengths at older ages varied considerably among year-classes.

The accuracy of backcalculations was examined by comparing mean calculated lengths at each annulus to measured total length at last annulus (shown in Appendix 15), using Wilcoxon Matched Pairs Ranked-Sign Tests (Appendix 16). No differences between calculated and empirical length at age were detected ( $P > 0.01$ ; Appendix 16). Therefore, I used empirical data for all age and growth analysis.



### 3.3 Growth of Adult Yellow Perch

Growth curves were asymptotic for male and female perch from Henderson and Savanne lakes with both sexes growing at a slower rate in Henderson Lake (Fig. 12).

Differences between sexes with respect to length at age within each year were assessed by Student's t-tests (Appendix 17). Since some age groups consisted of only one individual no comparisons were made. Savanne females were larger than males by at least age 3 but were significantly larger only at: ages 3,5, and 8 in 1981; ages 6 and 7 in 1982 ( $P < 0.01$ ; Appendix 17, Fig. 12). Henderson females were larger than males by at least age 6 and 7 but significantly so only at age 10 ( $P < 0.01$ ; Appendix 17, Fig. 12), in both 1981 and 1982.

#### 4. LENGTH - FREQUENCY DISTRIBUTIONS

Gillnet length-frequency distributions with the range in length for each age class of both perch populations are shown in Figure 13 and Appendix 18b. The summary statistics for the number and total length of perch captured with experimental gillnets are as follows:

Lake	Year	N	Total length (mm)		
			Mean	Range	SD
Henderson	1981	1211	106.0	70-208	26.0
	1982	3098	106.2	70-212	26.0
Savanne	1981	1631	121.8	68-287	38.8
	1982	1970	123.6	71-266	35.6

The mean and range in length of perch effectively recruited to gillnets in either lake was not affected when the 63.5 mm stretched mesh

Figure 12. Difference in growth in mean total length (cm) at age between male and female yellow perch in Henderson and Savanne lakes, Ontario, 1981 and 1982. (empirical data)

1981	—————	Male	○
1982	- - - - -	Female	●

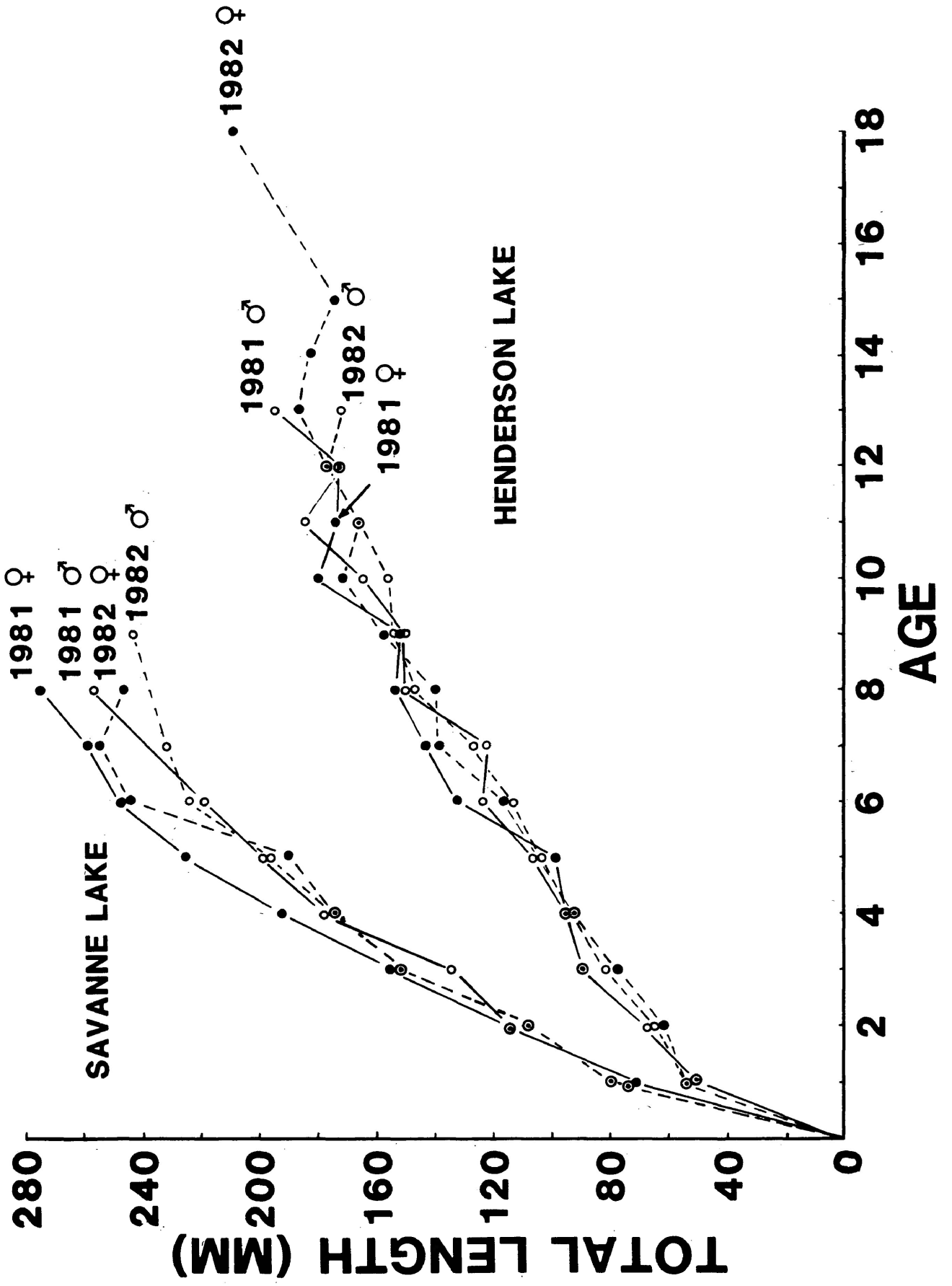
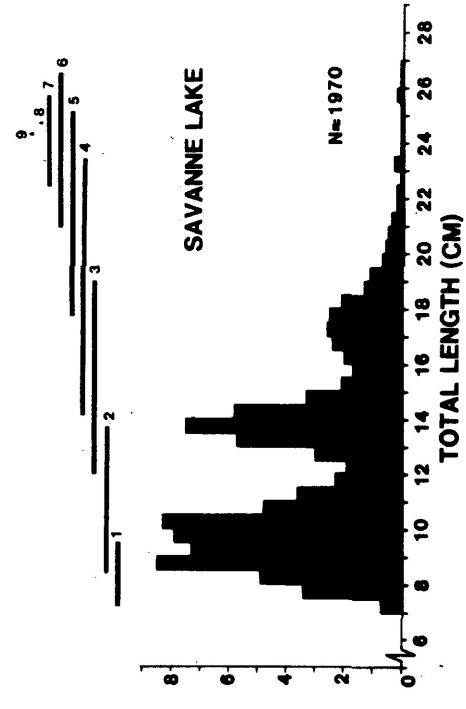
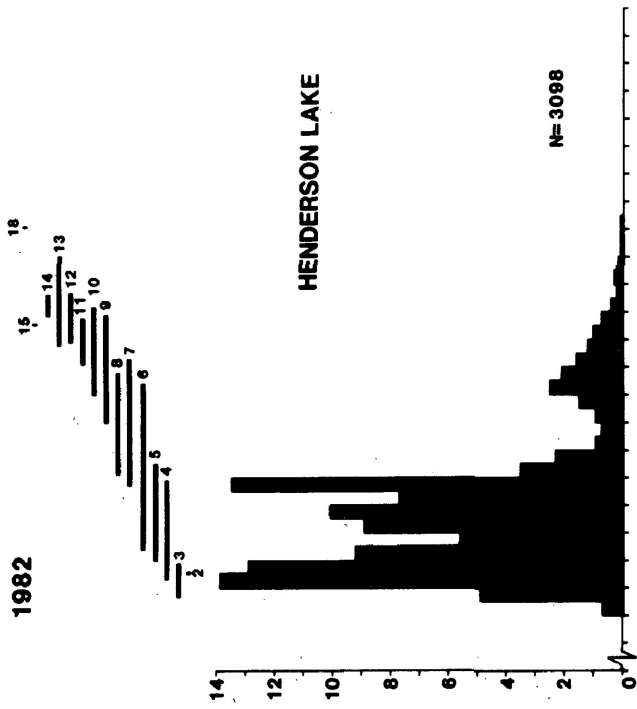
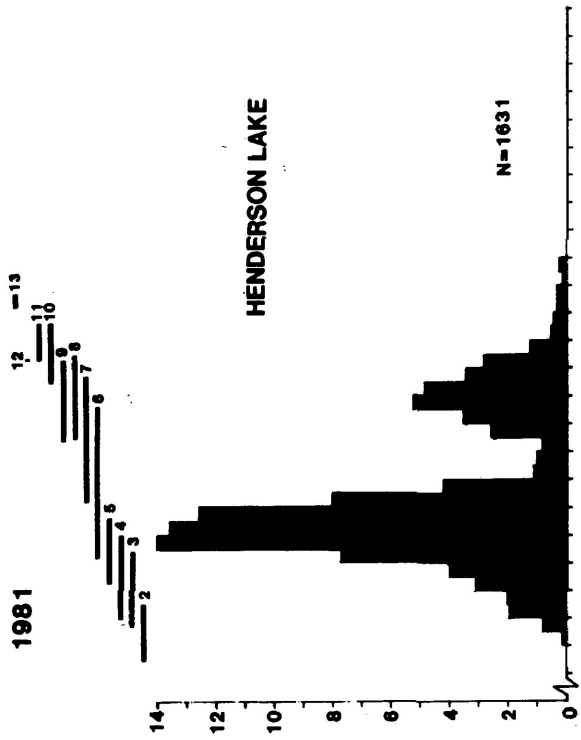


Figure 13. Length - frequency distributions of gillnetted yellow perch in Henderson and Savanne lakes, Ontario, 1981 and 1982, expressed as percentages of the total caught. Horizontal bars indicate the range in total length of each age class. (stretched mesh sizes: 25.4, 38.1, 50.8, 63.5 mm in 1981; 19.1, 25.4, 38.1, 50.8 mm in 1982)

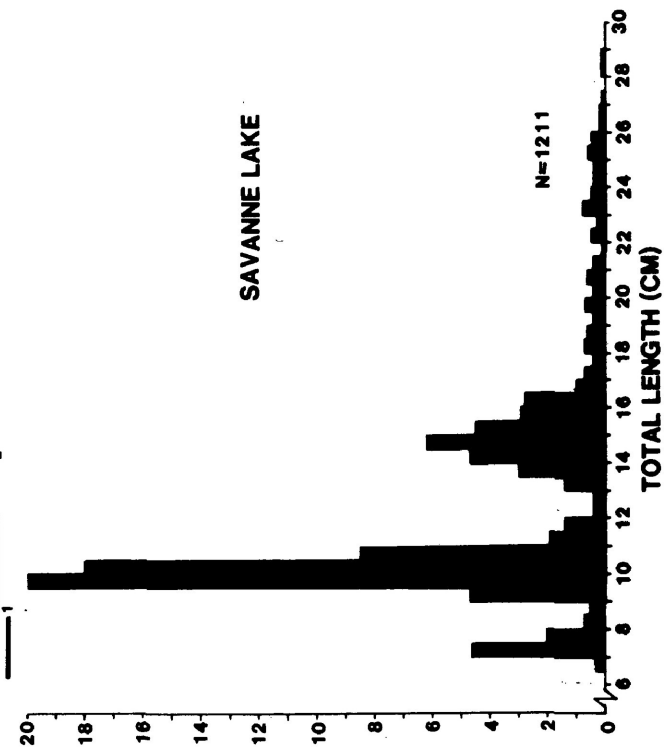
1982



1981



PERCENT OF TOTAL CATCH



TOTAL LENGTH (CM)

panel was replaced with a 19.1 mm stretched mesh panel.

#### 4.1 Savanne Lake

There was good correspondence between length ranges for age classes 1 to 3 and the first three length frequency polygons in 1981. However, these modal groups were not distinct in 1982 (Fig. 13). The addition of the smaller mesh did not affect the length range of vulnerable perch but the proportion of perch less than 9 cm increased in 1982. This probably reflects the greater abundance of the 1981 year-class relative to that of 1980, the latter appearing as the first age class in both the 1982 and 1981 distributions (Fig. 13).

Age 2 fish (1979 year-class) dominated the 1981 catch and shared dominance of the 1982 catch with the 1980 and 1981 year-classes (age 2 and 1) (Fig. 13). The 1979 year-class was abundant in the gillnet catch which also corresponded with its initial large relative abundance first detected by seines, thus establishing it as a dominant year-class (Table 8). The 1979 year-class proved to be the most abundant recorded in seine catches since records began in 1972, whereas the 1980 and 1981 year-classes were only half as abundant (Table 8). Hence, experimental gillnet catches in Savanne Lake did reflect individual year-class strength at least within the first three years.

#### 4.2 Henderson Lake

Individual year-classes could not be distinguished in the length-frequency distributions (Fig. 13). Slow growth and large variation in growth among individuals of the same year-class caused early modal extinction (Fig. 13).

## 5. GEAR SELECTIVITY

The length frequency distributions of gillnetted perch were compared to those from other sampling gears (Appendix 6b). Bag seines and electro-shockers are operated actively and are less selective than passive gears such as gillnets.

### 5.1 Savanne Lake

Significant differences between mesh sizes (19.1, 25.4, 38.1, 50.8 mm) occurred in terms of the mean length of perch, although the ranges in length of perch captured in each mesh was similar (K-W ANOVA,  $X = 1323.2$ ,  $N = 1914$ ,  $P < 0.01$ ; Appendix 6a).

Frequency histograms were constructed for perch captured with monofilament gillnets, bag seines, and electro-shocker (Fig.14). The modal lengths of perch captured by each gear type were similar.

### 5.2 Henderson Lake

Significantly different sized perch were captured in the various mesh sizes even though ranges in length of perch captured in each mesh was similar (K-W ANOVA,  $X = 1184.1$ ,  $N = 1970$ ,  $P < 0.01$ ; Appendix 6a).

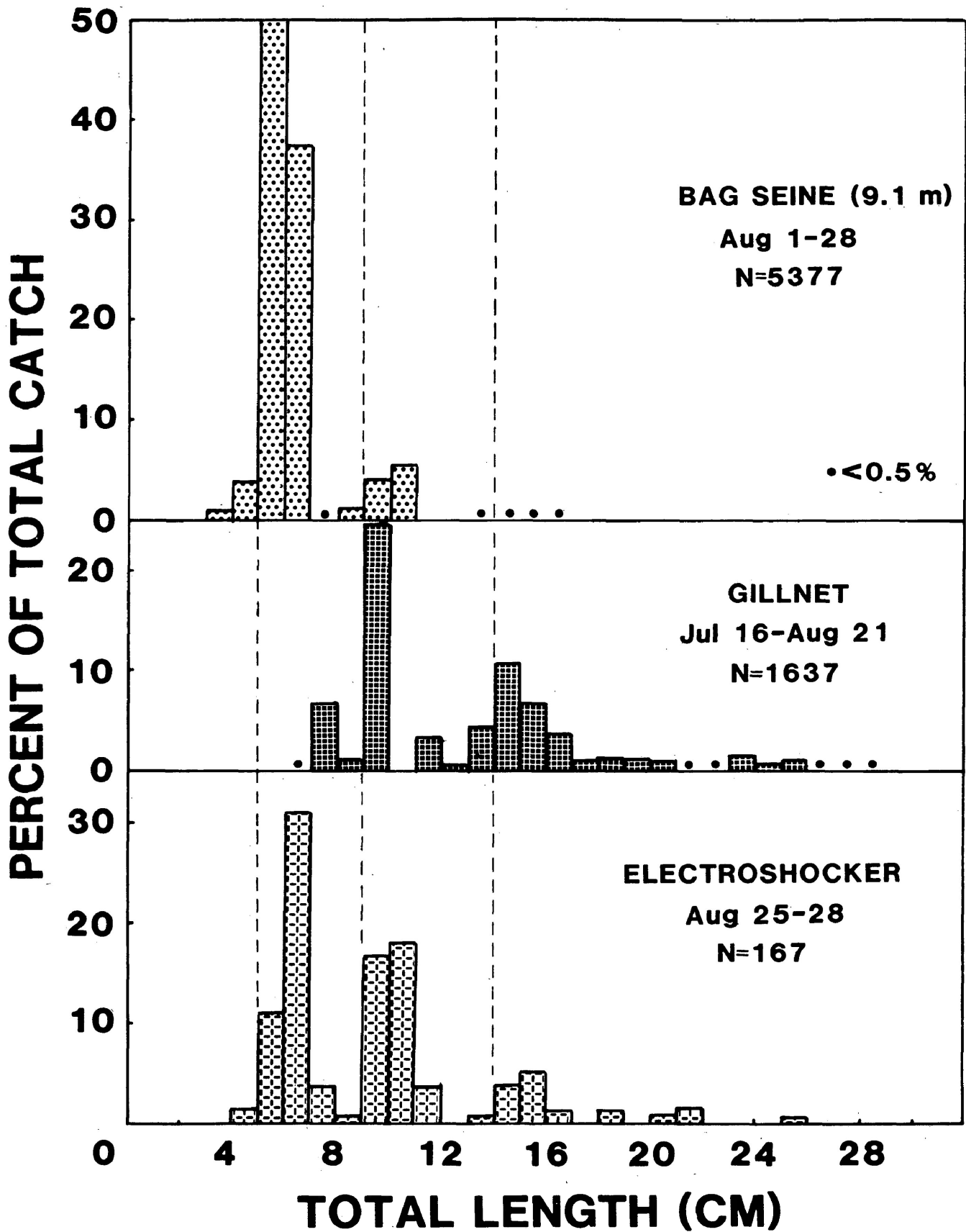
### 5.3 Conclusion

The good agreement between passive and active gears, the absence of Lee's phenomenon in backcalculations (i.e. no size-selective mortality), and the sensitivity of monofilament gillnets to dominant year-classes, meant that gillnets adequately measured the size structure of the vulnerable perch population in Savanne Lake. Slow growth of perch in Henderson Lake causes modal extinction of younger age classes, therefore gillnet selectivity cannot be confirmed.

Figure 14. Length - frequency distributions of yellow perch sampled with experimental, monofilament gillnets (19.1, 25.4, 38.1, 50.8 mm stretched mesh), electroshocker, and bag seine (9.1 m by 1.4 m) in Savanne Lake, Ontario, 1981, expressed as percentages of the total catch.



# SAVANNE LAKE



Electrofishing gear needs to be employed so comparative samples can be obtained.

## 6. AGE COMPOSITION

Age structures of perch captured with monofilament gillnets in Henderson and Savanne lakes, 1981 and 1982, derived from aged subsamples (Appendix 5), are shown in Figure 15.

Savanne Lake's perch population is comprised of 9 year-classes (1973-1981), while the perch population in Henderson Lake consists of 18 year-classes (1964-1981).

### 6.1 Savanne Lake

The age structure was similar in both years with the majority of the population being less than 3 years of age. The first effectively recruited age class was age 2. This age class dominated the catch in both years, making up 38% and 43% of the total catches in 1981 and 1982, respectively. Adding the 19.1 mm stretched mesh panel in 1982 did not alter the estimated age of effective recruitment.

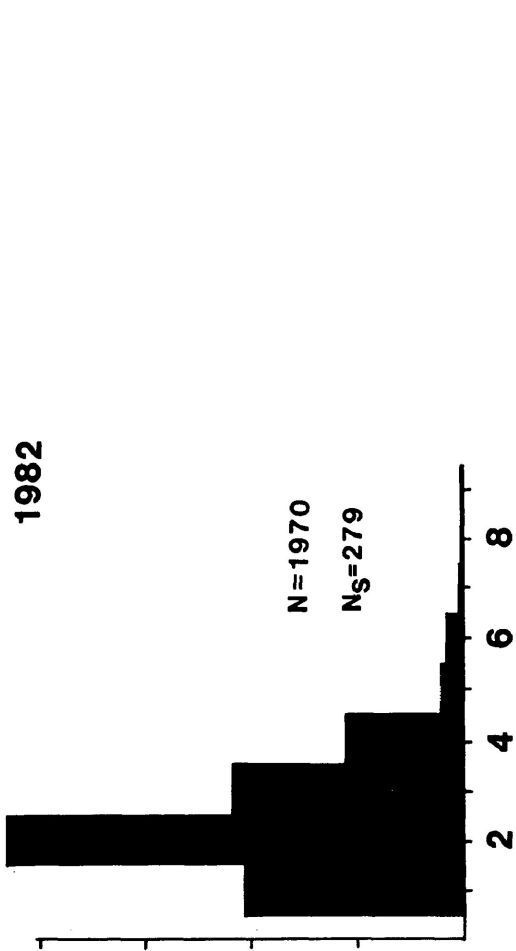
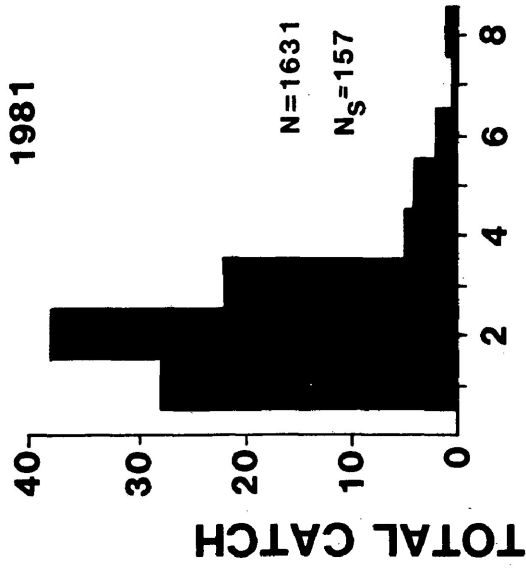
### 6.2 Henderson Lake

In 1982, the age structure was comprised of younger ages. For example, ages 2 to 5 made up 69% of the total catch in 1982 compared to 36% in 1981 (Fig. 15). This resulted from increased recruitment of younger perch following the addition of the 19.1 mm stretched mesh panel.

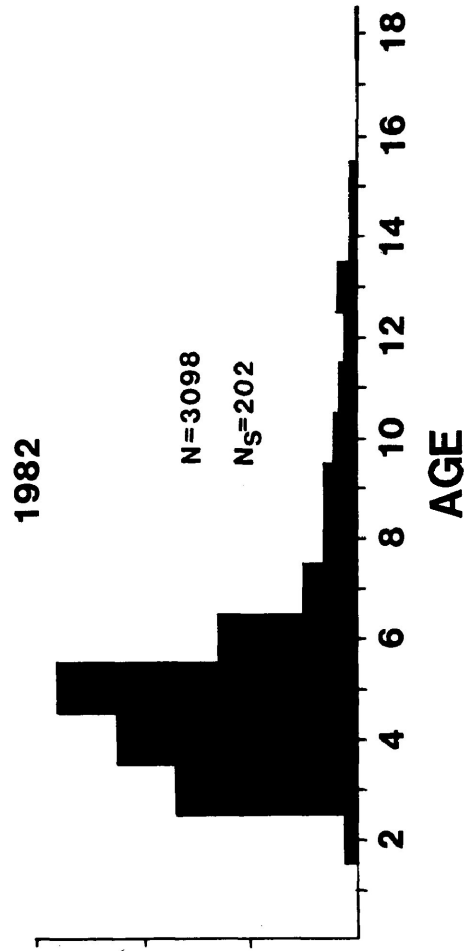
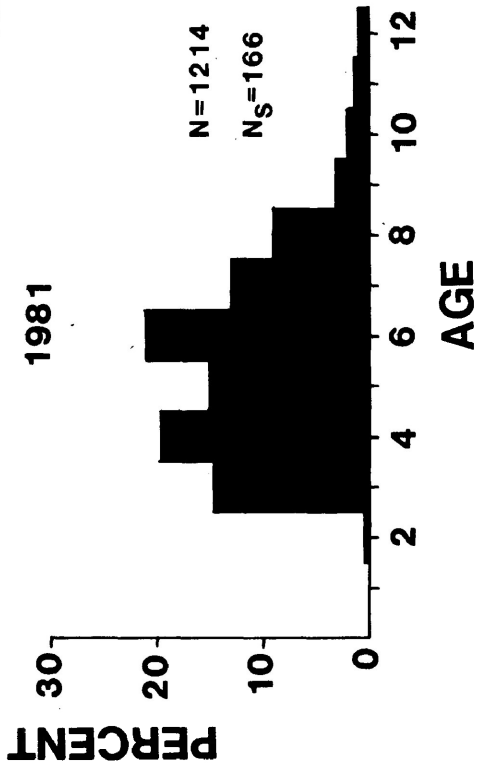
The first effectively recruited age class was age 5 in both years. Ages 3 to 7 dominated the 1981 catch and ages 3 to 6 in 1982, contributing 70.4% and 63.8% of the total catches, respectively. In

Figure 15. Age composition of the experimental, monofilament gillnet catches of yellow perch in Henderson and Savanne lakes, Ontario, 1981 and 1982, expressed as percentages of the total catch. (stretched mesh sizes: 25.4, 38.1, 50.8, 63.5 mm in 1981; 19.1, 25.4, 38.1, 50.8 mm in 1982; N is total number in the catch and  $N_s$  is the sample size of aged fish)

**SAVANNE LAKE**



**HENDERSON LAKE**



contrast to the Savanne catch, the majority of the fish in the Henderson catch were older than age 3 (Fig. 15).

## 7. MORTALITY

Catch curves were constructed from gillnet catches (Fig. 16). The frequency data generated both catch curves and instantaneous mortality rates ( $Z$ ) (Appendix 19). Since, catch curves were constructed from the gillnet samples taken throughout the field season, estimates of " $Z$ " and corresponding instantaneous survival rate ( $S$ ) pertain to the time interval approximately from the middle of one season to the middle of the next. Mortality and survival rates were calculated between ages and are shown in Table 11.

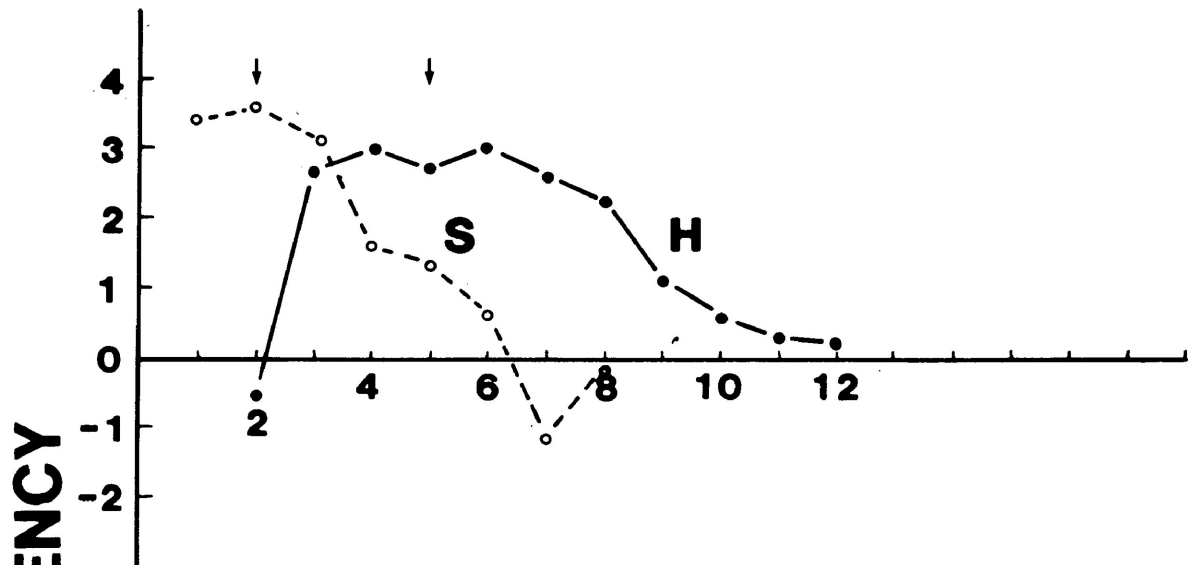
### 7.1 Savanne Lake

Savanne Lake perch have higher mortality rates as indicated by the steeper descending right limb of the catch curve (Fig. 16). The steepness of this portion of the curve may result from the relatively low abundance of YOY perch prior to 1979 (except for 1975), when compared to annual abundance since 1979 (Table 8). Relative year-class strength prior to 1979 was only 32% of the strong 1979 year-class, and below that of year-classes 1980 to 1983 (Table 8). Apparently maximum mortality rates occur if an initially strong year-class is followed by a relatively weak one. Mortality rates between ages may thus be influenced by their relative abundance as YOY. For example, in 1981 and 1982, high mortality rates (1.78 and 1.59) occurred between the 1974 and 1975 year-classes. (Table 8; Fig. 16). In this case, the much weaker 1974 year-class (13.3% of the 1979 year-class) was followed by the strong 1975 year-class (96.7% of the 1979 year-class). However, this pattern

Figure 16. Catch curves for the yellow perch populations in Henderson and Savanne lakes, Ontario, 1981 and 1982. Arrows indicate age of effective recruitment to the gear. (stretched mesh sizes: 25.4, 38.1, 50.8, 63.5 mm in 1981; 19.1, 25.4, 38.1, 50.8 mm in 1982.

