A STUDY OF THE SEX RATIO OF THE YELLOW PERCH IN TWO LAURENTIAN LAKES OF THE PROVINCE OF QUEBEC

by

GEORGE EDWIN NEWSOME

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ABSTRACT

A study of the yellow perch (*Perca fluviatilis flavescens* L.) in two Laurentian lakes of the Province of Quebec revealed in both cases stunted growth and a marked predominance of males which made up about 70% of the catch. Approximately 2900 specimens of various ages were collected by gill nets, seine and traps. Analysis of the age frequency distribution of the catch shows a higher mortality of immature and mature females than of males.

The seasonal variation of fat content in males and females was measured and the fat levels at time of death due to starvation under laboratory conditions determined. The results showed that the mature females approach the critical level of fat content at least four months prior to spawning, when most of the total body fat is concentrated in the ovary. Whereas, the males seem to be able to maintain a higher fat level in the body. The higher mortality of immature females may be explained by differences in areas chosen for schooling between the sexes which would make them more vulnerable to predation and cannibalism.

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INTRODUCTION

Although common to lakes and streams of eastern and central North America (Hubbs and Lagler, 1947), the yellow perch (*Perca fluviatilis flavescens* L.) is not a native fish to many of the glacial, oligotrophic lakes in the Laurentian mountain region of Quebec. Since its introduction to many of these lakes, the yellow perch has become the dominant species which has resulted in a significant decline in the sport fishery for brook trout (*Salvelinus fontinalis*) (Bergeron *et al*., 1968).

Recent studies of the yellow perch in these Laurentian lakes have shown various degrees of stunting (Grimaldi, 1967; Knap, 1967; Bergeron et al., 1968). Eschmeyer (1937, 1938) and Herman *et al*., (1964) have also observed that in small infertile lakes, yellow perch show strong tendencies towards overcrowding resulting in a decline in their growth rates. Similarly, Schneberger (1935), while investigating the growth of three populations of yellow perch in Wisconsin, concluded that the growth rate was inversely proportional to the size of the population.

In addition, the investigations conducted by Grimaldi (1967), Knap (1967) and Bergeron *et al*. (1968), have all shown a strong predominance of males (70% of the catch) in the Laurentian populations of yellow perch that they have studied. On the other hand, other authors have shown that in their natural waters, females have become more abundant with increasing age (Schneberger, 1935; Beckman, 1946; Worthington, 1950; McCormack, 1965). Most notable of these is the work of Beckman who investigated yellow perch populations in 198 Michigan lakes. Grimaldi's study (1967) of five populations of yellow perch in the Province of Quebec showed a similar situation in regard to the sex ratio.

Two authors have reported a predominance of males among populations of yellow perch other than those reported in the Province of Quebec. Schneberger (1935) reported a predominance of males (56%) in Nebish Lake, Wisconsin, and Eschmeyer (1937) found, in South Twin Lake, Michigan, a stunted population with 57 percent males but neither values approach the 70 percent predominance of males observed in some of the Laurentian lakes where the yellow perch was artificially introduced.

The object of the present study was to verify the previous observations of the peculiar sex ratios of the yellow perch in some Laurentian lakes, and attempt to explain the phenomenon by a study of the seasonal variation of total body fat.

Despite the vital ecological importance of the body fat content in fish in relation to food consumption, reproduction, and survival, there seems to be little information concerning seasonal changes and the effects of environmental conditions.

Many fish store fat before the spawning period, and when feeding ceases, energy for activity and the development of sex products is derived from fat reserves and to some extent from proteins (Hoar, 1957; Love, 1957). Greene (1919) (in Bailey, 1952), p. 40) observed in the king salmon (Oncorhynchus tshawytscha), a decline of body fat from 15.5 percent to 2.2 percent before and after spawning. In the voluminous literature of the yellow perch of North America and Europe no information of body fat content could be found.

Turner (1919) and Le Cren (1951) found that prior to spawning, the ovary of the yellow perch may contribute as much as eight percent to the total body weight and Pearce and Achtenberg (1920) and Keast (1968) observed cessation of feeding before spawning. Le Cren (1951) in his study of the seasonal cycles of gonad weights and relative condition factor of the perch of Lake Windermere, observed: "It is significant that a large proportion of the food available for growth and growth potential of the mature fish (perch), particularly the females, must be devoted each year to the annual production of gonad products."

The Laurentian lakes where the predominance of male yellow perch has been observed, are mostly oligotrophic with evidence of overcrowding and stunting of the fish. It was felt that a limited food supply, and spring spawning occurring at the end of long winters, could cause, in the females, a serious depletion of body fat from the production of ova alone, and thus, place a greater selective pressure against them.

MATERIAL, SITES OF STUDY AND METHODS

Material

The present study of the sex ratio of the yellow perch (*Perca fluviatilis flavescens* L.), utilized 2985 preserved specimens taken from two Laurentian lakes between May of 1968 and October of 1969; 106 live perch were also used for a laboratory experiment of starvation.

Sites of study

The lakes chosen for the study were Lake Tamaracouta and Lake Archambault, located in the Laurentian mountains north of Montreal (see Figure 1). Both supported sport fishing for trout, *Salvelinus fontinalis* and *S. namaycush*, prior to the establishment of the yellow perch probably around 1940-1950 (Bergeron, *et al.*, 1968). These lakes were chosen for the study because of the availability of background information, history, as well as familiarity of the regions surrounding each of the lakes. More extensive observations were made on Lake Tamaracouta because of its proximity to Montreal (41 miles).

The morphometric characteristics of Lake Tamaracouta are given in Table 1, and its morphology illustrated in Figure 2, which also shows the location of the six sampling stations chosen for this study of the yellow perch.

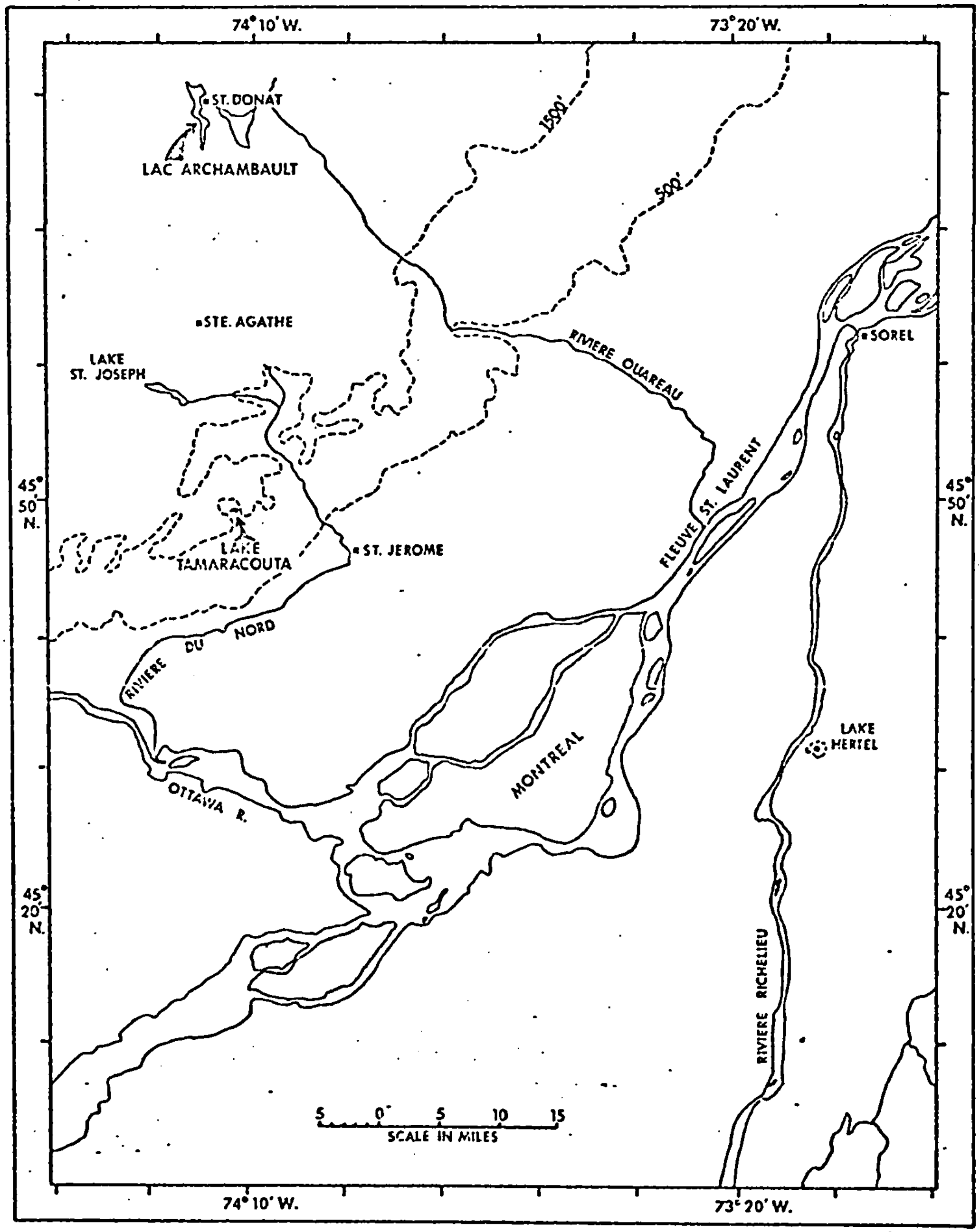

Figure 1. Map showing the location, in the Province of Quebec, of Lake Tamaracouta and Lake Archambault, where a study of the sex ratios of yellow perch populations was conducted.

Table 1. Geographic and morphometric characteristics of Lake Tamaracouta and Lake Archambault.

