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A Comparison of Aging Techniques and Growth of Yellow Perch (*Perca flavescens*) from Selected Alberta Lakes

by

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A THESIS

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Abstract

Several Alberta perch populations exhibiting different maximum sizes of adult fish were studied to validate an aging technique, compare growth rates of the fish, and to examine the successional growth of perch stocked into a lake which did not contain any fish.

A comparison of aging techniques indicated that cross-sections of the anal spines were more satisfactory than opercula, cleithra, dorsal and pelvic fin cross-sections, and scales. Otolith sections also gave good results but took considerable effort to prepare. The two symmetrical spines in the anal fin gave four sides on which annuli could be counted to determine the age of each fish. Loss of visibility of inner annuli and crowding of outer annuli occurred much less frequently in the anal spines than in the other structures examined. In cross-sections of spines cut several millimeters from the origin of the fin, the first annulus was not apparent but was replaced by a light triangular shaped mark.

Annulus formation in perch from Pine Lake, ages 1 through 7, occurred between May 16 and May 28, 1980. The new annulus in thirty-one 10+ to 14+ perch from Pine Lake occurred between June 11 and June 19.

Fork length and anal spine radius were highly correlated ($r > 0.81$) and linear regression equations were calculated for the Pine, Lessard and Clear Lake populations. Comparison of the lines by analysis of covariance indicated that each line was best described by the empirical data for that relationship.

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Annulus formation in perch from Pine Lake, ages 1 through 7, occurred between May 10 and May 20, 1980. The new annulus in thirty-one 10+ to 14+ perch from Pine Lake occurred between June 1 and June 10.

Fork length and anal spine radius were highly correlated (r = 0.971) and linear regression equations were calculated for the Pine, Lessard and Clear Lake populations. Comparison of the lines by analysis of covariance indicated that each line was best described by the empirical data for that relationship.

Growth of 0+ perch was similar for the Pine, Ste. Anne, and

Goose Lake populations. The Lessard Lake fish were approximately 10mm larger than the others by fall, having attained a fork length of almost 60mm. The results of periodic seine netting indicated that different subgroups of the year-class were being sampled and that smaller fish stay inshore longer in the fall than their larger siblings. No selective over-winter mortality of the smallest 0+ perch was noted. Up to 10mm of growth in length occurred in these fish over winter. The fish studied were usually shorter at each age than reported for other North American populations but were similar to some European populations living at similar latitudes.

Female perch sampled in the fall were longer and heavier than the males of comparable age in the same population. These differences were apparent but not statistically significant until age 3. Differences in total weight between the sexes increased with age more than did differences in fork length.

Anal spine radii measurements were used with the anal spine radius to body fork length relationship to back-calculate the size of Pine, Lessard and Clear Lake perch. Length of the fish at each age was quite similar for the 1976 through 1980 year-classes of female and male perch in Pine and Clear Lakes. Female and male perch from the Lessard Lake 1977 through 1980 year-classes showed a progressive decline in length.

Comparison of log age versus log length, and log length versus log weight relationships between sexes and populations was inconclusive because variance ratios were usually too large to permit analysis of

Goose Lake populations. The Lessard Lake fish were approximately 10mm larger than the others by fall, having attained a fork length of almost 90mm. The results of periodic seine netting indicated that different subgroups of the year-class were being sampled and that smaller fish stay inshore longer in the fall than their larger siblings. No selective over-winter mortality of the smallest fry perch was noted. Up to 10mm of growth in length occurred in these fish over winter. The fish studied were usually shorter at each age than reported for other North American populations but were similar to some European populations living at similar latitudes.

Female perch sampled in the fall were longer and heavier than the males of comparable age in the same population. These differences were apparent but not statistically significant until age 3. Differences in total weight between the sexes increased with age more than did differences in fork length.

Anal spine annuli measurements were used with the anal spine radius to body fork length relationship to back-calculate the size of Pine, Lessard and Clear Lake perch. Length of the fish at each age was quite similar for the 1975 through 1980 year-classes of female and male perch in Pine and Clear Lakes. Female and male perch from the Lessard Lake 1977 through 1980 year-classes showed a progressive decline in length.

Comparison of log age versus log length, and log length versus log weight relationships between sexes and populations was inconclusive because variance ratios were usually too large to permit analysis of covariance. Superimposing the growth curves on common graphs showed the similarity of these relationships for female and male perch.

The "stunted" Clear Lake perch had similar growth rates to the other populations examined, but none of the fish from Clear lake were older than age 6+. Perch from Pine and Goose Lakes reached ages of 15+ and 10+ respectively. No rapid compensatory growth was noted in the growth histories of the fish from Clear Lake to indicate that the population was recovering from a drastic decline in numbers. Predation and angling mortality did not appear to be sufficiently large to restrict the age of the fish. It is suggested that a shortage of suitable food and hence energy may limit the size attained by the adult fish.

The perch stocked into Lessard Lake appear to have grown faster than the other populations studied; however, this is biased toward a higher value by the enhanced growth of the stocked fish and the 1977 year-class. The 1979 year-class, although young at the time of sampling, had a growth curve very similar to the other populations. Similar rapid declines in growth rates of stocked fish have been recorded for other perch populations. Unless the fish stocked into Lessard Lake live longer than the Clear Lake donor stock, little additional angling opportunity will result from this introduction.

The growth rates of the perch populations examined are among the slowest reported in the literature. Most fish just reached a length of about 160mm by the time of formation of the fourth annulus. The faster growth of other North American populations is probably due to the longer growing seasons and warmer water temperatures of more southerly latitudes.

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I am indebted to many people for assitance and encouragement during the course of this study. Dr. M.J. Paetz, former Director of Fisheries, and the Alberta Fish and Wildlife Division permitted flexibility in my work time and supported the field work. Dr. W.C. Mackay supervised the study. Dr.'s J.S. Nelson and J. Butler also joined my supervisory committee and provided useful suggestions.

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Table of Contents

Page

List of Tables

List of Figures

Figure		Page

Figure		Page

List of Plates

Chapter 1. THE STUDY

1.1 Introduction

The yellow perch (*Perca flavescens*) is a popular sport and commercial fish of lakes and slow flowing rivers throughout much of central and eastern North America. Alberta populations represent the northwestern limit of their range (Scott and Crossman, 1973). The majority of perch populations in Alberta occur in the eutrophic and mesotrophic waters of the east central lakeland area. Natural populations occur at scattered locations throughout the remainder of the province except for the western mountains and the Hay and Laird River drainages (Paetz and Nelson, 1970). Fish stocking activities have artificially expanded the distribution of perch within Alberta. The primary purpose of these introductions has been to establish fishable populations in lakes near urban centers thus increasing the availability of these fish to anglers.

The yellow perch is one of the most important sportfish species in Alberta. Three million perch were captured in 1980 by the licenced anglers (Table 1.01). The total perch harvest in the province for that year is estimated at almost four million fish as 33% of Alberta anglers legally fish without a licence by privilege of their age (Carss et al, 1978). In this latter study of Alberta's recreational fishermen, the legally unlicenced anglers caught 26% of the total catch.

Table 1.01. Results of the 1975[1] and 1980[2] (preliminary) survey of licenced Alberta anglers.

Species	Number of fish caught 1975	1981
Perch	922,374	3,006,210
Pike	1,466,249	2,782,643
Trout	1,343,776	2,113,486
Walleye	332,777	892,291
Lake whitefish	335,603	471,187
Goldeye	62,799	188,969
Mountain whitefish	-	809,091
Grayling	58,972	155,195
Others	35,339	154,369
Resident licences sold	214,266	295,772
Total days fished	2,204,521	4,429,493
Average days fished/angler	11.5	17.6
Total expenditures	$105,872,181	$232,118,211

1. Alberta Fish and Wildlife Division, and Recreational Fisheries Branch, Ottawa. 1978.

2. Alberta Fish and Wildlife Division, and Recreational Fisheries Branch, Ottawa. 1981.

Despite the obvious importance of the perch to the recreational fishery, very little information is available for perch populations in western Canada. Only two formal studies have been completed in Alberta. Langer (1974) studied the relationship of mouth structure to seasonal changes in feeding habits. Tanasichuk (1978) examined seasonal aspects of somatic and gonadal energetics. The perch studied by both workers were from Lac Ste. Anne. These fish seldom reach the age of 4+ and are too small to be of recreational interest.

One important aspect of Tanasichuk's study was the introduction to Alberta fishery workers of the use of the operculum to age perch. Yellow perch age and growth data compiled by the Alberta Fish and Wildlife Division still largely depend on counting annuli on scales to age these fish. This is apparently true throughout most of North America despite extensive preference for the operculum in Europe (Le Cren, 1947) and proven use of the bone in North America (Bardach, 1955). Even Schneider's (1972) description of the absence of up to three annuli from the scales of known age yellow perch has had little effect on the North American workers preference for scales.

Very little attention has been paid to subsequent growth of perch stocked into previously fishless lakes. Fishery workers generally assume that all perch populations have the same genetic growth potential. As a result the only selective process considered for a donor stock is the ease of access and distance to the lake to be stocked. In some cases this has meant transferring presumed "stunted" perch to a new environment. We assume that these fish or at least their progeny will exhibit more normal growth rates and produce viable populations of

interest to anglers. Alm (1946) suggests that this assumption is true provided the water body the fish are introduced to contains the necessary habitat and food resources. The duration of this improved growth rate should be dependent on the average growing conditions present in the new environment and the reproductive capacity of the stocked fish.

The intent of my thesis was to study a few selected perch populations in Alberta including a stocked population of perch. The specific objectives were:

1. To validate an aging technique for these perch.
2. To determine and compare the ages and growth rates of perch from selected Alberta populations with apparent different maximum sizes.
3. To determine the successional growth rates of an introduced population of yellow perch which originated from stock which was thought to be "stunted".

This thesis is organized into three chapters. The first contains a general introduction to the study including descriptions of the selected sites and common methods and materials used. The results of the comparison and validation of aging techniques are presented in Chapter 2. The comparisons of the growth rates of the studied populations are discussed in Chapter 3. More detailed descriptions of the specific objectives and methods used are provided in each of the latter two chapters.

1.2 Description of the Study Area

Fish samples were obtained from six lakes located between 52° 04' N - 113° 27' W and 56° 14' N - 115° 14' W in central Alberta, Canada (Figure 1.01). The general vegetation zones around the lakes included aspen parkland (Pine Lake), the mixed wood transition area (Ste. Anne, Lessard, Clear and Goose Lakes) and the boreal forest proper (Cranberry Lake).

The lakes have similar physical characteristics (Table 1.02) being from 131 to 620 ha in surface area except for Lac Ste. Anne which is considerably larger. The mean depth of all six lakes is between 3.6 and 6.0 m. Pine Lake (Figure 1.02) has some limitations to sportfish production due to reduced oxygen levels in the deep water (Anonymous, 1970). Lac Ste. Anne (Figure 1.03) is not considered to have any serious limitations to sportfish production (Lane, 1971). Only Lessard (Figure 1.04) and Clear (Figure 1.05) Lakes do not have well defined inlets and outlets. Lessard, Clear, and Goose (Figure 1.06) Lakes have some limitations to sportfish production due to shallow depths and oxygen depletion in the deeper portions of the lakes (Clements, 1975; Erickson and Smith, 1969; and Paterson, 1960 respectively). Cranberry Lake (Figure 1.07) has not been surveyed (D. Walty, pers. comm.).

Perch and northern pike are the only species of fish common to all six lakes (Table 1.03). They are native to Pine, Ste. Anne and Cranberry Lakes. Pike are native to Goose Lake and a small population of perch may

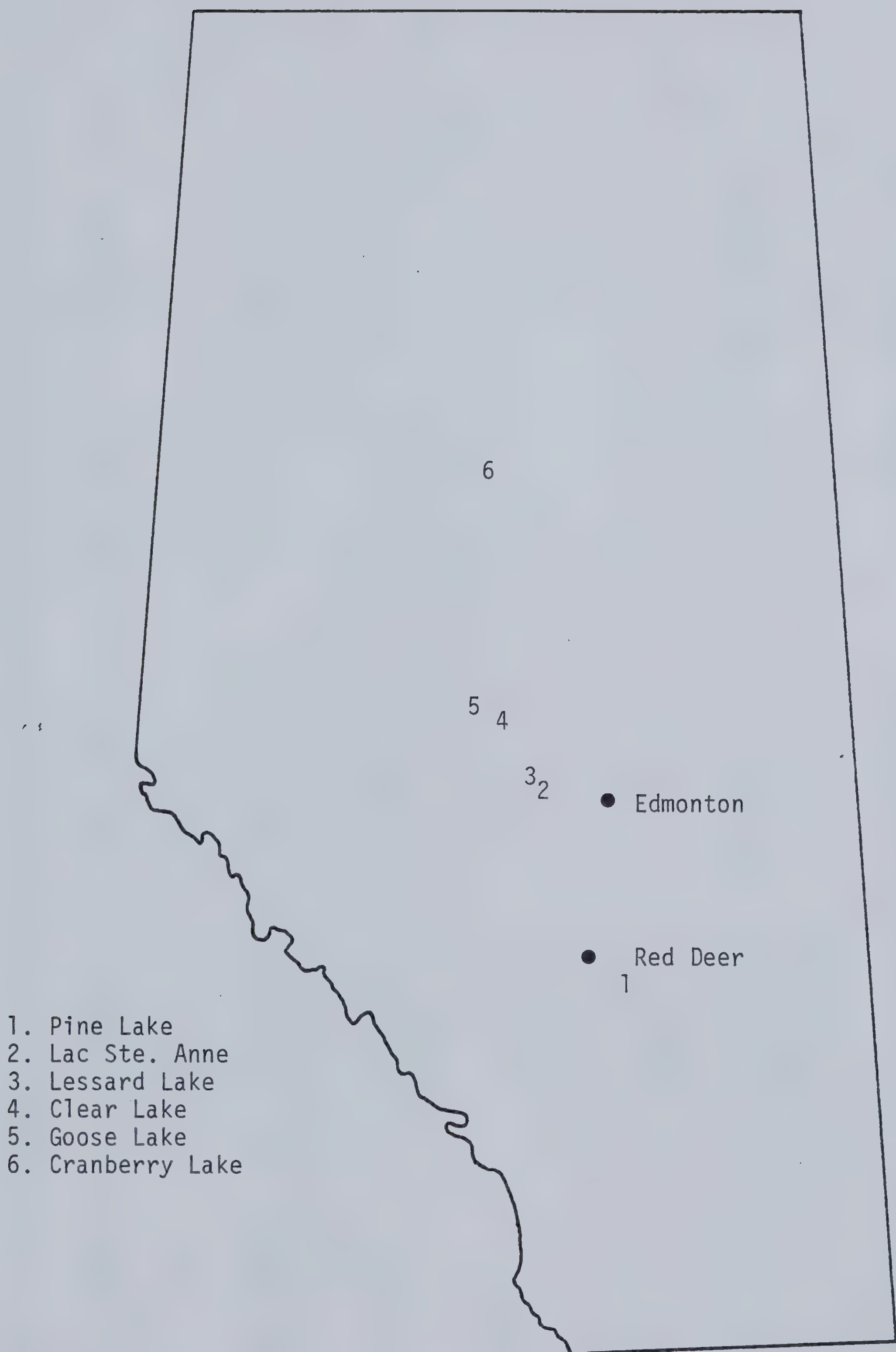

Figure 1.01. Perch collection sites in Alberta.

Table 1.02. Physical characteristics of the study lakes.

Lake	Location	Surface Area (ha)	Maximum Depth (m)	Mean Depth (m)
Pine[1]	52° 04' N 113° 27' W	401	12.2	6.0
Ste. Anne[2]	53° 42' N 114° 25' W	5656	9.7	4.9
Lessard[3]	53° 47' N 114° 39' W	341	5.8	3.8
Clear[4]	54° 14' N 114° 47' W	131	9.1	3.6
Goose[5]	54° 20' N 115° 08' W	310	7.9	4.5
Cranberry[6]	56° 14' N 115° 04' W	620	5.5	Not available

Sources
1. calculated from Alberta Environment hydrograph
2. Lane, 1971.
3. Clements, 1975.
4. Erickson and Smith, 1969.
5. Paterson, 1960.
6. D. Walty, pers. comm.

Figure 1.02. General features and morphometry of Pine Lake (redrawn from Alberta Environment June, 1967, hydrograph). Depth contours in meters.

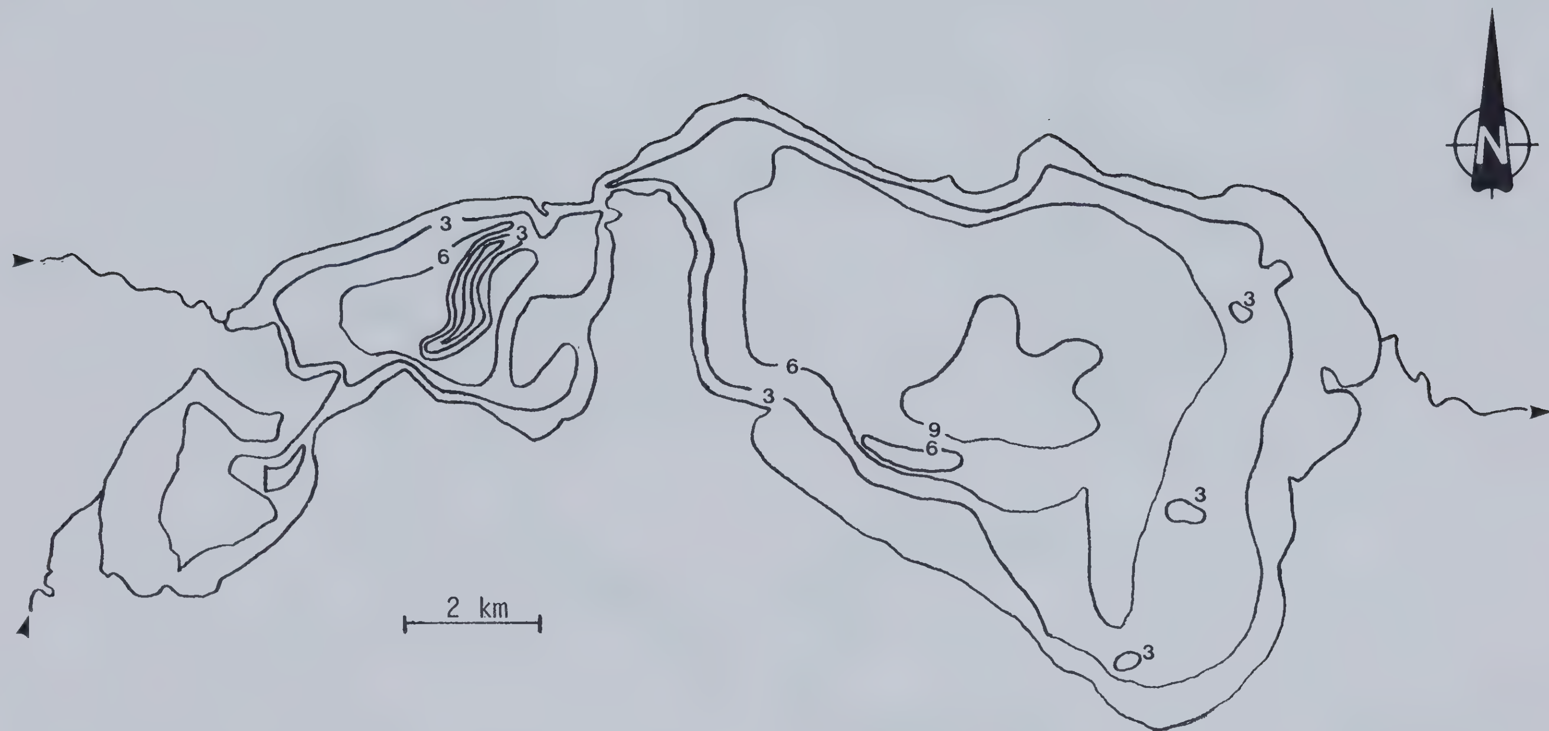

Figure 1.03. General features and morphometry of Lac Ste. Anne (redrawn from Alberta Environment June, 1965, hydrograph). Depth contours in meters.

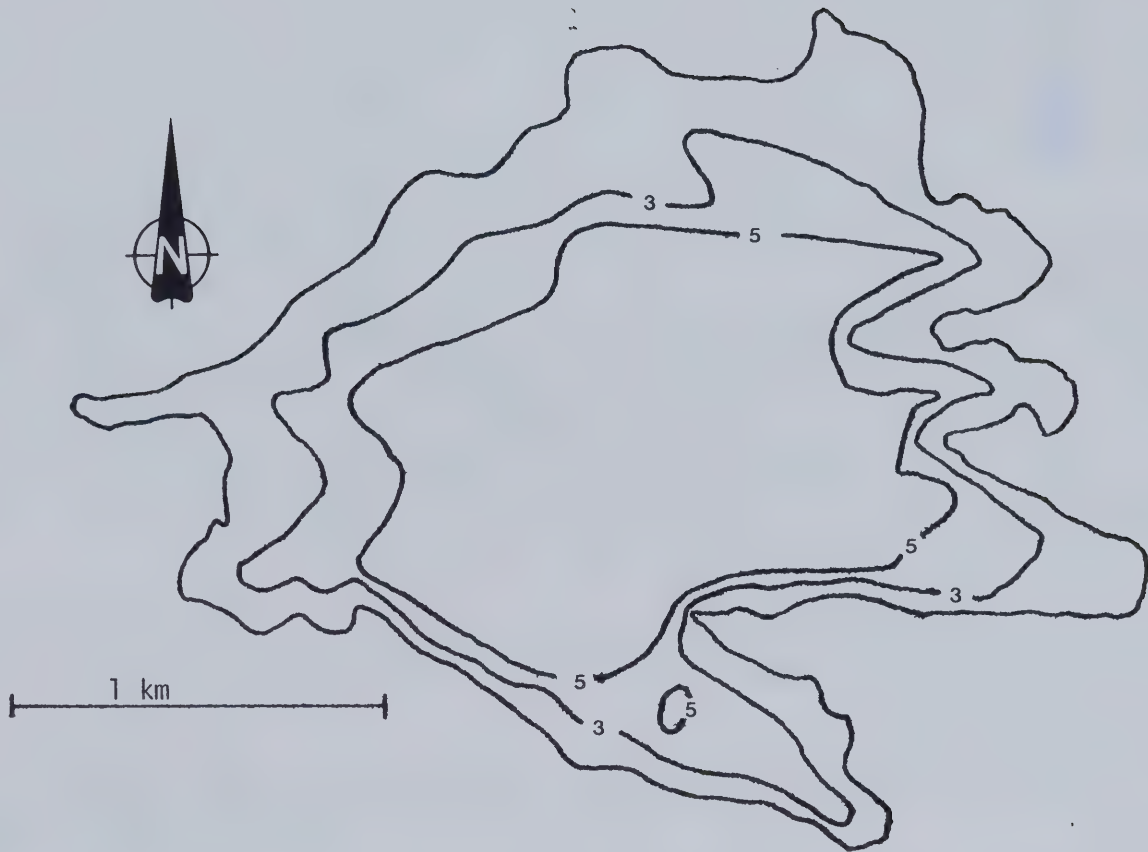

Figure 1.04. General features and morphometry of Lessard Lake (redrawn from Clements, 1975). Depth contours in meters.

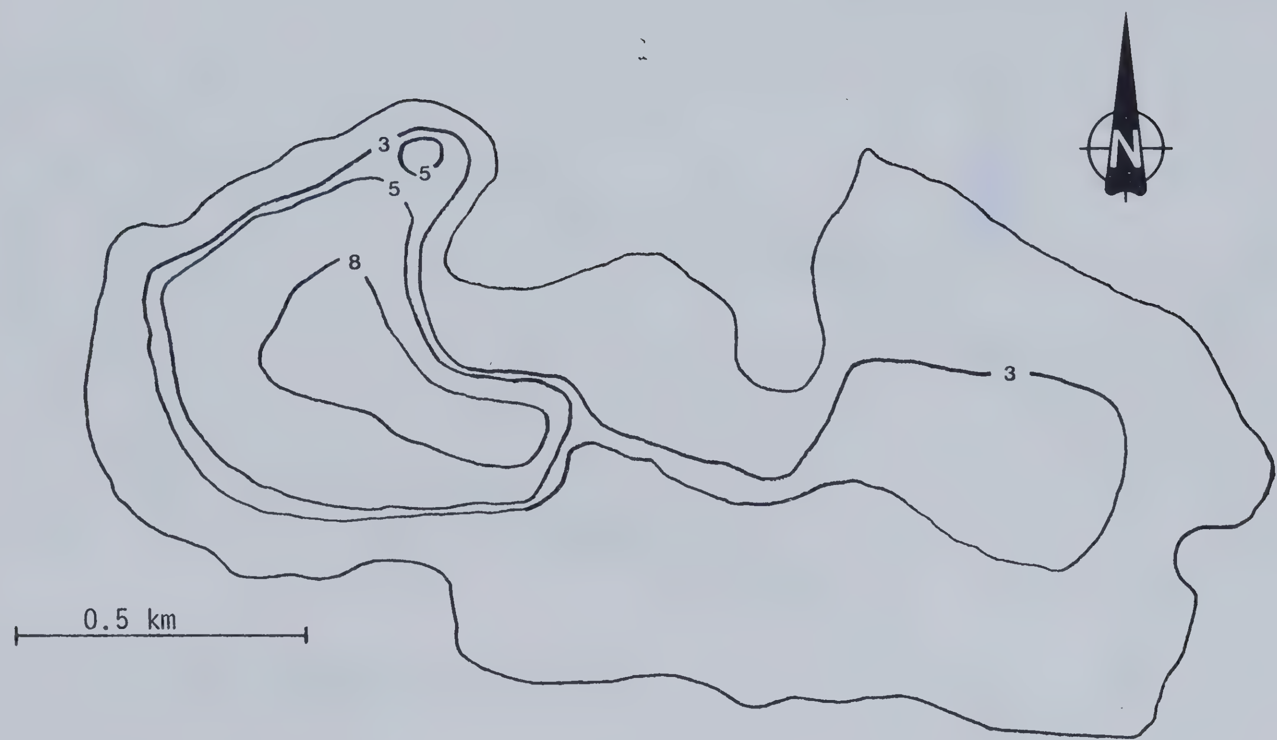

Figure 1.05. General features and morphometry of Clear Lake (redrawn from Erickson and Smith, 1969). Depth contours in meters.

Figure 1.06. General features and morphometry of Goose Lake (redrawn from Alberta Environment June, 1968, hydrograph). Depth contours in meters.

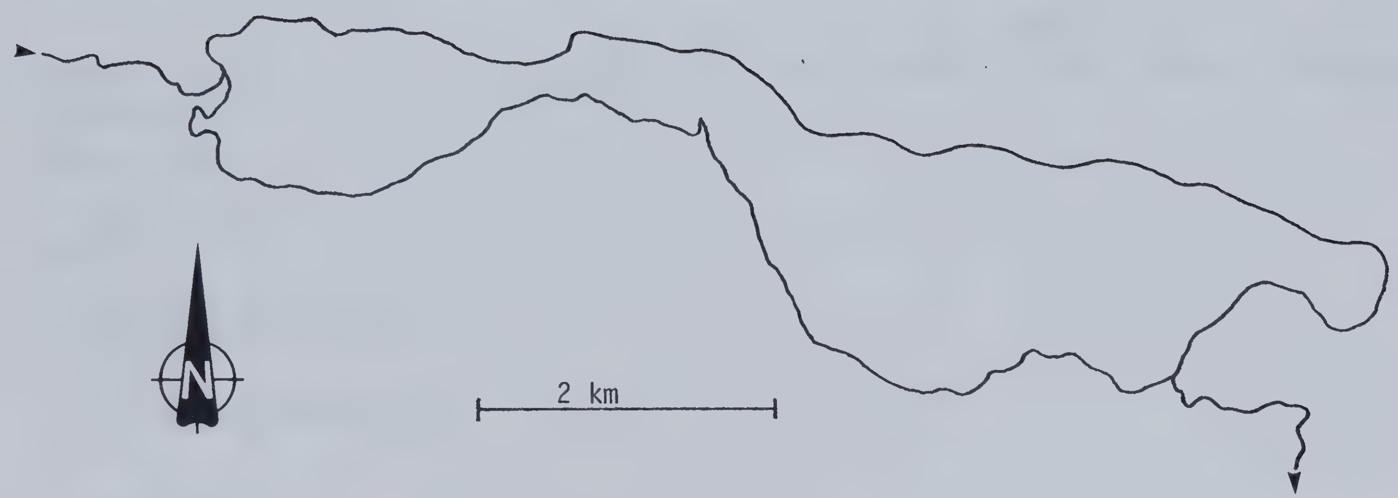

Figure 1.07. General features of Cranberry Lake (redrawn from National Topographic series map).

Table 1.03. Fish species present in the study lakes (s = stocked).

	Lake					
Species	Pine	Ste Anne	Lessard	Clear	Goose	Cranberry
Yellow perch	+	+	s	s	+s	+
Northern pike	+	+	s	s	+	+
(*Esox lucius*)						
Walleye	s	+				+
(*Stizostedion vitreum*)						
Whitefish		+				+
(*Coregonus clupeaformis*)						
Tullibee						+
(*C. artedi*)						
White sucker	+	+			+	+
(*Catostomus commersoni*)						
Burbot		+				+
(*Lota lota*)						
Iowa darter	+					
(*Etheostoma exile*)						
Brook stickleback		+				
(*Culaea inconstans*)						
Spottail shiner		+				
(*Notropis hudsonius*)						

also have been naturally present (Yule and Harke, 1960). Goose Lake was stocked in August of 1961 with 14,000 perch fingerlings (Alberta Fish and Wildlife Division Fish Planting Records). Pike were stocked in Clear Lake prior to 1957 (Thomas, 1957). Perch may originally have been present in the lake but it is thought that local residents stocked them in the early 1960's. The pike and perch populations originally present in Lessard Lake were eliminated by a severe winterkill in 1973-74 (Clements, 1975). The lake was restocked in 1976 with an estimated 130,000 perch and a few pike from Clear Lake (K. Zelt, pers. comm.).

The lake whitefish populations in Lac Ste. Anne and Cranberry Lake support annual commercial fisheries. A native population of walleye occurs in Lac Ste. Anne and small numbers of this species have been captured in the Cranberry Lake commercial fishery. The walleye population in Pine Lake is the result of walleye egg plantings from 1960-63 and 1971-74 (Hunt, 1967). Walleye eggs were also planted in Goose Lake in 1962 and 1963 but no walleye have ever been captured (Alberta Fish and Wildlife Division Fish Planting Records).

The assumed status of the perch populations in these lakes at the time this study began was:

- Pine and Goose Lakes contained "normal" sized perch
- Clear Lake contained "stunted" perch
- Lac Ste. Anne perch were small because of their short life-span and their growth had been well documented
- large Cranberry Lake perch were available from the commercial fishery
- the growth rates of the perch stocked into Lessard Lake appeared to be greater than that of the fish in Clear Lake.

1.3 General Methods

Yellow perch collections were made from Pine, Ste. Anne, Lessard, Clear and Goose Lakes between April 19, 1979, and November 1, 1980. Shoreline areas were sampled throughout the open water season for young of the year (0+) perch using a 1.8 x 15 m minnow seine complete with a 1.8 m^3 bag. The seine had a mesh size of 6 mm and was constructed of braided nylon colored black by the net preservative "Netset" (Nichols Net and Twine Company, East St. Louis, Illinois). Additional shoreline as well as some pelagic grab collections of individual 0+ yellow perch were made with a D-shaped invertebrate dip net.

Gill net collections were made using a graduated mesh monofilament net consisting of nine 1.8 x 23 m panels. Stretched mesh sizes were 25, 38, 51, 63, 76, 89, 102, 113 and 127 mm. The last four panels of the net were removed for most of the 1980 sample collections because they were only catching pike and suckers rather than perch. All gill net collections were made in open water except for the April 19, 1979, sample from Pine Lake. Approximately 1 m of ice covered the lake at the time of this set.

Overnight gill net sets in September and October were used at each lake except Lac Ste. Anne, to collect the perch samples for age and growth comparisons. Daylight net sets of short duration (1 to 4 hrs.) and angling during the spring and summer of 1980 also provided samples from Pine Lake.

The December 6, 1979, sample of perch from Cranberry Lake was caught in a 102 mm braided nylon commercial fisheries net. The fish were purchased at the Joussard Fish Plant on Lesser Slave Lake.

All fish were sampled while fresh except for two samples of perch from Pine Lake collected in the spring of 1980 and used for studies of annulus formation. These two samples had to be frozen for 1 week before they could be processed.

Fish were measured to the nearest millimeter for fork length. Round (total body weight including food in the gut) and gonad weights were measured to the nearest gram. The sex of each fish was determined and recorded using the following five point system for males and females.

Female		Male
1	immature	6
2	maturing	7
3	mature	8
4	ripe	9
5	spent	10

The desired structures for age determination were removed from the fish and stored in scale envelopes at 5 C until processed.

Nearly all of the April 19, 1979, yellow perch sample from Pine Lake were separately labelled and stored in the freezer. Most other specimens were discarded after sampling because their storage would have required excessive freezer space.

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Chapter 2. DETERMINATION OF AGE

2.1 Introduction

Accurate determination of the age of collected fish samples is required for assessment of growth and hence for the formulation of management strategies. The most useful body structures for aging fish are ones that: are easy to collect and prepare; do not require excessive equipment for examination; show distinct annuli with a minimum of false annuli; and whose size can be mathematically related to fish length so that back-calculations of growth can be made.

Scales are obviously the easiest structures to remove and prepare for aging. They have remained the standard aging structure for perch in North America despite some major negative characteristics. These include the presence of false annuli, scale resorption and regeneration (Bagenal, 1978; Deelder and Willemse, 1973; Ottaway and Simkiss, 1977; Joeris, 1956) and failure to form annuli on the scales (Schneider, 1972). Some of these problems are probably due to the ability of teleosts to demineralize the scales if calcium is required for other body functions. Fish are not able to recycle calcium deposited in their acellular bones (Simkiss, 1974). Since formation of the translucent and opaque zones of fish bones is partially due to the incorporation of different amounts of calcium (Casselman, 1974), these structures hold more promise than scales for accurate aging results.

European workers have long recognized the inherent difficulties of aging perch with scales. As early as 1913, Arnold (cited by Neuman, 1976) had reported on the occurrence of annular marks on opercula. Nilsson (1921, cited by Le Cren, 1947) and Worthington (1941, cited by Le Cren, 1947) believed that annuli were easier to count on opercula than on scales although Alm (1946) concluded that the bone was too difficult to read to be of practical use. General European acceptance of the method occurred after Le Cren (1947) published his paper demonstrating the advantages of aging perch using the operculum. The technique has never gained widespread acceptance in North America. Bardach (1955) and Tanasichuk (1978) used the bone to age perch in Wisconsin and Alberta respectively. Neither of these authors specifically mention excessive problems with loss of the first annulus as reported by European workers (Le Cren, 1947, 1955; Chugunova, 1963; Neuman, 1976). This may have been because the majority of fish studied by both authors were under the age of 5.

