AGE DETERMINATION AND BIOLOGICAL STUDIES OF NORTHERN PIKE ESOX LUCIUS LINNAEUS 1758 FROM LOBSTICK AREA, SMALLWOOD RESERVOIR, LABRADOR

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by

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ABSTRACT

A sample of 415 northern pike was taken from below Lobstick structure, Smallwood Reservoir, during the summers of 1977 and 1978. Four methods of age determination, scales, opercula, cleithra and otoliths, were compared to determine if different methods provided comparable ages for the same fish. Analysis of covariance showed significant differences between empirical and back-calculated age-length regressions using scales, opercula and cleithra; there were no differences using otoliths. Otoliths were used to study age and growth of pike from Lobstick. The maximum age recorded was 15 years, with 49% of the fish in the 7 and 8 age-groups. The fish ranged in length from 9.3 to 87.5 cm, with a mean fork length of 62.0 cm. The weight increased as the 3.0634 power of the length. Coefficient of condition values of mature fish, sampled from June to September, were highest in early June and lowest in late June. Instantaneous total mortality rates, calculated from a catch curve, were higher for females (0.37) than for males (0.32). The overall sex ratio was close to 1:1. Males were predominantly (50%) mature by age 5, or at 40 cm, females by age 8, or at 60 cm. Observation of ovaries of mature pike indicated that all pike did not spawn each year. Fecundity estimates of fish 51.0 to 87.5 cm in length ranged from 5732 to 62,000 with a mean of 28,016. Of the 86 stomachs examined for food contents, 62% were empty. Whitefish was the principal item (64%) where food was present.

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PREFACE

"Heibrum's pike with a length of 9 1/2 ells, a weight of 17 1/2 lispund, and an age of 267 years, has always appeared to me something of an exaggeration. Especially its age seemed to be most unbelievable. I thought: is it in agreement with the order established within the animal kingdom that nobler and more useful animals should have such a short span of life compared with that of the pike? That the pike after having lived 70 or 80 years shall, according to ancient belief, still enjoy the spring-time of life, while even man is already wasted?"

(Hederström 1759)

INTRODUCTION

Hederström recognized the difficulty in aging northern pike; he suggested that a fish could be aged by its vertebral rings similar to a tree being aged by its growth rings. Variations of this technique have been used to age northern pike for the past 220 years. Since annular growth zones were first detected on pike scales by Hoffbauer (1905), they have been used extensively in age and growth assessments (Miller and Kennedy 1948; Williams 1955; Frost and Kipling 1959; Casselman 1967). Several hard tissues have also been used; opercula (Svetovidov 1929; Frost and Kipling 1959), teeth (Astanin 1947), fin rays (Johnson 1959), otoliths (Hatfield et al. 1972) and cleithra (Casselman in preparation).

The Department of Fisheries and Oceans has conducted several fish studies of natural lakes and the Smallwood Reservoir in western Labrador. These investigations of Jacopie Lake (Bruce 1974), Lobstick and Sandgirt Lakes (Bruce 1975), Ten Mile Lake (Parsons 1975) and Ossokmanuan Reservoir (Bruce and Parsons 1979) have dealt, in part, with the biology of northern pike.

In the summers of 1977 and 1978, a more detailed biological study was conducted on northern pike from waters below Lobstick structure, a release gate for the Smallwood Reservoir. The area was chosen because of its accessibility and the known presence of a large population of northern pike.

The study was designed to compare four methods of age determination; scales, opercula, cleithra and otoliths. The comparisons were made to determine if different methods provided comparable ages for the same fish. The phenomenon of different ages for fish aged by scales and opercula has been documented (LeCren 1947; Frost and Kipling 1959; Hansen 1978). Aging studies of another esocid, the muskellunge, have shown that fish older than 9+ years could not be aged from scales, but cleithra were useful for fish as old as 16+ years (Harrison and Hadley 1979). The previous use of otoliths for age determination of pike has been limited (Hatfield et al. 1972); they have been used extensively to age other freshwater and marine species, reviews of which have been presented by Graham (1929), Trout (1956) and Chugunova (1959). Differences have also been shown between ages derived from scales and otoliths of other northern freshwater fish. For example, Dubois and Lagueux (1968) found that, for lake trout, such differences increased with older fish. Similarly, for largemouth bass, Maraldo and MacCrimmon (1979) found that ages greater than 7 years assigned from scales were more likely to underestimate true ages than those assigned from otoliths. Such aging discrepancies produce different estimates of growth, mortality, age at maturity and abundance of year-classes, which complicate stock assessment and management decisions.

Differences between the growth rates generated by each of the four aging methods were analyzed to try to determine if the results of any one method were more reliable than another. Growth measurements obtained from one aging method may be precise if visible annuli are easily delineated; however, those measurements may not be biologically meaningful if for some reason one or more annuli are obscured and are not counted in aging the fish. Even if the 'annuli' are easily delineated, it must be determined that they are yearly and not false checks caused by a cessation of growth during spawning or adverse environmental conditions. Empirical and back-calculated growth rates should not differ significantly assuming that the aging structure accurately reflects the growth of the fish and that no aging errors have been made. Lee's phenomenon, a decrease in the lengths of younger fish calculated from successively older age-groups, could produce differences between empirical and back-calculated growth rates. It has been documented for pike sampled by gillnet (Wolfert and Miller 1978); however, Miller and Kennedy (1948) suggest that for pike, Lee's phenomenon is probably an artefact introduced by inaccurate methods of growth computation. The aging method which showed the least variation between empirical and back-calculated growth rates was used in investigations of the size and age structure, growth rates, and reproductive biology of pike from the Lobstick area.

DESCRIPTION OF STUDY AREA

The development of the upper Churchill River hydroelectric potential has created a single large water system over much of the Labrador plateau (Fig. 1). Lobstick structure (53°52'N, 65°01'W) (Fig. 2), approximately 90 km northwest of the town of Churchill Falls, releases water from the 5700 km^2 Smallwood Reservoir. From Lobstick, the water flows southeast, approximately 60 km, to Jacopie Lake where it is retained in two forebays before entering the powerhouse at Churchill Falls.

Below Lobstick, the system follows a natural river channel, widening approximately 2 km below the structure into slow-moving areas with numerous backwaters and bays (Fig. 3). The river narrows again approximately 12 km downstream. All samples were taken from the area immediately below the structure to approximately 16 km downriver.

Surface water temperature below Lobstick structure (Fig. 4), during the summer of 1978, increased from 2 C in June to 15 C in July, and dropped to 8 C by September.

The daily water flow through Lobstick structure during the summer of 1978 ranged from 550 to 3130 M^3/sec. Water level fluctuations up to 1.5 m, observed in the system below Lobstick structure, were due to the variable rates of water flow through the structure (Fig. 5). Entire backwaters and bays were flooded or drained within a few hours due to the rapid water level fluctuations.

A heavy growth of deciduous bushes extends to the water's edge throughout much of the study area; combinations of marsh and low bushes are found along some backwaters. At times of high water, these areas are inundated and small ponds and bogs are united with the main system.

The bedrock of the area consists of archaean granites and gneisses dating back to the Cambrian era (Powell 1971). Limnological studies of the area (Duthie and Ostrofsky 1974) suggest that the bedrock, which is poor in nutrients and slow to weather, is important in determining the water chemistry of the system.

The fish fauna of the area consists of at least ten species. Large concentrations of lake whitefish (Coregonus clupeaformis) are present immediately below Lobstick structure. Other species present include: northern pike (Esox lucius), longnose suckers (Catostomus catostomus), white suckers (C. commersoni), lake trout (Salvelinus namaycush), brook trout (S. fontinalis), landlocked salmon (Salmo salar), burbot (Lota lota), round whitefish (Prosopium cylindraceum), and lake chub (Couesius plumbeus).

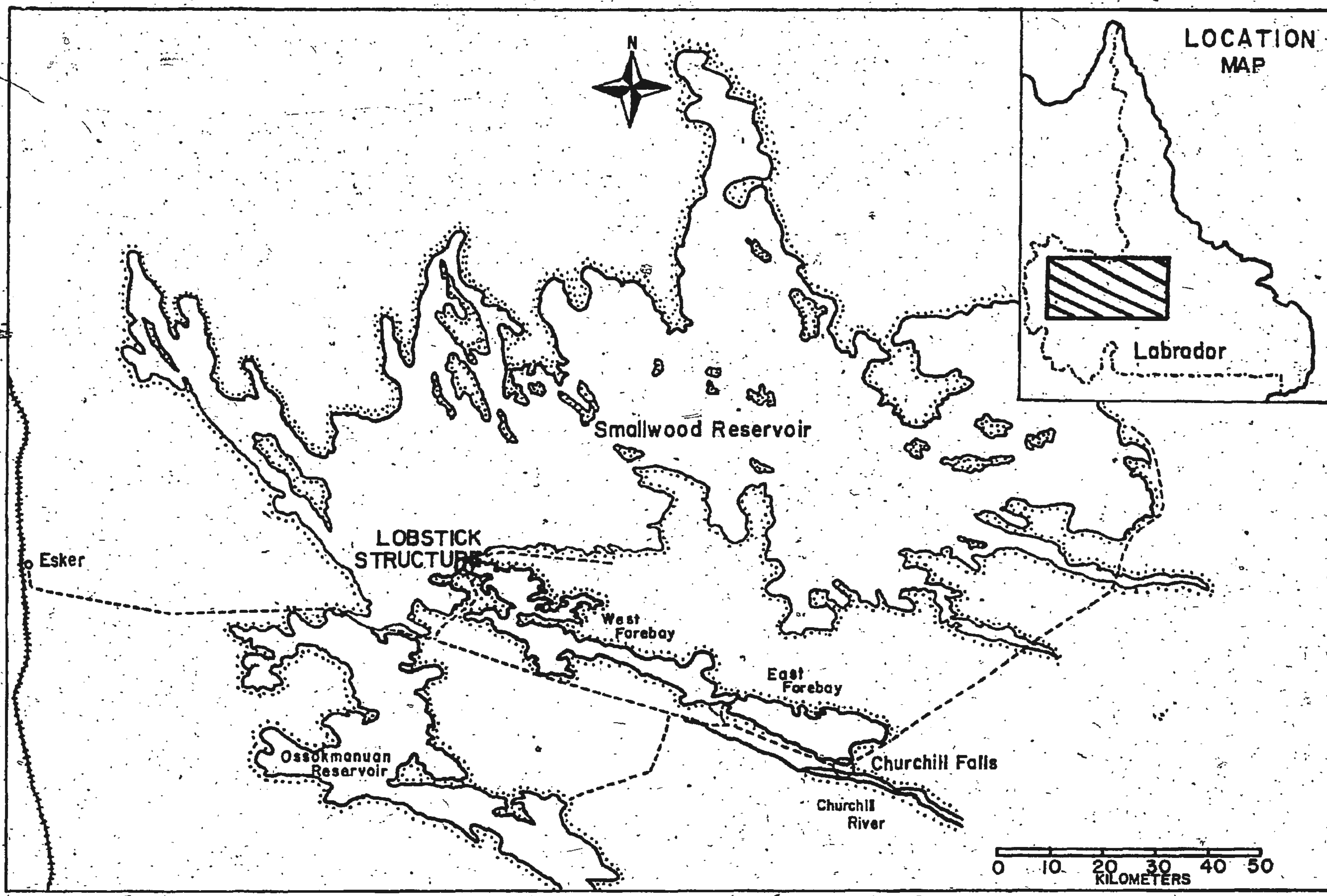

Fig. 1. Location map of Smallwood Reservoir and Lobstick structure.

Fig. 2. Lobstick structure, Smallwood Reservoir.

Fig. 3. Fyke net in flooded backwater below the Lobstick structure.

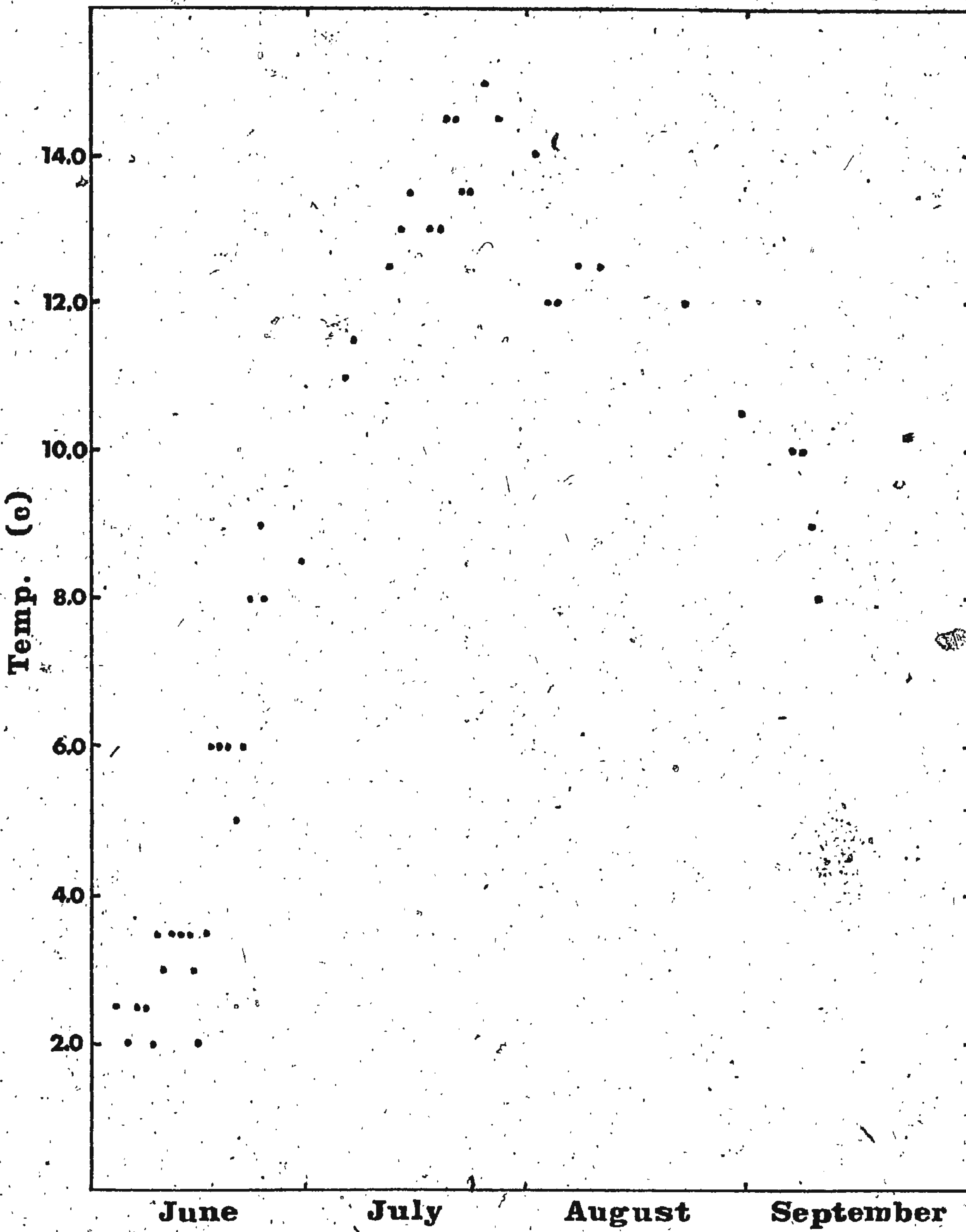

Fig. 4. Lobstick surface water temperature (C) from June to September 1978.

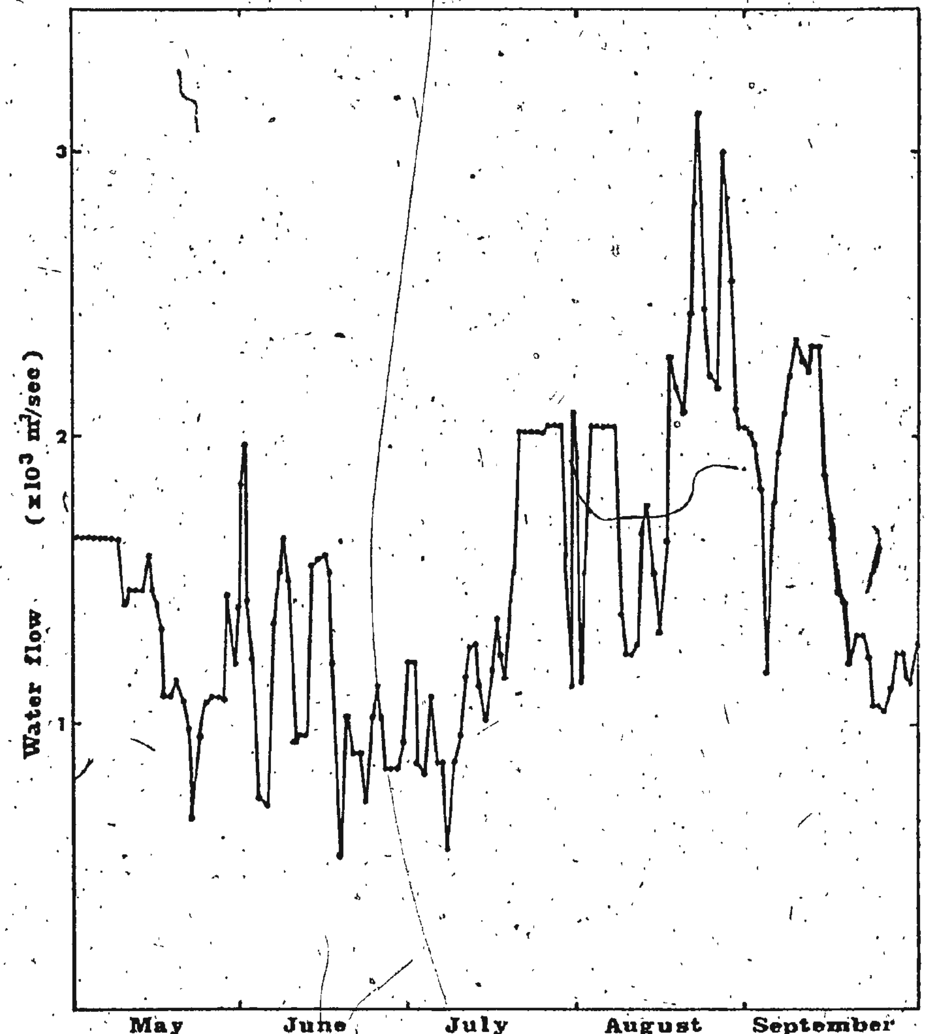

Fig. 5. Average daily water flow (M^3/sec) through Lobstick Structure May-September, 1978.

MATERIALS AND METHODS

Several methods were used to collect pike: angling, fyke nets, gillnet, seine and plexiglass traps. The fyke nets, or live traps, were constructed of 1.9 cm stretched mesh knitted nylon. They consisted of a 30.5 m leader, two 9.1 m wings, a body of one 1.2 m frame, one 0.9 m frame, three 0.6 m frames and a trailing cod end. The leader and wings were 1.8 m deep. The gillnet, with 7.6 cm stretched monofilament nylon mesh, was 45.5 m long and 1.8 m deep. The seine, constructed of 1.5 cm stretched mesh knitted nylon, was 30.5 m long and 3.0 m deep with a central bag-like extension of 4.0 m. The plexiglass traps, similar in design to the fyke nets, were constructed of 6 mm commercial grade plexiglass (Casselman and Harvey 1973). They consisted of a 1.5 m stretched mesh knitted nylon leader, two 0.8 m plexiglass wings and a two compartment plexiglass trap body, measuring 0.9 m long, 0.4 m wide and 0.4 m deep.

A sample of 415 pike was collected. Due to the restricted field season in Labrador, samples were collected from May through September. Most of the samples were taken in June, prior to and after the pike had spawned. A subsample of 213 of the 415 pike was selected for age determination studies. This subsample included all of the smaller fish (0-55 cm) collected and a representative sample of the large length classes (56-90 cm). The subsample facilitated faster analysis of age and growth using each of the four aging structures.