Character	Tamaracouta	Archambault
Longitude	74°-12'W.	74°-14'W.
Latitude	45°-49'N.	46°-19'N.
Altitude above sea level in m.	275	380
Length in m.	1340	3380
Width in m.	180	2420
Area in hectares	37	533
Maximum depth in m.	30	38
Average depth in m.	15.8	15.8
Development of shoreline	1.79	2.88
Development of volume	1.82	1.18

Station 1, located at the western tip of the lake near the mouth of one of the two inlet streams, consists of a sandy shoal which slopes gently to a depth of three meters and then rapidly drops to a depth greater than 10 meters. On either side of the mouth of the stream, the bottom is composed of fine sand and mud. The dominant aquatic vegetation of the area is the water lily (Nymphaea sp.), although the pickerel weed (Pontederia sp.) and pipeworth (Eriocaulon sp.) are common in the shallower waters.

Station 2, located in the northwest corner of the lake is similar to station 1, however, the bottom deposits are of a finer grade sand with fewer rooted aquatic plants primarily Pontederia sp. Station 3 was located on the north shore at the base of a rock ledge

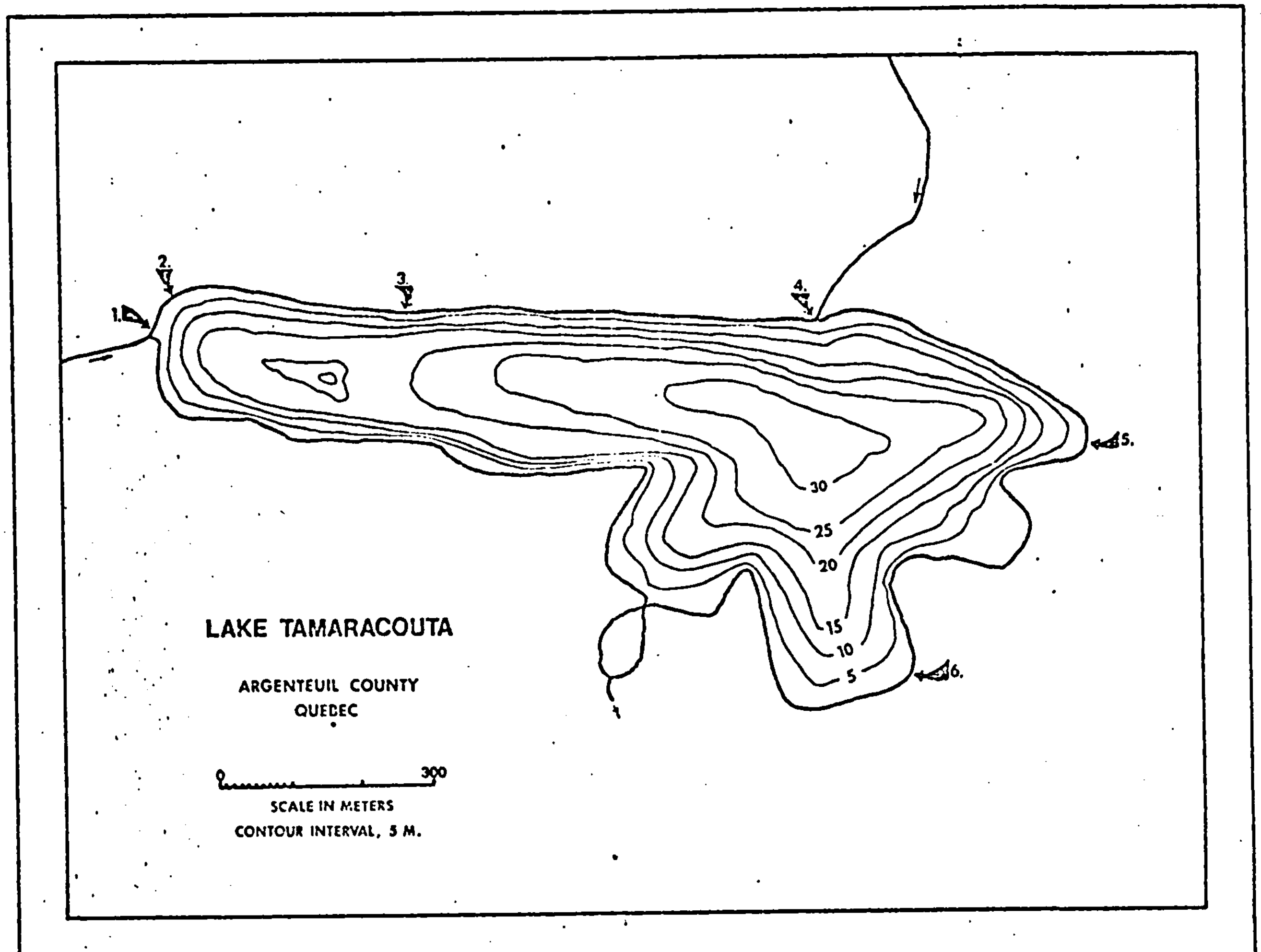

Figure 2. Bathymetric map of Lake Tamaracouta showing various sampling stations where yellow perch were captured for a study of the sex ratios.

which drops to a depth of 10 meters. Station 4, located at the mouth of the second tributary of the lake, is similar to station 1. Station 5, at the eastern tip of the lake is similar to station 2, but considerable amounts of dead wood, brought to the bay by the prevailing westerly winds, are scattered over the area. Station 6, at the southeast corner of the lake, consists of a beach of coarse sand which grades into mud at a depth of approximately one meter, supports an abundant vegetation, namely Potamogeton sp. at depths greater than two meters, with Nymphaea sp. and Eriocaulon sp. common to the shallow zones.

The morphometric characteristics of Lake Archambault are given in Table 1, and its morphology illustrated in Figure 3, which also shows the two sampling stations selected for the study, both located off the eastern shore in the southern reach of the lake.

Station 1 was situated off a rocky point. The bottom slopes gently to a depth of 15 meters and in the shallower zone is composed primarily of boulders of various sizes. Station 2, located in the shallow bay adjacent to station 1, consists of an extensive sandy beach with a gently sloping bottom. Rooted aquatic vegetation is absent from station 1 and very sparse at station 2.

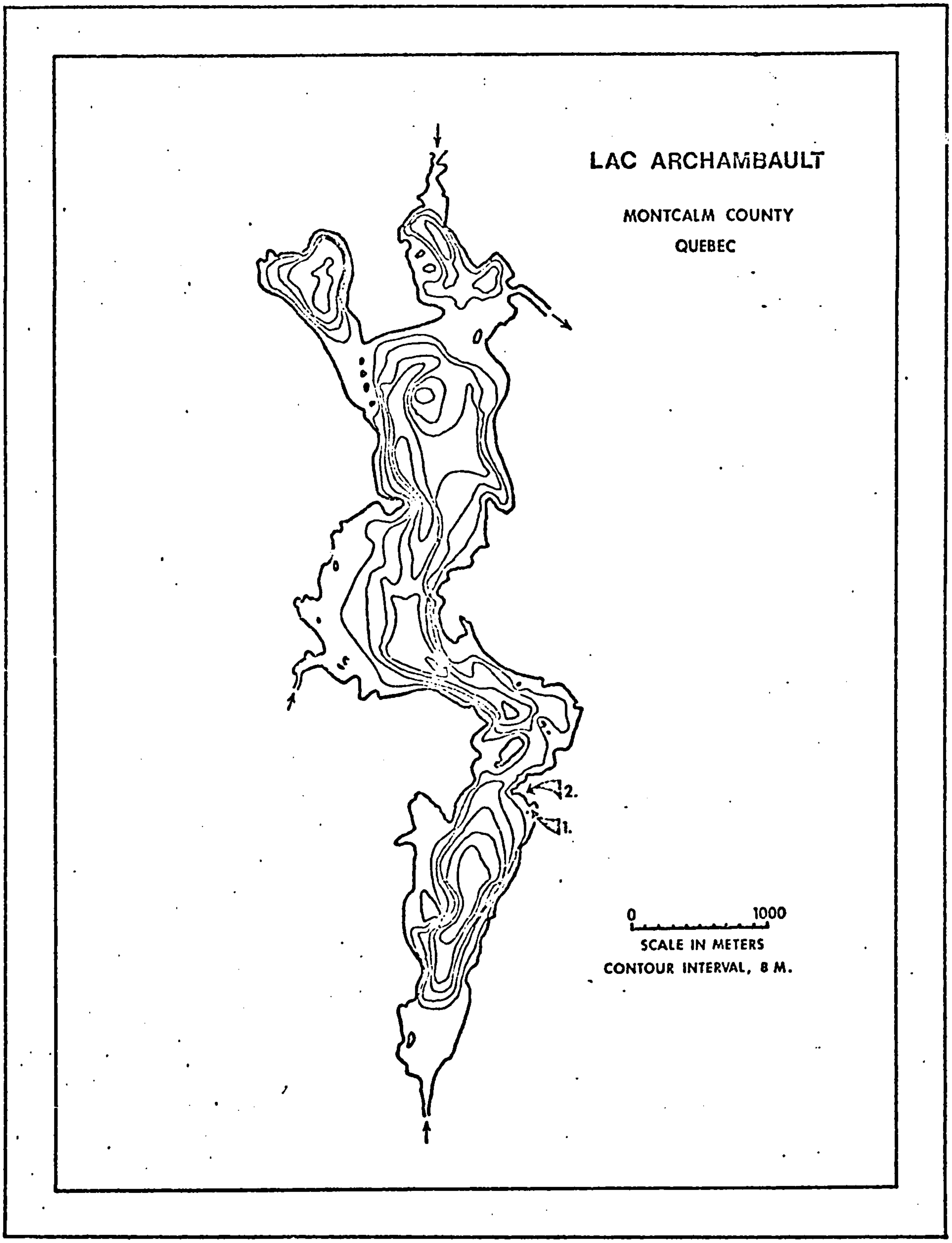

Figure 3. Bathymetric map of Lake Archambault showing various sampling stations where yellow perch were captured for a study of the sex ratios.