Other workers have examined finray cross-sections in order to avoid the problem of lost annuli and the need to use projection equipment to measure opercula for back-calculation (Boiko 1951 - cited by Deelder and Willemse, 1973; Willemsen, 1977). These authors do not specify which fin was used; however, Griffiths (1975) successfully used pelvic fin sections to age perch in New Zealand.

Accurate age determination requires that only one annulus be formed in each year of the fish's life. Le Cren (1947) and Griffiths demonstrated the validity of the operculum and pelvic fin ray aging

methods respectively. The precise timing of annulus formation is variable. In temperate fish stocks it usually occurs shortly after ice breakup in the spring. Further variation in timing may occur between immature and mature fish of the same population (Clugston et al, 1978; Joeris, 1956; Jobes, 1952). If the variation in timing of annulus formation between year-classes is greater than a few weeks, errors and confusion may occur in assigning ages to fish captured during the period of annulus formation. Tanasichuk (1978) found that annulus formation in 1+ and 2+ perch from Lac Ste. Anne occured between May 1 and June 1.

A useful aging technique also permits the accurate back-calculation of length at the time of each preceeding annulus formation for each fish. Jobes (1933) used a direct proportional ratio for back-calculating lengths from perch scales. Bardach's (1955) plot of scale radius to body length showed extreme scattering and no linear relationship. Joeris (1956), Hile and Jobes (1941) and Jobes (1952) found straight line scale radius to body length relationships for perch larger than 102 mm total length, 90 mm standard length, and 107 mm total length respectively. Le Cren (1947) cited the work of Svetovidov (1929) and Segerstrale (1933) in arguing for the necessity to develop an aging structure-body length relationship from empirical data. Le Cren's operculum to body length data for perch from Lake Windermere produced an allometric curve. Similar results were obtained by Agnedal (1968, cited by Neuman, 1976), Mann (1978) and Craig (1980), but Bardach's Wisconsin perch showed a linear relationship. Griffiths found a linear relationship for pelvic fin ray radius to body length and used a Lee equation (Hile, 1970) to

describe the line. These authors have shown differences in structure size to body length relationship between populations and between females and males of the same population.

The objectives of this portion of my study were:

1. To validate an aging technique for perch.
2. To follow fish growth through one year to determine the timing of annulus formation.
3. To compare the aging structure-body length relationships of several perch populations from Alberta.

2.2 Methods and Materials

The left operculum was removed from all perch collected between April 19 and November 1, 1979. Each bone was placed in individually numbered scale envelopes and kept in a refrigerator until cleaned. The opercula were cleaned by placing them in hot (not boiling) water until the flesh had cooked. The tissue was then easily removed by wiping it off with a paper towel and the bone was dried in air for several weeks. Attempts were made to enhance the visibility of the annuli using transmitted light, polarizing filters (Le Cren, 1947), emersion of the bone in cedar wood oil (Baganal, 1978) and by grinding the outer surface of the operculum with fine sandpaper.

Subsequent to this work, I examined several other hard structures in an attempt to identify the best method for aging these perch. The right operculum, left cleithrum, first dorsal fin spines, pelvic and anal fins,

otoliths and some scales were removed from 156 perch from Pine Lake and 56 perch from Cranberry Lake for the comparison.

The right opercula and cleithra (Casselman and Crossman, 1979), were cleaned by the method described previously for the left operculum. The visible annuli were counted on the shaft (anterior blade) and heel of the cleithra (Casselman, 1974). Annuli were also counted in the sharply curved area along the dorsal edge of the cleithrum and directly opposite from the heel of the bone. This curved area is referred to as the elbow of the cleithrum, throughout this thesis.

Fin rays and spines were removed intact or else cut as close to the body surface as possible with side-cutter pliers. They were allowed to air dry before being embedded in 24 hour epoxy. A jewellers saw with a #7/0 or #8/0 Hercules blade (Hammel Riglander Company, New York, New York), or a Buehler Isomet low-speed saw (Buehler Company, Evanston, Illinois) were used to cut several 0.5 mm thick sections from the base of the bones perpendicular to the axis of the fin rays. The Isomet saw used a diamond tipped blade 0.015 mm thick and 76 mm diameter at a cutting speed of 300 rpm. Fin cross-sections were placed on glass slides and covered with the liquid glass Flotex (Lerner Laboratories, Stamford, Connecticut) to make permanent slides.

Approximately one dozen scales were removed from the left side of the perch, below the lateral line in the area of the distal portion of the pectoral fin (Lagler, 1959). Scales were sandwiched between two glass slides to be read.

Forty-seven perch from the Pine Lake sample were selected for otolith sectioning. Each otolith was prepared by embedding it in 24 hour epoxy in a plastic drinking straw split in half. Several sections were made through the center of the otolith using the Isomet saw. The otolith cross-sections were placed on glass slides and covered with liquid glass medium.

All aging material was examined using a binocular microscope with 6.4, 20 and 40 X objectives and 10 X oculars equipped with a micrometer.

The age of each test fish was determined by examining the operculum and anal fin sections together. All these perch were then set aside for two weeks. The fish were then checked, one structure group at a time (e.g. annuli on the scales for all fish were counted). This process was repeated until all the structures had been examined. During this test the number of distinctly visible annuli on each structure was noted without comparison to the previously determined age of each fish.

The left operculum and anal fin sections were used to age all perch collected in 1980. A subsample of 40 fish were also aged using the dentary bone and preoperculum.

The age of each fish was taken to be equivalent to the number of annuli. The presence of a growth zone outside the last complete annulus was required in order to include the last annulus in the count. No arbitrary anniversary date was used so a 1+ fish would not become 2 until the second annulus had formed. This fish would be classed as 2+ once the start of the summer growth band was distinctly visible outside the second annulus.

Annulus formation was assessed by examining all perch opercula and anal spine sections collected during this study. Additional fish were collected at approximately 10 day intervals between May 6 and June 19, 1980, at Pine Lake.

The anal spine radius - fork length relationship was assessed graphically. If the relationship was linear it was then described by a regression equation of the form:

$$y = bx + a$$

where: y = fish fork length,

x = anal spine radius,

b = slope of the line,

a = a constant.

The equation was fitted by the least squares method. Regression lines were compared by analysis of covariance (Snedecor and Cochran, 1967).

2.3 Results and Discussion

2.3a Comparison of Aging Techniques

Collection of 0+ perch and analysis of length frequency histograms (Figure 2.01) were used to identify the first annulus on the operculum . No annular marks could be seen on the opercula from the 0+ perch (40-60 mm fork length). The size of their opercula was about 3.5 mm as measured from the origin to the centre of the posterior edge (Le Cren, 1947). This closely corresponded to the approximately 4 mm distance from the

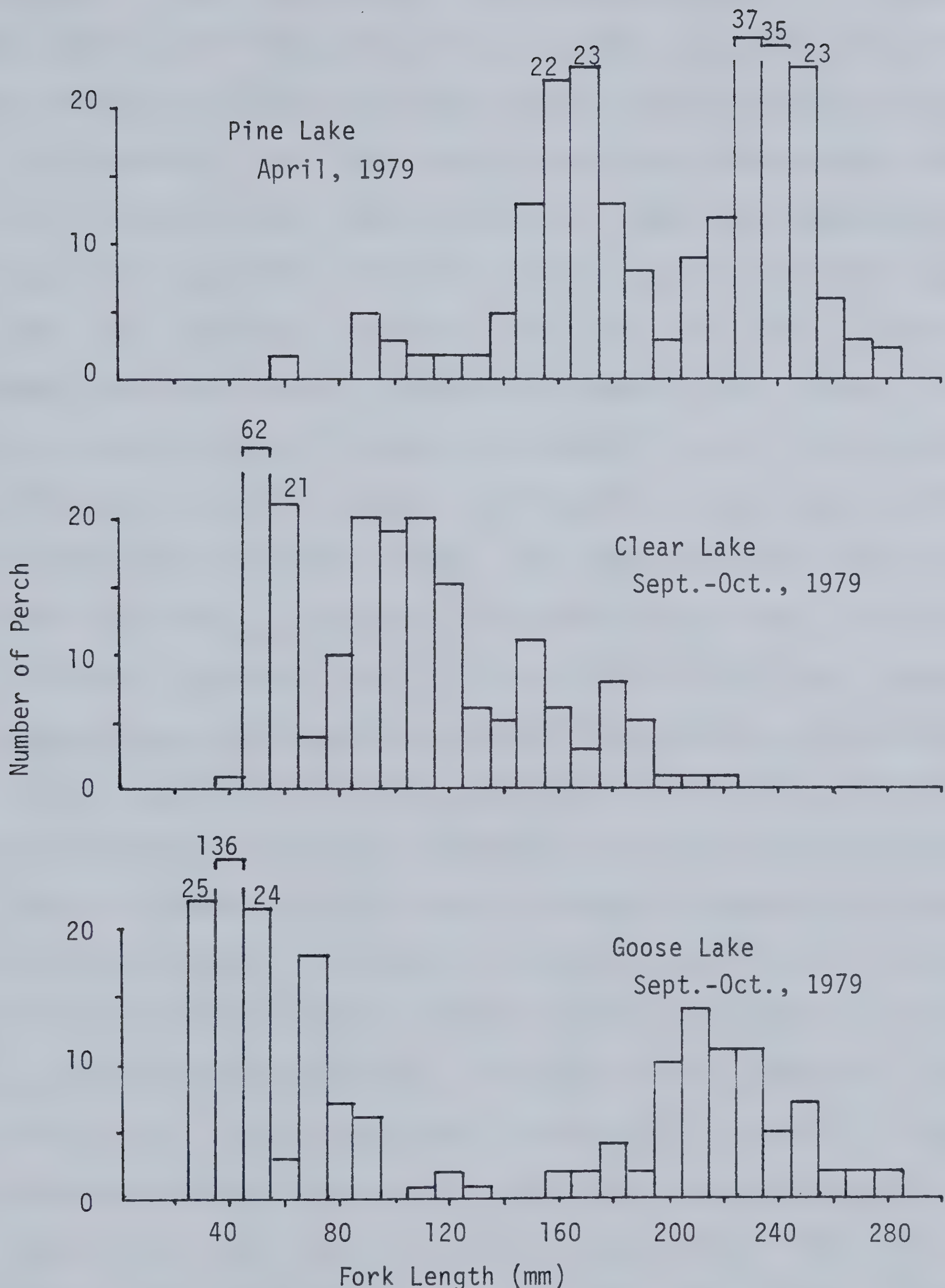

Figure 2.01. Number of perch in each 10mm grouping of fork length, in the 1979 samples from Pine, Clear and Goose Lakes.

bone origin to the first annulus in the 80-90 mm perch. The assumed minimal growth of 0+ perch from fall to spring was supported by the capture of two 55 mm long perch just prior to spring ice-out in Pine Lake. In addition, a late June sample from Clear Lake contained eight perch with an average fork length of 69 mm. These fish showed only a small amount of new growth after their single annuli. In slightly larger fish the first annulus was often indistinct and length frequency histograms could not readily be used to separate age classes. The problem of obscured annuli became more apparent in the largest perch. These fish had very thick opercula, particularly at the bases, and the outer surface was irregularly ridged. The ridges radiated to the outer edge from the origin. Comparison of the opercula of these fish to 1+ perch indicated a probable loss of the visibility of the first, second, and sometimes even third annulus although the condition was variable. Ages assigned to the larger fish according to the number of visible annuli were suspect. Two fish of apparently different size classes would have the same number of visible annuli although in obviously different places on the operculum. Attempts to enhance the visibility of the inner annuli using transmitted light, polarizing filters, and emersion of the bone in cedar oil were unsuccessful. Grinding of the outer plane of the operculum did not improve resolution of the annuli. Excessive grinding cut through previously visible annuli indicating that thickening of the bone occurred on both surfaces. Due to the concave shape of the operculum it was not possible to grind the inner surface without destroying the origin and most of the outer edges of the bone.

The loss of visibility of up to three annuli due to bone thickening is considered excessive where accurate aging results are needed. A more complete examination of aging techniques was therefore completed beginning with the 1+ perch from Pine Lake. The results indicated that single annular marks could also be distinguished on the cleithra, dorsal fin spines, pelvic and anal fin spines and soft rays, scales and otoliths. The use of these structures for aging purposes was examined with one hundred fifty-six perch from Pine Lake and fifty-six perch from Cranberry Lake.

Of the structures tested, the annuli were most visible on the cross-section of the anal spines and on the operculum. The substantial size of the two anal spines relative to the other spines and soft fin rays of the perch, provided for greater distance between consecutive annuli. This reduced the amount of crowding of the outer annuli which were then easier to distinguish. The symmetrical shape of the two bones allowed the annuli to be counted in a number of different directions from the origin (Plate 2.01). In addition, no faint lines (false annuli) were noted on the sections of the anal spines. This finding agrees with those of Chugunova (1963) and Boiko (1951, cited by Deelder and Willemse, 1973). The other structure was the operculum, despite the almost universal loss of visibility of the annuli located close to the origin of the bone. Annuli near the outer edge of the opercula remained distinct. Faint lines (false annuli) were always visible on the opercula but they could be distinguished from true annuli by their very thin width and their short length across the bone face. A combined counting of the

Plate 2.01. Cross-section of the two anal spines from a 7+ perch showing the distinctness of all the annuli. Anal spine radial distances were measured from the center of the first spine along a line between the points of the two arrows. The operculum from this fish is shown in Plate 2.04. (Magnification 18.6 X).

Plate 2.02. Cross-section of the anal spines from a 4+ perch showing the replacement of the lost first annulus in the first spine, with a triangular shaped light area. The first annulus is still visible in the second spine. (Magnification 18.6 X).

Plate 2.03. The right operculum from a 0+ perch and the left operculum from a 1+ perch demonstrating the faintness of the first annulus in the 1+ fish. (Magnification 3.2 X).

Plate 2.04. The left operculum from the same 7+ perch as the anal spine cross-section shown in Plate 2.01. Note the lack of a visible first and second annulus on the operculum and the faintness of the central portion of the third and fourth annuli. The arrow marks the origin point and direction used when measuring an operculum. (Magnification 3.2 X).

A = anterior, P = posterior, D = dorsal, V = ventral.

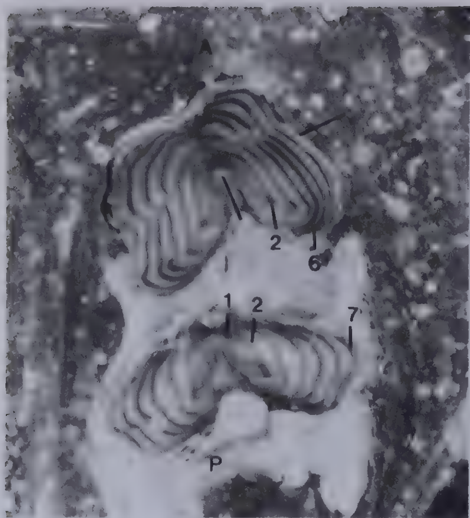

Plate 2.01.

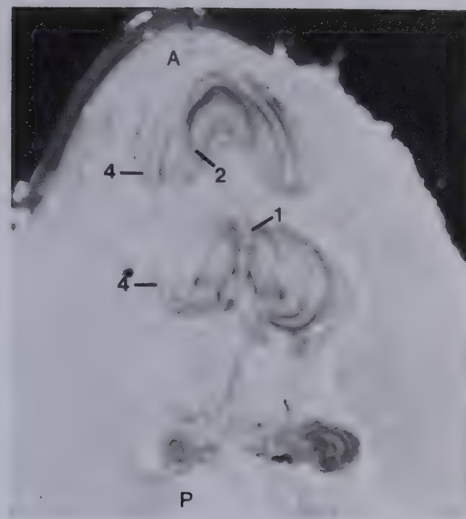

Plate 2.02.

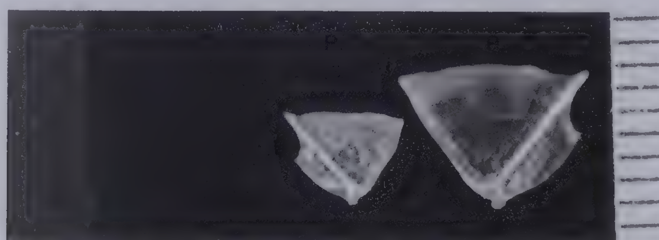

Plate 2.03.

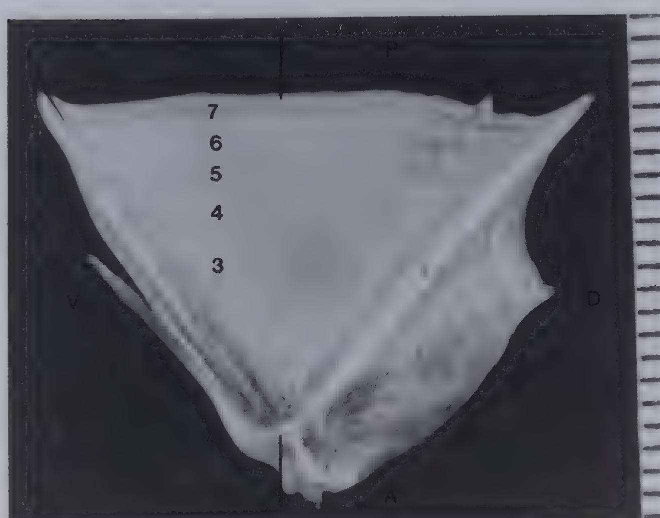

Plate 2.04.

Plate 2.05. Interior surface of the heel and elbow area of the left cleithrum from a 9+ perch. Eight annuli were visible on the heel but only six crowded annuli were evident in the elbow area. (Magnification 3.2 X).

Plate 2.06. Exterior surface of the shaft area of the left cleithrum from a 9+ perch. Seven annuli were clearly visible. (Magnification 3.2 X).

Plate 2.07. Cross-section of two dorsal fin spines from a 7+ perch. Note the absence of a visible first annulus in the more anterior spine. (Magnification 18.6 X).

Plate 2.08. Cross-section of the pelvic fin from a 1+ perch. The large size and symmetrical shape of the spine made the annulus more distinct than on the soft rays. (Magnification 18.6 X).

Plate 2.09. Pelvic fin cross-section from a perch having just formed it fourth annulus. Note that the first annulus in the soft rays was barely visible as a tiny bud. (Magnification 18.6 X).

A = anterior, P = posterior, D = dorsal, V = ventral.

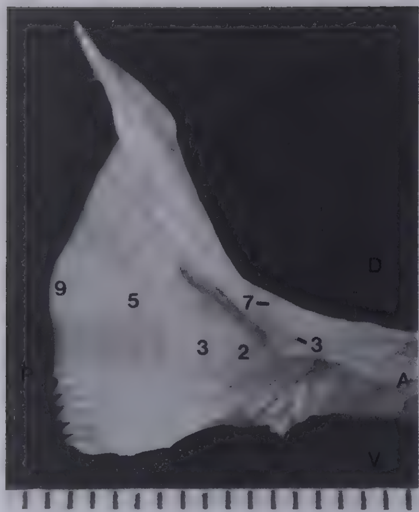

Plate 2.05.

Plate 2.06.

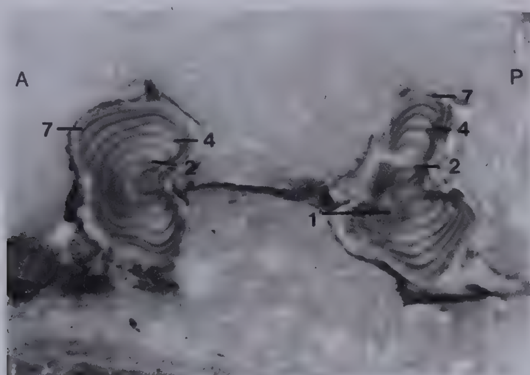

Plate 2.07.

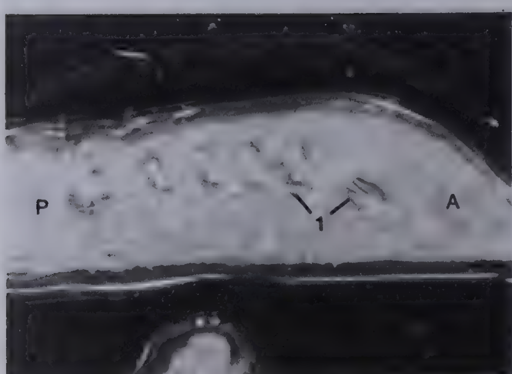

Plate 2.08.

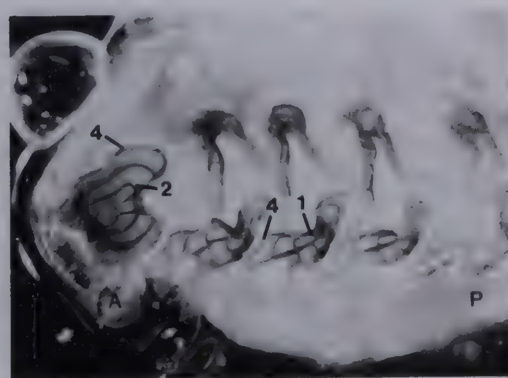

Plate 2.09.

Plate 2.10. The exterior surface of a scale from an 11+ perch, showing the obscuration of the first few annuli and crowding of the outer annuli (Magnification 5.8 X).

Plate 2.11. Exterior surface of scales from 0+ and 1+ perch. The first annulus was approximately 0.5 mm from the scale origin. (Magnification 18.6 X).

Plate 2.12. Whole otoliths from 0+ and 1+ perch. Note the dense core of the otolith which was surrounded by a transparent growth band before the faint first annulus. (Magnification 18.6 X).

Plate 2.13. Cross-section of the otolith from the same 1+ perch as the whole otolith shown in Plate 2.12. (Magnification 18.6 X).

Plate 2.14. Cross-section of an otolith from a 9+ perch. The annuli were quite distinct except where lateral cracks occurred through the cross-section of the bone. (Magnification 18.6 X).

Plate 2.10.

Plate 2.11.

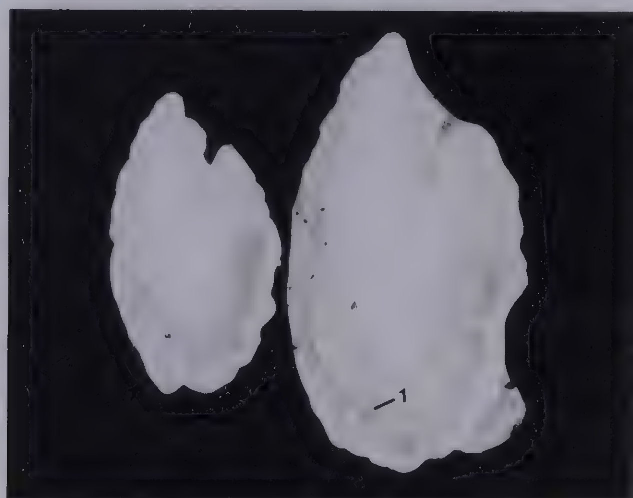

Plate 2.12.

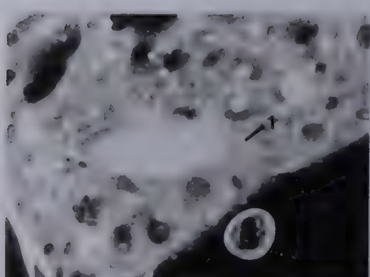

Plate 2.13.

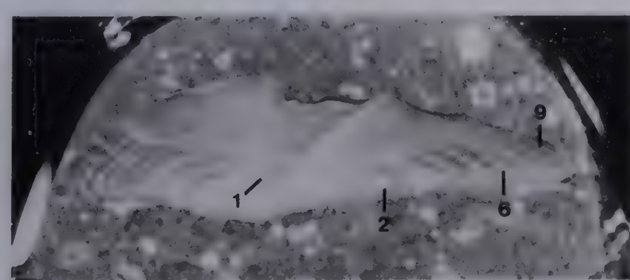

Plate 2.14.

annuli visible on the operculum and the sections of the anal spines was used to determine the age each fish would be assigned. The number of visible annuli on one structure (e.g. scales) was counted, for each sample fish. This procedure was repeated until all the structures had been checked. The number of visible annuli were then compared to the initially assigned age of each fish.

<u>Anal spine sections</u> - The sections of spines from the anal fin were the most reliable structure for aging perch (Tables 2.01 and 2.02). The soft anal fin ray sections were not so easily read. These rays split into two separate branches and hence were much smaller in size. The lack of symmetry and crowding of outer annuli made anal fin rays much more difficult to interpret than anal fin spines.

The disagreement between annuli counts on the anal spines and the assigned age was usually due to poor sections. Sections that were cut too thick or on a sharp angle did not show distinct annuli. These sections appeared relatively opaque because insufficient light passed through the annuli to make them appear as dark bands within the sections.

Another occasional problem was cracks in the anal spines of fins that had been removed from the fish using side-cutter pliers. The section of the spines could still be used as long as the crack did not destroy the center of the bone. Several sections could usually be cut from these rays to obtain a good section for aging. The use of the epoxy matrix greatly facilitated the production of good sections from cracked rays. Removal of the entire fin and supporting interhemal bones with a knife prevented the problem of cracked rays.

Table 2.01. Comparison of the number of visible annuli on sections of the anal fin spines to the assigned age of perch from Pine Lake.

Age	N	Difference in the Annuli Count					
		-2	-1	0	+1	+2	NA*
1+	8			8			
2+	8			5			3
3+	23		2	21			
4+	4			3			1
5+	2			2			
6+	1			1			
7+	4			4			
8+	1			1			
9+	10			10			
10+	6			5			1
11+	83		7	74			2
12+	4			4			
13+	2			1			1
Total	156		9	139			8

*NA - not available for comparison.

Table 2.02. Comparison of the number of visible annuli on sections of the anal fin spines to the assigned age of perch from Cranberry Lake.

		Difference in the Annuli Count					
Age	N	-2	-1	0	+1	+2	NA*
6+	1			1			
7+	2			2			
8+	5			5			
9+	8			8			
10+	27			26			1
11+	-						
12+	11		2	9			
13+	1			1			
14+	-						
15+	1		1				
Total	56		3	52			1

*NA - not available for comparison.

The small anal spines from young or very small perch were awkward to section with the jewellers saw. Vibration from the cutting action shattered some of these sections despite the use of an epoxy matrix. The Buehler Isomet saw produced good sections from the fins of these fish.

The location on the fin where the section was cut also affected the number of annuli present. Sections taken too far from the base lost the distinct first annulus and the smaller size of the spine meant that outer annuli were more crowded. A faint triangle inside the second annulus (Plate 2.02) was the typical sign of a lost fin ray annulus. As long as care was taken to start near the fin base several sections could be made without losing the first annulus.

The disadvantages of using the anal fin for aging are:

1. it is not desirable to remove this major fin from fish captured live and intended for release.
2. it is somewhat difficult to section very small anal fin spines without shattering them when using a hand held jewellers saw.

The advantages of aging perch with sections of spines from the anal fin include:

1. all annuli are quite distinct and easy to read.
2. both anal spines are relatively symmetrical and the annuli can be counted in several places on the two bones.
3. several sections can be made from the spines without losing any annuli.
4. false annuli which appeared on the operculum were not present on the sections of spines from the anal fin.

Opercula - As expected the right and left operculum from each fish were almost mirror images. Eighty percent of the spring sample of perch from Pine Lake had the same number of annuli visible on both bones (Table 2.03). This correlation is 12% lower than that of the Wisconsin perch studied by Bardach (1955). The discrepancy is most likely due to the younger age of his perch. The majority of the differences in annuli counts between opercula in this study occurred in perch over the age of 10 and were probably due to excessive thickening of the bone.

Table 2.04 shows that from the age of 3+ onward, the vast majority (93%) of opercula from perch caught in Pine Lake show at least one less annulus than the fish's assigned age. However, even 1+ and 2+ perch may not show a distinct first annulus on the operculum although it will be clearly visible on the section of the anal spines. This first annulus was visible in only five of the eight 2+ perch opercula examined. Loss of visibility of the second and even third annulus occurred in 20% of the perch from Pine Lake which were older than 9+. This is consistent with the suggestion that the concealment of these early annuli is due to thickening of the bone base as the fish ages. The extensive increase in bone mass can be seen in Plates 2.03 and 2.04 which show opercula from 0+ and 1+ perch, and from a 7+ perch from Pine Lake. The first, second and central portion of the fourth annulus are indistinct in the latter sample.

The visibility of annuli on the opercula of perch from Cranberry Lake (Table 2.05) was practically identical to the Pine Lake sample.

Table 2.03. Comparison of the number of visible annuli on each operculum of perch from Pine Lake.

		Left Bone			Right Bone		
Age	N	+2	+1	Agree	+1	+2	NA*
1+	8						8
2+	8			5			3
3+	23		1	18	3		1
4+	5		1	3			1
5+	2			2			
6+	1						1
7+	4		1	3			
8+	1		1				
9+	10		3	6			1
10+	6			6			
11+	83	1	12	62	2	1	5
12+	4		1	3			
13+	2			2			
Total	156	1	20	109	5	1	20

*NA - not available for comparison.

Table 2.04. Comparison of the number of visible annuli on the left operculum to the assigned age of perch from Pine Lake.

Age	N	Difference in the Annuli Count					
		-3	-2	-1	0	+1	NA*
1+	8			1	7		
2+	8			3	5		
3+	23			21	2		
4+	4			3	1		
5+	2			1	1		
6+	1			1			
7+	4			4			
8+	1			1			
9+	10		2	7	1		
10+	6		2	4			
11+	83	2	14	62	5		
12+	4		1	3			
13+	2			2			
Total	156	2	19	113	22		

*NA - not available for comparison.

Table 2.05. Comparison of the number of visible annuli on the left operculum to the assigned age of perch from Cranberry Lake.

		Difference in the Annuli Count				
Age	N	-3	-2	-1	0	+1
6+	1			1		
7+	2			2		
8+	5			5		
9+	8			6	2	
10+	27		3	23	1	
11+	-					
12+	11		1	6	4	
13+	1			1		
14+	-					
15+	1		1			
Total	56		5	44	7	

Almost all (88%) of these bones from the Cranberry Lake sample had an indistinguishable first annulus and 14% of the fish over the age of 9+ had obscured second annuli.

Bardach (1955) did not observe loss of inner annuli, however, his perch were almost twice as long at age 1 as the perch in this study. Greater fish size at formation of the first annulus would move the annulus farther from the bone origin where it would be less susceptible to being obscured from thickening of the bone. In addition, the majority of Bardach's fish were less than 5 years of age. European workers have frequently reported problems with indistinct or obscured first annuli (Le Cren, 1947; Chugunova, 1963; Alm, 1946; Neumann, 1976) but no specific reports of obscured second and third annuli have been made. Fish studied in these latter cases have been younger than the older fish in my study.

Neuman also reported difficulties interpreting diffuse lines on the opercula and eliminated almost 15% (over 500 perch) of his total sample because of this problem. No specimens in my study had faint lines on the opercula which were not clearly distinct from the true annuli.

The disadvantages of using the operculum to age perch include:

1. it cannot be removed from fish intended for release.
2. thickness of the bone base in larger and/or older perch may partially or completely obscure some earlier annuli.

The advantages of aging perch using this bone are:

1. it is easy to remove, clean and handle.

2. provided the average growth in a sample of perch has been consistent, the size of the operculum at formation of the first and second annulus could be measured and used to account for obscured annuli when aging older perch.
3. the outermost annuli are generally distinct.
4. thin lines which might be considered false annuli are relatively easy to separate from true annuli.

Cleithra - Perch could not be satisfactorily aged using this bone (Tables 2.06 and 2.07). Of the three parts of the structure examined, the heel of the cleithrum provided the best correlation to the assigned age of the fish. However, interpretation of some bones was difficult due to the thickness of the bone and concealment of some annuli. Only ten percent of the cleithra from perch caught in Pine Lake showed the same number of annuli on the heel as the assigned age. In most older fish annuli near the origin of the heel were obscured. It was often not possible to follow an annulus from one side of the heel to the other. Only portions of the annuli could be seen where good light penetration occurred and caused the annuli to appear as darker bands (Plate 2.05).

By comparison, 55% of the annuli counts on the cleithrum heel differed from the assigned age by one year in the sample of perch from Cranberry Lake. An additional 34% of these fish showed two or three fewer annuli on the heel of the cleithrum than the assigned age. Almost 95% of the Cranberry Lake perch were large female fish.

Table 2.06. Comparison of the number of visible annuli on the heel, elbow and shaft of the cleithrum to the assigned age of perch from Pine Lake.

		Difference in the Annuli Count														
		Heel Area					Elbow Area					Shaft Area				
Age	N	>-2	-2	-1	0	NA*	>-2	-2	-1	0	NA*	>-2	-2	-1	0	NA*
1+	8				8					6	2				1	7
2+	8			4	4				7	1				2	2	4
3+	23		1	21	1			10	13				5	14	1	3
4+	4			4				1	3					4		
5+	2			1		1		1			1			1		1
6+	1					1					1					1
7+	4			4				2	2						4	
8+	1		1							1			1			
9+	10		2	8			2	4	3		1		2	7		1
10+	6			6			2	1	3				2	3		1
11+	83	8	27	42	3	3	35	27	18		3	8	34	22		17
12+	4		2	2			2	2				1	2			1
13+	2	1		1			2					1				1
Total	156	9	33	93	16	5	43	48	49	8	8	10	46	53	8	39

*NA - not available for comparison.

Table 2.07. Comparison of the number of visible annuli on the heel, elbow and shaft of the cleithrum to the assigned age of perch from Cranberry Lake.

		Difference in the Annuli Count											
		Heel Area				Elbow Area				Shaft Area			
Age	N	>-2	-2	-1	0	>-2	-2	-1	0	>-2	-2	-1	0
6+	1		1				1					1	
7+	2			1	1		1	1			1	1	
8+	5		1	3	1	1	3	1			5		
9+	8	1		7			6	2			3	5	
10+	27	1	5	17	4	2	15	9	1	1	14	10	2
11+	-												
12+	11	3	5	3		7	4			8		2	1
13+	1	1				1				1			
14+	-												
15+	1	1				1				1			
Total	56	7	12	31	6	12	30	13	1	11	23	19	3

The elbow area was the least satisfactory of the three locations on the cleithrum where annuli could be counted. The amount of bone thickening in the elbow area was quite variable and appeared to depend on the particular growth of the bone in each fish. This area also grows the least overall hence successive annuli are very thin and crowded together in older fish (Plate 2.06). Ages determined using this part of the bone on fish from Pine Lake showed that approximately 30% of the samples fell into each category of one, two, or more than two fewer distinct annuli than the assigned age of the fish (Table 2.06). Similar scattered results occurred with the Cranberry Lake sample (Table 2.07).