Scales were removed from the right side of each fish just below the dorsal fin and above the lateral line. The sagittae, the largest of the three pairs of otoliths, were removed after making a mid-sagittal cut through the skull. The operculum and cleithrum were removed from the right side of the body and were immediately cleaned using a scalpel and water. Scales, otoliths, cleithra and opercula henceforth called "aging structures" were each placed between paper and stored in an envelope.

Fork length, the distance from the most anterior extremity to the notch in the caudal fin, and total length, the distance from the most anterior extremity to the tip of the caudal fin, were measured to the nearest 0.1 cm. A conversion factor was calculated for fork length to total length. Total weight was measured to the nearest 0.01 kg using a Chatillon balance.

Sex and stage of maturity were determined by gross inspection of the gonads. Males were designated immature if the testes were small, narrow and threadlike, and showed no sign of vascularization. Maturing males had larger, prominent, highly vascularized testes. The testes of spent males showed this vascularization but were flaccid and not as prominent. Females were designated immature if the ovaries were small and narrow, with minute eggs less than 1 mm in diameter. Maturing ovaries of females were larger and very prominent, filling much of the body cavity. The ovaries of spent females were large, flaccid and bloodshot, and sometimes contained a few residual eggs.

The scales were examined using a Bausch and Lomb micro-projector (22 x) and aged according to the method of Williams (1955). Drawings were made of each scale and annular increments of growth were measured from these drawings. The opercula and cleithra were examined using a Bausch and Lomb dissecting microscope (6.67 x). The opercula were aged according to Frost and Kipling (1959), the cleithra according to Casselman (1974). For both opercula and cleithra, annular increments of growth were measured using an optical micrometer. Prior to aging, the otoliths were ground and burnt, a modification of the technique outlined by Christensen (1964). The lateral surfaces of the otoliths were polished using a wet stone; the otoliths were then placed on a hot plate at a temperature that caused them to brown in about 20 sec. They were dropped immediately into 95% alcohol, then heated again, dropped once more in alcohol, and allowed to cool. When examined, they were immersed in alcohol and viewed against a black background (Schott 1965) using a Wild M7 binocular microscope (30 x). The otoliths were aged according to Christensen (1964) and Tesch (1968). Each otolith image was drawn, using a camera lucida attached to the microscope; annular growth measurements were made from the drawings (MacKay 1967).

To determine growth, total lengths and annual growth increments of the aging structures were measured. The radius of each aging structure was measured from the mid-point of the nucleus to the margin along a standard axis. The distance from the nucleus to each annulus was also measured along this axis. The opercular nucleus was chosen as the point where a line drawn from the opposite indentations of the articulating "nub" is bisected; measurements were made on the concave (inner) surface of the bone at right angles to the line used in locating the chosen centre (Frost and Kipling 1959). The cleithral radius was measured from the origin to the point where the tip of the anterior blade intersects the medial costa (Casselman 1974). The origin was chosen as the point of intersection of two lines, one drawn along the medial costa and the other along the interior margin of the bone from the tip of the dorsal spine. Otolith radius was measured along an axis from the nucleus to the edge of the postrostrum.

To back-calculate growth of pike, the actual relationship between the growth of each aging structure and the length of the fish was determined. Individual fish lengths and the corresponding aging structure lengths were used to calculate these relationships. Linear and curvilinear body : aging structure relationships were derived; the curved relationships were used based upon their higher correlation coefficients. Each of the exponential equations was converted to a straight line using the following transformation:

$$\log l = K + n (\log S)$$

where l is fish length, K is the Y-intercept (in log units), n is the slope of the relationship and S is the length of the aging structure (Monastyrsky 1930).

Back-calculated age-length relationships were determined by fitting average annular aging structure lengths in the appropriate body : aging structure regression.

Analysis of covariance (Zar 1974) was used to statistically test the age-length regressions generated by each of the aging methods. The covariance analysis was used for comparison of both slopes and adjusted means. Also, in some cases, more than two regressions were compared simultaneously. By comparing adjusted means, the elevations of the regressions were compared. Adjusted means were tested only if the slopes of the regressions were significantly different. Therefore, if either the slopes or adjusted means of the lines differed significantly at $p = 0.05$, the regressions were considered significantly different.

The coefficient of condition was calculated by the following equation:

$$K = \frac{W \times 10^5}{L^3}$$

where W is whole weight (kg), L is fork length (cm) and 10^5 is a constant which allows K to assume a value near unity (Hile 1936).

Ovaries from 49 ripe females were preserved in Gilson's fluid (Simpson 1951). Fecundity was determined for 32 ovaries using an electronic DECCA batch counter (Boyar and Clifford 1967) and for the remaining 17 by volumetric displacement (Kandler and Pirwitz 1957). The volumetric method was used for those ovaries in which egg casings were too decomposed by the Gilson's fluid to be counted electronically. Egg number was estimated twice, using the batch counter, for a subsample of five ovaries. Estimates obtained from the two runs deviated less than 3%. Egg count estimates, on a subsample of five ovaries, using both the batch counter and volumetric method, deviated less than 10%.

The degree of fullness of the stomach and its contents were recorded for a sample of 386 fish. Frequency of occurrence was used as a qualitative method of food analysis.

RESULTS

I. Age determination

The empirical relationships between the length of each aging structure and the length of the fish are presented in Tables 1-4 and Figs. 6-9. The regression lines are graphic representations of the calculated regressions (Table 5), while the scatter plots and ranges represent the empirical data of average fork lengths and average lengths of the particular aging structure. Regression equations were calculated for sexes separated and combined. All aging structure lengths in Tables 1-5 are magnified lengths.

Empirical and back-calculated age-length data are presented in Tables 6-9 and Figs. 10-13. Scatter plots and ranges represent empirical average fork lengths at age; curves represent back-calculated relationships derived from the appropriate body : aging structure regression (Table 5).

Analyses of covariance were used to test for significant difference at $p = 0.05$ between slopes or adjusted means for the following age-length regressions:

Regression	Table No.
males vs. females for each aging method; empirical and back-calculated.	10
empirical vs. back-calculated for each aging method; sexes separated and combined.	11
scales vs. opercula vs. cleithra vs. otoliths; empirical and back-calculated; sexes separated and combined.	12

Regression	Table No.
otoliths vs. scales, otoliths vs. cleithra, otoliths vs. opercula, scales vs. opercula, scales vs. cleithra, and opercula vs. cleithra; back-calculated; sexes separated and combined.	13

Empirical age-length regressions for males did not differ significantly from females, using any of the four aging methods (Table 10). The difference between back-calculated age-length regressions for males and females was significant, for each of the four aging methods.

Empirical and back-calculated age-length regressions differed significantly using scales, opercula and cleithra (Table 11). However, using otoliths, the difference was not significant.

Empirical age-length regressions did not differ significantly, when comparing all four aging methods whereas back-calculated regressions did differ significantly (Table 12). For sexes separated and combined, the back-calculated age-length regressions generated by each aging method differed significantly from those generated by any other method with one exception; for females, the back-calculated age-length regressions, using otoliths or scales, did not differ significantly (Table 13).

II. Biological studies

A. Size and age composition

1. Length

The fork length distribution (Table 14) is unimodal with the

Table 1. The relationship between fork length (cm) and magnified (cm x 22) scale length of northern pike from Lobstick, Labrador.

Fork length (cm)	Scale Length (cm x 22)								
	Males			Females			Combined		
	Mean	Range	Sample Size	Mean	Range	Sample Size	Mean	Range	Sample Size
10.0	1.3	1.2- 1.4	2	1.8	-	1	1.5	1.2- 1.8	3
14.0	-	-	0	-	-	0	-	-	0
18.0	-	-	0	-	-	0	-	-	0
22.0	-	-	0	-	-	0	-	-	0
26.0	5.2	-	1	-	-	0	5.2	-	1
30.0	6.9	-	1	-	-	0	6.9	-	1
34.0	-	-	0	7.7	-	1	7.7	-	1
38.0	8.8	8.6- 9.0	2	8.6	7.9- 9.6	5	8.6	7.9- 9.6	7
42.0	9.8	8.9-10.7	7	9.2	8.8- 9.8	3	9.6	8.8-10.7	10
46.0	10.0	8.8-11.5	3	10.1	9.7-11.3	5	10.1	8.8-11.5	8
50.0	11.4	10.6-12.5	9	11.1	10.0-11.8	5	11.3	10.0-12.5	14
54.0	11.9	10.3-13.1	14	12.0	10.9-13.9	9	12.0	10.3-13.9	23
58.0	13.4	12.4-15.7	16	12.8	11.8-13.7	6	13.2	11.8-15.7	22
62.0	13.7	12.4-15.6	14	13.4	12.1-14.3	6	13.6	12.1-15.6	20
66.0	14.6	13.4-16.8	17	13.8	12.4-15.4	18	14.2	12.4-16.8	35
70.0	14.8	13.0-16.5	19	15.1	12.6-17.3	18	15.0	12.6-17.3	37
74.0	15.3	12.3-17.4	3	15.0	13.4-16.2	13	15.1	12.3-17.4	16
78.0	18.4	-	1	15.7	14.4-16.8	6	16.1	14.4-18.4	7
82.0	-	-	0	16.1	13.5-17.5	7	16.1	13.5-17.5	7
86.0	-	-	0	18.6	-	1	18.6	-	1

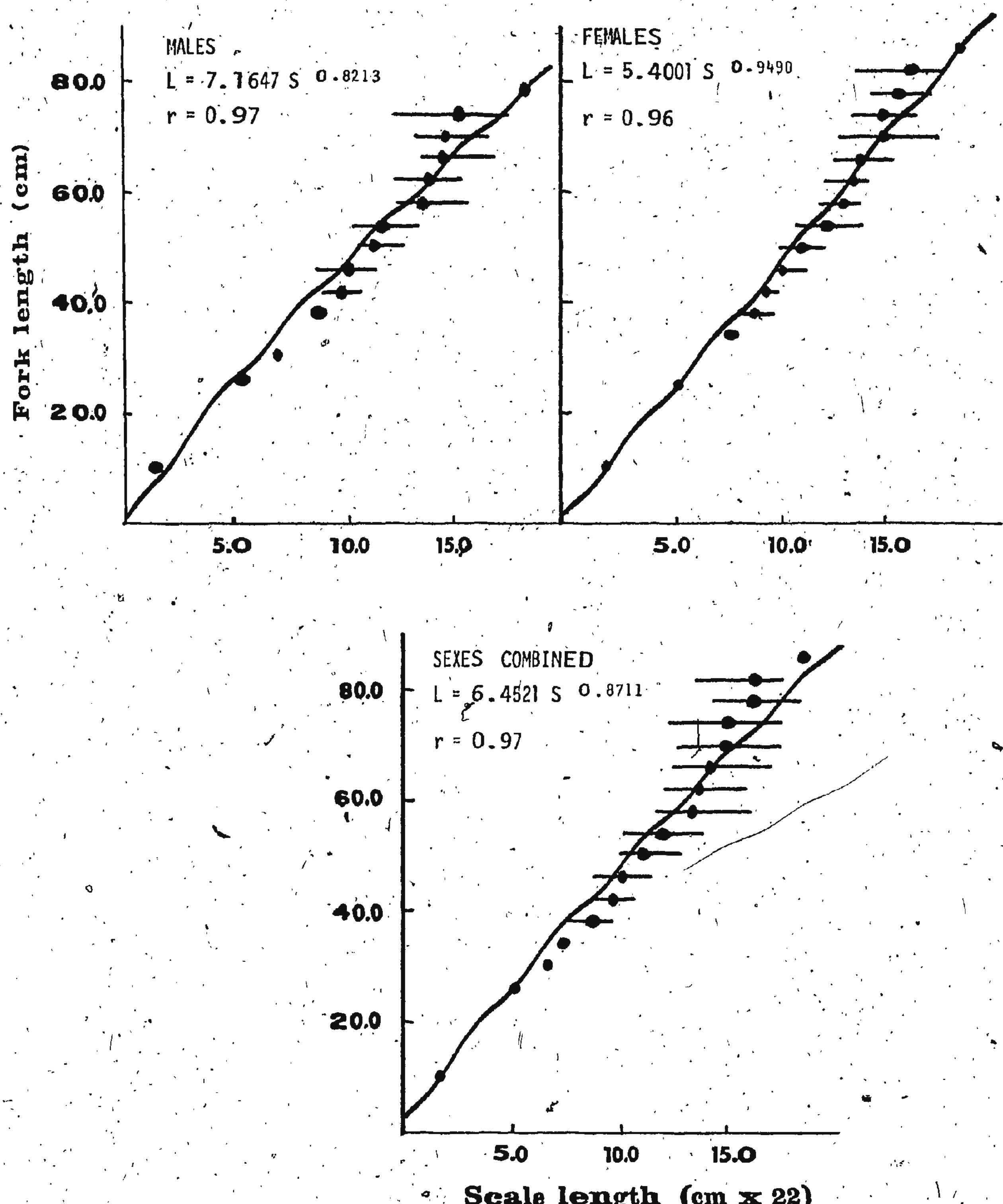

Fig. 6. Empirical (scatter plots and ranges) and calculated (fitted curves) body length-scale length relationships of northern pike from Lobstick, Labrador.

Table 2. The relationship between fork length of fish (cm) and magnified (cm x 6.67) operculum length of northern pike from Lobstick, Labrador.

Fork length (cm)	Operculum Length (cm x 6.67)								
	Males			Females			Combined		
	Mean	Range	Sample Size	Mean	Range	Sample Size	Mean	Range	Sample Size
10.0	3.4	3.3- 3.5	2	3.7	-	1	3.5	3.3- 3.7	3
14.0	-	-	0	-	-	0	-	-	0
18.0	-	-	0	-	-	0	-	-	0
22.0	-	-	0	-	-	0	-	-	0
26.0	8.9	-	1	-	-	0	8.9	-	1
30.0	10.1	-	1	-	-	0	10.1	-	1
34.0	-	-	0	11.8	-	1	11.8	-	1
38.0	13.5	13.0-13.9	2	13.1	12.1-13.6	5	13.2	12.1-13.9	7
42.0	14.6	13.5-15.5	7	14.3	13.7-15.0	3	14.5	13.5-15.5	10
46.0	14.9	14.3-15.5	3	16.5	15.7-17.0	5	15.9	14.3-17.0	8
50.0	18.4	17.1-19.8	9	17.5	16.6-18.0	5	18.1	16.6-19.8	14
54.0	19.1	18.4-20.5	14	19.4	18.1-21.3	9	19.2	18.1-21.3	23
58.0	20.7	19.5-22.4	16	20.8	20.2-21.5	6	20.8	19.5-22.4	22
62.0	21.8	19.6-24.4	14	22.3	21.4-23.6	6	21.9	19.6-24.4	20
66.0	23.1	20.7-24.3	17	23.6	21.0-26.1	18	23.3	20.7-26.1	35
70.0	24.6	23.3-26.5	19	25.4	22.8-28.0	18	25.0	22.8-28.0	37
74.0	26.5	24.3-27.8	3	25.9	23.5-29.0	13	26.0	24.3-27.8	16
78.0	27.8	-	1	26.6	25.8-27.2	6	26.8	25.8-27.8	7
82.0	-	-	0	28.2	27.3-30.6	7	28.2	27.3-30.6	7
86.0	-	-	0	31.7	-	1	31.7	-	1

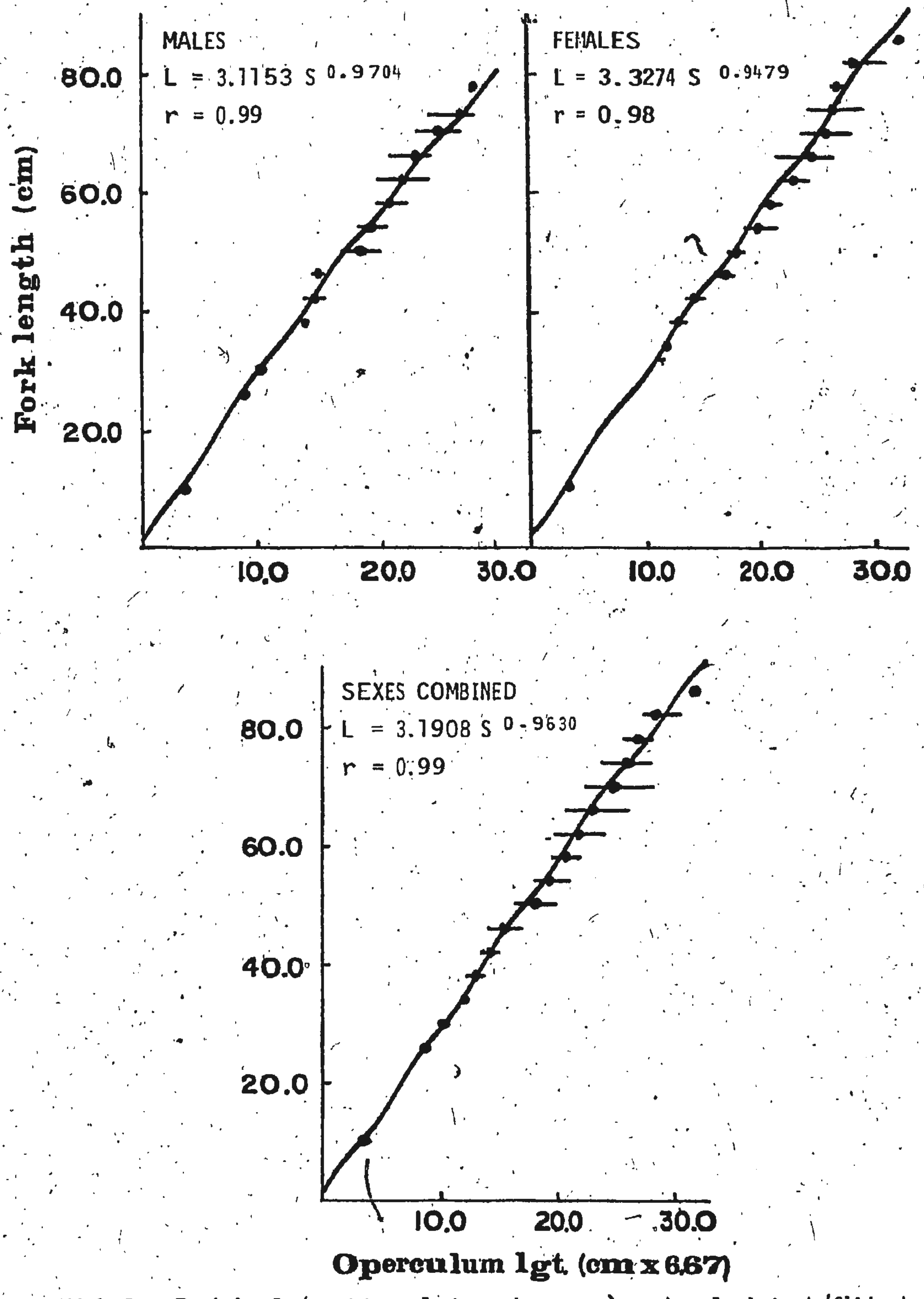

Fig. 7. Empirical (scatter plots and ranges) and calculated (fitted curves) body length-operculum length relationships of northern pike from Lobstick, Labrador.

Table 3. The relationship between fork length of fish (cm) and magnified (cm x 6.67) cleithrum length of northern pike from Lobstick, Labrador.