Methods

Since the study was concerned with the sex ratio of the two populations of perch and the seasonal changes in the distribution of body fat, samples were obtained at different times during each season. Winter sampling was restricted to Lake Tamaracouta since it was within easy access from Montreal.

Methods of capture

Three methods of capture were employed during the study. They were gill nets, seine and Windermere traps. Table 2 shows the sampling stations, the methods used and the size of the catch at each of the sampling dates.

The gill nets were made of green nylon monofilament of various mesh sizes (0.6 cm to 3.8 cm, stretched), 15 meters (50 feet) long and 2.4 meters (8 feet) deep. Gangs of three to five nets resting on the bottom were set perpendicular to the shore line from a depth of slightly less than three meters to depth of more than 10 meters depending on the particular station sampled and the number of nets per gang. They were usually set in the afternoon, left overnight and retrieved the following morning, thus allowing a fishing period of approximately 16 hours.

Table 2. Location, methods of capture (N:gill nets, S:seine, T:traps) and size of the catch of yellow perch taken at different times from Lake Tamaracouta and Lake Archambault for a study of the sex ratio and fat content.

Date	Sampling Station 1	2	3	4	5	6	Number of Fish
Lake Tamaracouta							
5/12/68		N			N		111
5/25/68	N						110
5/30/68	N			N			18
7/ 9/68	S	N			N		59
8/11/68	N		N				35
8/17/68	N		N				145
9/22/68	N&S		N&S			S	173
2/ 2/69	T						18
2/19/69	T						18
3/19/69	T						594
3/25/69	T						120
4/ 1/69	T						16 1/
5/ 9/69	T						128
5/14/69	T						77
6/21/69	T						61
7/13/69	T						250
8/ 3/69	T						22
10/13/69	T						106 2/
							2061
Lake Archambault							
5/11/68	N						74
5/23/68	N						49
6/ 4/68	N&S	S					16
6/ 6/68	N						182
6/13/68	N	S					85
7/13/68	N	S					152
7/24/68	N						68
8/16/68	N						97 1/
9/19/68	N						120
10/13/68	N						81
							924

1/ Fat determinations were not made on these samples.

2/ This sample was used for a starvation experiment in the laboratory.

Seining was done with a 15-meter (50-foot) nylon seine with a 1.3 cm. (1/2") mesh and a depth of 2.4 meters (8 feet).

Three Windermere traps (Worthington, 1950) were used in Lake Tamaracouta at station 1 in 1969. They were constructed of 1.3 cm. (1/2") mesh hardware cloth and measured 1.2 meters (4 feet) in length and 0.6 meters (2 feet) in diameter. Fish were led into the traps through conical openings at both ends, each with a 7.6 cm. (3") diameter aperture. The traps were set on the bottom with the long axis parallel to the slope at a depth of two to four meters for periods varying from one to seven days, depending on the season. In the summer, fishing periods were the same as those used for gill nets but during the winter, when fishing was done through the ice, the traps were left for periods up to seven days.

Immediately after capture, the fish were preserved in solutions of 10% formaldehyde or kept on ice for periods of usually not more than three hours and then frozen.

Study for the preserved samples

The age of each fish was determined by scalimetry using scales removed from the third row below the lateral line and above the vent; one to three scales were read for each fish. The fish were then sexed by examination of the gonads and the total and standard lengths measured to the nearest millimeter.

Fat determinations were conducted on selected samples taken during the study as designated in Table 2. Each sample was divided in age classes and also according to sex. These sex groups were equally divided and the gonads removed from half of each sex-age group. Where odd numbers of fish were encountered, the extra fish was assigned to the group with gonads removed. Among some of the young year classes, notably the one-year-old fish, removal of gonads was not possible and in these cases only one fat determination per age-sex class was made.

The fish were dried in a drying oven (Precision, Model 28) at 70°C. until a constant weight was attained which usually took approximately three days; they were then finely ground in a Waring Blendor and two to six grams of the homogenate were weighed for fat determination by ether extraction using a Goldfisch apparatus. Three hours of reflux distillation was found to be the optimum time for complete extraction. Comparisons in the extractability of fat from fresh and preserved samples showed that preservation in 10% formaldehyde had no significant effect on the accuracy of the determination. The amount of fat extracted was expressed as a percent of the dry weight of the tissue homogenate used in the extraction.

Starvation experiment

During the winter of 1969-70, a laboratory experiment was conducted to determine the amount of fat left in perch at time of death due to starvation. On October 13, 1969, 106 perch were taken from Lake Tamaracouta using Windermere traps and immediately brought back to the laboratory at Sir George Williams University. They were equally divided into four groups and held in four rectangular white porcelain tanks (137 cm X 56 cm X 51 cm) supplied with dechlorinated city water (Montreal) delivered through plastic (P.V.C.) pipes; a flow of about six liters/minute was maintained in each tank. The temperature of the water was not controlled but followed the seasonal variations. On October 13, 1969, the temperature in Lake Tamaracouta was 7°C. and the temperature in the holding tanks at the beginning of the experiment was 8°C. The temperature in the holding tanks declined to a minimum of 3°C by mid-December, remaining at this point until mid-April, 1970 when it slowly rose to 15°C. at the end of the experiment on May 21, 1970.

The tanks were illuminated by fluorescent tubes and an eight-hour photoperiod was controlled by a time switch. Each tank was covered by a sheet of transparent blue plastic to minimize disturbance of the fish and also allow visual observation.

The perch were starved for the whole length of the experiment; as mortality occurred, fish were removed as soon as possible and preserved in 10% formaldehyde. The experiment lasted until all fish had died.

RESULTS

Growth in length.

Although not the primary aim of this study, an assessment of the suitability of the habitats for growth of the two populations of yellow perch was deemed necessary because of the important implications that the environment may have on the sex ratio; the main interest of the present research.

The growth curves for the two populations were obtained from the pooled samples of May 12 and May 25, 1968 for Lake Tamaracouta (147 males and 74 females), and May 11 and May 23, 1968 for Lake Archambault (83 males and 40 females). The use of samples taken at this time eliminated the necessity of correcting for summer growth.

The growth in length of males and females combined for each of the two lakes is illustrated in Figure 4. These eye-fitted curves are compared with the mean growth curve and its 95 percent confidence belt for a number of native yellow perch populations of North America as obtained from various authors (Hile and Jobes, 1940; 1942; Carlander, 1950; Jobes, 1952; and Grimaldi, 1967).

No significant difference could be found between the growth of males and females in Lake Archambault ($p \gg 0.9$) or in Lake Tamaracouta ($p \gg 0.9$) although the mean total lengths for females beyond the third year were

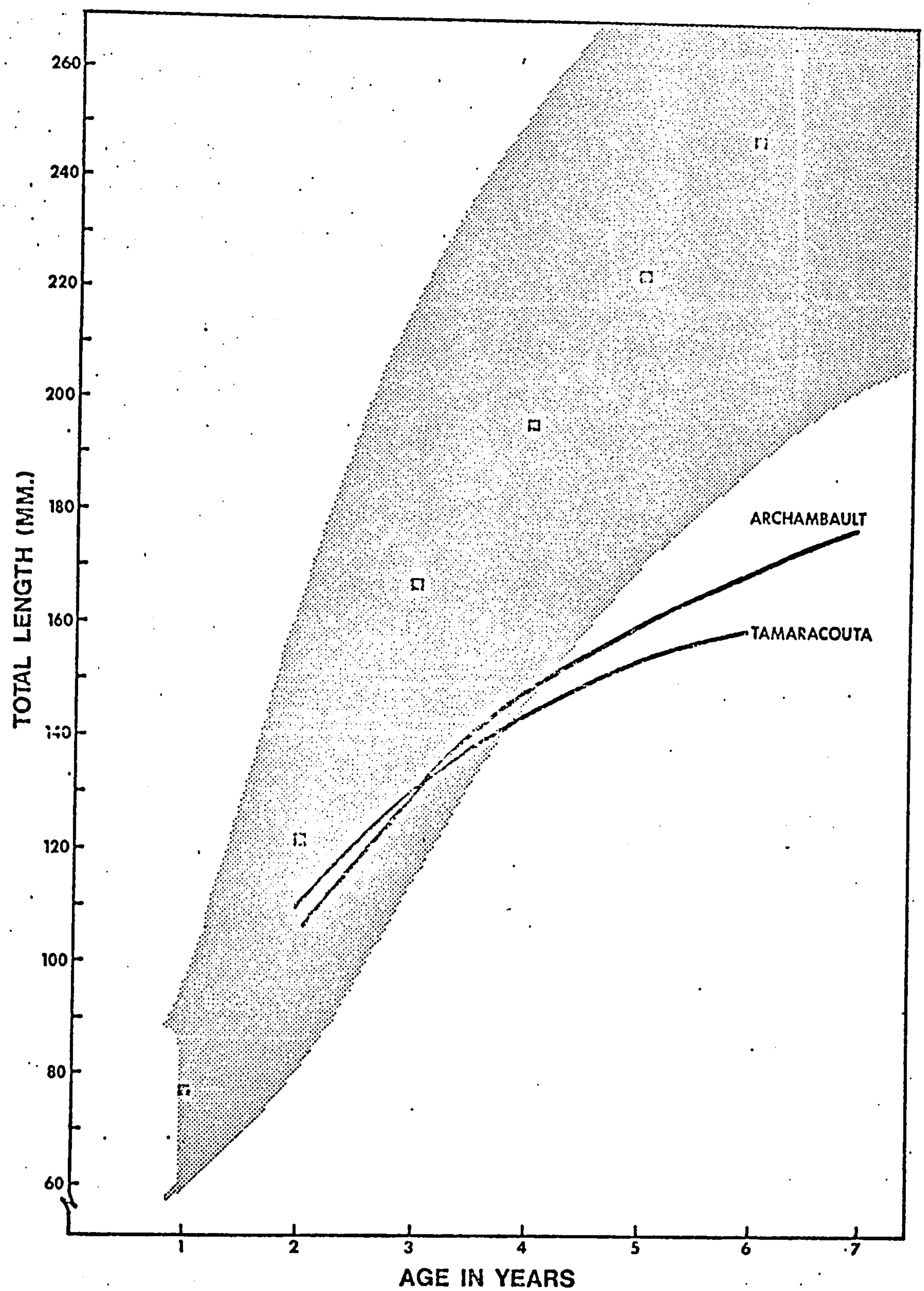

Figure 4. Relationship between the total length and the age of yellow perch taken from Lake Tamaracouta and Lake Archambault, compared with the 95% confidence belt for the mean total length (■) of a number of yellow perch populations in North America.