Henderson Lake ●————●  
Savanne Lake ○-----○

**1981**



**1982**

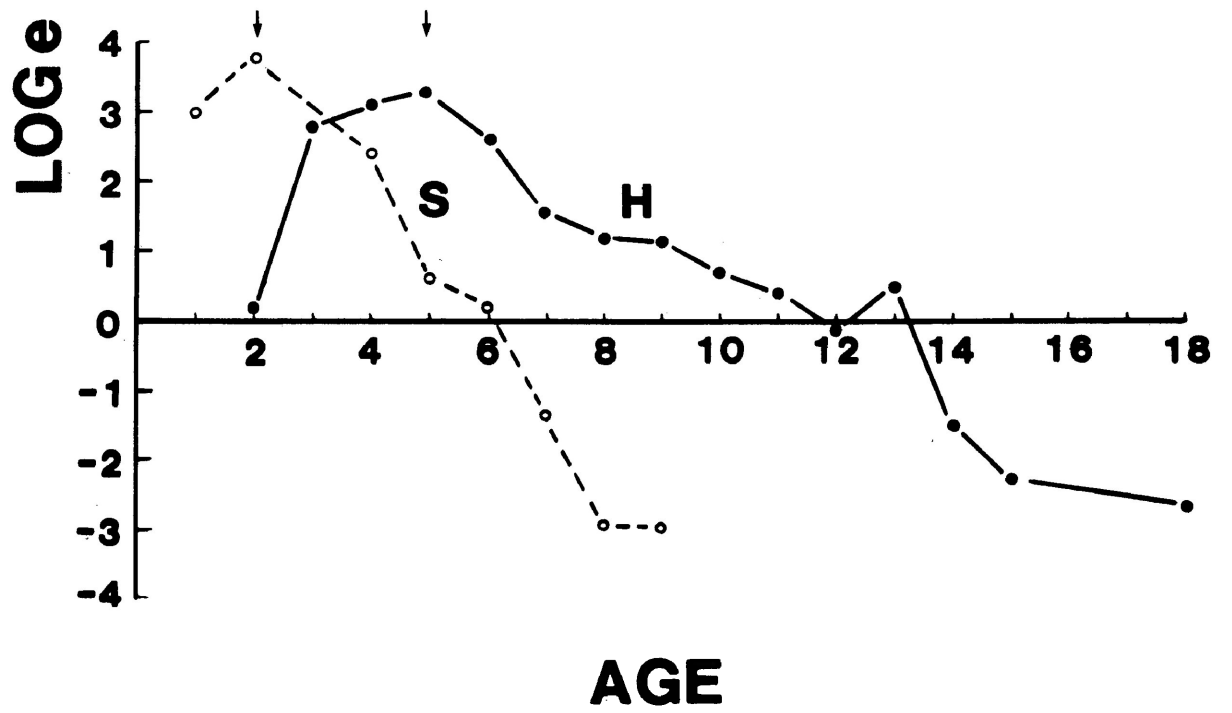


Table 11. Instantaneous mortality rates (Z) and corresponding survival rates (S) between ages (year-classes) of yellow perch vulnerable to experimental monofilament gill nets in Henderson and Savanne lakes, Ontario, 1981 and 1982.

Age interval	Year-classes (Year-class strength) <sup>a</sup>	1981				1982			
		Savanne		Henderson		Savanne		Henderson	
		Z	S	Z	S	Z	S	Z	S
2 - 3	1979-1978 (100 - NA)	.52	.60			.70	.50		
3 - 4	1978-1977 (NA-28.6)	1.49	.23			.65	.52		
4 - 5	1977-1976 (28.6-32.1)	.30	.74			1.84	.16		
5 - 6	1976-1975 (32.1-96.7)	.71	.49			.34	.71	.77	.46
6 - 7	1975-1974 (96.7-13.3)	1.78	.17	.45	.64	1.63	.20	.96	.38
7 - 8	1974-1973 (13.3-8.0)			.38	.68	1.59	.20	.43	.65
8 - 9	1973-1972 (8.0-11.5)			1.10	.33		1.00	.06	.94
9 - 10				.57	.57			.37	.90
10 - 11				.27	.76			.32	.73
11 - 12				.06	.94			.56	.57
12 - 13								.64	.53
13 - 14								1.99	.14
14 - 15								.85	.43
15 - 16								.41	.66

<sup>a</sup> Year-class strength calculated as a percent of year of maximum relative abundance (1979) for Savanne Lake only, taken from Table (8).



was not always consistent.

When the year-classes since 1979 become vulnerable to gillnets, we may be able to identify the effects of initial year-class strength on mortality patterns at later ages.

## 7.2 Henderson Lake

Henderson Lake catch curves have broad domes in contrast to those of Savanne Lake. This suggests that recruitment occurs across several age classes resulting from a larger range in length among individuals of each year-class (Fig. 14).

Mortality rates of Henderson perch are generally lower at comparable ages than those of Savanne perch (Table 11). The effect of initial year-class strength on the subsequent distribution of mortality and recruitment at later ages for the Henderson population requires additional data. YOY recruitment in Henderson Lake has been measured only since 1981, while age of effective recruitment is at 5 years of age.

## 8. LENGTH-WEIGHT RELATIONSHIPS

Natural logarithmic transformations of weight versus total length provided the best linear fit resulting in Pearson's correlation coefficients of at least 0.98, as determined by least squares regression (Appendix 20). There were no significant differences between sexes with respect to the slopes or intercepts of the regression lines for either population with the exception of the length-weight relationships in June, 1982 in both lakes when intercepts were significantly different (ANCOV,  $P < 0.01$ ). I therefore used equations for combined sexes for further interpretation (Table 12).

Table 12. Regression statistics for  $\log_e$  weight versus  $\log_e$  total length for combined sexes of yellow perch from Henderson and Savanne lakes, Ontario, 1981 and 1982.

Lake	Year	Sampling time	N	r	SE	Equation ( $\log_e - \log_e$ ) <sup>a</sup>	95% CI
Savanne	1981	Jul 21-24	251	1.0	0.092	$W = -5.291 + 3.178TL$	3.00-3.36
		Aug 5-22	262	1.0	0.093	$W = -5.546 + 3.291TL$	3.11-3.47
Henderson	1981	Jun 27	192	.99	0.031	$W = -4.903 + 3.137TL$	3.08-3.20
		-Jul 26	425	.98	0.019	$W = -5.075 + 3.185TL$	3.15-3.22
		Jul 26 -Aug 28	617	1.0	0.013	$W = -4.839 + 3.100TL$	3.08-3.13
Savanne	1982	May 18	404	.99	0.023	$W = -5.370 + 3.260TL$	3.31-3.22
		-Jun 19	371	.99	0.018	$W = -5.201 + 3.323TL$	3.26-3.38
		Jul 2 -Jul 19	619	.99	0.022	$W = -5.370 + 3.347TL$	3.30-3.39
		Aug 1 -Aug 21	439	.99	0.019	$W = -5.065 + 3.146TL$	3.11-3.18
Henderson	1982	May 22	762	.99	0.014	$W = -4.766 + 3.069TL$	3.04-3.10
		-Jun 24	420	.99	0.020	$W = -5.089 + 3.176TL$	3.14-3.22
		Jul 1 -Jul 31					
		Aug 1 -Aug 31					

<sup>a</sup>  $W = \log_e W$  ;  $TL = \log_e TL$ .

Growth was not isometric except for the July, 1982 relationship for Savanne perch, since the 95% confidence limits did not include 3.0 (Table 12). Growth increased in late summer as indicated by the greater slopes (Table 12).

## 9. CONDITION

Since growth was not isometric, condition factors were calculated individually and then averaged for each age and 1.0 cm length interval. No significant differences were apparent between sexes in terms of condition at age and length for either population (Wilcoxon Matched-Pairs Ranked-sign Test,  $P > 0.01$ ; Appendix 20). Therefore, condition factors at each age and length interval for combined sexes were used (Table 13). Condition of Savanne perch was better than that of Henderson perch at each age and length interval, in both years. Fulton's condition factor ranged from 1.04 to 1.55 for Savanne perch and from 0.75 to 1.14 for Henderson perch (Table 13).

Though condition of perch improved with age and length in both populations, the magnitude of change was greater for Savanne perch (Table 13).

## 10. MATURITY

### 10.1 Differences Between Methods

There were large differences in the estimated mean age and length at maturity depending on the method used. For example, mean ages of maturity, as estimated by the Abrosov's and Lysack methods, were up to two times greater than the values estimated by the modified Abrosov and Probit methods (Table 14).

Both the Abrosov and the modified Abrosov methods become biased by

Table 13. Mean Fulton's Condition Factor (F) at age and length interval (1.0 cm) for combined sexes of yellow perch from Henderson and Savanne lakes, Ontario, 1981 and 1982 (Jul-Aug). (Sample sizes are in brackets).

Age	1981		1982		Length interval (cm)	1981		1982	
	Sav.	Hend.	Sav.	Hend.		Sav.	Hend.	Sav.	Hend.
1	1.10(89)		1.05(37)		6.0-6.9	1.14(4)		1.10(44)	
2	1.21(88)	1.01(4)	1.05(69)	0.75(1)	7.0-7.9	1.12(106)	1.02(11)	1.07(151)	1.03(53)
3	1.28(41)	1.01(42)	1.22(43)	0.88(12)	8.0	1.03(14)	0.98(46)	1.08(184)	0.93(204)
4	1.30(10)	1.04(29)	1.25(33)	0.88(26)	9.0	1.06(7)	1.03(66)	1.04(192)	0.92(155)
5	1.44(18)	1.02(12)	1.24(6)	0.87(51)	10.0	1.23(3)	1.02(28)	1.11(107)	0.98(229)
6	1.37(6)	1.09(10)	1.34(8)	0.87(26)	11	1.19(53)	1.01(9)	1.27(82)	0.96(161)
7		1.06(7)	1.21(1)	0.89(14)	12	1.20(26)	1.05(4)	1.23(237)	0.99(94)
8	1.55(3)	0.99(3)	1.15(1)	0.96(9)	13	1.23(25)	1.12(5)	1.20(177)	1.07(33)
9		1.09(2)		0.96(10)	14	1.17(25)	1.11(8)	L.20(75)	1.06(48)
10		1.13(2)		0.93(12)	15	1.21(16)	1.06(6)	1.31(86)	0.99(85)
11		1.14(1)		1.02(10)	16	1.37(24)	1.07(2)	1.33(99)	0.97(54)
12		0.95(1)		0.98(9)	17	1.33(17)	1.07(4)	1.33(64)	1.01(17)
13		1.07(2)		0.98(13)	18	1.33(24)	1.10(1)	1.34(27)	0.98(9)
14				0.94(3)	19	1.32(17)	1.07(2)	1.30(17)	1.00(5)
15				0.98(1)	20	1.33(16)		1.31(8)	0.99(2)
18				0.99(2)	21	1.43(12)		1.45(3)	
					22	1.37(17)		1.37(5)	
					23	1.41(23)		1.27(3)	
					24	1.31(14)		1.39(4)	
					25	1.41(11)		1.22(1)	
					26				
					27				
					28				
Mean	1.21(259)	1.03(115)	1.14(198)	0.91(199)		1.24(492)	1.02(192)	1.18(1566)	0.97(1191)

Table 14. Mean age and length (cm) at maturity of yellow perch from Henderson and Savanne lakes, Ontario, 1981 and 1982, using 5 methods

Lake	Year	Sex	N	Mean age at maturity					Mean length at maturity				
				Abrosov	Modified Abrosov	Lysack's	Probit	Empirical <sup>a</sup>	N	Lysack's	Probit	Empirical <sup>a</sup>	
Henderson	1981	♂	116	5.1	4.1	7.4 <sup>ns</sup>	3.7	3.3	123	10.8	9.3	9.1	
		♀	185	6.5	5.6	7.3	5.0	5.1	160	12.6	10.5	10.8	
	1982	♂	125	5.1	3.1	5.9 <sup>ns</sup>	3.1	2.8	209	9.6	6.9	6.8	
		♀	186	7.0	4.0	8.2	4.9	5.4	222	12.9	10.4	10.0	
Savanne	1981	♂	171	3.1	2.5	3.5 <sup>ns</sup>	2.2	1.8	239	12.9	9.6	10.0	
		♀	155	4.7	4.1	5.6	3.4	3.5	311	16.8	11.1	11.8	
	1982	♂	170	3.7	1.5	4.4 <sup>ns</sup>	1.8	2.0	292	17.5 <sup>ns</sup>	11.9	10.8	
		♀	158	4.8	3.3	5.2 <sup>ns</sup>	3.5	3.2	272	19.4	15.3	14.8	

<sup>a</sup>Age and length at 50% maturity determined by inspection (Fig. 17).

<sup>ns</sup>Value from non-significant regressions (Appendix 23).

the occurrence of poorly represented age classes which cause negative "Z" values (see equations 3 and 4 on page 24). This problem occurred in several data sets, notably: the 1981 Henderson male and female age and length at maturity schedules; the 1982 Henderson female age at maturity schedule; the 1981 Savanne male length at maturity schedule; and the 1982 Savanne male and female length at maturity schedules (Appendix 21). Since these methods are biased by small sample size, real annual differences are easily obscured.

Both the Probit and Lysack regression methods have an advantage over the former two methods since they generate a rate of maturity in addition to an estimate of mean age or length at maturity. This slope or rate of maturity is more sensitive to annual changes in maturity induced by exploitation than a simple estimate of mean age at maturity (Lysack 1980).

The linear equations generated by the two regression methods describing the age and length at maturity relationships for male and female perch from Henderson and Savanne lakes are summarized in Appendix 22. The regression lines derived from Probit transformation generally provided a better fit than those following Lysack's natural logarithmic ( $\text{Log}_e$ ) transformations (Appendix 22). The major discrepancy resulted from the absence of conformity between maturity schedules and assumptions of a cumulative normal distribution implicit in Lysack's transformation formula.

The Lysack method works best when the data fits a logistic curve. Ricker (pers. comm.) emphasized three assumptions about the use of a logistic curve:

- (1) The inflection point is always 50%,
- (2) The curve is symmetrical around this inflection point, and

(3) All ages have at least a few immature and a few mature individuals so the distribution is asymptotic at, but not including 0 and 100%.

Data rarely fit the first two assumptions. As for the third assumption, Lysack's method incorporates the two asymptotic values when transforming cumulative maturity percentages to  $-\text{Log}_e\left[\frac{(K-Y)}{Y} + 1\right]$ , where K is equal to 100%.

Also, adding one to the  $(K-Y)/Y$  segment of the equation, although eliminating fractions which cause negative values following  $\text{Log}_e$  transformation, shifts the position of the data points which in turn affects the inflection point (Ricker pers. comm.). This is the reason why the Lysack method generates larger mean age and length at maturity estimates compared to those generated by the Probit method (Table 14).

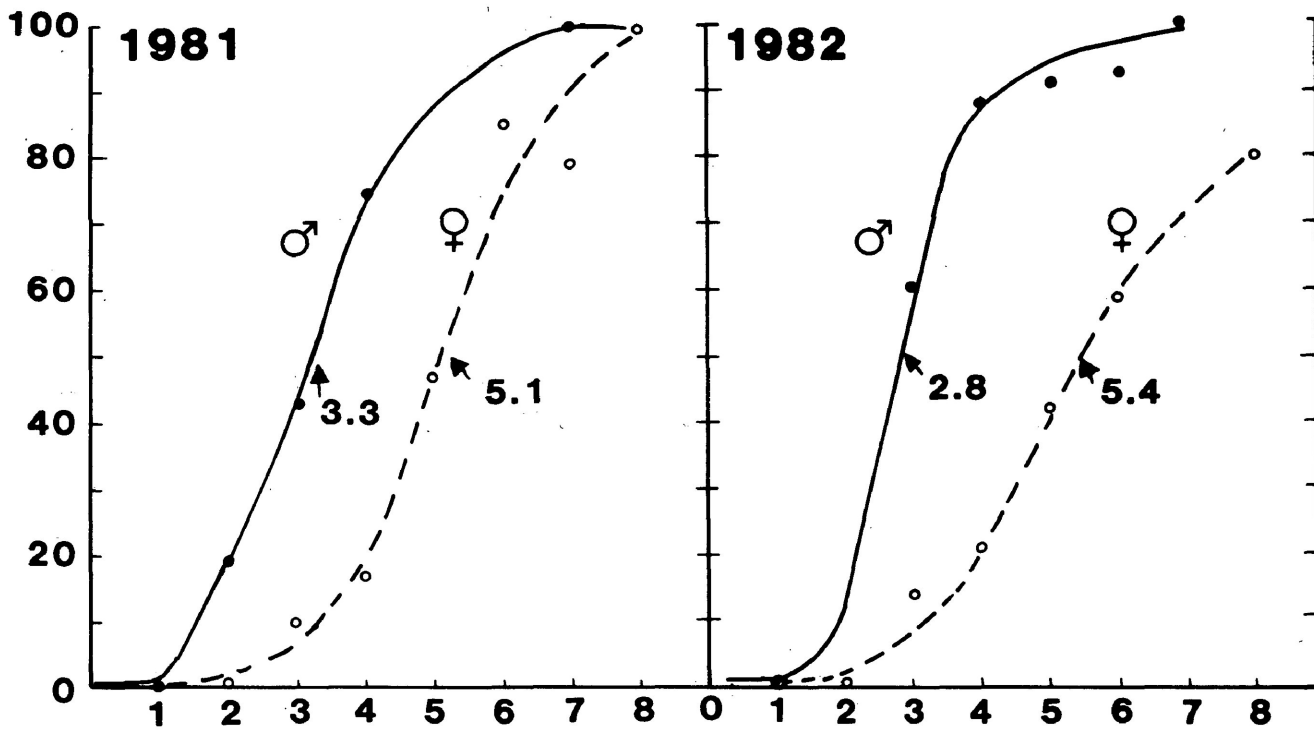
The advantage of the Probit method over that of Lysack's regression method is best seen by comparing mean age at maturity values obtained from cumulative frequency curves fitted by inspection and assuming that the inflection point is at 50% (Fig. 17; Table 14). Empirically derived mean age and length at maturity estimates compare well with those from the Probit method but Lysack's often are twice as large. Although the Probit method is restricted by the same assumptions concerning the normal cumulative frequency distribution as Lysack's, it provides a more realistic value for mean age and length at maturity. Differences in the accuracy of estimation of rate of maturity by the two methods is dependent on how well the transformed data fits the least squares regression model. For the maturity schedules of perch from Henderson and Savanne lakes, the Probit transformation generally provided a better fit than the  $\text{Log}_e$  transformation (Appendix 22). Therefore interpretation of rate and age at maturity will be based on the results obtained from

Figure 17. Relationships between percentage maturity and A) Spawning Age, B) Total length (cm) for male and female yellow perch in Henderson and Savanne lakes, Ontario, 1981 and 1982. (values indicate age and length to 50% maturity)

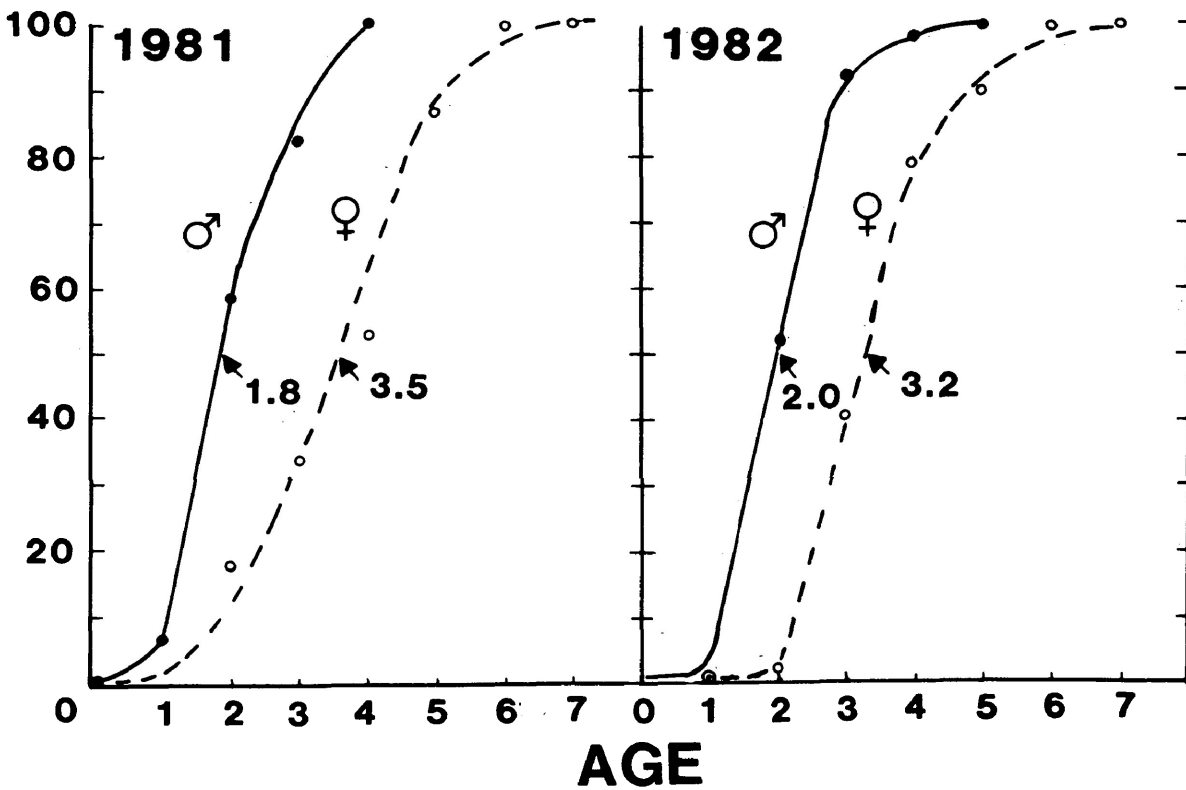


**A**

**HENDERSON LAKE**

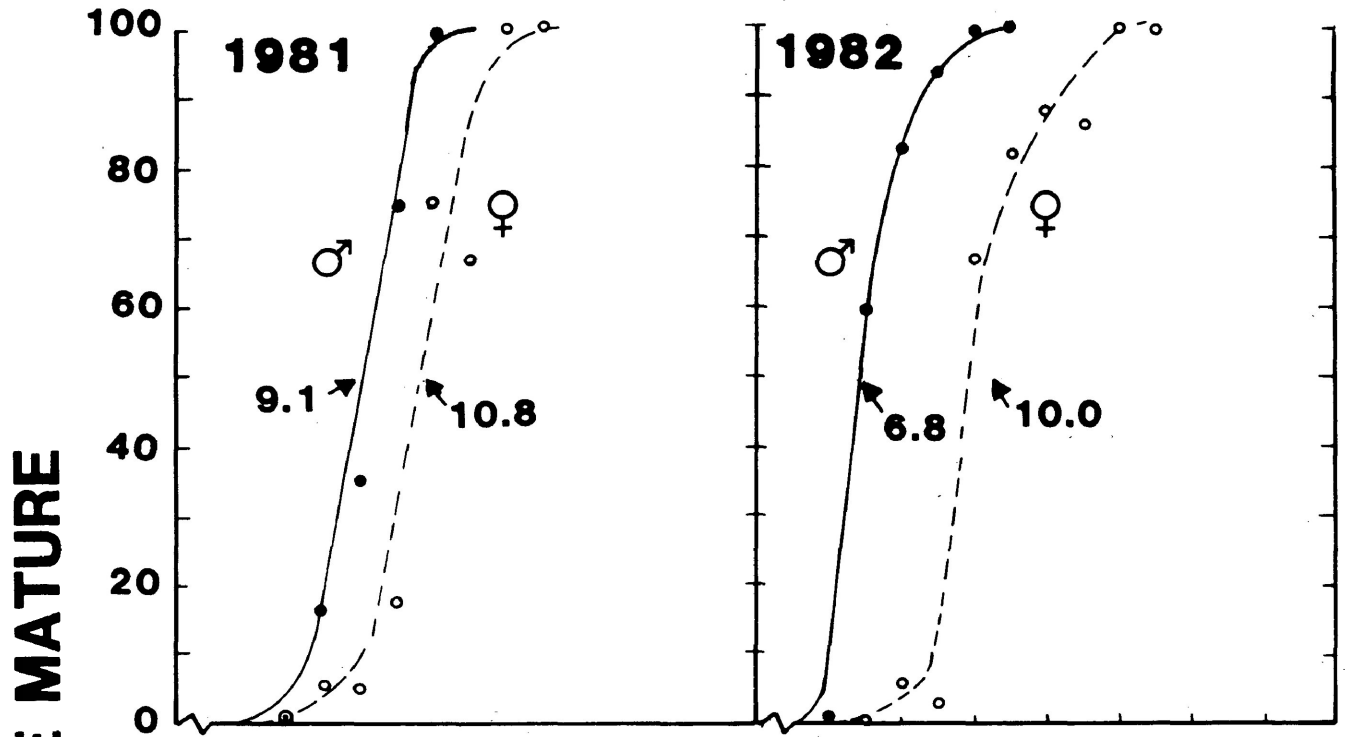


**SAVANNE LAKE**

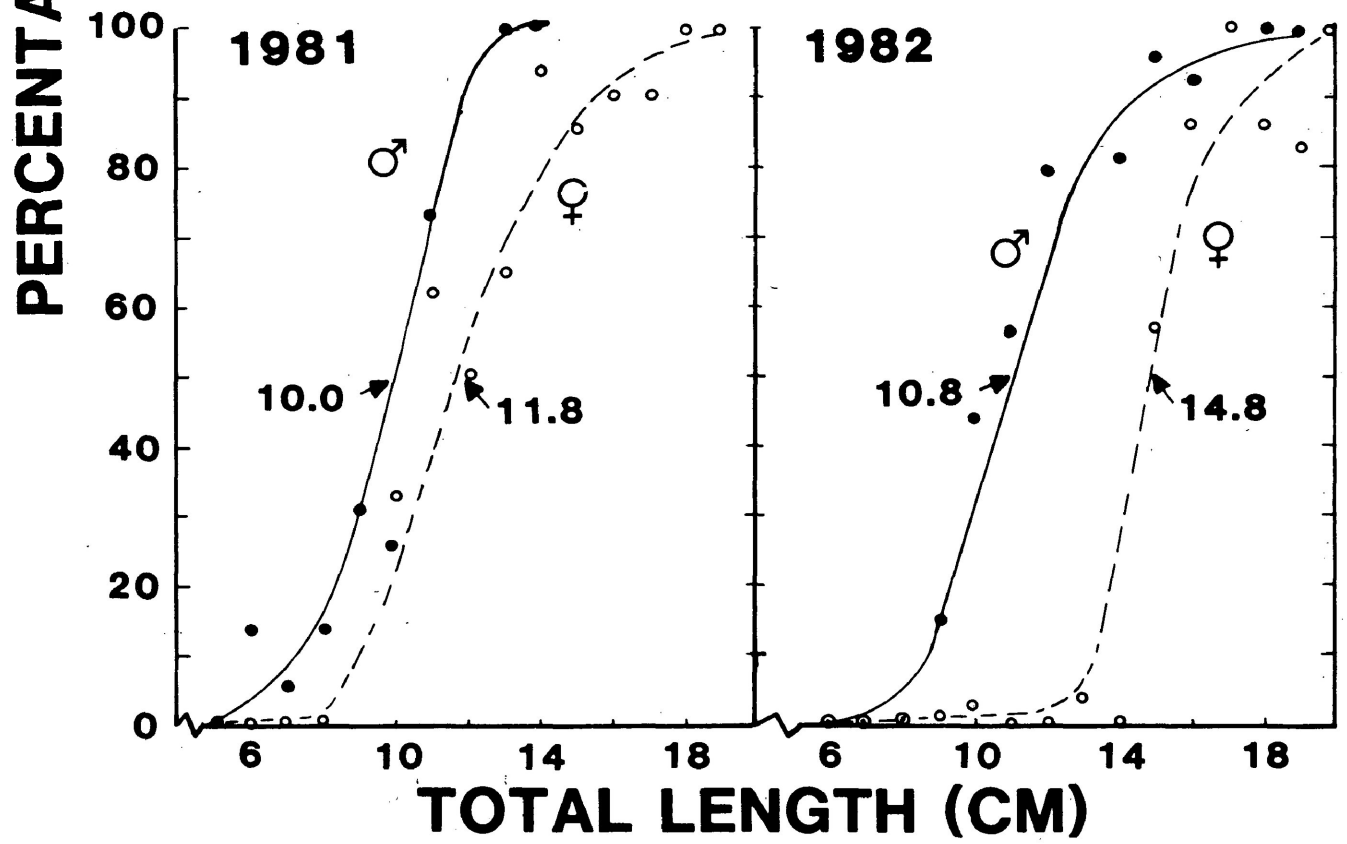


**B**

**HENDERSON LAKE**



**SAVANNE LAKE**



the Probit method.