Fork length (cm)	Cleithrum length (cm x 6.67)								
	Males			Females			Combined		
	Mean	Range	Sample Size	Mean	Range	Sample Size	Mean	Range	Sample Size
10.0	6.9	6.8- 7.0	2	7.7	-	1	7.2	6.8- 7.7	3
14.0	-	-	0	-	-	0	-	-	0
18.0	-	-	0	-	-	0	-	-	0
22.0	-	-	0	-	-	0	-	-	0
26.0	18.5	-	1	-	-	0	18.5	-	1
30.0	21.0	-	1	-	-	0	21.0	-	1
34.0	-	-	0	22.5	-	1	22.5	-	1
38.0	26.0	25.0-27.0	2	26.3	25.5-27.0	5	26.2	25.0-27.0	7
42.0	27.9	26.5-30.0	7	27.7	27.0-29.0	3	27.8	26.5-30.0	10
46.0	33.8	30.0-40.5	3	30.9	30.0-31.5	5	32.0	30.0-40.5	8
50.0	33.9	30.5-36.0	9	32.8	30.5-35.0	5	33.5	30.5-36.0	14
54.0	35.9	32.5-42.0	14	36.4	34.0-38.5	9	36.1	32.5-42.0	23
58.0	39.5	37.0-43.5	16	38.8	37.5-39.5	6	39.3	37.0-43.5	22
62.0	40.3	36.0-43.0	14	39.8	35.5-42.0	6	40.1	35.5-43.0	20
66.0	43.6	41.5-45.0	17	43.5	40.0-46.0	18	43.5	40.0-46.0	35
70.0	46.4	44.5-48.5	19	45.5	35.0-48.0	18	45.9	35.0-48.5	37
74.0	47.3	42.5-50.0	3	48.0	43.0-50.0	13	47.9	42.5-50.0	16
78.0	50.0	-	1	49.9	48.5-51.0	6	49.9	48.5-51.0	7
82.0	-	-	0	52.0	47.0-56.0	7	52.0	47.0-56.0	7
86.0	-	-	0	60.0	-	1	60.0	-	1

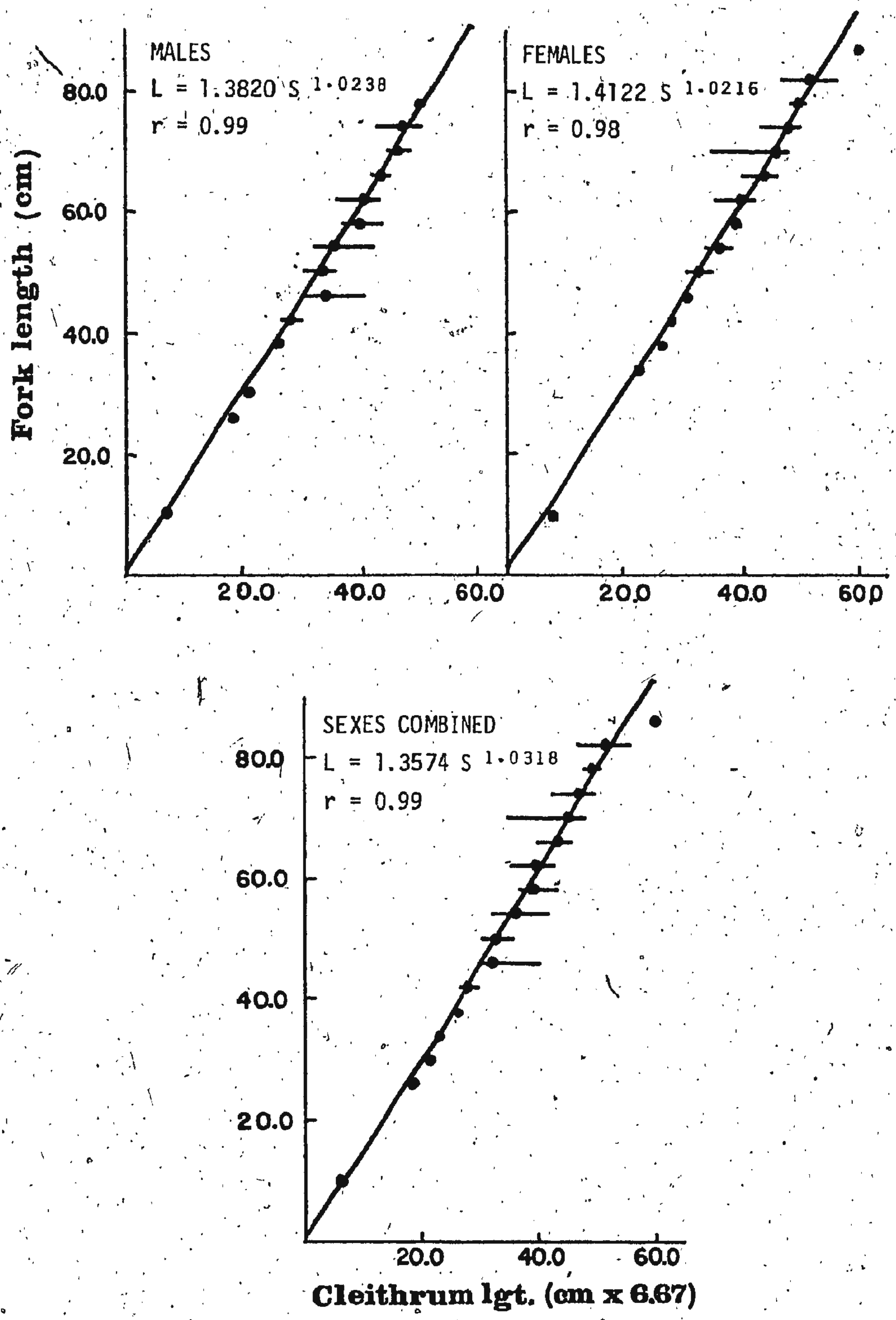

Fig. 8. Empirical (scatter plots and ranges) and calculated (fitted curves) body length-cleithrum length relationships of northern pike from Lobstick, Labrador.

Table 4. The relationship between fork length of fish (cm) and magnified (cm x 30) otolith length of northern pike from Lobstick, Labrador.

Fork length (cm)	Otolith Length (cm x 30)								
	Males			Females			Combined		
	Mean	Range	Sample Size	Mean	Range	Sample Size	Mean	Range	Sample Size
10.0	1.9	-	2	1.8	-	1	1.9	1.8- 1.9	3
14.0	-	-	0	-	-	0	-	-	0
18.0	-	-	0	-	-	0	-	-	0
22.0	-	-	0	-	-	0	-	-	0
26.0	4.8	-	1	-	-	0	4.8	-	1
30.0	5.5	-	1	-	-	0	5.5	-	1
34.0	-	-	0	5.0	-	1	5.0	-	1
38.0	6.4	6.3- 6.5	2	6.5	5.9- 6.8	5	6.5	5.9- 6.8	7
42.0	6.7	6.3- 7.4	7	6.6	6.5- 6.8	3	6.7	6.3- 7.4	10
46.0	7.3	6.5- 7.7	3	6.8	6.4- 7.6	5	7.0	6.4- 7.7	8
50.0	7.6	6.8- 8.8	9	7.5	7.1- 8.1	5	7.6	6.8- 8.8	14
54.0	7.7	6.9- 8.4	14	7.7	6.8- 8.5	9	7.7	6.8- 8.5	23
58.0	8.0	7.1- 8.7	16	8.0	7.0- 8.5	6	8.0	7.0- 8.7	22
62.0	8.2	7.2- 8.9	14	7.9	7.5- 8.6	6	8.1	7.2- 8.9	20
66.0	8.8	8.2- 9.5	17	8.2	5.2- 9.4	18	8.5	5.2- 9.5	35
70.0	9.2	8.2-10.2	19	8.8	7.8- 9.9	18	9.0	7.8-10.2	37
74.0	9.1	8.6- 9.5	3	9.3	8.5-10.0	13	9.3	8.5-10.0	16
78.0	10.3	-	1	9.4	8.7-10.0	6	9.6	8.7-10.0	7
82.0	-	-	0	10.1	9.1-11.5	7	10.1	9.1-11.5	7
86.0	-	-	0	11.2	-	1	11.2	-	1

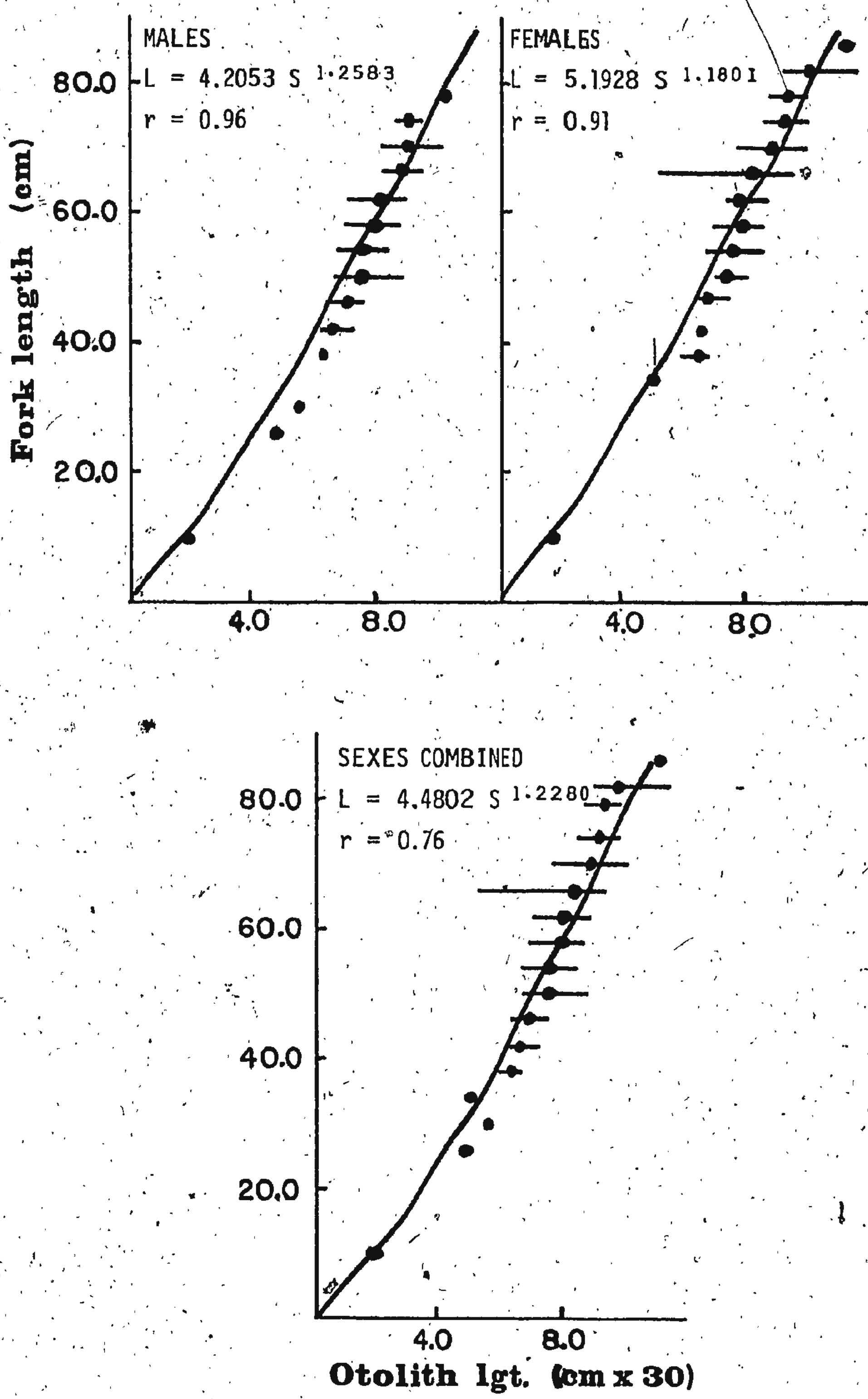

Fig. 9. Empirical (scatter plots and ranges) and calculated (fitted curves) body length-otolith relationships of northern pike from Lobstick, Labrador.

Table 5. Logarithmic and exponential forms of the regression equations for the relationship between fish fork length (L) and length of the aging structure (S), using scales, opercula, cleithra and otoliths, of northern pike from Lobstick, Labrador.

	Logarithmic Form	Exponential Form	Correlation Coefficient
SCALES (cm x 22)			
Males	log L = 0.8213 log S + 0.8552	$L = 7.1647\ S^{0.8213}$	0.97
Females	log L = 0.9490 log S + 0.7324	$L = 5.4001\ S^{0.9490}$	0.96
Sexes Combined	log L = 0.8711 log S + 0.8097	$L = 6.4521\ S^{0.8711}$	0.97
OPERCULA (cm x 6.67)			
Males	log L = 0.9704 log S + 0.4935	$L = 3.1153\ S^{0.9704}$	0.99
Females	log L = 0.9479 log S + 0.5221	$L = 3.3274\ S^{0.9479}$	0.98
Sexes Combined	log L = 0.9630 log S + 0.5039	$L = 3.1908\ S^{0.9630}$	0.99
CLEITHRA (cm x 6.67)			
Males	log L = 1.0238 log S + 0.1405	$L = 1.3820\ S^{1.0238}$	0.99
Females	log L = 1.0216 log S + 0.1499	$L = 1.4122\ S^{1.0216}$	0.98
Sexes Combined	log L = 1.0318 log S + 0.1327	$L = 1.3574\ S^{1.0318}$	0.99
OTOLITHS (cm x 30)			
Males	log L = 1.2583 log S + 0.6238	$L = 4.2053\ S^{1.2583}$	0.96
Females	log L = 1.1801 log S + 0.7154	$L = 5.1928\ S^{1.1801}$	0.91
Sexes Combined	log L = 1.2280 log S + 0.6513	$L = 4.4802\ S^{1.2280}$	0.76

Table 6. Empirical and back-calculated average fork lengths (cm), using scales, of the different age-groups of northern pike from Lobstick, Labrador.

Age (years)	Fork Lengths (cm)											
	Males				Females				Combined			
	Empirical			Back-calc.	Empirical			Back-calc.	Empirical			Back-calc.
	Mean	Range	Sample Size		Mean	Range	Sample Size		Mean	Range	Sample Size	
1	9.5	9.3-9.6	2	15.7	10.7	-	1	13.4	9.9	9.3-10.7	3	14.8
2	-	-	0	25.0	-	-	0	22.8	-	-	0	24.2
3	27.5	-	1	34.3	-	-	0	32.2	27.5	-	1	33.6
4	43.3	-	1	41.6	-	-	0	40.8	43.3	-	1	41.5
5	46.3	40.0-52.5	2	47.9	40.2	35.5-46.4	6	47.8	41.7	35.5-52.5	8	48.1
6	50.0	31.2-65.6	11	51.5	47.0	37.0-59.0	11	55.6	48.5	31.2-65.6	22	53.5
7	56.4	37.0-66.5	29	55.3	60.1	46.0-77.0	18	60.9	57.8	37.0-77.0	47	58.0
8	56.4	41.7-67.0	14	57.9	64.7	53.4-74.2	23	65.2	61.5	41.7-74.2	37	61.4
9	63.7	44.0-75.0	29	61.4	67.5	49.5-73.5	15	68.2	65.0	44.0-75.0	44	64.5
10	67.2	57.5-74.3	13	63.4	72.5	55.0-80.8	19	71.7	70.4	55.0-80.8	32	67.6
11	67.8	52.0-78.0	5	66.4	76.8	62.5-84.0	6	73.0	72.7	52.0-84.0	11	69.7
12	69.5	-	1	71.1	80.0	77.0-82.4	4	74.0	77.9	69.5-82.4	5	71.9
13	73.1	-	1	74.8	-	-	0	82.1	73.1	-	1	78.1
14	-	-	0	-	-	-	0	84.3	-	-	0	80.4
15	-	-	0	-	87.5	-	1	86.6	87.5	-	1	82.3

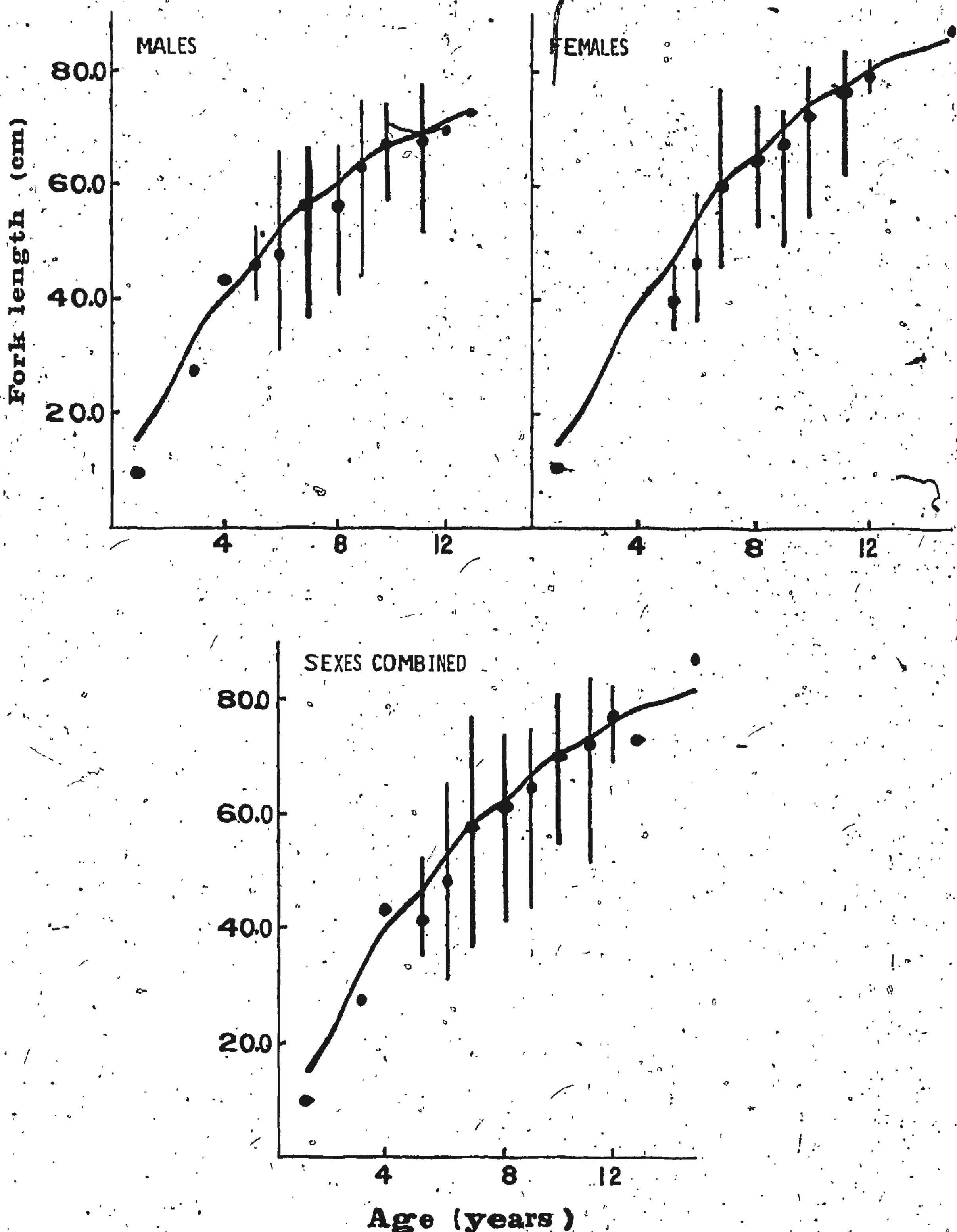

Fig. 10. Empirical (scatter plots and ranges) and calculated (fitted curves) average lengths (cm), using scales, of the different age-groups of northern pike from Lobstick, Labrador.

Table 7. Empirical and back-calculated average fork lengths (cm), using opercula, of the different age-groups of northern pike from Lobstick, Labrador.