consistently greater than those of the males. It was noted, however, that the variability of the total length of females was also greater than that of the males. A significant difference ($0.01 > p > 0.001$) between the two populations was found and, as shown in Figure 4, the growth of yellow perch in Lake Tamaracouta is slower than in Lake Archambault, beyond the third year of life. Extrapolation of both growth curves to the first year class would suggest a total length similar to that of "average perch" of North America. Deviation from the "average growth curve" seems to take place soon after the first year and becomes accentuated after the third year. The results indicate that the two lakes support yellow perch populations with a markedly reduced growth, bringing additional evidence of stunting in yellow perch populations living in mountain lakes where they were artificially introduced.

Age frequency distribution.

The age frequency distribution of male and female yellow perch taken from the two lakes is illustrated in Figure 5. The small representation of the young year classes, particularly in Lake Tamaracouta, can certainly be attributed to the selectivity of the capture methods and

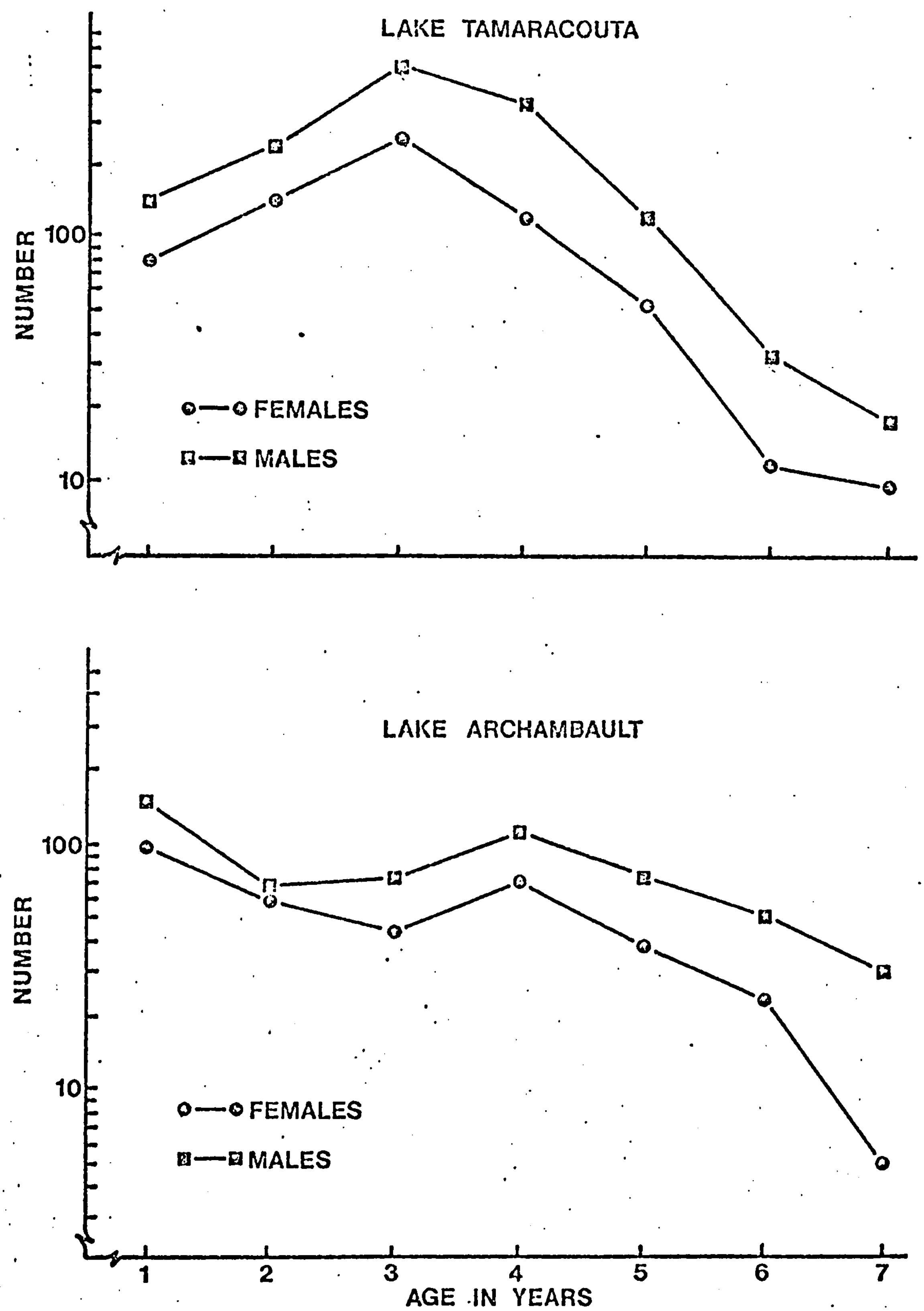

Figure 5. Age-frequency distribution of male and female yellow perch taken from Lake Tamaracouta between May 1968 and October 1969, and Lake Archambault between May 1968, and October 1968.

the degree of fishing efforts deployed in the two lakes. The gill nets were selective for relatively large individuals and the traps although not selective for size, failed to capture the young fish possibly because of their improper location. Seining, although not selective to size, was restricted to areas relatively free of obstructions thus limiting its use throughout the lakes. In Lake Archambault, seining brought a larger number of one year old yellow perch compared to that obtained in Lake Tamaracouta, but this apparent higher relative abundance is due to a less intense fishing for the older age groups with gill nets. It is important to mention that despite repeated efforts in both lakes, to locate and capture young-of-the-year in shallow waters, these were observed only once at station 6 in Lake Tamaracouta; on July 27, 1970, a school of yellow perch fry were sighted and 41 specimens were collected with a seine; the mean total length and the 95 percent confidence interval of these fish was 42.8 $\pm$ 3.48 mm.

Mortality rates.

The annual mortality rates of males and females were calculated after Ricker (1958, p. 44) starting with three-year-old fish for Lake Tamaracouta and four-year-old fish for Lake Archambault. These results, presented in Table 3, indicate that, on the average, the mortality rates between the ages of three and seven years are not significantly different between the males and females of Lake Tamaracouta ($0.5 > p > 0.4$) but that the mortality of females in Lake Archambault is significantly greater ($0.02 > p > 0.01$) over a similar life span. It should, however, be noted that in Lake Tamaracouta there is a heavier mortality among females between three and four years old. Moreover, assuming an equal sex ratio in the newly hatched fish it appears, from Figure 5, that in both lakes females suffer a much heavier mortality than males between the time of hatching and the age of three since, at that age, there are close to twice as many males as females.

Table 3: Observed annual mortality rate (a) of yellow perch taken from Lake Tamaracouta and Lake Archambault between 1968 and 1969.

Lake Tamaracouta

Age	No. males	a	No. females	a	Total	a
3	500	-	245	-	745	-
4	351	0.30	124	0.49	475	0.36
5	123	0.65	53	0.57	176	0.63
6	33	0.73	12	0.77	45	0.74
7	18	0.45	10	0.17	28	0.38

Lake Archambault

Age	No. males	a	No. females	a	Total	a
4	116	-	74	-	190	-
5	73	0.37	33	0.55	106	0.44
6	53	0.27	24	0.27	77	0.27
7	31	0.42	5	0.79	36	0.53

Sex ratios

From the observed differences of mortality rate between males and females in both lakes, the males always outnumber the females. This is illustrated in Figure 6 which shows the variation in the proportion of females to males at different ages for the two lakes studied. It appears that, in both lakes, the proportion of females steadily declines from the time of hatching to the age of four years, after which it stabilizes; in the two lakes, the proportion of one-year-old females is significantly smaller (approx. 38%).