## 10.2 Sex-Specific and Population Differences

In both lakes mature females were both 1-1.5 years older and larger in size than males as established from estimates of both the mean and the 100% age and length at maturity (Table 14). However, male and female Savanne perch grew faster and matured earlier (1-2 years) and at larger sizes than Henderson perch in both years (Tables 15 and 16).

There is also evidence for size-related maturity within individual year-classes. In the 1982 age at maturity schedule for female perch from Henderson Lake, 12 of 15, age 8 females were mature (Appendix 21). The three immature females ranged in length from 12.1 to 12.8 cm with a mean of 12.4 cm. Whereas the mature females averaged 15.1 cm in length. This indicated that the faster growing individuals matured earlier within this year-class and possibly the same is true for other year-classes.

## 11. FECUNDITY

### 11.1 Savanne Lake

Absolute fecundity estimates varied from 5,306 eggs for an age 4 female (16.3 cm, 54.3 g) to 32,015 eggs for an age 6 female (25.9 cm, 248.1 g) in 1981 and 1982 samples (Table 17).

Since only 9 females were captured in 1981 with no representatives at lengths between 18 and 24 cm, regression analysis was not done. However, in 1982, fecundity was linearly related to age, total length, total weight, and ovary weight with total weight being the best predictor (Appendix 24). Logarithmic transformations of both variables did not improve the correlation between fecundity and age, weight, and length but  $\text{Log}_e$  ovary weight became a better predictor than total

Table 15. Instantaneous rates of maturity ( $R_m$ ), in terms of age, with 95% confidence limits (CL), as determined by the Probit Method for male and female yellow perch in Henderson and Savanne lakes, Ontario, 1981 and 1982.

Lake	Year	Male		Female	
		$R_m$	95% CL	$R_m$	95% CL
Henderson	1981	0.56	$\pm .46$	0.81	$\pm .27$
	1982	0.73	$\pm .24$	0.68	$\pm .37$
Savanne	1981	1.44	$\pm .36$	0.96	$\pm .35$
	1982	0.96	$\pm .23$	1.17	$\pm .25$

Table 16. Age and total length interval (cm) at 100% maturity for male and female yellow perch in Henderson and Savanne lakes, Ontario, 1981 and 1982.

Lake	Year	Male			Female		
		N	Age	Length	N	Age	Length
Henderson	1981	116	7	11.0-11.9	185	8	13.0-13.9
	1982	125	7	10.0-10.9	186	7-9	14.0-14.9
Savanne	1981	171	4	13.0-13.9	155	6	18.0-18.9
	1982	170	5	18.0-18.9	158	7	18.0-21.0

Table 17. Absolute fecundity, Gonadosomatic Index (GSI), and number of eggs per gram of fish according to length (cm) of yellow perch in Henderson and Savanne lakes, Ontario, 1981 and 1982. (\* indicates 1982 samples from Savanne Lake).

A. Savanne Lake, 1981 and 1982

Length	N	No. eggs per fish		No. eggs per gm fish		GSI
		Range	Mean	Mean	SD	
15.0-15.9	2	6704- 9121	7913	159.8	12.0	2.45
16.0-16.9	2	5306- 6213	5760	106.6	12.6	1.25
17.0-17.9	3	8054-10416	9066	132.8	10.0	3.71
18.0-18.9	2	8921- 9500	9211	125.8	14.0	1.18*
19.0-19.9	4	6994-18670	11499	119.6	41.6	1.30*
20.0-20.9	4	13639-16580	14977	140.3	8.9	3.32*
21.0-21.9	3	15659-18622	17294	136.6	9.8	1.97*
22.0-22.9	1		16593	127.6		2.65*
24.0-24.9	1		28174	120.8		4.95
25.0-25.9	1		32015	129.0		4.86
26.0-26.9	1		31137	117.9		3.08*
<b>Total</b>	<b>24</b>	<b>5306-32015</b>		<b>131.5</b>	<b>11.2</b>	<b>2.15</b>

B. (i) Henderson Lake, 1981

10.0-10.9	3	2036- 2886	2528	229.4	37.7	4.55
11.0-11.9	5	1916- 2829	2450	177.6	19.4	5.20
12.0-12.9	2	3411- 3270	3341	188.8	1.9	5.24
13.0-13.9	1		5159	186.9		6.30
14.0-14.9	2	6445- 7613	7029	218.0	19.0	5.80
15.0-15.9	7	3835- 7672	6531	175.1	31.5	6.00
16.0-16.9	3	7470- 8361	7797	188.9	21.2	7.40
17.0-17.9	3	9044- 9947	9512	180.6	20.5	6.80
18.0-18.9	2	9985-10490	10238	178.2	2.5	6.00
19.0-19.9	2	12492-12788	12640	170.3	1.2	7.00
<b>Total</b>	<b>30</b>	<b>1916-12788</b>		<b>186.9</b>	<b>27.6</b>	<b>5.8</b>

B. (ii) Henderson Lake, 1982

9.0- 9.9	1		885	118.0		0.70
10.0-10.9	5	2480- 4125	3065	300.4	91.7	1.30
11.0-11.9	10	1850- 2872	2234	157.8	22.6	1.00
12.0-12.9	5	2073- 4401	3051	164.4	70.3	1.13
13.0-13.9	4	1552- 4824	3196	143.7	63.4	1.20
14.0-14.9	4	2602- 6075	4840	155.9	60.8	1.25
15.0-15.9	5	5172- 8319	6594	167.6	40.1	1.27
16.0-16.9	5	6820-12213	9628	216.3	41.4	1.59
17.0-17.9	1		11450	229.0		1.24
18.0-18.9	4	11409-14712	12639	211.5	31.1	1.50
19.0-19.9	3	15714-16598	16051	227.8	26.5	1.58
20.0-20.9	1		14579	153.5		1.28
<b>Total</b>	<b>48</b>	<b>885-16598</b>		<b>188.4</b>	<b>66.4</b>	<b>1.22</b>

weight (Appendix 24)..

There were significant differences between years for the fecundity and total length relationships (ANCOV,  $F = 9.353$ , 1 and 22 df,  $P < 0.01$ ; Appendix 25) and the fecundity and ovary weight relationships (ANCOV,  $F = 21.068$ , 1 and 18 df,  $P < 0.01$ ; Appendix 25). However there was no significant difference between years with respect to fecundity at age relationships (ANCOV,  $F = 0.009$ , 1 and 18 df,  $P > 0.01$ ; Appendix 25). I therefore combined the fecundity at age data from 1981 and 1982 for comparison with Henderson Lake.

### 11.2 Henderson Lake

Absolute fecundity estimates varied from 885 eggs for an age 3 female (9.2 cm, 7.5 g) to 16,598 for an age 10 female (20.4 cm, 95.0 g) in 1981 and 1982 samples (Table 17).

Regressions of absolute fecundity with length, weight, age, and ovary weight were significant in both years (Appendix 24). Logarithmic transformations did not improve the correlations. Wet ovary weight and length were the best predictors of fecundity in both 1981 and 1982.

There were significant differences between years with regard to the slopes ( $P < 0.01$ ), but not the intercepts ( $P > 0.01$ ) of the fecundity and age and the fecundity and total length relationships (Appendix 25). Therefore, I could not combine 1981 and 1982 data.

The apparent annual variation in fecundity at age and length may be due to the difference in sampling times. The 5 fold decline of the 1982 Gonadosomatic Index (GSI) (LeCren 1951), relative to that of 1981 (Oct 31 to Nov 2) was due to earlier sampling in 1982 (Aug 26-30) (Table 17). Though the gravimetric method for determining fecundity might be biased, the same sampling time differences also occurred for data collected from

Savanne Lake in 1981 and 1982 providing a similar GSI for females of comparable lengths (Table 17). Also, variability in fecundity values among females of the same length interval and age can only be reduced by using large sample sizes in order to improve between year comparisons.

### 11.3 Population Differences

Estimates of egg production were grouped by 1.0 cm length intervals and by spawning age (Table 18). Fecundity of perch in Savanne Lake was higher than that of Henderson perch at comparable ages (Fig. 18; Table 17). However Henderson perch produced more eggs than Savanne perch at comparable lengths up to 19 cm, reflecting the shorter length at maturity. Overall, the rate of egg production with respect to total fish length was greater in Savanne Lake (Fig. 19).

## 12. FEEDING ANALYSIS

The percentage frequency of occurrence of major prey items was observed in stomachs of perch from Henderson and Savanne lakes (Fig. 20; Appendix 25). Rare and/or incidental prey items were combined as, Other Invertebrates. Included in this category are: unidentified insects, plecoptera, megaloptera, coleoptera, as well as hydracarina and nemertina.

### 12.1 Savanne Lake

Major prey items observed in perch stomachs showed little annual variation. However the relative importance of these prey varied between years for each of four size groups of perch examined in June, July, and August (Fig. 20; Appendix 25).

Table 18. Total length (cm), number of eggs per fish, and weight of fish (g) according to spawning age for yellow perch in Henderson and Savanne lakes, Ontario, 1981 and 1982.

A Savanne Lake, 1981 and 1982

Age	N	Total length		No. eggs per fish		Total weight	
		Range	Mean	Range	Mean	Range	Mean
3	1	15.4			6704	44.3	
4	13	15.9-20.8	18.4	5306-15534	9801	53.8-104.0	78.8
5	4	20.8-22.1	21.3	15659-18622	16864	118.0-130.0	123.0
6	2	24.6-25.9	25.3	28174-32015	30095	233.2-248.1	240.7
7	1		26.3		31137		264.0
	21	15.4-26.3		5306-32015		44.3-264.0	

B. (i) Henderson Lake, 1981

4	3	10.3-11.1	10.6	2036- 2662	2356	9.9- 12.0	10.8
5	6	10.8-12.3	11.5	1916- 3270	2672	12.8- 17.2	14.5
6	3	12.5-15.9	14.0	3411- 8015	5528	18.2- 37.5	27.8
7	2	14.7-15.7	15.2	6475- 7613	7044	32.9- 41.0	37.0
8	4	14.8-15.7	15.3	6228- 7672	6800	31.5- 42.7	35.8
9	4	15.3-16.3	15.9	3835- 8361	6599	33.2- 43.1	38.2
10	4	16.1-18.1	16.8	7470-10490	9238	42.0- 63.2	52.4
11	1		18.0		9985		56.6
12	1		17.5		9546		50.7
13	2	19.1-19.4	19.3	12492-12788	12640	73.5- 75.5	74.3
	30	10.3-19.4		1916-12788		9.9- 75.5	

B. (ii) Henderson Lake, 1982

3	1		9.2		885		7.5
4	3	10.1-11.5	10.8	1944- 3174	2533	9.0- 13.5	11.1
5	10	10.1-12.5	11.4	1850- 4401	2726	9.0- 23.8	14.9
6	9	11.5-15.0	12.8	1552- 6757	3018	13.0- 36.0	21.0
7	4	13.3-15.0	14.4	4824- 6075	5244	22.5- 35.0	30.6
8	6	13.1-18.1	15.4	3280-11483	7090	20.2- 57.0	39.8
9	4	15.7-18.6	17.0	5903-11450	9684	38.0- 65.0	47.9
10	2	19.1-19.4	19.3	15841-16598	16220	64.0- 84.0	74.0
11	6	16.2-19.0	17.4	7854-15714	12447	42.0- 66.0	55.4
	45	9.2-19.4		885-16598		7.5- 84.0	



Figure 18. Relationships between absolute fecundity and spawning age for yellow perch in Henderson and Savanne lakes, Ontario, 1981 and 1982. ( ↓ indicates age at 50% maturity; ↑ indicates age at 100% maturity)

Savanne 1981-82 X—————X  
Henderson-1981 O-----O  
Henderson-1982 ●—————●

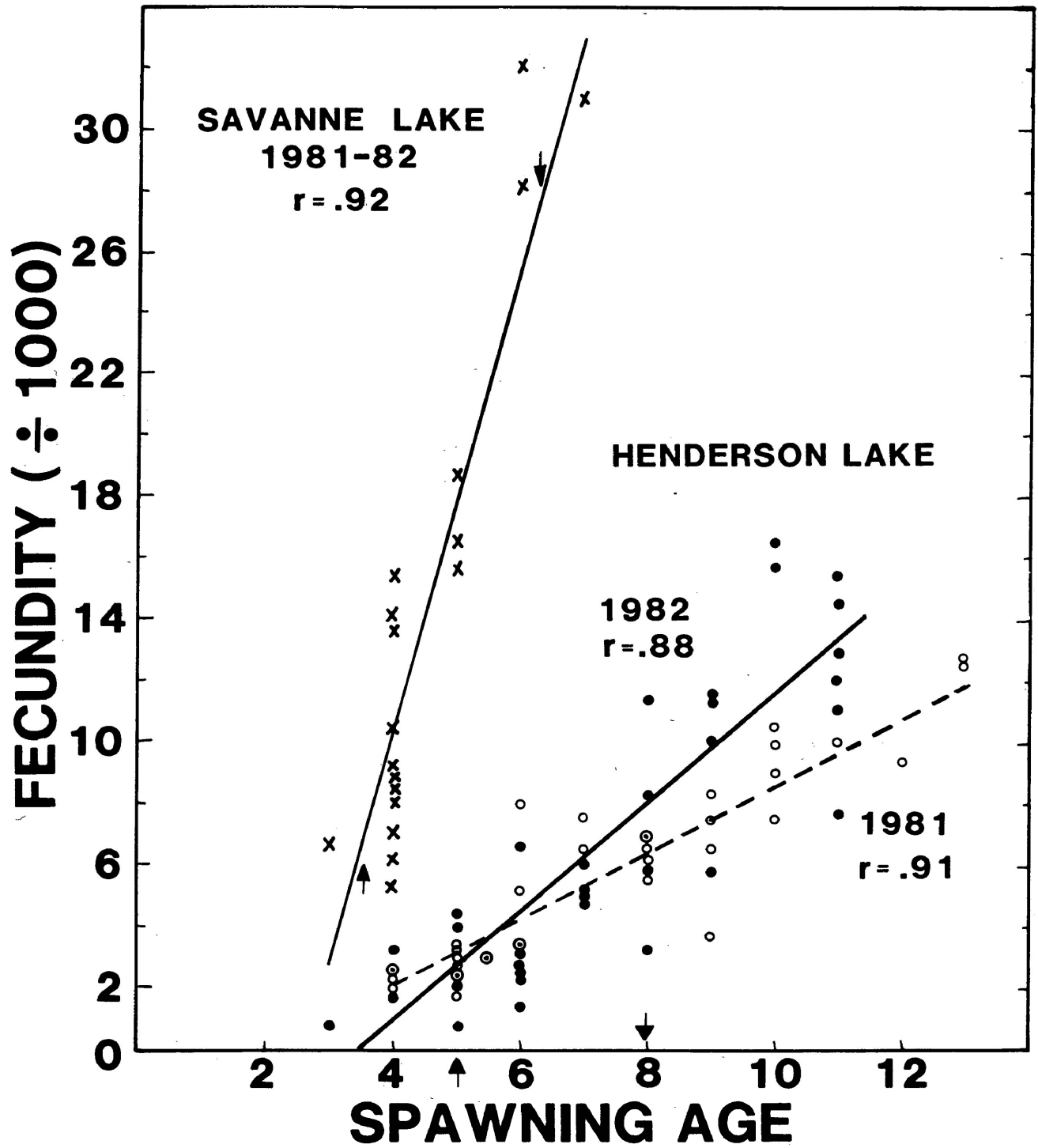


Figure 19. Relationships between absolute fecundity and total length (cm) for yellow perch in Henderson and Savanne lakes, Ontario, 1981 and 1982. (↓ indicates length at 50% maturity; ↑ indicates length at 100% maturity)

Savanne-1982    X—————X  
Henderson-1981   O-----O  
Henderson-1982   ●—————●

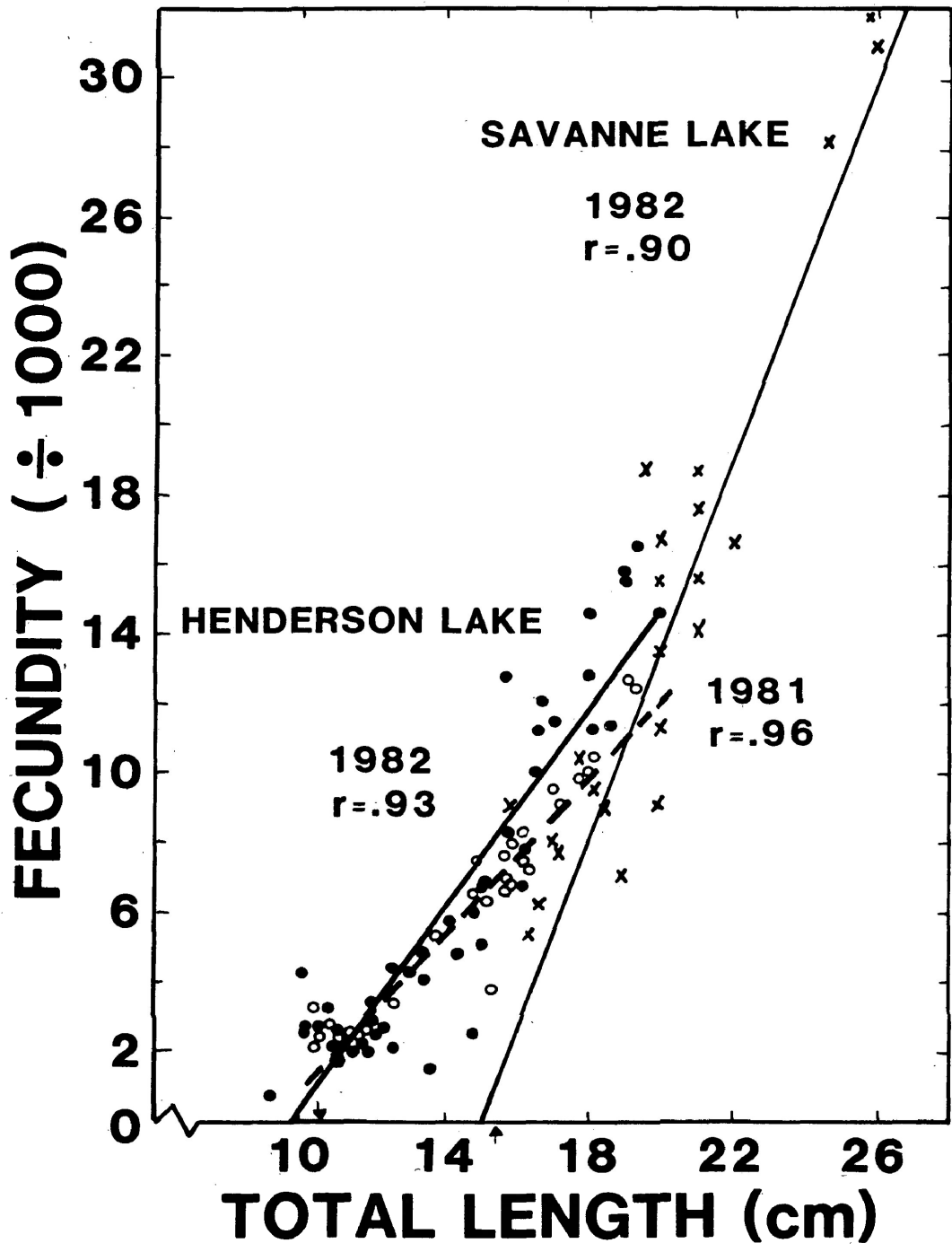
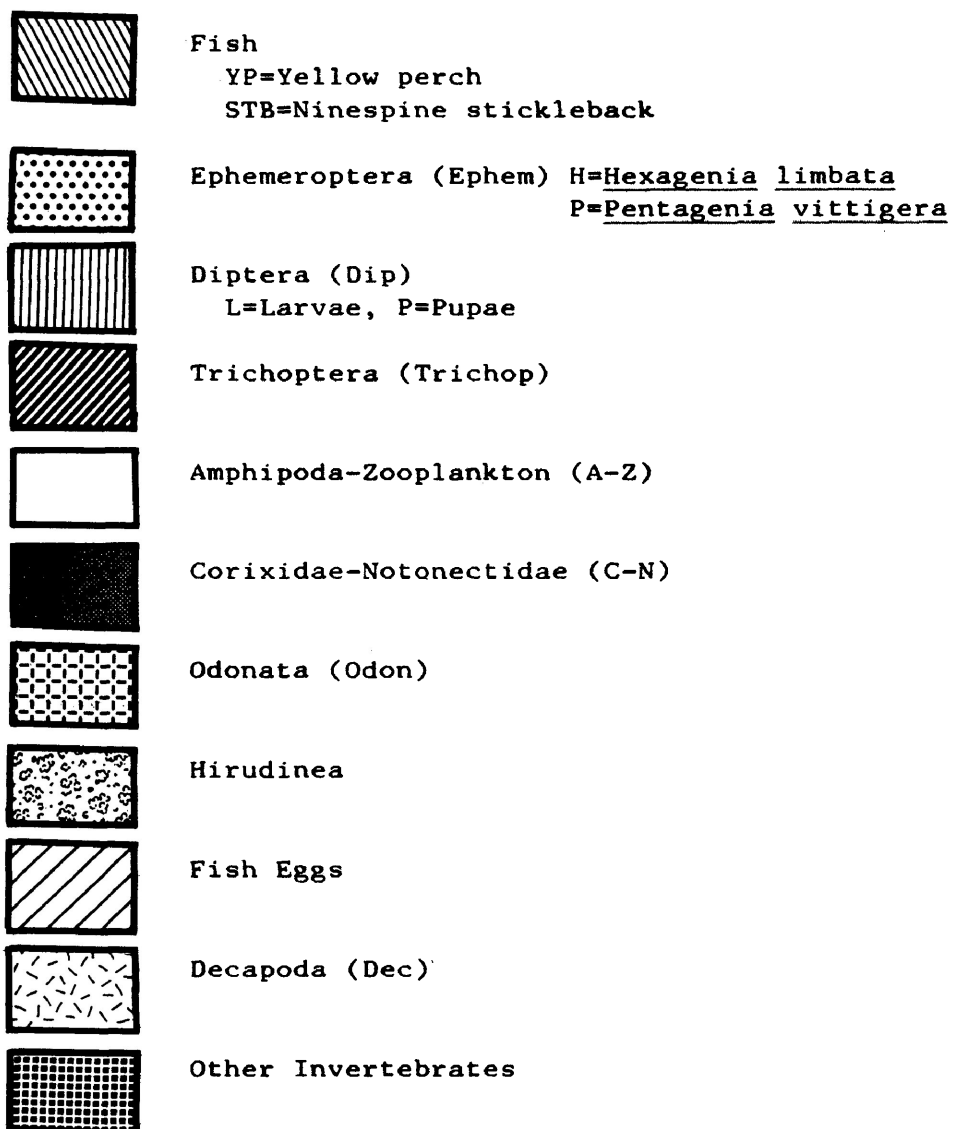
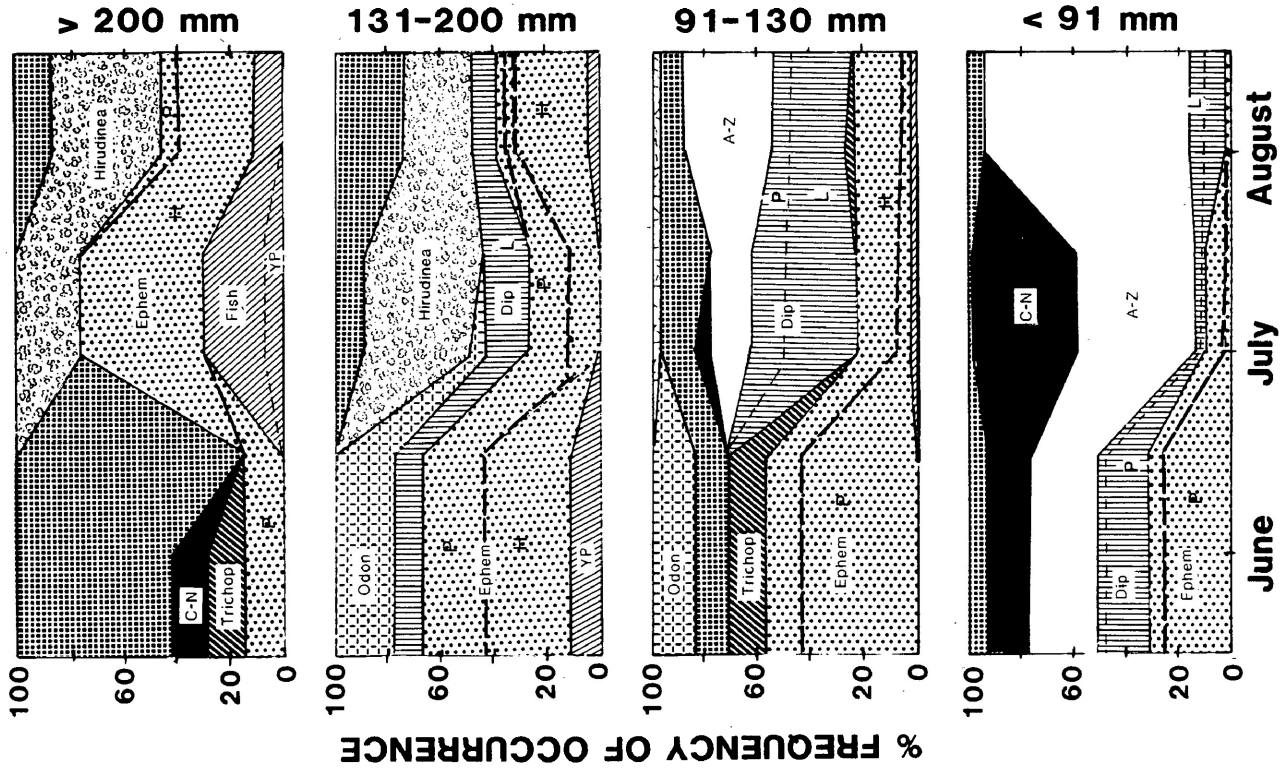


Figure 20. Seasonal and size-related variation in percentage frequency of occurrence of food items identified in stomachs of yellow perch in Henderson and Savanne lakes, Ontario, (a) 1981 and (b) 1982.