Age (years)	Fork Lengths (cm)											
	Males				Females				Combined			
	Empirical			Back-calc.	Empirical			Back-calc.	Empirical			Back-calc.
	Mean	Range	Sample Size		Mean	Range	Sample Size		Mean	Range	Sample Size	
1	9.5	9.3-9.6	2	24.7	10.7	-	1	26.3	9.9	9.3-9.6	3	25.5
2	-	-	0	33.5	-	-	0	35.8	-	-	0	34.7
3	33.8	27.5-40.0	2	41.2	40.2	35.5-48.0	3	43.6	37.6	27.5-48.0	5	42.5
4	39.8	31.2-43.3	5	47.5	41.5	37.5-46.4	7	51.3	40.8	31.2-46.4	12	49.5
5	50.2	41.7-57.5	17	52.9	48.5	40.0-56.5	7	56.5	49.7	40.0-57.5	24	54.8
6	57.2	50.2-66.0	25	57.3	60.3	45.5-73.4	18	62.2	58.5	45.5-73.4	43	60.0
7	62.1	37.0-71.3	29	62.0	67.1	51.0-78.1	39	66.8	65.0	37.0-78.1	68	64.4
8	68.1	63.4-74.3	14	65.4	77.1	62.0-80.8	14	69.3	69.6	62.0-80.8	28	67.6
9	69.1	64.6-75.0	8	67.7	72.2	49.5-83.3	9	71.6	70.8	49.5-83.3	17	69.9
10	68.6	65.0-71.4	4	68.3	78.2	74.0-82.4	2	74.0	71.8	65.0-82.4	6	71.2
11	73.6	69.7-78.0	3	72.1	82.0	79.9-84.0	2	77.5	76.9	69.7-84.0	5	75.5
12	-	-	0	-	-	-	0	76.2	-	-	0	76.8
13	-	-	0	-	80.5	-	1	79.6	80.5	-	1	80.3
14	-	-	0	-	-	-	0	86.0	-	-	0	86.9
15	-	-	0	-	87.5	-	1	88.1	87.5	-	1	89.0

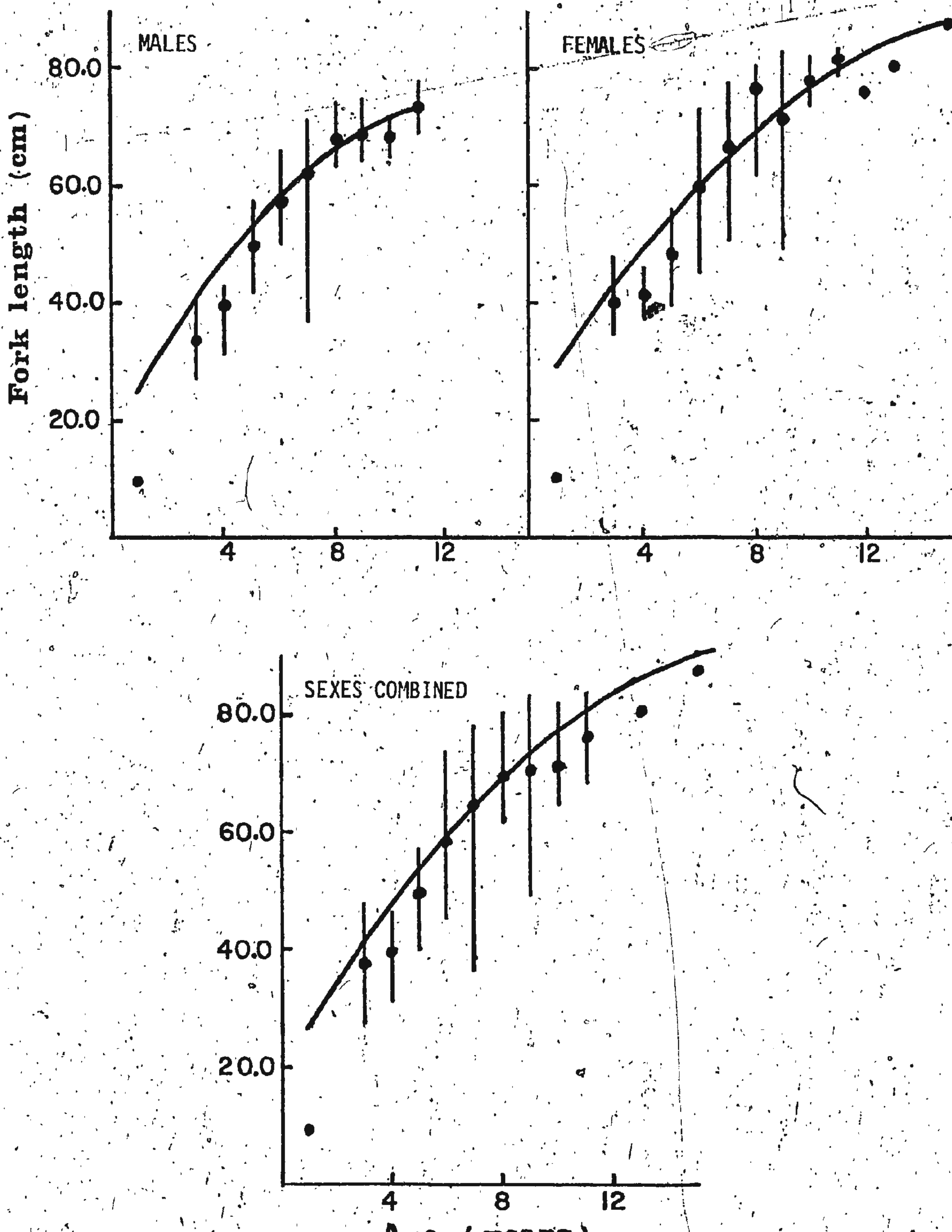

Fig. 11. Empirical (scatter plots and ranges) and calculated (fitted curves) average lengths (cm), using opercula, of the different age-groups of northern pike from Lobstick, Labrador.

Table 8. Empirical and back-calculated average fork lengths (cm), using cleithra, of the different age-groups of northern pike from Lobstick, Labrador.

Age (years)	Fork Lengths (cm)											
	Males				Females				Combined			
	Empirical			Back-calc.	Empirical			Back-calc.	Empirical			Back-calc.
	Mean	Range	Sample Size		Mean	Range	Sample Size		Mean	Range	Sample Size	
1	9.5	9.3-9.6	2	17.4	10.7	-	1	18.1	9.9	9.3-10.7	3	17.6
2	-	-	0	28.9	-	-	0	29.3	-	-	0	29.0
3	27.5	-	1	37.6	35.5	-	1	38.5	31.5	27.5-35.5	2	38.1
4	39.7	31.2-43.3	5	44.9	43.5	37.5-50.5	4	46.3	41.4	31.2-50.5	9	45.7
5	48.3	40.5-55.5	14	51.0	47.2	39.5-56.5	11	52.5	47.8	39.5-56.5	25	51.9
6	58.1	50.5-66.0	34	56.3	58.3	37.0-72.0	19	58.5	58.1	37.0-72.0	53	57.7
7	61.1	48.0-75.0	25	60.3	66.5	51.0-77.0	29	63.6	64.0	48.0-77.0	54	62.4
8	68.6	64.3-74.3	12	64.0	70.3	62.0-80.8	18	66.7	69.6	62.0-80.8	30	65.9
9	68.0	61.0-72.0	8	65.8	72.1	49.5-80.5	12	69.6	70.5	49.5-80.5	20	68.2
10	68.6	65.0-71.4	6	67.4	72.2	55.3-84.0	5	73.0	70.2	55.3-84.0	11	70.8
11	78.0	-	1	68.8	82.9	82.4-83.3	2	76.9	81.2	78.0-83.3	3	74.5
12	73.1	-	1	64.2	-	-	0	77.3	73.1	-	1	73.2
13	-	-	0	-	80.5	-	1	81.2	80.5	-	1	81.2
14	-	-	0	-	-	-	0	86.3	-	-	0	86.4
15	-	-	0	-	87.5	-	1	92.6	87.5	-	1	92.8

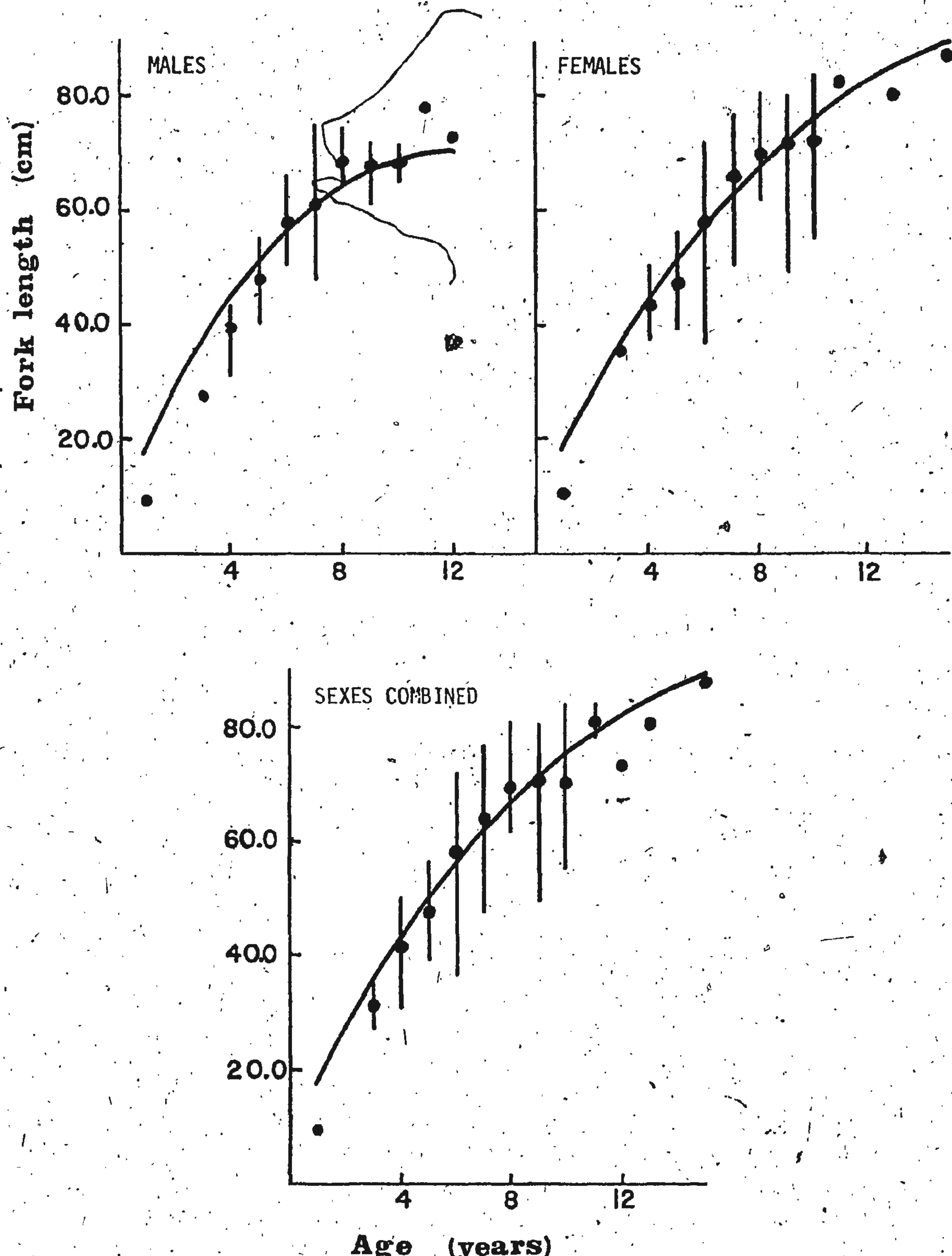

Fig. 12. Empirical (scatter plots and ranges) and calculated (fitted curves) average lengths (cm), using cleithra, of the different age-groups of northern pike from Lobstick, Labrador.

Table 9. Empirical and back-calculated average fork lengths (cm), using otoliths, of the different age-groups of northern pike from Lobstick, Labrador.

Age (years)	Fork Lengths (cm)											
	Males				Females				Combined			
	Empirical			Back-calc.	Empirical			Back-calc.	Empirical			Back-calc.
	Mean	Range	Sample Size		Mean	Range	Sample Size		Mean	Range	Sample Size	
1	9.5	9.3-9.6	2	10.6	10.7	-	1	12.8	9.9	9.3-10.7	3	11.3
2	-	-	0	21.4	-	-	0	23.9	-	-	0	21.9
3	27.5	-	1	30.5	-	-	0	33.9	27.5	-	1	31.2
4	42.9	31.2-54.5	2	37.5	-	-	0	41.3	42.9	31.2-54.5	2	38.4
5	47.5	37.0-54.2	5	43.7	47.0	40.0-56.5	7	47.2	47.2	37.0-56.5	12	44.3
6	51.0	40.0-62.6	13	48.9	47.3	35.5-67.0	11	53.2	49.3	35.5-67.0	24	49.7
7	58.9	44.5-71.3	25	54.0	60.9	37.5-72.0	27	57.9	59.9	37.5-72.0	52	54.6
8	59.4	41.7-75.0	24	57.6	68.1	53.4-80.8	28	62.8	64.1	41.7-80.8	52	58.7
9	62.0	43.5-74.3	19	61.8	68.2	49.5-78.4	15	67.2	64.7	43.5-78.4	34	62.9
10	66.0	62.7-70.0	9	66.1	75.4	64.7-83.3	6	70.9	70.1	62.7-83.3	15	67.0
11	71.3	68.0-78.0	8	69.7	74.8	70.5-79.9	3	74.2	72.2	68.0-79.9	11	70.4
12	69.5	-	1	66.8	79.1	75.3-84.0	3	78.4	76.7	69.5-84.0	4	74.3
13	-	-	0	-	-	-	0	79.8	-	-	0	77.0
14	-	-	0	-	80.5	-	1	83.9	80.5	-	1	81.1
15	-	-	0	-	85.0	82.4-87.5	2	91.3	85.0	82.4-87.5	2	88.5

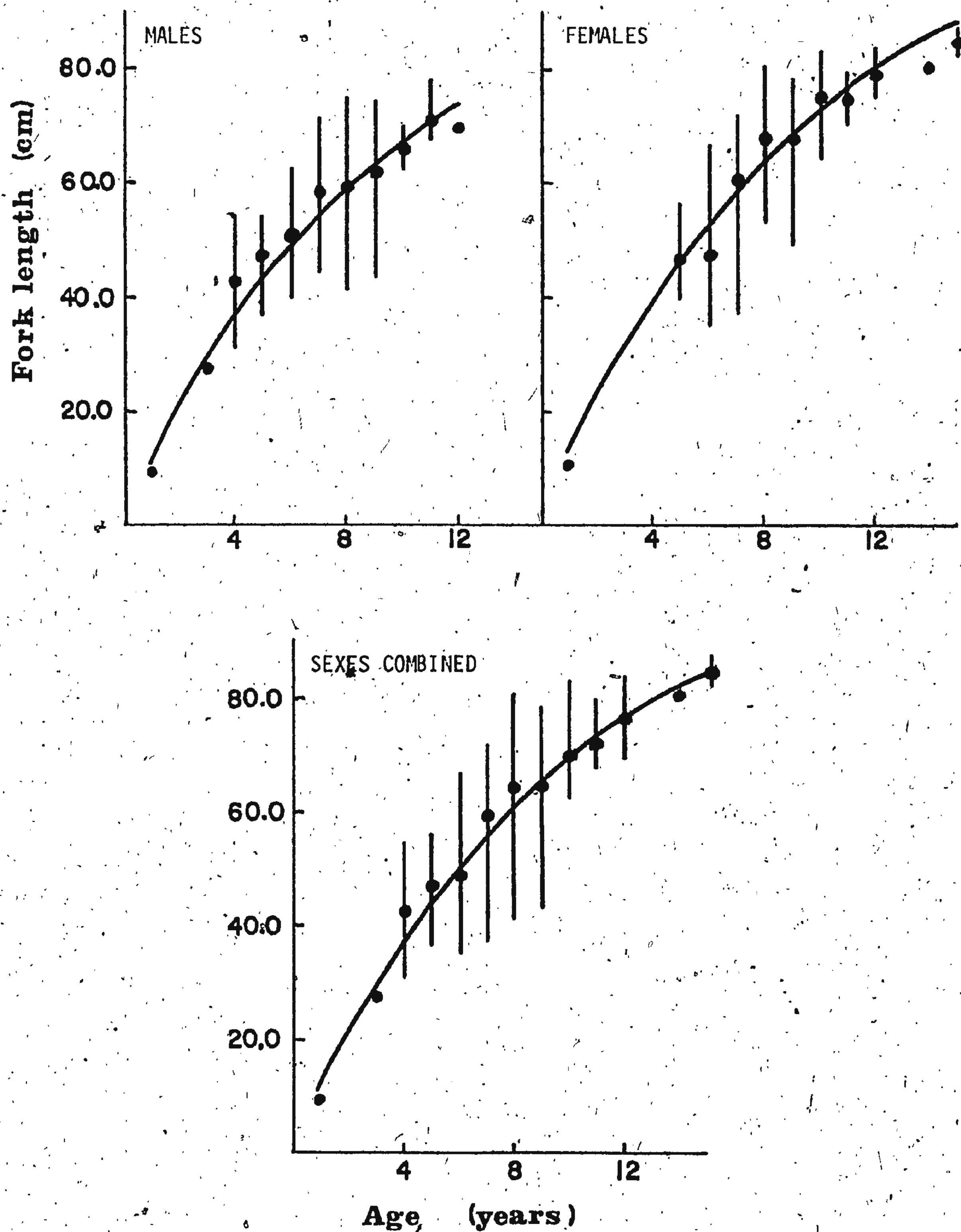

Fig. 13. Empirical (scatter plots and ranges) and calculated (fitted curves) average lengths (cm), using otoliths, of the different age-groups of northern pike from Lobstick, Labrador.

Table 10. Summary of results of covariance analyses for empirical and back-calculated age-length regressions, males vs. females, of northern pike from Lobstick, Labrador ($p = 0.05$; significant difference indicated by '*').

Method of Aging		Mean Squares: Within Samples	Mean Squares: Regression Coefficients	Slope: F	Slope: P	Mean Squares: Common Regression	Mean Squares: Adjusted Means	Adjusted Means: F	Adjusted Means: P
Scales	Empirical	.001419	.000070	0.05	0.822	.001329	.002788	2.10	0.165
	Back-calculated	.000735	.007998	10.88	0.004*	.001051	.001234	1.17	0.290
Opercula	Empirical	.003278	.000058	0.02	0.891	.003088	.006607	2.14	0.159
	Back-calculated	.000104	.000006	0.06	0.811	.000099	.004842	48.85	<0.001*
Cleithra	Empirical	.002217	.001122	0.51	0.507	.002153	.004969	2.31	0.144
	Back-calculated	.000914	.000927	1.01	0.327	.000915	.003878	4.24	0.049*
Otoliths	Empirical	.001986	.000002	0.00	0.977	.001854	.003770	2.03	0.172
	Back-calculated	.001675	.000490	0.46	0.512	.001040	.011229	10.80	0.004*

Table 11. Summary of results of covariance analyses for age-length regressions (sexes combined and separated), empirical vs. back-calculated, of northern pike from Lobstick, Labrador (p = 0.05; significant difference indicated by '*').

Method of Aging		Mean Squares: Within Samples	Mean Squares: Regression Coefficients	Slope: F	Slope: P	Mean Squares: Common Regression	Mean Squares: Adjusted Means	Adjusted Means: F	Adjusted Means: P
Scales	Males	.001981	.018885	9.53	0.006*	.002786	.003669	1.32	0.263
	Females	.001089	.006472	5.94	0.025*	.001406	.001887	1.34	0.262
	Sexes Combined	.001468	.015513	10.57	0.004*	.002079	.002944	1.42	0.245
Opercula	Males	.001754	.067087	38.24	<0.001*	.005597	.015864	2.83	0.107
	Females	.002415	.057054	23.63	<0.001*	.005016	.010225	2.04	0.165
	Sexes Combined	.002259	.058289	25.80	<0.001*	.004927	.013726	2.79	0.107
Cleithra	Males	.002251	.042907	19.06	0.001*	.004390	.003913	0.89	0.641
	Females	.001944	.018139	9.33	0.006*	.002716	.003298	1.21	0.283
	Sexes Combined	.002061	.024871	12.07	0.002*	.003053	.004853	1.59	0.218
Otoliths	Males	.002444	.001367	0.56	0.530	.002387	.000484	0.20	0.661
	Females	.001397	.001967	1.41	0.250	.001427	.000306	0.21	0.653
	Sexes Combined	.001771	.001439	0.81	0.619	.001757	.000215	0.12	0.729

Table 12. Summary of results of covariance analyses for empirical and back-calculated age-length regressions (sexes combined and separated), scales vs. opercula vs. cleithra vs. otoliths, of northern pike from Lobstick, Labrador (p = 0.05; significant difference indicated by '*').