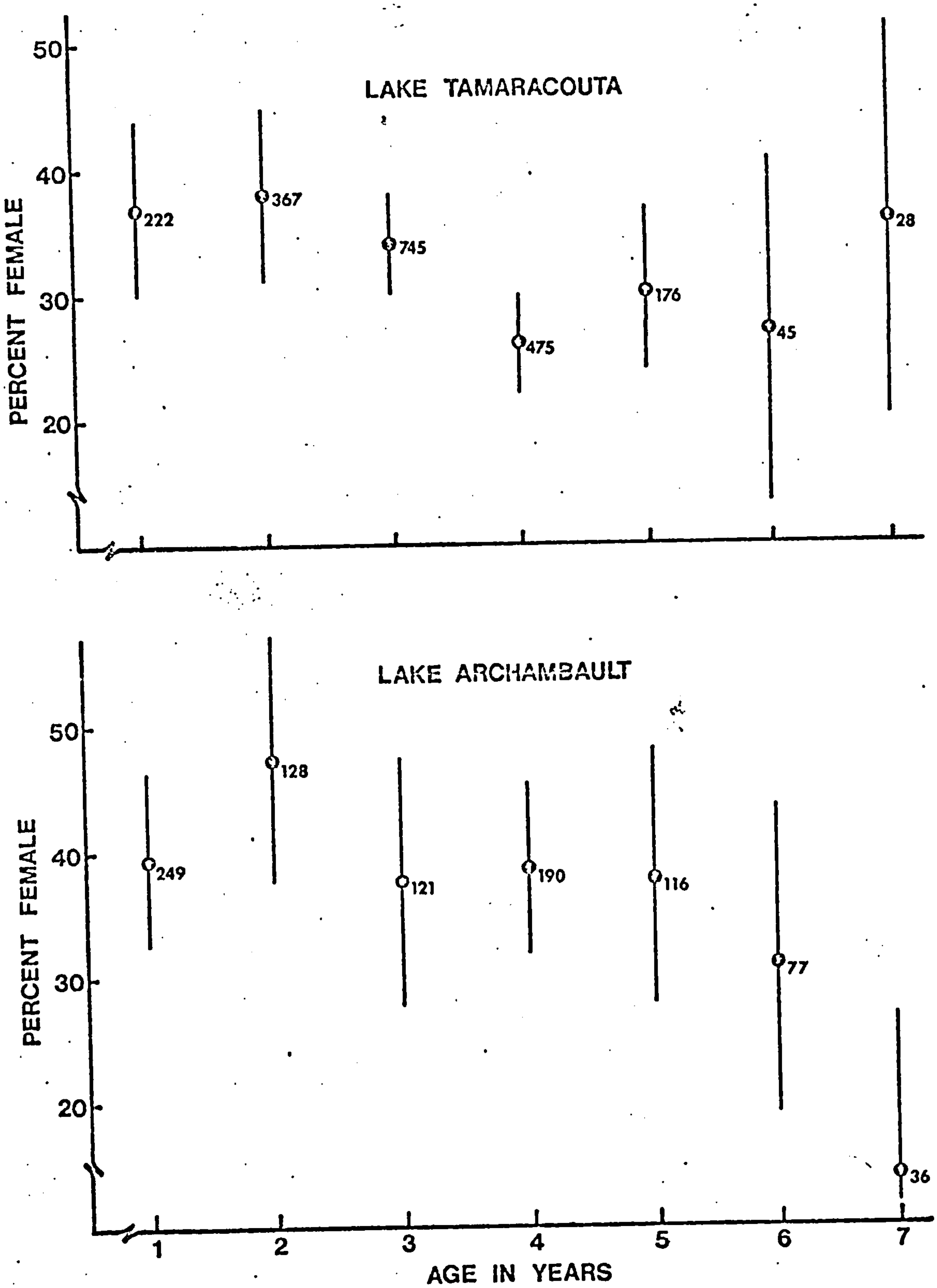

Figure 6. Proportion and 95% confidence limits of females present in each year class of yellow perch taken from Lake Tamaracouta and Lake Archambault. The numbers to the right of each point represent the sample sizes.

Seasonal variation of body fat

Statistical treatment of the data.

The results of the measurements of body fat content were grouped according to the sexual maturity of the fish from which the determinations were made. Fish of two years old and younger (year beginning June 1) were grouped as immature while those older than two were grouped as mature; both groups were equally divided into subgroups consisting of intact fish and fish with gonads removed. When more than one sample of fish were taken in the same month, the results of the fat determinations were pooled regardless of the year of capture. The date ascribed to the pooled observations was determined by weighting each sample date by the number of fish captured on that date and dividing the weighted monthly sum by the size of the actual total monthly catch. Thus, for example, samples taken on February 2, and February 19, 1969 were pooled and recorded as February 10. The sample taken from Lake Tamaracouta on May 30, 1968 was not pooled with other samples taken in the same month because the spawning period is generally completed by that date and fish taken at this time could be used to estimate the amount of body fat remaining at the termination of spawning activity.

The mean percent body fat for each month was arrived at by dividing the weighted sum of the individual sample measurements by the total number of fish in the group.

An estimate of the variance, $\hat{s}^2$, was obtained from the following equation (McLaughlin, personal communication)

$$\hat{s}^2 = \frac{\Sigma n_i (X_i - \overline{X})^2}{N - 1}$$

where, n_i is the number of fish in the sample from which an extraction of fat was made, X_i the percent fat measured, $\overline{X}$ the weighted mean of the pooled samples and N the number of sample extraction measurements pooled. The estimated variance was used to calculate the 95 percent confidence limits of the weighted mean percent fat for each recorded date.

Fat content in immature and mature fish.

The results of the measurements of fat content in immature and mature yellow perch are presented in Tables 4 and 5 respectively, giving the mean percent fat and the 95 percent confidence limits.

Before considering the seasonal changes of body fat content it was important to determine the difference, if any, among the various groups of fish taken at the same date. For this, t-tests at the 95 percent level of

Table 4. Mean percent fat and 95% confidence intervals at each mean date of samples of immature male and female yellow perch, with and without gonads.

	MALES								FEMALES							
	TESTIS INTACT				TESTIS REMOVED				OVARY INTACT				OVARY REMOVED			
Mean Date	No. Fish	No. Values	Mean %Fat	95% Confidence Interval	No. Fish	No. Values	Mean %Fat	95% Confidence Interval	No. Fish	No. Values	Mean %Fat	95% Confidence Interval	No. Fish	No. Values	Mean %Fat	95% Confidence Interval
Lake Tamaracouta																
Feb. 10	3	1	5.27	-	2	1	3.86	-	2	1	7.31	-	2	1	6.78	-
Mar. 20	-	-	-	-	-	-	-	-	3	1	7.28	-	4	1	5.13	-
May 16	13	1	4.66	-	14	1	4.31	-	7	1	5.56	-	8	2	6.13	±16.89
June 21	9	2	5.68	±16.98	9	2	4.22	±37.63	5	2	6.36	± 6.28	7	2	5.79	±12.38
July 12	50	3	13.48	± 3.39	8	1	9.45	-	45	4	11.92	± 4.72	24	2	9.72	±31.43
Aug. 14	42	5	12.89	± 4.25	13	3	7.35	± 8.39	23	5	12.86	± 3.39	7	3	9.99	± 4.31
Sep. 22	42	3	10.72	± 2.81	39	2	9.50	±17.10	32	3	10.28	± 7.19	30	2	10.24	±29.61
Lake Archambault																
June 8	36	3	6.21	± 2.03	36	3	5.85	± 3.68	24	3	6.68	± 4.42	8	3	6.57	± 7.54
July 16	46	4	11.66	± 2.04	12	3	10.10	± 8.27	34	4	11.81	± 4.20	10	3	8.01	± 5.92
Sep. 10	24	2	18.39	± 0.54	24	2	18.19	±20.13	18	2	17.05	±21.80	19	2	14.62	±37.21
Oct. 13	12	2	10.48	±28.90	14	2	10.16	±25.39	8	2	10.33	±18.03	9	2	10.12	± 5.36

Table 5. Mean percent fat and 95% confidence intervals at each mean date of samples of mature male and female yellow perch, with and without gonads.

	MALES								FEMALES							
	TESTIS INTACT				TESTIS REMOVED				OVARY INTACT				OVARY REMOVED			
Mean Date	No. Fish	No. Values	Mean %Fat	95% Confidence Interval	No. Fish	No. Values	Mean %Fat	95% Confidence Interval	No. Fish	No. Values	Mean %Fat	95% Confidence Interval	No. Fish	No. Values	Mean %Fat	95% Confidence Interval
Lake Tamaracouta																
Feb. 10	9	5	6.31	± 3.13	13	6	4.56	± 1.01	4	3	6.27	± 4.12	2	2	1.98	± 7.88
Mar. 20	210	9	6.14	± 0.95	214	10	5.70	± 0.67	50	7	5.35	± 1.15	53	7	2.94	± 0.92
May 16	96	11	5.67	± 0.57	98	10	5.27	± 0.81	36	9	4.92	± 0.95	38	9	3.09	± 0.79
May 30	4	2	3.39	± 9.90	5	3	3.01	± 1.89	4	2	4.31	±15.23	4	2	2.82	± 2.20
June 21	6	2	2.55	± 0.73	7	3	2.41	± 5.60	9	3	5.55	± 4.01	9	3	3.79	± 3.53
July 12	47	5	6.83	± 1.57	50	5	6.39	± 0.76	22	5	5.20	± 2.04	23	5	5.23	± 2.30
Aug. 14	40	5	7.97	± 2.79	50	9	6.17	± 1.40	12	5	5.19	± 1.98	13	6	5.36	± 0.72
Sep. 22	11	2	5.90	± 1.21	12	3	5.97	± 5.53	6	1	7.05	-	7	2	4.74	± 4.48
Lake Archambault																
May 16	28	7	3.51	± 1.77	32	7	2.69	± 0.94	16	6	4.83	± 1.80	19	6	3.78	± 1.06
June 8	16	8	2.72	± 1.22	21	10	2.61	± 0.79	8	4	2.03	± 1.30	12	6	1.76	± 0.34
July 16	42	7	3.46	± 0.87	45	7	4.32	± 0.99	14	5	2.70	± 0.77	17	6	3.05	± 1.40
Sep. 10	6	2	5.07	± 2.14	7	2	5.51	±19.81	5	2	4.03	± 4.72	8	3	5.34	± 6.48
Oct. 13	15	3	3.84	± 2.82	17	3	5.66	± 8.46	3	2	4.69	±34.68	3	2	6.06	±40.91

significance were performed to compare immature and mature fish, with and without gonads. The results of the t-tests indicated that in the immature and mature males, there were no differences in fat content between fish with or without testis, indicating that the testis contributes no significant amount of fat. In females a similar situation occurred except among mature fish in late winter and spring before spawning. The samples of mature females taken from Lake Tamaracouta on February 10, March 20, and May 16 (see Table 5) showed a significant difference between fish with and without ovaries.

Seasonal changes of body fat content.