Thirty-seven and thirty-four percent respectively, of the cleithra from perch collected in Pine and Cranberry Lakes showed one less annulus on the cleithrum shaft than the assigned age (Tables 2.06 and 2.07). Twenty-nine and forty-one percent respectively, of these same samples showed two fewer annuli than the assigned age. In addition to these inconsistent results, the thin structure of this portion of the bone lead to significant numbers shattering during processing. This was particularly true in the smaller perch from Pine Lake where 25% of all the samples were damaged during removal, cleaning and storage. Also, annuli near the origin of the shaft were obscured by bone growth and thickening. Later outer annuli were somewhat difficult to read due to crowding, the complex shape of the bone and its thinness (Plate 2.06). The latter gave rise to possible false annuli where sharp lines appeared on part of the bone.

As can be seen from these results, the cleithrum is not a particularly useful bone for aging perch. The disadvantages include:

1. the fish must be killed.
2. the bone is difficult to remove without shattering.
3. early annuli may be totally obscured by subsequent growth and thickening of the bone.
4. annuli are not very distinct and often cannot be followed across the entire face of each bone part.
5. a consistent number of annuli are not distinctly visible on any one part of the bone for fish of apparently the same age.

There are no advantages to using this bone.

Dorsal fin spine sections - The data in Table 2.08 show that aging results are not as accurate or consistent when using these bones as compared to anal spine sections. Only 51% of the sections of the spines from the first dorsal fin of perch from Pine Lake showed the same number of annuli as the assigned age compared to 88% agreement for the anal spine sections. Another 38% of the ages determined for the perch from Pine Lake differed from the assigned age by one year. The discrepancy was most apparent in fish over the age of 7+ but the results have been biased by the large number of 11+ fish. The two main causes of the difference in the number of visible annuli were loss of the inner annuli and crowding of the outer annuli. A cross-section of two dorsal fin spines from a 7+ perch is shown in Plate 2.07. The characteristically dark line of the first annulus in the anterior ray has been replaced by

Table 2.08. Comparison of the number of visible annuli on sections of the dorsal fin spines to the assigned age of perch from Pine Lake.

		Difference in the Annuli Count					
Age	N	>-2	-2	-1	0	1	NA*
1+	8				8		
2+	8				6		2
3+	23			10	13		
4+	4				3		1
5+	2				2		
6+	1				1		
7+	4				4		
8+	1		1				
9+	10			4	5		1
10+	6			1	4	1	
11+	83	2	10	39	31		1
12+	4	1		3			
13+	2		2				
Total	156	3	13	57	77	1	5

*NA - not available for comparison.

the light triangular shaped area which appeared to be characteristic of a lost annulus. The annuli are nicely separated in this example but in older fish or sections taken farther from the base, a greater degree of crowding is evident. This could sometimes be alleviated by switching to transmitted light. However, the closeness of the annuli usually resulted in the appearance of a general light band around the outside of the fin and individual annuli could not be discerned. A problem was also evident with the spines from smaller fish where the vibration of the jewellers saw partially or completely shattered the section being cut.

The larger and faster growing Cranberry Lake perch showed more distinctive separation of the annuli and 73% of the sample agreed with the assigned age of the fish (Table 2.09).

The disadvantages of using the dorsal fin spine sections include:

1. it is not desirable to split the fin of live specimens in order to get the larger spines in the middle of the fin.
2. some cracking of the spines occurred during their removal with side-cutter pliers.
3. the spines are not as symmetrical as the anal spines.
4. the dorsal fin spines are smaller than the anal fin spines thus reducing the distances between successive annuli and making them more difficult to count.

There are no advantages to using this bone over anal spine sections. One minor advantage to using the dorsal spines rather than the operculum for 4+ to 7+ fish is that the first few annuli may be more distinct in the cross-sections.

Table 2.09. Comparison of the number of visible annuli on sections of the dorsal fin spines to the assigned age of perch from Cranberry Lake.

		Difference in the Annuli Count			
Age	N	> -2	-2	-1	0
6+	1				1
7+	2				2
8+	5			1	4
9+	8			3	5
10+	27		1	3	23
11+	-				
12+	11	1	2	2	6
13+	1		1		
14+	-				
15+	1		1		
Total	56	1	5	9	41

Pelvic fin sections - The results in Table 2.10 show that 46% of the ages determined from pelvic fin sections for perch from Pine Lake agreed with the assigned age as compared to 88% for the anal spines and 49% for the dorsal spines. Another 39% of the pelvic fin section annuli counts differed from the assigned age by one year. The major problem with these bones was their small size which led to crowded outer annuli. The larger Cranberry Lake perch had bigger rays which were easier to read. Seventy-eight percent of these latter pelvic sections agreed with the assigned age of the perch (Table 2.11).

As expected, the annuli in the pelvic fin sections from the youngest fish were easy to count because the young fish grow faster and there is more distance between consecutive annuli. However, concealment of the first annulus on all soft rays can occur in relatively young fish. This is due to the small size and different shape of the these rays. Instead of having a circular shaped annulus like the spine, the annulus pattern in the soft rays is axe-head shaped. The first annulus is visible in three rays of a 1+ perch (Plate 2.08). It is clearly discernible in the spine but is only very faintly visible in the rays of a perch having just formed its fourth annulus (Plate 2.09). In the soft pelvic rays the first annulus appears as a very small bud and is obviously much harder to find in older than in younger perch. This can lead to a one year discrepancy between the number of annuli visible on the spine and soft pelvic fin rays.

Table 2.10. Comparison of the number of visible annuli on sections of the pelvic fin spine to the assigned age of perch from Pine Lake.

		Difference in the Annuli Count					
Age	N	>-2	-2	-1	0	+1	NA*
1+	8				7	1	
2+	8				8		
3+	23			7	13		3
4+	4				3		1
5+	2			1	1		
6+	1				1		
7+	4			1	3		
8+	1			1			
9+	10			3	7		
10+	6			3	3		
11+	83	6	12	38	26		1
12+	4			4			
13+	2			2			
Total	156	6	12	60	72	1	5

*NA - not available for comparison.

Table 2.11. Comparison of the number of visible annuli on sections of the pelvic fin spine to the assigned age of perch from Cranberry Lake.

		Difference in the Annuli Count		
Age	N	-2	-1	0
6+	1			1
7+	2			2
8+	5			5
9+	8			8
10+	27		6	21
11+	-			
12+	11	3	2	6
13+	1			1
14+	-			
15+	1	1		
Total	56	4	8	44

Loss of the first annulus occurred when sections were cut progressively farther from the base of the pelvic fin. The triangular shaped light band reported as evidence of loss of these annuli in the anal and dorsal spine sections also occurred in sections of the pelvic fin spine.

The disadvantages of using the pelvic fin sections to age yellow perch include:

1. the small rays result in rapid loss of the first annuli and crowded outer annuli.
2. the pelvic fin spine is the only bone which provides good aging opportunities. Its lack of symmetry makes it more difficult to follow annuli around the circumference of the bone than in anal spine sections.

One advantage for using this fin with live fish is that the single spine can be easily removed from the fish without causing apparent excessive damage.

Scales - Significant differences were noted between the age determined from scales and the assigned age of the perch from Pine and Cranberry Lakes. In both cases the scales were counted separately from and before the annuli of the bony structures. As shown in Tables 2.12 and 2.13, 57% of ages determined from scales of the Pine Lake samples agreed with the assigned age compared to only 23% agreement for the Cranberry Lake perch. A further 32% of the Pine Lake samples differed by one year from the assigned age. This figure was 55% for the samples from Cranberry Lake.

Table 2.12. Comparison of the number of visible annuli on the scales to the assigned age of perch from Pine Lake.

Age	N	Difference in the Annuli Count				
		>-2	-2	-1	0	NA*
1+	8				8	
2+	8				8	
3+	23			2	20	1
4+	4				4	
5+	2				2	
6+	1				1	
7+	4			2	2	
8+	1				1	
9+	10			4	6	
10+	6		1	1	4	
11+	83	1	12	37	31	2
12+	4		2	2		
13+	2		1	1		
Total	156	1	16	49	87	3

*NA - not available for comparison.

Table 2.13. Comparison of the number of visible annuli on the scales to the assigned age of perch from Cranberry Lake.

		Difference in the Annuli Count			
Age	N	>-2	-2	-1	0
6+	1			1	
7+		2			2
8+	5		1	2	2
9+	8		2	4	2
10+	27	1	5	19	2
11+	-				
12+	11		1	5	5
13+	1	1			
14+	-				
15+	1	1			
Total	56	3	9	31	13

One of the major difficulties encountered in using the scales to count annuli was the absence of any small fish in the Cranberry Lake sample. Without these fish it is very difficult to develop a good understanding of where the first annulus will occur on any structure used for aging fish. If the first annulus is small and occurs close to the center of a large scale, it can easily be missed (Plate 2.10). The scales from a 1+ Pine Lake perch and a 0+ Clear Lake perch (Plate 2.11) show that the first annulus occurred approximately 0.5 mm from the scale origin. Even with young-of-the-year fish included in the sample, aging with scales was difficult because considerable practice was required to successfully interpret the differences in the circuli.

A second factor affecting the visibility of the annuli on the scales was their thickness. Scales from the larger perch from both lakes were too thick to produce useful reproductions on acetate slides. To get acceptable inner annuli reproduction the roller press tension was too light to reproduce the thinner outer areas of the scales. When tension was increased the outer annuli could be brought into focus. Under this pressure the inner portion of the scale physically destroyed the flat plane of the slide and the scale impression could not be read. This thickness also severely limited the use of a Bausch and Lomb microprojector. With this machine the thickness of the scale centers could partially be overcome by increasing the light intensity. However, the thick central area on the back of the scale was not clear but very bubbly in appearance. This was caused by the closely bunched fibrillar lamellae of the connective tissue which is present under the bony plate

of the scale proper (Everhart and Youngs, 1981). This tissue shows through the scale and makes it difficult to distinguish the early annuli and circuli on the scale face. The problem was greater in the Cranberry Lake fish which had larger and thicker scales than in the perch from Pine Lake.

Another problem which affected the success of determining ages from scales from both perch populations was regeneration of the scales. The degree of regeneration varied from a very small portion of the center of the scale face to an almost complete loss of all the scale circuli. This problem was noted in 42% of the Pine Lake perch and 40% of the Cranberry Lake perch. Usually 1 to 3 scales of the 6 to 10 scales collected were affected. Taking a greater number of scales from each fish would help prevent this from being a problem.

Crowding of outer annuli in older fish also occurred in both populations sampled. This was a greater problem in the Pine Lake perch which were smaller and grew less between successive annuli (Plate 2.10) than the perch from Cranberry Lake. In many cases the yearly growth increment appeared to be about the same width as the annulus.

The advantages of using scales for aging are:

1. a few can be removed from live fish with little damage.
2. they are easy to store.

The disadvantages are:

1. scale regeneration was noted in 40% of the samples.
2. outer annuli in the scales from older fish can be crowded together and be difficult to interpret.
3. the first annulus may not be easily distinguishable.

4. thickness of the central scale area may obscure annuli and prevent the use of mechanical aging aids.
5. it is more difficult and takes more time to develop confidence using scales as opposed to bony parts to age perch.
6. it is easier to teach someone to age perch using the bony structures.

Otoliths - Although it was possible to age young perch using the whole otolith, this did not remain true for older fish due to the thick centers and minimal annual growth shown on the outside edges of this bone. The number of annuli on sections cut from otoliths held in 24 hour epoxy did provide good agreement with the assigned ages (Table 2.14). Whole and sectioned otoliths show a central kernal of dense matter surrounded by a transparent ring before the first annulus. This is evident in the otoliths from a 0+ and a 1+ perch which are compared in Plate 2.12 and in the otolith section from the 1+ perch (Plate 2.13). Chugunova (1963) previously described this feature of fish otoliths. Regardless of age, usually only one otolith section clearly displayed the maximum number of annuli because the small size of the otolith restricted the number of sections which could be cut from the central area of each bone.

The major problem encountered with sectioning was cracking or splitting of the otolith (Plate 2.14). This occurred in at least a few sections of every bone that was cut. In some cases the cracks would run parallel to the annuli and appear as an annulus. These could be distinguished from the true annuli by slowly switching from reflected to

Table 2.14. Comparison of the number of visible annuli on sections of the otolith to the assigned age of perch from Pine Lake.

Age	N	Difference in the Annuli Count		
		-2	-1	0
1+	5			5
2+	4			4
3+	5		1	4
4+	3			3
5+	2			2
6+	1			1
7+	4			4
8+	1			1
9+	6			6
10+	1			1
11+	12		3	9
12+	2			2
13+	1			1
Total	47		4	43

transmitted light and by following each annulus along the outside edge of the otolith.

The only advantage to using otolith sections is that once they are prepared the sections are relatively easy to read.

The disadvantages include:

1. they are difficult to remove from the fish.
2. they are fragile and tend to crack during storage and sectioning.
3. acceptable sections were very difficult to make with the hand held jewellers saw despite the epoxy matrix.
4. only one or at most two sections will show the maximum number of true annuli because of cracking and the small size of the otolith.

<u>Dentary bones</u> - As with other major structural bones, the great increase in size of the perch after the first year apparently results in the first annulus being lost into the general foundation of the dentary bone (Table 2.15). Although this sample is obviously biased for the younger fish, it is important to note that loss of the first annulus from the operculum also occurs in young fish. In the single 10+ perch collected in this sample, 8 annuli could be distinguished on the dentary bone. Crowding of outer annuli appeared to be a problem in older fish.

There are no advantages to using the dentary bone over other structural bones.

The disadvantages include:

1. it is more difficult to remove than the operculum.

Table 2.15. Comparison of the number of visible annuli on the dentary bone to the assigned age of perch from Pine Lake.

Age	N	Difference in the Annuli Count -2	-1	0
2+	1		1	
3+	35	3	32	
4+	3	1	2	
10+	1	1		
Total	40	5	35	

Table 2.16. Comparison of the number of visible annuli on the preoperculum to the assigned age of perch from Pine Lake

Age	N	Difference in the Annuli Count -2	-1	0
2+	1		1	
3+	35		35	
4+	1	1	2	
10+	1		1	
Total	40	1	39	

2. its smaller size results in more crowding of the outer annuli than on the operculum.

Preoperculum - The results of this comparison were very similar to those for the dentary bone sample. Although it is apparent that the growth of young fish quickly obscures the first annulus (Table 2.16), the growth pattern of the bone in older fish makes it difficult to discern all the annuli. Annuli can be counted along the dorso-ventral axis of the bone because sufficient expansion of the bone occurs during growth to separate the annuli. The anterior-posterior axis of the bone does not have this same degree of expansion and many annuli cannot be distinguished.

There are no advantages to using this bone over other structural bones.

The disadvantages are the same as stated for dentary bones.

Cross-sections of the anal spines and otoliths had the highest correlations between the number of visible annuli on each structure and the previously determined age of the perch (Table 2.17). However, the difficulty and time required to produce the otolith sections outweighed their usefulness since they were no better than the anal spine sections. The sections of pelvic and dorsal fin spines provided variable agreement depending on the growth rate of the fish. The annuli were more crowded in the smaller fish from Pine

Table 2.17. Percentage agreement between the assigned age and the number of visible annuli on the various structures used to age perch from Pine (P) and Cranberry (C) Lakes.

			Difference in the Annuli Count (%)				
Structure	Lake	N	>-1	1	0	+1	NA*
Anal spines	P	156		5.7	89.1		5.2
	C	56		5.4	92.9		1.7
Operculum	P	156	13.5	72.4	14.1		
	C	56	8.9	78.6	12.5		
Cleithrum (heel)	P	156	26.9	59.6	10.3		3.2
	C	56	33.9	55.4	10.7		
Cleithrum (elbow)	P	156	58.3	31.4	5.1		5.2
	C	56	75.0	23.2	1.8		
Cleithrum (shaft)	P	156	35.9	36.5	2.6		25.0
	C	56	60.7	33.9	5.4		
Spiny dorsal fin	P	156	16.7	36.5	49.4	0.6	3.8
	C	56	10.7	15.1	73.2		
Pelvic spine	P	156	11.5	38.5	46.2	0.6	3.2
	C	56	7.1	14.3	78.6		
Scales	P	156	10.9	31.4	55.8		1.9
	C	56	21.4	55.4	23.2		
Otolith	P	47		8.5	91.5		
Dentary	P	40	12.5	87.5			
Preoperculum	P	40	2.5	97.5			

*NA - not available for comparison.

Lake and the agreement was much lower than for the larger, faster growing Cranberry Lake perch. The operculum was a useful aging structure because it showed a consistent concealment of annuli. However, if the fish were older than 6 the obscuration of more than one annulus reduced the effectiveness of the structure for back-calculating growth. The dentary bone and preoperculum produced similar results but the sample was too biased with young fish to provide a reasonable assessment. As they are more difficult to remove and read than the operculum there is no advantage to using these bones. The ages determined from perch cleithra and scales were too erratic to be an acceptable aging technique for the fish studied. Scales could be acceptable for populations of relatively young fish but the problems of regeneration, resorption, false annuli and the difficulty in counting annuli makes them less reliable than anal spines or opercula.

2.3b Annulus Formation

No new annulus formation was recorded in yellow perch from Pine Lake captured in late fall prior to freeze-up (1979 and 1980) or in spring just prior to and immediately after ice-out (April 19, 1979, and May 6, 1980 respectively). A very narrow transparent band was visible on the outside edge of the opercula from the latter two samples. A similar description of pre-annulus formation on these bones was given by Bardach (1955) and Le Cren (1947) but they did not consider the annulus to be formed until the new opaque growth band was evident on the bone.

By May 16, 1980, the narrow transparent band was quite visible and it appeared that most fish were about to form their new annulus. Only six ripe males actually showed a very small amount of new growth. The youngest of these fish had just formed its third annulus. The other five fish had formed their fourth annuli (Table 2.18). The majority of the 3+, 4+, and 7+ fish captured May 16 had not formed their new annuli. It is quite likely that if fish younger than age 3 had been captured, at least some of them would have already formed a new annulus. Annulus formation by the youngest fish first has been noted by Clugston et al (1978) and Joeris (1956). In these studies of South Carolina and Michigan perch populations it appears that an early spring contributes to a greater separation between young and old fish in the timing of annulus formation. Joeris also reported that his Marinette Lake stock did not show any relationship between timing of annulus formation and fish age or sexual maturity in 1952 when an early spring did not occur. Jobes (1952) reported similar findings for perch in Lake Erie. Fish populations in central Alberta probably follow the latter scenario because our growing seasons (average 5 months) are short. Spawning takes place almost immediately after ice-out and all the fish have similar growing periods. All Pine Lake perch up to age 8 had formed their new annuli by May 28. Annulus formation in thirty-one older perch (10+, 11+, 12+, 13+ and 14+) occurred between June 11 and June 19, 1980. It is possible that larger fish require a greater metabolic input than small fish each spring before new growth occurs. In the largest fish a delay in annulus formation thus occurs until sufficient food to provide that energy has been obtained.

Table 2.18. Time of annulus formation in yellow perch from Pine Lake, spring 1980.

Date	Number of perch with no new annulus (eg. 1+) and with the new annulus formed (eg. 2) by year class.															
	0+	1	1+	2	2+	3	3+	4	4+	5	5+	6	6+	7	7+	8
May 6			5		10		80		9							
May 16						1	21	5	5						2	
May 28		50		14		11		17		7		1		1		
June 6		4		6		4		1								
June 11								6		7						
June 19						4		21		3						

Perch captured at Clear Lake showed that annulus formation occurred in the 1, 2, 3, and 4 year old fish between May 20 and June 17, 1980. One 5+ and one 6+ fish had not formed their new annuli on the latter date.

The annulus formation dates cited in this study are in general agreement with Tanasichuk's (1978) reported dates of May 1 to June 1 in Lac Ste. Anne's one and two year old perch. The dates are a little later than reported for Great Britain (May: Mann, 1978) and the north central United States lakes (April - May: Bardach, 1955; May: Joeris, 1956; April: Jobes, 1952). However, these latter authors have also found variations of up to two months in the timing of annulus formation in different years for the same site. Annulus formation in South Carolina waters could be expected to be more stable. Clugston et al (1978) reported that age 1 perch had finished forming their new annuli by April 15. His age 2 fish were finished by May 15 and all perch age classes had completed annulus formation by June 1.

Annulus formation for most perch in my study did coincide with spawning as the fish were ripe May 16 and spent by May 28, 1980. Only one fish under age 8 had formed a new annulus prior to spawning. This was a ripe age 5+ female perch captured June 11.

2.3c Relationship of Anal Spine Radius to Fork Length

The greater distinction of all annuli on the anal spine sections as opposed to opercula should improve the accuracy of the back-calculated lengths. In addition, all measurements can be made with a dissecting

microscope equipped with an ocular micometer. This avoids the need for projecting devices and filters required for back-calculation of lengths on the operculum.

Plots of anal spine radius versus fork length indicated linear relationships for male and female perch from Pine, Lessard, and Clear Lakes. This is in agreement with Griffiths' (1975) findings for pelvic fin spine sections. Linear relationships have also been reported for opercula (Bardach, 1955) but allometric relationships for opercula are more common (Le Cren, 1947; Bardach, 1955; Mann, 1978). Bardach's scale samples were too scattered for him to confidently ascribe any mathematical relationship between scale dimensions and body length.

The initial calculations of the linear equations for relationships between fork length (y, in mm) and radius of the first anal spine (x, in mm) by the least squares method produced the following results:

Pine Lake	females	$y = 132.31\,x + 79.7$
		($N = 63$, $r = 0.79$, $p < 0.001$)
	males	$y = 152.12\,x + 67.8$
		($N = 46$, $r = 0.91$, $p < 0.001$)
Lessard Lake	females	$y = 259.05\,x + 57.7$
		($N = 64$, $r = 0.89$, $p < 0.001$)
	males	$y = 229.51\,x + 46.8$
		($N = 44$, $r = 0.82$, $p < 0.001$)
Clear Lake	sexes combined	$y = 63.61\,x + 118.2$
		($N = 18$, $r = 0.46$, $0.10 > p < 0.05$)

Female and male growth relationships were considered separately when numbers warranted. Sufficient samples were not available to do this with the perch from Clear Lake. The gillnet samples used for these calculations contained very small numbers of 1+ fish from Pine and Clear Lakes. The absence of smaller fish has resulted in higher "y" intercepts than expected for Pine and Clear Lakes. The intercepts for Pine Lake perch are greater than the size of the 0+ fish captured so no back-calculation to age 1 could be made. The Clear Lake "y" intercept of 118.21 is so large that it prevents back-calculation of length to age 3. This represents a loss of more than 50% of the possible sample data since no fish older than age 6+ were captured during the study.

To overcome this problem, I examined the distance in mm from the origin to the first annulus on the anal spine sections of the Clear Lake fish and three Pine Lake samples collected in the fall of 1980. There was no significant difference in the measured distance from the origin to the first annulus in the perch collected from Clear Lake (Oct. 10 and 15, 1980) and Pine Lake (September 11, 17, and 23, 1980) (Table 2.19). In addition, there was apparently little difference in the growth of 0+ perch from these two lakes. These factors suggested that a sample of one year old fish from either lake could be measured to provide additional data points for both lakes. Twenty-two immature perch captured in Pine Lake on May 28, 1980, were selected. These fish had just formed their first annulus. The additional data points were added to the Pine and Clear Lake samples only. They were not added to the Lessard Lake samples

Table 2.19. Comparison of the measured distance (mm) from the origin to the first annulus on the anal spine cross-sections.

Samples	Date	N	$\overline{x}$	s^2
A. Clear Lake	Oct. 1980	18	0.112	0.00047
B. Pine Lake	Sept. 11, 1980	51	0.107	0.00050
C. Pine Lake	Sept. 17, 1980	34	0.114	0.00043
D. Pine Lake	Sept. 23, 1980	24	0.106	0.00023

Sample Comparison	F Test	d.f.	Significant difference at 95% level
A to B	passed	67	no
A to C	passed	50	no
A to D	passed	40	no
B to C	passed	83	no
B to D	failed	63.5	no
C to D	passed	56	no

because these latter fish were significantly larger than fish from Pine and Clear Lakes at the end of their first year and thus a different body structure to body length relationship was expected.

The additional data points, which were clustered around the 65 mm fork length, did not change the linear relationship of the anal spine radii versus fork length. The modified least squares equations were:

Pine Lake	females	$y = 177.10\ x + 47.18$
		$(N = 85,\ r = 0.95,\ p < 0.001)$
	males	$y = 177.00\ x + 45.25$
		$(N = 68,\ r = 0.97,\ p < 0.001)$
Clear Lake	sexes combined	$y = 186.99\ x + 46.49$
		$(N = 40,\ r = 0.89,\ p < 0.001)$

Although the additional twenty-two points were not added to the Lessard Lake sample, they would have fallen on the existing linear line. This indicates a similar anal spine section radius to body fork length relationship between the three populations for fish of this size.

Comparison of the anal spine radius-fork length relationships (Figure 2.02) by analysis of covariance (Table 2.20) indicated no statistical difference ($p > 0.01$) between the regression lines calculated for male and female Pine Lake perch. The regression line for the combined Pine Lake perch data was:

$$y = 177.37\ x + 46.18$$

$$(N = 153,\ r = 0.96,\ p < 0.001)$$

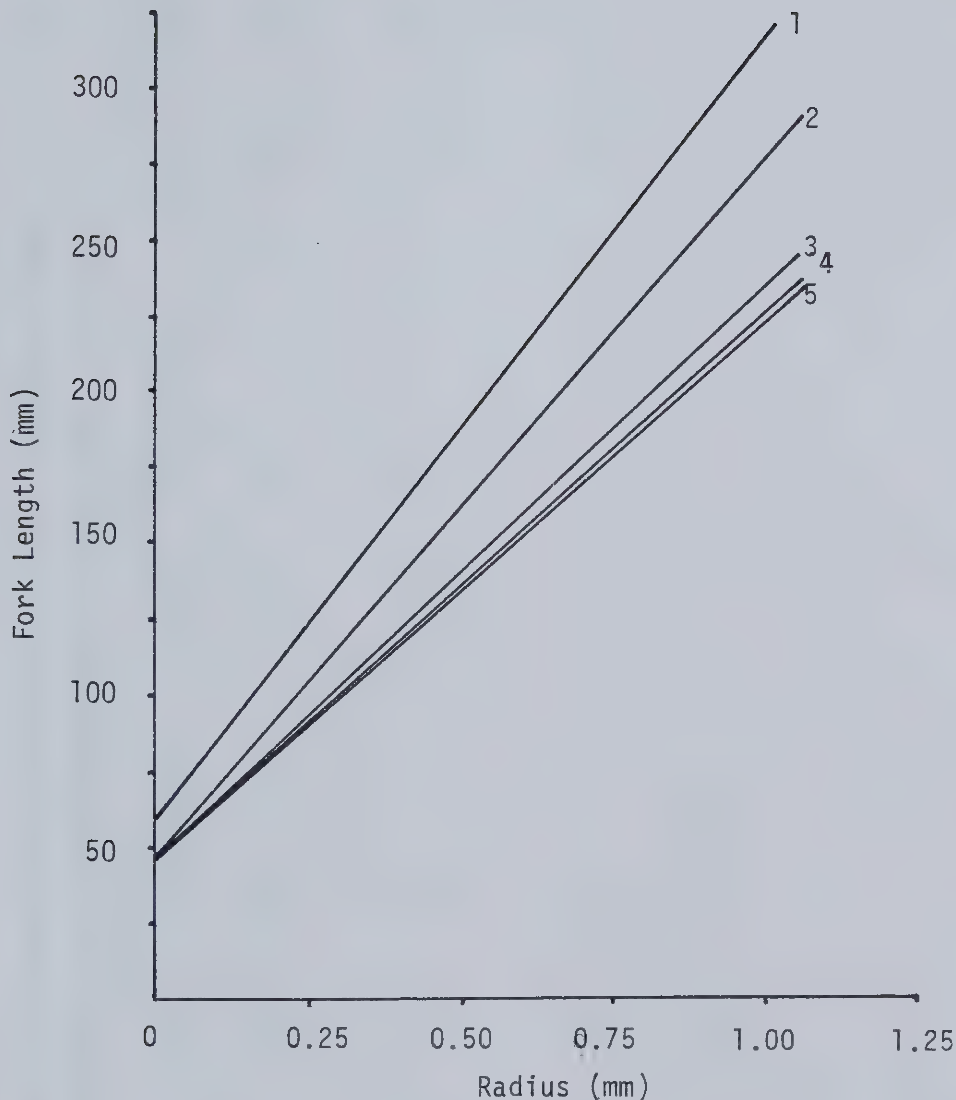

Figure 2.02. Relationship of fork length to the radius of the anal spine in female (1) and male (2) perch from Lessard, female and male perch from Clear (3), and female (4) and male (5) perch from Pine Lakes respectively.

Table 2.20. Occurrence of significant differences between anal spine radius - fork length linear relationships. Comparisons were made by analysis of covariance.

	Variances		Slopes		Elevations	
Test Comparisons	Test F	Significant	Test F	Significant	Test F	Significant
Pine L. females vs. Pine L. males	1.59	No	0.01	No	0.69	No
Lessard L. females vs. Lessard L. males	1.02	No	0.98	No	27.27	Yes $p < 0.01$
Pine L. combined vs. Lessard L. males	2.37	Yes $p<0.01$				
Pine L. combined vs. Lessard L. females	2.41	Yes $p<0.01$				

continued

Table 2.20 continued. Occurrence of significant differences between anal spine radius - fork length linear relationships. Comparisons were made by analysis of covariance.

	Variances		Slopes		Elevations	
Test Comparisons	Test F	Significant	Test F	Significant	Test F	Significant
Pine L. combined vs. Clear L. combined	1.93	Yes $p<0.01$				
Clear L. combined vs. Lessard L. males	1.23	No	2.20	No	11.26	Yes $p<0.01$
Clear L. combined vs. Lessard L. females	1.25	No	9.70	Yes $p<0.01$		

The Clear Lake regression line appears to be very similar to the Pine Lake lines; however, statistical comparisons could not be made because the variances were not homogeneous. The lack of variance homogeneity prevented reliable statistical comparisons of the Pine and Lessard Lake lines.

The regression lines for the male and female Lessard Lake perch have statistically similar slopes ($p > 0.05$) but not elevations ($p < 0.01$). The statistical tests indicated similar slopes for the male Lessard Lake perch and the Clear Lake perch, but the elevations were different ($p < 0.01$). The slope similarity was probably due to the addition of the one year old samples to the Clear Lake regression data and the small number of older Clear Lake perch available. Comparison of the Lessard Lake male data and the original Clear Lake sample (N = 18) indicated statistically different slopes of the regression lines ($p < 0.01$).

The results of the comparisons of the regression lines are not conclusive but do support the argument for development of unique regression lines from empirical sample data.

2.4 Summary

Initial attempts to age yellow perch using the left operculum were not entirely successful due to the almost universal loss of inner annuli. It is believed these annuli became obscured as the fish grew in size and the thickness of the bone increased. A comparison of nine body structures revealed that sections of the anal spines provided the most

accurate and practical aging technique. Use of anal spine sections and opercula in combination provided the most satisfactory aging results. Despite being the standard North American method, ages obtained from scales were shown to be reliable only for the younger fish. Interpretation of scales from fish older than 6 years became difficult and time consuming due to obscuration of inner annuli and crowding of outer annuli.

Annulus formation in Pine Lake perch occurred between May 16 and May 28, 1980. It occurred at the same time as spawning. No significant difference was noted in the timing of annulus formation in yellow perch between the ages of 1 and 7 years. Lack of earlier annulus formation in younger fish was attributed to Alberta's short open water season.

Linear regressions with high correlations were found by the least squares method for five anal spine radius versus body fork length relationships. Analysis of the lines by covariance indicated that each line was best described by the empirical data for that relationship.

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Chapter 3. GROWTH OF YELLOW PERCH

3.1 Introduction

Despite the highly variable growth rates exhibited by various yellow and European perch populations, the fish have very similar beginnings (Le Cren, 1951; Scott and Crossman, 1973; Thorpe, 1977a). Adult perch spawn in the spring when water temperatures approach 8 - 10 C. Several males usually spawn with each female whose fertilized eggs remain attached to one another in a unique hollow mucilaginous sheath. The egg strand, which is usually attached to submerged vegetation or debris, remains intact until the eggs hatch approximately two weeks after spawning. The emerging fry are only about 6mm in length but move out to the open water column of the lake. They remain pelagic until midsummer when they return to the littoral area of the lake. Growth of these young of the year perch is quite similar in localized areas, even where large differences in the maximum size of the adult fish occurs. The growth is also considered to be independent of the size or strength of the new year-class (Paxton et al, 1981; Schneider, 1972).

The typical rapid initial rate of growth of the fish progressively declines in subsequent years. Female fish usually grow slightly faster than males and thus attain a larger size (Jobes, 1952; Le Cren, 1958). Part of this difference is undoubtedly due to the earlier achievement of sexual maturity in the male fish. Some fish spawn at age 1 although sexual maturation at ages 2-3 is much more common (Clugston et al,

1978; Le Cren, 1951; Mann, 1978; Tarby, 1974). Female perch usually mature one year after the males in any particular population. Later maturation permits some growth advantage as energy which would have been put into reproductive tissue is incorporated into somatic tissue instead.

The annual cycle of development of the reproductive tissue is quite different for male and female perch (Le Cren, 1951; Mann, 1978). Development of the paired testes begins in late summer. By October their weight will represent 5-8% of the total body weight (Turner cited by Hokanson, 1977). This percentage remains very stable through the winter to spawning in the spring. Once maturation occurs in the female perch, the single ovary also begins to develop in late summer and constitutes about 5% of the fish's weight by October (Brazo et al, 1975). Development of the ovary continues over winter becoming 20-25% of the total body weight prior to spawning.

After spawning, the nutrients obtained by the fish through eating are used initially to replace an energy deficit apparently caused by the reproductive function. Le Cren (1951) determined that growth in length did not begin until the mature fish had increased their relative condition factors from 80% to 90-95% of the September maximum value. This occurred about mid-June. Initiation of new growth in approximately 50% of the perch in Lake Memphremagog, Quebec-Vermont, also began in mid-June and took place when the water temperature reached 13 C (Nakashima and Leggett, 1975). Relatively rapid growth occurs during the summer but growth rate declines with cooler temperatures in the fall (Langford and Martin, 1941; Le Cren, 1958; Mann, 1978). These authors

report little over-winter growth. However, Tanasichuk's (1978) samples of young perch from Lac Ste. Anne indicated that significant growth could occur between October and January in 1+ perch and 2+ male perch. Whether these are artifacts due to selective mortality or sampling is not known. The 2+ female perch he caught grew best between June and October. The reduction in growth rate and similarity of the ratio of gonad weight to body weight for male and female perch makes the September to early October period ideal for comparative sampling.