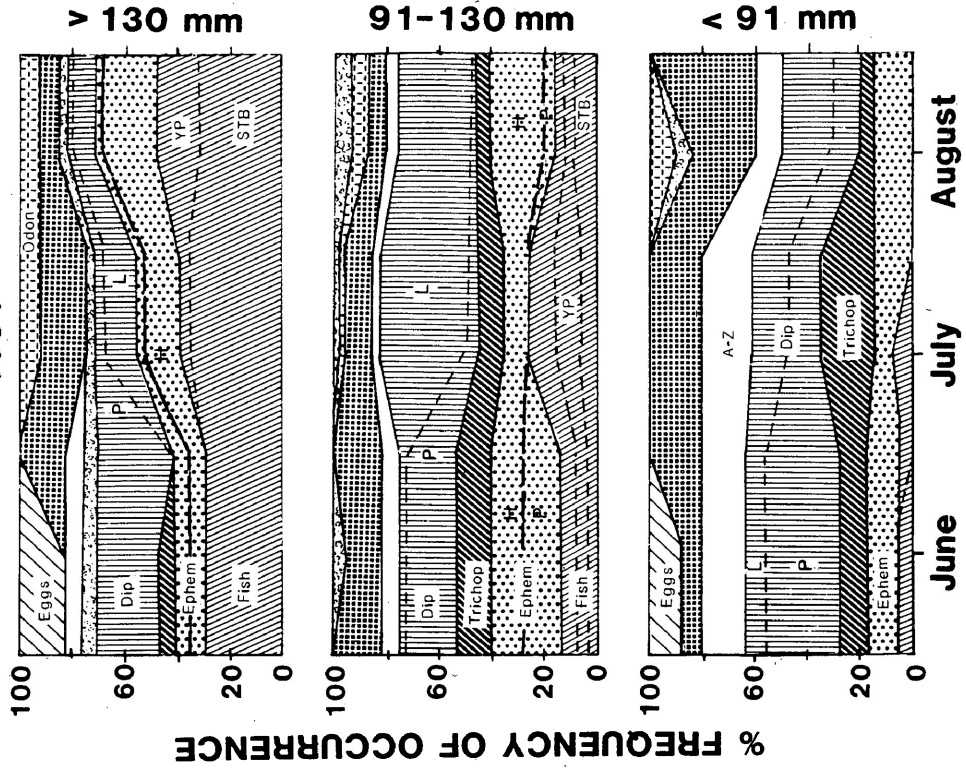


**SAVANNE LAKE  
1981**

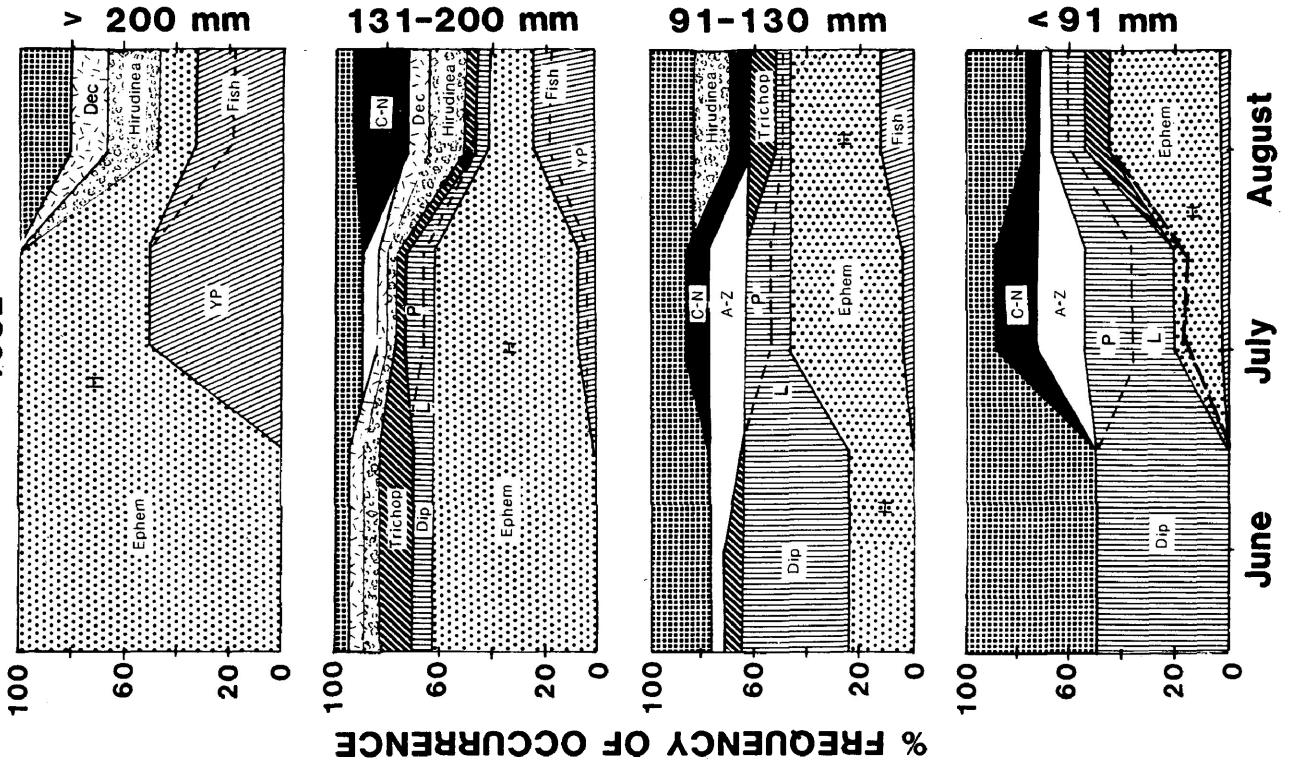


**A**

**HENDERSON LAKE  
1981**

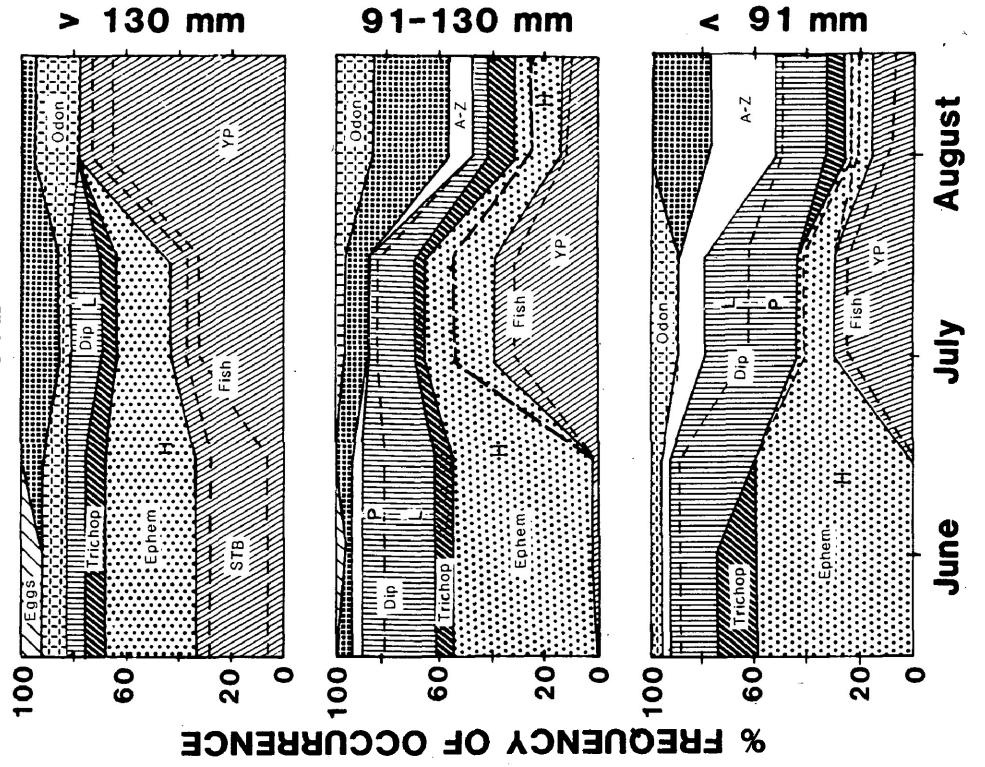


**SAVANNE LAKE  
1982**



**B**

**HENDERSON LAKE  
1982**



### 12.1.1 < 91 mm

Amphipods and cladocerans were the major prey items in 1981, especially in August being observed in 26% to 78% of stomachs examined. Diptera larvae (L) and pupae (P) (19%), and the mayfly, Pentagenia vittigera (32%) were important prey in June while corixids and notonectids were important (39%) in July.

In 1982, diptera P were the major prey in 1982, observed in 13% to 50% of stomachs examined. Other invertebrates shared dominance with diptera L and P in June, 1982 while amphipods-cladocerans and corixids-notonectids became important prey in July. In August, the mayfly, Hexagenia limbata was the major prey, observed in 42% of stomachs examined.

### 12.1.2 91 mm-130 mm

Mayflies, primarily H. limbata, observed in 24% to 57% of the stomachs examined, were an important prey in all months in both years. Diptera L and P were also important, especially in July and August, 1981 (29-40%) and in June, 1982 (41%). Amphipoda-cladocera, and trichoptera were seasonally important.

### 12.1.3 131 mm-200 mm

Mayflies, (primarily H. limbata and P. vittigera), were important in the early summer of both years, observed in 18% to 63% of stomachs examined. In 1981, leeches became important in July and August, being observed in 27% and 41% of stomachs examined. Diptera L and P, in contrast were of minor importance only to this size group in all months (8-11%). Odonata (Anisoptera) and fish, (primarily perch), were seasonally important in 1981.



In August 1982, fish (primarily perch) (24%) and corixids-notonectids (20%) replaced mayflies as an important food, with dipterans, trichopterans, leeches, decapods and other invertebrates serving a minor role from June to August.

#### 12.1.4 > 200 mm

In larger perch, both annual and seasonal differences occurred in the dominant prey items observed. In 1981, the mayflies, P. vittigera in June and H. limbata in July and August were the major prey observed in 14% to 47% of stomachs examined. By July and August, they were supplemented by leeches (23%) and 1+ perch (30%). In June, 1981, unidentified insects were observed in over half (57%) of the stomachs examined. However in 1982, H. limbata was the only prey item observed in June and shared dominance with YOY perch in July. By August 1982, fish, primarily YOY perch, were observed in 33% of the stomachs examined and were supplemented by leeches (20%), decapods (13%), mayflies (H. limbata), and other invertebrates (20%).

#### 12.1.5 Seasonal Trends

Fish, primarily YOY and 1+ perch are important in July and August and were especially so in 1982. Mayflies and diptera L and P are more important early summer foods. Leeches, trichopterans, corixids-notonectids, and decapods are usually observed in late summer.

#### 12.1.6 Size-Related Trends

Mayflies, primarily H. limbata and P. vittigera are a very important prey item for perch exceeding 9 cm in length. Whereas, the smaller prey items (amphipods-cladocerans and diptera L and P), are a

dominant food for perch under 9 cm in length.

## 12.2 Henderson Lake

In Henderson Lake diets show little taxonomic variation regardless of perch size. Unlike Savanne perch, little seasonal variation in prey utilization occurred in 1981 but taxonomic variation increased in 1982 (Fig. 20; Appendix 25).

### 12.2.1 < 91 mm

In 1981, diptera P and L were very important in all months being observed in 26% to 35% of stomachs examined. Amphipods-cladocerans, trichopterans, and mayflies supplement the diet in all months while fish ova, fish (predominantly perch), odonata, and leeches are utilized seasonally.

Similarly, diptera P and L became important in all months in 1982, especially July, comprising 19% to 35% of the stomachs examined. However, H. limbata were important in June, 1982 (59%), supplementing the dipteran diet in July along with perch (39%), amphipods-cladocerans (9%), and anisopterans (9%). By August, fish (primarily perch and unidentified fish) (16%), amphipods-cladocerans (24%), and diptera P (21%) became important. Trichopterans and odonata were utilized only seasonally.

### 12.2.2 91-130 mm

Diets were similar to those of smaller perch (less than 91 mm), in both years except that mayflies and fish, primarily ninespine sticklebacks and perch were more important in all months. Diptera P, mayflies (H. limbata and P. vittigera), with fish dominated the

diet in all months in 1981. In 1982, mayflies (H. limbata, 26%) and diptera L and P (20%) dominated the June diet but by July mainly perch (39%) and diptera L (16%) along with mayflies (H. limbata 26%) became important. By August, H. limbata (17%), perch (13%), anisoptera (14%), and other invertebrates (30%) dominated. Sticklebacks were not observed in perch stomachs in 1982. Fish ova, amphipods-cladocerans, and trichopterans served an incidental role in all months.

### 12.2.3 131-200 mm

The observed diet of larger Henderson perch was similar to that of smaller perch (91-130 mm) except that fish, ninespine sticklebacks in 1981 and perch in 1982 increased in importance, being observed in up to 79% of stomachs examined. Compared to 1982, little seasonal variation occurred in 1981 except for a slight preference for fish in August, 1981. Fish, primarily ninespine sticklebacks were frequently observed in all months (29-48%), supplemented by diptera P (24%), mayflies, primarily H. limbata (12%), and fish ova (18%) in June. Whereas, Diptera L (14%), H. limbata (15%), and other invertebrates (17%) were important supplemental foods in July and H. limbata (20%) in August. Odonata, leeches, amphipods-cladocerans, and trichopterans were utilized only seasonally.

Whereas, in 1982, fish made up 79% of the observed diet by late summer. H. limbata was important only in June and July (34% and 21%, respectively). Trichopterans, diptera L and P, odonata, and amphipods-cladocerans were of minor importance. Fish ova were only seasonally important.

#### 12.2.4 Seasonal Trends

Diet reflects seasonal variability in 1982 when mayflies and diptera predominated in early summer and fish, primarily perch increased in importance by late summer, especially in perch greater than 13 cm. Fish ova became important in early summer for perch in all size groups. Ninespine sticklebacks were very important in 1981 but diminished to insignificance by 1982.

#### 12.2.5 Size-Related Trends

All sizes of perch in Henderson Lake fed on fish and diets were similar among all size groups.

#### 12.3 Population Comparisons

Although there is some similarity in prey items utilized by perch in both lakes (Appendix 25), the proportion of invertebrates to fish prey varies considerably (Table 19). Fish (ninespine sticklebacks in 1981 and perch in 1982) were significantly more important in diets of Henderson Lake perch. The importance of fish relative to invertebrates increased with size varying from 1:24.6 for perch < 91 mm in 1981 to 1.1:1 for perch > 13 cm in 1982 (Table 19). Interestingly, mimic and blacknose shiners were not utilized as forage by Henderson perch despite their great abundance. In Savanne Lake, perch were relatively more important in 1982 than in 1981, with ratios increasing from 1:110.1 for perch < 9 cm to 1:4.6 for perch > 20 cm in 1982 (Table 19).

Table 19. Comparison of the frequency of occurrence of fish (F) to invertebrates (I) in diets of different size groups of yellow perch from Henderson and Savanne lakes, Ontario, 1981 and 1982.

Lake	Year	91 mm			91-130 mm				
		N	% Freq. of occ.	Ratio	N	% Freq. of occ.	Ratio		
								F	I
Henderson	1981	228	3.9	96.1	1:24.6	362	17.7	82.3	1: 4.7
	1982	173	15.1	84.9	1: 5.6	261	18.1	81.9	1: 4.5
Savanne	1981	332	0	100	-	285	0.5	99.5	1:199
	1982	227	0.9	99.1	1:110	241	4.7	95.3	1:20.3
		131-200 mm			200 mm				
	Year	N	% Freq. of occ.	Ratio	N	% Freq. of occ.	Ratio		
								F	I
Henderson	1981	138	38.7	61.3	1: 1.6	NA			
	1982	127	52.1	47.9	1.1: 1	NA			
Savanne	1981	215	4.7	95.3	1:20.3	42	13.6	86.4	1: 6.4
	1982	228	10.5	89.5	1: 8.5	14	17.8	82.2	1: 4.6

NA No perch larger than 20 cm were captured in Henderson Lake.

## DISCUSSION

## 1. GILLNET CATCH-PER-UNIT-EFFORT AS AN INDEX OF YELLOW PERCH ACTIVITY AND ABUNDANCE

Diurnal variation in distribution and activity patterns of fish can influence CPUE obtained from the use of stationary sampling gear such as gillnets. While activity cycles reflect onshore and offshore movements related to feeding periodicity (Keast and Welsh 1968; Helfman 1981), CPUE may also be influenced by predation and environmental factors such as temperature and water clarity.

Coincidental dawn and dusk activity peaks are reflected by the CPUE of perch and walleye in both lakes, with diurnal activity peaking in July and August when water temperatures reach the preferendum (19-21 C), for perch (Ferguson 1958). Rate of movement and density of yellow perch schools increase with temperature in summer (Hergenrader and Hasler 1966). Temperature is, in fact, more important than substrate cover and benthic prey availability in influencing yellow perch CPUE (Hubert and Sandheinrich 1983).

The amplitude of perch diel activity in Savanne Lake may be as much an adaptive response to walleye predation as to temperature. Since young yellow perch, age 0+ and 1+, are the dominant prey of walleye in Savanne Lake (Mosindy 1980), the diel activity shown by perch also reflects a predator avoidance response. This is reflected by the peak activity periods for perch in Savanne Lake which occurs after sunrise and before sunset, in contrast to walleye activity which peaks before sunrise and after sunset. These phototactic responses by walleye producing an avoidance strategy by perch, are well documented (Maloney and Johnson

1965; Forney 1971; Heyerdahl and Smith 1971; Ali et al 1977; Helfman 1981). In contrast to the abrupt activity peaks observed for Savanne perch, those for Henderson perch are less abrupt and are prolonged at dawn and dusk, slowly declining to low activity levels at midday and at night (Fig. 8). From 1979 to 1981, few Henderson perch were eaten by walleye, since ninespine sticklebacks served as the dominant prey (Nunan 1982). However, when the ninespine stickleback population collapsed walleye switched to perch as the dominant prey. For this reason perch do not exhibit as yet, a strong avoidance strategy in this lake. Rather, they remain exposed to potential predation for a much longer time before sunrise and after sunset than do Savanne perch. If the ninespine stickleback population remains depressed, Henderson perch may eventually exhibit the same response as the perch in Savanne Lake. On the other hand, this response may not become pronounced, since the greater water clarity and macrophyte growth in Henderson Lake compared to Savanne Lake, provides cover at times when vulnerability of perch to predation increases.

The apparent diel activity of Henderson perch is a response not only to light levels, but also reflects forage availability rather than predator avoidance. Diurnal predators such as perch continue to feed as late as they can see and competition for food restricts offshore movements to late evening (Helfman 1981). The greater density of mature perch in Henderson Lake likely leads to a higher level of intraspecific competition. Therefore, forage availability, in addition to low predation, may be forcing perch to feed inshore for longer periods of time at dawn and dusk. Vegetation removal in Henderson Lake, by affecting predator-prey activity could modify perch activity.

Use of stationary gear such as gillnets to assess abundance of a

fish stock must be standardized relative to location, time, and meteorological conditions in order to reduce sample variability (Hubert and Sandheinrich 1983). Perch abundance should be assessed at the end of June, when water temperatures of these lakes approximate those preferred by perch. Since peak activity periods of perch occur in both lakes from 0400-0800 hrs and from 1800-2200 hrs, they should constitute the standardized sampling periods. Although the relative abundance of perch recruited to gillnets was comparable between years and between lakes, Savanne perch recruited at age 2 while Henderson perch recruited at age 5. Henderson perch are therefore much more abundant since ages 2 to 4 were not vulnerable to gillnets.

## 2. YEAR-CLASS STRENGTH OF YOUNG-OF-THE-YEAR YELLOW PERCH AND WALLEYE

Mean abundance (#/hectare seined) is not a good measure of year-class strength because light and temperature increase non-random variability. To reduce this sampling bias, we seined during the day when light intensity remained relatively constant. In addition, seining schedules were not initiated until late May or early July when water temperatures are approximately 19 C, the optimum for perch. YOY perch year-class abundance also affected seine catches. For example, the large 1981 year-class in Savanne Lake, as determined by seining, also constituted a relatively large proportion of the total gillnet catch indicating that both gears are sensitive to changes in perch abundance. Therefore, mean and range of relative abundance in seine hauls apparently measures trends in yellow perch year-class strength.

Perch year-class abundance fluctuates widely in both Henderson and Savanne lakes which is normal for perch (Forney 1971). Both climatic and biological factors influence reproductive success, year-class strength,



abundance, and survival of YOY yellow perch.

Year-class strength of perch in Lake Michigan and egg production and fry density in Lake Erie were related to the rate at which water temperature increased in the spring (Busch et al 1975; Clady 1976; Eshenroder 1977; Wells 1977). However, in Savanne Lake, spring water temperature measured as GDD > 15 C was not correlated with year-class abundance.

Although temperature did not directly affect abundance, it may act indirectly by affecting food availability. For example, low temperature may delay insect emergence, zooplankton hatch, and plankton blooms so that food availability is not synchronized with the early life feeding requirements of larval fish. Variable survival of fingerling perch may be directly attributed to annual variation in density of planktonic food organisms (Noble 1975; Clady 1977). Besides affecting food production and availability, water temperature also affects feeding behavior. For example, Smith (1977) found that walleye fry do not initiate feeding behavior until water temperature ranged from 9-15 C. As a result, if the water temperature does not reach 9-15 c, fry do not start feeding, but instead die when the yolk was absorbed. The same is probably true for perch.

While above average precipitation increases spring water level, inundates vegetation, and influences perch year-class abundance and reproductive success in some percid lakes (Nelson and Walburg 1977), this does not occur in others (Carlander and Payne 1977; Weber and Les 1982). YOY perch and walleye abundance in Savanne Lake appear unaffected by these meteorological factors. However, precipitation accumulation may not be the best predictor of water levels since spring run-off inputs, which were not measured, contribute to spring water levels.

Biological factors such as predation and cannibalism can also regulate perch year-class strength (Alm 1946; Forney 1971). Cannibalism reportedly acts as a depensatory mortality factor affecting year-class strength of both European and yellow perch populations (Alm 1946; Sumari 1971; Schneider 1972), or it can be compensatory, dependent on the availability of alternate forage (Eschmeyer 1937; Maloney and Johnson 1965; Tarby 1974; Kelso and Ward 1977). The incidence of cannibalism in both Henderson and Savanne perch diets varied, but occurred most often in Henderson perch.

The availability of alternate forage determines the frequency of occurrence of cannibalism in these populations. By late summer, the presence of mayflies in diets of both Henderson and Savanne perch decreases, while cannibalism increases reflecting the decreased abundance of mayflies. The occurrence of perch in the diet increases in late summer for both populations. At this time, young perch usually develop a conspicuous barred pattern and display inshore-offshore movements, thereby becoming more susceptible to predation by large perch and walleye (Tarby 1974).

In populations of stunted perch, strong year-classes, as that seen in Henderson Lake in 1981, might through cannibalism suppress subsequent year-classes for several years especially when zooplankton becomes scarce (Smyly 1952; Schneider 1972). For example, in 1982, cannibalism by Henderson perch increased, even among perch less than 91 mm in length. The occurrence of amphipods, zooplankton, and mayflies correspondingly declined in the presence of the abundant 1981 perch year-class. In the same year, the occurrence of perch in diets of all size groups of Savanne perch also increased and was coincident with the decline of amphipods, zooplankton, and mayflies.

Forney (1971) found that walleye predation during the summer influences YOY perch mortality, especially when YOY perch abundance is low. Similarly, predation by both perch and walleye may affect the abundance of young Henderson perch. Prior to the year-class failure of ninespine sticklebacks in 1982, YOY perch abundance was relatively high, but following the prey shift by walleye to perch cannibalism increased and YOY perch abundance declined drastically. Although abundance of Henderson YOY perch has been very low since 1981, Savanne YOY perch abundance, at the same time, has been relatively high. Since both lakes experience similar climatic conditions, predation and cannibalism are probably more important in determining survival of YOY perch and the subsequent age class structure of Henderson perch.

In Savanne Lake, perch are the dominant prey of walleye, yet there was no relationship between year-class strength of perch and walleye, suggesting that different factors affect the strength of perch and walleye year-classes in this lake. While in other lakes, strong walleye year-classes were correlated with the occurrence of strong perch year-classes that hatched in the same year (Forney 1971; Carlander and Payne 1977; Smith 1977). The effect of walleye predation on Savanne YOY perch abundance would be best examined by relating recruitment of older perch to the gear to the abundance of predators in the year of hatch.

At dawn and dusk, walleye of all ages closely associate with young perch in littoral areas of Savanne Lake, but not in Henderson Lake. Maloney and Johnson (1965) state that this perch-walleye association, during at least their first summer, represents a natural food chain. In Savanne Lake, YOY walleye abundance was lowest in those years when YOY perch grew rapidly, indicating YOY walleye rely on the vulnerability of YOY perch. Since YOY walleye do not consume perch larger than half their

own length, fast growing perch fry would become less vulnerable to predation (Olsen 1979). In contrast, slow-growing perch would be available over longer periods. In this way, growth rate becomes more important than density in determining the utilization of perch fry by YOY walleye (Ney 1978). Since Henderson walleye and perch are never captured together in littoral areas, regardless of the time of day, this interaction must occur offshore in open water areas previously occupied by ninespine sticklebacks.

In Henderson Lake, perch associate with large schools of mimic and blacknose shiners. In fact, shiners are dominant in seine catches when YOY perch abundance is low. In contrast, Savanne YOY perch are the only component of the littoral fish community abundant enough to serve as an available forage illustrating the between lake difference in complexity of the forage base.

### 3. GROWTH

#### 3.1 Growth of Young-of-the-Year Yellow Perch

In Savanne Lake, YOY perch, though exhibiting wide annual variation in growth rates, display good growth (60-70 mm) relative to other populations (Grimaldi and Leduc 1973; Ney and Smith 1975; Pycha and Smith 1955; Mills and Forney 1981; Weber and Les 1982). In contrast, Henderson YOY perch exhibit poor growth despite living under climatic conditions similar to those in Savanne. Henderson YOY perch have growth rates that were always well below those of other stunted populations. Apparently, these other stunted perch exhibited good growth for the first 2 to 3 years then slowed when food of sufficient quality and size was unavailable (Alm 1946; Deelder 1951; Grimaldi and Leduc 1973; Schneider 1972).

Generally, attempts to attribute variation in first year growth to climatic factors have not been successful (Coble 1966; Forney 1971; Ney and Smith 1975; Thorpe 1977). Savanne YOY perch growth rates were not related to water temperature measured as GDD > 15 C. In this case, both lakes experience similar climatic conditions, so observed growth differences probably relate to food availability, both in terms of overall production and its synchronization with critical life stages of young perch.

### 3.2 Growth and Condition of Adult Yellow Perch

All age groups of Savanne perch grow well compared to other populations located at approximately the same latitude. But, all ages of perch in Henderson Lake are severely stunted, even when compared to other slow growing populations, e.g. Hertel Lake, Quebec (Table 20).

Generally, after one to two years of age, even stunted female perch grow faster than males (Alm 1946; Schneider 1972; Grimaldi and Leduc 1973; Thorpe 1977). This trend occurs after age 4 for Savanne perch and age 6-7 for Henderson perch. However, these growth differences are only slight and presumably result from the low energy regime and short growing season. Since gonad development is initiated by mid-August in both Henderson and Savanne lakes, it can induce termination of growth, thus shortening the growing season (LeCren 1951). Although slow growth of walleye and northern pike in Savanne and Henderson lakes has been attributed to the relative infertility of these northern, boreal lakes (Sandhu 1979; Mosindy 1980; Nunan 1982), it is more likely due to the lack of coolwater refugia in these lakes causing an increase in metabolic demand

resulting in poor growth. Summer die-off of adult walleye have

occurred in Savanne Lake (Colby pers. comm.). Growth rate differences between the two populations arise from a combination of biotic and abiotic factors. Temperature most directly influences the growth rate of yellow perch in Lake Huron (Coble 1966), and European perch in Lake Windermere (LeCren 1958). Since both Henderson Lake and Savanne Lake experience similar temperature regimes, it may be that temperature indirectly influences food supply by affecting timing of emergence of insects and plankton blooms as reported in some Quebec perch lakes (Grimaldi and Leduc 1973) and in the Baltic Sea for European perch (Neuman 1974).

Growth rate was inversely related to density of perch in Saginaw Bay, Lake Huron, and Lake Mendota. Decreased growth of perch in these lakes was attributed to crowding rather than food limitation, since the fish were in good condition (Alm 1946; Beckman 1950; El-Zarka 1959; Bardach 1951). However, for perch in Henderson Lake, poor growth occurs in conjunction with low condition over the entire growing season, in both 1981 and 1982. By comparing differences in condition of similar-sized perch from the two populations, condition factor measures both environmental quality and reflects the relative size of the food resource available per individual in different habitats (Weatherley 1972; Colby et al 1979). The poor growth and condition exhibited by all ages of Henderson perch is related to inadequate food supply per individual.

#### 4. AGE STRUCTURE, LONGEVITY, AND MORTALITY

Fluctuations in year-class strength of unexploited percid populations causes survival estimates to be variable. For this reason, survival rates estimated from consecutive year-classes must be used with

caution (Ryder and Kerr 1978). Instantaneous survival and mortality rates were calculated from age structures of perch sampled with gillnets. The similarity of the catch curves in both sampling years even though different effort was expended, provides some evidence that gillnet samples were representative of the populations and that the apparent differences in the rates of survival and mortality, between the two populations, are real.