Where there were no significant differences of fat content between fish with or without gonads (Table 4 and 5) each pair of mean percent fat values were pooled (weighted) and the mean value was taken to represent the fat content of the fish at the date of sampling and used to present, in Figures 7 and 8, the seasonal changes of body fat in mature and immature males and females of the two lakes.

As seen from Figure 7, the mature male and female yellow perch of Lake Tamaracouta end the winter with about 5 to 6 percent fat in their bodies. During the pre-spawning period it is apparent that although

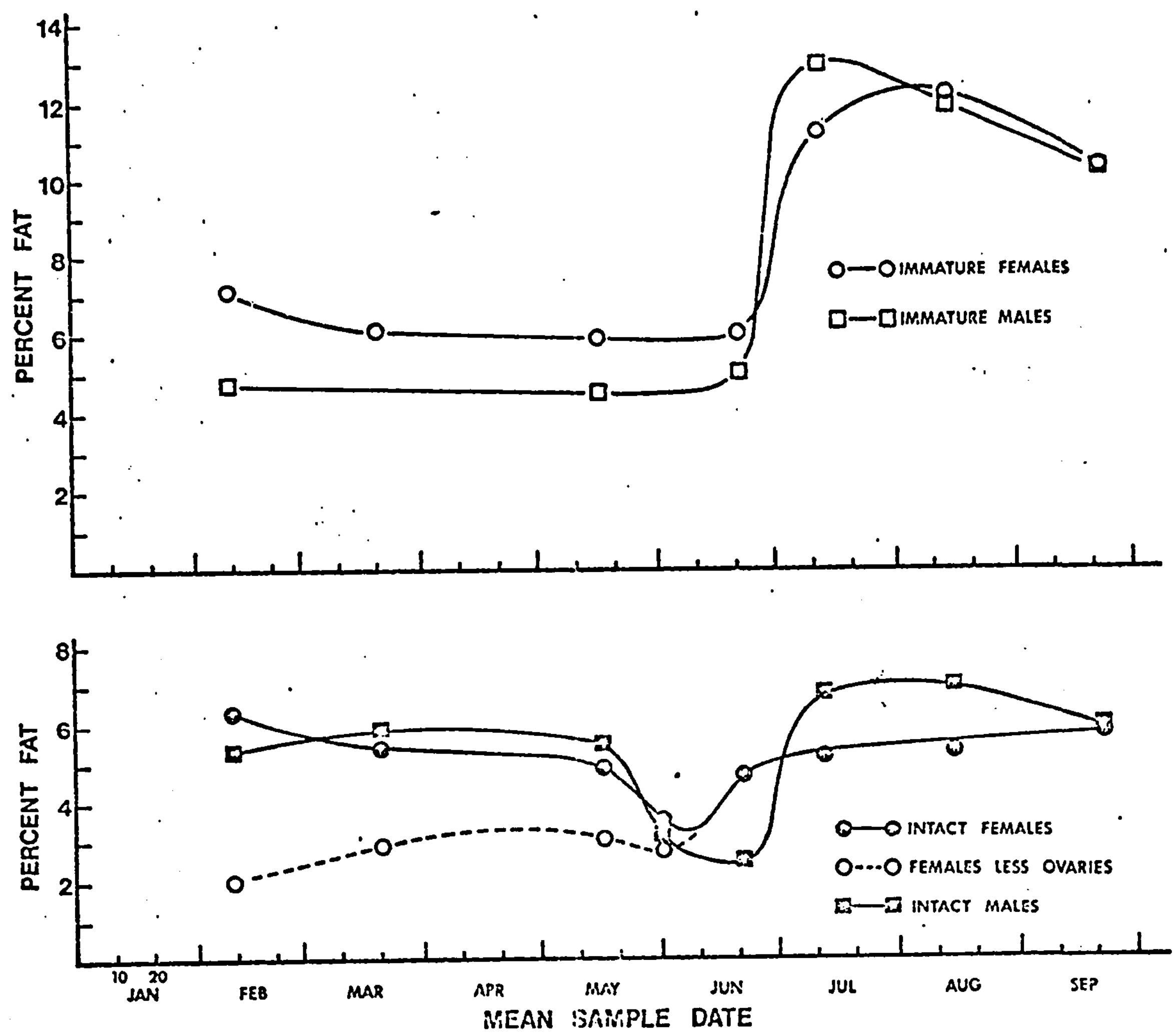

Figure 7. Seasonal variation of fat content in immature (above) and mature (below) yellow perch taken from Lake Tamaracouta between May 1968 and September 1969.

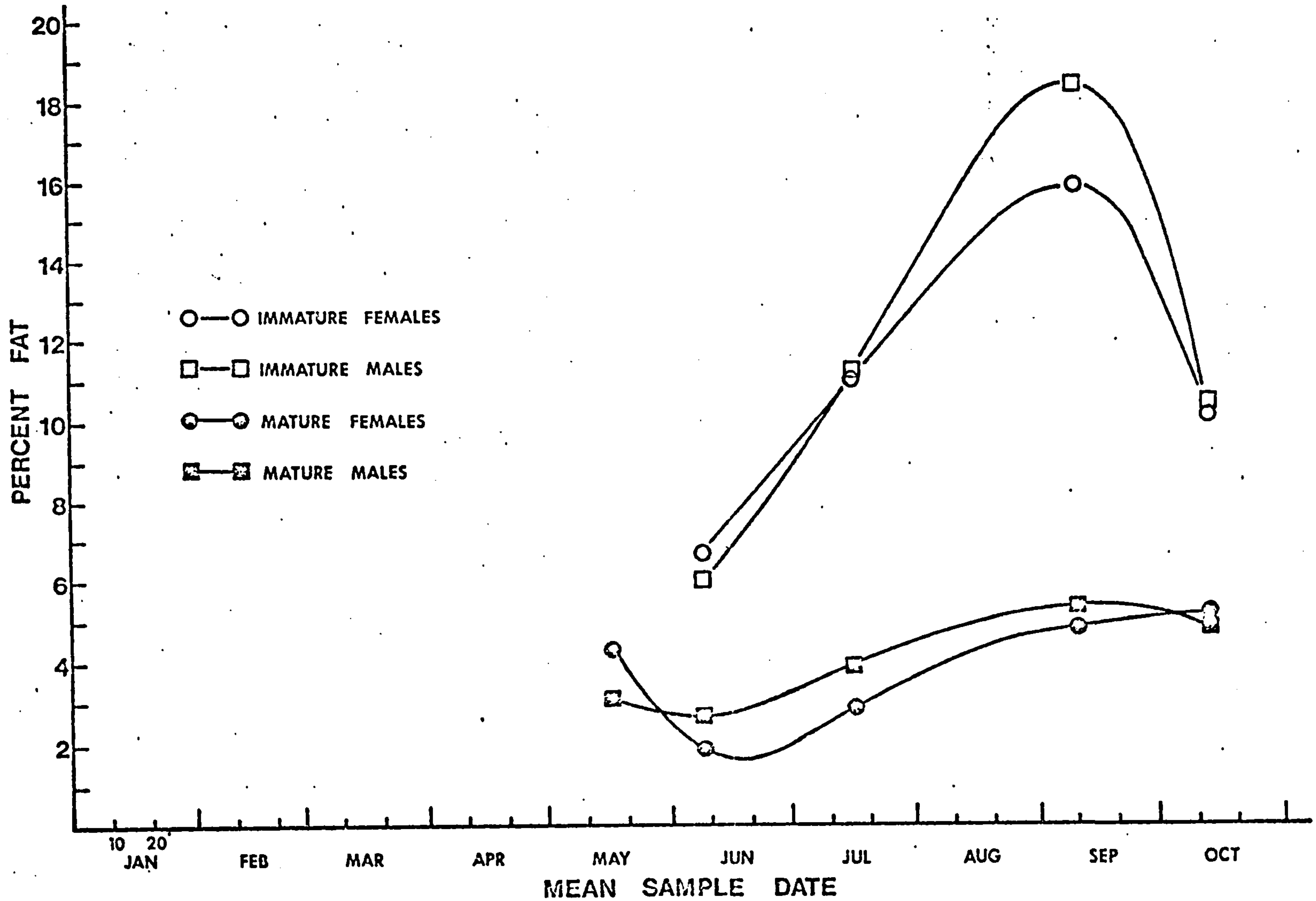

Figure 8. Seasonal variation of fat content in immature (above) and mature (below) yellow perch taken from Lake Archambault during 1968.

the total fat content is similar in males and females its distribution is different. As previously shown in Table 5, little, if any, fat is located in the testis but in the females the ovaries alone may contain 50 to 70 percent of the total fat content.

During and immediately after spawning a sharp decline of body fat occurs in both sexes, the males continuing to lose fat well into the month of June, lagging behind the mature females which by that time have almost completely replaced the fat lost at spawning. The males then rapidly rebuild their fat reserves during July and August when they reach their maximum of seven percent for the year, a level that the females may attain, if at all, only in the fall.

The fat content of immature perch of both sexes, taken from Lake Tamaracouta, are also shown in Figure 7. The level of fat in both sexes is similar to that found in mature males and females during the winter months but, compared to the mature fish, there is no apparent decline during spawning time; unfortunately, the sample of May 30, 1968 did not contain immature fish.

In late June immature fish rapidly restore their fat reserves, attaining in July a level of fat about twice as high as that found in the mature fish for the same period. The decline in fat content appears to begin around the first of August for the immature fish and mature males but mature females continue to increase their fat content well into September.

In Lake Archambault, although no sample could be obtained before spawning, the results of the fat determinations at different times of the year, as shown in Figure 8, do not differ significantly from those obtained from immature and mature fish of Lake Tamaracouta. However, the delayed fat recovery observed in the mature males of Lake Tamaracouta does not occur and mature female perch of Lake Archambault have a lower fat content than the mature males after spawning; the rate of recovery is also slower for both sexes compared to that observed for fish taken from Lake Tamaracouta.