Yellow perch in Canada usually have a slightly shorter maximum life span than the pike, whitefish, and walleye that commonly occur in the same waters. Scott and Crossman (1973) list the usual maximum age of yellow perch at 9-10 years. Lind (1977) states that the maximum age of the closely related European perch is about 20 years while the mean maximum age and mean age are 10-12 and 4-5 years respectively. The preference for use of the scales to age yellow perch may have resulted in underestimates of the ages reached by these fish in North America.

Variations in growth rate and longevity lead to significant differences in the maximum sizes of fish and thus angler attraction. During the winters of 1981-82 and 1982-83 many Alberta anglers travelled significant distances to fish in Laurier Lake where the catch per unit effort was quite high although the fish were not exceptionally large (D. Giggs, pers. comm.). Many of these people lived closer to lakes with small sized perch in them yet the fish were seldom harvested. These small perch are generally assumed to be old, slow growing fish and are commonly referred to as stunted. In at least one of these cases the

small size of the fish is due to a short life span. For example, few perch over the age of 4 are ever captured at Lac Ste. Anne, Alberta (Dr. W.C. Mackay, pers. comm.). It is not known how widespread this phenomenon is in Alberta. Although a considerable number of lakes are known to contain small perch, very few populations have been examined because there is little or no angling or commercial fishing pressure on them.

The perch in at least one of these lakes (Clear Lake) are periodically used to restock other fish-less water bodies. If these fish are slow growing then a reduction in the Clear Lake population could be expected to stimulate growth. The fish being stocked should have a faster growth rate because the small introduced population will likely have a relatively abundant food and habitat base. However, if the fish are short-lived because of genetic factors they may carry this trait to the stocked water body and thus limit development of a new fishery. No follow-up tests have been conducted to determine the long term success of one of these introductions.

The objectives of this part of my study were to:

1. Compare the growth rates of 0+ perch collected from Pine, Ste. Anne, Lessard, Clear and Goose Lakes.
2. Determine the extent of sexual dimorphism in the perch collected.
3. Determine the recent growth histories of year-classes of yellow perch in Pine, Clear (donor population) and Lessard Lakes (stocked with Clear Lake perch in 1976).

4. Compare the growth rates of yellow perch captured in the fall from Pine, Lessard, Clear and Goose Lakes.

3.2 Methods and Materials

Young of the year perch collected throughout the summer during the course of this study and fall and spring samples of older fish, were used to compare growth of perch between sexes and between the study lakes (Chapter 1, Section 1.2).

The Student's T test (Snedecor and Cochran, 1967) was used to compare the growth rates of 0+ perch. The mean length and weight at each age of female and male perch from Pine, Lessard, Clear and Goose Lakes were also compared. The mean fork length, with 95% confidence intervals, of each age class was plotted on graph paper and the points were joined by a smooth curved line to approximate the growth curve. Data points for the fish were plotted at three-quarters of the distance between the ages noted on the x-axis in order to recognize that completion of most of the growth in length had occurred by the time the fall samples were obtained. For example, if a 2+ perch collected in October had a mean length of 120mm, this was plotted at age 2.75. Although this fish would chronologically be 2.4 years old, most of the growth in length had occurred by fall. This shifting of the position of the data points provides a truer picture of the growth of these fish than provided by plotting the chronological age.

Fork length at previous annulus formation was calculated for Pine, Lessard, and Clear Lake samples using the formula (Everhart and Youngs, 1981):

$$L' = C + \frac{S'}{S}(L-C)$$

where: L' = fork length when annulus X formed,

C = an empirically determined correction factor,

S' = distance from origin to annulus X on the aging structure,

S = total length of the aging structure, and

L = fork length of the fish when sampled.

The correction factor for each fish population had previously been determined by linear regression (Chapter 2, Section 2.3c). Anal fin spine radial distances were measured with a Wild M5 dissecting microscope equipped with an ocular micrometer. The length of each fish at the time of formation of each annulus was then calculated. The individual data points for each age class were then combined to determine the mean and 95% confidence limits.

Between population comparisons of female and male perch growth rates were made using log-log transformations of the age versus length and length versus weight data. Logarithims to the base 10 were used in this study. Only fall and spring data and back-calculated lengths at annulus formation were used for this comparison. Samples collected during the summer when growth was most rapid were not used in order to avoid artifically causing excessive variations in the data groups.

Ages of spring-sampled and back-calculated fish were assigned as occurring at the time of annulus formation. The late September-early October samples were considered to occur at four-tenths of the actual year assuming that annulus formation occurred about May 21. A 5+ perch was therefore given age 5.4 for the linear regression calculation. This arbitrary method is not as desirable as assigning age on the basis of the amount of yearly growth completed. I considered it to be the most valid procedure in this study because I could not precisely define the percentage of growth completed at any time for all the samples. In addition, future studies may be comprised of samples collected at some other time of the year and probably the amount of growth completed will also not be accurately known. Analysis of covariance (Snedecor and Cochran, 1967) was used to compare the growth of female and male fish from each study lake. Comparisons were also made of the growth of the fish of each sex, between each of the lakes examined.

Total, fork and standard lengths were measured for 81 perch from Pine Lake in order to calculate conversion values for comparison with other studies. The measured fish ranged in size from 87 to 279 mm. The linear relationships developed from the data were described by the equations:

1. $FL = 1.133\ SL + 1.754$,

   $(N = 81,\ r = 0.999,\ p < 0.001)$

2. $FL = 0.960\ TL - 0.077$,

   $(N = 81,\ r = 0.999,\ p < 0.001)$

where: FL = fork length (mm),

SL = standard length (mm), and

TL = total length (mm).

3.3 Results and Discussion

3.3a Growth of 0+ Perch

Young-of-the-year yellow perch with a fork length of approximately 20mm first appeared in the littoral areas of the lakes studied, in late June of 1979 and 1980. Significant numbers were not captured by seine until after mid-July although great variability occurred from week to week and between years for the same sampling sites (Tables 3.01, 3.02 and 3.03). The appearance of the young perch in the littoral area corresponds to the metamorphosis from larval to true fingerling stage. The timing of the movement agrees with the findings of Guma'a (1978, Lake Windermere, England), Karas and Neuman (1981, heated Baltic bay, Sweden), Kelso and Ward (1977, West Blue Lake, Manitoba), Spanovskaya and Grygorash (1977, three Moscow area reservoirs, USSR), and Swenson (1977, Lake of the Woods and Shagawa Lake, Minnesota). Spawning at all these sites occurred during the month of May. By comparison, perch populations near the southern limit of their range spawn earlier (mid-March to mid-April) and transformation of the fry from pelagic to littoral habitat occurs in late May to early June (Clugston et al, 1978, Keowee Reservoir, South Carolina).

The occurrence of perch spawning activities over several weeks means that the larger 0+ perch will have become demersal while the younger, smaller fish are still swimming in the open water portion of the lake (Clugston et al, 1978). Samples collected from Clear Lake on July 16 and

Table 3.01. Number, mean fork length (mm) ±95% confidence interval, and average weight (g) of 0+ yellow perch from Lac Ste. Anne. The number of released fish is noted in brackets.

Date	Number Examined	Mean Fork Length	Average Weight
June 30/79	21	20.6 ± 0.3	-
July 22/79	4	26.3 ± 4.2	-
Aug. 18/79	76 (318)	35.6 ± 1.1	0.6
Sept. 15/79	2	48.5	1.5
July 3/80	23	27.7 ± 0.9	0.2
July 9/80	36	30.7 ± 0.5	-
July 16/80	30	34.9 ± 2.4	-
Aug. 19/80	26	44.2 ± 1.4	1.1
Sept. 9/80	30	47.9 ± 1.2	1.2
Sept. 16/80	14	52.1 ± 4.1	1.5
Sept. 25/80	4	52.3 ± 2.7	1.5
Sept. 30/80	3	47.0 ± 4.3	1.0
Oct. 8/80	30	46.7 ± 0.8	1.1

Table 3.02. Number, mean fork length (mm) ± 95% confidence interval, and average weight (g) of 0+ yellow perch from Clear Lake. The number of released fish is noted in brackets.

Date	Number Examined	Mean Fork Length	Average Weight
June 30/79	1	19	-
July 6/79	2	22.5	-
Aug. 18/79	111 (5430)	39.0 ± 0.8	0.7
Oct. 12/79	79	53.0 ± 1.2	1.7
Nov. 1/79	8	50.8 ± 3.5	-
June 17/80	7	15.9 ± 4.1	0.06
July 3/80	35	23.7 ± 0.8	0.8
July 9/80	64	23.4 ± 1.0	-
July 16/80	43	32.0 ± 1.1	-
July 24/80	56	32.3 ± 1.7	0.5
Aug.19/80	33	41.3 ± 2.0	1.0
Sept. 9/80	29	40.5 ± 1.9	0.7
Oct. 8/80	60	47.8 ± 1.6	1.2

Table 3.03. Number, mean fork length (mm) ± 95% confidence interval, and average weight (g) of 0+ yellow perch from Goose Lake. The number of released fish is noted in brackets.

Date	Number Examined	Mean Fork Length	Average Weight
July 22/79	1	25	-
Aug. 18/79	98	38.5 ±0.9	0.7
Sept. 15/79	86 (3509)	40.3 ±0.9	0.8
July 9/80	46	21.2 ±0.8	-
July 16/80	20	36.5 ±3.1	-
July 24/80	33	34.9 ±2.0	0.7
Aug 19/80	41	44.8 ±1.7	1.3
Sept. 9/80	30	34.1 ±1.8	0.5
Sept. 16/80	30	45.2 ±2.4	1.1
Sept. 25/80	30	39.2 ±1.5	0.7
Oct. 8/80	30	40.4 ±1.0	1.2

August 19, 1980, indicated that 0+ perch in the open water had significantly shorter ($p < 0.05$) fork lengths than littoral zone perch caught on the same dates.

	pelagic	littoral
July 16	$\bar{x} = 20.8 \pm 0.9$ mm	$\bar{x} = 32.0 \pm 1.1$ mm
	N = 25	N = 43
August 19	$\bar{x} = 30.7 \pm 5.2$ mm	$\bar{x} = 41.3 \pm 2.0$ mm
	N = 7	N = 33

Physical deformity that may have been related to late spawning and temperature shock also affected the growth of 0+ perch. A sample of thirteen fish with seriously decurved spinal columns was captured at Lac Ste. Anne on July 9, 1980. They were significantly ($p < 0.01$) smaller ($\bar{x} = 19.3 \pm 0.8$mm) than apparently normal perch captured in the same seine haul ($\bar{x} = 30.7 \pm 0.5$ mm, N = 36). I believe the deformed fish came from one egg mass as they were almost identical in size and appearance and were collected in a very small area.

Good numbers of 0+ perch were usually captured during both open water seasons at Clear, Goose, and Ste. Anne Lakes. Few young of the year perch were ever captured at the Pine Lake sampling site and no 0+ perch were captured at Lessard Lake until October 8, 1980. This lake develops large algal blooms and the single available seining site was at the

bottom of the main bay on the windward side of the lake. During most of the summer this resulted in the presence of heavy concentrations of decaying algae which the perch did not inhabit.

Growth of 0+ perch was quite similar for all the populations studied including the "stunted" perch of Clear Lake and the short-lived perch of Lac Ste. Anne. This is in agreement with other studies which have found that growth of 0+ perch is not generally affected by the presence of older perch (Pycha and Smith, 1954; Schneider, 1972), nor the strength of the 0+ year-class (Paxton et al, 1981; Willemsen, 1977). In this study, 0+ perch reached a fork length of 30 - 35mm by mid-July and 40 - 45mm by mid-August (Tables 3.01, 3.02 and 3.03). At this latter date their average weight was approximately 1 g. As this weight is the same mass as the accuracy of the scale used in the field, it was only possible to obtain grouped weights rather than individual weights for these fish. Young-of-the-year perch had a fork length of 45 - 55mm and a round weight of about 1.5g by the end of September (Figures 3.01, 3.02 and 3.03). However, data from seine hauls is misleading because samples were collected during the course of this work whose mean size and 95% confidence limits could not be fitted into a smooth growth curve of the 0+ fish for that lake (Figures 3.01 and 3.02). This is most evident in the Goose Lake samples (Figure 3.03) where data from 1980 indicate two separate growth curves plus an additional single data point. The discrepancy is believed to be due to the unintentional sampling of young of-the-year perch which probably hatched at different times and were in separate schools in the littoral area. This problem became more apparent

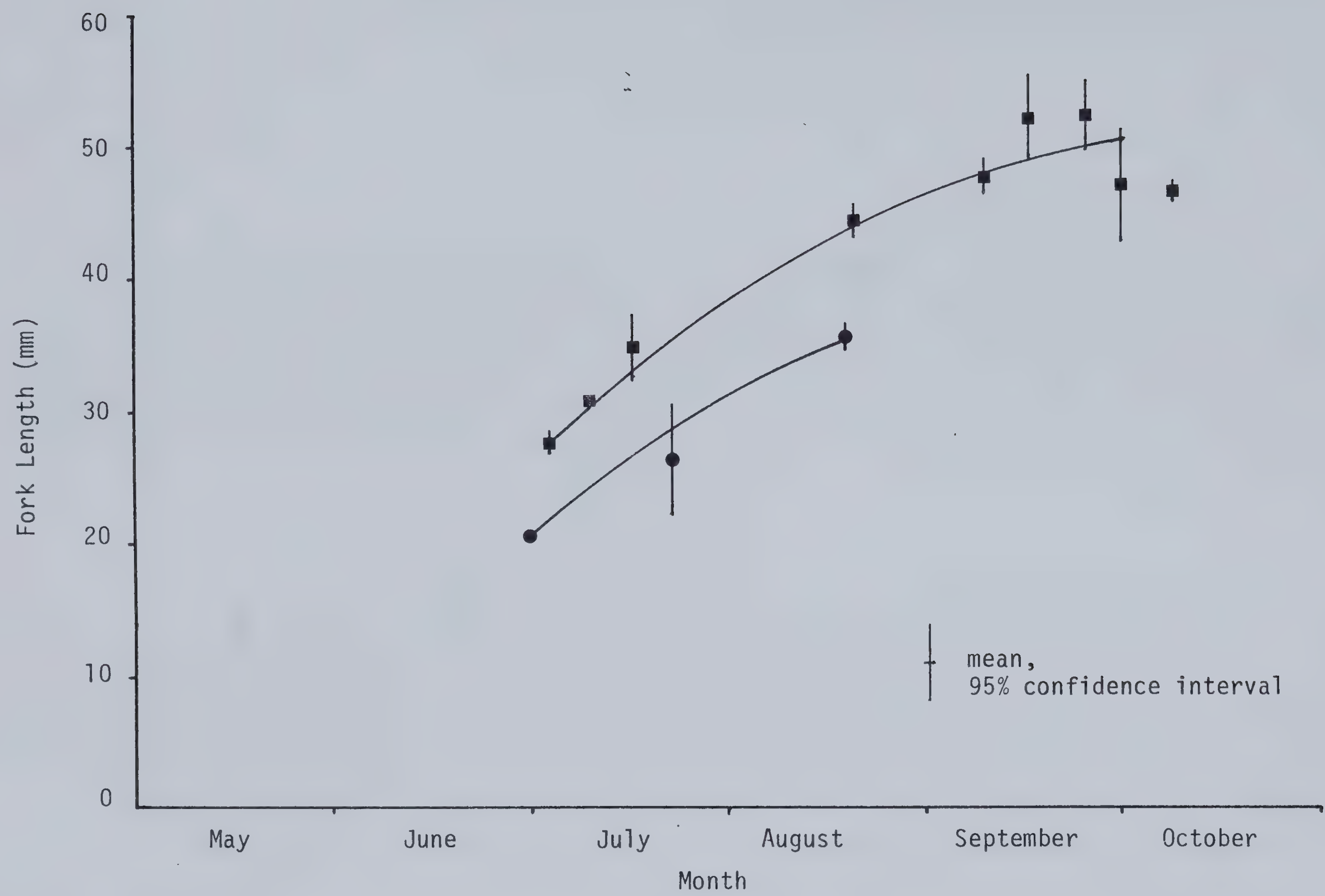


Figure 3.01. Growth in length of 0+ perch from Lac Ste. Anne in 1979(●) and 1980(■).

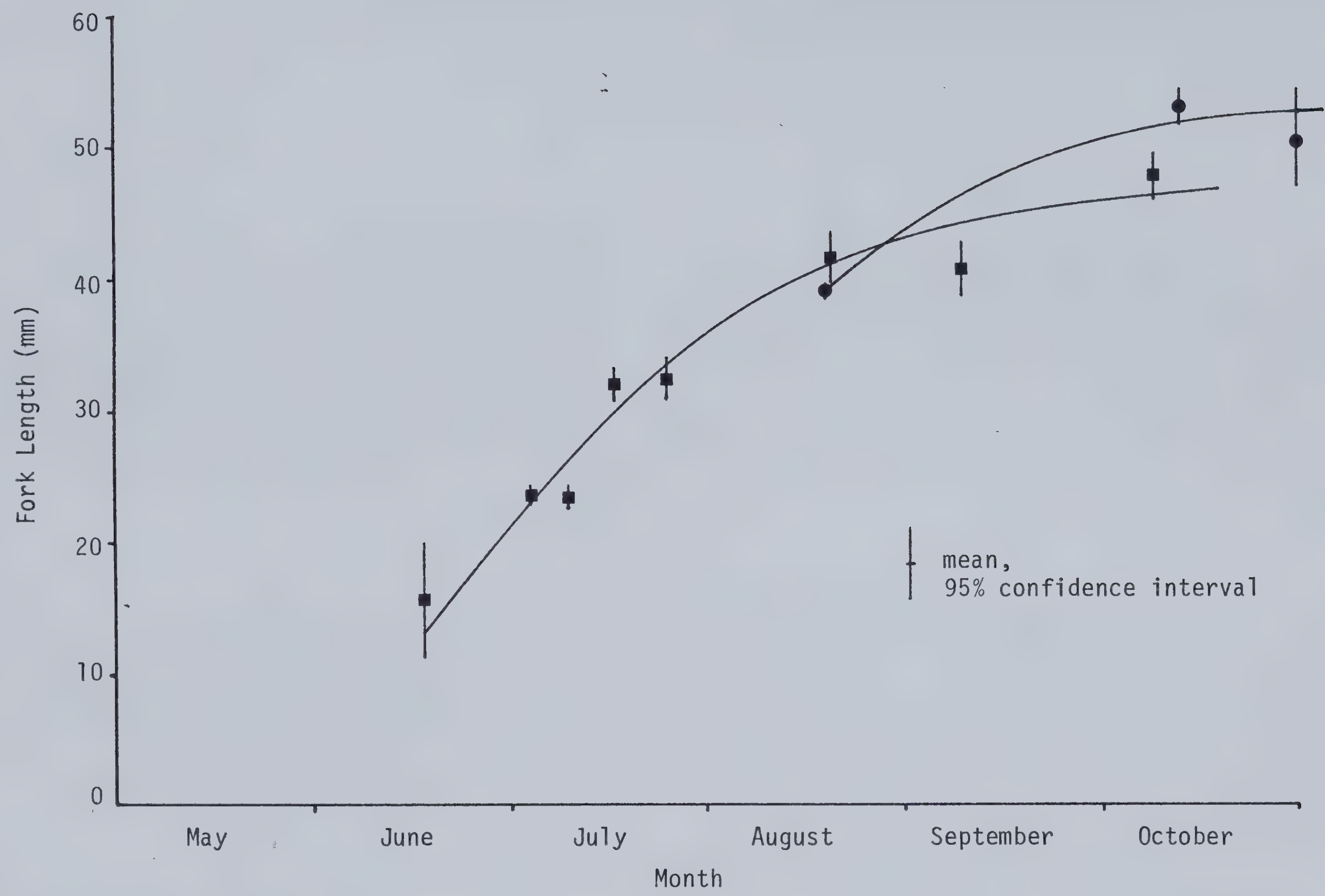


Figure 3.02. Growth in length of 0+ perch from Clear Lake in 1979(●) and 1980(■).

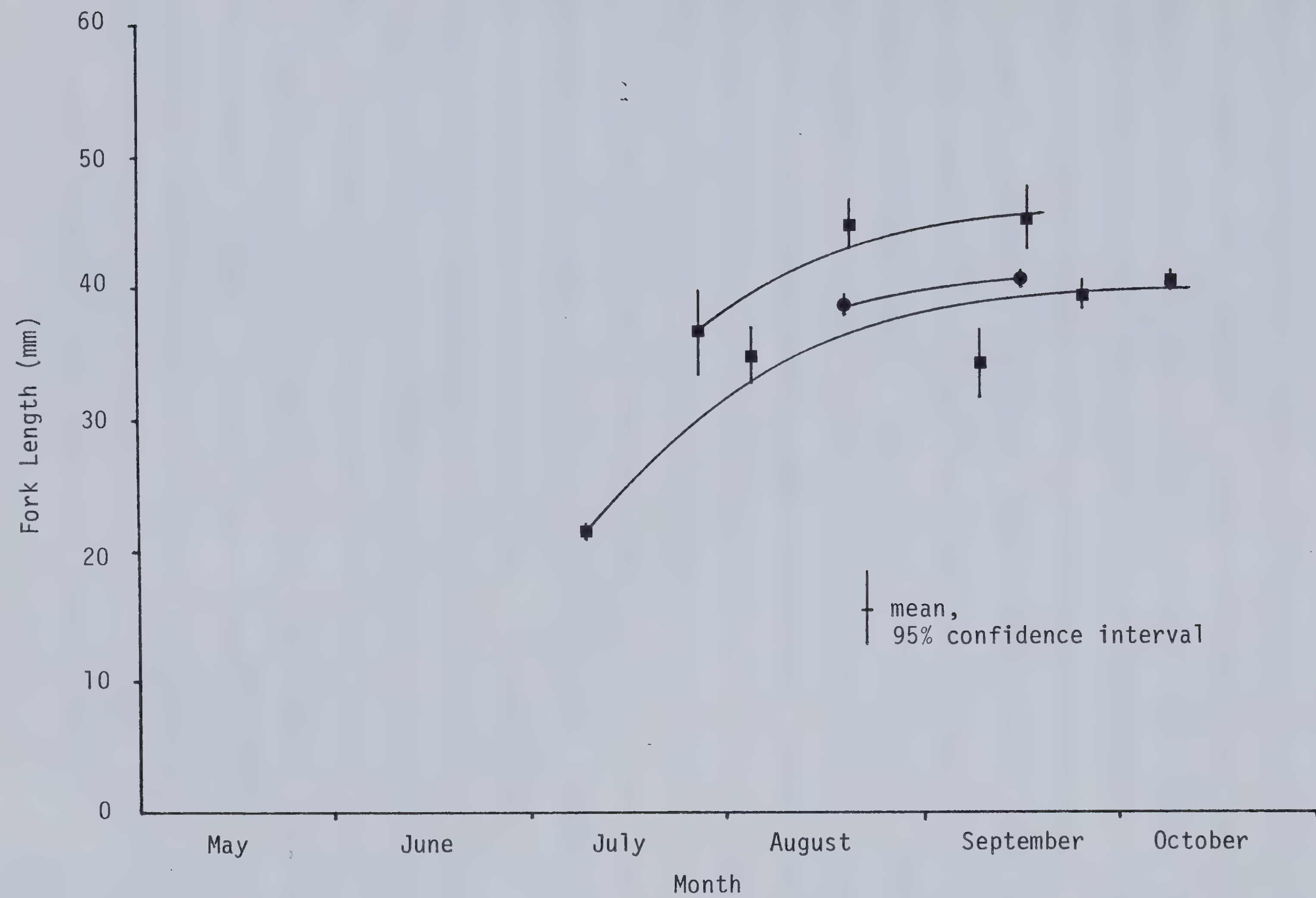


Figure 3.03. Growth in length of 0+ perch from Goose Lake in 1979(●) and 1980(■). The presence of two growth curves and a separate data point from the 1980 samples indicates that different sub-groups were present in the population.

as fall approached when the mean fork length of collected 0+ perch actually began to decline. Since the fish were not physically shrinking it is apparent that the smaller young-of-the-year perch were remaining longer in the shallow littoral area. All perch move to deeper water as winter approaches (Guma'a 1978) and it is not unreasonable to expect the larger fish to move out of their protective summer habitat first.

Further evidence of non-random sampling was evident when comparing sizes of 0+ perch collected from Ste. Anne, Clear and Goose Lakes in 1980 (Figure 3.04, Table 3.04). Seven significant ($p < 0.05$, Student's T test) reversals or changes in order of size occurred in the samples. It is highly unlikely that growth rates and mean fork length would change sufficiently in one week to cause these reversals. It is particularly unlikely that fish would shrink significantly in one week.

Young-of-the-year perch from the short-lived Lac Ste. Anne perch population were generally the largest of the 0+ fish collected although the actual size difference was often slight. Pine Lake perch ($x = 42.8 \pm 2.9$mm, N = 11) collected August 13, 1980, were similar ($p > 0.05$) in fork length to Ste. Anne, Clear and Goose Lake samples collected on August 19, 1980. A September 17, 1980, sample of 0+ perch from Pine Lake ($x = 46.8 \pm 5.1$mm, N = 5) was also similar to the fork length of September 16, 1980, samples collected from Ste. Anne and Goose Lakes. The single sample of 0+ perch captured in Lessard Lake ($x = 59.6 \pm 1.6$mm, N = 17) on October 8, 1980, was significantly ($p < 0.05$) larger than all other 0+ perch samples collected during the fall seining program.

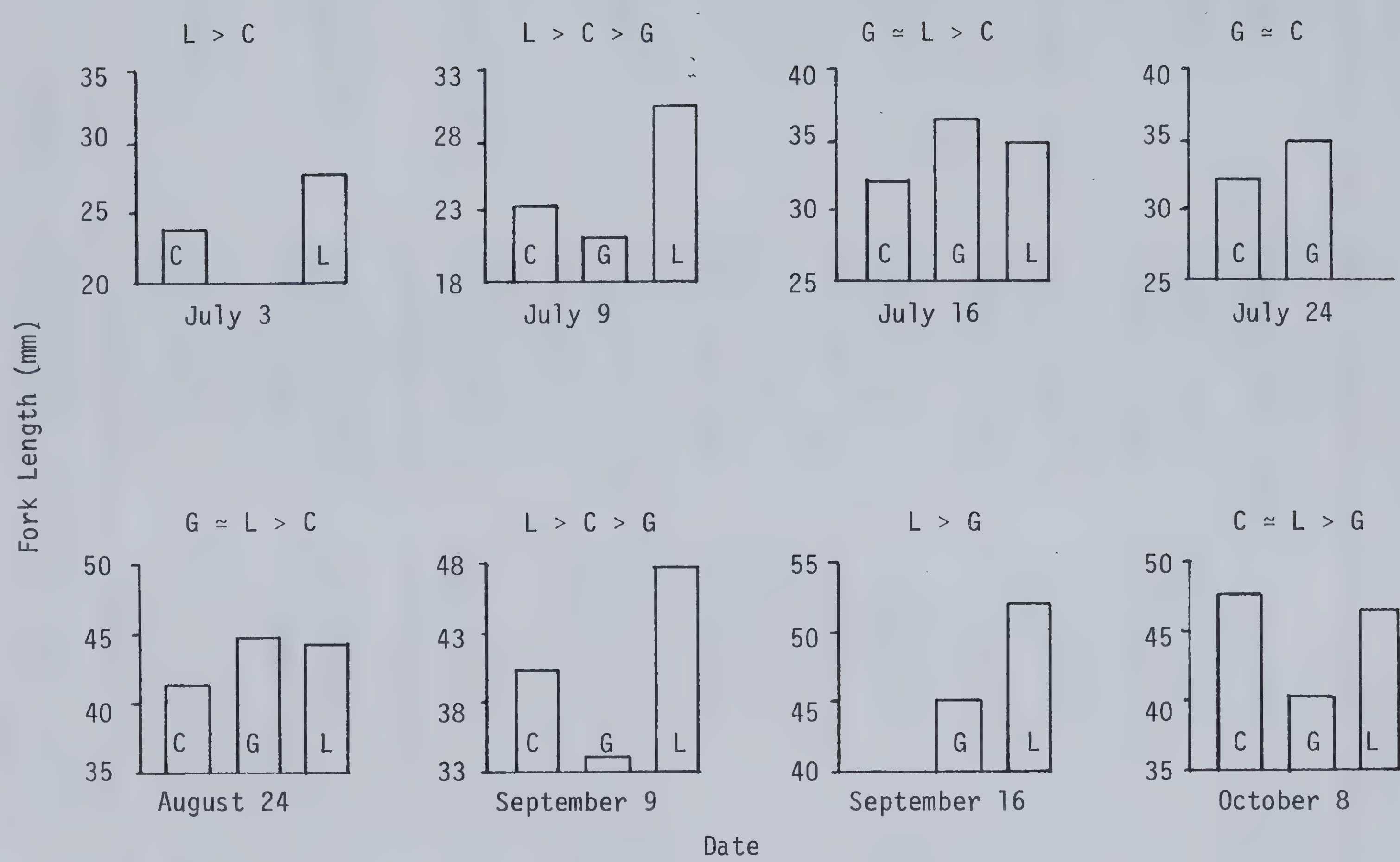


Figure 3.04. Comparison of the mean fork length of 0+ perch collected in 1980 from Clear(C), Goose(G) and Ste. Anne(L) Lakes showing equivalent(≃) and significantly($p<0.05$) greater(>) lengths.

Table 3.04. Comparison of mean fork length of 0+ perch captured in 1980 from Clear, Goose and Ste. Anne Lakes. The number of specimens examined and the 95% confidence interval of the mean is provided for each sample.

Date	Greatest Fork Length →			Smallest Fork Length
July 3	Lac Ste. Anne N = 23 $\bar{x}$ = 27.7 ±0.9	>	Clear Lake N = 35 $\bar{x}$ = 23.7 ±0.8	
July 9	Lac Ste. Anne N = 36 $\bar{x}$ = 30.7 ±0.5	>	Clear Lake N = 64 $\bar{x}$ = 23.4 ±1.0 >	Goose Lake N = 46 $\bar{x}$ = 21.2 ±0.8
July 16	Goose Lake N = 20 $\bar{x}$ = 36.5 ±3.1	≃	Lac Ste Anne N = 30 $\bar{x}$ = 34.9 ±2.4 >	Clear Lake N = 43 $\bar{x}$ = 32.0 ±1.1
July 24	Goose Lake N = 33 $\bar{x}$ = 34.9 ±2.0	≃	Clear Lake N = 56 $\bar{x}$ = 32.3 ±1.7	
August 19	Goose Lake N = 41 $\bar{x}$ = 44.8 ±1.7	≃	Lac Ste. Anne N = 26 $\bar{x}$ = 44.2 ±1.4 >	Clear Lake N = 33 $\bar{x}$ = 41.3 ±2.0
September 9	Lac Ste. Anne N = 30 $\bar{x}$ = 47.9 ±1.2	>	Clear Lake N = 29 $\bar{x}$ = 40.5 ±1.9 >	Goose Lake N = 30 $\bar{x}$ = 34.1 ±1.8
September 16	Lac Ste. Anne N = 14 $\bar{x}$ = 52.1 ±4.1	>	Goose Lake N = 30 $\bar{x}$ = 45.2 ±2.4	
October 8	Clear Lake N = 60 $\bar{x}$ = 47.8 ±1.3	≃	Lac Ste. Anne N = 30 $\bar{x}$ = 46.7 ±0.7 >	Goose Lake N = 30 $\bar{x}$ = 40.4 ±0.9

≃ samples not significantly larger ($p > 0.05$) in size.
> significantly larger size ($p < 0.05$).

Two samples taken one year apart in each of Goose and Ste. Anne Lakes indicated that the 0+ perch were significantly larger in 1980 than 1979 (Figures 3.01 and 3.03). This was also true for the mid-August samples from Clear Lake (1980 : $x = 41.3 \pm 2.0$mm, N = 33; vs 1979 : $x = 39.0 \pm 0.8$mm, N = 111). However, the October 12, 1979, and October 8, 1980, sample results from Clear Lake were reversed (1979 : $x = 53.0 \pm 1.2$mm, N = 79; vs 1980 : $x = 47.8 \pm 1.6$mm, N = 60) (Figure 3.02). It seems probable that the 0+ perch grew larger in 1980 but the difference would be quite small and its significance is masked by the considerable variation in seining results cited.

Despite the obvious sampling variability, if one assumes that growth over the summer is reasonably constant, the young-of-the-year perch in this study grew approximately 25mm between the end of June and the end of August. This average growth rate (0.40mm/day) is similar to that reported by Spanovskaya and Grygorash (1977) for three reservoirs in the Soviet Union. It is lower than the 0.722mm/day growth reported in Red Lake, Minnesota (Ney and Smith, 1975), and the tripling in length recorded by Kelso and Ward (1977) for 0+ perch in West Blue Lake, Manitoba. The latter growth rate is very similar to that recorded in Lake Windermere, England, in 1975 and 1976 (Guma'a, 1978).