		Mean Squares		Slope		Mean Squares		Adjusted Means	
		Within Samples	Regression Coefficients	F	P	Common Regression	Adjusted Means	F	P
Empirical	Males	.002898	.000626	0.22	0.885	.002704	.002719	1.01	0.403
	Females	.002409	.000063	0.03	0.994	.002181	.003822	1.75	0.176
	Sexes Combined	.003047	.000114	0.04	0.990	.002821	.004210	1.49	0.231
Back-calculated	Males	.000623	.016496	26.49	<0.001*	.001844	.021795	11.82	<0.001*
	Females	.000597	.021449	35.90	<0.001*	.001735	.015325	8.83	<0.001*
	Sexes Combined	.000544	.018767	34.51	<0.001*	.001538	.021535	14.00	<0.001*

Table 13. Summary of results of covariance analyses for back-calculated age-length regressions (sexes combined and separated), otoliths vs. scales, otoliths vs. cleithra, otoliths vs. opercula, scales vs. opercula, scales vs. cleithra, and opercula vs. cleithra of northern pike from Lobstick, Labrador (p = 0.05; significant difference indicated by '*').

		Mean Squares		Slope		Mean Squares		Adjusted Means	
		Within Samples	Regression Coefficients	F	P	Common Regression	Adjusted Means	F	P
Otoliths vs. Scales	Males	.000824	.013558	16.44	0.001*	.001946	.006126	4.10	0.055
	Females	.000869	.000012	0.01	0.902	.000837	.000001	0.00	0.967
	Sexes Combined	.000746	.006945	9.31	0.005*	.000976	.003142	3.22	0.081
Otoliths vs. Cleithra	Males	.000878	.018205	20.74	<0.001*	.001790	.026730	14.94	0.001*
	Females	.000616	.010194	16.54	0.001*	.000971	.010550	10.86	0.003*
	Sexes Combined	.000696	.015849	22.77	<0.001*	.001257	.025052	19.93	<0.001*
Otoliths vs. Opercula	Males	.000557	.048672	87.34	<0.001*	.003090	.058121	18.81	0.001*
	Females	.000493	.048220	97.73	<0.001*	.002261	.032701	14.46	0.001*
	Sexes Combined	.000463	.054211	117.21	<0.001*	.002453	.053990	22.01	<0.001*
Scales vs. Opercula	Males	.000368	.010854	29.52	<0.001*	.000920	.026508	28.83	<0.001*
	Females	.000579	.010467	80.72	<0.001*	.002287	.032282	14.12	0.001*
	Sexes Combined	.000391	.022350	57.09	<0.001*	.001205	.031085	25.80	<0.001*
Scales vs. Cleithra	Males	.000688	.000342	0.50	0.504	.000670	.007263	10.84	0.004*
	Females	.000701	.009501	13.54	0.001*	.001274	.010313	10.04	0.004*
	Sexes Combined	.000625	.001811	2.90	0.097	.000669	.010045	15.62	0.001*
Opercula vs. Cleithra	Males	.000421	.007343	17.45	0.001*	.000785	.006020	7.67	0.012*
	Females	.000326	.014071	43.12	<0.001*	.000835	.006103	7.31	0.011*
	Sexes Combined	.000342	.011436	33.48	0.001*	.000753	.005488	7.29	0.011*

Table 14. Length distribution of northern pike from Lobstick for sexes combined and sexes separated (sample size in parenthesis).

Length class (cm)	Percentage of fish in each length class					
	Males		Females		Sexes Combined	
0.0- 4.9	-		-		-	
5.0- 9.9	1.1	(2)	-		0.5	(2)
10.0-14.9	-		0.4	(1)	0.2	(1)
15.0-19.9	-		-		-	
20.0-24.9	-		-		-	
25.0-29.9	0.5	(1)	-		0.2	(1)
30.0-34.9	0.5	(1)	-		0.2	(1)
35.0-39.9	0.5	(1)	2.7	(6)	1.7	(7)
40.0-44.9	6.3	(12)	3.6	(8)	4.8	(20)
45.0-49.9	5.3	(10)	5.3	(12)	5.3	(22)
50.0-54.9	13.7	(26)	7.6	(17)	10.4	(43)
55.0-59.9	20.5	(39)	10.2	(23)	14.9	(62)
60.0-64.9	18.4	(35)	14.2	(32)	16.2	(67)
65.0-69.9	22.1	(42)	22.2	(50)	22.2	(92)
70.0-74.9	10.0	(19)	17.8	(40)	14.2	(59)
75.0-79.9	1.1	(2)	10.2	(23)	6.0	(25)
80.0-84.9	-		4.9	(11)	2.7	(11)
85.0-89.9	-		0.9	(2)	0.5	(2)
Totals	100	(190)	100	(225)	100	(415)
Mean length	59.3		64.3		62.0	
Range	9.3-78.0		10.7-87.5		9.3-87.5	
Std. dev.	10.34		11.51		11.26	
Std. error	0.75		0.77		0.55	

majority of fish (78%) between 50 and 75 cm. Males and females showed different length distributions, females growing longer than males. The average length of males and females differed significantly ($t = 4.50$, d.f. = 413, $p < 0.001$).

A conversion factor for fork length to total length was calculated: fork length = 0.94 total length.

2. Weight

Similar to the length distribution, the total weight distribution is unimodal (Table 15). For males, 43% of the fish weighed between 1.00 and 2.00 kg; for females, 36% weighed between 2.00 and 3.00 kg. The heaviest fish collected were females; males and females differed significantly in average weight ($t = 5.13$, d.f. = 413, $p < 0.001$).

3. Age

Age composition, as determined from otoliths, ranged from 1 to 15, with 56% in the 7-9 age-classes (Table 16). As with length and weight distributions, females tended to be older than males; the oldest male sampled was 12 and the oldest female 15.

B. Growth

1. Length-weight relationship

The length-weight regressions for males and females (Table 17) different significantly ($F = 16.49$, d.f. = 1,410, $p < 0.001$). There was good correlation between length and weight ($r^2 = 0.98$ for males,

$r = 0.99$ for females). The exponent values for both sexes were close to 3; for males $n = 2.96$, for females $n = 3.18$.

The mean weights calculated (using the computed length-weight equations) for the mean lengths of fish in each length group are the bases for the curves in Fig. 14. There was good agreement between the empirical and calculated weights for the sexes separated and combined (Table 18). Minor discrepancies occurred at the extremes; in the smaller and larger length classes, where the number of fish sampled was small.

2. Length distribution of age groups

The length distribution of age groups (Table 9 and Fig. 13) shows an overlap in length between age groups, especially in the 6-10 age groups where sample sizes are larger. The overlap is greatest for 8-year-old males, which range from 41.7 to 75.0 cm and for 7-year-old females, which range from 37.5 to 72.0 cm. Comparisons of northern pike growth rates from four areas of Labrador are given in Table 19. Since Bruce (1974, 1975) and Parsons (1975) used scales for age determination, age-length data using both scales and otoliths have been included in this comparison.

3. Weight distribution of age groups

Empirical and calculated age-weight data are given in Table 20 and Fig. 15. The calculated weights were obtained from the length-weight relationships using the back-calculated lengths for each age group. The curves in Fig. 15 are graphic representations of the

Table 15. Weight distribution of northern pike from Lobstick for sexes combined and sexes separated (sample size in parenthesis).

Weight class (kg)	Percentage of fish in each weight class					
	Males		Females		Sexes Combined	
0.00-0.49	5.8	(11)	5.4	(12)	5.5	(23)
0.50-0.99	12.1	(23)	8.9	(20)	10.4	(43)
1.00-1.49	21.6	(41)	13.3	(30)	17.1	(71)
1.50-1.99	21.6	(41)	13.8	(31)	17.4	(72)
2.00-2.49	19.5	(37)	18.2	(41)	18.8	(78)
2.50-2.99	14.7	(28)	17.3	(39)	16.1	(67)
3.00-3.49	4.2	(8)	11.6	(26)	8.2	(34)
3.50-3.99	0.5	(1)	5.8	(13)	3.4	(14)
4.00-4.49	-		2.2	(5)	1.2	(5)
4.50-4.99	-		2.2	(5)	1.2	(5)
5.00-5.49	-		1.3	(3)	0.7	(3)
Totals	100	(190)	100	(225)	100	(415)
Mean weight	1.72		2.22		1.99	
Range	0.01-3.68		0.01-5.30		0.01-5.30	
Std. dev.	0.77		1.10		0.99	
Std. error	0.06		0.07		0.05	

Table 16. Age composition of northern pike from Lobstick for sexes combined and sexes separated (sample size in parenthesis).

Age (years)	Percentage of fish in each age class					
	Males		Females		Sexes Combined	
1	1.9	(2)	1.0	(1)	1.4	(3)
2	-	(0)	-	(0)	-	(0)
3	0.9	(1)	-	(0)	0.5	(1)
4	1.9	(2)	-	(0)	0.9	(2)
5	4.6	(5)	6.7	(7)	5.6	(12)
6	11.9	(13)	10.6	(11)	11.3	(24)
7	22.9	(25)	26.0	(27)	24.4	(52)
8	22.0	(24)	26.9	(28)	24.4	(52)
9	17.4	(19)	14.4	(15)	16.0	(34)
10	8.3	(9)	5.7	(6)	7.0	(15)
11	7.3	(8)	2.9	(3)	5.2	(11)
12	0.9	(1)	2.9	(3)	1.9	(4)
13	-	(0)	-	(0)	-	(0)
14	-	(0)	1.0	(1)	0.5	(1)
15	-	(0)	1.9	(2)	0.9	(2)
Totals	100	(109)	100	(104)	100	(213)

Table 17. Logarithmic and exponential regression equations for the relationship between fork length (L cm) and whole weight (W kg) of northern pike from Lobstick, Labrador.

	Log regression form	Exponential form	r
Males	$\log W = 2.9615 \log L - 5.0578$	$W = 0.000009\ L^{2.9615}$	0.98
Females	$\log W = 3.1822 \log L - 5.4561$	$W = 0.000003\ L^{3.1822}$	0.99
Sexes Combined	$\log W = 3.0634 \log L - 5.2401$	$W = 0.000006\ L^{3.0634}$	0.98

Table 18. Empirical and calculated average whole weights (kg) of the different fork length (cm) intervals of northern pike from Lobstick, Labrador.

Average length (cm)	Males			Females			Sexes Combined		
	Empirical Weight (kg)	Calculated Weight (kg)	No. of fish	Empirical Weight (kg)	Calculated Weight (kg)	No. of fish	Empirical Weight (kg)	Calculated Weight (kg)	No. of fish
5.0	0.01	0.00	2	-	0.00	0	0.01	0.00	2
15.0	-	0.03	0	0.01	0.02	1	0.01	0.02	1
25.0	0.14	0.12	1	-	0.10	0	0.14	0.12	1
35.0	0.28	0.33	2	0.37	0.29	6	0.35	0.31	8
45.0	0.67	0.69	22	0.60	0.64	20	0.64	0.67	42
55.0	1.27	1.25	64	1.27	1.21	41	1.27	1.23	105
65.0	2.18	2.05	78	2.17	2.06	81	2.17	2.06	159
75.0	2.87	3.13	21	3.15	3.24	63	3.08	3.19	84
85.0	-	4.53	0	4.47	4.83	13	4.47	4.68	13

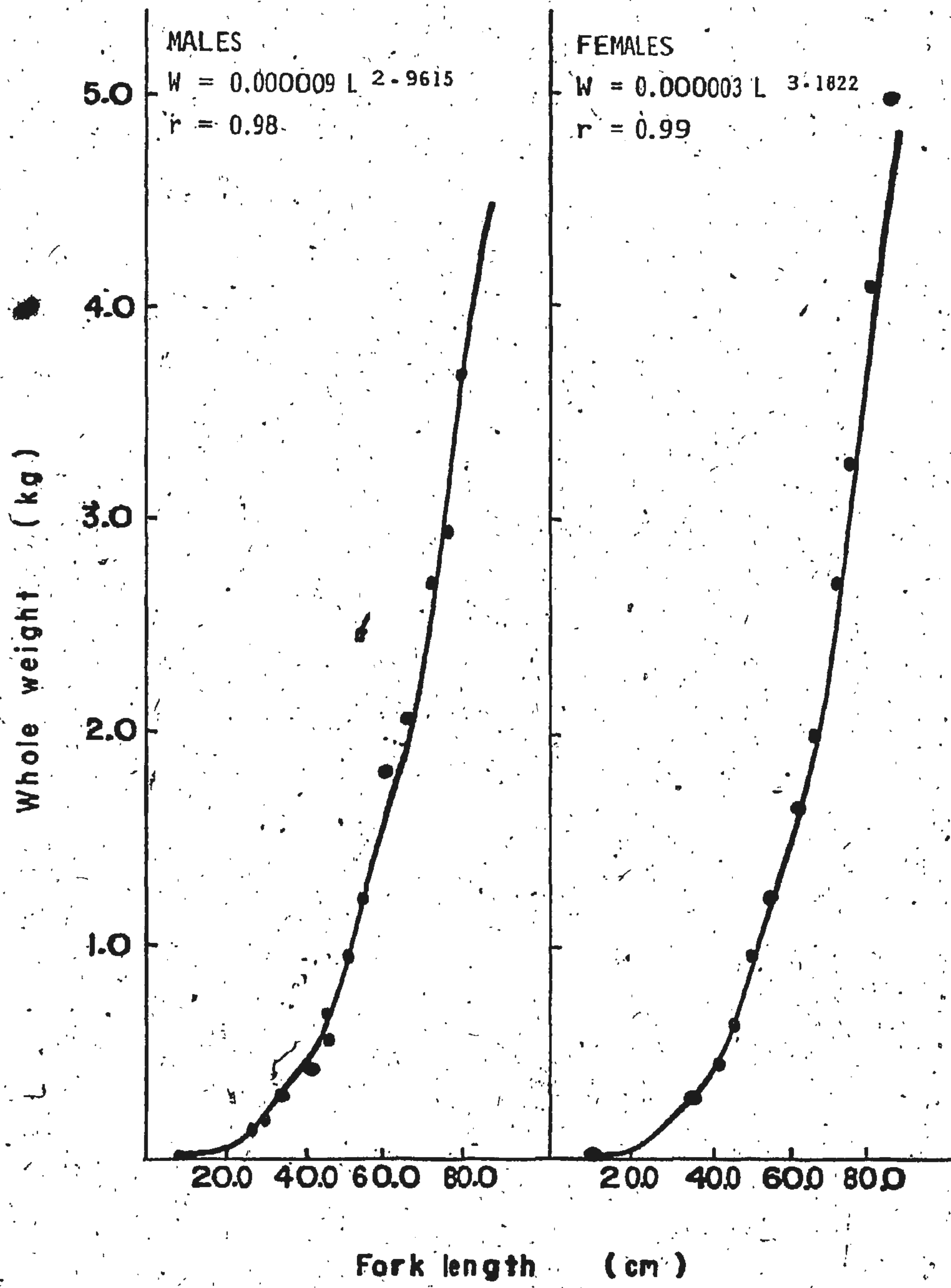

Fig. 14. Length-weight relationship, sexes separated, of northern pike from Lobstick, Labrador.

Table 19. Comparison of the calculated fork lengths (cm) of the different age-groups, sexes combined, of northern pike from four areas of Labrador (sample size in parenthesis).

Age (years)	Fork length (cm)				
	Lobstick structure (212)		Lobstick and Sandgirt Lakes (38) Bruce, 1975	Jacopie Lake (101) Bruce, 1974	Ten Mile Lake (115) Parsons, 1975
	Otoliths	Scales	Scales	Scales	Scales
1	11.3	14.8	12.0	10.2	7.8
2	21.9	24.2	20.2	19.7	20.2
3	31.2	33.6	27.6	29.5	31.7
4	38.4	41.5	33.9	36.1	41.9
5	44.3	48.1	40.1	46.1	50.5
6	49.7	53.5	46.0	51.7	57.3
7	54.6	58.0	50.7	56.2	60.8
8	58.7	61.4	55.8	60.1	64.6
9	62.9	64.5	62.6	62.9	67.6
10	67.0	67.6	66.0	65.5	69.6
11	70.4	69.7		67.5	70.2
12	74.3	71.9		70.0	71.4
13	77.0	78.1		71.1	
14	81.1	80.4		73.0	
15	88.5	82.3			

Table 20. Empirical and calculated average weights of the different age-groups of northern pike from Lobstick, Labrador.

Age (years)	Whole Weight (kg)											
	Males				Females				Combined			
	Empirical			Calc.	Empirical			Calc.	Empirical			Calc.
	Mean	Range	Sample Size		Mean	Range	Sample Size		Mean	Range	Sample Size	
1	0.01	-	2	0.01	0.01	-	1	0.01	0.01	-	3	0.01
2	-	-	0	0.08	-	-	0	0.09	-	-	0	0.07
3	0.14	-	1	0.22	-	-	0	0.26	0.14	-	1	0.22
4	0.70	0.19-1.20	2	0.40	-	-	0	0.49	0.70	0.19-1.20	2	0.41
5	0.81	0.37-1.09	5	0.63	0.71	0.40-1.20	7	0.74	0.75	0.37-1.20	12	0.64
6	0.96	0.42-1.75	13	0.88	0.86	0.26-2.32	11	1.09	0.91	0.26-2.32	24	0.91
7	1.58	0.35-2.85	25	1.18	1.82	0.40-3.16	27	1.42	1.71	0.35-3.16	52	1.21
8	1.60	0.38-3.14	24	1.43	2.42	1.10-3.80	28	1.84	2.04	0.38-3.80	52	1.51
9	1.92	0.48-3.18	19	1.76	2.60	0.70-4.05	15	2.29	2.22	0.48-4.05	34	1.86
10	2.35	1.65-2.93	9	2.15	3.41	2.22-4.38	6	2.71	2.78	1.65-4.38	15	2.26
11	2.91	2.50-3.68	8	2.52	3.08	2.50-3.85	3	3.13	2.96	2.50-3.85	11	2.63
12	3.16	-	1	2.22	4.08	3.37-4.58	3	3.73	3.85	3.37-4.58	4	3.11
13	-	-	0	-	-	-	0	3.95	-	-	0	3.46
14	-	-	0	-	4.30	-	1	4.63	4.30	-	1	4.04
15	-	-	0	-	4.91	4.74-5.08	2	6.07	4.91	4.74-5.08	2	5.30

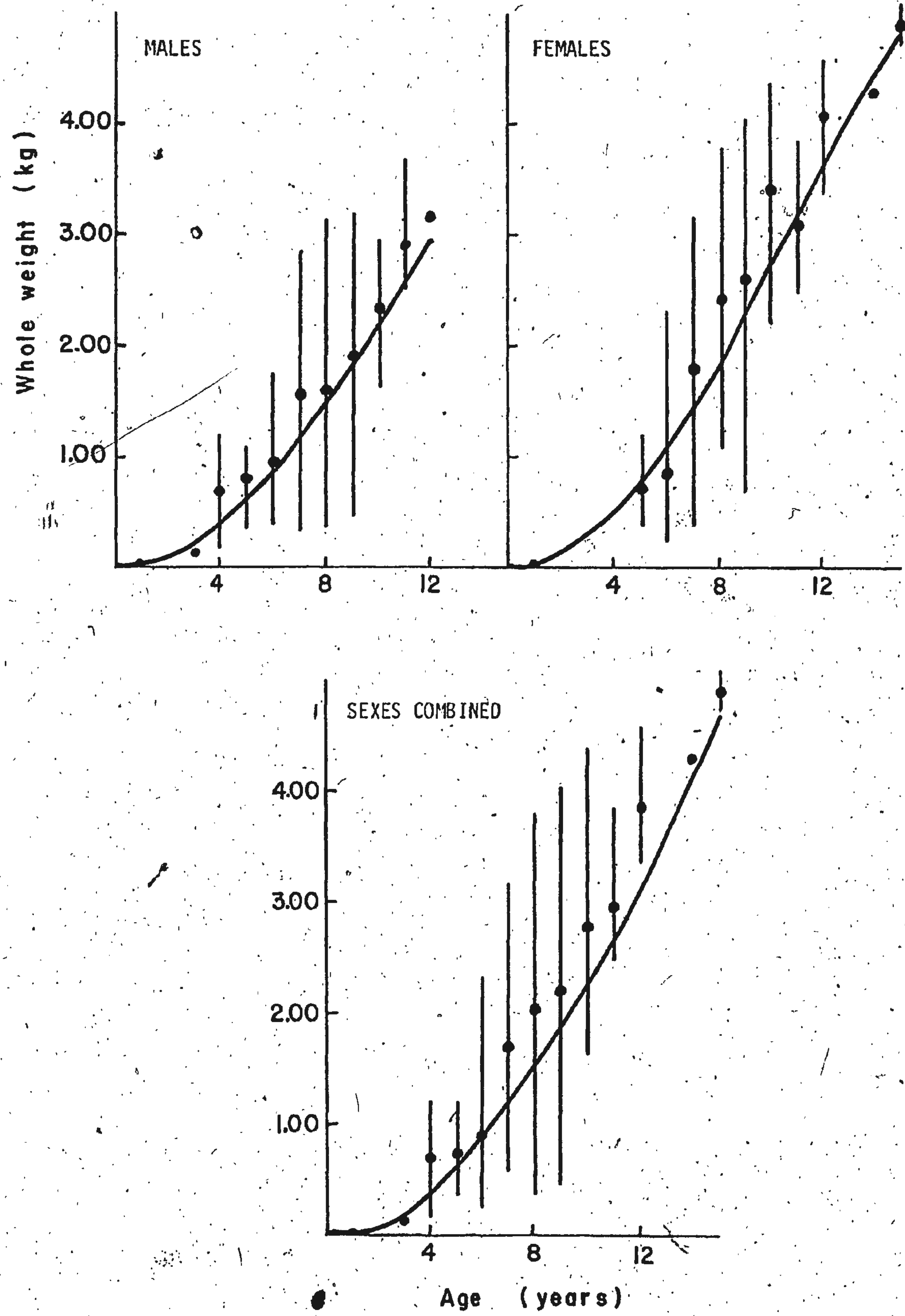

Fig. 15. Empirical (scatter plots and ranges) and calculated (fitted curves) average weights (kg) of the different age-groups of northern pike from Lobstick, Labrador.

calculated age-weight data; the scatter plots and ranges represent the empirical data.