Immature perch of Lake Archambault restore their fat reserves at a slower rate compared to those of Lake Tamaracouta, but the level eventually attained in September is much higher and declines at a greater rate in late fall.

Starvation Experiment

The starvation experiment was designed to verify, in the laboratory, the possibility of differential mortality rates between males and females and to determine the amount of fat left at the time of death. The sex and age distribution of the perch used for this experiment are shown in Table 6, and the survival time and dates of death for male and female fish are given in Table 7.

Table 6: Age and sex distribution of yellow perch used in a starvation experiment under laboratory conditions.

Age at death	No. Males	No. Females	Total
2	15	6	21
3	34	31	65
4	6	10	16
5	2	1	3
6	1	0	1
	58	48	106

Table 7: Date of mortality and survival time of male and female yellow perch following starvation under laboratory conditions.

Date	Days from start	Mortality males	Mortality females	Mortality total
Dec. 16/69	65	0	1	1
Jan. 23/70	103	0	1	1
Feb. 2/70	113	1	0	1
May 11/70	211	0	2	2
May 14/70	214	1	3	4
May 15/70	215	2	1	3
May 16/70	216	2	8	10
May 18/70	218	22	10	32
May 19/70	219	21	20	41
May 21/70	221	9	2	11
		58	48	106
Mean survival time (days		217	212	

($t = 1.09$; $0.4 > p > 0.2$)

As seen from Table 7, no significant differences could be found between the mean survival time of males and females ($0.4 > p > 0.2$), most of the mortalities in both sexes occurring within the last 10 days of the experiment. Spawning occurred in the tanks from May 16 to May 19, when a total of 16 females deposited eggs, three of which died during oviposition.

All the fish in this experiment were divided into age-sex groups and fat determinations made as previously described. The fat content in mature and immature perch of both sexes, with and without gonads, are presented in Table 8. For the immature fish of both sexes it was impossible to obtain variance estimates but approximately equal fat contents were found in males with and without testis and in females with and without ovaries.

In the mature males, with and without testis, there were no significant differences ($p > 0.9$) of fat content; similarly, no significant difference was observed between mature females, with and without ovaries ($0.4 > p > 0.2$). The values were then pooled and a comparison between the sexes again showed no significant difference ($0.2 > p > 0.1$). Similarly no significant difference was found between immature and mature perch ($0.4 > p > 0.2$) and the results of the entire sample were pooled which gave a mean percent fat and 95% confidence interval, per dry weight of tissue of 2.10% $\pm$ 0.079.

Table 8. Mean percent fat, and 95% confidence intervals, in immature and mature male and female yellow perch at time of death due to starvation under laboratory conditions.

	MALES								FEMALES							
	TESTIS INTACT				TESTIS REMOVED				OVARY INTACT				OVARY REMOVED			
	No. Fish	No. Values	Mean %Fat	95% Confidence Interval	No. Fish	No. Values	Mean %Fat	95% Confidence Interval	No. Fish	No. Values	Mean %Fat	95% Confidence Interval	No. Fish	No. Values	Mean %Fat	95% Confidence Interval
Immature Perch	7	1	2.12	-	8	1	2.17	-	3	1	2.16	-	3	1	2.14	-
Mature Perch	21	3	2.02	±0.615	22	4	2.03	±0.269	20	2	2.11	±0.660	22	3	2.19	±0.277

DISCUSSION

The yellow perch is of primary interest to the sport fishery in many regions of the Province of Quebec and also supports some commercial fishing. However, their introduction to a number of Laurentian lakes has caused a serious decline in the more valuable trout sport fishery and recent investigations of a few of these lakes have shown large populations of stunted yellow perch with a marked predominance of males. There is a great need for research into the biology of the yellow perch in this region, leading to the development of managerial practices which may bring the problem under control.

The present investigation confirmed the previous observations of stunting and the marked predominance of the males and gives some explanation of the selective mortality of females through a comparative study of the seasonal variation of body fat content in males and females.

Even in their native, shallow, eutrophic waters, the yellow perch tends to overpopulate. This well documented situation is often accompanied by poor growth (Herman *et al.*, 1964) and studies of stunted yellow perch populations have generally shown a relatively normal growth rate for the first two years followed by a noticeable drop (Eschmeyer, 1937; Deedler, 1951; Grimaldi, 1967). Under most favourable conditions, the growth rate of perch usually declines after the second or third year of life probably due to the attainment of sexual maturity since a considerable amount of food energy is diverted to reproductive functions. Another cause, probably acting simultaneously and which has been observed by a number of investigators, is a change of diet from small to larger prey (Allen, 1935; Moffett and Hunt, 1945; Deedler, 1951; Pycha and Smith, 1955; Maloney and Johnson, 1957; Tharratt, 1959). Young perch feed heavily on zooplankton and small aquatic insect larvae; with increasing age, perch change their diet preying more heavily on larger insect larvae and fish. The availability of these larger organisms, especially fish, may seriously limit the growth of the older perch. This is supported in a recent study by Warnick (1966) who showed, in two lakes of North Dakota, an increased growth rate of yellow perch following the introduction of fathead minnows as a prey fish.

In the present investigation there were no studies of food habits but cursory qualitative observations in both lakes suggest a fairly abundant supply of planktonic crustacea, notably cladocerans and copepods, but a limited supply of aquatic insects and small fish probably due to the oligotrophic nature of the two lakes.

The yellow perch appears to grow better in Lake Archambault than in Lake Tamaracouta (see Figure 4) and this may be attributed to the different morphologies of the two lakes. The area of Lake Archambault (see Figure 3) is about 15 times that of Lake Tamaracouta, has three major tributaries and offers a number of large shallow bays which are more suitable as feeding grounds for perch than a deep trough-like lake such as Lake Tamaracouta (see Figure 2).

Researchers in North America and Europe have shown that, in general, the female perch outlive and outnumber the males (Beckman, 1946; Worthington, 1950; McCormack, 1965; Breder and Rosen, 1966; Grimaldi, 1967). However, recent investigations of a few populations in Laurentian mountain lakes where yellow perch have been introduced indicated a strong predominance of males, especially in year classes older than three years (Grimaldi, 1967; Knap, 1967; Bergeron *et al.*, 1968). The results of the present study agree with their findings and show that even among the first year class, males are more abundant than females, which make up only 40 percent of the one-year-old fish (see Figure 6). The two lakes studied are widely different and the populations of yellow perch are not directly comparable. Nevertheless, if the samples taken from Lake Tamaracouta and Lake Archambault are pooled and the proportion of females in both lakes is plotted against age (see Figure 9), a clearer picture of the change in sex ratio with time among mountain lakes yellow perch populations may be obtained. Assuming a 1:1 sex ratio at hatching Figure 9 suggests two periods of higher mortality of females; one during the first year of life and the second between the ages of two and four. Beyond the fourth year, the abundance of females appears to remain relatively constant at approximately 30 percent. This would explain the predominance of males (70% of the catch) reported by Grimaldi (1967), Knap (1967), and Bergeron et al. (1968), since their samples contained few specimens younger than three years old primarily due to gear selectivity although Knap collected dead fish floating on the surface or in shallow water following the treatment of the lake in September with sodium cyanide for reclamation purposes; it is interesting to note that despite the non-selectivity of this collecting method, no young-of-the-year and very few one-year-old fish were found, suggesting that very young fish were concentrated in the center of the lake where they sank in the deep water after death.