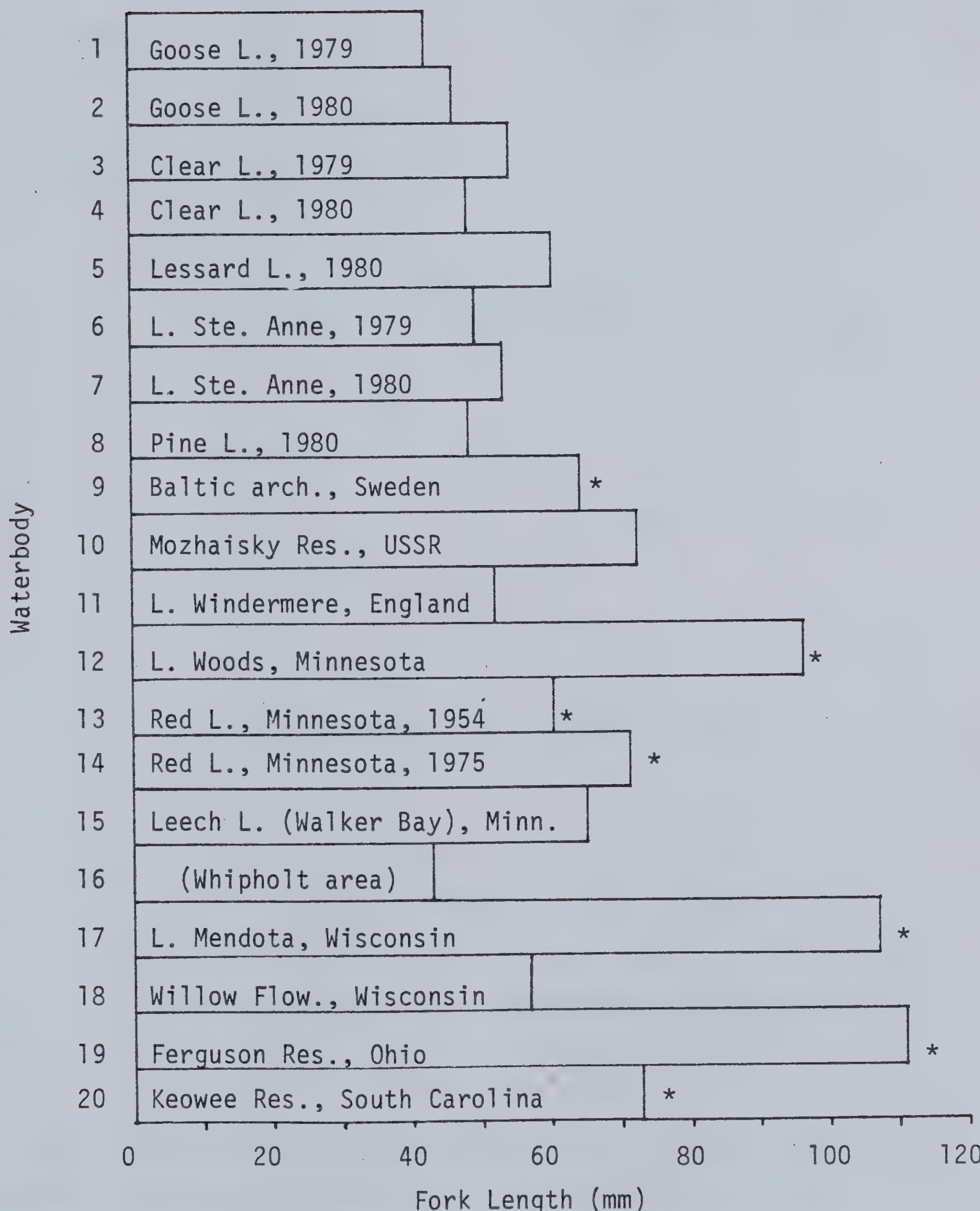
Growth of young-of-the-year perch slows in September and October (Figures 3.01, 3.02 and 3.03). The curves developed may have exaggerated the decline in growth rate as the larger 0+ perch had already moved out of the seining areas and the late fall samples probably represent the smallest 0+ perch and the last fish to leave the shallows. Figure 3.05

compares the growth achieved to November by 0+ perch in my study and similar information from the literature for other North American and European sites. The general trend apparent from this data is that the 0+ perch from my study had slightly slower growth rates than the average of the North American and European examples cited. Part of this difference is due to the inclusion of samples where the size stated is the fish size at formation of the first annulus rather than growth to the first autumn. Le Cren (1947) and Guma'a (1978) state that very little growth occurs over winter. Karas and Neuman (1981) demonstrated that 0+ perch in a heated Baltic bay could gain up to 10mm in length over their first winter. Their data showed that the increase in length was not due to differential mortality of the smaller young-of-the-year perch. The capture of small perch averaging 66.1 and 66.7mm fork length from Pine and Clear Lakes, early in the year, indicated that some over-winter growth or differential mortality occurred in the perch I studied. Selective mortality of the smaller perch may have occurred in Clear Lake (Figure 3.06) although the June 17, 1980, sample size was too small to be totally reliable. Size dependent mortality does not appear to have occurred in the 1979 year-classes in Lac Ste. Anne and Pine Lake (Figure 3.07). Karas and Neuman (1981) did not find differential over-winter mortality in their study of 0+ perch in the Baltic archipelagoes.

The 60 - 66mm fork length size at annulus 1 of the perch I studied agreed well with the back-calculated length of the Pine and Clear Lake perch. It also agreed quite well with many of the growth rates shown in Figure 3.05, particularly bars 9 - 11. These samples are from European

Figure 3.05. Comparison of growth of 0+ perch in Alberta with other populations in Europe and North America. The sample locations for the growth rates cited from the literature, have been listed in order of decreasing latitude.

1. Goose Lake, Alberta, 1979.
2. Goose Lake, Alberta, 1980.
3. Clear Lake, Alberta, 1979.
4. Clear Lake, Alberta, 1980.
5. Lessard Lake, Alberta, 1980.
6. Lac Ste. Anne, Alberta, 1979.
7. Lac Ste. Anne, Alberta, 1980.
8. Pine Lake, Alberta, 1980.
9. Baltic archipelagoes, Sweden (Neuman, 1976).
10. Mozhaisky Reservoir, USSR (Spanovskaya and Grygorash, 1977).
11. Lake Windermere, England (Le Cren, 1951).
12. Lake of the Woods, Minnesota (Carlander, 1950).
13. Red Lakes, Minnesota (Pycha and Smith, 1954).
14. Red Lakes, Minnesota (Ney and Smith, 1975).
15. Leech Lake (Walker Bay), Minnesota (Schupp, 1978).
16. Leech Lake (Whipholt area), Minnesota (Schupp, 1978).
17. Lake Mendota, Wisconsin (Bardach, 1955).
18. Willow Flowage, Wisconsin (Schott et al, 1978).
19. Ferguson Reservoir, Ohio (Paxton et al, 1981).
20. Keowee Reservoir, South Carolina (Clugston et al, 1978).



* - size of fish at first annulus.

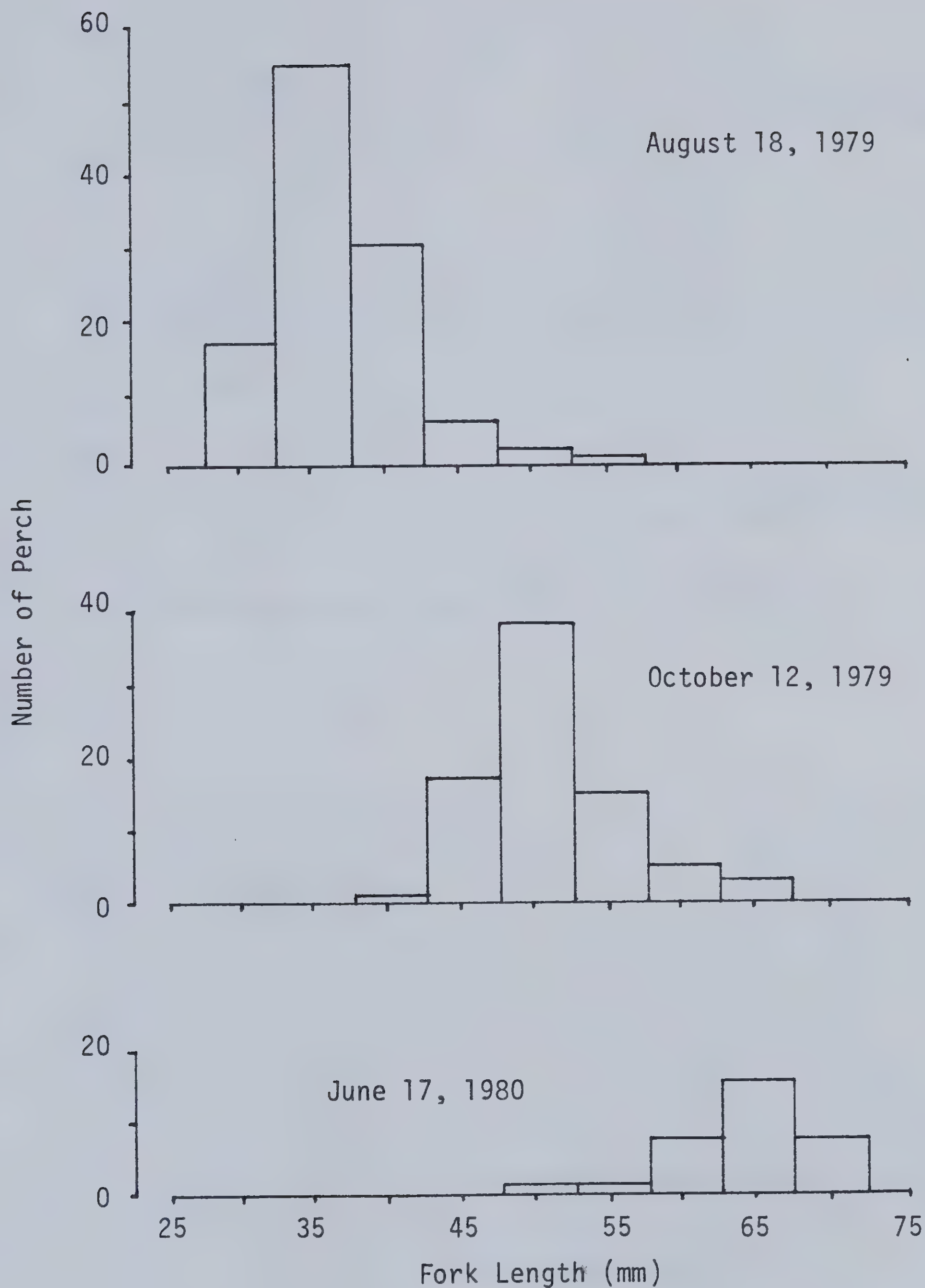


Figure 3.06. Length frequency histograms for the 1979 year-class of yellow perch collected from Clear Lake on three different dates.

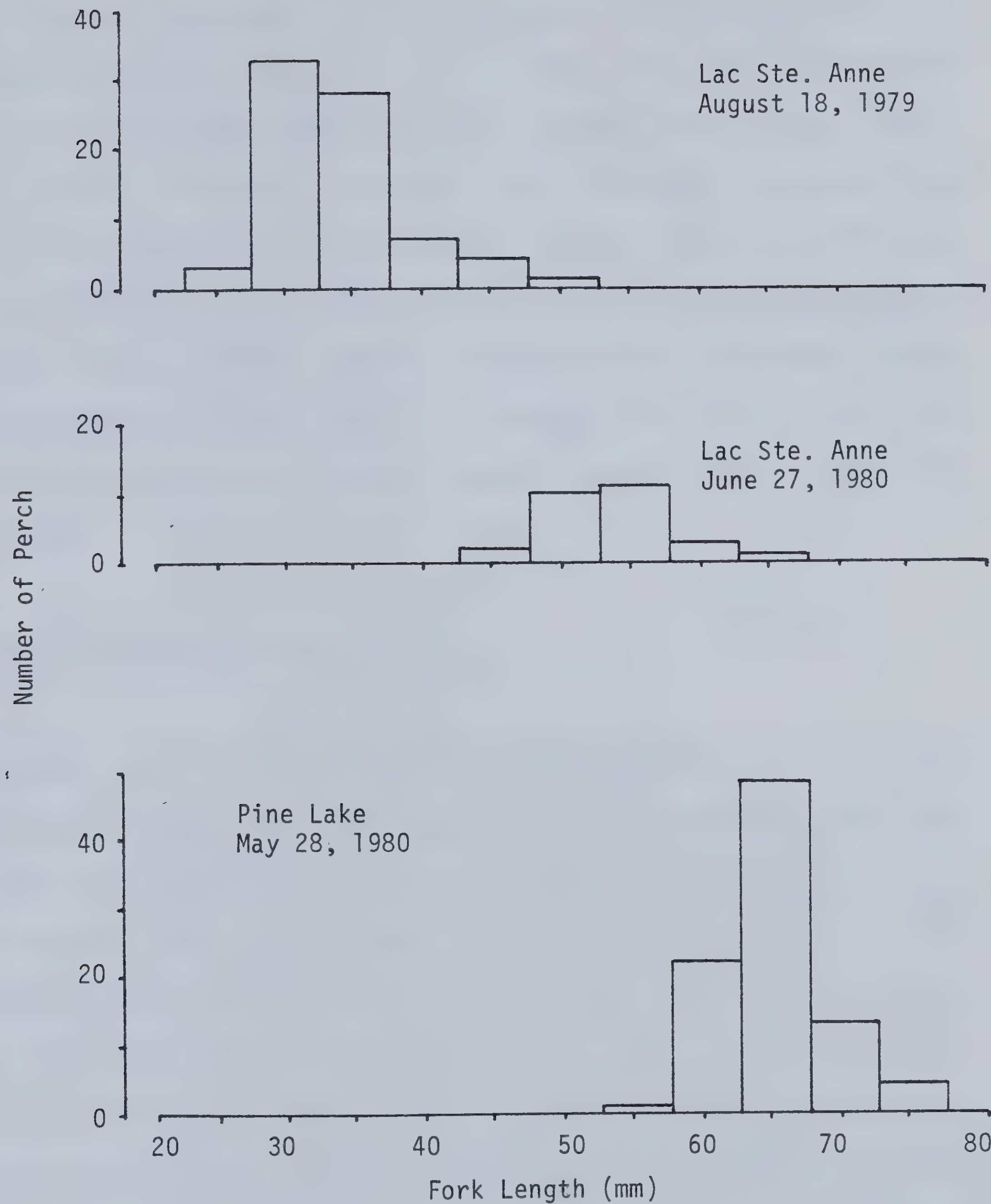


Figure 3.07. Length frequency histograms for the 1979 year-classes of yellow perch from Lac Ste. Anne and Pine Lake, demonstrating the absence of size selective over winter mortality.

waters at similar latitudes and with comparable growing conditions to those found in Alberta. Bars 12 - 20 in Figure 3.05 show growth of 0+ perch from North American waters that are arranged from highest ($49^{o}N$) to lowest ($34^{o}N$) latitudes. The growth rates recorded in my study are slightly less than those in the examples shown. The size difference becomes more apparent in the more southern waters which should produce larger fish during a longer growing season. Karas and Neuman (1981) found that young-of-the-year perch in a heated Baltic bay had the best growth during the warmest and longest summers, possibly due to an earlier hatching date.

3.3b Sexual Dimorphism in Growth

Differential growth rates for male and female perch have been widely reported and my sample data also demonstrated this phenomenon for adult perch. Male and female 0+ perch captured October 8, 1980, in Ste. Anne, Clear and Goose Lakes did not have significantly different ($p < 0.05$) fork lengths (Figure 3.08, Appendix 3.01) or round weights (Figure 3.09, Appendix 3.02) although the female fish were usually slightly larger. The back-calculated age 1 female perch from Pine Lake were significantly larger than the male perch captured at the same time. However, the sexes differed in mean fork length by less than 3 mm. A sample of 1+ perch from Pine Lake that was collected August 13, 1980 did not exhibit significantly different sizes between female and male perch.

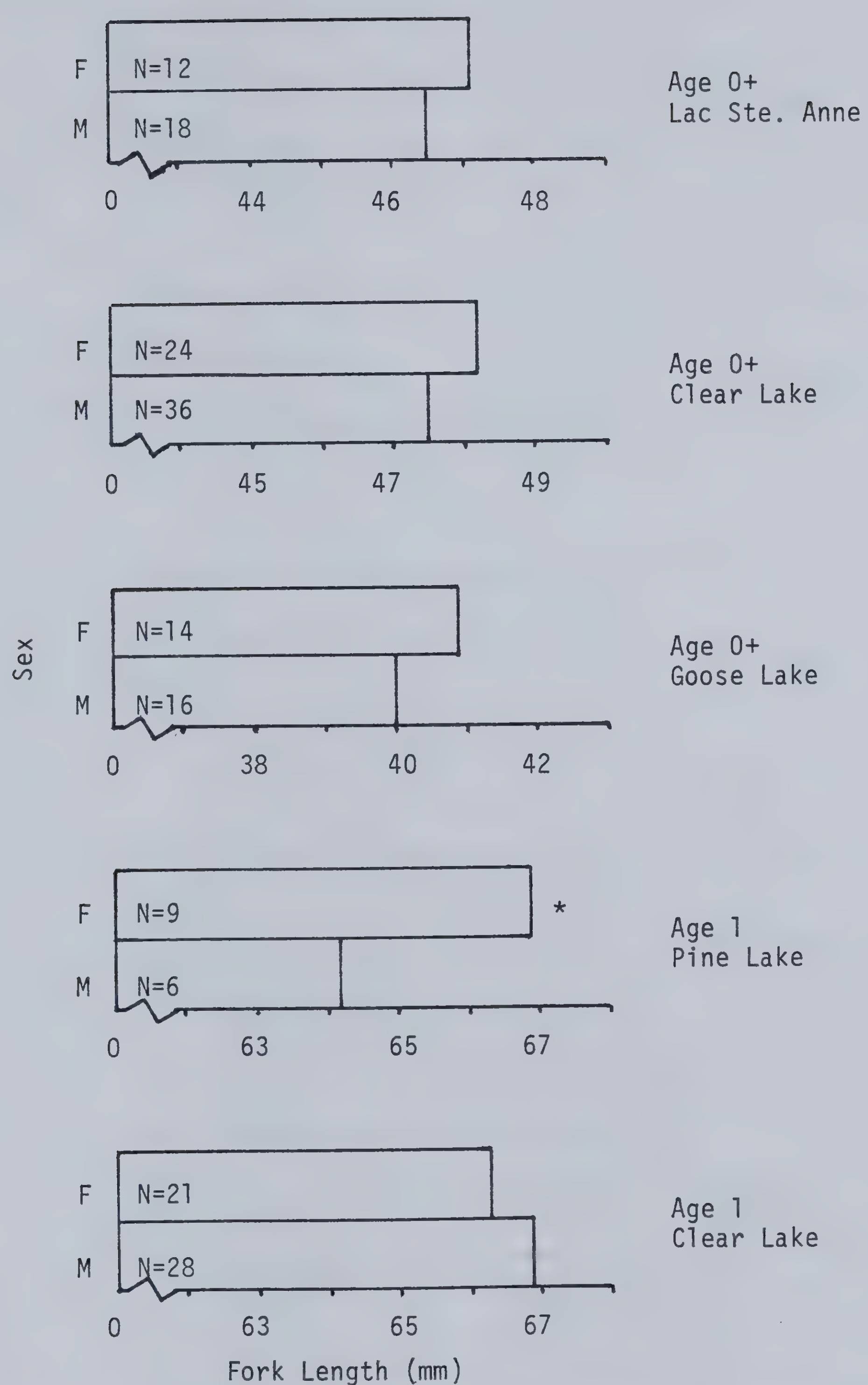


Figure 3.08. Comparison of the fork lengths of female(F) and male(M) perch of equal age. An asterisk indicates significantly ($p<0.05$) longer fish.

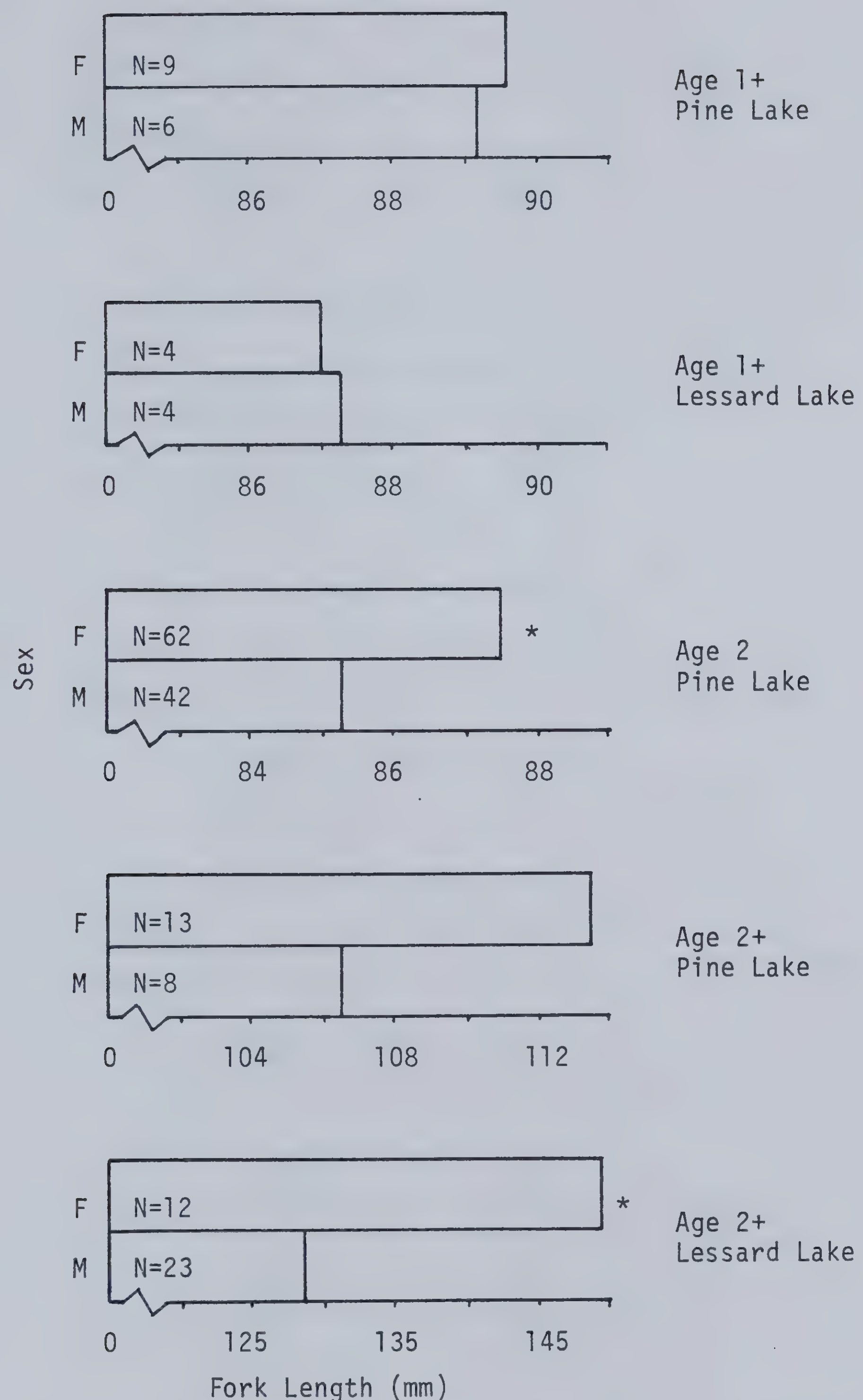


Figure 3.08 continued. Comparison of the fork lengths of female(F) and male(M) perch of equal age. An asterisk indicates significantly ($p<0.05$) longer fish.

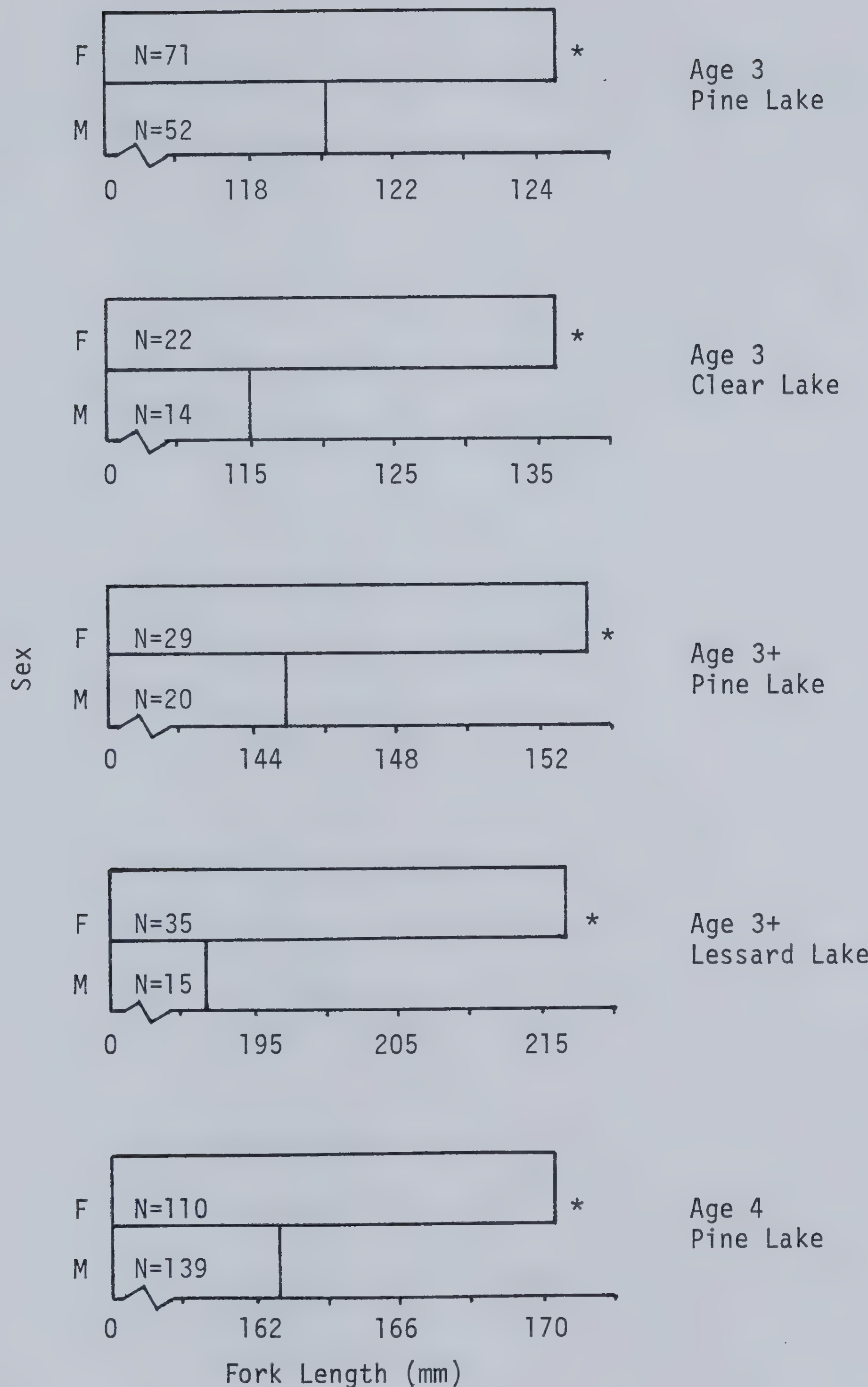


Figure 3.08 continued. Comparison of the fork lengths of female(F) and male(M) perch of equal age. An asterisk indicates significantly ($p<0.05$) longer fish.

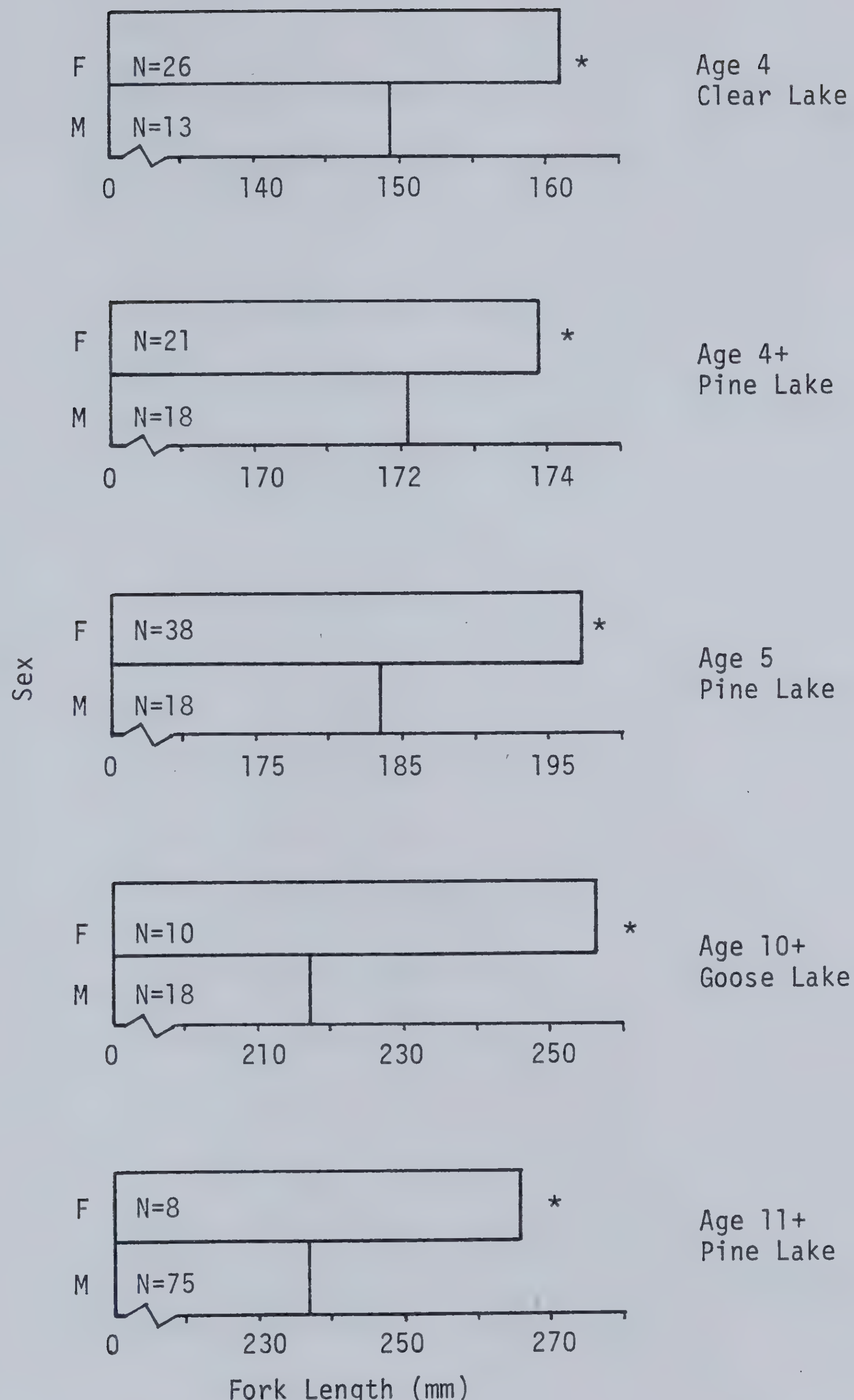


Figure 3.08 continued. Comparison of the fork lengths of female(F) and male(M) perch of equal age. An asterisk indicates significantly ($p<0.05$) longer fish.

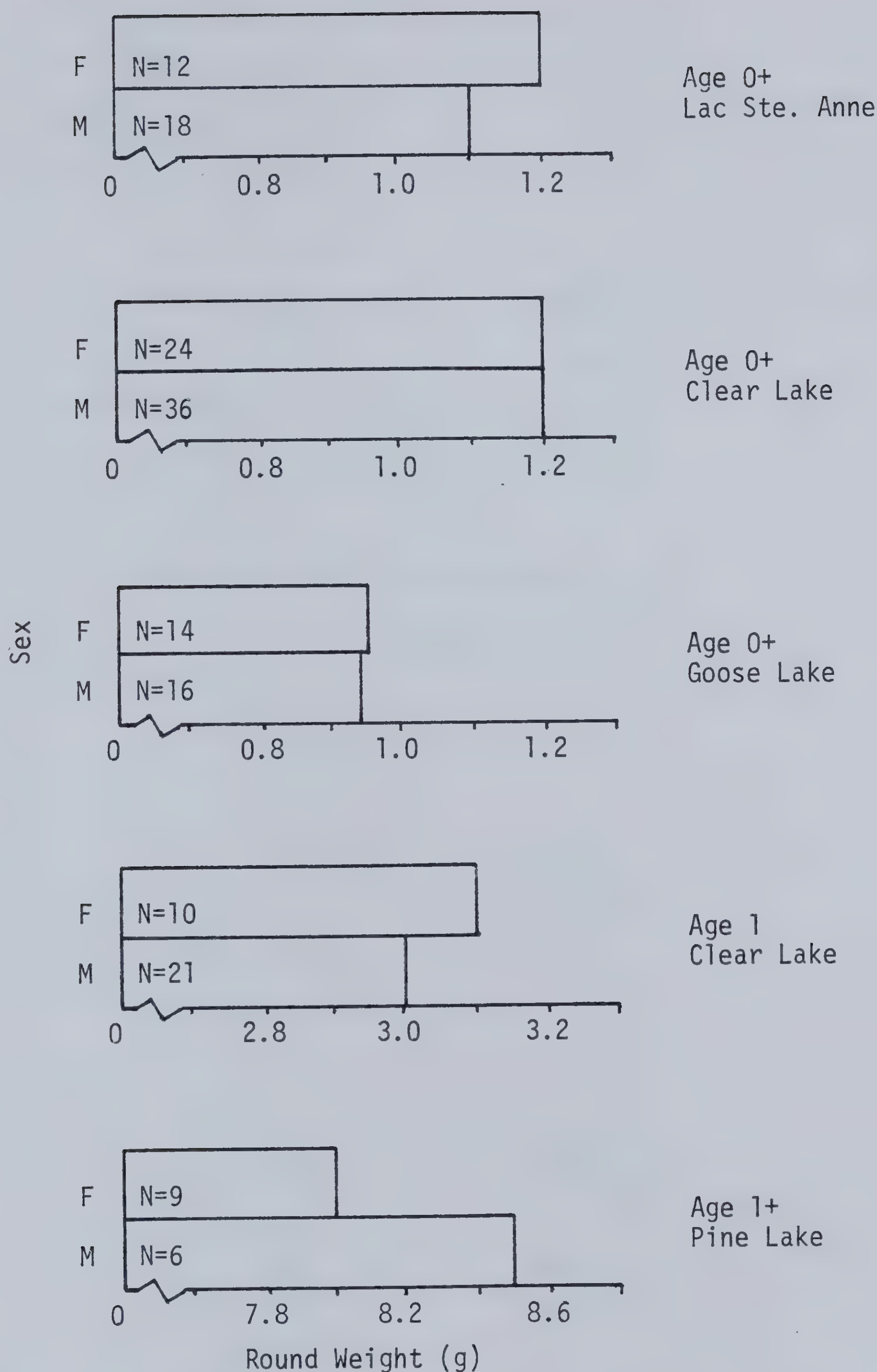


Figure 3.09. Comparison of the round weights of female(F) and male(M) perch of equal age. An asterisk indicates significantly($p<0.05$) heavier fish.