Age class structure reflects the differential survival of perch cohorts (Sumari 1971; Neilson 1980). Percids in northern lakes adapt to variable climatic conditions by enduring a high mortality rate early in the life cycle in exchange for greater longevity and lower adult mortality. Climate in northern boreal localities probably produces large fluctuations in early mortality of year-classes of unexploited percid populations. As a result, the lengthened life span develops as an adaptive response to this variable production of year-classes (Momot unpub.). Slow-growing Henderson perch live up to a maximum of 18 years, in contrast to the faster-growing Savanne perch, which live to 9 years of age. Schneider (1972) found that after the first year of life, mortality of perch was insensitive to changes in density. As a result, an over-abundant, slow growing year-class of fingerling perch produces few fish of a useful size. Similarly, age 5+ Henderson perch exhibit reduced mortality, slow growth, and make up 100% of the catch. In contrast, Savanne perch greater than age 5 contribute very little to the total CPUE in Savanne Lake (5.4% in 1981 and 2.8% in 1982), reflecting the higher mortality of young perch. Prior to 1983, Henderson perch were a minor prey item, whereas young Savanne perch, 60-110 mm in length, were the major forage of walleye and northern pike. As a result, Savanne

perch have lower survival to older ages and better growth. This identifies predation as the major factor influencing age class structure of perch in these lakes. Alm (1959) found no correlation between life span and growth rate of European perch, since rapidly growing fish in ponds lived to a great age. He concluded instead, that long life span in stunted perch populations was related to low predation pressure.

## 5. MATURITY

Generally, females mature later and at larger sizes than males (Thorpe 1977). This trend also occurs in both the Henderson and the Savanne populations. Maturation, like growth, is a flexible life history characteristic mainly influenced by environmental factors such as temperature, and biological factors such as available forage, exploitation, and predation.

Maturity varies inversely with growth rate for perch, as well as for other fish species (Forney 1965; Colby et al 1979; Thorpe 1977; McComish 1981; Weber and Les 1982). Because perch grew more rapidly in Savanne Lake than in Henderson Lake, they had a lower age to maturity for both males and females, as well as faster maturation rates (1.4 times greater for females and 1.3 to 2.6 times greater for males). Maturation also varied within individual year-classes. Faster growing individuals matured earlier in at least one year-class in Henderson Lake, while the slow growing individuals were immature. This also occurs for European perch, where maturity was reached earlier by faster growing fish within a year-class (Alm 1953; 1959).

Since the environment, especially energy availability, greatly influences growth rate, northern stocks mature later than exploited and/or more southern stocks (Kennedy 1949; Wolfert 1969; Colby and



Nepszy 1981). Since both study lakes experience similar temperature regimes, apparent differences in maturation must be due to differences in predation pressure and forage availability.

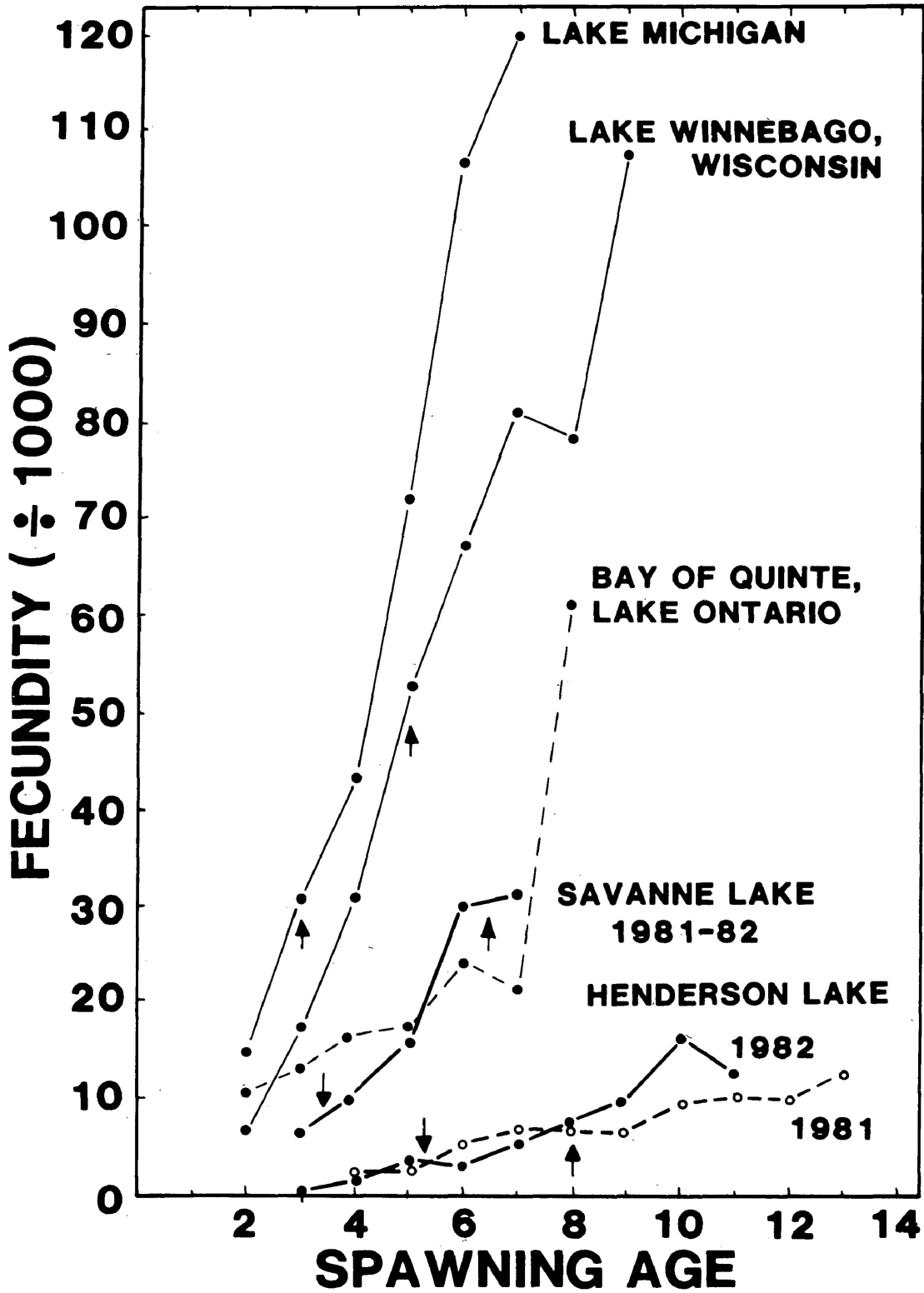
## 6. FECUNDITY

In Savanne and Henderson lakes, the absolute fecundity, as related to age of perch, is generally lower than in larger bodies of water situated at lower latitudes (Fig. 21). However, fecundity of Savanne perch compares favorably with that of perch from the Bay of Quinte, Lake Ontario (Sheri and Power 1969). Faster growth rates, larger visceral space available for gonad development, and better feeding conditions are usually associated with higher fecundity (Tsai and Gibson 1971; Thorpe 1977). Hence, the fecundity of Savanne perch is considered to be relatively high for a northern population, while the fecundity of Henderson perch is very low. On the other hand, reproductive resilience of Savanne perch is lower than that of Henderson perch, since fewer individuals survive to older ages when individual fecundity is highest.

Perch fecundity varies among fish of the same age and/or length in both populations. This probably reflects an individual's food ration since experimentally modifying the diets of salmonids can alter fecundity and, no doubt, the same can occur for perch (Scott 1962; Bagenal 1969). The significant increase in the slope of the fecundity-age relationship for Henderson perch from 1981 to 1982 may result from improved feeding conditions or simply reflect the variability of fecundity for this population.

Perch fecundity levels are influenced by environmental conditions and food availability in the year prior to spawning. Some perch stocks, therefore do not spawn in years when available energy for development

Figure 21. Comparison of fecundity related to age of yellow perch from various localities. ( ↓ indicates mean age to maturity; ↑ indicates age to 100% maturity)



and maturation of gonads proves insufficient (Thorpe 1977). In low energy systems such as Henderson Lake, some of the earlier maturing females may resorb eggs as a result of the low availability of overwintering forage. Also, a shortage of food may increase the proportion of atretic oocytes (Wootton 1979). For this study, fecundity was assessed in late summer and fall in the year prior to spawning, therefore actual spawning success was not observed.

Fecundity of Henderson walleye also falls among the lowest values reported, supporting the concept that the energy regime of this lake plays an important part in regulating population size (Nunan 1982). However, when walleye in Henderson Lake were heavily exploited from 1981 to 1983, age-specific fecundity increased (Reid pers. comm.). If density of mature perch is reduced by predation by the heavily exploited walleye, availability of forage may subsequently increase allowing perch to exhibit a similar fecundity response.

#### 7. PREY UTILIZATION BY YELLOW PERCH

Perch are visual, opportunistic feeders (Keast and Welsh 1968; Keast 1977; Thorpe 1977). In cold, temperate lakes where different prey types peak seasonally in number at different times, this generalist feeding strategy is advantageous (Keast 1978), and it is utilized by both Henderson and Savanne perch whose diets reflect both annual and seasonal changes.

Invertebrate life cycle events also determine the availability of forage items and play a role in patterns of prey utilization by perch (Clady and Hutchinson 1976; Keast 1977). For example, the mayfly, Hexagenia limbata, has its peak emergence in late June or early July, in even years in Savanne Lake (Riklik and Momot 1982). This

greater numerical abundance is reflected by the increased frequency of occurrence of H. limbata in all perch stomachs in June and July of 1982 compared to 1981, in both lakes. Savanne perch consumed smaller mayfly species in 1981. For example, in 1982 the smaller mayfly Pentagenia vittigera was replaced by the larger mayfly H. limbata. This suggests that P. vittigera may have its highest production in odd years when H. limbata is at a low in its cycle. However, the production of P. vittigera has not been studied in these lakes.

In 1982, the frequency of fish increased in the diets of even the smallest perch within both populations. In Savanne Lake, YOY perch being twice as abundant in 1982 compared to 1981 were eaten by perch of all sizes. In Henderson Lake, since YOY perch in 1982 were one tenth as abundant as in 1981, the increased consumption of YOY perch in 1982 was not the result of greater abundance. In 1981, the majority of fish consumed were ninespine sticklebacks. However after the drastic decline of ninespine sticklebacks in 1982, perch became the next most available forage fish.

Seasonal changes in selection of diet items by perch also depends on the availability of other foods. All sizes of Henderson perch consumed fish eggs in June, 1981, but eggs were not selected in 1982, when the mayfly, H. limbata, reached peak abundance. Similarly, when the abundance of mayflies decreased by the end of July, fish, leeches, dragonfly nymphs, amphipods, and zooplankton became more important in late summer for both populations. Similarly, Mosindy (1980) in Savanne Lake and Nunan (1982) in Henderson Lake found that considerable annual variation in patterns of prey utilization by both walleye and northern pike could be related to food item availability.

## 8. FACTORS CONTRIBUTING TO THE STUNTING OF YELLOW PERCH IN HENDERSON LAKE

### 8.1 Introduction

The poor growth and condition exhibited by all ages of Henderson perch suggest that their food supply in Henderson Lake is inadequate. Reports of stunting in perch populations show that relatively good growth occurs for the first few years, but upon reaching 12 to 14 cm in length, perch exhibited poor growth when the supply of forage fish became scarce or the size of the prey becomes either too large or small for the predator (Eschmeyer 1937; Deelder 1951; Alm 1959; Grimaldi and Leduc 1973). However, fish are common in diets of Henderson perch exceeding 13 cm in length and by 1982, perch of this size foraged more on fish than on invertebrates (Table 19). Yet, Henderson perch grew poorly even as young-of-the-year. Therefore, this stunted growth condition must be aggravated through competition and predation as well as by some physical characteristic of the lake.

### 8.2 Evidence for Competition Contributing to Slow Growth of Yellow Perch

In addition to being opportunistic feeders, perch avoid inter- and intraspecific competition by consuming a wide range of prey sizes and types during ontogeny. (Keast and Welsh 1968, 1977; Clady 1974; Persson 1983). Generally, as Savanne perch grow larger their diets exhibit changes in prey type and size. Large prey items such as YOY perch, leeches, dragonfly nymphs, and crayfish became increasingly important for large perch while smaller prey items such as amphipods, zooplankton, and dipteran larvae and pupae are more important for small perch. However, in Henderson Lake, all three size groups of perch show a large

degree of overlap in prey types utilized throughout the growing season. In Henderson Lake, mayflies, especially H. limbata, and fish (ninespine sticklebacks in 1981 and perch in 1982) are the two most important prey of perch longer than 91 mm, while dipteran larvae and pupae are used in addition to fish by perch less than 91 mm (Fig. 20). Johnson (1977) suggested that when the frequency of occurrence of a food item exceeds 25% in different size classes or species sampled at the same time, a potential competitive situation exists. Mayflies occurred in 20-30% of perch examined from all size groups by August, 1981 and 36-57% in June, 1982. Young perch occurred in 21-35% of perch examined in July, 1982 (Fig. 20). This diet overlap provides some evidence that intraspecific competition may contribute to the poor growth and condition of Henderson perch. For example, Schneider (1972) found growth of perch in three size groups depended on density of perch within each size group, but was independent of density of other groups. Lack of predation on Henderson perch until recently, has resulted in good survival to older ages but poor growth has caused the population to consist of a large number of older, uniformly-sized individuals. Should there be increased predation pressure by walleye and northern pike, any growth response or improvement in condition of perch would suggest that intraspecific competition may have been at work.

Since freshwater fish communities are characterized by lack of specialization, species inhabiting them exhibit flexibility in feeding habits and, in general, share many resources. Cannibalism and mutual predation become obscured by the effects of competition between species (Larkin 1956). Often perch and walleye consume many of the same forage organisms, but feeding periodicity usually precludes direct interactions (Tarby 1974; Kelso and Ward 1977; Paxton et al 1981). This interspecific

overlap, while very apparent in Henderson Lake, becomes less evident in Savanne Lake. In the latter, perch feed primarily on invertebrates (77%), while walleye and pike feed primarily on fish (81%), especially juvenile perch (60-110 mm) (Sandhu 1979; Mosindy 1981). Nunan (1982) found walleye and northern pike, like perch greater than 91 mm, select mayflies, (particularly H. limbata), and fish, (ninespine sticklebacks in 1981 and perch in 1982). Frequency of occurrence of ninespine sticklebacks in diets of perch greater than 131 mm in length, walleye, and northern pike was 30-40%, 30%, and 20%, respectively (Nunan 1982).

Removing white suckers from lakes with limited fish species diversity appears to benefit percid populations (Johnson 1977). The most commonly observed instances of potential competition were between white suckers and yellow perch in a small (245 ha) lake in Minnesota. In this lake, white suckers fed exclusively on invertebrate foods, particularly dipteran larvae, mayfly nymphs (Hexagenia spp.), and amphipods. Removal of 85% of the estimated standing crop of adult white suckers resulted in: a 15 fold increase in perch biomass; improved growth of perch; a one third increase in walleye biomass; an increase in the incidence of mayflies (Hexagenia spp.) in the diet of perch along with a decrease in the incidence of smaller invertebrates; and an increase of YOY perch in walleye diets. The diet of white suckers in Henderson Lake has yet to be studied. The fact that different species of fish eat the same foods is not, by itself, just cause for assuming they are competing. However, the poor growth and condition would suggest that the forage supply is limited. Therefore, the mutual predation by perch, northern pike, walleye, and possibly white suckers can only act to deplete an already low forage supply.



Similar to the adults, Henderson YOY perch grew more slowly than YOY perch in Savanne Lake. Food availability is probably responsible for this difference. Cohabiting fish species usually segregate their forage utilization in both space and time (Keast and Welsh 1968; Keast 1977; Werner and Hall 1979; Moyle 1973). In Savanne Lake, YOY perch comprise at least 80% of the total inshore fish fauna. However, in Henderson Lake, mimic and blacknose shiners are often as abundant as YOY perch in seine catches. Both species of shiners are day-active, invertebrate feeders, foraging on the same prey items as young perch, particularly dipteran larvae and pupae, amphipods, cladocerans, and emerging mayflies. In addition, mimic shiners also feed on green and blue-green algae. (Moyle 1973; Scott and Crossman 1975). If, in Henderson Lake, the production of zooplankton and benthos is low, then competition between perch and shiners for the same forage base will greatly contribute to the poor growth of the perch. Intermediate production has yet to be studied in these lakes. Schneider (1972) suggested that although minnows might reduce recruitment of YOY perch by acting as competitors, they also serve to transfer primary production and small invertebrates into a form utilizable by older perch. However, shiners are not utilized as forage by older perch, walleye, or northern pike. As a result, shiners may constitute an energy sink in this lake. For example, the introduction of minnows to single-species perch ponds reduced YOY perch growth and recruitment (Schneider 1972). Therefore, implementing a bait fishery in Henderson Lake might improve the growth and condition of YOY perch and could be a worthwhile experiment for future consideration.

### 8.3 The Effects of Feeding Behavior and the Physical Structure of Lakes on the Growth of Yellow Perch

Perch grow best in large, weed-free, mesotrophic lakes which have a good fish forage base (Thorpe 1977). Both study lakes are mesotrophic and most Henderson and Savanne perch greater than 13 cm in length eat fish and large invertebrates. However, both lakes differ with regard to basin heterogeneity, water clarity, surface area, and area of macrophyte production. Such differences through the provision of more refugia for prey species influence growth of perch by reducing both predator-prey interactions and foraging efficiency (Cooper and Crowder 1978).

Size of perch has been directly correlated with lake area (Alm 1946; Grimaldi and Leduc 1973). Henderson Lake is approximately half the size of Savanne Lake. Associated with its smaller size, Henderson Lake has a population of stunted perch, few of which reach a length of 20 cm compared to a maximum of 28 cm for Savanne perch. Keast (1977) concluded that perch grew best in larger water bodies that allow the fish to feed at a greater range of depths, allowing for a greater amplitude of diurnal feeding movements. Lack of habitat segregation within different size groups of perch and between perch and associated species may limit the amount of space available for foraging. This increases competitive interactions for reduced food resources and results in stunting. Feeding behavior of both European and yellow perch is referred to as "pack-hunting" (Deelder 1951; Nursall 1973). Perch generally aggregate in schools according to size. These aggregations loosely associate in the lake, forage independently, and respond to foraging of other individuals. For example, small, homogeneous water-bodies with limited cover for prey allows fish predation to suppress abundance of the mayfly, H. limbata, to the point where they are not available in

adequate quantity for good growth (Keast 1977). In this way, benthos can be locally depleted in a small lake such as Henderson, particularly where large numbers of uniformly-sized perch occur.

Henderson Lake and Savanne Lake not only differ in area, but also in the amount of macrophyte cover, which is observably greater in Henderson Lake. In Henderson Lake, most of the north basin area consists of a thick mat of emergent vegetation so open water areas are restricted to the south basin. Savanne Lake, in contrast, is essentially a homogeneous, open water lake, with only the border areas of bays being vegetated. When macrophytes reach high densities, fish productivity declines because of a reduction in feeding effectiveness, which in turn increases the probability of stunting (Dunst 1974). In Henderson Lake, the dense aquatic vegetation, especially in the shallow, north basin, may hamper the foraging efficiency of visual predators, such as perch, walleye, and northern pike. Deelder (1951) and Nursall (1973) found that the "pack-hunting" behavior of both perch species is efficient in open-water and clear littoral areas, but becomes hindered in water grown over with plants. As a result, European perch require an open water prey fish to attain good growth and the same is probably true for yellow perch (Deelder 1951). However, Henderson perch exhibited stunted growth even when ninespine sticklebacks were the preferred forage fish. This means that competition rather than the availability of an open water prey fish is a more important factor contributing to stunting of Henderson perch. Before 1982, both walleye and perch fed preferentially on ninespine sticklebacks, which inhabit open water areas, despite the presence of large numbers of blacknose and mimic shiners in littoral areas. This may explain, in part, why the ninespine stickleback population collapsed through depensatory predation by perch, walleye,

and northern pike, despite the presence of large numbers of shiners and young perch in littoral areas. Similarly, Nursall (1973) showed that perch, as continual foragers, seem to be most attracted by individual prey organisms and that shiner schools were not attacked by perch.

Stunted populations, consisting of large numbers of uniformly-sized individuals, are commonly observed in structurally complex environments (Cooper and Crowder 1979). For example, in a similar comparative study on percid lakes in Quebec, thick vegetation combined with exploitation of the top predator, northern pike, allowed the perch population to expand beyond the limits of an optimum food supply. Thus, the presence of predators combined with lack of cover helped prevent overpopulation and led to good perch growth (Grimaldi and Leduc 1973). Similarly, the larger area of available cover in Henderson Lake increases the survival of both perch and shiners and, in this way, reduces the effectiveness of predation by both walleye and perch resulting in an imbalance in the predator-prey ratio. Since the decline of ninespine sticklebacks, walleye, and perch have both switched to perch as the primary forage fish. It appears macrophyte production in Henderson Lake limits foraging efficiency, so the switch from ninespine sticklebacks to perch may not lead to an increase in production of walleye or growth of perch, but in fact may cause a decrease once walleye density approaches its pre-exploitation level. This is because the energy expenditure necessary to feed on perch in weedy areas of the lake may be greater than the energy needed to capture ninespine sticklebacks in open water. The fact that Henderson perch grow poorly even when more vulnerable prey (ninespine sticklebacks) is present, may mean competition is more important than forage type in affecting growth of perch in this lake. In contrast, in the less transparent, open water habitat of Savanne Lake,

foraging efficiency of perch and walleye is probably much better, since it occurs over a greater weed-free area in the lake, resulting in better growth and production of both walleye and perch.

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Appendix 1. Linear regressions of opercular bone length (mm) - total fish length (mm) relationships for male (M), female (F), and combined sexes (C) of Henderson and Savanne yellow perch populations, 1981 and 1982.

Lake	Year	Sex	N	Slope	Y-intercept (mm)	r	F - value
Savanne	1981	M	107	18.16	3.22	.99	6749.9 **
		F	112	18.44	1.63	.99	5092.8 **
		C	225	18.34	2.15	.99	11813.5 **
	1982	M	138	14.19	24.75	.95	1284.4 **
		F	119	17.62	6.09	.99	4123.8 **
		C	259	15.18	20.01	.96	2893.0 **
Henderson	1981	M	77	17.10	7.42	.99	3983.2 **
		F	125	17.67	6.21	.99	4810.2 **
		C	207	17.56	6.72	.99	8368.1 **
	1982	M	127	19.20	0.85	.99	5653.2 **
		F	151	17.97	6.43	.99	8181.7 **
		C	276	18.27	5.02	.99	14259.7 **

\*\* Significant at  $P < 0.01$ .

Appendix 2. Length and age frequency distributions of male (M), female (F), and combined sexes (C) of yellow perch used for backcalculations, from Henderson and Savanne lakes, Ontario, 1981 and 1982. (Gillnet samples of perch less than 7 cm were augmented with samples from seines).

Length interval  (mm)	Savanne						Henderson					
	1981			1982			1981			1982		
	M	F	C	M	F	C	M	F	C	M	F	C
40-49							2		2	3	5	8
50-59							6	5	12	15	15	30
60-69	9	4	14				3	11	15	18	10	28
70-79	31	22	54	6	10	16	5	5	10	3	2	5
80-89	4	5	10	8	10	18	13	15	31	14	14	28
90-99	1		1	10	3	13	22	29	53	17	12	29
100-109	6	15	22	10	17	29	6	15	22	10	11	21
110-119	24	18	42	13	12	2	5	3	8	20	15	35
120-129	11	8	20	8	5	13	4	2	6	9	11	20
130-139	5	9	15		4	4	3	10	13		3	3
140-149	1	1	2	10	9	19	2	14	16	1	3	4
150-159	1	2	3	17	10	27	2	7	9	7	9	16
160-169	3	9	12	14	11	25	2	2	4	6	10	16
170-179	2	3	5	10	9	19		4	4	3	17	20
180-189	3	2	5	4	5	9	2	1	3	1	8	9
190-199	2	1	3	5	4	9		2	2		3	3
200-209	3	2	5	8	2	10					1	1
210-219	3	2	5	3	1	4					2	2
220-229	2	3	5	6		6						
230-239		3	3	2	3	5						
240-249	1	1	2	3	2	5						
250-259	2	2	4	1	3	4						
260-269		4	4		1	1						
270-279		2	2									
280-289		1	1									
Total	114	119	239	138	121	261	77	125	210	127	151	278

Appendix 3. Comparison of age estimates from yellow perch opercular bones from Henderson and Savanne lakes, Ontario, 1981 determined by three biologists.

Henderson						Savanne		
1981			1982			1981		
Serial number	J.B.	B.R.	Serial number	D.B.	B.R.	Serial number	J.B.	B.R.
012	2+	2+	119	13	14	040	5	5
173	6	7	139	6	6	125	3	3
176	4	4+	163	7,8	8	053	6	6
177	4	10	272	9	9	024	4	3
089	5	10	271	7,8	8	235	3	3
259	4	4	021	6	6	084	3	3
105	3	6	028	2	2	196	2	2
162	3	3	030	2	2	195	3	3
109	2	4	069	1	1	172	3	2
112	2	5	122	5	5	116	2	2
082	2	5	124	5	5	036	2	2
139	2	2	117	3	3	052	2	2
138	3	5	111	5	5	080	3	2
273	2	3	048	2	2	238	1	1
197	1	2	148	4	4	145	1	1
134	1	2+	174	4	4	214	1	1
123	1	1	262	6	6	178	1	1
128	1	1	219	8,9	9	095	1	1
100	4	7	027	2	2	059	4	2
257	3	5	033	1	1	026	5	3
297	1	3				106	9	9
319	2	5				021	5	3
060	2	3						
255	4	5						
122	1	2+						
036	2	4+						
293	1	3+						

N = 29

N = 20

N = 22

NOTE: J.B. = J. Babaluk; B.R. = B. Ritchie; D.B. = D. Baccante



Appendix 4. Comparison of the number of annuli estimated from opercular bones with estimates from fourth dorsal spines of yellow perch from Henderson and Savanne lakes, Ontario, 1981 and 1982.

Savanne			Henderson					
Serial number	Opercular bone	Dorsal spine	Serial number	Opercular bone	Dorsal spine	Serial number	Opercular bone	Dorsal spine
131	5	5	126	3	3	454	11	10
133	3	3	125	3	3	455	11	10
130	5	5	059	3	3	456	7	7
132	5	5	104	5	5	453	10	9
135	3	3	163	3	3	422	9	7
137	2	2	193	7	7	458	8	6
164	3	3	151	3	3	412	8	8
054	5	5	134	4	4	411	8	7
057	2	2	198	3	3	401	7	7
053	6	6	028	2	2	399	6	8
127	3	3	080	4	4	397	8	8
047	2	2	064	4	3	394	7	5
023	3	3	031	2	2	393	7	6
002	6	6	063	3	3	395	8	7
025	5	5	062	3	3	392	8	7
015	6	6	040	2	2	391	9	7
016	4	4	288	8	8	381	9	6
001	7	7	004	3	3	389	7	7
019	4	4	003	4	4	388	7	6
018	5	4	017	2	2	403	6	6
017	5	5	020	4	4	387	8	8
020	3	3	019	3	3	384	8	6
021	3	3	271	4	4	406	10	8
024	3	3	273	4	4	404	7	6
026	3	3	319	5	6	385	6	6
027	2	2	284	6	6			
022	3	3	311	4	4			
042	5	5	297	7	6			
044	3	3	216	7	7			
041	5	5	300	3	3			
040	5	5	215	6	6			
029	2	2	298	6	6			
043	2	2	274	6	6			
045	2	2	272	4	4			
046	2	2	136	5	5			
048	2	2	164	6	6			
312	4	4	313	3	3			
066	4	4	291	5	6			
314	3	3	079	4	5			

N = 79  
(72 Ties)

N = 24  
(7 Ties)

Appendix 5. Length - frequency distributions of subsamples used to determine age compositions (combined sexes), of yellow perch sampled with experimental gillnets in Henderson and Savanne lakes, 1981 and 1982.

Length interval	Savanne		Henderson	
	(cm)			
	1981	1982	1981	1982
60-69	10	0	0	0
70-79	15	17	9	1
80-89	9	18	25	23
90-99	1	13	40	29
100-109	18	29	16	21
110-119	30	25	7	34
120-129	14	14	4	20
130-139	13	8	4	3
140-149	5	19	16	4
150-159	2	27	16	16
160-169	7	26	12	16
170-179	6	20	9	20
180-189	4	10	4	9
190-199	4	9	2	3
200-209	4	11	0	1
210-219	1	7	0	2
220-229	1	6		
230-239	1	8		
240-249	1	5		
250-259	4	5		
260-269	3	1		
270-279	1	0		
280-289	1	0		
<b>Total</b>	<b>157</b>	<b>279</b>	<b>166</b>	<b>202</b>
<b>Percent of total catch</b>	<b>9.6</b>	<b>14.2</b>	<b>13.7</b>	<b>6.5</b>

Appendix 6a. Mean, median, standard deviation, and range of total length of yellow perch sampled with monofilament gillnets (GN), electroshocker (ES), and fyke net (FN) in Henderson and Savanne lakes, Ontario, 1981 and 1982.