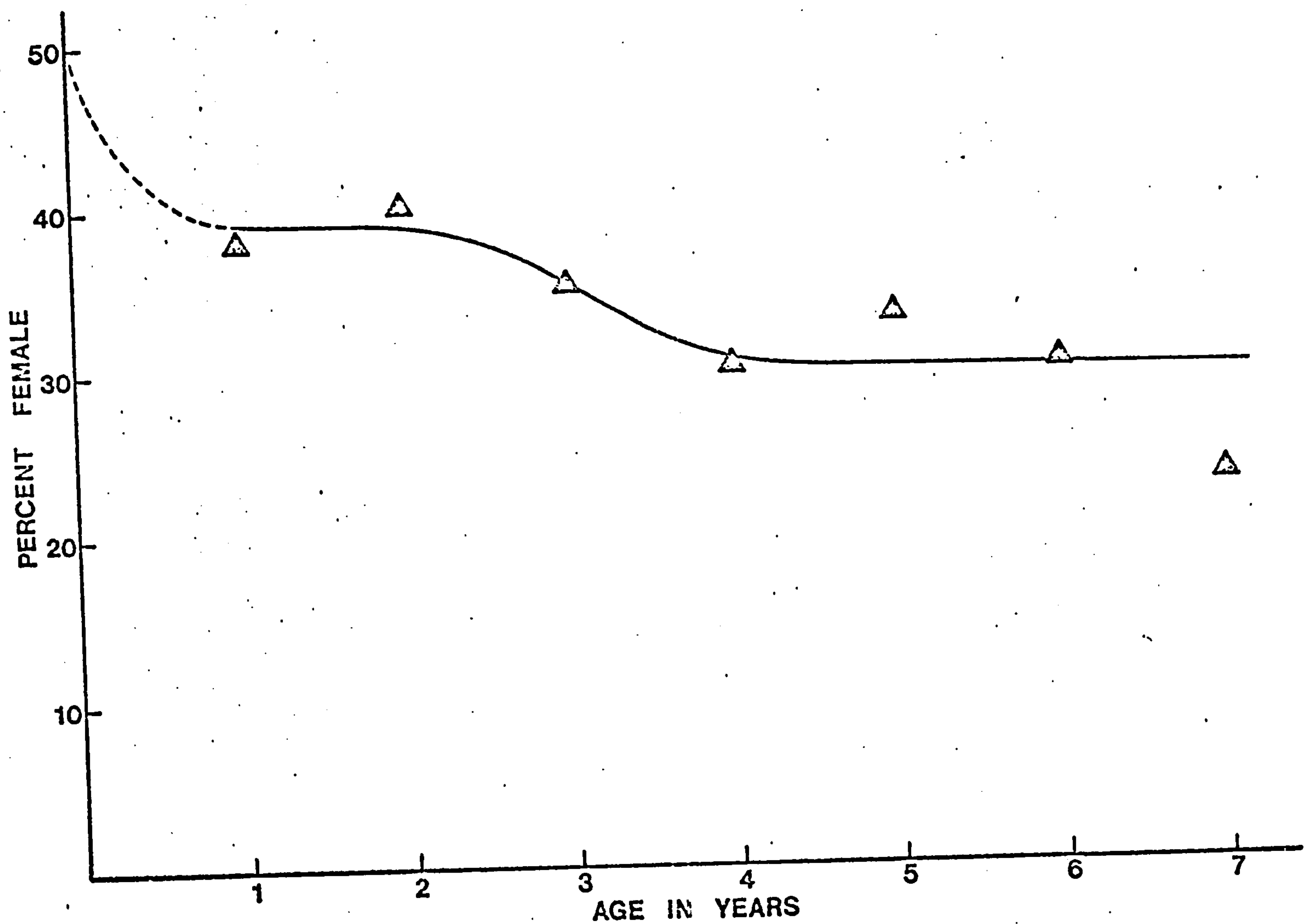

Figure 9. Proportion of females in each year class in the pooled samples of yellow perch taken from Lake Tamaracouta and Lake Archambault in 1968 and 1969.

The higher mortality rate of females of two to four years old (see Figure 9) coincides with the attainment of sexual maturity (Breder and Rosen, 1966) and may be explained by food availability and the observed seasonal variation of the fat content.

The yellow perch is considered to be an active winter feeder; however, observations made on gravid females taken during the present investigation show that the mature female yellow perch are probably incapable of taking food due to the size of the ovary which completely compresses the digestive organs. The results of fat determinations conducted during this study, as shown in Figure 7, indicate that most of the total body fat of mature female yellow perch is concentrated in the ovary for at least four months prior to spawning and is unavailable as a source of energy for maintenance purposes. The remaining two to three percent total body fat per dry weight of tissues outside the ovary (Figure 7) is probably the only major source of energy during the winter period.

The results of the starvation experiment, however, indicate that the "constant element" (Hoar, 1966) of fat for perch is approximately 2.2 percent of the total dry weight of the fish and if the fat content falls below this level death ensues. From Figure 7 it can be seen that in

February the amount of fat available to the mature females, excluding the fat present in the ovary, falls below this critical level. The observed rise of fat content in mature females less ovaries between February and May (Figure 7), may be explained by the deaths of mature females with the lowest total body fat content (ovarian fat excluded) which would result in a higher value of fat content for the population at subsequent sampling dates.

In Lake Archambault, the fat content in mature females falls below the critical 2.2 percent level in early June (Figure 8), but since samples of fish were not available prior to the spawning period it is impossible to know the exact level of fat present in mature females with ovaries removed. However, it may be expected that a similar situation exists for female perch of Lake Archambault as have been observed among the females of Lake Tamaracouta.

The mature male perch of Lake Tamaracouta approach the critical fat level (Figure 7) for a short time immediately after spawning in June but quickly recover their fat reserves and surpass the mature females in fat content by early July. A similar situation appears to occur for mature male perch of Lake Archambault but the recovery rate is slower. The reason for this cannot be explained but may be linked with differences in availability of food.

The fat content in immature male and female perch of both lakes never falls to the low levels observed among the mature fish and, during the late summer and fall, their fat content is very high, double that of the mature fish during the same period (see Figures 7 and 8).

It therefore appears that, among stunted populations of yellow perch in some Laurentian lakes, adult females may not obtain enough food to build up sufficiently large fat reserves to maintain normal body and reproductive functions throughout the winter in preparation for spring spawning.

Pearce and Achtenberg (1920) and Keast (1968) found that perch of both sexes do not feed immediately prior to and during the spawning period. This may also apply to the two populations studied here, where a sharp decline of fat content was observed during the May spawning period (see Figure 7 and 8). The females, however, rebuild their fat reserves faster than the males, especially those in Lake Tamaracouta. The spawning period usually begins in the middle of May and lasts for a month (Echo, 1955). During this time the males remain on the spawning grounds while the females arrive, depost their eggs and depart (Herman *et al.*, 1964; Breder and Rosen, 1966) presumably to resume feeding thus rapidly replacing the lost fat reserves.

Whereas the depletion of limited fat reserves appears to explain the selective mortality of mature females (see Figure 9) it does not seem to apply to one-year-old females. The lowest observed fat content in immature perch is well above those found in mature perch through the period of the year studied (see Figures 7 and 8). The obvious severe mortality suffered by young females may be explained by a difference in selection of schooling areas by young males and females.

After hatching, the young perch fry are found near the surface over deep water where they feed on zoo-plankton (Tharratt, 1959; Schumann, 1963; McCormack, 1965). As the summer progresses, the fingerlings move into the littoral zone where they feed on small aquatic insect larvae; in late summer or early fall they move back into deeper waters (Herman *et al.*, 1964). A number of authors (Eschmeyer, 1938, Weller, 1938; Jobes, 1952; Tharratt, 1959) suggest that the adult perch are segregated according to sex; the females living in the shallow water and feeding primarily on fish and the adult males in deeper water feeding on insect larvae, typically chironomids (Eschmeyer, 1938; Tharratt, 1959). The adult fish migrate daily to and from the feeding grounds (Keast and Welch, 1968); during the day the older fish seek deeper, open water above the thermocline and move to the feeding grounds in late afternoon where, after dark, they spend the night resting on the bottom. At dawn, feeding resumes and after a short time they move back to deeper waters (Hasler and Bardach, 1949).

The males generally attain sexual maturity at the end of their second year of life, one year earlier than the females (Hasler, 1945; Kennedy, 1949; Alm, 1954; Herman et al., 1964) and maturation of the testis probably begins at the end of their first year. Assuming a similar behavior of the yellow perch in Laurentian lakes as in other American waters, it may be suggested that, at the end of the first summer, young-of-the-year male perch may join the adult males leaving the young-of-the-year females in the shallow waters.

The steep rocky littoral zones of the Laurentian lakes support only sparse amounts of rooted aquatic plants which afford little cover for the young female perch and may leave them more vulnerable to predation than the young males. As well, adult female perch feed more extensively on fish than the adult males (Tharratt, 1959) and cannibalism is well known among perch (Couey, 1935). These factors may place a greater selective pressure against young females-of-the-year and possibly cause the observed decline in the sex ratio among fish of the first year class.

Excessively weedy eutrophic waters are known to favor overpopulation among yellow perch, causing various degrees of stunting (Deedler, 1951; Grimaldi, 1967); under these circumstances, the females may take advantage of the vegetation cover and always dominate the older year classes probably because the males, which inhabit deeper water, are more vulnerable to large predators such as bass, pike and walleye. In this respect, the study of Grimaldi (1967) is noteworthy. In his study of the growth of yellow perch in various bodies of water in the Province of Quebec he found that, in Lake Hertel (see Figure 1), a shallow densely weeded lake and harbouring pike, the yellow perch were stunted but females were predominant (55%). In the same study, Grimaldi found that in Lake St. Joseph (see Figure 1) a typical oligotrophic lake of the Laurentians but with smallmouth bass, the growth of the yellow perch was not stunted but comparable to that in the St. Lawrence river basin; on the other hand the females accounted for only 30 percent of the catch.

It appears from these studies of the yellow perch that stunting the growth and sex ratio are not necessarily linked together but that the nature of the lakes, in particular food supply, cover and predators, may act separately on the sex ratio. In Lake Tamaracouta and Lake Archambault the only known predator is the lake trout *Salvelinus namaycush*, but its role is probably insignificant because of their preference for deep water. On the other hand, in Lake St. Joseph predation by smallmouth bass may be more significant due to the more littoral habitat of this fish, overlapping with that of the yellow perch.

Further research on the dynamics of yellow perch populations in areas where, following its introduction, it has become an undesirable fish should concentrate on the feeding behavior of males and females at different ages and particularly on mortality in the first two years of life.

SUMMARY

Samples of yellow perch were taken at various times between May, 1968 and October, 1969 from Lake Tamaracouta, Argenteuil County, Quebec and during 1968 from Lake Archambault, Montcalm County, Quebec, using gill nets, seine and traps. The fish were aged, sexed and measured for total length and each age-sex class the samples of fish were equally divided and the gonads removed from half of the fish. The fish were dried to constant weight, finely ground and the fat content measured by ether extraction on two to six grams of dry homogenate. A group of 106 fish taken from Lake Tamaracouta in the fall of 1969 were kept unfed in the laboratory to determine the amount of fat present in the bodies of perch at time of death due to starvation.

The results of the study confirmed previous observations of stunting and of a predominance of the males among some Laurentian populations of yellow perch where males make up to 70 percent of the catch.

The age frequency distribution revealed two periods of high mortality among the females; the first occurring within the first year and the second, from the second to the fourth year.

Results of the starvation experiment showed that the critical level of fat remaining in the bodies of perch at time of death due to starvation was 2.10 $\pm$ 0.079 percent. Fat determinations conducted on samples of fish taken at various times from both lakes showed that mature females with ovaries removed approach this critical level of fat at least four months prior to spawning which may explain in the higher mortality observed among female perch between the ages of two and four.

During the winter and prior to spawning, fat content in, immature perch of both sexes, mature males and females with gonads intact ranged between four and five percent of the dry weight of the fish. By summer and early fall the amount of fat had risen to between 14 and 18 percent for immature perch and between five and eight percent for mature perch.

The higher mortality of young-of-the-year female perch may be explained by possible segregation of the sexes which may place a greater selective pressure, due to predation, against them.

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