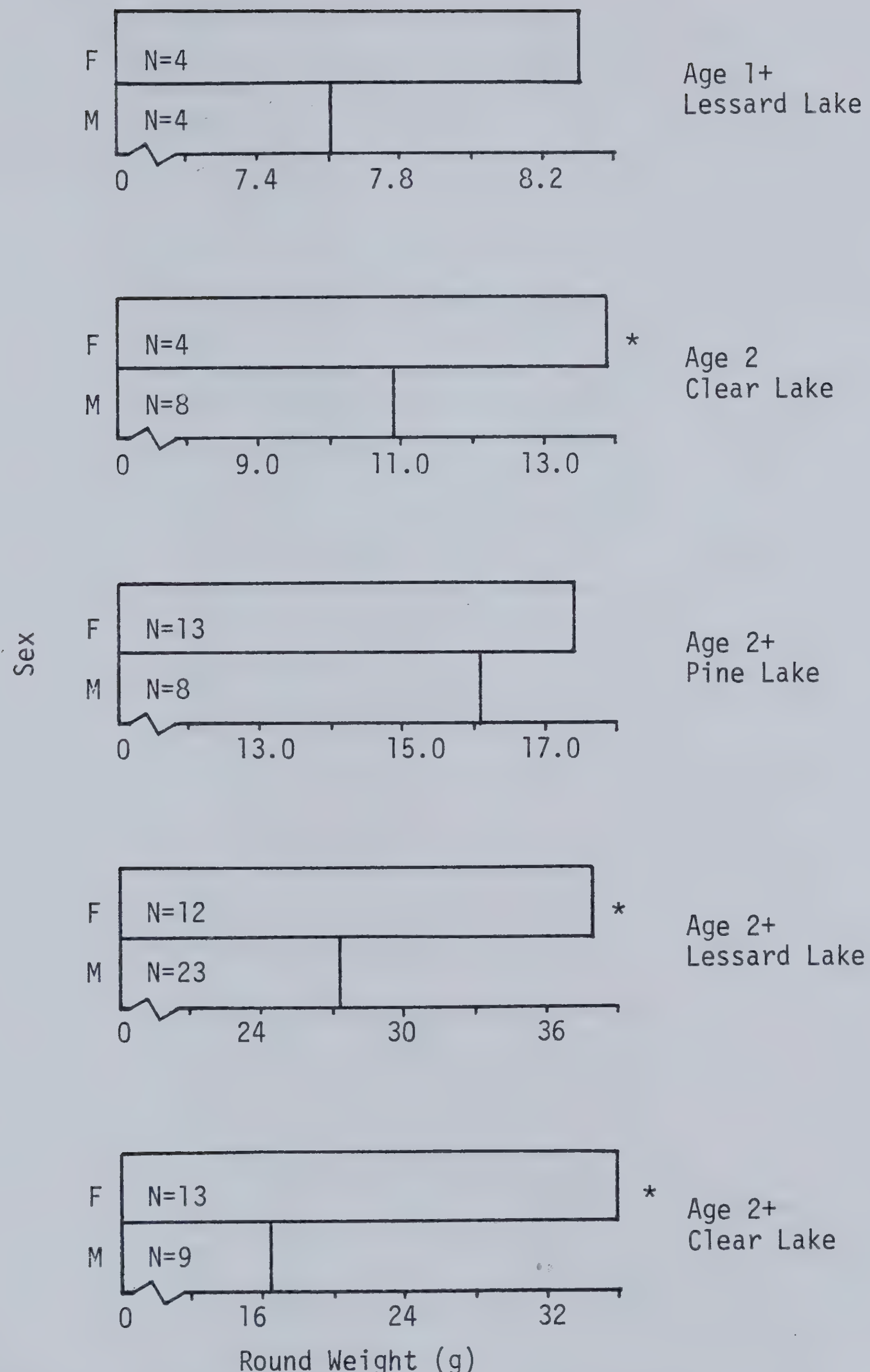


Figure 3.09 continued. Comparison of the round weights of female(F) and male(M) perch of equal age. An asterisk indicates significantly ($p<0.05$) heavier fish.

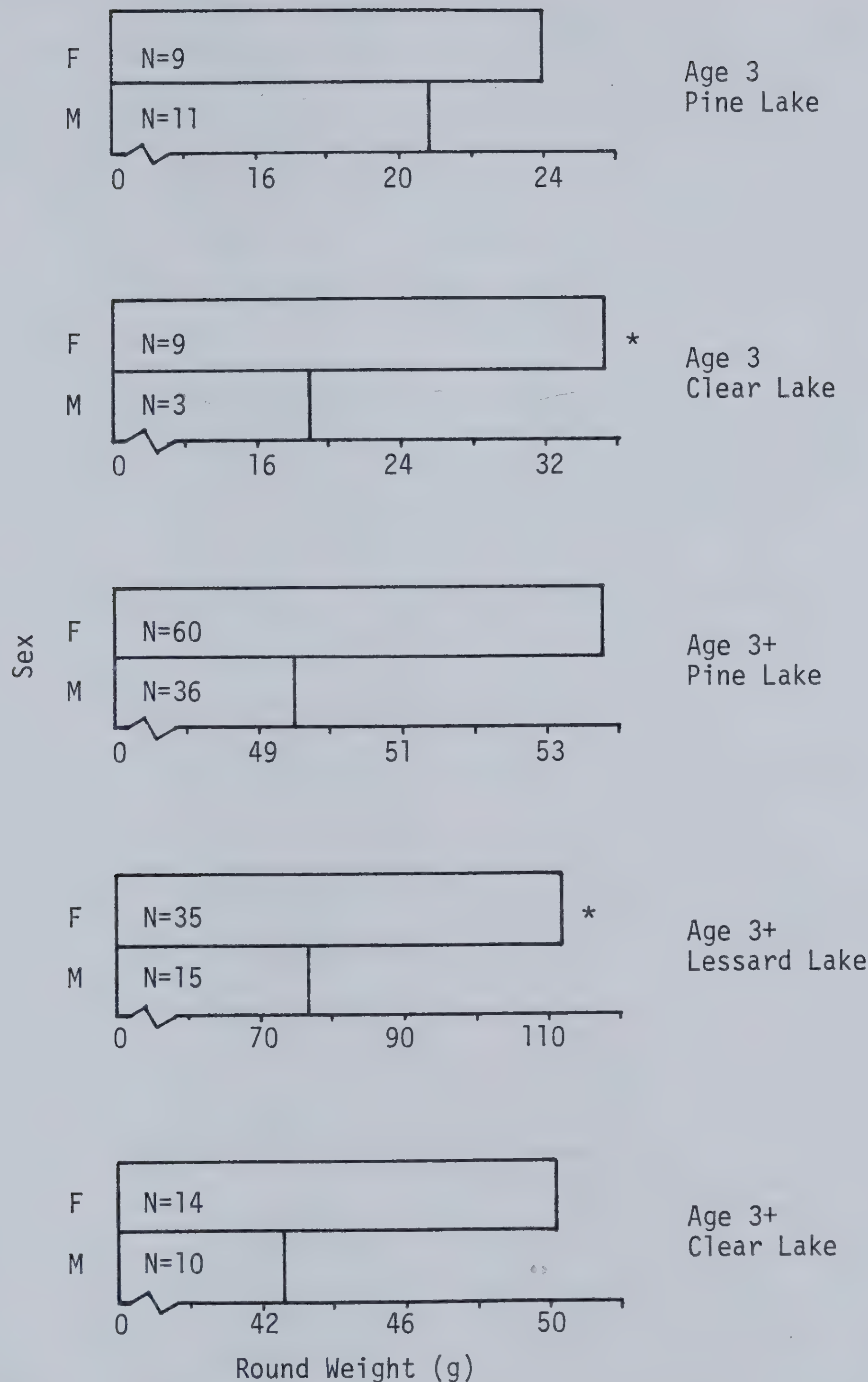


Figure 3.09 continued. Comparison of the round weights of female(F) and male(M) perch of equal age. An asterisk indicates significantly ($p<0.05$) heavier fish.

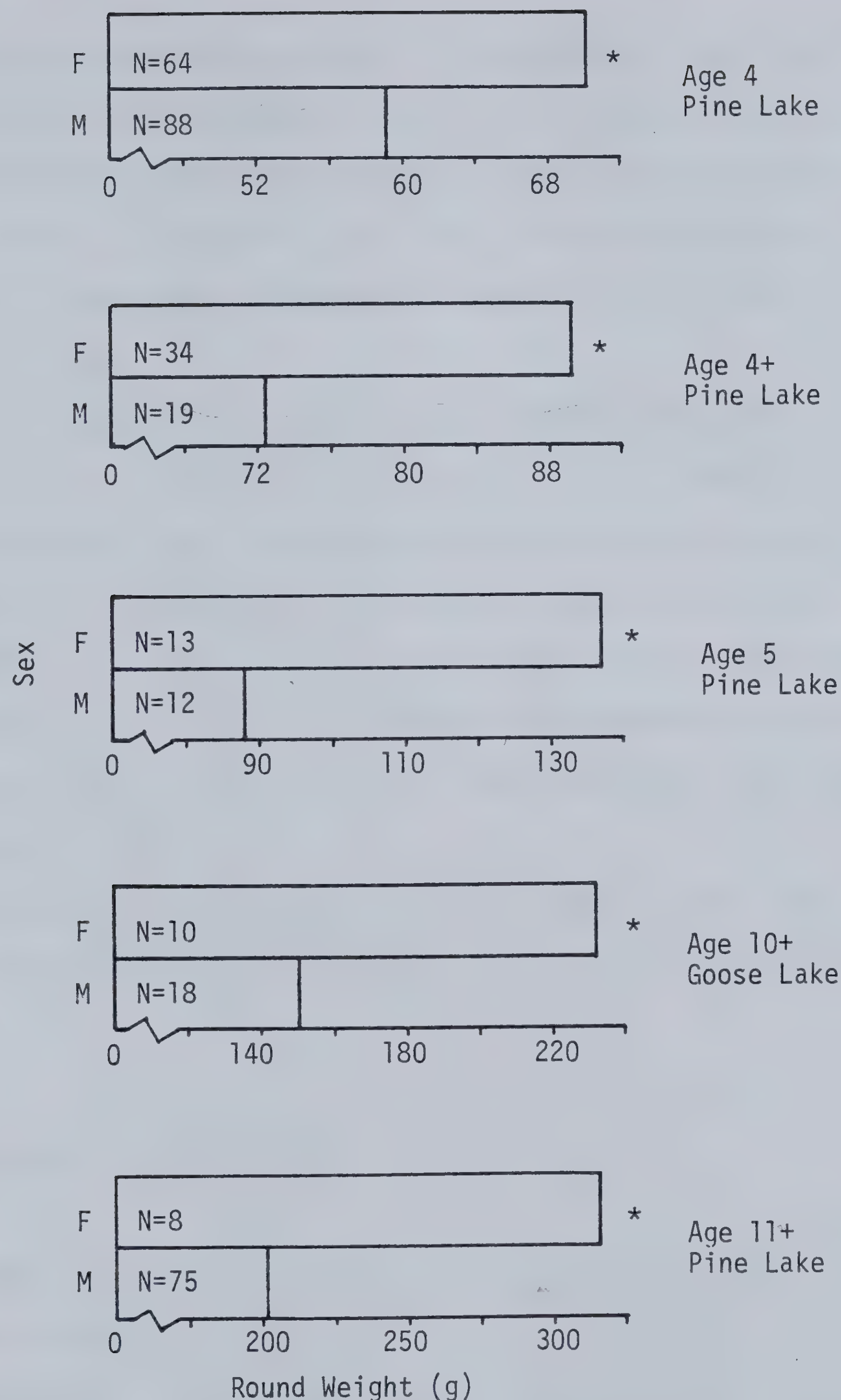


Figure 3.09 continued. Comparison of the round weights of female(F) and male(M) perch of equal age. An asterisk indicates significantly ($p<0.05$) heavier fish.

Female perch from Pine Lake were statistically longer and heavier than males in the spring sample of age 2 fish. This occurred at a fork length of 91mm and a round weight of 14g. These values are quite similar to those reported by Schott et al. (1978) for an experimental feeding study where the sexes were different in size at a fork length of 105 mm and a weight of 15g.

By age 3 the mean fork length and round weight of the female perch in all my samples were significantly larger ($p < 0.05$) than for the male perch from the same lakes. The mean sizes of the female fish at this age ranged from 126 to 148mm fork length and 24 to 38g round weight. These are essentially the same age and sizes at which sexual dimorphism has been reported in other studies throughout North America (Brazo et al, 1975; Hile and Jobes, 1942; Paxton and Stevenson, 1978) and Europe (Le Cren, 1947; Mann, 1978).

The consistently faster growth of the female perch after age 2 warranted separate treatment of the female and male growth data for each population.

3.3c Year-class Growth Histories

Accurately back-calculated growth of test fish provides a record of the growth of individual perch and thus of year-classes within the sampled water body. It also increases the effective sample size provided growth has been relatively constant. Obviously this provides the greatest amount of data for the youngest age classes.

The anal spine radius was used to relate fork length to age (Chapter 2, Section 2.3c). Analysis of the data by the least squares method gave the following equations relating the radius of the anal spine to fork length:

Pine Lake	females	$y = 177.10x + 47.18$
		($N = 85$, $r = 0.95$, $p < 0.001$)
	males	$y = 177.00x + 45.25$
		($N = 68$, $r = 0.97$, $p < 0.001$)
Clear Lake	sexes combined	$y = 186.99x + 46.49$
		($N = 40$, $r = 0.89$, $p < 0.001$)
Lessard Lake	females	$y = 259.05x + 57.73$
		($N = 64$, $r = 0.89$, $p < 0.001$)
	males	$y = 229.51x + 46.78$
		($N = 44$, $r = 0.82$, $p < 0.001$)

where: x = anal spine radius (mm), and

y = fork length (mm).

The constants from these equations were used to back-calculate the length of each fish at the formation of each annulus.

The growth of female perch from Pine Lake (Figure 3.10, Appendix 3.03) was quite stable from 1976 through 1978. Growth of the age 1 fish in 1980 seems low but this value was obtained from a fall seine sample and was not the actual size of these fish at formation of the first annulus. Over winter growth of young of the year perch as described in

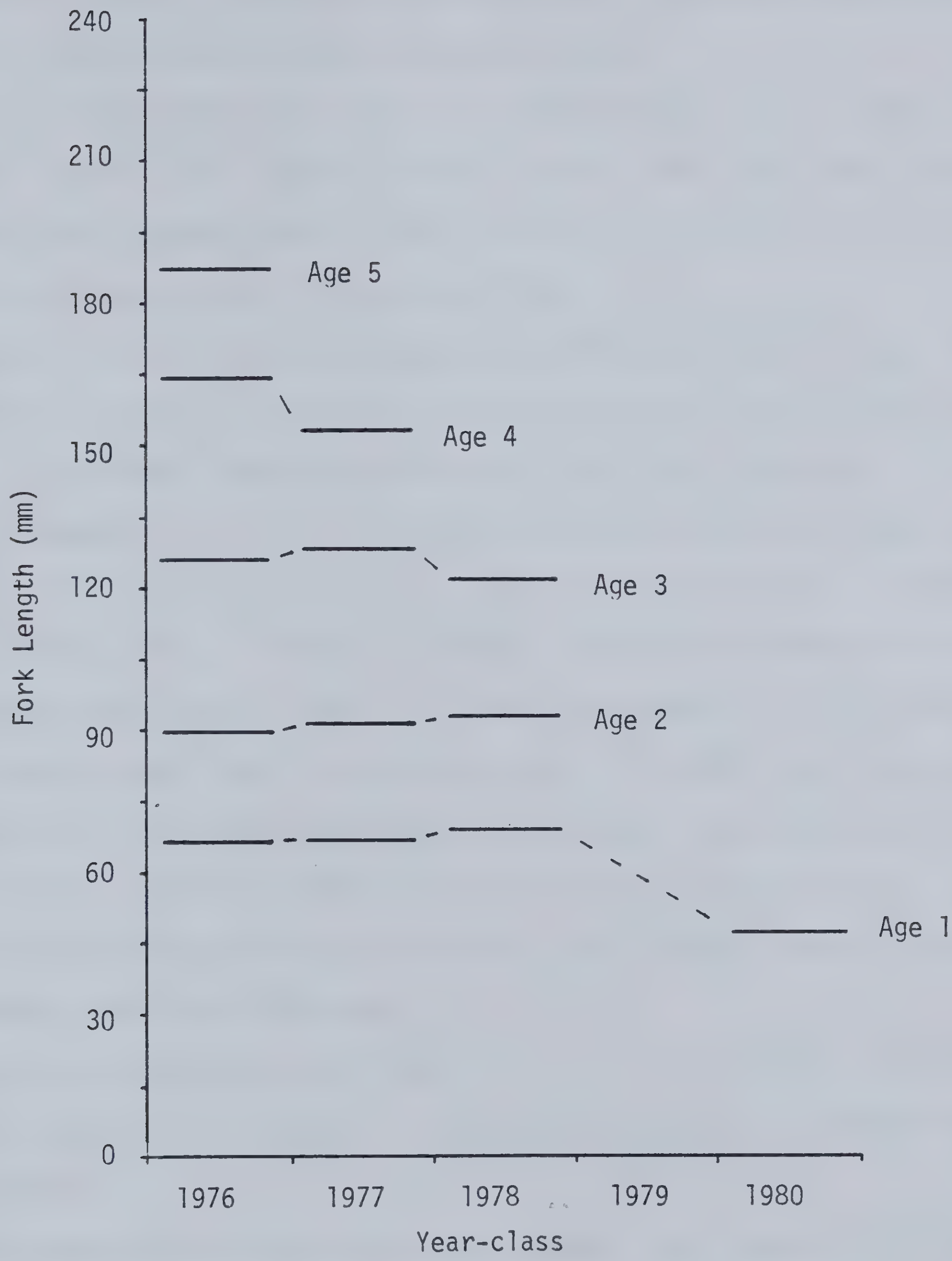


Figure 3.10. Mean back-calculated fork length at annulus formation in four year-classes of female perch from Pine Lake.

this study (Section 3.3a) would bring the size of the 1980 year-class up to the 60 - 65mm average reached in previous years.

Growth of male Pine Lake perch was also relatively stable from 1975 to 1979 (Figure 3.11, Appendix 3.03). Jobes (1952) and Mann (1978) reported stable growth rates for perch populations that are not subjectd to rapid and large changes in population size.

Figure 3.12 shows that the combined growth rates of the female and male perch from Clear Lake were quite stable through the 1976 to 1979 period. The length shown at each annulus for this population is not strictly comparable with the female and male perch data from Pine Lake because I have previously shown that sexual dimorphism occurs in growth rates (Section 3.36). However, I consider it valid to combine the data in this instance because Figure 3.12 shows the stability of the yearly growth rates rather than the specific amount of growth that occurred. The individual female and male growth rates in the sample obtained from Clear Lake in the fall of 1980 were quite stable (Appendix 3.04). The female and male data were only combined to give a larger sample size and thus improve statistical accuracy.

The relatively stable growth rates calculated for the Pine and Clear Lake fish were suitable for use in calculating the existing growth rates of these fish.

In contrast, the size of both female (Figure 3.13, Appendix 3.05) and male (Figure 3.14, Appendix 3.05) fish at annulus formation in Lessard Lake declined progressively. Since the methods used for the Pine and

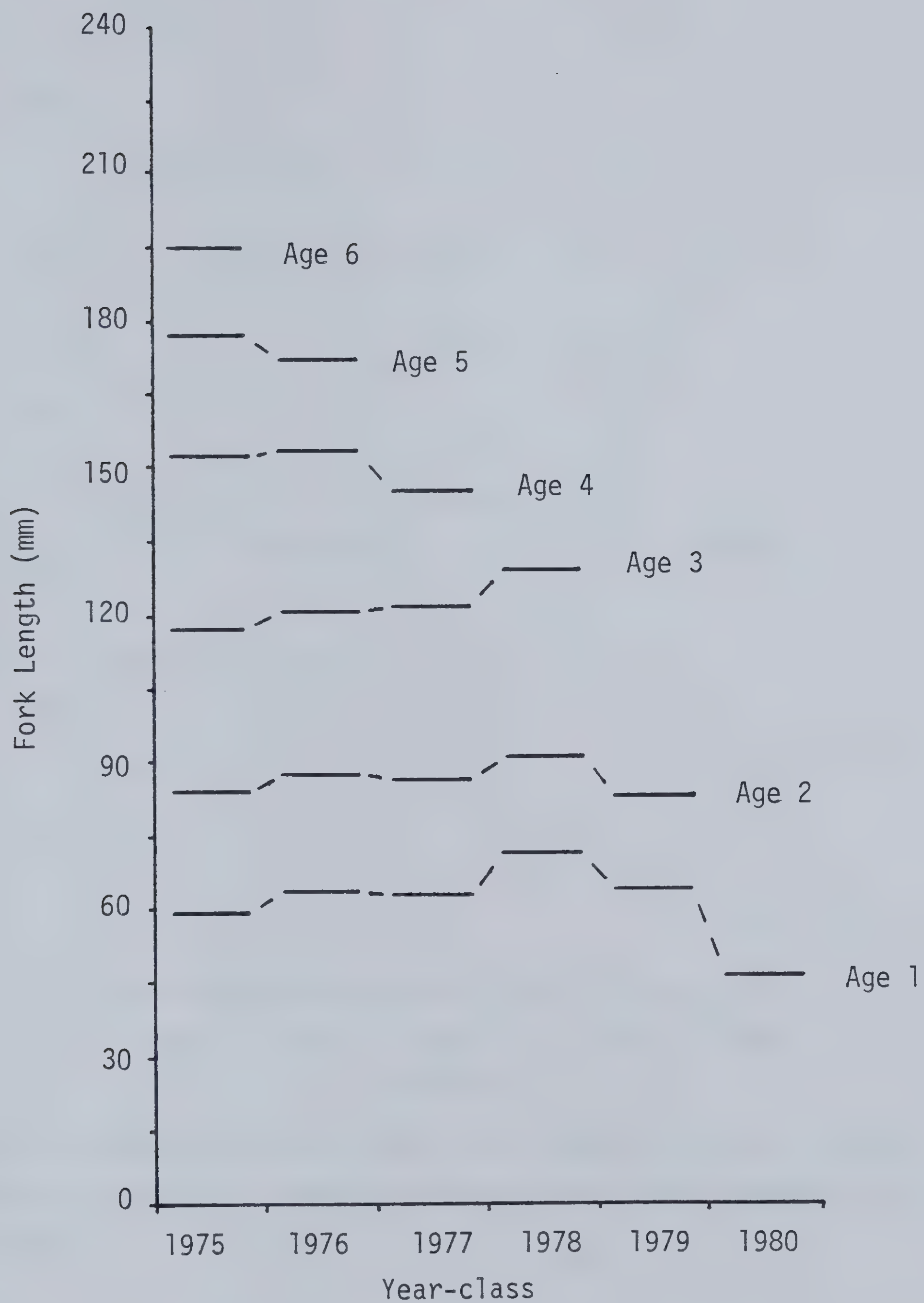


Figure 3.11. Mean back-calculated fork length at annulus formation in five year-classes of male perch from Pine Lake.

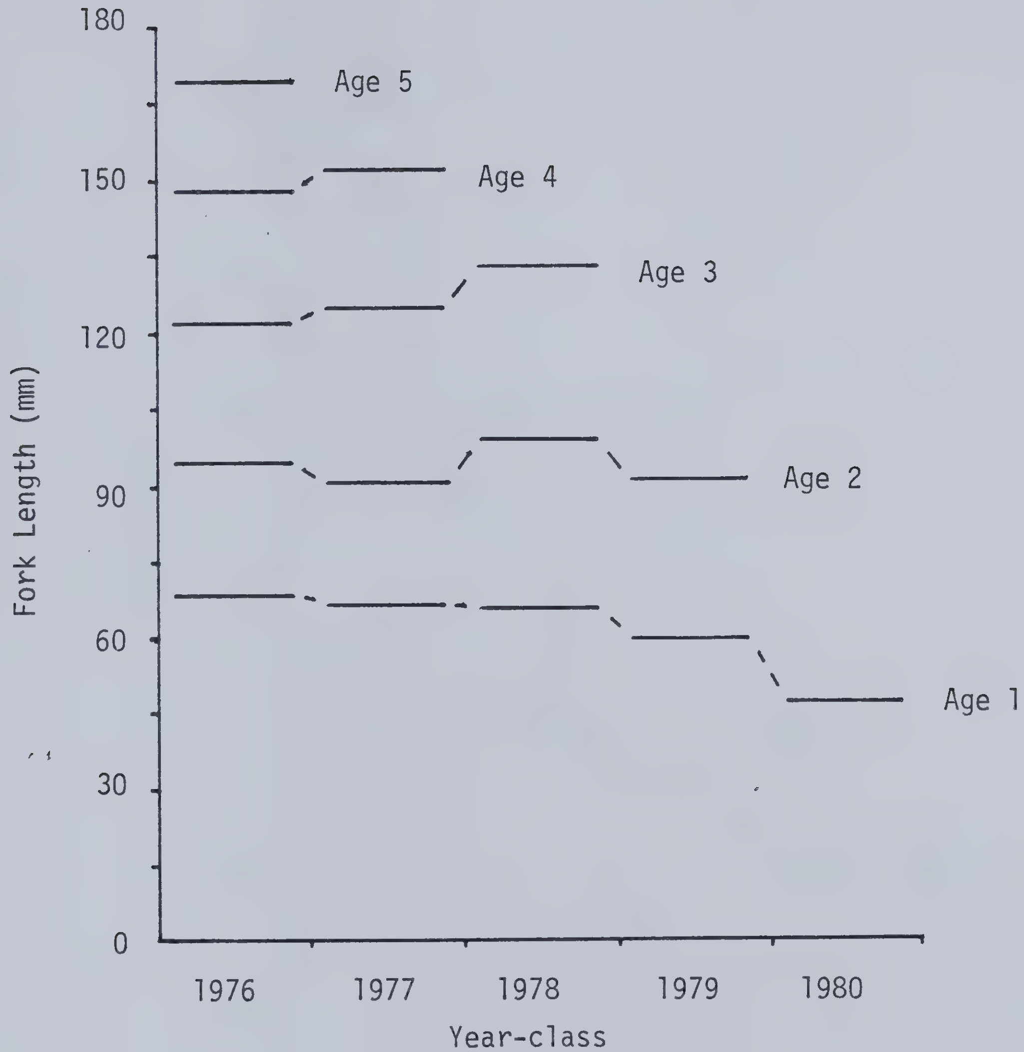


Figure 3.12. Mean back-calculated fork length at annulus formation in four year-classes of female and male perch (data combined) from Clear Lake.

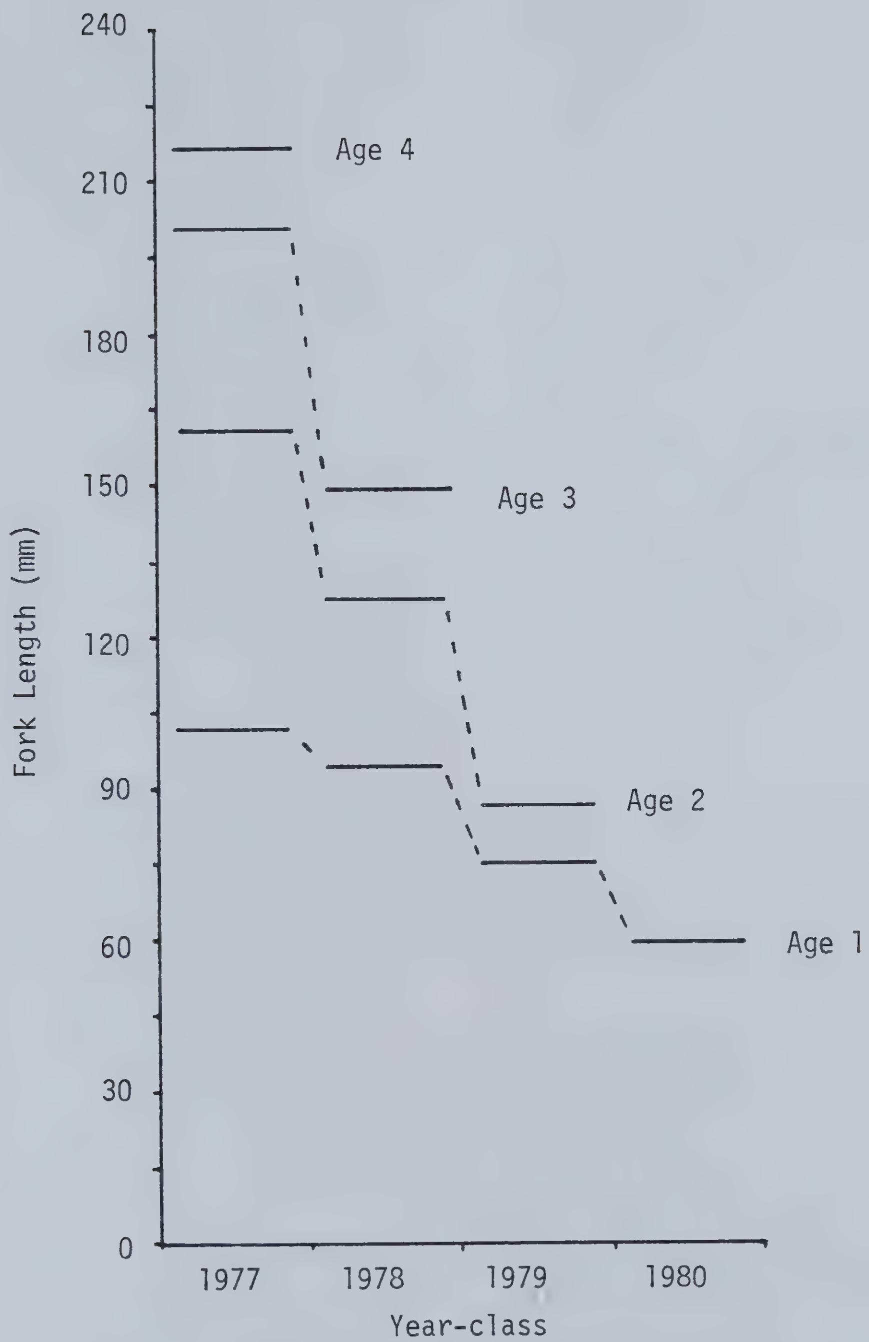


Figure 3.13. Mean back-calculated fork length at annulus formation in three year-classes of female perch from Lessard Lake.

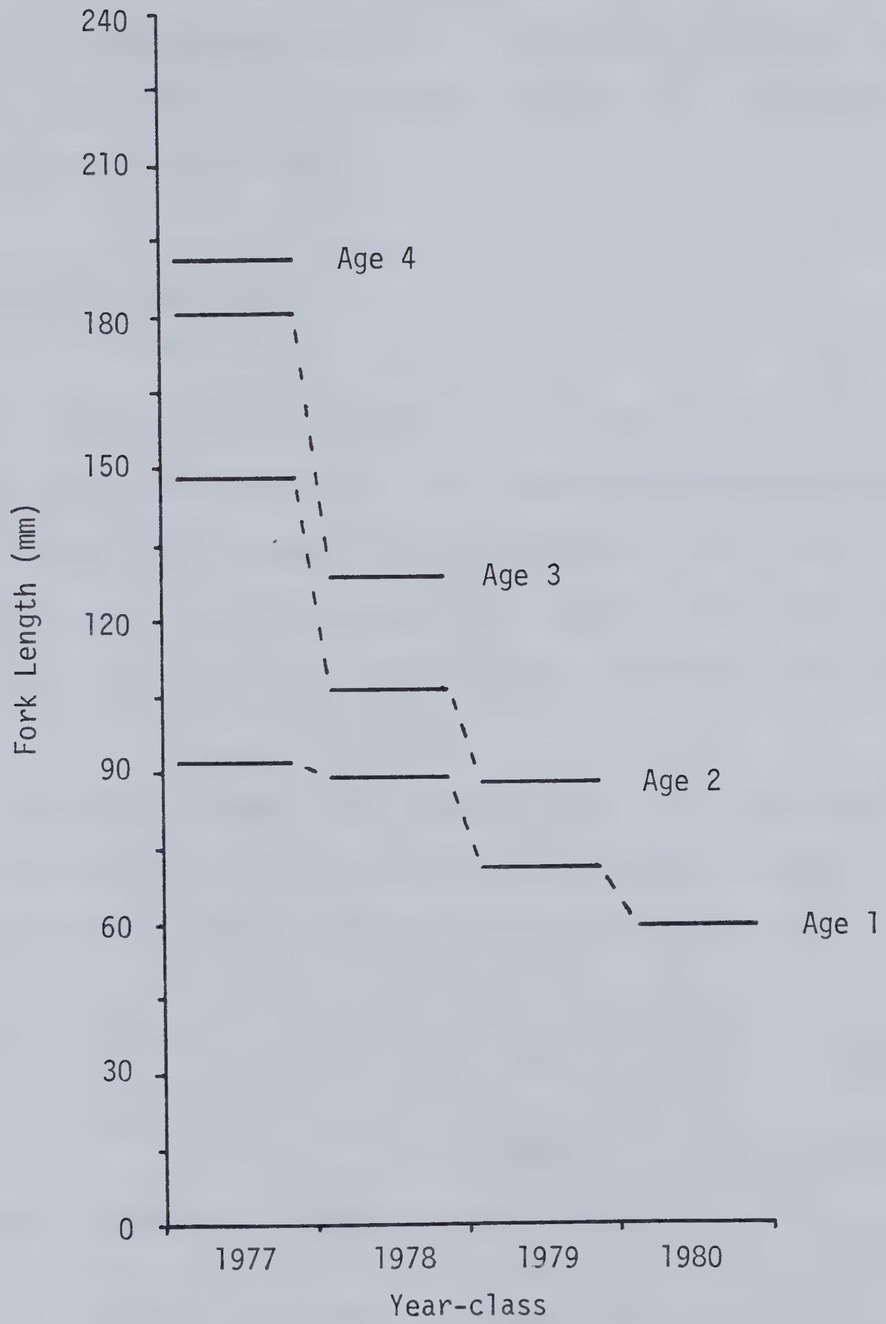


Figure 3.14. Mean back-calculated fork length at annulus formation in three year-classes of male perch from Lessard Lake.

Clear Lake samples were identical it is apparent that the declining growth of the Lessard Lake year-classes is not due to sampling error. This precluded using the back-calculated lengths in estimating the existing growth rate of these fish.

3.3d Comparison of Growth Rates

The general growth curves developed for the female and male perch from Pine, Lessard, Clear and Goose Lakes appear very similar (Figures 3.15, 3.16, 3.17 and 3.18 respectively and Appendices 3.06, 3.07, 3.08 and 3.09 respectively). All demonstrate the typically more rapid growth of the young fish and the larger ultimate size attained by the female perch.