Lake	Gear	Mesh Size (mm)	N	Total length (mm)			
				Mean	Median	Range	SD
Savanne	FN		79	136.3	119.7	95-260	39.23
	ES		167	92.8	NA	50-260	37.90
	GN	19.1	592	94.6	88.2	71-261	23.59
		25.4	555	108.8	104.5	80-234	17.44
		38.0	584	146.9	141.5	100-259	18.50
	50.8	183	182.2	180.4	96-266	29.00	
Henderson	GN	19.1	975	89.9	85.9	70-204	14.80
		25.4	735	110.0	108.8	72-176	12.17
		38.0	242	153.0	155.2	87-199	20.41
		50.8	17	182.5	181.0	153-208	19.77

Appendix 6b. Length-frequency distributions of yellow perch sampled with various gears in Henderson and Savanne lakes, Ontario, 1981 and 1982. (ES = electroshocker<sup>a</sup>; FN = 1.81 m fyke net<sup>b</sup>; GN = gillnet<sup>c</sup>, 61 m long with stretched meshes: 19.1, 25.4, 38.1, 50.8 m; BS = Bag Seine, 9.1 m by 1.2 m, 18.2 by 1.2 m - Henderson Lake<sup>d</sup>, 18.2 by 1.8 m - Savanne Lake<sup>e</sup>).

Length interval (mm)	Savanne								Henderson					
	GN				ES	FN	BS		GN				BS	
	Stretched mesh (mm)													
	19.0	25.4	38.1	50.8			9.1m	18.2m	19.0	25.4	38.1	50.8	9.1m	18.2m
20-29													1	1581
30-39													2919	662
40-49					2		86	5045					4693	1
50-59					18		1341	1443					261	289
60-69					52		3226	19					12	714
70-79	81				6		302		90	8			53	87
80-89	240	15			1		21		546	27	2		95	17
90-99	167	131		1	27	1	135		220	32	2		35	6
100-109	34	216	4	4	30	12	231		47	317	9		30	15
110-119	7	99	6	4	6	26	20		18	239	13		43	11
120-129	15	40	1			15			23	81	4		26	8
130-139	17	24	203	3	1	5			10	17	5		28	5
140-149	11	15	130	5	6	2	3		7	3	39		9	3
150-159	3	1	63	1	8	5	6		8	4	83	2	8	5
160-169	3	6	61	17	2	3	6		1	5	44	4	6	6
170-179	4	2	46	47	2	1			3	2	24	2	8	
180-189	1	2	19	41	2	1					9	1	3	
190-199			4	24							8	4	1	1
200-209			2	14	1	1			2			4		
210-219			2	6	2	2								
220-229				3	2	2								
230-239			1	4		2								
240-249			1	2										
250-259			1	4	1	1								
260-269				2		1								
<b>Total</b>	<b>592</b>	<b>555</b>	<b>584</b>	<b>183</b>	<b>167</b>	<b>80</b>	<b>5377</b>	<b>6507</b>	<b>975</b>	<b>735</b>	<b>242</b>	<b>17</b>	<b>8231</b>	<b>3411</b>

<sup>a</sup> ES data taken from Baccante (unpub.).

<sup>b</sup> FN data from May.

<sup>c</sup> GN data from May - August in both lakes.

<sup>d</sup> July, 1982 data.

<sup>e</sup> August, 1982 data.

Appendix 7. Example of the determination of mean age to maturity using Probit transformation and least squares regression.

The following maturity at age schedule for male yellow perch from Henderson Lake, Ontario, 1982 was used:

Age	Sample size	Mature		Probit	$-\text{Log}_e [(K-Y)/Y+1]$
		N	%		
1	18	0	0.0 *		-1.099
2	19	2	11.0	3.733	-0.637
3	10	6	60.0	5.253	-0.470
4	8	7	88.0	6.175	-0.113
5	32	29	91.0	6.341	-0.086
6	14	3	93.0	6.476	-0.068
7	7	7	99.9 *	8.091	0.0
8	1	1	"		
9	3	3	"		
10	5	5	"		
11	3	3	"		
12	1	1	"		
13	4	4	"		

<sup>a</sup> Taken from Probit Tables in Finney (1971).

<sup>b</sup>  $K=100\%$ ;  $Y=\%$  mature according to Lysack (1980).

\* No 0% or 100% values occur for Probits, therefore 100% is considered 99.9%.

Probit and natural logarithmic transformations when regressed against age produced significant ( $P < 0.05$ ) regression lines:

1) Probit vs Age;

$$Y = 0.726(X) + 2.750,$$

$$r = 0.95,$$

95% CL for the slope = 0.24, and

50% intercept = 3.10 years.

## Appendix 7. Continued

2) Lysack's  $\text{Log}_e$  transformation vs Age;

$$Y = 0.354(X) - 2.095,$$

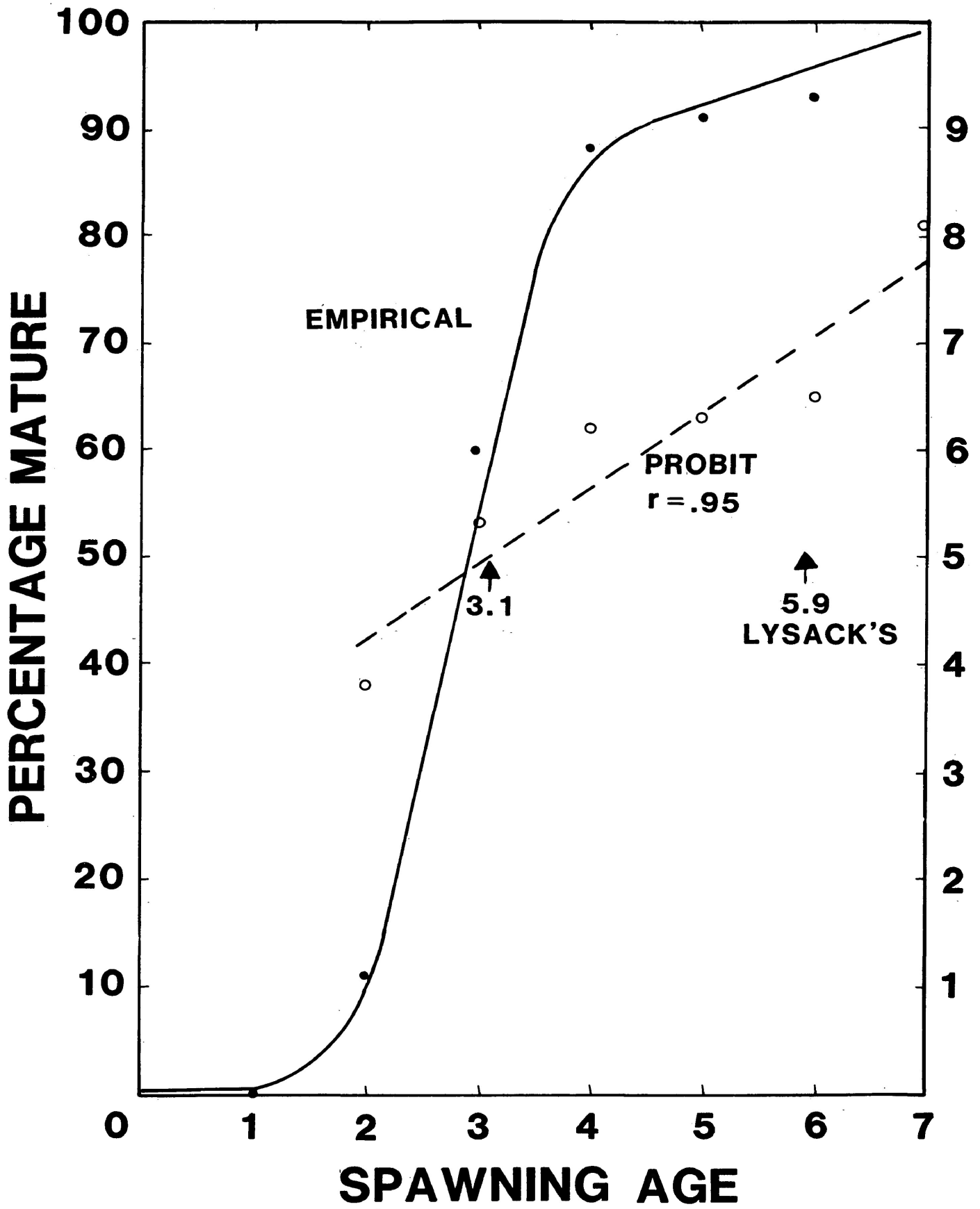
$$r = 0.77,$$

95% CL for the slope = 0.28, and

$$50\% \text{ intercept} = 2.095/0.354 = 5.92 \text{ years.}$$

Both the empirical data and the probit regression line are shown in the following figure with the estimates of mean age at maturity from the Probit method and Lysack's regression method

Appendix 7. Graph showing empirical percentage maturity at spawning age data and the corresponding probit transformation and regression line. Age at 50% maturity estimated by the Probit and Lysack methods are indicated by arrows.





Appendix 8a. Daily water temperatures (C) for Henderson and Savanne lakes, Ontario, 1981 and 1982.

Month	Day	1981		1982	
		Henderson	Savanne	Henderson	Savanne
May	22			13.0	12.0
	23	14.0	16.7	14.0	13.8
	24			14.0	15.0
	25			14.0	17.0
June	3			16.0	15.8
	4			16.0	17.0
	6	17.0	17.7		
	7	17.5	18.0		
	8	17.0	17.9		
	9	17.0	17.5		
	10	17.0	17.3		
	21			17.0	16.5
	22			17.0	16.3
	23	19.0	18.9		
	24	17.5	18.0		
July	25	17.0	17.1		
	26	19.0	19.1		
	27	18.0	19.8		
	5			19.0	19.0
	13	25.0	25.2	22.0	20.3
	14	24.0	24.5		
	17			22.0	22.0
	22			22.0	21.6
	25	21.0	19.9		
	26	21.0	20.1		
	27	21.0	20.4		
	28	21.0	21.8		
	29	21.0	21.3		
30	20.0	21.1			
August	9	21.0	21.2	22.0	
	10	21.0	20.4	18.5	
	11	21.0	20.8	18.0	
	12	21.0	21.2		
	13	21.0	20.5		
	23	21.5	21.4	19.0	
	24	20.0	20.6	19.0	
25	20.0	21.2	19.0		
October	31	6.0			

Appendix 8b. Daily beach temperature (°C) in Savanne Lake, Ontario from: May to October 1981; May to July, 1982; May to October, 1983.

1981		June		July		August		September		October	
Date	Temp.	Date	Temp.	Date	Temp.	Date	Temp.	Date	Temp.	Date	Temp.
		1	15.2	1	19.9	1	22.6	1	18.9	1	7.2
		2	15.4	2	20.5	2	24.9	2	19.3	2	8.0
		3	15.4	3	21.6	3	24.3	3	18.5	3	7.2
		4	18.6	4	22.0	4	23.4	4	16.9	4	7.1
		5	18.3	5	23.6	5	22.7	5	17.3	5	7.7
		6	17.7	6	26.9	6	21.9	6	16.7	6	7.6
		7	18.0	7	26.1	7	21.7	7	16.5	7	7.6
		8	17.9	8	24.9	8	22.9	8	15.4	8	7.7
		9	17.5	9	24.0	9	21.2	9	16.5	9	7.7
		10	17.3	10	24.1	10	20.4	10	19.7	10	7.3
		11	17.8	11	24.8	11	20.8	11	17.8	11	7.7
		12	19.0	12	26.1	12	21.2	12	17.8	12	8.4
		13	19.0	13	25.2	13	20.5	13	17.7	13	8.3
		14	18.1	14	24.5	14	21.2	14	16.0	14	8.3
		15	18.3	15	24.0	15	20.0	15	15.3	15	7.9
		16	18.0	16	24.9	16	22.1	16	14.4	16	8.2
		17	18.1	17	24.0	17	21.2	17	13.8	17	8.3
		18	16.2	18	25.7	18	21.5	18	13.8	18	7.3
		19	17.1	19	25.9	19	22.2	19	13.4	19	6.0
		20	17.4	20	24.2	20	21.2	20	13.2	20	5.2
		21	16.9	21	22.2	21	20.6	21	13.6	21	4.8
		22	17.0	22	26.3	22	20.1	22	13.0	22	4.5
		23	18.9	23	22.1	23	21.4	23	12.1	23	4.1
		24	15.6	24	21.0	24	20.6	24	14.2	24	3.0
		25	14.8	25	19.9	25	21.2	25	13.1	25	2.4
		26	15.5	26	20.1	26	21.3	26	12.2	26	2.6
		27	18.2	27	20.4	27	21.2	27	10.6	27	
		28	18.3	28	21.8	28	20.9	28	9.0	28	End of
		29	17.1	29	21.3	29	20.6	29	10.1	29	Recording
		30	15.7	30	21.1	30	22.1	30	8.6	30	
		31	15.4	31	21.5	31	20.9				

Ice out - last week in April  
 Thermograph locations: May 12 to Oct. 14 T  
 Oct. 14 to Nov. 5 D

Freeze-up - second week in November  
 Refer to Figure (2) for thermograph locations

Appendix 8b. Continued

1982		May		June		July	
Date	Temp.	Date	Temp.	Date	Temp.	Date	Temp.
		1	16.0	1	19.0		
		2	15.0	2	19.0		
		3	15.8	3	18.8		
		4	17.0	4	18.5		
		5	17.0	5	19.0		
		6	17.0	6	20.0		
		7	17.0	7	20.0		
		8	17.0	8	19.5		
		9	16.5	9	19.3		
		10	15.8	10	18.8		
	8.3	11	15.5	11	18.8		
11	9.3	12	15.5	12	20.5		
12	9.3	13	16.3	13	20.3		
13	10.5	14	17.3	14	21.0		
14	10.3	15	17.0	15	20.8		
15	10.5	16	16.3	16	22.5		
16	10.8	17	16.3	17	22.0		
17	11.3	18	16.3	18	21.0		
18	11.3	19	16.3	19	21.0		
19	11.0	20	17.0	20	21.0		
20	11.5	21	16.5	21	chart changed		
21	12.0	22	16.3	22	21.6		
22	13.8	23	18.5	23	22.1		
23	15.0	24	19.0	24	22.3		
24	17.0	25	17.0	25	21.5		
25	18.5	26	17.8	26	21.5		
26	17.8	27	18.0	27	21.7		
27	19.0	28	18.5				
28	19.5	29	18.3				
29	19.5	30	17.5				
30	19.0						
31							

Thermograph malfunctioned  
no temperatures for rest  
of year

Freeze-up - November 10

Ice out - May 4  
Thermograph locations: May 10 to May 11 **D**  
May 12 to Sept. 29 **T**  
Sept. 29 - Oct. 10 **D**

Appendix 8b. Continued

1983		May		June		July		August		October	
Date	Temp.	Date	Temp.	Date	Temp.	Date	Temp.	Date	Temp.	Date	Temp.
		1	14								
		2	13								
		3	14								
		4		4	24					4	11
		5		5						5	
		6		6						6	
		7	12	7						7	
		8	13	8						8	
		9	12	9						9	
				10						10	
11	6			11						11	
12	7			12						12	9
13	8			13						13	8
14	8			14						14	7
15	7			15							
16	9			16				16	22		
17	10			17				17			
18	10.5			18				18	25		
19	12			19							
20	12			20	26						
21	12			21							
22	12			22							
23	13			23							
24	12			24							
25	11			25							
26	13			26							
27	13.5			27	24						
31	12										

NOTE: Because of thermograph malfunction, temperatures are means recorded during the following sampling periods: May 11 to June 9 - trapnetting  
 July 4 to Aug. 18 - seine netting  
 Oct. 4 to Oct. 14 - trap and gill netting

Ice out - May 8  
 Freeze-up - About second week in November

Appendix 9. Accumulated precipitation (mm) from May to August, 1972 - 1983, at Raith, Ontario, an Environment Canada Meteorological Station, Number TCPL 64.

Year	May	June	July	August
1972	54.9	92.0	169.7	17.0
1973	56.1	56.9	113.0	122.2
1974	91.7	56.4	65.0	161.8
1975	53.6	93.5	71.1	67.3
1976	5.8	132.6	94.2	12.7
1977	105.1	104.6	88.8	178.2
1978	93.3	78.7	93.4	86.0
1979	77.1	107.4	*85.6	116.0
1980	45.0	51.6	108.9	70.0
1981	69.2	168.6	51.6	39.6
1982	74.3	63.8	288.4	50.9
1983	49.7	107.7	120.4	NA

\* This record is from Upsala Meteorological Station - TCPL 62 (39 km NW of Savanne Lake).

Appendix 10. Catch-per-unit-effort for: yellow perch effectively recruited to experimental, monofilament gillnets in Henderson and Savanne lakes, Ontario, 1981 and 1982; age 5+ (20.0 cm) yellow perch in Savanne Lake, 1981 and 1982 (CNO is catch number; locations shown in Figure 4a).

Sampling time (hrs)	Month	Henderson Lake (Age 5+; 10+ cm)				Savanne Lake (Age 2+; 11+ cm)				Savanne Lake (Age 5+; 20+ cm)				
		CNO		CPUE		CNO		CPUE		CNO		CPUE		
		Location	Location	Location	Location	Location	Location	Location	Location	Location	Location	Location	Location	
0400-0800	July	12	1a	3.50	27	1a	0.45	0	0	27	1a	0.45	0	
		13	2a	0.5	28	2a	1.67	0	0	28	2a	1.67	0	
		14	3a	6.36	29	3a	0.95	0	0	29	3a	0.95	0	
	Aug.	21	1a	4.50	36	3c	2.25	1.25	0	36	3c	2.25	1.25	
		22	2d	13.65	37	2d	4.05	0	0	37	2d	4.05	0	
		23	3b	9.07	38	1c	0	0	0	38	1c	0	0	
		27	1b	4.00	51	3b	4.47	0.52	0	51	3b	4.47	0.52	
		28	2c	1.78	52	2b	4.05	0.24	0	52	2b	4.05	0.24	
		29	3d	15.08	53	1d	10.93	0.23	0	53	1d	10.93	0.23	
		39	3d	14.0	54	3a	3.42	0.49	0	54	3a	3.42	0.49	
		40	2d	1.87	55	2d	6.83	0.48	0	55	2d	6.83	0.48	
		41	1b	5.00	56	1b	6.00	0	0	56	1b	6.00	0	
		1200 - 1600	July	6	1a	5.18	21	3a	4.25	0.25	21	3a	4.25	0.25
				7	2a	5.12	22	2a	1.96	0	22	2a	1.96	0
8	3a			6.98	23	1a	7.28	.23	23	1a	7.28	.23		
Aug.	18		1b	2.25	30	3b	4.67	0	30	3b	4.67	0		
	19		2a	4.75	31	2b	3.26	.23	31	2b	3.26	.23		
	20		3d	6.25	32	1b	2.33	0	32	1b	2.33	0		
	30		3d	3.75	39	1d	1.90	0	39	1d	1.90	0		
	31		2b	3.73	40	2b	0.42	0	40	2b	0.42	0		
	32		1c	11.25	41	3c	1.62	0.24	41	3c	1.62	0.24		
	36		3b	5.25	45	3d	2.67	0.47	45	3d	2.67	0.47		
	37		2a	4.25	46	2a	0.80	0.66	46	2a	0.80	0.66		
	38		1a	6.19	47	1a	0	0	47	1a	0	0		
	2000 - 2400		July	9	1a	10.70	24	3a	2.50	0.25	24	3a	2.50	0.25
				10	2a	11.33	25	2a	0.71	0	25	2a	0.71	0
11		3a		9.56	26	1a	2.55	0.21	26	1a	2.55	0.21		
Aug.		15	3a	6.59	33	3b	6.14	0.29	33	3b	6.14	0.29		
		16	2b	9.41	34	2c	3.57	0.48	34	2c	3.57	0.48		
		17	1a	6.51	35	1d	2.82	0	35	1d	2.82	0		
		24	1c	5.24	42	1b	5.13	0	42	1b	5.13	0		
		25	2a	9.11	43	2c	5.78	0.66	43	2c	5.78	0.66		
		26	3a	1.80	44	3c	4.58	0.21	44	3c	4.58	0.21		
		33	3c	4.57	48	3a	7.70	0.51	48	3a	7.70	0.51		
		34	2c	4.00	49	2c	14.14	0.72	49	2c	14.14	0.72		
		35	1d	16.50	50	1c	10.44	0.22	50	1c	10.44	0.22		

## Appendix 10. Continued

Sampling time (hrs)	Month	Henderson Lake (Age 5+; 10+ cm)			Savanne Lake (Age 2+; 11+ cm)			Savanne Lake (Age 5+; 20+ cm)		
		CNO	Location	CPUE	CNO	Location	CPUE	CNO	Location	CPUE
2400- 0300	June	20	1a	1.21	19	1c	0.33		0	
		21	2c	0.60	20	2c	0		0	
	July	22	3d	0.30	21	3b	1.85		0	
		34	1d	0	40	1a	1.06		0	
		35	2c	0.61	41	2b	0.33		0	
	Aug.	36	3a	0.25	42	3b	0.67		0	
		70	1c	0.33	76	1a	0		0	
71		2c	0	77	2a	0.67		0		
		72	3b	0.66	73	3c	1.52		0.30	
0300- 0600	June	22	1c	6.01	28	1c	0.66		0	
		23	2c	15.34	29	2b	2.42		0	
	July	24	3a	5.23	30	3b	3.71		0.57	
		40	1a	9.99	49	1c	3.72		0	
		41	2b	6.67	50	2d	1.14		0.29	
	Aug.	42	3b	1.00	51	3c	0.66		0	
		76	1d	5.21	73	1b	3.99		0	
77		2c	5.87	74	2b	0.96		0.24		
		78	3a	10.10	75	3a	1.84		0	
0600- 0900	June	10	1c	4.34	10	1a	4.33		0.33	
		11	2d	6.16	11	2b	1.54		0.33	
	July	12	3a	2.16	12	3b	1.14		0	
		49	1a	21.00	31	1d	10.15		0	
		50	2d	10.29	32	2a	6.00		0	
	Aug.	51	3a	12.92	33	3a	8.29		0	
		55	1b	7.33	55	1a	14.33		0.66	
		56	2c	3.13	56	2b	6.06		0.30	
		57	3c	4.07	57	3a	17.60		1.95	
0900- 1200	June	7	1c	1.14	22	1a	6.00		0.66	
		8	2b	1.66	23	2d	2.00		0	
	July	9	3a	2.46	24	3a	0.33		0	
		31	1d	3.33	52	1b	3.00		0	
		32	2a	7.67	53	2a	5.00		0	
			33	3a	3.67	54	3a	1.00		0
			43	1b	8.33					
		44	2a	15.66						
		45	3c	2.00						

Appendix 10. Continued

	Aug.	64	la	5.54	64	la	13.67	0
		65	2d	1.84	65	2d	4.00	0
	June	66	3c	4.31	66	3c	8.66	0.33
1200-		1	1d	3.44	1	1b	1.67	0.33
1500		2	2a	1.86	2	2c	0.62	0.31
		3	3d	4.00	3	3d	0.92	0
		7			7	1d	3.01	0
		8			8	2a	4.67	0
	July	9			9	3d	3.00	0
		43	1d	4.00	43	1b	5.99	0
		53	2a	2.66	44	2c	2.12	0
		54	3b	10.67	45	3a	6.77	0
	Aug	61	1d	2.50	67	1b	4.34	0
		62	2a	4.69	68	2b	2.77	0.33
		63	3d	2.81	69	3a	6.34	0.66
	June	13	1b	2.34	13	1d	0.34	0
1500-		14	2b	5.32	14	2a	1.00	0
1800		15	3d	0	15	3a	2.34	0
		16	1b	0.86	16	1a	5.68	0.33
		17			17	2b	2.33	0
		18			18	3a	0.33	0
	July	46	1c	5.66	34	1a	3.34	0.37
		47	2b	15.00	35	2c	2.50	0.51
		48	3d	9.34	36	3d	3.67	0.33
	Aug.	58	1a	0	38	1b	6.67	0.33
		59	2b	5.67	59	3a	6.47	0
		60	3a	2.81	60	2b	6.00	0.33
	June	4	1b	0.94	4	1c	7.89	0
		5	2a	5.75	5	2d	7.15	0.29
		6	3b	1.88	6	3c	4.06	0.31
	July	28	1b	5.43	37	1c	14.58	0.29
		29	2d	12.32	38	2d	17.23	0.31
		30	3d	13.03	39	3a	5.34	0
	Aug.	67	1b	9.70	61	1d	8.67	0
		68	2b	25.30	62	2a	8.66	0.99
		69	3a	7.17	63	3d	7.34	0.99
	June	17	1d	0.67	25	1b	1.68	0
		18	2a	4.68	26	2c	3.34	0
		19	3a	10.01	27	3d	2.66	0
	July	37	1c	26.07	46	1d	11.34	0
		38	2d	3.94	47	2a	6.85	0.29
		39	3d	12.25	48	3d	0.86	0
	Aug.	73	1a	3.00	70	1c	0.67	0
		74	2a	1.00	71	2c	1.00	0
		75	3b	1.33	72	3b	1.00	0



Appendix 11. Dates and total length (mm) of vulnerability to bag seines (B.S.) and spawning times for fish species in Henderson and Savanne Lakes, Ontario, (1981 - 1983).

A. Henderson Lake

Year	Species	Vulnerable to B.S.		Spawning date
		Date	Length	
1981	YOY Y. Perch	Jun 24	22-24	
	" Mimic Shiner	Aug 9	15-18	
	" Blacknose Shiner	Aug 9	15-18	
	" C. W. Sucker	Jul 13	20	
	" Iowa Darter	Jul 13	20	
	AD. Y. Perch			Before May 24
	" Walleye			"
	" C. W. Suckers			1st week - Jun
	" N. Pike			"
	" Ninespine Stickleback			Jun 26 +
" Mimic & Blacknose Shiners			Jun 22 - 27	
1982	YOY Y. Perch	Jun 22	18-35	
	" Mimic & Blacknose Shiners	Aug 10-24	20-26	
	" C. W. Sucker	Jul 17	19-24	
	AD. Y. Perch			approx. May 15
	" Walleye			"
	" N. Pike			"
	" C. W. Sucker			"
" Ninespine Stickleback			"	
" Iowa Darter			"	
1983	YOY Y. Perch	Jun 11		
	" Mimic Shiner	Jul 20		
	" Blacknose Shiner	Aug 2		
	" C. W. Sucker	Jul 28		
	" Iowa Darter	Jul 28-Aug 2		

B. Savanne Lake

1981	YOY Y. Perch	Jun 7	35	
	" C. W. Sucker	Jun 28	21-23	
	" Burbot	Jun 2	18-21	
	" Walleye	Jun 28	20-23	
	" Trout-perch	Jul 10	20-25	
	AD. Y. Perch			Before May 11
	" Walleye			May 11 - 15
	" C. W. Suckers			"
	" Trout-perch			May 11
	" Johnny darter			May 15
1982	YOY Y. Perch	Jul 1	19-28	
	" C.W. Suckers	Jul 1		
	" Burbot	Jul 1		

NOTE: Mayflies emerged first week of June in 1981 and began emerging May 24 in 1982 from Henderson Lake.

Appendix 12. Linear regression statistics: Pearson's correlation coefficients (r), slopes (m), intercepts (Int), and standard errors of the slopes (SEm) for growth rates of YOY yellow perch in Henderson Lake, 1981-1983 and YOY yellow perch and walleye in Savanne Lake, 1972-1983, Ontario.