Similar to the length distribution, the weight distribution of age groups (Table 20) exhibits overlap in weight between age groups, the largest overlap being for 9-year-old females which range in weight from 0.70 to 4.05 kg.

4. Coefficient of condition

Only condition values of mature fish, with empty stomachs at the time of capture, were used to show the change in the coefficient of condition from June to September (Table 21 and Fig. 16). Of the fish sampled, maximum condition was reached by the middle of June; minimum condition values were recorded in late June.

5. Mortality and survival

An estimate of the rate of natural mortality was made by transforming numbers of fish caught at each age (Table 16) to natural logarithms and plotting against age (Fig. 17). A least squares regression line was fitted to the descending points, the slope of which was used to estimate Z, the instantaneous total mortality rate. Tables provided by Ricker (1975) were used to estimate the annual mortality rate (A), and the annual survival rate (S). The results obtained were: for males Z = 0.32, A = 0.27 and S = 0.73; for females Z = 0.37, A = 0.39 and S = 0.61.

C. Reproductive Biology

1. Sex ratios

The ratio of males to females did not differ significantly for

Table 21. Change in coefficient of condition, from June to September 1978, of mature northern pike, stomachs empty at time of capture, from Lobstick, Labrador.

Date of Capture	Males			Females			Sexes Combined		
	Mean	Range	Sample Size	Mean	Range	Sample Size	Mean	Range	Sample Size
5 June	0.74	0.62-0.88	10	0.73	0.71-0.74	2	0.74	0.62-0.88	12
6 June	0.68	0.54-0.76	7	0.72	0.68-0.75	4	0.69	0.54-0.76	11
8 June	0.81	-	1	0.79	-	1	0.80	0.79-0.81	2
9 June	0.76	0.69-0.86	14	0.75	0.68-0.82	7	0.76	0.68-0.86	21
10 June	0.75	0.69-0.83	6	0.78	0.72-0.82	8	0.77	0.69-0.83	14
13 June	0.70	0.62-0.79	12	0.88	0.82-0.91	4	0.75	0.62-0.91	16
14 June	0.73	0.62-0.89	17	0.79	0.65-0.97	15	0.76	0.62-0.97	32
16 June	-	-	0	0.83	0.78-0.86	4	0.83	0.78-0.86	4
20 June	0.57	0.49-0.70	3	-	-	0	0.57	0.49-0.70	3
23 June	-	-	0	0.71	0.60-0.79	3	0.71	0.60-0.79	3
7 July	0.77	-	1	0.63	-	1	0.70	0.63-0.77	2
14 July	0.64	0.56-0.75	3	0.85	0.83-0.88	2	0.72	0.56-0.88	5
21 July	0.73	-	1	0.73	0.63-0.82	2	0.73	0.63-0.82	3
22 July	-	-	0	0.79	0.71-0.86	2	0.79	0.71-0.86	2
8 Sept.	0.75	0.71-0.80	4	0.72	0.61-0.82	4	0.73	0.61-0.82	8

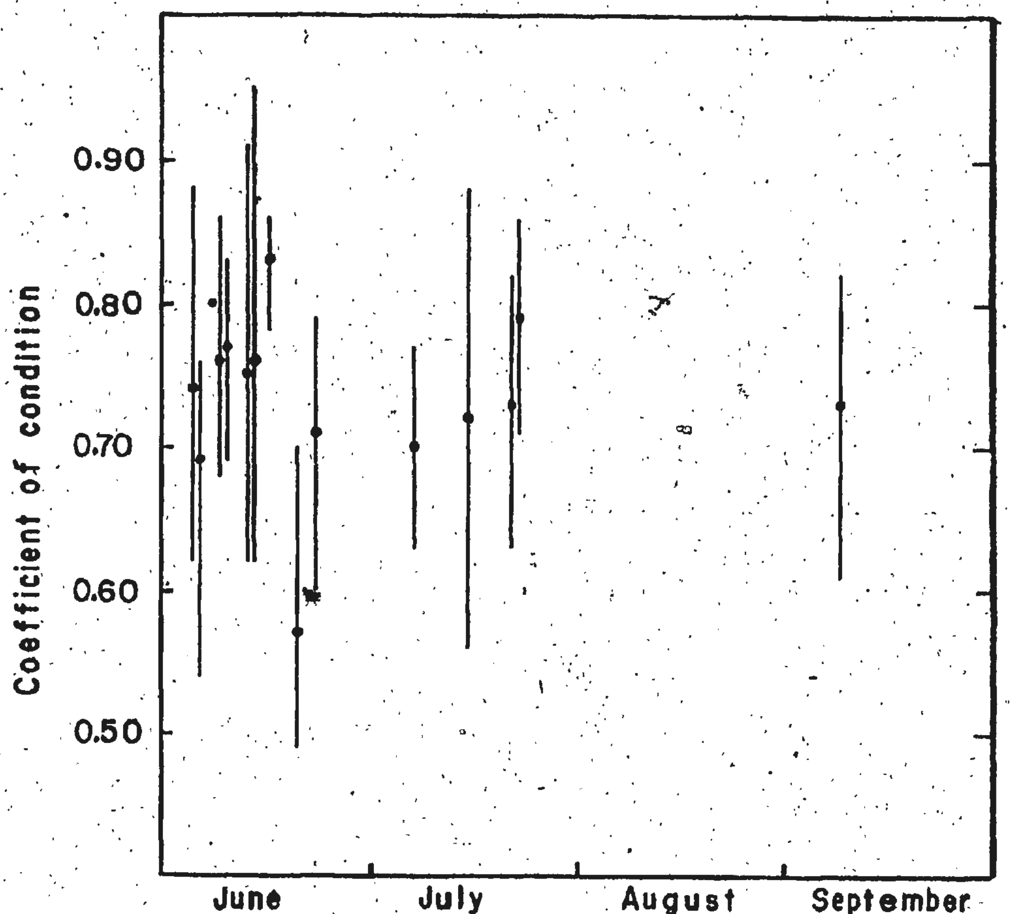

Fig. 16. Change in coefficient of condition, from June to September 1978, of mature northern pike, sexes combined, stomachs empty at time of capture, from Lobstick, Labrador.

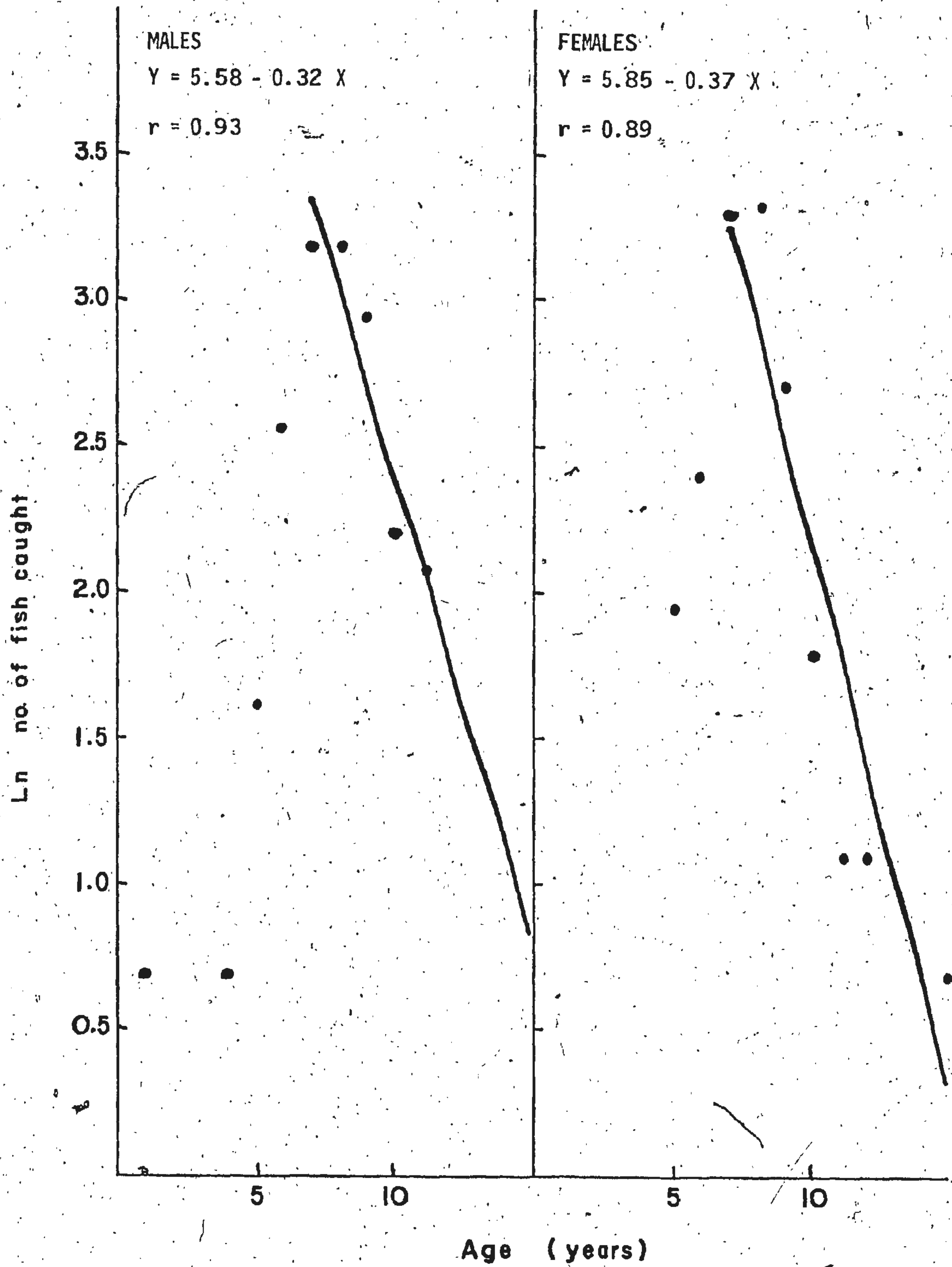

Fig. 17. A plot of number of fish caught (natural logarithm scale) on age (arithmetic scale), used to estimate the instantaneous total mortality rate of northern pike from Lobstick, Labrador.

any age group (Table 22). Data were grouped for ages 1-6 and 10-15 where sample sizes were small. The overall male to female ratio was 1.04:1.00.

2. Age and length at first maturity

The percentage of mature fish, by age group, (Table 23) shows that males are predominantly (50%) mature by age 5; females are not predominantly mature until age 8.

The percentage of mature fish, by length class, (Table 24) shows that males are predominantly mature at 40 cm, females at 60 cm. For sexes combined, the pike are not entirely mature until 75 cm.

3. Fecundity

Fork lengths were grouped into 5.0 cm intervals and the mean number of eggs per female was determined for each (Table 25 and Fig. 18). The empirical data, fitted to a log regression, gave the equation:

$$\log F = 3.71 \log L - 2.48 \quad (r = 0.77)$$

where 'F' is the number of eggs and 'L' is fork length (cm). The calculated number of eggs per female was computed from this equation.

Weights were grouped into 0.50 kg intervals and the mean number of eggs per female was determined for each (Table 26 and Fig. 19). The empirical data, fitted to a log regression, gave the equation:

$$\log F = 1.21 \log W + 3.83 \quad (r = 0.81)$$

where 'F' is number of eggs and 'W' is whole weight (kg).

Table 22. Sex ratios of northern pike, by age-group, from Lobstick, Labrador.

	Age (years)					
	1-6	7	8	9	10-15	Total
Male	23	25	24	19	18	109
Female	19	27	28	15	15	104
X^2 value	0.38	0.18	0.31	0.47	0.27	0.08
Significant difference	None	None	None	None	None	None

Table 23. Percentages of mature northern pike, by age-class, from Lobstick, Labrador (sample size in parenthesis).

Age (years)	Percentage of mature fish		
	Males	Females	Sexes Combined
1	0.0 (2)	0.0 (1)	0.0 (3)
2	- (0)	- (0)	- (0)
3	0.0 (1)	- (0)	0.0 (1)
4	50.0 (2)	- (0)	50.0 (2)
5	75.0 (5)	28.6 (7)	45.4 (12)
6	76.9 (13)	41.7 (11)	60.0 (24)
7	87.5 (25)	42.3 (27)	64.0 (52)
8	100.0 (24)	60.7 (28)	78.8 (52)
9	94.1 (19)	94.4 (15)	94.3 (34)
10	100.0 (9)	100.0 (6)	100.0 (15)
11	100.0 (8)	100.0 (3)	100.0 (11)
12	100.0 (1)	100.0 (3)	100.0 (4)
13	- (0)	- (0)	- (0)
14	- (0)	100.0 (1)	100.0 (1)
15	- (0)	100.0 (2)	100.0 (2)

Table 24. Percentages of mature northern pike, by length class, from Lobstick, Labrador (sample size in parenthesis).

Fork length (cm)	Percentage of mature fish					
	Males		Females		Sexes Combined	
2.5	-	(0)	-	(0)	-	(0)
7.5	0.0	(2)	-	(0)	0.0	(2)
12.5	-	(0)	0.0	(1)	0.0	(1)
17.5	-	(0)	-	(0)	-	(0)
22.5	-	(0)	-	(0)	-	(0)
27.5	0.0	(1)	-	(0)	0.0	(1)
32.5	0.0	(1)	-	(0)	0.0	(1)
37.5	100.0	(1)	33.3	(6)	42.9	(7)
42.5	75.0	(12)	12.5	(8)	50.0	(20)
47.5	90.0	(10)	16.7	(12)	50.0	(22)
52.5	88.0	(25)	25.0	(16)	63.4	(41)
57.5	89.5	(38)	33.3	(24)	67.7	(62)
62.5	100.0	(36)	61.3	(31)	82.1	(67)
67.5	97.6	(42)	73.5	(49)	84.6	(91)
72.5	100.0	(19)	92.3	(39)	94.8	(58)
77.5	100.0	(2)	100.0	(21)	100.0	(23)
82.5	-	(0)	100.0	(11)	100.0	(11)
87.5	-	(0)	100.0	(2)	100.0	(2)

Table 25. The relationship between the number of mature eggs (greater than 1.0 mm in diameter) and fork length (cm) for 49 northern pike from Lobstick, Labrador.

Fork length (cm)	Actual Number of Eggs per Female		Number of fish	Calculated Number of Eggs per Female
	Mean	Range		
52.5	11423	-	1	8062
57.5	11544	6367-16720	2	11298
62.5	13969	5732-21983	5	15394
67.5	21695	10382-29200	9	20481
72.5	27348	13570-40000	15	26699
77.5	33414	24100-47500	10	34194
82.5	46945	29752-73873	5	43121
87.5	47050	32100-62000	2	53640

Table 26. The relationship between the number of mature eggs (greater than 1.0 mm in diameter) per female and weight (kg) for 49 northern pike from Lobstick, Labrador.

Whole weight (kg)	Actual Number of Eggs per Female		Number of fish	Calculated Number of Eggs per Female
	Mean	Range		
1.25	8895	6367-11423	2	8942
1.75	14712	12991-16720	4	13435
2.25	18488	5732-29200	7	18210
2.75	24524	13570-38836	10	23215
3.25	28304	15330-40000	10	28415
3.75	32799	28000-42800	9	33787
4.25	46333	39500-52000	3	39312
4.75	55087	36300-73873	2	44975
5.25	47050	32100-62000	2	50765

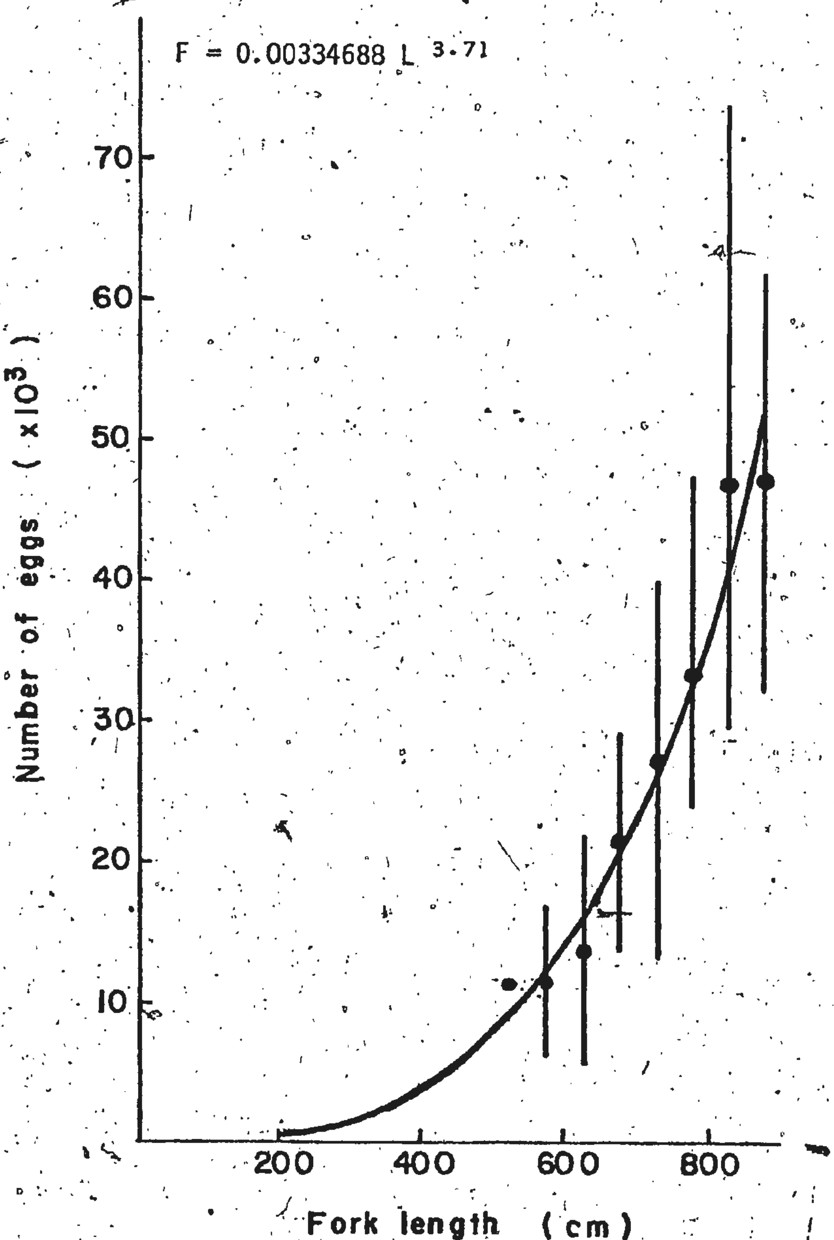

Fig. 18. The relationship between fork length (cm) and egg number in northern pike from Lobstick, Labrador (scatter plots and ranges represent empirical results; fitted curve represents calculated regression).