In order to better compare the growth curves, the individual age versus length data points were used to calculate regression equations by the least squares method. This produced the following equations:

Pine Lake	females	$\log L = 1.8453 + 0.6031 \log A$ ($N = 455$, $r = 0.953$, $p < 0.001$)
	males	$\log L = 1.8627 + 0.5001 \log A$ ($N = 483$, $r = 0.957$, $p < 0.001$)
Lessard Lake	females	$\log L = 1.9933 + 0.5950 \log A$ ($N = 81$, $r = 0.979$, $p < 0.001$)
	males	$\log L = 1.9550 + 0.4959 \log A$ ($N = 59$, $r = 0.947$, $p < 0.001$)
Clear Lake	females	$\log L = 1.8835 + 0.5635 \log A$ ($N = 103$, $r = 0.966$, $p < 0.001$)

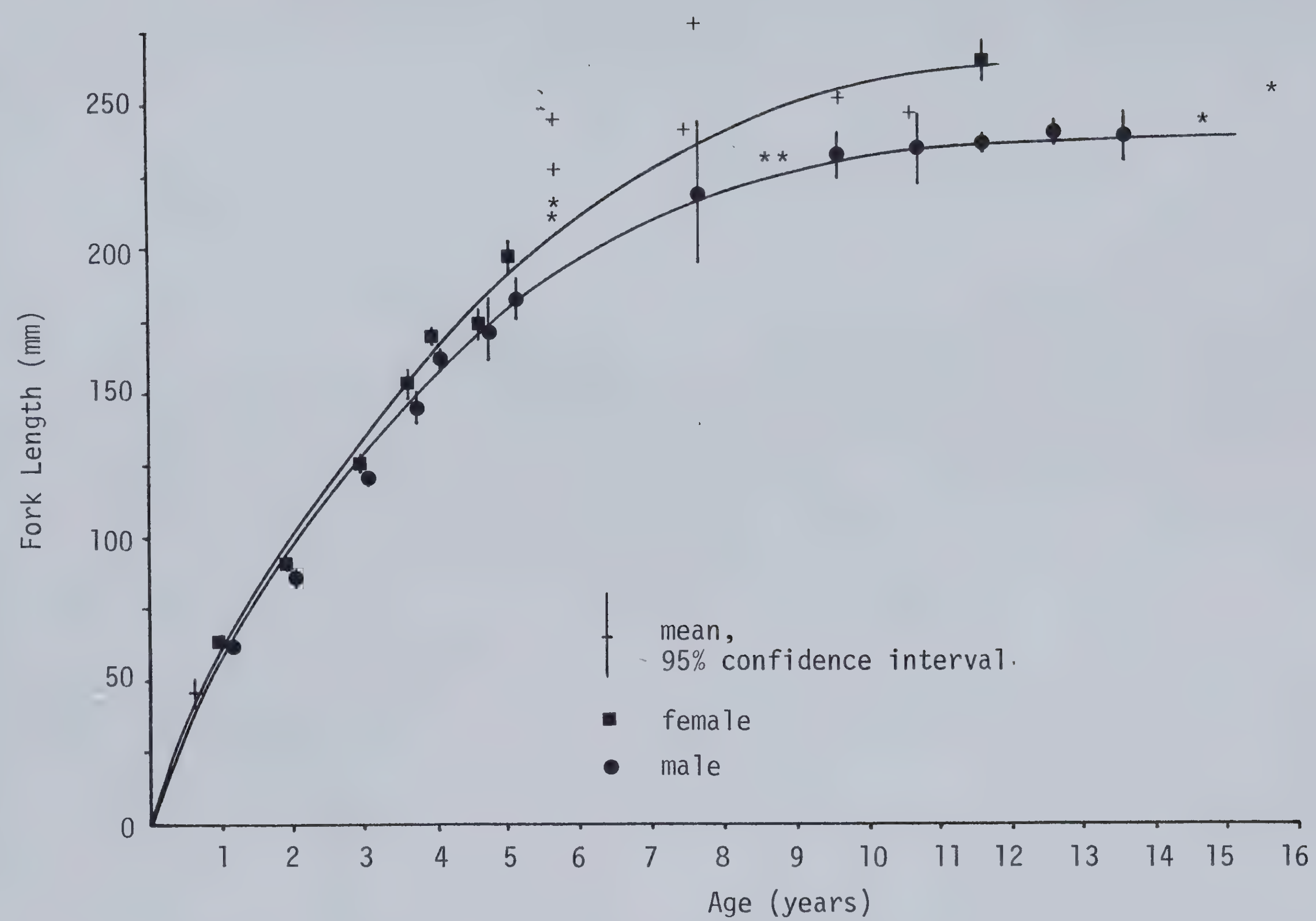


Figure 3.15. Growth in length of female and male yellow perch from Pine Lake. Datum points are also provided for some individual female(+) and male(*) fish.

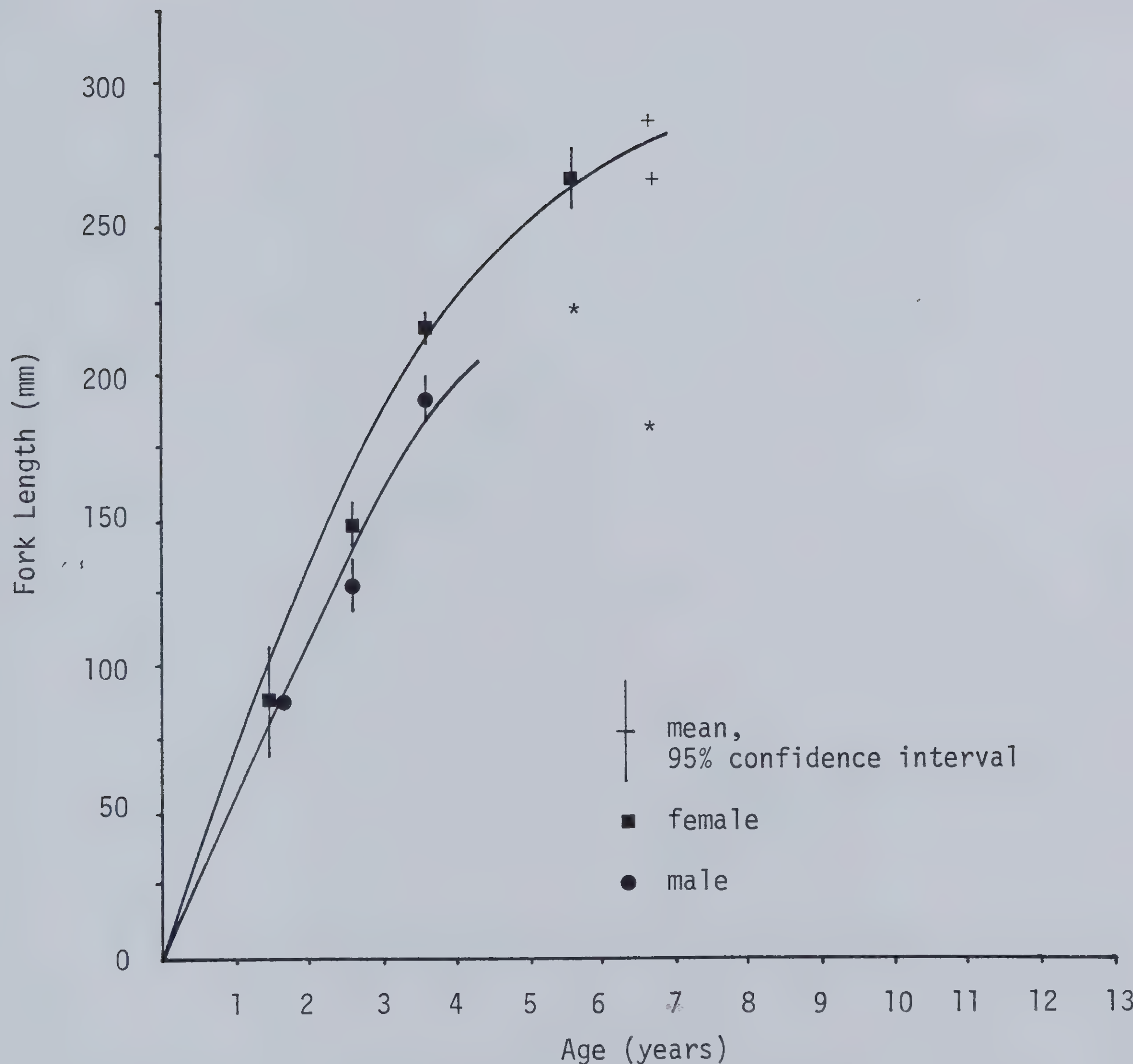


Figure 3.16. Growth in length of female and male yellow perch from Lessard Lake. Datum points are also provided for some individual female(+) and male(*) fish.

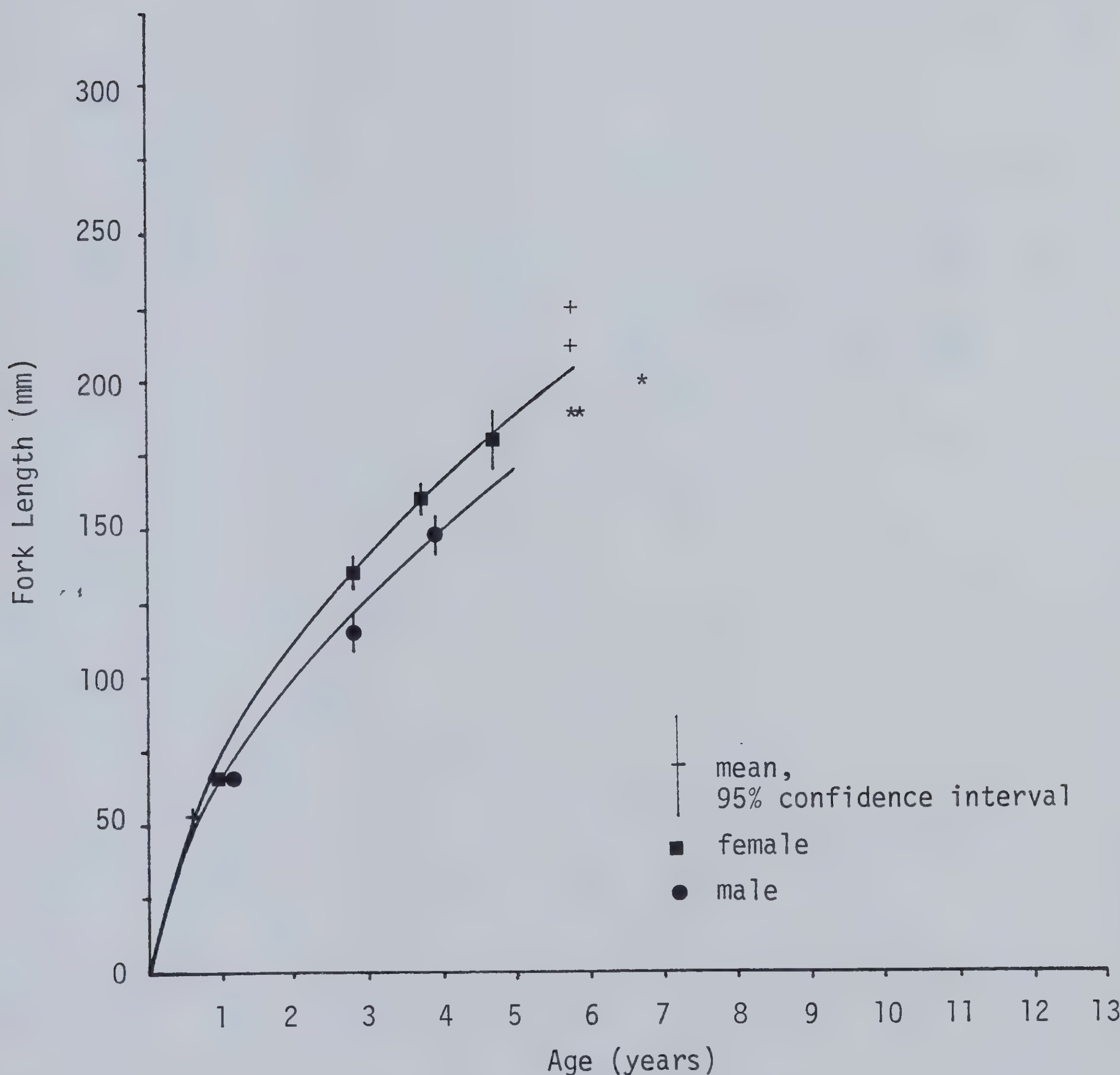


Figure 3.17. Growth in length of female and male yellow perch from Clear Lake. Datum points are also provided for some individual female(+) and male(*) fish.

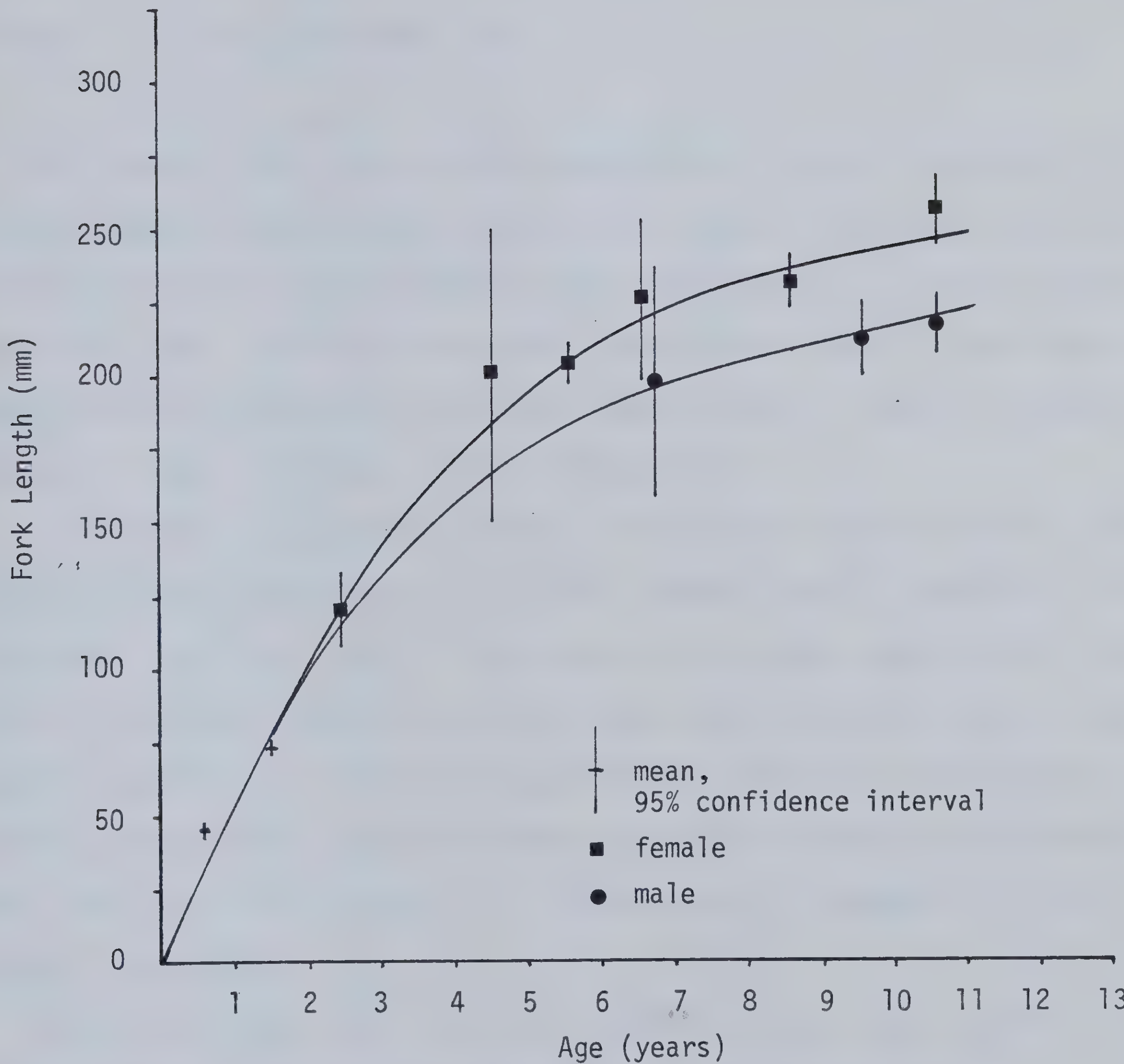


Figure 3.18. Growth in length of female and male yellow perch from Goose Lake. Data points for immature fish(+) were used for the growth of 0+ and 1+ fish.

	males	$\log L = 1.8679 + 0.5104 \log A$ (N = 79, r = 0.973, $p < 0.001$)
Goose Lake	females	$\log L = 1.8702 + 0.5151 \log A$ (N = 118, r = 0.971, $p < 0.001$)
	males	$\log L = 1.8578 + 0.4597 \log A$ (N = 112, r = 0.972, $p < 0.001$)

where: L = fork length (mm), and

A = age.

As expected from the previous examination of sexual dimorphism in length (Section 3.3b), the intercepts and slopes were larger for the female perch. The single exception was the intercept of the male perch from Pine Lake. This value was only 2.9mm larger than for the female perch from this lake and is probably larger because of the much greater number of large, older male perch in the samples.

The slopes of the growth equations for the female perch from Pine and Clear Lake were significantly ($p < 0.05$) greater than for the males from the same lake (Table 3.05). The slopes of the growth equations for the perch from Lessard and Goose Lakes were very similar to the slopes of the growth equations for the perch from Pine and Clear Lakes respectively. However, no reliable analysis of covariance could be made for the Lessard and Goose Lake perch because the variance ratios exceeded the F-test values (Table 3.05).

The length-weight data for these populations was also converted to linear equations to facilitate comparisons. The equations were:

Pine Lake	females	$\log W = -4.6365 + 2.8911 \log L$ (N = 113, r = 0.996, $p < 0.001$)

Table 3.05. Comparison of the regression lines of log age versus log fork length for female (F) and male (M) perch from each study lake.

Lake	Sex	df(N-2)	Test Value and Significance at 95% level		
			Variance	Slope	Elevation
Pine	F	452	1.06 NS	80.85 S	
	M	481			
Lessard	F	78	1.65 S		
	M	56			
Clear	F	100	1.30 NS	6.65 S	
	M	76			
Goose	F	115	2.23 S		
	M	109			

NS = no significant difference between the samples.

S = significant difference between the samples.

	males	$\log W = -4.8431 + 2.9975 \log L$ ($N = 113$, $r = 0.998$, $p < 0.001$)
Lessard Lake	females	$\log W = -5.0343 + 3.0352 \log L$ ($N = 81$, $r = 0.999$, $p < 0.001$)
	males	$\log W = -5.0414 + 3.0432 \log L$ ($N = 59$, $r = 0.997$, $p < 0.001$)
Clear Lake	females	$\log W = -5.1814 + 3.1126 \log L$ ($N = 68$, $r = 0.999$, $p < 0.001$)
	males	$\log W = -5.0983 + 3.0719 \log L$ ($N = 60$, $r = 0.997$, $p < 0.001$)
Goose Lake	females	$\log W = -4.8939 + 3.0031 \log L$ ($N = 88$, $r = 0.999$, $p < 0.001$)
	males	$\log W = -5.0256 + 3.0742 \log L$ ($N = 82$, $r = 0.998$, $p < 0.001$)

where: W = round weight (g), and
L = fork length (mm).

The slope and intercept values of these lines were very similar between each lake's male and female perch. They were also similar to the equation developed by Jobes (1952) for perch from Lake Erie ($\log W = -4.755 + 3.015 \log L$, where L = standard length) and by Kelso and Ward (1977) for fish from West Blue Lake, Manitoba ($\log W = -5.509 + 3.052 \log L$, where L = fork length).

Unlike the sexual dimorphism work, the equations developed in my study indicate that fish of either sex but equal length have approximately the same weight when sampled in the fall. Comparison of the length-weight relationship by analysis of covariance (Table 3.06) showed that female and male perch from Lessard Lake have similar slopes and elevations. The female and male perch from Clear Lake could not be

Table 3.06. Comparison of the regression lines of log fork length versus log weight for female (F) and male (M) perch from each study lake.

Lake	Sex	df(N-2)	Test Value and Significance at 95% level		
			Variance	Slope	Elevation
Pine Lake	F	110	1.20 NS	11.41 S	
	M	110			
Lessard Lake	F	78	1.40 NS	0.06 NS	1.29 NS
	M	56			
Clear Lake	F	65	2.38 S		
	M	57			
Goose Lake	F	85	1.19 NS	6.88 S	
	M	79			

NS = no significant difference between the samples.
S = significant difference between the samples.

compared because the variance ratio was too large. The slopes of the lines for the Pine and Goose Lakes data sets were significantly ($p < 0.05$) different according to these calculations. Male perch from Pine and Goose Lakes were actually very slightly heavier than female perch of the same length from these lakes when sampled at this time of year.

Comparisons between lakes of the age versus fork length relationships for each sex by analysis of covariance were generally inconclusive (Tables 3.07 and 3.08). The variance ratios were too large to permit reliable comparisons of the Pine and Goose Lake females, the Lessard and Goose Lake females, Clear and Goose Lake females, Pine and Goose Lake males, Lessard and Clear Lake males, and the Lessard and Goose Lake males. The slopes of the lines were significantly different ($p < 0.05$) between the Pine and Clear Lake females indicating a faster growth rate for the female perch from Pine Lake. Male perch from Clear Lake had a significantly ($p < 0.05$) faster rate of growth than male perch from Goose Lake. The slopes of the age versus fork length relationships were not different between the Pine and Lessard Lake females, Lessard and Clear Lake females, Pine and Lessard Lake males, and the Pine and Clear Lake male perch, indicating similar growth rates. Of the latter four data groups only the Pine and Clear Lake male perch also had similar ($p > 0.05$) elevations demonstrating that these fish were of equivalent size at each equal age. The female perch from Lessard Lake had 40% and 31% longer fork lengths at each age than the female perch from Pine and Clear Lakes respectively. Male perch from Lessard Lake were 23% longer at each age than male perch from Pine Lake.

Table 3.07. Comparison of the regression lines of log age versus log fork length for the female perch from the study lakes.

Lake	df(N-2)	Test Value and Significance at 95% level		
		Variance	Slope	Elevation
Pine L.	453	1.23 NS	0.19 NS	460.90 S
Lessard L.	79			
Pine L.	453	1.09 NS	5.34 S	
Clear L.	101			
Pine L.	453	1.53 S		
Goose L.	117			
Lessard L.	79	1.35 NS	2.19 NS	202.35 S
Clear L.	101			
Lessard L.	79	1.88 S		
Goose L.	116			
Clear L.	101	1.40 S		
Goose L.	116			

NS = no significant difference between the samples.
S = significant difference between the samples.

Table 3.08. Comparison of the regression lines of log age versus log fork length for the male perch from the study lakes.

Lake	df(N-2)	Test Value and Significance at 95% level		
		Variance	Slope	Elevation
Pine L.	481	1.26 NS	0.03 NS	111.69 S
Lessard L.	57			
Pine L.	481	1.26 NS	0.36 NS	0.67 NS
Clear L.	77			
Pine L.	481	1.55 S		
Goose L.	110			
Lessard L.	57	1.59 S		
Clear L.	77			
Lessard L.	57	1.95 S		
Goose L.	110			
Clear L.	77	1.23 NS	10.79 S	
Goose L.	110			

NS = no significant difference between the samples.
S = significant difference between the samples.

Similar comparisons between populations were also made by analysis of covariance of the length versus weight relationships. Variance ratios were too large to compare the Pine and Lessard Lake females, Pine and Clear Lake females, Pine and Goose Lake females, Pine and Clear Lake males, and the Clear and Goose Lake male perch (Tables 3.09 and 3.10). Fish weights typically vary much more than length for a given age. Significantly ($p < 0.05$) different slopes occurred in the relationships of fork length versus round weight between the Lessard and Clear Lake females, Clear and Goose Lake females, and Pine and Goose Lake male perch. Female perch from Clear Lake had a slightly more rapid rate of weight gain than female perch from Lessard and Goose Lakes. Male perch from Goose Lake gained weight more rapidly than male perch from Pine Lake. The Lessard and Goose Lake females, Pine and Lessard Lake males, and Lessard and Goose Lake male perch had similar slopes but significantly ($p < 0.05$) different elevations demonstrating that the rate of weight gain was similar in the adult perch but that one population of each pair was slightly heavier. Female perch from Goose Lake were 18% heavier than female perch from Lessard Lake. Male perch from Lessard Lake were lighter than male perch of equal length from Pine and Goose Lakes by 27% and 20% respectively. The slope and elevation of the Lessard and Clear Lake male perch fork length versus round weight relationships were similar indicating equivalent weight for fish of corresponding lengths from the two populations.

Table 3.09. Comparison of the regression lines of log fork length versus log weight for the female perch from the study lakes.

		Test Value and Significance at 95% level		
Lake	df(N-2)	Variance	Slope	Elevation
Pine L.	111	1.60 S		
Lessard L.	79			
Pine L.	111	1.85 S		
Clear L.	66			
Pine L.	111	1.50 S		
Goose L.	86			
Lessard L.	79	1.15 NS	9.93 S	
Clear L.	66			
Lessard L.	79	1.07 NS	1.63 NS	129.81 S
Goose L.	86			
Clear L.	66	1.23 NS	19.60 S	
Goose L.	86			

NS = no significant difference between the samples.
S = significant difference between the samples.

Table 3.10. Comparison of the regression lines of log fork length versus log weight for the male perch from the study lakes.

Lake	df(N-2)	Test Value and Significance at 95% level		
		Variance	Slope	Elevation
Pine L.	111	1.05 NS	1.65 NS	171.38 S
Lessard L.	57			
Pine L.	111	1.55 S		
Clear L.	58			
Pine L.	111	1.05 NS	7.11 S	
Goose L.	80			
Lessard L.	57	1.48 NS	0.42 NS	0.04 NS
Clear L.	58			
Lessard L.	57	1.11 NS	0.70 NS	108.05 S
Goose L.	80			
Clear L.	58	1.63 S		
Goose L.	80			

NS = no significant difference between the samples.
S = significant difference between the samples.

The comparison of the growth equations was relatively inconclusive as just over half of the sample comparisons could not be completed because the ratio of sample variances exceeded the F test values. From the comparisons that were completed it was apparent that perch from Lessard Lake had a longer length than fish of equal age from Pine or Clear Lakes. It was also determined that the perch from Clear Lake had fairly similar rates of growth when compared to perch from Pine and Goose Lakes. Transposing the growth curves to common graphs (Figures 3.19 and 3.20) shows the similarity of the growth rates of the perch from the study lakes. This includes the "stunted" perch from Clear Lake which actually exhibit very similar growth rates to the other populations. The most notable difference is that they apparently do not live as long and hence never achieve the larger desirable size of the Pine and Goose Lake fish. Only 20% of the Clear Lake female and male perch captured in the gill nets were older than age 4. The oldest females sampled were age 5+ and one 6+ male was caught. This is very similar to the perch in nearby Lac Ste. Anne but it is not known why this short life-span occurs. Clear Lake is known to be susceptible to winter-kill, however no major kill was recorded in the years immediately preceeding this study. Oxygen levels in Clear Lake were reported to be 0.4 ppm at a depth of 1.8 m at one sample site on the lake when tested April 9, 1974 (Doran, 1974). This could have resulted in a substantial fish kill although no fish kill was reported and Harvey (1974) reported good numbers of pike being caught in Clear Lake on July 20, 1974. The stable back-calculated year-class

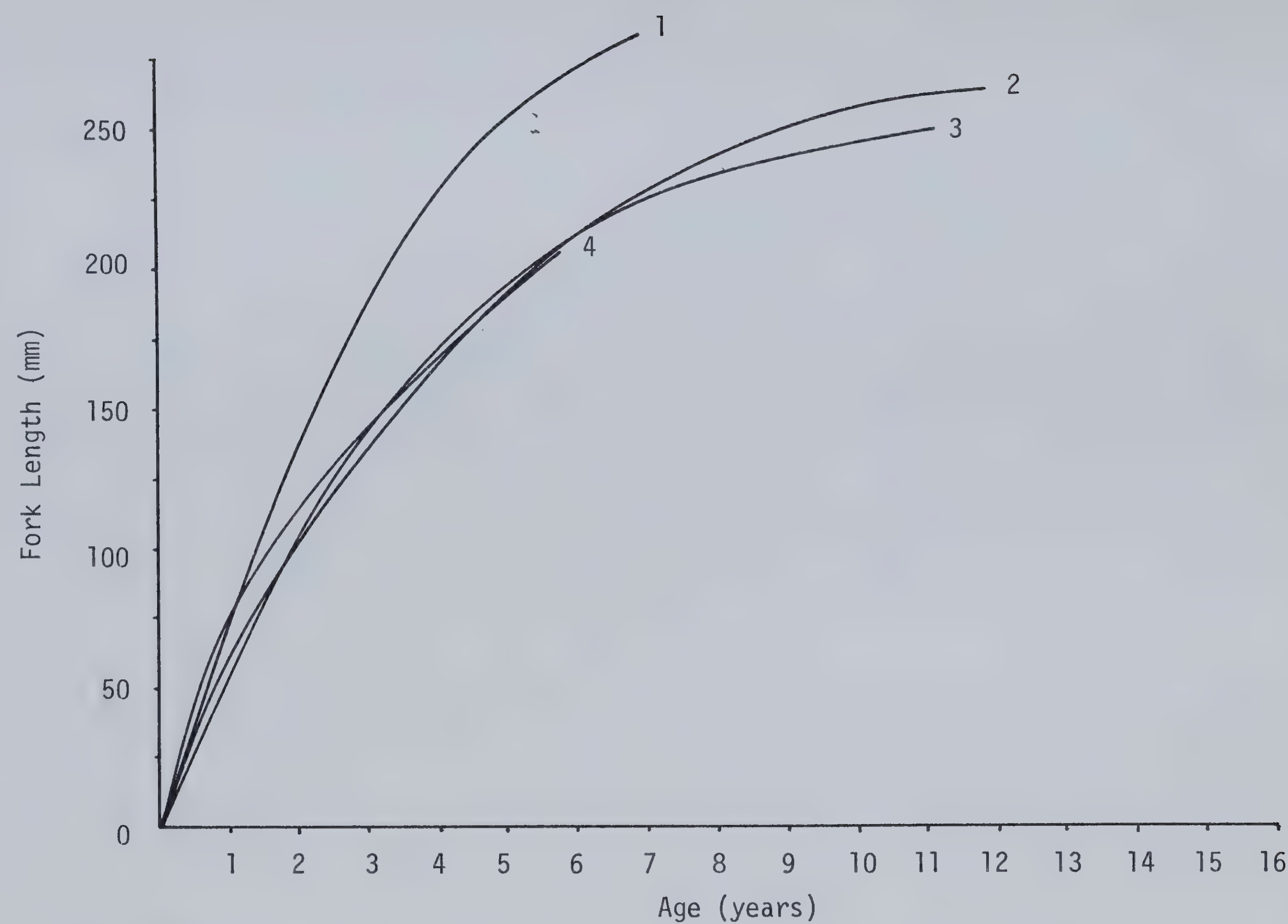


Figure 3.19. Growth in length of female yellow perch from Lessard(1), Pine(2), Goose(3) and Clear(4) Lakes.

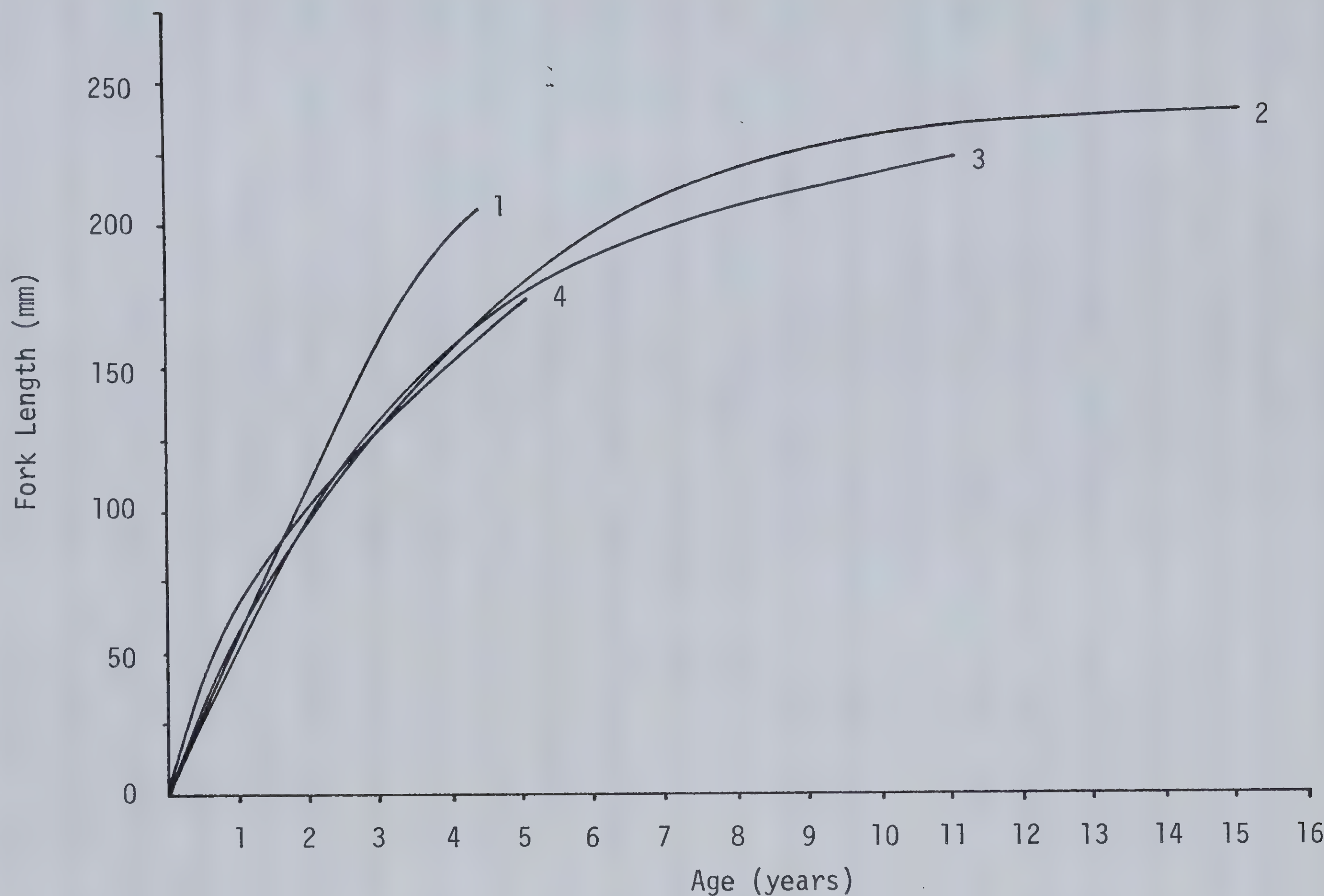


Figure 3.20. Growth in length of male yellow perch from Lessard(1), Pine(2), Goose(3) and Clear(4) Lakes.

growth histories also indicate that the population is not in the process of recovering from any severe decline in numbers and presumed increase in food availability. The pike population in Clear Lake is not believed to be large enough to limit the age achieved by the perch. Many grebes (Order Podicipediformes) were present on the lake but any fish captured by them would probably be age 0+ and 1+. Angling mortality is likely very minimal because of the small size of the perch and the little fishing effort observed during the study.