A. Henderson Lake - YOY Yellow Perch

Year	N	Total length vs time (mm/day)				Total weight vs time (g/day)				TW vs TL (g/mm)			
		r	m	Int	SEm	r	m	Int	SEm	r	m	Int	SEm
1981	7	.963	.219	-9.85	.274	.993	.010	-1.61	.005	.939	.041	-1.01	.007
1982	6	.995	.533	-73.9	.260	.981	.019	-3.34	.018	.966	.034	-0.71	.005
1983	9	.871	.247	-27.3	.528	.882	.009	-1.53	.018	.985	.035	-0.53	.002

B. Savanne Lake - YOY Yellow Perch

1972	6	.984	.321	-23.9	.984	.723	.104	26.1	.500	.814	.357	20.0	.130
1974	10	.951	.435	-57.1	.503	.950	.022	-3.8	.025	.969	.049	-1.2	.004
1976	8	.980	.463	-45.7	.422	.961	.050	-8.9	.058	.886	.097	-3.4	.021
1977	9	.986	.468	-46.0	.299	.974	.038	-6.4	.033	.951	.078	-2.5	.010
1979	9	.980	.692	-97.6	.530	.988	.047	-8.6	.030	.984	.067	-1.8	.005
1980	13	.992	.484	-56.2	.186	.970	.035	-6.3	.030	.970	.071	-2.2	.005
1981	5	.993	.657	-91.3	.441	.999	.041	-7.4	.011	.996	.062	-1.7	.003
1982	8	.995	.561	-77.5	.290	.958	.027	-4.9	.036	.941	.047	-1.1	.008
1983	5	.976	.705	-103.1	.899	.998	.049	-9.1	.016	.987	.067	-1.8	.006

2. Savanne Lake - YOY Walleye

Total length vs time				
Year	N	r	m	Int
1972	12	.958	1.08	-133.7
1973	10	.872	.87	117.3
1974	10	.919	1.35	-212.1
1975	14	.907	1.24	-174.7
1976	9	.925	1.17	-151.3
1977	10	.904	1.23	-168.6
1979	10	.980	1.12	-167.4
1980	13	.826	.94	-110.6
1981	11	.980	1.19	-173.5
1982	7	.884	1.75	-293.0
1983	4	.991	1.61	-251.1

Appendix 13a. Differences between male and female total length - opercular bone length relationships for yellow perch in Henderson and Savanne lakes, Ontario, 1981 and 1982, as determined by Analysis of Covariance. (\*\* indicates significant values at  $P < 0.01$ ).

A. Savanne Lake

Line	N	Slope	Intercept	Residuals		
				df	SS	MS
1981 M	113	18.102	3.503	112	3042.10678	27.16167
1981 F	119	18.579	0.945	117	7176.42872	61.33700
				228	10218.53550	44.06727
Common				229	10320.40541	45.06727
				1	101.867	
Total				230	10338.98530	44.95211
				1	18.583	

F-slope =  $101.867/44.818 = 2.273$  with 1,228 df.

F-intercept =  $18.583/45.06727 = 0.412$  with 1,229 df.

1982 M	138	14.190	24.742	136	27293.92697	200.69064
1982 F	121	17.578	6.348	119	6901.70880	57.99755
				255	34195.63577	134.10053
Common				256	40108.500	156.674
				1	5912.865	
Total				257	44971.293	174.986
				1	4862.575	

\*\* F-slope =  $5912.865/134.101 = 44.093$  with 1,255 df.

\*\* F-intercept =  $4862.575/156.674 = 31.036$  with 1,256 df.

## Appendix 13a. Continued

## B. Henderson Lake

Line	N	Slope	Intercept	Residuals		
				df	SS	MS
1981 M	77	17.410	7.420	75	1272.32323	16.96431
1981 F	125	17.669	6.205	123	3501.40588	28.46671
				198	4773.72911	45.43102
Common				199	4783.609	24.038
				1	9.880	
Total				200	4785.172	23.925
				1	1.563	

F-slope =  $9.880/45.431 = 0.218$  with 1,198 df.

F-intercept =  $1.563/24.038 = 0.065$  with 1,199 df.

1982 M	127	19.198	0.851	125	3257.94536	26.06356
1982 F	151	17.965	6.425	149	5620.25520	37.71983
				274	8878.20056	63.78339
Common				275	9306.500	33.842
				1	428.230	
Total				276	9384.471	34.002
				1	77.971	

F-slope =  $428.230/32.402 = 6.715$  with 1,274 df.

F-intercept =  $77.971/33.842 = 2.304$  with 1,275 df.

Appendix 13b. Differences between years for male and female total length - opercular bone length relationships of yellow perch from Henderson and Savanne lakes, Ontario, 1981 and 1982, as determined by Analysis of Covariance (\*\* indicates significant values at  $P < 0.01$ ).

A.i.) Savanne Lake - Male

Line	N	Slope	Intercept	Residuals		
				df	SS	MS
1981	113	18.102	3.503	113	3042.10678	27.40637
1982	138	14.190	24.742	136	27293.92697	200.69064
				247	30336.03375	122.81795
Common				248	37509.313	151.247
				1	7173.280	
Total				249	39705.094	159.458
				1	2195.781	

\*\*  $F\text{-slope} = 7173.280/122.818 = 58.406$  with 1,247 df.

\*\*  $F\text{-intercept} = 2195.781/151.247 = 14.518$  with 1,248 df.

A.ii.) Savanne Lake - Female

1981	119	18.579	0.945	117	7176.42872	61.33700
1982	121	17.578	6.348	119	6901.70880	57.99755
				236	14078.13752	59.65312
Common				237	14569.813	61.476
				1	491.676	
Total				238	14815.384	62.250
				1	245.571	

$F\text{-slope} = 491.676/59.653 = 8.242$  with 1,236 df.

\*\*  $F\text{-intercept} = 245.571/61.476 = 3.995$  with 1,237 df.

## Appendix 13b. Continued

## B.i.) Henderson Lake - Male

Line	N	Slope	Intercept	Residuals		
				df	SS	MS
1981	77	17.410	7.420	75	1272.32323	16.96431
1982	127	19.198	0.851	125	3257.94536	26.06356
				200	4530.269	43.59991
Common				201	4987.625	24.814
				1	457.356	
Total				202	5332.094	26.965
				1	344.469	

\*\* F-slope =  $457.356/43.600 = 10.490$  with 1,200 df.

\*\* F-intercept =  $344.469/24.814 = 13.880$  with 1,201 df.

## B.ii.) Henderson Lake - Female

1981	125	17.669	6.205	123	3501.40588	28.46671
1982	151	17.965	6.425	149	5620.25520	37.71983
				272	9121.661	66.197
Common				273	9148.313	33.150
				1	26.652	
Total				274	9411.886	34.350
				1	263.573	

F-slope =  $26.652/66.197 = 0.403$  with 1,272 df.

\*\* F-intercept =  $263.573/33.150 = 7.951$  with 1,272 df.

Appendix 14. Mean (S D) calculated total lengths (mm) at the end of each year of life based on opercular bone measurements of male (M), female (F), and combined sexes (C) of yellow perch from Savanne Lake, captured with monofilament gill nets, May - June, 1981.

Year- class	Sex	N	Annulus										
			1	2	3	4	5	6	7	8			
1980	M	43	65.7( 2.99)										
	F	31	65.8( 3.30)										
	C	77	65.8( 3.26)										
1979	M	38	62.1( 4.18)	108.5( 9.41)									
	F	43	62.7( 4.61)	108.6( 8.95)									
	C	83	62.3( 4.39)	108.5( 9.04)									
1978	M	14	63.5( 5.04)	109.3( 8.22)	125.3( 37.20)								
	F	22	67.3( 7.24)	111.0( 10.12)	147.9( 36.63)								
	C	37	65.6( 6.74)	110.7( 9.40)	138.9( 37.54)								
1977	M	5	64.1( 22.50)	103.1( 20.68)	133.6( 18.31)	169.3( 11.55)							
	F	5	61.9( 8.41)	115.8( 17.62)	157.7( 30.40)	186.7( 39.84)							
	C	10	62.7( 16.15)	109.2( 19.53)	145.4( 26.98)	177.8( 29.19)							
1976	M	7	64.1( 6.79)	103.7( 7.16)	135.8( 14.41)	168.7( 11.56)	196.2( 13.21)						
	F	8	62.9( 4.35)	104.0( 6.26)	139.6( 7.45)	184.7( 10.39)	224.5( 16.03)						
	C	15	63.3( 5.42)	103.8( 6.49)	137.8( 11.06)	177.2( 13.49)	211.3( 20.42)						
1975	M	4	66.3( 13.33)	109.5( 4.00)	141.1( 13.31)	170.7( 4.93)	202.0( 3.55)	219.5( 4.90)					
	F	3	59.6( 7.06)	106.3( 16.11)	131.5( 28.80)	177.9( 39.33)	219.3( 28.48)	246.3( 18.50)					
	C	7	63.2( 10.72)	107.9( 9.92)	136.9( 19.69)	173.7( 25.31)	209.4( 19.04)	231.0( 18.22)					
1974	M	0											
	F	6	63.1( 17.66)	95.9( 14.80)	143.8( 16.63)	182.4( 22.07)	206.4( 22.65)	233.8( 21.92)	254.9( 16.87)				
	C	5	66.1( 18.34)	100.5( 12.58)	145.7( 17.95)	186.0( 22.46)	210.0( 23.19)	234.5( 24.40)	255.5( 20.07)				
1973	M	2	60.0( 0.79)	98.5( 20.50)	162.7( 16.83)	182.4( 2.56)	207.0( 7.38)	222.3( 4.11)	238.3( 2.96)	247.4( 0.09)			
	F	1	51.3	113.0	174.6	180.6	204.4	236.2	266.1	280.0			
	C	4	55.1( 4.82)	90.6( 16.12)	146.8( 21.07)	178.0( 7.72)	202.3( 8.98)	228.1( 7.42)	250.1( 13.97)	261.8( 16.74)			
Mean (SE)	M	113	64.0( 0.60)	107.2( 1.24)	135.9( 2.43)	170.8( 2.38)	199.7( 2.95)	220.5( 1.85)	238.5( 1.90)	247.6( 0.14)			
	F	119	64.2( 0.60)	108.3( 1.16)	149.7( 2.94)	183.5( 5.01)	216.6( 4.83)	237.9( 6.14)	257.2( 6.37)	276.0( 4.00)			

Appendix 14. Mean (S D) calculated total lengths (mm) at the end of each year of life based on opercular bone measurements of male (M), female (F), and combined sexes (C) of yellow perch from Savanne Lake, captured with monofilament gill-nets, May - June, 1982.

Year- Sex N	Annulus								
	1	2	3	4	5	6	7	8	9
1981	M 14 73.2( 4.92)								
	F 20 72.0( 5.18)								
	C 34 73.0( 4.77)								
1980	M 38 71.0( 4.79)	106.2( 9.48)							
	F 37 63.0( 4.39)	107.1( 8.02)							
	C 77 69.1( 4.49)	106.6( 8.71)							
1979	M 37 74.3( 4.39)	112.4( 9.94)	150.4( 15.08)						
	F 32 65.6( 3.95)	107.1( 7.81)	151.3( 13.58)						
	C 69 72.5( 4.21)	111.2( 9.00)	150.9( 14.40)						
1978	M 28 76.0( 4.92)	115.5( 8.43)	149.2( 14.49)	174.8( 17.66)					
	F 18 66.6( 5.81)	108.4( 8.59)	145.8( 11.55)	172.9( 16.85)					
	C 46 74.0( 5.32)	113.7( 8.38)	148.3( 13.34)	174.1( 17.15)					
1977	M 5 69.4( 3.34)	117.1( 7.85)	149.1( 7.26)	174.7( 14.32)	196.8( 10.91)				
	F 5 63.7( 7.93)	102.7( 7.12)	142.6( 7.43)	168.7( 10.21)	191.0( 10.39)				
	C 10 69.6( 6.65)	112.2( 7.60)	142.0( 7.02)	172.2( 11.89)	193.9( 10.49)				
1976	M 11 75.7( 5.45)	111.1( 6.21)	136.8( 7.71)	165.5( 9.90)	196.3( 16.46)	223.0( 16.11)			
	F 6 67.2( 4.22)	105.8( 6.50)	133.8( 11.69)	172.9( 20.10)	215.4( 22.91)	243.9( 12.08)			
	C 17 74.1( 5.64)	110.1( 6.35)	136.4( 8.72)	168.3( 14.13)	202.8( 20.16)	230.2( 17.60)			
1975	M 4 75.2( 3.11)	111.8( 6.16)	135.9( 10.64)	160.7( 14.17)	181.7( 13.08)	208.6( 6.86)	230.6( 6.81)		
	F 2 61.8( 2.05)	109.4( 5.29)	140.6( 22.65)	182.5( 6.29)	217.1( 3.57)	240.0( 0.62)	255.5( 2.12)		
	C 6 72.0( 2.65)	111.9( 6.95)	141.3( 17.34)	168.2( 18.28)	193.4( 22.55)	219.0( 17.73)	238.9( 13.92)		
1974	M 0								
	F 2 59.6( 8.29)	87.3( 7.38)	134.8( 1.49)	166.5( 0.53)	195.0( 7.40)	212.2( 6.06)	234.0( 7.08)	250.4( 4.81)	
	C 1 75.9	108.1	140.3	170.8	203.0	218.2	230.1	247.0	
1973	M 1 65.9	99.6	143.2	165.7	186.9	199.4	209.3	231.8	243.0
	F 0								
	C 1 62.1	96.5	141.1	164.0	185.7	198.4	208.6	231.5	243.0
Mean	M 138 73.5( 0.43)	111.2( 0.87)	147.4( 1.54)	171.3( 2.27)	193.2( 3.26)	217.9( 3.93)	224.8( 4.38)	231.8( 0.00)	243.0
(SE)	F 122 65.9( 0.51)	107.0( 0.78)	147.0( 1.68)	172.4( 2.72)	205.3( 4.96)	239.5( 4.33)	246.7( 8.87)	247.0( 3.40)	



Appendix 14. Mean (SE) calculated total lengths (mm) at the end of each year of life based on opercular bone measurements of male (M) and female (F) and combined sexes (C) of yellow perch from Henderson Lake, captured with monofilament gill nets, May - June, 1981.

Year- Sex N	Annulus												
	1	2	3	4	5	6	7	8	9	10	11	12	13
M 7	49.4(3.73)												
F 3	50.9(0.84)												
C 11	50.0(3.03)												
M 7	49.6(7.14)	55.9(23.29)											
F 14	52.0(3.36)	61.9( 4.43)											
C 22	51.2(4.83)	59.9(13.32)											
M 24	49.9(3.96)	69.5( 7.26)	84.6( 9.53)										
F 27	50.4(4.57)	70.6( 6.51)	83.3(17.02)										
C 53	50.1(4.24)	70.0( 6.73)	84.0(13.59)										
M 12	48.4(3.41)	66.9( 3.83)	82.0( 6.12)	92.7( 5.71)									
F 28	45.9(3.23)	65.1( 4.55)	81.6( 5.22)	92.5( 5.76)									
C 43	46.5(3.38)	65.3( 4.36)	81.4( 5.49)	92.3( 5.84)									
M 10	44.0(3.54)	57.5(18.62)	71.1(23.22)	84.2(27.96)	93.9(31.92)								
F 9	46.0(3.38)	56.7(19.70)	67.7(24.26)	79.3(28.13)	87.7(31.96)								
C 20	44.6(9.70)	57.3(18.15)	69.6(22.52)	81.9(26.66)	90.9(30.40)								
M 7	48.6(4.44)	70.0( 7.68)	84.6( 7.86)	98.7( 7.24)	111.9( 4.88)	121.2( 6.06)							
F 15	48.8(2.94)	68.9( 6.86)	85.9( 9.85)	102.2(10.24)	116.0(11.04)	126.2(11.79)							
C 22	48.8(3.41)	69.3( 6.96)	85.5( 9.11)	101.1( 9.39)	114.4( 9.60)	124.5(10.44)							
M 1	54.0	70.1	84.4	91.6	96.9	109.5	116.6						
F 13	52.0(3.18)	69.9( 3.79)	88.2( 4.55)	104.4( 6.63)	118.8( 6.66)	129.3( 6.13)	138.4( 7.53)						
C 14	52.4(3.06)	70.2( 3.64)	88.1( 4.50)	103.6( 7.26)	117.3( 8.70)	127.9( 7.94)	136.9( 9.30)						
M 1	43.5	60.7	76.1	88.2	103.6	122.5	136.3	144.9					
F 5	50.9(4.89)	69.1( 6.68)	84.4( 8.90)	102.4( 7.96)	117.9(10.65)	131.1(12.19)	144.5( 9.94)	150.5(10.11)					
C 6	49.9(5.50)	67.8( 7.02)	83.1( 8.73)	100.1( 9.29)	115.6(11.24)	129.7(11.47)	143.1( 9.51)	149.6( 9.33)					
M 2	44.9(2.92)	61.9( 5.57)	75.5( 0.94)	90.0( 4.75)	101.1( 3.70)	111.3( 8.65)	125.8( 7.65)	136.0( 7.79)	145.4( 9.12)				
F 1	49.5	65.7	81.8	98.0	112.4	128.6	137.6	143.0	146.6				
C 3	46.2(3.73)	63.0( 4.69)	77.5( 4.03)	92.6( 5.93)	104.8( 7.24)	117.0(11.83)	129.7( 8.77)	138.3( 6.86)	145.8( 6.49)				
M 2	50.1(2.22)	72.4( 3.32)	90.2( 3.19)	106.2( 3.00)	120.4( 5.50)	132.8( 7.92)	143.5( 5.33)	149.8( 4.03)	155.1( 1.48)	162.2(1.09)			
F 2	48.7( .55)	68.6( 2.35)	92.9( 4.04)	101.9( 0.91)	121.8( 4.54)	135.3( 0.95)	148.8( 2.65)	158.8( 6.31)	170.4( 7.30)	177.7(4.70)			
C 4	49.3(1.37)	70.4( 2.96)	91.5( 3.54)	104.0( 2.87)	121.1( 4.24)	134.1( 4.89)	146.2( 4.67)	154.2( 6.79)	162.8( 9.89)	170.0(9.35)			
M 1	49.7	66.6	86.9	98.0	107.2	117.4	127.5	144.4	154.6	166.4	185.0		
F 2	47.8(6.99)	74.6( 1.80)	92.7( 0.73)	105.7( 0.38)	119.5( 0.18)	130.8( 3.49)	145.5( 0.05)	153.2( 1.21)	162.8( 2.54)	167.1(1.36)	174.0(1.41)		
C 3	48.5(4.97)	72.0( 5.18)	90.8( 3.74)	103.4( 4.32)	115.4( 7.54)	126.3( 8.35)	139.5(10.54)	150.3( 5.29)	160.0( 5.15)	166.8(1.06)	177.7(6.43)		
M 0													
F 1	55.2	82.4	96.9	106.0	116.8	124.1	131.3	140.4	147.6	156.7	165.8	173.0	
C 1	55.5	82.7	97.1	106.1	117.0	124.2	131.4	140.5	147.7	156.7	165.8	173.0	
M 0													
F 2	48.1(5.61)	69.7( 2.08)	88.6( 0.38)	103.1( 0.68)	114.8( 0.26)	127.5( 1.19)	142.0( 2.25)	153.8( 4.40)	164.6( 2.62)	172.8(4.51)	181.0(6.39)	187.3(5.57)	192.8(5.97)
C 2	48.5(5.60)	70.0( 2.08)	88.8( 0.37)	103.3( 0.69)	115.0( 0.27)	127.7( 1.20)	144.1( 2.25)	153.9( 4.39)	164.7( 2.63)	172.9(4.51)	181.1(6.38)	187.4(5.56)	192.8(5.96)
Mean	49.1(0.50)	67.3( 0.82)	82.9( 1.06)	93.9( 1.32)	107.2( 1.92)	120.4( 2.31)	131.3( 4.08)	143.5( 3.00)	151.1( 3.12)	163.6(1.46)	185.0(0.00)		
F 122	49.2(0.39)	67.6( 0.60)	85.0( 0.85)	98.6( 1.36)	114.3( 1.62)	128.5( 1.41)	140.9( 1.52)	151.3( 2.25)	161.2( 3.44)	170.3(2.98)	175.2(3.19)	182.6(5.29)	192.8(4.22)
C 204	49.1(0.30)	67.4( 0.48)	84.1( 0.66)	96.8( 1.02)	111.7( 1.34)	126.5( 1.29)	138.9( 1.61)	148.9( 1.97)	157.4( 2.75)	168.3(2.30)	176.8(3.08)	182.6(5.30)	192.8(4.22)



Appendix 15a. Mean (SE) calculated and empirical total length at annulus of male, female, and combined sexes of yellow perch from Savanne Lake, Ontario, 1981-1982.

A G E	1981																	
	Male			Female			Combined											
	Calculated	Empirical		Calculated	Empirical		Calculated	Empirical										
N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE							
1	113	63.98	0.60	43	72.40	0.63	119	64.18	0.60	31	73.94	0.92	208	64.02	.42	77	73.12	0.53
2	70	107.20	1.24	38	113.84	1.30	88	108.30	1.16	43	115.02	1.32	161	107.87	.83	83	114.42	0.92
3	32	135.82	2.43	14	135.29	3.87	45	149.74	2.94	22	155.86	3.88	76	143.80	2.12	37	147.43	3.19
4	18	170.75	2.38	5	178.00	4.32	23	183.54	5.01	5	193.00	17.05	41	177.91	3.14	10	185.50	8.66
5	13	199.68	2.95	7	199.29	4.86	18	216.58	4.83	8	225.88	5.52	31	209.50	3.39	15	213.47	5.04
6	6	220.49	1.85	4	220.00	2.12	10	237.86	6.14	3	247.00	10.69	16	231.35	4.39	7	231.57	6.97
7	2	238.60	1.90	0			7	257.23	6.37	5	259.00	8.86	9	253.06	5.61	5	259.00	8.86
8	2	247.60	0.14	2	257.50	0.50	1	276.00	4.00	2	296.00	4.00	4	261.78	8.37	4	266.75	5.59

1982

A G E	1982																	
	Male			Female			Combined											
	Calculated	Empirical		Calculated	Empirical		Calculated	Empirical										
N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE							
1	138	73.51	0.43	14	79.93	1.45	122	65.93	0.51	20	78.45	0.81	261	71.77	0.32	34	79.06	0.76
2	124	111.15	0.86	38	107.61	1.65	102	106.96	0.78	37	110.11	1.57	227	110.06	0.59	77	108.64	1.12
3	86	147.43	1.54	37	153.08	2.16	65	147.03	1.68	32	154.03	2.64	150	147.66	1.13	69	153.52	1.67
4	49	161.33	2.27	28	175.93	3.27	33	172.39	2.72	18	196.28	3.82	81	172.05	1.76	46	176.07	2.47
5	21	193.18	3.26	5	197.40	5.18	15	205.27	4.96	5	191.00	4.65	35	198.16	3.03	10	194.20	3.45
6	16	217.94	3.93	11	224.82	4.39	10	239.48	4.33	6	245.83	4.99	25	225.73	3.64	17	232.24	4.11
7	5	224.81	4.38	4	231.50	4.11	4	246.67	8.67	2	255.50	1.50	9	232.12	5.31	6	239.50	5.70
8	1	231.78	0.00	0			2	247.00	3.40	1	247.00	0.00	2	239.27	7.73	1	247.00	0.00
9	1	243.00	0.00	1	243.00	0.00	0			0			1	243.00	0.00	1	243.00	0.00

Appendix 15b. Mean (SE) calculated and empirical total length at annulus of male, female, and combined sexes of yellow perch from Henderson Lake, Ontario, 1981-1982. 1981

A G E	Male						Female						Combined					
	Calculated			Empirical			Calculated			Empirical			Calculated			Empirical		
	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE
1	74	49.05	0.50	7	51.29	1.51	123	49.21	0.39	3	54.33	0.67	204	49.09	0.30	11	52.27	1.04
2	67	67.33	0.87	7	67.29	3.83	119	67.61	0.60	14	63.86	1.73	191	67.38	0.48	22	64.86	1.63
3	60	82.87	1.06	24	89.71	1.80	104	85.02	0.85	27	90.07	1.98	169	84.05	0.66	53	89.77	1.29
4	36	93.92	1.32	12	94.50	1.94	78	98.61	1.36	28	95.93	1.34	118	96.83	1.02	43	95.21	1.09
5	24	107.20	1.92	10	105.50	3.97	44	114.27	1.62	9	99.00	4.13	73	111.72	1.34	20	101.95	2.78
6	14	120.42	2.32	7	123.86	2.37	41	128.52	1.41	15	131.93	3.36	55	126.48	1.29	22	129.36	2.51
7	7	131.29	4.08	1	122.00	0.00	26	140.89	1.52	13	144.23	2.13	33	138.87	1.61	14	142.64	2.53
8	6	143.42	3.00	1	150.00	0.00	13	151.34	2.25	5	154.40	4.06	19	148.86	1.97	6	153.67	3.39
9	5	151.11	3.12	2	150.00	6.50	8	161.24	3.44	1	152.00	0.00	13	157.35	2.75	3	151.00	3.79
10	3	163.62	1.47	2	164.00	1.00	7	170.27	2.98	2	179.50	1.50	10	168.28	2.30	4	171.75	4.54
11	1	185.00	0.00	1	185.00	0.00	5	175.17	3.19	2	174.00	1.00	6	176.81	3.08	3	177.67	3.71
12	0			1	173.00	0.00	3	182.56	5.29	1	173.00	0.00	3	182.57	5.30	1	173.00	0.00
13	0			0			2	192.78	4.22	2	194.50	2.50	2	192.79	4.22	2	194.50	2.50

1982

A G E	Male						Female						Combined					
	Calculated			Empirical			Calculated			Empirical			Calculated			Empirical		
	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE
1	127	44.62	0.43	18	53.11	1.17	148	48.07	0.36	20	53.13	1.27	278	47.00	0.28	38	53.13	0.86
2	109	62.21	0.66	21	65.48	1.77	128	65.45	0.57	9	62.33	1.05	240	64.31	0.43	30	64.53	1.30
3	88	78.82	0.79	10	82.10	2.03	119	82.21	0.77	6	77.83	3.44	210	81.00	0.56	16	80.50	1.82
4	78	93.36	0.94	8	93.38	3.70	113	96.93	0.91	21	93.86	2.64	193	95.59	0.66	29	93.72	2.13
5	70	104.56	1.00	32	103.63	1.68	92	109.78	1.04	21	105.48	2.52	166	107.61	0.75	53	104.36	1.46
6	38	116.07	1.32	14	114.07	2.12	71	121.73	1.29	14	116.64	3.58	112	119.81	0.91	28	115.36	2.06
7	24	128.42	1.83	7	126.86	4.28	57	133.42	1.45	7	139.00	4.71	85	131.99	1.18	14	132.93	3.50
8	17	140.46	1.91	1	148.00	0.00	50	144.44	1.56	8	141.00	5.47	70	143.45	1.28	9	141.78	4.89
9	16	148.62	1.96	3	155.00	2.08	42	154.68	1.45	7	158.00	5.07	60	153.03	1.22	10	157.10	3.54
10	13	155.92	2.00	5	156.60	2.75	35	162.88	1.37	8	172.00	2.18	51	161.07	1.21	13	166.08	2.71
11	8	161.38	3.15	3	166.33	2.60	27	168.44	1.27	7	167.43	2.18	38	166.92	1.27	10	167.10	1.64
12	5	168.74	4.13	1	177.00	0.00	20	175.61	1.54	8	176.00	2.02	28	174.34	1.51	9	176.11	1.78
13	4	171.50	4.05	4	171.50	4.05	12	182.02	2.13	9	188.11	2.50	19	179.76	2.10	13	183.00	3.00
14				0			3	184.85	3.51	3	182.67	2.40	7	184.80	3.52	3	182.67	2.40
15				0			3	185.41	5.28	1	175.00	0.00	3	185.32	5.23	1	175.00	0.00
16				0			2	198.28	0.46	2	198.19		2	198.19	0.46	0		
17				0			2	205.90	1.12	0			2	205.87	1.12	0		
18				0			2	211.00	1.00	2	211.00	1.00	2	211.00	1.00	2	211.00	1.00

Appendix 16. Differences between mean calculated and mean empirical total lengths at age for males (M), females (F), and combined sexes (C) of yellow perch from Henderson and Savanne lakes, Ontario, 1981 and 1982, determined by Wilcoxon Matched Pairs Sign Tests.

Lake	Year	Sex	No. of age groups	Z-score	Two-tailed probability
Savanne	1981	F	8	-2.366	0.018 *
		M	7	-1.352	0.176
		C	8	-2.521	0.012 *
	1982	F	8	-1.183	0.237
		M	8	-2.197	0.028 *
		C	9	-2.030	0.042 *
Henderson	1981	F	13	-0.035	0.972
		M	11	-0.770	0.441
		C	13	-0.245	0.807
	1982	F	14	-3.180	0.778
		M	14	-1.412	0.158
		C	13	-0.769	0.442

\* Significant at  $P < 0.05$ .

\*\* Significant at  $P < 0.01$ .

Appendix 17. Differences between mean empirical total length (mm) at age of male and female yellow perch in Henderson and Savanne lakes, Ontario, 1981 and 1982 using Student t-tests.