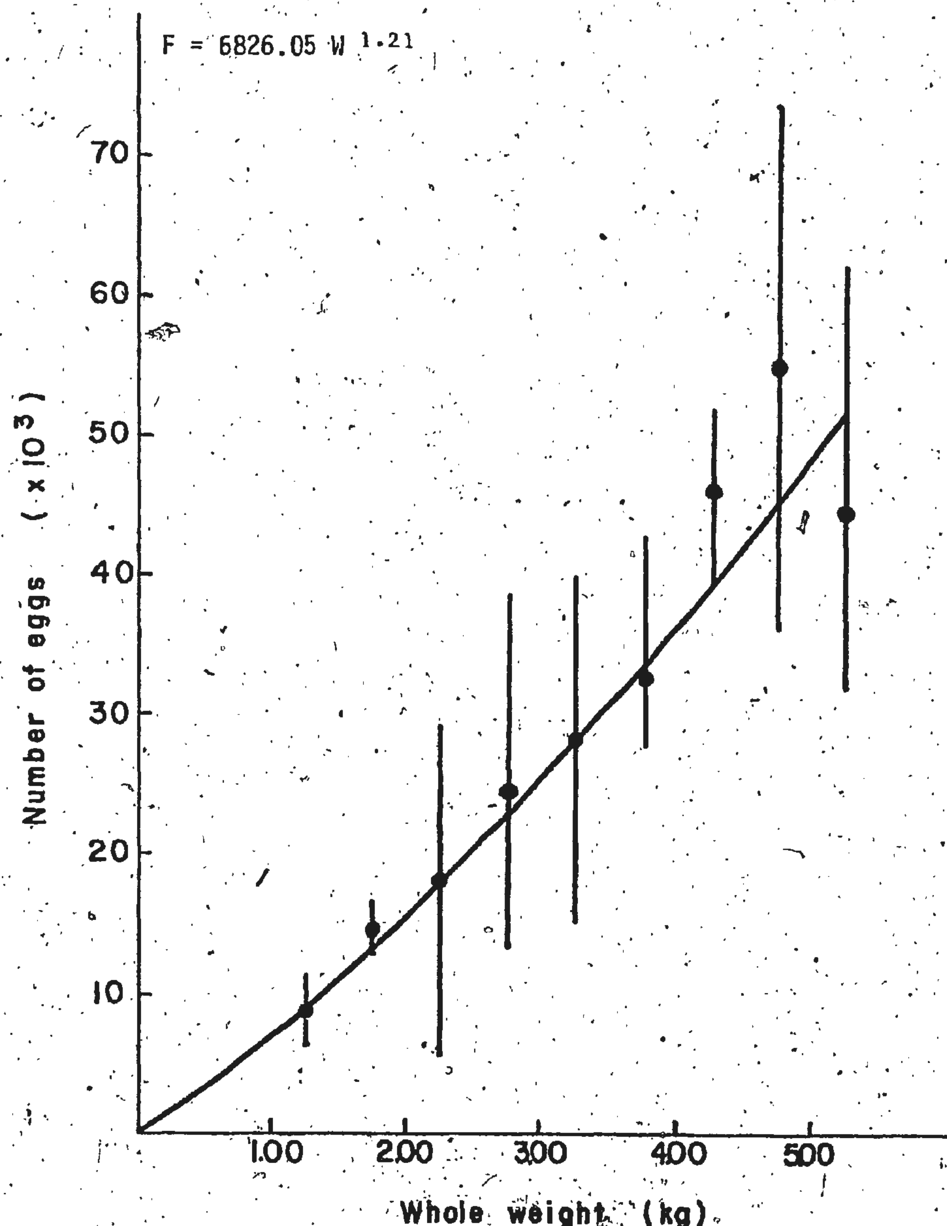

Fig. 19. The relationship between whole weight (kg) and egg number in northern pike from Lobstick, Labrador (scatter plots and ranges represent empirical results; fitted curve represents calculated regression).

The relationship between the number of mature eggs per female and age is given in Table 27 and Fig. 20. The empirical data, fitted to a log regression, gave the equation:

$$\log F = 1.36 \log A + 3.11 \quad (r = 0.54)$$

where 'F' is the number of eggs and 'A' is age (years).

D. Food habits

Of the 386 stomachs examined for food contents, 240 or 62% were empty. The principal food items were whitefish (64%) and unidentifiable fish remains (25%). Insects (5%), lake chub (3%) and burbot (3%) were also present.

Of the fish angled, 70% had empty stomachs as opposed to approximately 50% for those caught by fyke net, gillnet or seine.

A comparison of the food eaten by pike of various sizes (Table 28) shows that larger fish tend to eat larger food items; the diet becomes entirely piscivorous, mostly whitefish, the mean size of which are larger than any of the insects or lake chub found in the stomachs of smaller pike. There is also an increase in the number of empty stomachs with increased fish size. This may be related to the sampling method as large fish were mostly angled.

Table 27. The relationship between the number of mature eggs (greater than 1.0 mm in diameter) per female and age (years) for 48 northern pike from Lobstick, Labrador.

Age (years)	Actual Number of Eggs per Female		Number of fish	Calculated Number of Eggs per Female
	Mean	Range		
5	6367	-	1	11391
6	5732	-	1	14597
7	19713	11423-28276	5	18002
8	25318	12991-42800	14	21586
9	29398	10382-73873	13	25336
10	33485	13570-52000	6	29240
11	38836	-	1	33287
12	31943	21983-47500	6	37468
13	-	-	0	41777
14	-	-	0	46207
15	32100	-	1	50753

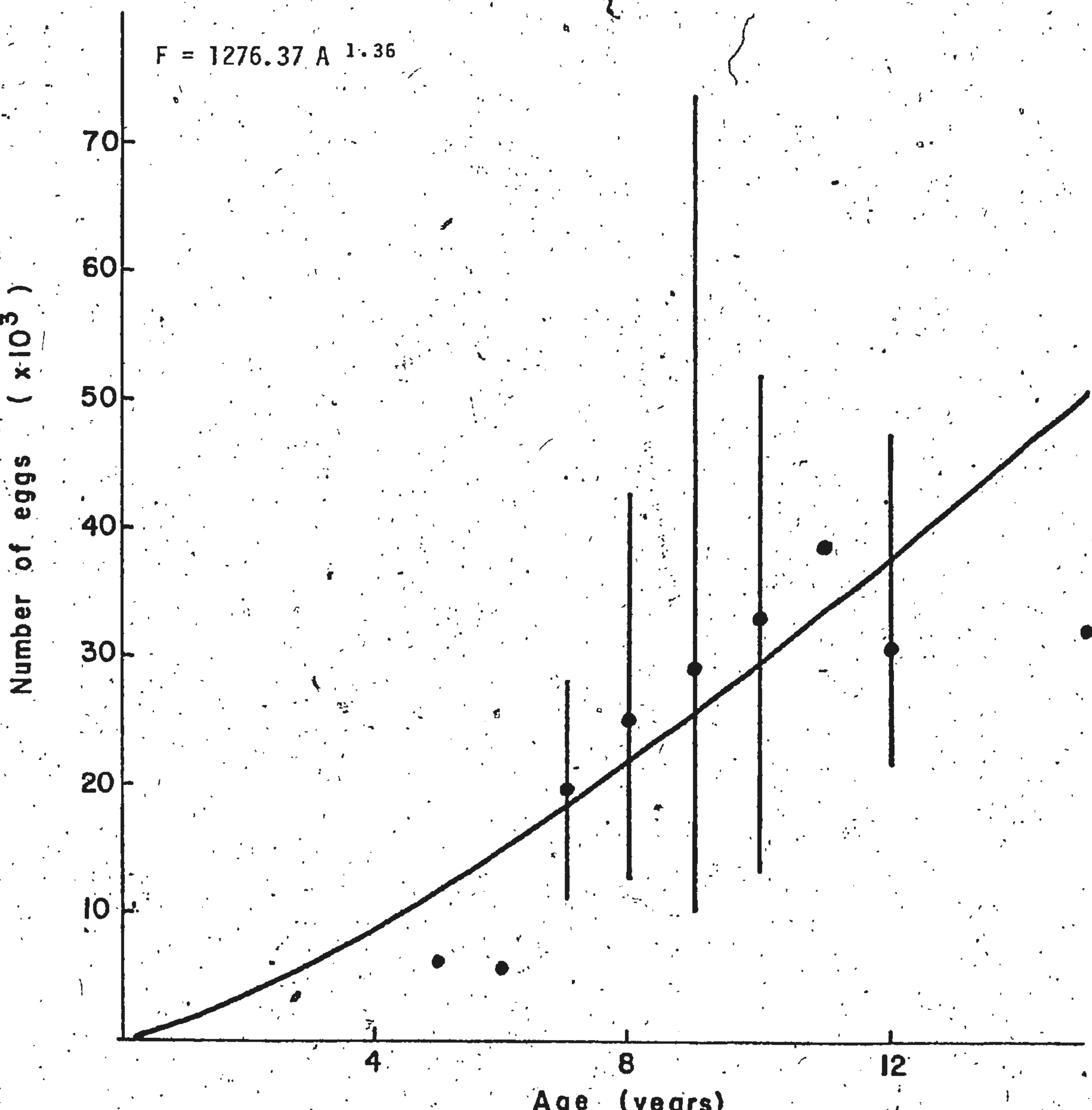

Fig. 20. The relationship between age (years) and egg number in northern pike from Lobstick, Labrador (scatter plots and ranges represent empirical results; fitted curve represents calculated regression).

Table 28. Percentage occurrence of food items in stomachs with food present from pike of various sizes from Lobstick, Labrador (sample size in parenthesis).

Food type	Fork length interval (cm)								
	0.0- 9.9	10.0-19.9	20.0-29.9	30.0-39.9	40.0-49.9	50.0-59.9	60.0-69.9	70.0-79.9	80.0-89.9
Whitefish	- (0)	- (0)	- (0)	- (0)	40.0 (8)	71.8 (28)	72.4 (42)	72.2 (13)	100.0 (3)
Unidentifiable Fish	- (0)	- (0)	100.0 (1)	40.0 (2)	20.0 (4)	23.0 (9)	24.2 (14)	27.8 (5)	- (0)
Insects	100.0 (1)	- (0)	- (0)	40.0 (2)	30.0 (6)	- (0)	- (0)	- (0)	- (0)
Lake Chub	- (0)	- (0)	- (0)	20.0 (1)	10.0 (2)	2.6 (1)	- (0)	- (0)	- (0)
Burbot	- (0)	- (0)	- (0)	- (0)	- (0)	2.6 (1)	3.4 (2)	- (0)	- (0)
Stomach empty	(1)	(1)	(0)	(4)	(24)	(55)	(80)	(58)	(10)

DISCUSSION

I. Age determination

The four methods of age determination chosen for this study have been previously used to assess age and growth of northern pike; scales (Williams 1955), opercula (Frost and Kipling 1959), cleithra (Casselman 1974) and otoliths (Hatfield et al. 1972). The results of this study show differences in both ages and age-length relationships derived from each aging structure.

Ideally, analyses of such differences should be studied over several years. Tag and recapture or radioactive marking experiments were not feasible due primarily to the time constraint of the study. However, the large population size and openness of the system would also have made it difficult to obtain sufficient recaptures. An alternative method of comparison had to be devised.

The method chosen involved comparison of age-length relationships derived from each aging structure. The basis for such comparison is that empirical and back-calculated age-length relationships should not differ, assuming that (1) the aging structure accurately reflects the growth of the fish, and (2) no aging errors have been made. Lee's phenomenon could cause a difference between empirical and back-calculated age-length relationships. However, these differences, if present, may be uniform for all of the aging methods. Harrison and Hadley (1979) found that for muskellunge Lee's phenomenon existed to a nearly equal extent in the back-calculated lengths obtained from cleithra and scales. If it can be shown that each of the four aging structures accurately reflects the growth of the fish, then the aging structure from which the most similar empirical and back-calculated growth curves are derived, would be the structure from which the fewest aging errors are likely to be made and consequently most meaningful to use in age and growth studies. Aging errors involve the addition or deletion of annuli to the age given by a structure. They also include problems in measuring annuli, determining the exact focus or position of annuli, and distinguishing true annuli from false checks. Although it was not possible to determine if every check was a true or false annulus, general measures were employed to distinguish between the two. Williams (1955) suggests that on scales "a good criterion for recognizing a false annulus is its absence at the anterior or high anterolateral fields since annuli usually are distinct here whereas the false annuli are not". On the bony structures, false annuli are recognizable because they show an abrupt instead of a gradual change or fading out from the opaque to the thin transparent zone (Frost and Kipling 1959). As growth slows in later years, this characteristic is harder to distinguish. At Lobstick, the problem of false annulus formation did not appear too severe. This may be accounted for by the abrupt seasonal changes in the area and the relatively little growth that occurs from the time of annulus formation until spawning occurs. Any check mark laid down during spawning would probably be indistinguishable from the true annulus.

There is a high correlation between the length of each of the aging structures and the length of the fish (Table 5), suggesting that all four aging structures accurately reflect the growth of the fish. Curvilinear relationships exist, although there is little difference between correlation coefficients for linear and curvilinear regressions. Overall results would have been similar if linear body: aging structure relationships had been used. Where curvilinear body: aging structure relationships exist, the length of the aging structure usually follows the growth pattern of the fish, increasing more slowly as the fish grows older. This is true for the body: scale length (Fig. 6) and body: opercular length (Fig. 7) relationships but not so for the body: cleithral (Fig. 8) or body: otolith (Fig. 9) relationships. Neither cleithral nor otolith growth is reduced with increased fish length; the increase in otolith length is more rapid relative to fish length throughout the early life history (0-50 cm) and is relatively proportional to fish length in the latter stages (50-90 cm). This is difficult to explain in relation to the reduction of growth exhibited by scales and opercula.

Analyses of covariance were used to test for statistical differences between the age-length regressions derived from each aging structure.

Empirical age-length relationships for males did not differ significantly from those for females, using any of the four aging structures (Table 10). All male and female back-calculated age-length relationships differed significantly; the slopes differed using scales, the adjusted means using opercula, cleithra and otoliths. The differences in adjusted means may be partly due to an insufficient sample of small fish which led to differences, between males and females, in the average lengths of opercula, cleithra and otoliths at annuli I and II. The difference in these values, when fitted in the appropriate body: aging structure regression, was sufficient to significantly affect the predicted adjusted means.

Differences occur between empirical and back-calculated age-length regressions using scales, opercula and cleithra (Table 11); there was no difference using otoliths. Comparison of empirical age-length regressions shows no difference in slopes or adjusted means between any of the four aging methods (Table 12). Given this similarity between empirical age-length regressions derived from all aging methods and the high correlation between the length of each aging structure and fish fork length (Table 5), this suggests that the otolith method, for which there are no empirical and back-calculated differences, is more reliable in assessing age and growth of northern pike from Lobstick. The difference in slopes between empirical and back-calculated age-length regressions, using scales, opercula, and cleithra, suggests that aging errors have been made. These errors could have been made in reading the ages or measuring annuli from the particular structure. Most problems involved either the first few or last few annuli on the structure. Identification of the first and second annuli on opercula was often difficult. This problem has been documented by Frost and Kipling (1969) who suggest that the first and second annuli are often obscured by the growth of spongy tissue at the base of the operculum. For scales, the problem involved measuring the first few annuli, the delineation of which were often unclear. These problems become evident in the back-calculation of lengths at age 1 ($\ell 1$). Scale, opercular and cleithral back-calculations give larger results for $\ell 1$; the results for otoliths are more comparable with empirical results than are any of the other three methods. Problems also exist in identifying the last few annuli on scales of older fish. The slow growth of older fish makes it difficult to distinguish annuli and measure increments of growth on the scale. This becomes evident when comparing growth curves generated from back-calculations of scale measurements to the other methods; back-calculated fork lengths at the older ages tend to be smaller than those derived from other aging structures. When comparing the number of zones in scales and opercular bones of roach, Hansen (1978) found there were fewer zones in scales from fish older than 7 years. Similarly, for muskellunge, Harrison and Hadley (1979) found that fish older than 9 years could not be aged from scales, but cleithra were useful for fish as old as 16 years.

Comparison of empirical age-length regressions showed no difference between any of the aging methods (Table 12). Back-calculated regressions of any aging method differed significantly from those of any other method with one exception; the regressions for females from otoliths and scales (Table 13). With the exception of the regressions from otoliths and scales, sexes separated and combined, all other comparisons of back-calculated age-length regressions differed very significantly, both in slopes and adjusted means. If otolith back-calculated age-length relationships are accepted as standards and comparisons are made to them, then opercular and cleithral relationships both predict too large lengths at younger ages. This could be explained if the first and/ or second annuli were obscured and not read from some of the opercula and cleithra. This would increase the values of the average lengths at annuli I and II and consequently increase the predicted fork lengths at ages 1 and 2 in the appropriate body: aging structure regression. Although this problem has been documented for opercula (Frost and Kipling 1959; Hansen 1978), it has not been documented for the cleithra of pike (Casselman 1974) or muskellunge (Harrison and Hadley 1979).

The relative similarity between age-length regressions derived from scales and otoliths must be considered in choosing a method for age and growth assessments. There are no statistical differences in the adjusted means predicted by scales and otoliths, for sexes separated or combined. The difference in the slopes, for males and sexes combined, is in the earlier years, scales predicting larger lengths than otoliths from ages 1 to 6. This can be related to the difficulty in delineating and measuring the first few annuli on some scales.

Otoliths were chosen as the preferable method for the age and growth study of northern pike from Lobstick. A case could be presented for the use of scales based upon the relative similarity of age-length relationships derived from the two methods and the ease of collection, handling and reading of scales.

II. Biological studies

The several methods used to sample northern pike from Lobstick helped limit the problem of size selectivity of gears. Gillnet selection for northern pike is by size with a lower limit only; all fish over a certain size are liable to capture (Kipling 1975). Of the 415 northern pike sampled at Lobstick, 9% (37 fish) were gillnetted. The fyke net, a passive fishing method, captures active members within a population; angling captures active and feeding fish. Fyke nets accounted for 29% (120 fish) and angling 56% (232 fish) of the sample. The seine was used to capture concentrations of pike in shallow water during the spawning season and accounted for 4% (17 fish) of the sample. The plexiglass trap was used in shallow water (< 0.5 m) to obtain a sample of the smaller size ranges of pike. It captured pike ranging in size from 9.3 to 51.0 cm and accounted for 2% (9 fish) of the sample.

In all fish biology studies, a representative sample of size ranges of the population is required to study age and growth, fecundity and food habits. Based upon sample size and number and types of gears used, the sample of larger length classes (50-90 cm) appears to be representative for the northern pike population at Lobstick. The small sample size of fish 0 to 50 cm probably does not truly represent the population but is due to sampling techniques. Of the five gears, the plexiglass trap was the only one capable of being used in the habitat of these fish. Seining was ineffective due to submerged bushes and vegetation in the flooded backwaters. Other sampling methods were considered; however, suitable electrofishing gear was not available and rotenone poisoning could not be used due to federal government policy restricting its use. Acknowledging the limitations imposed by the sampling methodology, the following discussion considers the biology of northern pike from Lobstick in relation to the biology of northern pike from other parts of its Canadian range.

The Smallwood Reservoir and release gate at Lobstick create a unique environment for all fish species below the structure. The structure acts as a barrier to upstream migration of all species but at least two species, lake trout and brook trout, can survive passage through the structure (Bruce unpublished data). This one-way movement of fish may help explain the large concentrations of fish immediately below the structure. The rate of water flow through Lobstick varies throughout the year. This causes fluctuating water levels which affect both the spawning and rearing areas available to most fish species. The effects of the large concentrations of fish and fluctuating water levels on the biology of northern pike from Lobstick will be considered more closely throughout the discussion.