If a major winter-kill of the perch in Clear Lake did not occur in 1974, as suggested by the stability of the back-calculated growth rate, the short life-span of the perch from Clear Lake is similar to other populations described in the literature. Wells (1977) reported that only 29% of his 1954 sample of perch from Lake Michigan were older than age 3. The mean fork lengths of his 3 year old female (157 mm) and male perch (148 mm) were 20 and 30 mm larger than the comparable Clear Lake fish. Although Wells does not speculate on the reason for the short life-span, he found that growth improved and the fish lived longer when the population size was substantially reduced and not allowed to recover. Thorpe's (1977a) summarization of examples of fast and slow growing fish from the same waters showed that the slower growing fish did not live as long. This directly conflicts with Craig's (1978a) findings that Lake Windermere perch had shorter life spans during periods of more rapid growth. Wells believed that the improved growth of the Lake Michigan perch was due to a reduction in the competition for food rather

than an increase in the abundance of prey. Le Cren (1958) and Mann (1978) report similar results for perch from Lake Windermere and the River Stour, England, respectively. Johnson (1977) reported a temporary increase in yellow perch growth rates in Wilson Lake, Minnesota, after intensive selective removal of adult white suckers. He also attributed the improved growth rate to reduced competition for food. The Clear Lake perch stomachs sampled in this study seldom contained prey although large variations in feeding do occur (Craig, 1978b). These perch also had the lowest intercepts in the length versus weight growth equations of any of the populations I studied. Schneider (1972) suggested that excessive competition for food could result if too many 0+ perch survived in lakes with limited benthic fauna. Thomas (1957) and Erickson and Smith (1969) suggested that Clear Lake would have poor production of bottom fauna because of oxygen depletion in the deep water and the presence of a relatively unproductive sand and muck bottom. The Clear Lake perch may therefore be short-lived because of excessive competition for limited suitable food resources. Despite a shortage of food it would be advantageous for a population of schooling fish like the perch to have a greater population size rather than fewer but larger individuals. Nakashima and Leggett (1975) state that the trophically richer south basin of Lake Memphremagog has a greater abundance of perch, but that these fish are not growing any faster than the fish in the much less productive north basin of the lake.

The growth curves drawn for the Lessard Lake yellow perch indicate a short life-span but more rapid rate of growth than seen in the other three populations. These fish were introduced from Clear Lake in 1976 so they have not been in the lake long enough to be any older. The more rapid growth curve is biased to a steeper angle because the oldest fish in this lake grew the fastest (Section 3.3c). When the back-calculated growth histories of each Lessard Lake year-class are graphed (Figures 3.21 and 3.22), it is apparent that the growth rate has progressively declined. Attempts to compare these lines by analysis of covariance produced the following linear relationships using log-log transformations:

female perch year-classes

1977 $\log L = 2.0137 + 0.6096 \log A$, ($N = 140$, $r = 0.982$, $p < 0.001$)

1978 $\log L = 1.9721 + 0.4970 \log A$, ($N = 36$, $r = 0.920$, $p < 0.001$)

1979 $\log L = 1.8700 + 0.4537 \log A$, ($N = 7$, $r = 0.576$, $p < 0.20$)

male perch year-classes

1977 $\log L = 1.9716 + 0.5989 \log A$, ($N = 60$, $r = 0.967$, $p < 0.001$)

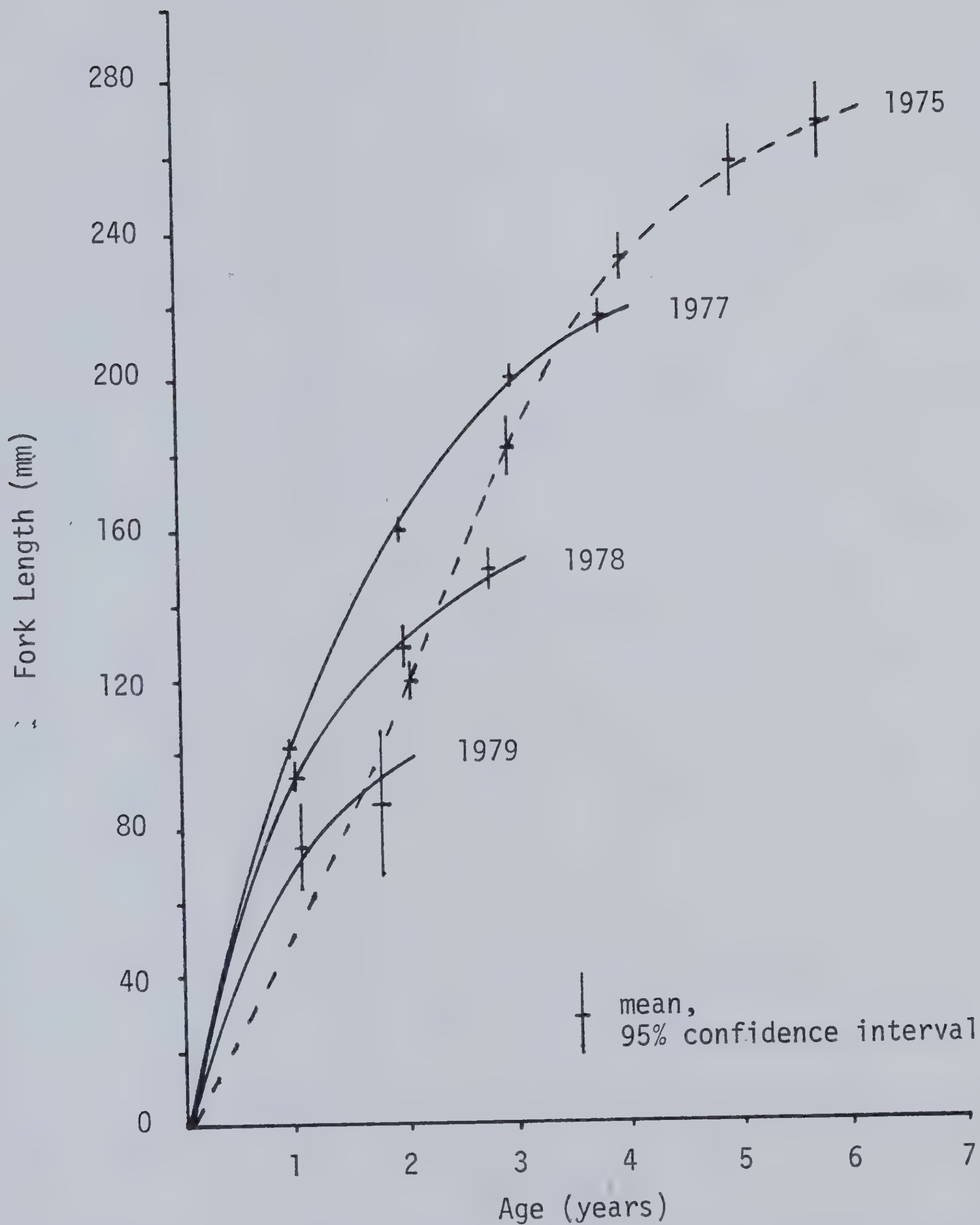


Figure 3.21. Back-calculated growth in length in four year-classes of female perch from Lessard Lake.

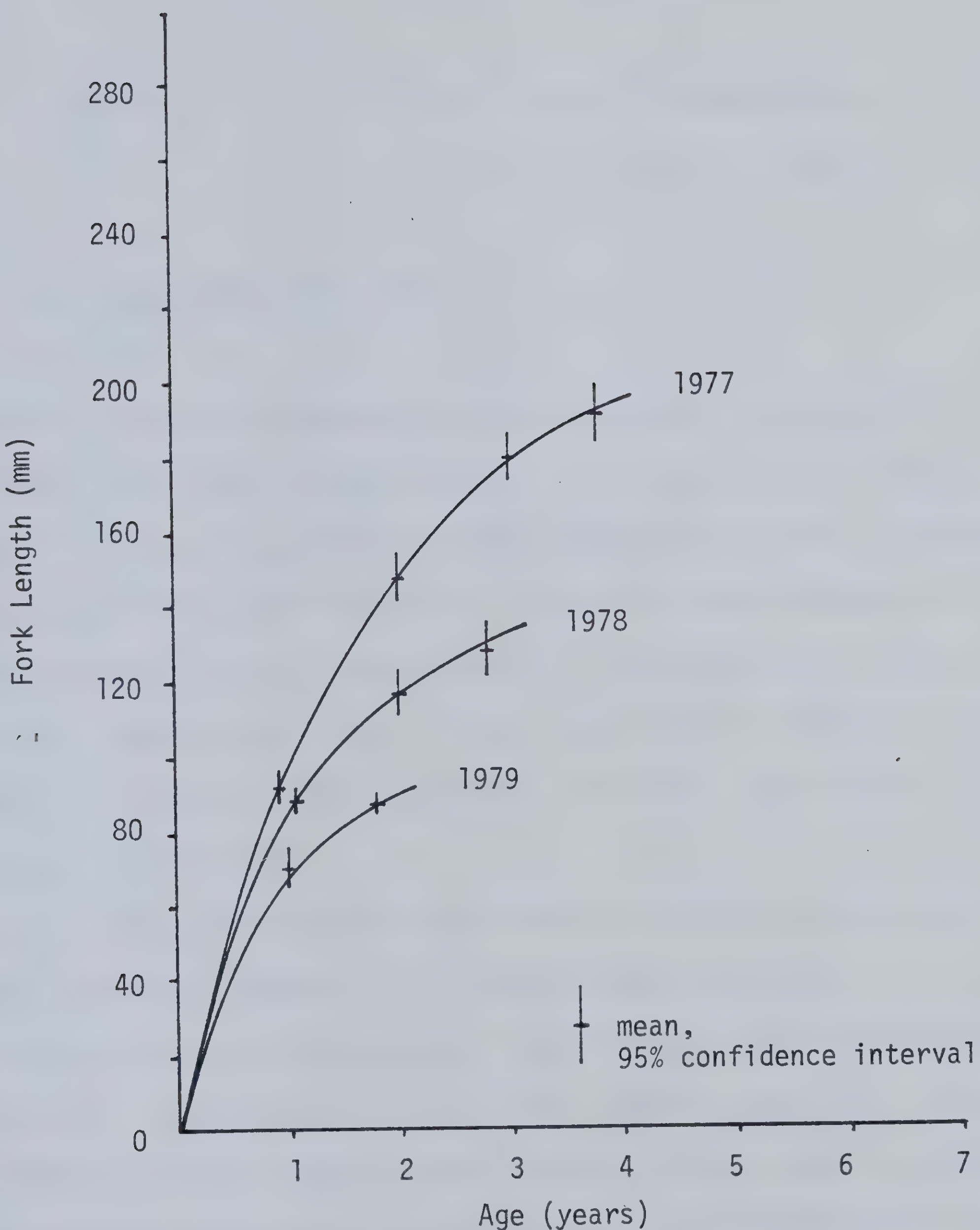


Figure 3.22. Back-calculated growth in length in three year-classes of male perch from Lessard Lake.

1978 $\log L = 1.9428 + 0.4157 \log A$,

$(N = 69, r = 0.788, p < 0.001)$

1979 $\log L = 1.8523 + 0.6049 \log A$,

$(N = 8, r = 0.963, p < 0.001)$

where: L = fork length (mm), and

A = age.

The equation for each subsequent year-class shows a progressive decline in intercept and slope except for the 1979 year-class of males. The slope of this line is greater than both the 1977 and 1978 year-classes. The absence of fish older than age 1+ in this limited sample would bias the slope of the line to a steeper pitch. Limitations in the size of the samples and ages of the fish in each year class resulted in widely different variances. This prevented reliable comparisons between year-classes (Table 3.11).

The declining growth rate is most likely due to increased competition for food and space because of a larger perch population. The growth curve of the 1979 Lessard Lake year-class, although limited in the age of the samples, is very similar to the growth curves of the other populations studied. There appears to be a rather rapid decrease in growth rate but benthic fauna production may also be limited and there is no quantitative measure of the annual spawning success. Schneider (1972) reported that growth in length of yellow perch in Jewett and Cassidy

Table 3.11. Comparison of the regression lines of log age versus log fork length for the female (F) and male (M) perch from Lessard Lake.

Year-class	Sex	df(N-2)	Test Value and Significance at 95% level: Variance	Slope	Elevation
1977	F	138	2.17 S		
1978	F	34			
1977	F	138	5.17 S		
1979	F	5			
1978	F	34	2.39 S		
1979	F	5			
1977	M	58	2.42 S		
1978	M	67			
1977	M	58	6.00 S		
1979	M	6			
1978	M	67	14.50 S		
1979	M	6			

NS = no significant difference between the samples.
S = significant difference between the samples.

Lakes, Michigan, was very low only two years after they had been stocked. Johnson (1977) found yellow perch growth rates declined five years after the population in Wilson Lake, Minnesota, had increased. Pivnicka and Svatora (1977) reported that perch growth rates declined within seven years of the first flooding of Klicava Reservoir, Czechoslovakia. Within four years of stocking, the perch in Lessard Lake have a growth rate similar to the donor stock. Unless the Lessard Lake fish live longer than the donor Clear Lake stock they will only provide limited recreational opportunities.

The Pine and Goose Lake populations had the most similar growth rates and life-spans although the former were slightly larger and older. The largest and oldest fish from each lake were usually females. Pivnicka and Svatora (1977) attribute this to the earlier maturation and higher mortality rate of male perch. Greater longevity of male perch has occassionally been recorded (Smith, 1977; Wells, 1977) and my Pine Lake sample consisted of more older males than females. However, the majority of these fish were collected in the spring prior to spawning. Sex ratios of percids captured at this time are usually heavily skewed in favor of the males. This is probably because they are actively searching for ripe females and the rapid escape movement efforts of the captured fish attracts more males.

Thorpe (1977b) quotes the growth rating developed by Tesch (1955) for perch as:

Category	Age - Group	Length (mm)
very good	II	> 200
good	III	> 200
moderate	III	> 160
poor	III	< 160
very poor	all fish	≤ 160

From Figures 3.19 and 3.20 it is apparent that the populations I studied have quite poor growth rates . Male and female perch had reached a fork length of approximately 160mm by the time they formed their fourth annuli. As few Clear Lake perch appear to live longer than this age or get larger, their growth is classed as very poor. Perch from Pine and Goose Lakes are considered to have poor growth rates because they do not reach the 160 mm fork length size until their fourth year. However, perch from these two populations live to ages 10-13 (years) and ultimately provide a desirable fish for anglers. The growth rate of the perch from Lessard Lake is classed as good. However, as previously noted the growth of the Lessard Lake fish was biased to greater sizes by the high growth rate of the fish initially produced in the lake.

Comparison with the published growth rates for other North American and European populations shows that the perch I studied have some of the lowest growth rates recorded (Table 3.12). Only perch from the Baltic archipelagoes and the 1959 year-class from Lake Windermere were as slow growing. These populations are from similar latitudes to the study lakes. It is not surprising that the North American perch populations

Table 3.12. Comparison of perch size (mm) in the study lakes, with other populations in North America and Europe.

Population and Reference	Sex	Length at Fourth Annulus	Maximum Length (and Age)
Goose Lake	F	152	278 (10+)
	M	136	247 (10+)
Clear Lake	F	167	225 (5+)
	M	150	200 (6+)
Lessard Lake	F	224	289 (5+)
	M	179	210 (3+)
Pine Lake	F	162	279 (11+)
	M	146	280 (15+)
Baltic archipelagoes, Sweden	F	153	259 (11)
(Neuman, 1976)	M	163	278 (11)
Lake Windermere, England			
(Craig, 1978a) 1959 year-class	F	158	269 (14)
1968 year-class	F	230	269 (7)
River Stour, England	F	271	323 (9)
(Mann, 1978)	M	245	288 (7)
Red Lakes, Minnesota	F	209	263 (10)
(Smith, 1977)	M	193	244 (11)
Lake Mendota, Wisconsin	F	237	256 (6)
(Bardach, 1955)	M	234	251 (6)
Oahe Reservoir, South Dakota	F	183	215 (6)
(Nelson and Walburg, 1977)	M	172	204 (6)
Sharpe Reservoir, South Dakota	F	179	196 (5)
(Nelson and Walburg, 1977)	M	172	185 (5)

Table 3.12 continued. Comparison of perch size (mm) in the study lakes, with other populations in North America and Europe.

Population and Reference		Sex	Length at Fourth Annulus	Maximum Length (and Age)
Lake Memphremagog, Vermont-Quebec (Nakashima and Leggett, 1975)		both	195	275 (8)
Lake Michigan	1954	F	181	181 (4)
(Wells, 1977)		M	168	185 (6)
	1975	F	231	334 (8)
		M	220	267 (7)
Lake Erie		F	245	283 (6)
(Jobes, 1952)		M	232	251 (5)
Ferguson Reservoir, Ohio		F	273	303 (5)
(Paxton and Stevenson, 1978)		M	244	253 (5)
Keowee Reservoir, South Carolina (Clugston et al., 1978)		both	208	240 (7)

from lower latitudes grew faster. These more southerly populations experience longer ice free periods and higher water temperatures. Nakashima and Leggett (1975) reported that new annual growth started in about half of their Lake Memphremagog samples when the water temperature reached 13 C. Le Cren (1958) found a positive correlation between growth and summer water temperatures. He concluded that growth begins in the spring when summer water temperatures are 13 - 14 C. Neuman (1976) stated that growth of perch in the Baltic archipelagoes was also positively related to water temperatures in the summer growing season.

3.4 Summary

Various aspects of the growth of yellow perch from Pine, Ste. Anne, Lessard, Clear and Goose Lakes were studied from samples collected between April, 1979 and November, 1980.

Young of the year perch from Pine, Ste. Anne, Clear and Goose Lakes grew to a length of approximately 50 mm by fall. Young of the year perch from Lessard Lake were significantly larger, with a fork length of 60mm. Frequent shifts in the population with the greatest fork length, and the presence of significantly different sizes of 0+ perch from Goose Lake, indicate the presence of different subgroups within the 0+ age-class. Over winter growth of approximately 10mm was recorded. Size selective over winter mortality of the smaller perch was not noted. The 0+ perch

from the study lakes exhibited similar growth rates to populations at similar latitudes in Europe. Growth rates reported for young of the year perch from most other North American populations were greater than in the study lakes.

Sexual dimorphism in length and weight was evident in most of the fall caught samples. No sexual dimorphism was noted for 0+ perch. It first occurred in age 2 fish at a fork length of 91mm and a round weight of 14g. All females were significantly larger and heavier than their male counter parts by age 3, in all the samples.

Growth histories for each year-class were calculated for the Pine, Lessard and Clear Lake fish using the anal fin spine radius-body fork length relationship. The female and male Pine and Clear Lake perch showed quite stable growth histories. Both the female and male perch from Lessard Lake showed large progressive declines in the growth rates achieved by succeeding age classes.

Comparisons of log age versus log length, and log length versus log weight for female and male perch within and between populations were completed by analysis of covariance. However, the results were inconclusive largely due to variance ratios which were too large to permit completion of the analysis. Superimposing the growth lines on common graphs indicated the general similarity of growth rates between the populations. The major differences were the short life-span of the Clear Lake perch (5-6 years) which may be due to a shortage of food. Perch from Pine and Goose Lakes lived to ages 15 and 11 years respectively.

The initial growth curves drawn for the Lessard Lake perch were biased by the more rapid initial growth of the stocked fish and the 1977 year-class. The growth rate of the 1979 year-class very closely approximated that of the other populations studied. Examples of similarly short stabilization periods for perch stocked into lakes were also given.

Growth of yellow perch in the study lakes was among the lowest reported for the species. The fish just reached a fork length of approximately 160mm by formation of the fourth annulus. The observed slower growth rate of these more northern populations is believed to be due to cooler temperatures and shorter growing seasons.

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Appendix 3.01. Significance of sexual dimorphism in length of yellow perch.

Age	Source and date of sample	Sex	N	x	s^2	F test	d.f.	Significant difference at 95%
0+	Lac Ste. Anne Oct. 8/80	F M	12 18	47.1 46.5	6.81 4.85	passed	28	No
	Clear Lake Oct. 8/80	F M	24 36	48.2 47.5	32.23 40.03	passed	58	No
	Goose Lake Oct. 8/80	F M	14 16	40.9 40.0	9.15 7.60	passed	28	No
1	Pine Lake backcalculation	F M	62 42	66.9 64.2	12.28 16.11	passed	102	Yes
	Clear Lake June 17/80 & backcalculation	F M	21 28	66.3 66.9	18.70 20.01	passed	47	No
1+	Pine Lake Aug. 13/8	F M	9 6	89.6 89.2	35.53 63.77	passed	13	No
	Lessard Lake Oct. 1/80	F M	4 4	87.0 87.3	148.67 2.25	failed	3.1	No
2	Pine Lake Sept./80 & backcalculation	F M	62 42	91.0 86.6	50.16 75.94	passed	102	Yes
2+	Pine Lake Aug.13/80	F M	13 8	113.5 106.5	95.77 25.43	failed	18.6	No
	Lessard Lake Oct. 1/80	F M	12 23	149.3 128.6	110.61 332.07	failed	32.5	Yes
3	Pine Lake May 6,16,28/80 Sept. 11,17,23/80 & backcalculation	F M	71 52	126.5 120.2	173.73 134.36	passed	121	Yes

Appendix 3.01. Continued.

Age	Source and date of sample	Sex	N	x	s^2	F test	d.f.	Significant difference at 95%
	Clear Lake Oct./79 Oct./80 & backcalculation	F M	22 14	135.5 115.0	177.22 152.45	passed	34	Yes
3+	Pine Lake Sept.11,17,23/80	F M	29 20	153.4 145.0	197.17 150.05	passed	47	Yes
3+	Lessard Lake Oct. 1/83	F M	35 15	216.8 191.7	190.44 156.64	passed	48	Yes
4	Pine Lake April 10/79 Oct. 18/83 May 6-June 19/80 & backcalculation	F M	110 139	170.4 162.7	205.52 209.77	passed	247	Yes
	Clear Lake Oct./79, Oct./80 June/80 and backcalculation	F M	26 13	161.1 149.2	184.60 114.96	passed	37	Yes
4+	Pine Lake Aug.13,Sept11/80	F M	21 18	173.9 172.1	134.33 174.34	passed	37	Yes
5	Pine Lake April 11, Oct. 18/79 May 6, May 28, Sept. 17/80	F M	38 18	197.3 183.5	234.39 176.85	passed	54	Yes
6+	Goose Lake* Oct. 10/80	F M	4 2	226.3 197.0	328.25 18.00	passed	4	No
8+	Goose Lake* Oct. 10/80	F M	11 2	232.5 194.0	158.68 450.00	passed	11	Yes

Appendix 3.01. Continued.

Age	Source and date of sample	Sex	N	x	s^2	F test	d.f.	Significant difference at 95%
9+	Goose Lake* Oct. 10/80	F M	2 7	250.0 212.6	128.00 216.29	passed	7	Yes
10+	Goose Lake Oct. 10/80	F M	10 18	256.7 217.3	281.35 188.35	passed	26	Yes
11+	Pine Lake April 11/	F M	8 75	266.0 237.0	71.41 92.09	passed	81	Yes

* not included in Figure 3.08 because of small sample size.

Appendix 3.02. Significance of sexual dimorphism in weight of yellow perch.

Age	Source and date of sample	Sex	N	$\bar{x}$	s^2	F test	d.f.	Significant difference at 95%
0+	Lac Ste. Anne Oct. 8/83	F M	12 18	1.2 1.1	0.05 0.05	passed	28	No
	Clear Lake Oct. 8/80	F M	24 36	1.2 1.2	0.20 0.15	passed	58	No
	Goose Lake Oct. 8/80	F M	14 16	0.95 0.94	0.04 0.02	passed	28	No
1	Clear Lake June 17/80	F M	10 21	3.1 3.0	0.22 0.35	passed	29	No
1+	Pine Lake Aug. 13/80	F M	9 6	8.0 8.5	8.25 6.70	passed	13	No
	Lessard Lake Oct. 1/80	F M	4 4	8.3 7.6	10.92 1.56	passed	6	No
2	Clear Lake June 17/80	F M	4 8	13.9 10.9	1.54 2.80	passed	10	Yes
2+	Pine Lake Aug. 13/80	F M	13 8	17.4 16.1	31.76 9.27	passed	19	No
	Lessard Lake Oct. 1/80	F M	12 23	37.9 27.3	47.36 113.64	passed	33	Yes
	Clear Lake Oct./79 and Oct./80	F M	13 9	35.9 16.6	82.74 45.78	passed	20	Yes
3	Pine Lake May 6,16,28/80	F M	9 11	24.0 20.9	45.00 37.29	passed	18	No
	Clear Lake June 17/80	F M	9 3	35.2 19.0	109.94 61.00	passed	10	Yes
3+	Pine Lake Oct. 10/79 and Sept. 11,17,23/80	F M	60 36	53.9 49.8	296.20 246.65	passed	94	No

Appendix 3.02. Continued.

Age	Source and date of sample	Sex	N	$\bar{x}$	s^2	F test	d.f.	Significant difference at 95%
3+	Lessard Lake Oct. 1/80	F M	35 15	112.3 76.5	563.48 200.84	failed	42.6	Yes
	Clear Lake Oct./79 Oct./80	F M	14 10	50.2 42.6	197.72 123.82	passed	22	No
4	Pine Lake April 10/79 and May 6,16,28/80	F M	64 88	70.2 59.2	348.00 250.78	passed	150	Yes
4+	Pine Lake Aug. 13/80	F M	12 4	67.6 78.3	269.36 976.92	failed	3.6	No
	Pine Lake Oct./79 and Sept/80	F M	34 19	89.6 72.6	416.60 351.47	passed	51	Yes
5	Pine Lake April/79 and May/80	F M	13 12	136.9 88.0	822.74 265.27	failed	19.3	Yes
6+	Goose Lake* Oct. 10/8	F M	4 2	147.8 105.0	1694.25 8.00	passed	4	No
	Goose Lake* Oct. 10/80	F M	11 2	166.0 107.0	476.80 512.00	passed	11	Yes
9+	Goose Lake* Oct. 10/8	F M	2 7	210.5 138.6	1012.50 692.96	passed	7	Yes
10+	Goose Lake Oct. 10/80	F M	10 18	231.6 150.0	2367.60 748.11	passed	26	Yes
11+	Pine Lake April 11/79	F M	8 75	202.0 316.0	1759.00 842.63	passed	81	Yes

* not included in Figure 3.09 because of small sample size.

Appendix 3.03. Back-calculated mean fork lengths (mm) of female and male yellow perch from Pine Lake.

		Age					
Year-class	N	1	2	3	4	5	6
Females							
1975	1	66.4	104.8	149.7	175.3	213.8	233*
1976	27	66.6	89.6	126.9	164.8	188.8*	
1977	30	66.9	91.6	128.4	153.9*		
1978	4	69.0	93.4	122.0*			
1979	0						
1980	5	46.8*					
Back-calculated mean fork length of all females		66.9	91.0	128.1	165.2	213.8	
95% CL		±0.9	±1.8	±3.4	±5.8		
N		62	62	58	28	1	
Males							
1975	2	58.9	83.9	117.1	152.5	177.5	195.5*
1976	17	64.6	87.5	120.4	153.9	172.5*	
1977	20	63.5	85.7	121.1	145.*		
1978	2	72.2	91.3	129.*			
1979	1	64.1	83.*				
1980	5	46.8*					
Back-calculated mean fork length of all males		64.2	86.7	120.6	153.7	177.5	
95% CL		±2.4	±2.7	±3.8	±6.8		
N		42	41	39	19	2	

* actual fork length of fish captured in September and October, 1980.

Appendix 3.04. Back-calculated mean fork lengths (mm) of female and male yellow perch from Clear Lake.

		Age				
Year-class	N	1	2	3	4	5
Females						
1976	4	68.9	94.1	124.2	151.4	175.8*
1977	5	66.0	91.0	127.1	158.8*	
1978	2	67.3	104.9	143.5*		
1979	0					
1980	60	47.8				
Males						
1976	1	65.3	96.3	114.9	135.1	146.*
1977	4	67.0	91.1	122.4	145.*	
1978	1	62.7	90.6	112.*		
1979	1	59.0	91.*			
1980	60	47.8*				
Sexes Combined						
1976	5	68.2	94.6	122.4	148.2	169.8*
1977	9	66.4	91.1	125.0	152.7*	
1978	3	65.7	100.0	133.7*		
1979	1	59.0	91.*			
1980	60	47.8*				
Back-calculated mean fork length of all fish		66.4	93.7	124.1	148.2	
95% CL		±2.0	±3.7	±3.5	±11.4	
N		18	17	14	5	

* actual fork length of fish captured October 10 and 15, 1980.

Appendix 3.05. Back-calculated mean fork lengths (mm) of female and male yellow perch from Lessard Lake.

		Age					
Year-class	N	1	2	3	4	5	6
Females							
1975	11	90.9 ± 2.6	119.2 ± 5.8	182.6 ± 8.1	232.4 ± 5.7	258.4 ± 9.2	268. ± 10.5*
1976	0						
1977	35	102.5 ± 1.7	160.9 ± 3.1	200.7 ± 3.6	216.8 ± 4.7*		
1978	12	94.7 ± 4.7	128.2 ± 6.9	149.3 ± 6.7*			
1979	4	75.7 ± 11.0	87.0 ± 19.4*				
1980	17	59.6 ± 1.6*					
Males							
1975	1	82.2	105.9	147.2	176.7	218.1	224
1976	0						
1977	15	92.4 ± 4.0	148.1 ± 7.0	180.5 ± 6.0	191.7 ± 6.9*		
1978	23	88.2 ± 3.1	116.6 ± 6.4	128.6 ± 7.9*			
1979	4	71.2 ± 4.9	87.3 ± 2.4*				
1980	17	59.6 ± 1.6*					

* actual fork length of fish captured October 1 and 8, 1980.

Appendix 3.06. Age versus fork length (mm) data for perch collected from Pine Lake.

Age	Female		Male	
	N	Mean ± 95% CL	N	Mean ± 95% CL
0+	11	42.8 ± 2.9[1]	11	42.8 ± 2.9
	5	46.8 ± 5.1	5	46.8 ± 5.1
1	62	66.9 ± 0.9	42	64.2 ± 2.4
1+	0		1	(83)
2	62	91.0 ± 1.8	41	86.7 ± 2.7
2+	6	123.2 ± 15.5	4	124.3 ± 13.1
3	67	126.8 ± 3.2	50	119.9 ± 3.2
3+	61	158.9 ± 3.8	35	153.5 ± 5.0
4	105	169.7 ± 2.7	113	162.4 ± 2.7
4+	12	170.6 ± 7.6[1]	23	174.4 ± 6.4
	35	189.4 ± 4.7		
5	14	206.3 ± 7.3	16	184.4 ± 7.9
5+	3	233.3 ± 21.1	3	199.7 ± 51.7
6+	0		1	(222)
7+	2	(275,257)	3	219.0 ± 25.2
8+	0		2	(227,230)
9+	1	(253)	9	229.7 ± 9.0
10+	1	(245)	11	234.5 ± 11.3
11+	8	265.6 ± 7.1	78	237.0 ± 2.2
12+	0		25	239.6 ± 4.0
13+	0		9	237.3 ± 10.0
14+	0		1	(241)
15+	0		1	(251)

1 August 13, 1980, sample data

log age versus log length data		
N	455	483
ΣX	194.8605	293.7354
ΣX^2	122.3295	249.9028
ΣY	957.1432	1046.5716
ΣY^2	2029.0371	2287.1721
ΣXY	433.3571	672.1113
$\bar{x}$	0.4283	0.6081
$\bar{y}$	2.1036	2.1668

Appendix 3.07. Age versus fork length (mm) data for perch collected in the fall from Lessard Lake.

	Female		Male	
Age	N	Mean ± 95% C.L.	N	Mean ± 95% C.L.
0+	17	59.6 ± 1.6	17	59.6 ± 1.6
1+	4	87.0 ± 19.4	4	87.3 ± 2.4
2+	12	149.3 ± 6.7	23	128.6 ± 7.9
3+	35	216.8 ± 4.7	15	191.7 ± 6.9
5+	11	268.2 ± 10.5		
6+	2	(287,266)		

log age versus log length data		
N	81	59
ΣX	26.6525	10.5366
ΣX^2	21.5989	10.3394
ΣY	177.3141	120.5688
ΣY^2	392.8948	248.7092
ΣXY	65.9769	25.7262
$\bar{x}$	0.3290	0.1786
$\bar{y}$	2.1891	2.0435

Appendix 3.08. Age versus fork length (mm) data for perch collected in the fall from Clear Lake.

	Female		Male	
Age	N	Mean ± 95% C.L.	N	Mean ± 95% C.L.
0+	24	48.2 ± 2.4	36	47.5 ± 2.1
1	11	67.3 ± 2.4	7	65.0 ± 4.0
1+	0		2	(100,91)
2	11	94.7 ± 5.9	6	91.9 ± 3.3
2+	13	142.2 ± 7.8	7	116.4 ± 11.1
3	9	125.8 ± 4.5	5	120.9 ± 7.1
3+	22	165.6 ± 6.2	10	151.6 ± 7.0
4	4	151.4 ± 10.3	1	(135.1)
4+	7	181.7 ± 8.7	2	(182,146)
5+	2	(225,211)	2	(190,190)
6+	0		1	(200)

log age versus log length data	Female	Male
N	103	79
ΣX	23.0673	2.2944
ΣX^2	20.3607	14.1754
ΣY	206.9962	148.7337
ΣY^2	421.1680	283.9036
ΣXY	54.9202	11.5212
$\bar{x}$	0.2240	0.0290
$\bar{y}$	2.0097	1.8827

Appendix 3.09. Age versus fork length (mm) data for perch collected in the fall from Goose Lake.

	Female		Male	
Age	N	Mean ± 95% C.L.	N	Mean ± 95% C.L.
0+	30	45.3 ± 2.6	30	45.3 ± 2.6
1+	45	73.4 ± 2.2	45	73.4 ± 2.2
2+	4	120.0 ± 13.2	4	120.0 ± 13.2
3+	1	(163)	2	(168,165)
4+	2	(205,197)	2	(195,176)
5+	7	204.6 ± 7.4	0	
6+	4	226.3 ± 28.8	2	(200,194)
7+	2	(222,239)	0	
8+	11	232.5 ± 8.5	2	(209,179)
9+	2	(258,242)	7	212.6 ± 13.6
10+	10	256.7 ± 12.0	18	217.3 ± 6.8

log age versus log length data

	Female	Male
N	118	112
ΣX	25.3138	21.9927
ΣX^2	40.3130	39.2669
ΣY	233.7223	218.1856
ΣY^2	472.7600	432.8668
ΣXY	68.1072	58.9096
$\overline{x}$	0.2145	0.1964
$\overline{y}$	1.9807	1.9481