Lake	Year	Age	Mean total length (N)		T-value	df
			Male	Female		
Savanne	1981	1	72.4 (43)	73.9 (31)	-1.382	56
		2	113.8 (38)	115.0 (43)	-0.637	79
		3	135.3 (14)	155.9 (22)	-3.024 **	32
		4	178.0 ( 5)	193.0 ( 5)	-0.796	∞
		5	199.2 ( 7)	225.9 ( 8)	-3.615 **	13
		6	220.0 ( 4)	247.0 (10)	-2.480	∞
		8	257.5 ( 2)	276.0 ( 2)	-4.591 **	13
	1982	1	79.3 (14)	78.5 (20)	-0.891	21
		2	107.6 (38)	110.1 (37)	-1.098	73
		3	153.1 (37)	154.0 (32)	-0.279	62
		4	175.9 (28)	176.3 (18)	-0.070	38
		5	197.4 ( 5)	191.0 ( 5)	0.919	11
		6	224.8 (11)	245.8 ( 6)	-3.160 **	12
		7	231.5 ( 4)	255.5 ( 2)	-5.482 **	4
Henderson	1981	1	51.3 ( 7)	54.3 ( 3)	-1.850	8
		2	67.3 ( 7)	63.9 (14)	0.817	9
		3	89.7 (24)	90.1 (27)	-0.135	84
		4	94.5 (12)	95.9 (28)	-0.607	22
		5	105.5 (10)	99.0 (29)	1.135	17
		6	123.9 ( 7)	131.9 (15)	-1.963	15
		10	164.0 ( 2)	179.5 ( 2)	-8.600	2
	1982	1	53.1 (18)	53.2 (20)	-0.023	36
		2	65.5 (21)	62.3 ( 9)	1.531	28
		3	82.1 (10)	77.8 ( 6)	1.069	9
		4	93.4 ( 8)	93.9 (21)	-0.106	15
		5	103.6 (32)	105.5 (21)	-0.611	37
		6	114.1 (14)	116.6 (14)	-0.618	21
		7	126.9 ( 7)	139.0 ( 7)	-1.908	8
9		155.0 ( 3)	158.0 ( 7)	-0.547	8	
10		156.6 ( 5)	172.0 ( 8)	-4.388 **	9	
11		166.3 ( 4)	167.4 ( 7)	-0.324	5	
13		171.5 ( 4)	188.1 ( 9)	-3.490	5	

<sup>a</sup> Unknown, unequal population variances.

∞ Infinity.

\*\* Significant at P < 0.01.

Appendix 18a. Total length - frequency distributions of yellow perch captured with monofilament gillnets in Henderson and Savanne lakes, Ontario, 1981 and 1982.

Length interval (mm)	Henderson				Savanne			
	1981		1982		1981		1982	
	N	%	N	%	N	%	N	%
65- 69					4	.25		
70- 74	1	.08	20	.65	75	4.6	14	.7
75- 79	10	.8	153	4.9	33	2.0	67	3.4
80- 84	23	1.9	429	13.9	11	.67	97	4.9
85- 89	24	2.0	401	12.8	8	.5	168	8.5
90- 94	37	3.1	284	9.2	76	4.7	144	7.3
95- 99	48	4.0	173	5.6	328	20.1	155	7.9
100-104	93	7.7	271	8.9	299	18.3	164	8.3
105-109	169	14.0	314	10.1	138	8.5	94	4.8
110-114	165	13.6	236	7.7	31	1.9	70	3.6
115-119	152	12.6	181	13.5	22	1.4	46	2.3
120-124	97	8.0	109	3.5	6	.4	37	1.9
125-129	51	4.2	71	2.3	7	.43	59	3.0
130-134	13	1.1	29	.94	23	1.4	112	5.7
135-139	12	1.0	23	.74	49	3.0	147	7.5
140-144	10	.8	28	.9	77	4.7	114	5.8
145-149	32	2.6	45	1.5	101	6.2	64	3.3
150-154	42	3.5	77	2.5	74	4.5	42	2.1
155-159	63	5.2	65	2.1	48	2.9	34	1.7
160-164	58	4.8	48	1.6	46	2.8	39	2.0
165-169	41	3.4	38	1.2	17	1.0	47	2.4
170-174	34	2.8	32	1.0	12	.7	51	2.6
175-179	15	1.2	23	.7	7	.4	49	2.5
180-184	6	.5	13	.4	12	.7	41	2.1
185-189	5	.4	7	.2	10	.6	25	1.3
190-194	4	.3	10	.3	6	.4	21	1.1
195-199	3	.25	6	.2	11	.7	14	.7
200-204	1	.08	4	.13	6	.4	11	.6
205-209	2	.2	4	.13	9	.6	9	.5
210-214			2	.07	6	.4	8	.4
215-219					2	.12	3	.15
220-224					8	.5	3	.15
225-229					5	.3	1	.05
230-234					13	.8	6	.3
235-239					8	.5	2	.1
240-244					6	.4	2	.1
245-249					7	.43	1	.05
250-254					10	.6	2	.1
255-259					8	.5	4	.2
260-264					3	.2	2	.1
265-269					3	.2	1	.05
270-274					1	.06		
275-279								
280-284					2	.1		
285-289					1	.06		
<b>Total</b>	<b>1211</b>		<b>3098</b>		<b>1631</b>		<b>1970</b>	

Appendix 18b. Mean, mode, standard deviation, minimum, and maximum for total length of aged yellow perch samples used to derive the age structures of experimental gillnet catches in Henderson and Savanne lakes, Ontario, 1981 and 1982.

A) Savanne Lake

Age	1981						1982					
	N	Mean	Min	Max	Mode	SD	N	Mean	Min	Max	Mode	SD
1	33	73	63	85	68	6.3	35	79	72	95	80	4.5
2	63	114	82	139	119	8.7	82	110	84	137	110	10.9
3	31	147	120	186	130	17.7	69	154	120	199	142	13.9
4	8	177	151	200	151	17.1	53	179	141	234	165	19.3
5	10	206	172	255	172	23.9	12	200	177	251	192	19.4
6	4	235	216	255	216	19.1	19	232	209	265	220	16.0
7	3	264	263	266	263	1.5	6	240	224	257	224	14.0
8	4	267	257	280	257	11.2	1	247				
9							1	243				
Total 156							278					

B) Henderson Lake

2	1						5	76	65	85	77	7.2
3	11	84	77	89	84	3.4	43	90	72	109	87	9.1
4	27	95	83	120	91	11.4	33	95	80	111	90	7.7
5	52	105	90	125	96	10.1	12	100	93	116	94	9.2
6	27	115	94	154	116	11.1	18	133	102	156	131	16.3
7	14	133	117	158	128	13.1	20	149	122	167	146	11.2
8	9	142	121	158	121	14.7	16	161	145	176	150	9.1
9	10	157	140	179	151	11.2	6	161	144	173	144	11.2
10	13	166	150	183	164	9.8	4	177	165	186	165	8.9
11	10	167	161	178	165	5.2	4	179	173	185	173	5.5
12	9	176	169	187	174	5.4	1	173				
13	13	183	163	200	188	10.9	2	195	192	197	192	3.5
14	3	183	178	186	178	4.2						
15	1	175										
18	2	211	210	212	210	1.4						
Total 203							164					



Appendix 19. Age - frequency of yellow perch sampled with experimental gillnets in Henderson and Savanne lakes, Ontario, 1981 and 1982. These were used to generate catch curves and instantaneous mortality rates (Z).

A) Savanne Lake

Age group	1981			1982		
	N	%	Log <sub>e</sub>	N	%	Log <sub>e</sub>
1	458	28.1	3.34	408	20.7	3.03
2	616	37.8	3.63	853	43.2	3.77
3	365	22.4	3.11	424	21.5	3.07
4	82	5.0	1.62	221	11.1	2.42
5	61	3.7	1.32	35	1.8	0.58
6	30	1.8	0.61	25	1.3	0.24
7	5	0.3	-1.17	5	0.3	-1.39
8	14	0.9	-0.15	1	0.05	-2.98
9				1	0.05	-2.98
<b>Total</b>	<b>1631</b>	<b>100</b>		<b>1970</b>	<b>100</b>	

B) Henderson Lake

2	7	0.5	-0.55	36	1.2	0.15
3	178	14.6	2.69	534	17.2	2.85
4	240	19.8	2.98	701	22.6	3.12
5	183	15.0	2.71	873	28.2	3.34
6	254	20.9	3.04	404	13.0	2.57
7	162	13.2	2.59	154	5.0	1.60
8	111	9.1	2.21	100	3.2	1.17
9	37	3.0	1.11	94	3.0	1.11
10	21	1.7	0.55	65	2.1	0.74
11	16	1.2	0.28	47	1.5	0.42
12	15	1.2	0.21	27	0.9	-0.14
13				51	1.7	0.50
14				7	0.2	-1.49
15				3	0.1	-2.34
18				2	0.1	-2.74
<b>Total</b>	<b>1214</b>	<b>100</b>		<b>3098</b>	<b>100</b>	

Appendix 20. Differences between male and female yellow perch with respect to Fulton's condition factor at each age and length interval (1.0 cm), as determined by Wilcoxon Matched-Pairs Ranked-Sign Tests. Fish were sampled July-August in 1981 and 1982, in Henderson and Savanne lakes, Ontario. (Significant at  $P < 0.01$ ).

Lake	Year	Age			Length		
		N	Z-score	P 2-tailed	N	Z-score	P 2-tailed
Henderson	1981	12	-1.41	0.201	13	-0.32	0.755
	1982	15	-3.19	0.010	15	-0.35	0.730
Savanne	1981	7	-1.45	0.501	20	-0.69	0.501
	1982	8	1.25	0.267	20	1.55	0.140

Appendix 21. Total length at maturity schedules for male and female yellow perch from Henderson and Savanne lakes, Ontario, 1981 and 1982.

Length interval	1981						1982						
	Male			Female			Male			Female			
	No. Mature	% Mature	Probit	No. Mature	% Mature	Probit	No. Mature	% Mature	Probit	No. Mature	% Mature	Probit	
7	7	0	0.0	4	0	0.0	5	3	60.0	5.253	4	0	0.0
8	29	5	17.0	17	1	6.0	58	48	83.0	5.954	47	3	6.0
9	25	9	36.0	40	20	5.0	34	32	94.0	6.555	33	1	3.0
10	20	15	75.0	22	4	18.0	31	31	100	8.091	10	7	67.0
11	11	11	100	8	6	75.0	38	38	100	5.674	39	32	82.0
12	7	7	100	3	2	67.0	18	18	100	5.440	16	14	88.0
13	1	1	100	6	6	100	1	1	100	8.091	7	6	86.0
14	5	5	100	20	20	100	4	4	100		5	5	100
15	12	12	100	14	14	100	14	14	100		19	19	100
16	5	5	100	12	12	100	2	2	100		15	15	100
17				2	2	100	1	1	100		13	13	100
18	1	1	100	5	5	100	1	1	100		6	6	100
19				1	1	100					7	7	100
20											1	1	100
Total	123			160			195				222		

## Appendix 21. Continued.

## b) Savanne Lake

Length	1981										1982									
	Male					Female					Male					Female				
	N	No. Mature	% Mature	Probit	N	No. Mature	% Mature	Probit	N	No. Mature	% Mature	Probit	N	No. Mature	% Mature	Probit	N	No. Mature	% Mature	Probit
6	7	1	14.3	3.933	2	0	0.0	-	0	0	0.0	-	0	0	0.0	-	15	0	0.0	-
7	52	3	5.8	3.428	52	0	0.0	-	21	0	0.0	-	16	0	0.0	-	16	0	0.0	-
8	7	1	14.3	3.933	6	0	0.0	-	11	0	0.0	-	14	0	0.0	-	14	0	0.0	-
9	16	5	31.3	4.513	18	5	28.0	4.418	20	3	15.0	3.964	58	1	1.7	2.880	32	1	3.0	3.119
10	39	10	25.6	4.345	49	16	33.0	4.533	78	34	44.0	4.850	32	1	3.0	3.119	9	0	0.0	-
11	38	28	73.7	5.634	52	32	62.0	5.305	54	31	57.0	5.176	15	0	0.0	-	15	0	0.0	-
12	10	7	70.0	5.524	18	9	50.0	5.000	9	7	80.0	5.842	15	0	0.0	-	24	1	4.2	3.272
13	11	11	100	8.091	23	15	65.0	5.385	3	0	0.0	-	23	0	0.0	-	23	0	0.0	-
14	12	12	100		17	16	94.0	6.555	16	13	81.0	5.878	21	12	57.0	5.176	21	12	57.0	5.176
15	9	9	100		14	12	86.0	6.080	27	26	96.0	6.751	14	12	86.0	6.080	14	12	86.0	6.080
16	6	6	100		19	17	90.0	6.282	29	27	93.0	6.476	6	6	100.0	8.091	6	6	100.0	8.091
17	6	6	100		10	9	90.0	6.282	12	10	83.0	5.954	7	6	86.0	6.081	7	6	86.0	6.081
18	3	3	100		7	7	100	8.091	5	5	100.0	8.091	6	5	83.0	5.954	6	5	83.0	5.954
19	3	3	100		4	4	100		2	2	100		2	2	100.0	8.091	2	2	100.0	8.091
20	3	3	100		6	6	100		3	3	100		2	2	100.0		2	2	100.0	
21	2	2	100		6	6	100		1	1	100		2	2	100		2	2	100	
22	1	1	100		4	4	100		4	4	100		1	1	100		1	1	100	
23	1	1	100		2	2	100		2	2	100		2	2	100		2	2	100	
24					1	1	100		1	1	100		2	2	100		2	2	100	
25					1	1	100		1	1	100		3	3	100		3	3	100	
Total	239				311				292				272							

Appendix 22. Age at maturity schedules for male and female yellow perch from Henderson and Savanne lakes, Ontario, 1981, 1982.  
 a) Henderson Lake

Spawning age	1981						1982					
	Male			Female			Male			Female		
	N	Mature	Probit	N	Mature	Probit	N	Mature	Probit	N	Mature	Probit
1	7	0	0.0	-	7	0	0.0	-	18	0	0.0	-
2	10	2	20.0	4.159	16	0	0.0	-	19	2	11.0	3.773
3	28	12	43.0	4.824	30	3	10.0	3.718	10	6	60.0	5.263
4	20	15	75.0	5.674	35	6	17.0	4.046	8	7	88.0	6.175
5	12	6	50.0	5.000	15	7	47.0	4.925	32	29	91.0	6.341
6	19	10	53.0	5.075	20	17	85.0	6.036	14	3	93.0	6.476
7	8	8	100.0	8.091	19	15	79.0	5.806	7	7	100.0	8.091
8	5	5	100		18	18	100.0	8.091	1	1	100	15*
9	3	3	100		8	8	100		3	3	100	11
10	3	3	100		6	6	100		5	5	100	10
11	1	1	100		5	5	100		3	3	100	13
12					2	2	100		1	1	100	8
13					4	4	100		4	4	100	9
14												3
15												1
16												1
17												1
18												2
Total	116				185				125			186

Appendix 22. Continued

Spawning age	1981						1982					
	Male			Female			Male			Female		
	No. Mature	% Mature	Probit	No. Mature	% Mature	Probit	No. Mature	% Mature	Probit	No. Mature	% Mature	Probit
1	43	3	7.0	31	0	0.0	15	0	0.0	20	0	
2	54	32	59.0	50	9	18.0	46	24	52.0	42	1	2.4
3	29	24	83.0	35	12	34.0	48	44	92.0	37	15	41.0
4	22	22	100.0	15	8	53.0	36	35	97.0	33	26	79.0
5	10	10	100.	15	13	87.0	8	8	100.0	10	9	90.0
6	6	6	100	6	6	100.0	13	13	100	14	14	100.0
7	5	5	100	1	1	100	4	4	100	1	1	100
8	2	2	100	2	2	100	1	1	100	1	1	100
9												
Total	171			155			170			158		

Appendix 23. Linear equations describing the relationships between rate of maturity and age (yrs) and total length (cm) as determined by two regression methods for yellow perch from Henderson and Savanne lakes, Ontario, 1981 and 1982.

1. Age - Independent variable

a) Savanne Lake

Year	Sex	Lysack's Method			Probit Method				
		Linear equation $Y = -\log_e(k-y/y + 1)$	95% C.I. (slope)	r	F value (df)	Linear equation Probit = $B_0X + B$	95% C.I. (slope)	r	F value (df)
1981	♂	$Y = -2.92 + 0.83X$	±.64	.87	6.41 (1,2)	$Y = 2.09 + 1.44X$	±.36	.98	62.79 (1,2)*
	♀	$Y = -2.46 + 0.44X$	±.10	.98	31.65 (1,6)*	$Y = 1.77 + 0.96X$	±.35	.95	28.65 (1,3)*
1982	♂	$Y = -0.90 + 0.20X$	±.18	.84	4.77 (1,2)	$Y = 3.25 + 0.96X$	±.23	.99	68.04 (1,2)*
	♀	$Y = -4.47 + 0.86X$	±.67	.83	6.43 (1,3)	$Y = 0.94 + 1.17X$	±.25	.98	85.24 (1,3)*

b) Henderson Lake

1981	♂	$Y = -1.74 + 0.24X$	±.17	.81	7.34 (1,4)	$Y = 2.93 + 0.56X$	±.46	.77	5.77 (1,4)
	♀	$Y = -3.50 + 0.48X$	±.17	.94	29.14 (1,4)*	$Y = 1.00 + 0.81X$	±.27	.95	35.52 (1,4)*
1982	♂	$Y = -2.10 + 0.35X$	±.28	.78	6.01 (1,4)	$Y = 2.75 + 0.72X$	±.24	.95	35.99 (1,4)*
	♀	$Y = -2.76 + 0.34X$	±.11	.94	38.16 (1,5)*	$Y = 1.66 + 0.68X$	±.37	.85	13.26 (1,5)*

2. Length - Independent variable

a) Savanne Lake

1981	♂	$Y = -4.73 + 0.37X$	±.13	.92	31.65 (1,6)*	$Y = -0.11 + 0.53X$	±.24	.87	18.62 (1,6)*
	♀	$Y = -2.27 + 0.14X$	±.04	.90	35.74 (1,8)*	$Y = 1.33 + 0.33X$	±.11	.91	38.02 (1,8)*
1982	♂	$Y = -2.64 + 0.15X$	±.09	.80	12.15 (1,7)*	$Y = 1.10 + 0.33X$	±.13	.89	26.60 (1,7)*
	♀	$Y = -7.91 + 0.41X$	±.12	.93	41.45 (1,7)*	$Y = -1.98 + 0.46X$	±.18	.88	24.95 (1,7)*

b) Henderson Lake

1981	♂	$Y = -6.52 + 0.61X$	±.16	.98	58.33 (1,2)*	$Y = -6.89 + 1.32X$	±.58	.95	19.84 (1,2)*
	♀	$Y = -8.35 + 0.67X$	±.25	.94	28.38 (1,4)*	$Y = -4.31 + 0.89X$	±.36	.92	23.31 (1,4)*
1982	♂	$Y = -1.60 + 0.17X$	±.08	.94	15.10 (1,2)	$Y = -1.28 + 0.91X$	±.30	.97	36.49 (1,2)*
	♀	$Y = -7.09 + 0.55X$	±.35	.82	9.33 (1,5)	$Y = -2.62 + 0.74X$	±.26	.93	31.37 (1,5)*

\* Significant at  $P < 0.05$ .

Appendix 24. Differences between years for fecundity versus age and total length (cm) relationships for yellow perch in Henderson Lake, Ontario, 1981 and 1982, as determined by Analysis of Covariance. (\*\* indicates significant values at  $P < 0.01$ ).

A) Fecundity related to age.

Line	N	Slope	Intercept	Residuals		
				df	SS	MS
1981	30	1094.3	-2121.6	28	50301569.2	1796484.6
1982	43	1770.7	-6383.8	41	203322613.7	4959088.1
				69	253624182.9	3675712.8
Common				70	301804928.0	4311499.0
				1	48180745.2	
Total				71	310073943.5	4367238.6
				1	8269095.5	

\*\*  $F\text{-slope} = 48180745.2/3675712.8 = 13.108$  with 1,69 df.

$F\text{-intercept} = 8269095.5/4311499.0 = 1.918$  with 1,70 df.

B) Fecundity related to total length (cm).

1981	30	1124.2	-10244.2	28	21692447.3	774730.3
1982	43	1445.3	-14260.3	41	133201695.4	3248821.8
				69	154894142.7	224800.0
Common				70	179079424.7	2387725.8
				1	24185282.3	
Total				71	186509754.0	2454100.0
				1	7430329.0	

\*\*  $F\text{-slope} = 24185282.3/2244800 = 10.774$  with 1,69 df.

$F\text{-intercept} = 74303290.0/2387725.8 = 3.112$  with 1,70 df.



Appendix 25. Frequency of occurrence (%) of various prey items found in stomachs of different size groups of yellow perch from Henderson and Savanne Lakes, Ontario, June - August, 1981 and 1982.

A. Henderson Lake - 1981

Prey item	June			July			August		
	<91	91-130	131-200	<91	91-131	131-200	<91	91-131	131-200
Total Fish	17(9.9)	7(13.1)	5(38.5)	3(7.3)	34(30.2)	24(47.2)	38(19.4)	131	45(60.9)
Perch - YOY									
- 1+		1(1.9)		3(7.3)	2(1.8)	1(2.0)	2(1.0)		3(4.1)
N. Stickleback		3(5.6)	5(38.5)		8(7.0)	13(25.5)	20(10.3)		28(37.8)
Burbot									
Walleye					2(1.8)				
N. Pike					1(1.0)				
Shiners					2(1.8)	1(2.0)			
W. Sucker									
Darters									
Unid. Fish	17(9.9)	3(5.6)			6(5.4)	2(4.0)	1(6.7)		3(4.1)
Fish Ova	30(17.5)	3(5.6)	3(23.1)						
Decapoda									
Hirudinea		1(1.9)	1(7.7)		3(2.6)	5(9.8)	8(4.1)		4(5.4)
Amphipoda	35(20.4)	3(5.6)			1(1.0)	2(3.9)	1(6.7)		3(4.1)
Cladocera	10(5.8)	1(1.9)		8(19.5)	1(1.0)		1(6.7)		4(2.1)
Ephemeroptera N.	32(18.7)	22(15.4)	2(15.4)	1(2.4)			1(6.7)		1(.5)
Hexagenia limbata	1(1.2)	7(13.0)	1(7.7)	4(9.6)	16(14.1)	10(19.6)	3(20.0)		58(29.7)
Pentagenia villosa	8(4.7)	7(13.0)		2(4.9)	11(9.7)	8(15.7)			38(19.5)
Ephemerella sp.	4(2.3)								10(5.1)
Ephenera sp.	1(.6)	1(1.9)							
Caenidae		3(5.6)							
Trichoptera N.	27(15.7)	10(18.5)	1(7.7)	9(22.0)	9(7.9)		1(6.7)		10(5.1)
Odonata N.	1(.6)	1(1.9)			3(2.6)	5(9.8)	2(13.3)		16(8.2)
Anisoptera		1(1.9)			3(2.6)	5(9.8)	2(13.3)		15(7.7)
Zygoptera	1(.6)								1(.5)
Diptera L.	17(9.9)	1(1.9)		6(14.6)	42(36.8)	8(15.7)	4(26.7)		67(34.4)
Diptera P.	75(43.6)	16(29.6)	4(30.8)	6(14.6)	7(6.1)	1(2.0)	2(13.3)		1(.5)
Corixidae	2(1.2)	2(3.7)			1(1.0)				1(1.4)
Notonectidae									
Plecoptera L.		1(1.9)		4(9.8)			1(6.7)		1(.5)
Megaloptera L.									
Coleoptera L.									
Hydracarina									
Nemertina									
Unid. Invert.	19(11.0)	8(14.8)	1(7.7)	5(12.2)	13(11.4)	4(7.8)	4(26.7)		15(7.7)
No. stomachs examined	172	54	13	41	114	51	15	194	74

Appendix 25. Continued

B. Henderson Lake - 1982

Prey item	June		July		August	
	<91-	91-131	131-200	<91	91-131	131-200
Total Fish	2(2.0)	21(46.7)	5(5.6)	8(7.8)	4(7.1)	11(18.0)
Perch - YOY			26(29.2)	36(35.3)	12(21.4)	5(8.2)
- 1+	1(1.0)	4(8.9)			7(12.4)	5(8.2)
N. Stickleback		13(28.9)	1(1.0)	2(3.6)		13(50.0)
Burbot						2(7.7)
Walleye						
N. Pike						
Shiners						
W. Sucker						
Darters						
Unid. fish	1(1.0)	4(8.9)	5(5.6)	8(7.8)	4(7.1)	1(1.6)
Fish ova	1(1.0)	5(11.1)				2(7.7)
Decapoda			4(4.5)	2(2.0)	1(1.8)	
Hirudinea	2(2.0)		1(1.1)	2(2.0)	2(3.6)	5(8.2)
Amphipoda	1(3.2)		9(10.1)	3(2.9)	2(3.6)	1(3.9)
Cladocera			1(1.1)			7(11.5)
Ephemeroptera N.	11(35.5)	21(46.7)	16(18.0)	29(28.4)	12(21.4)	13(21.3)
Hexagenia limbata	11(35.5)	21(46.7)	13(14.6)	16(15.7)	5(8.9)	8(13.1)
Pentagenia vittigera			2(2.3)	3(2.9)		2(3.3)
Ephemerella sp.						2(3.8)
Ephemera sp.						
Caenidae						
Trichoptera N.	5(16.1)	7(2.1)	4(8.9)	2(2.0)	3(5.4)	8(13.1)
Odonata N.	1(3.2)	1(1.0)	6(13.3)	3(2.9)	2(3.6)	11(18.0)
Anisoptera			4(8.9)	3(2.9)	2(3.6)	4(15.4)
Zygoptera	1(3.2)	1(1.0)	2(4.4)			2(7.7)
Diptera L	5(16.1)	25(25.5)	2(4.4)	31(34.8)	5(8.9)	1(1.6)
Diptera P	1(3.2)	11(11.2)	2(4.4)	7(7.9)	2(3.6)	4(6.6)
Corixidae			1(1.1)			
Notonectidae						
Plecoptera L				1(1.0)	1(1.8)	
Megaloptera L						
Coleoptera L	3(3.1)		3(3.4)	3(2.9)	2(3.6)	3(4.9)
Hydracarina						
Nemertina						
Unid. invert.			2(2.3)	1(1.0)	1(1.8)	15(24.6)
No. stomachs examined	31	98	45	89	102	53
						61
						26

Appendix 25. Continued

C. Savanne Lake - 1981

Prey Item	June			July			August					
	<91	91-130	131-200	>201	<91	91-130	131-200	>201	<91	91-130	131-200	>201
Total Fish			1 (20.0)		1 (1.0)		4 (25.5)		2 (1.1)		6 (3.9)	5 (15.1)
Perch - YOY												
- 1+							3 (5.5)				5 (3.2)	3 (9.1)
N. Stickleback												
Burbot												
Walleye												
N. Pike												
Shiners												
W. Sucker												
Darters												
Unid. fish												
Fish Ova			1 (20.0)		1 (1.0)		1 (20.0)				1 (.7)	2 (6.0)
Decapoda												
Hirudinea												
Amphipoda												
Cladocera												
Ephemeroptera N.	51 (31.1)				25 (23.4)							
	20 (12.2)				42 (39.3)							
	85 (52.0)	4 (80.0)	5 (100.0)	1 (25.0)	14 (13.2)							
	5 (3.1)		3 (60.0)		8 (7.5)							
Pentagenia vittigera	67 (40.9)	3 (60.0)	2 (40.0)	1 (25.0)	2 (1.9)							
Ephemerella sp.	8 (4.9)				1 (1.0)							
<del>Ephemerella</del> sp.												
Caenidae												
Trichoptera N.	2 (1.2)	1 (20.0)		1 (25.0)								
Odonata N.		1 (20.0)	2 (40.0)									
Anisoptera		1 (20.0)	2 (40.0)									
Zygoptera												
Diptera L	5 (3.1)											
Diptera P	47 (28.7)				2 (1.9)							
Corixidae	39 (23.8)				47 (53.3)							
Notonectidae	2 (1.2)											
Plecoptera L			2 (50.0)									
Megaloptera L												
Coleoptera L												
Hydracarina												
Nemertina	2 (1.2)											
Unid. Invert.	15 (9.2)	1 (20.0)	1 (20.0)	2 (50.0)	1 (1.0)							
					13 (12.5)		3 (5.5)					
No. Stomachs examined	164	5	5	4	107	104	55	5	61	176	155	33