Similar to other unexploited fish populations in northern lakes (Johnson 1976; Power 1978), the northern pike from Lobstick exhibit large mean lengths and weights which cluster around a modal value (Tables 14 and 15). This is natural for a piscivorous species, which, as it increases in size, has fewer natural predators. There is little fishing mortality; therefore, most removals from the population are due to natural mortality.

Estimates were made of the instantaneous total mortality rate (Z) for males and females (Fig. 17). The limitations of such estimates must be considered before any conclusions can be made. Estimates of 'Z' from catch curves assume that 1) survival and/or mortality rate is uniform with age over the range of age groups in question, 2) there has been no change in mortality rate with time, 3) the sample is taken randomly from the age groups involved, and 4) the age groups in question were equal in numbers at the time each was recruited to the population being sampled (Baranov 1918). Survival and/or mortality rate may differ with age, the pike having fewer predators as it increases in size. Also, the sample of pike from Lobstick is not representative of the population as the younger age groups are poorly represented. However, only the descending points of the catch curve were used to estimate 'Z' and over this range of age groups, survival and mortality rates are likely to be uniform and the sample is representative. Little is known concerning mortality rate over time and recruitment strength of age groups of northern pike from Lobstick. Therefore, conclusions concerning magnitude of the estimates of 'Z' would be unreliable; however, comparisons can be made between the values derived for males and females. Since the instantaneous fishing mortality (F) is low, the instantaneous total mortality (Z) can be used as an estimate of the instantaneous natural mortality (M) as $Z = F + M$. The estimate of Z for males is 0.32, for females 0.37, suggesting a higher natural mortality rate for females. These differences, if biologically real, may be related to the energetics of reproduction, the female gonads being larger than the male's and requiring more energy for development. Medford and Mackay (1978) found that mature ovaries of pike contained 14.5 times more protein and 10.5 times more lipid than mature testes. Diana and Mackay (1979) found that testicular growth occurred entirely in August of each year. Ovary caloric growth began in August and nearly all ovarian growth (81%) occurred from October to March. No gonad growth occurred from March to May, yet as much as 68% of the total liver energy was used during spawning, suggesting that these depletions were mainly due to spawning related activities, rather than gonad growth. The stress placed on females due to ovarian development during the winter and spring may contribute to their higher natural mortality rate.

Field observations at Lobstick corroborated the findings of Svärdson (1947) who suggested, based on evidence from marking experiments, that pike do not necessarily spawn each year. Several ovaries contained large eggs (> 1 mm) retained from a previous year's spawning and immature eggs (< 1 mm) which would not be ready for release until the following year. This may also be related to the rate of gonad development. Growth data, to be discussed later, suggest that food available to pike at Lobstick is abundant. However, most growth occurs during the summer when there are large concentrations of whitefish below Lobstick and water temperatures are relatively high. Nothing is known of food availability at Lobstick during winter. In Lac Ste. Anne, Alberta, energy accumulation occurs in both sexes during winter and summer, about 35% of pike growth occurring in the winter at a temperature of ~ 1 C. Ovarian growth, which occurs during the winter, must result from food intake, as there is no depletion of somatic energy during this time (Diana and Mackay 1979). If development of the ovaries is slowed during winter and early spring, spawning may be delayed to the following year until gonad development is complete and sufficient somatic energy reserves are accumulated.

Common with other pike populations (Miller and Kennedy 1948; Frost and Kipling 1967; Wolfert and Miller 1978), Lobstick pike exhibit great ranges in length and weight at each age (Tables 9 and 20). This suggests that there are large differences in growth rate within and possibly between year-classes. Differences within year-classes may be partly explained by natural variations between individuals which would affect such parameters as gonad weight, whole weight and fork length. Differing environmental conditions such as water temperatures and fluctuating water levels could cause differences in growth rates between year-classes. Prey are concentrated into smaller areas at times of low water making them more easily available to the pike. The randomness of these fluctuations from year to year could cause differential growth rates between year-classes. Frost and Kipling (1967) suggest that variation in growth of different year-classes is correlated with yearly temperature variations, pike in the year-classes which experienced highest cumulative temperatures being about 5 cm longer at age 4 years than those which experienced the lowest temperature regime.

The calculated fork lengths of the different age groups of pike from Lobstick can be compared with those of other Labrador populations of pike (Table 19). Calculated lengths of older fish are larger for Lobstick pike than for other Labrador pike. As stated earlier, this may partly be explained by problems in measuring annular growth on scales of older fish. However, it also suggests that food supply available to pike at Lobstick is more abundant than for the other Labrador populations since growth of the older fish does not decrease as rapidly. This suggestion is supported by the abundance of whitefish below Lobstick structure during the summer. Analysis of food habits (Table 28) shows that as pike increase in size, their diet consists mostly of whitefish. Whitefish was the only food found in fish over 70 cm.

The growth rate of Lobstick pike is similar to that of pike in other northern Canadian Lakes (Miller and Kennedy 1948). These relatively unexploited populations are characterized by slow growth rates, high age at first maturity, and long life span. In contrast, more southern populations, such as those in Lake Ontario (Wolfert and Miller 1978) exhibit faster growth, lower age at first maturity and shorter life span. These differences are probably due both to differences in climate and exploitation rate. The length attained by fish in most northern Canadian lakes in ten years is reached by Lake Ontario pike in less than three years, the faster growth being related to warmer water temperatures. Also, the higher rate of exploitation in Lake Ontario reduces the numbers of pike present, decreases the competition for resources and thus leads to an increased growth rate. The faster growth rate allows the pike to reach the size at which it will first spawn at an earlier age (Frost and Kipling 1967). Lobstick pike are predominantly (50%) mature at age six, Lake Ontario pike at age three. The maximum age of pike sampled at Lobstick was fifteen years, in Lake Ontario ten years, the reduced life span in Lake Ontario probably being due to the rate of exploitation.

Fecundity, the number of mature eggs per female, increases with size of pike (Carbine 1944; Frost and Kipling 1967). The slope of the length-fecundity regression is a useful comparison of the rate of increase of fecundity between populations. The slope of this regression for Lobstick pike is large (3.71) compared to other populations, 3.16 for Gilbert Lake, Wisconsin (Priegel and Krohn 1975) and 3.56 for the River Stour, England (Mann 1976). This large value may be explained by the large size at first maturity of female pike at Lobstick.

The range of coefficient of condition values for mature pike from Lobstick (Table 21) shows a trend toward higher values for females than for males. This can be explained by the larger size of female gonads as the condition value includes a whole weight measurement for each fish. The observed drop in the coefficients of condition for males and females from the middle to the end of June (Fig. 16) corresponds with the time when spawning was observed to occur. Spawning would cause a decrease in weight in both males and females which would be reflected in their coefficients of condition. Water temperatures during this time (Fig. 4) ranged from 2.0 to 9.0 C, within the range recorded for pike spawning in Wisconsin (3.4-10.6 C) (Priegel and Krohn 1975) and England (6.0-8.0 C) (Frost and Kipling 1967).

Fabricus and Gustafson (1958) have shown that stable or rising water level is necessary for the successful spawning of pike.

Hassler (1970) suggests that rapid water temperature fluctuations and silt deposition may contribute to year-class failure of pike. At Lobstick, rates of water flow and consequently water levels fluctuated widely during the spawning season (Fig. 5). Shallow bays where pike were found concentrated oneday were dry the next day. This was common throughout the spawning season both in 1977 and 1978 and presumably has occurred ever since the formation of the Smallwood Reservoir in 1971. Over 75% of the fish sampled were age seven or older. Although gear selectivity is certainly a factor, the small sample of younger age groups may not be entirely due to the sampling technique; fluctuating water levels during the spawning season since 1971 may have reduced the spawning success of pike, leading to reduced populations of the younger age groups. Peak spring runoff occurs during June in the Lobstick area. Normally, water levels would be high, flooding backwaters and marshes, areas suitable for pike spawning. Control of the rate of flow through Lobstick structure alters this pattern, delaying peak water levels below the structure until July or August, after the reservoir has been refilled following winter drawdown.

In documenting the problems of age determination of northern pike, this study has answered some questions but has left several yet to be resolved. These unanswered questions and the methodology to study them may form the basis of future research.

The study involved the comparison of four methods of age determination. To obtain a more complete comparison of methods, other structures such as vertebrae, fin rays, metapterygoids, and teeth could also be included in future work.

The time constraints of the study prevented analyses which may have proved the accuracy of each aging method. A tag and recapture experiment on a smaller population of pike would elucidate some of the results presented in this paper. Tagged fish, captured in fyke nets once each year for four or five years, could be measured, weighed, and injected with tetracycline hydrochloride (Jensen and Cumming 1967). After such time, a sufficient sample of tagged fish could be taken from which the annual increments of growth on each of the bony structures could be determined. Similar results could be obtained for scales. Direct comparisons of aging results could then be made. Such a study would help solve the problem of identifying false annuli. The tetracycline, if injected at the same time each year, would act as an annular mark.

Further questions on the biology of pike from Lobstick also need to be considered. The phenomenon of alternate year spawning has been documented but is not fully understood. Questions concerning the physiological mechanism and frequency of occurrence within a population need to be answered. In studying the mechanism, the availability of food for pike during the winter at Lobstick may be considered. A detailed study on the spawning success of pike may help determine if water level fluctuations below Lobstick are affecting year-class strength. Consideration should be given to these and other problems before stock assessments and sound management policies can be made.

SUMMARY

In the summers of 1977 and 1978, a sample of 415 pike was taken, by angling, gillnet, fyke net, seine and plexiglass trap, from below Lobstick structure, Smallwood Reservoir, Labrador.

Four methods of age determination, scales, opercula, cleithra and otoliths, were evaluated by comparing empirical and back-calculated growth rates generated by each.

Analysis of covariance showed no significant difference between empirical and back-calculated age-length regressions using otoliths; there were differences using scales, opercula and cleithra. Otoliths were chosen for the study of age and growth of northern pike from Lobstick.

Northern pike from Lobstick, similar to other unexploited fish populations in northern lakes, exhibit large mean lengths (62.0 cm) and weights (1.99 kg) which cluster around a modal value.

The growth rate of Lobstick pike is similar to that of pike in other northern Canadian lakes but much slower than in more southern waters.

Common with other pike populations, Lobstick pike exhibit great ranges in length and weight at each age.

Calculations of mortality and survival, based upon a catch curve, suggest that the instantaneous total mortality (Z) for females (0.37) is higher than for males (0.32).

Observation of ovaries of mature pike from Lobstick show that all pike do not spawn each year.

The rate of increase of fecundity with respect to length of pike from Lobstick is faster than that of other more southern populations.

Males are predominantly (50%) mature by age 5, or at 40 cm, females by age 8, or at 60 cm. For sexes combined, the pike are not entirely mature until 75 cm.

Stomach analysis showed that as pike grow, their diet becomes entirely piscivorous, and consists mostly of whitefish.

LITERATURE CITED

Astanin, L.P. 1947. On the determination of the age of fishes [in Russian, English summary]. Zool. Zh. 26: 287-288.

Baranov, F.I. 1918. On the question of the biological basis of fisheries [in Russian]. Nauchn. Issled. Ikhtiologicheskii Inst. Izv. 1: 81-128.

Boyar, H.C. and R.A. Clifford. 1967. An automatic device for counting dry fish eggs. Trans. Am. Fish. Soc. 96: 361-363.

Bruce, W.J. 1974. The limnology and fish populations of Jacopie Lake, West Forebay, Smallwood Reservoir, Labrador. Fish. Mar. Serv. Tech. Rep. Ser. No. NEW/T-74-2: 74 p.

_________ 1975. Experimental gillnet fishing at Lobstick and Sandgirt Lakes, Smallwood Reservoir, Western Labrador, 1974. Fish. Mar. Serv. Int. Rep. Ser. No. NEW/1-73-3: 35 p.

Bruce, W.J. and R.F. Parsons. 1979. Biology of the fishes of Ossokmanuan Reservoir, Labrador, 1976. Fish. Mar. Serv. Tech. Rep. No. 836.

Carbine, W.F. 1944. Egg production of the northern pike *Esox lucius* L., and the percentage survival of eggs and young on the spawning grounds. Pap. Mich. Acad. Sci. 29: 123-137.

Casselman, J.M. 1967. Age and growth of northern pike *Esox lucius* Linnaeus, of the upper St. Lawrence River. M.S. Thesis, Univ. Guelph, Guelph, Ontario. 219 p.

_________ 1974. Analysis of hard tissue of pike *Esox lucius* L. with special reference to age and growth. P. 13-27. *In* T.B. Bagenal (ed.). Ageing of fish - Proceedings of an international symposium. Reading, England, 19-20 July 1973. Unwin Brothers Ltd., England. 234 p.

_________ (In preparation). Cleithral method of determining age and growth of northern pike and other esocids.

Casselman, J.M. and H.H. Harvey. 1973. Fish traps of clear plastic. Prog. Fish Cult. 35: 218-220.

Christensen, J.M. 1964. Burning of otoliths, a technique for age determination of soles and other fish. J. Cons. Perm. Int. Explor. Mer. 29: 73-81.

Chugunova, N.I. 1959. Handbook for the study of age and growth of fishes. Akademiya Nauk Press, Moscow. 164 p.

Diana, J.S. and W.C. Mackay. 1979. Timing and magnitude of energy deposition and loss in the body, liver, and gonads of northern pike (Esox lucius). J. Fish. Res. Board Can. 36: 481-487.

Dubois, A. and R. Lagueux. 1968. Etude comparée de l'âge scalaire et de l'âge otolithique de la touladi (Salvelinus namaycush), Lac Mistassini, Québec. Natur. Can. 95: 907-928. [Translated by Fish. Res. Board Can. Transl. Ser. No. 2883].

Duthie, H.C. and M.L. Ostrofsky. 1974. Plankton, chemistry and physics of lakes in the Churchill Falls region of Labrador. J. Fish. Res. Board Can. 31: 1105-1117.

Fabricus, E. and K.J. Gustafson. 1958. Some new observations on the spawning behaviour of the pike, Esox lucius L. Rept. Inst. Freshwat. Res. Drottningholm 39: 23-54.

Frost, W.E. and C. Kipling. 1959. The determination of the age and growth of pike (Esox lucius L.) from scales and opercular bones. J. Cons. Perm. Int. Explor. Mer. 24: 314-341.

—————— 1967. A study of reproduction, early life, weight-length relationship and growth of pike, Esox lucius L., in Windermere. J. Anim. Ecol. 36: 651-693.

Graham, M. 1929. Studies of age determination in fish. Part II. A survey of the literature. U.K. Min. Agric. Fish., Fish. Invest. (Ser. 2) 11(3): 50 p.

Hansen, L.P. 1978. Age determination of roach Rutilus rutilus (L.) from scales and opercular bones. Arch. FischWiss. 29: 93-98.

Harrison, E.J. and W.F. Hadley. 1979. A comparison of the use of cleithra to the use of scales for age and growth studies. Trans. Am. Fish. Soc. 108: 452-456.

Hassler, T.J. 1970. Environmental influences on early development and year-class strength of northern pike in lakes Oahe and Sharpe, South Dakota. Trans. Am. Fish. Soc. 99: 369-375.

Hatfield, C.T., J.N. Stein, M.R. Falk, and C.S. Jessop. 1972. Fish resources of the Mackenzie River valley. Environment Canada, Fisheries Service, Interim Rep. 1, 1, 247 p.

Hederström, H. 1759. Rön om Fiskars Ålder. Handl. Kungl. Vetenskapsakademin (Stockholm) 20: 222-229. (Re-published in Rep. Inst. Freshwat. Res. Drottningholm. 40: 161-164 (1959) as Observations on the age of fishes).

Hile, R. 1936. Age and growth of the cisco, Leucichthys artedi (LeSueur), in the lakes of the northeastern highlands, Wisconsin. Bull. U.S. Bur. Fish. 48: 211-317.

Hoffbauer, C. 1905. Weitere Beitrage zur Alters-und-Wachstumsbestimmung der Fische, spez. des Karpfens. Zeitschr. Fisch. 12: 111-142.

Jensen, A.C. and K.B. Cumming. 1967. Use of lead compounds and tetracycline to mark scales and otoliths of marine fishes. Prog. Fish Cult. 29: 166-167.

Johnson, L.D. 1959. Story of a thousand stomachs. Wis. Conserv. Bull. 24: 7-9.

Johnson, L. 1976. Ecology of arctic populations of lake trout, Salvelinus namaycush, lake whitefish, Coregonus clupeaformis, arctic char, S. alpinus and associated species in unexploited lakes of the Canadian Northwest Territories. J. Fish. Res. Board Can. 33: 2459-2488.

Kandler, R. and W. Pirwitz. 1957. Über die fruchtbarkeit der plattfische im Nordsee-Ostsee-Raum. Kieler Meeresforsch. 13: 11-34.

Kipling, C. 1975. The effects of variation in growth on the gillnet selection of a population of pike. EIFAC Tech. Paper 1975, 23 (Suppl. 1 Vol. 1). 80-89.

LeCren, E.D. 1947. The determination of the age and growth of the perch (Perca fluviatilis) from the opercular bone. J. Anim. Ecol. 16: 188-204.

MacKay, K.T. 1967. An ecological study of mackerel, Scomber scombrus, in the coastal waters of Canada. Fish. Res. Board Can. Tech. Rep. No. 31.

Mann, R.H.K. 1976. Observations on the age, growth, reproduction and food of the pike Esox lucius (L.) in two rivers in southern England. J. Fish Biol. 8: 179-197.

Maraldo, D.C. and H.R. MacCrimmon. 1979. Comparison of ageing methods and growth rates for largemouth bass, Micropterus salmoides Lacépède, from northern latitudes. Env. Biol. Fish. 4: 263-271.

Medford, B.A. and W.C. Mackay. 1978. Protein and lipid content of gonads, liver, and muscle of northern pike (Esox lucius) in relation to gonad growth. J. Fish. Res. Board Can. 35: 213-219.

Miller, R.B. and W.A. Kennedy. 1948. Pike (Esox lucius) from four northern Canadian lakes. J. Fish. Res. Board Can. 7: 190-199.

Monastyrsky, G.N. 1930. Methods of determining the growth in length of fish by their scales [in Russian]. Trudy nauch. ryb. Khozy. 5: 4.

Parsons, R.F. 1975. The limnology and fish biology of Ten Mile Lake, Labrador. Fish. Mar. Serv. Tech. Rep. Ser. No. NEW/ T-75-3: 75 p.

Powell, Sheppard T. Associates (Canada) Ltd. 1971. Churchill Falls power project. Water quality and biological study 1970-71. Vol. 1A.

Power, G. 1978. Fish population structure in arctic lakes. J. Fish. Res. Board Can. 35: 53-59.

Priegel, G.R. and D.C. Krohn. 1975. Characteristics of a northern pike spawning population. Wisc. Dept. Nat. Resources Tech. Bull. No. 86.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. No. 191.

Schott, J.W. 1965. A visual aid for age determination of immersed otoliths. Calif. Fish Game 51: 56.

Simpson, A.C. 1951. The fecundity of the plaice. U.K. Min. Agr. Fish., Fish. Invest., Ser. 2: 17(5): 27 p.

Svärdson, G. 1947. Gäddlekstudier. Södra Sveriges Fiskeriför. Skrifter 1946: 34-59.

Svetovidov, A.N. 1929. To the question of age and growth of perch, rudd and pike from the Lake Krugloe [in Russian, English summary]. Russk. Zool. Zh. 9: 3-22.

Tesch, F.W. 1968. Age and growth. p. 93-123. In W.E. Ricker (ed.). Methods for assessment of fish production in fresh waters. IBP Handbook No. 3, Blackwell Scientific Publications, Oxford and Edinburgh.

Trout, G.C. 1956. The otolith and age determination. ICNAF Doc. No. 353 B-38.

Williams, J.E. 1955. Determination of age from the scales of northern pike (*Esox lucius* L.). Ph.D. Thesis, University of Michigan, Ann Arbor, Michigan. 185 p.

Wolfert, D.R. and T.J. Miller. 1978. Age, growth, and food of northern pike in eastern Lake Ontario. Trans. Am. Fish. Soc. 107: 696-702.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall Inc., Englewood Cliffs, N.J. 620 p.