Age, Growth, and Maturity of Round Whitefish (*Prosopium cylindraceum*) From the Leaf River, Ungava, Quebec

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Data on the age, growth, and maturity of round whitefish (*Prosopium cylindraceum*) from the Leaf River, Ungava, generally confirmed or extended observations previously reported for two other Ungava rivers. On the basis of back-calculated lengths, Leaf and Koksoak River round whitefish had similar growth rates except that the Leaf River specimens showed an atypical decrease in the second year. Scale increments in the year of the study suggested that the growing season extended from mid-June to mid-September. Both sexes matured at ages 4–6, but proportionately more females than males were mature at ages 4 and 5. Females matured at lengths between 190–199 mm and 240–249 mm while males matured at lengths 10–20 mm greater, as in the Koksoak River. Apparently, not all mature females spawned annually.

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Les données recueillies sur l'âge, la croissance, et la maturité du ménomini rond (*Prosopium cylindraceum*) de la rivière aux Feuilles, Ungava, confirment d'une façon générale ou complètent des observations faites dans deux autres rivières de l'Ungava et déjà publiées. Sur la base de rétrocalculs des longueurs, les ménominis de la rivière aux Feuilles ont le même rythme de croissance que ceux de la rivière Koksoak, sauf que les individus de la rivière aux Feuilles accusent une diminution anormale du taux de croissance dans leur deuxième année. La croissance de l'écaille durant l'année où s'est poursuivie cette étude nous porte à croire que la saison de croissance s'étend de la mi-juin à la mi-septembre. Les deux sexes atteignent la maturité sexuelle à l'âge de 4 à 6 ans, mais proportionnellement plus de femelles sont mûres à l'âge de 4 et 5 ans. Les femelles atteignent la maturité à des longueurs allant de 190–199 à 240–249 mm, alors que les mâles deviennent mûrs à des longueur de 10–20 mm plus grandes, tout comme dans la rivière Koksoak. Toutes les femelles mûres, semble-t-il, ne fraient pas annuellement.

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THE round whitefish (*Prosopium cylindraceum*) has been less intensively studied than most other North American coregonids. A report on age and growth of this species in the Koksoak and George Rivers is the only one currently available from Ungava (Mackay and Power 1968). This note on round whitefish from the Leaf River describes a more extensive study of a totally unexploited population, confirms several observations by Mackay and Power (1968), and provides additional insights into the life history of this species in Ungava. Comparisons are also made with studies conducted in the Great Lakes.

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Jessop et al. (1971) describe the river system and provide details of the fish species present.

Materials and general methods — The study is based on a total of 807 round whitefish caught in the Leaf River between June 28 and September 8, 1968. Gillnets of monofilament nylon ranging from 0.5- to 2.5-inch stretched mesh in 0.5-inch intervals were used to capture 579 of the larger specimens while fry and fingerlings were taken by beach seine (161 specimens) and rotenone (67 specimens). From five to eight nets of several mesh sizes were set from shore at various locations and allowed to fish 24 hr/day throughout the study period. Most fish of the intermediate size (approximately 15–30 cm) were caught in the 1–1½-inch mesh nets, while the ½-inch mesh nets took 9–13-cm fish and the 2–2½-inch nets caught the largest fish. The seine and rotenone methods were not as frequently employed as the gillnets, nor used in the same locations.

Fork lengths were measured to the nearest millimeter. Weights of the larger fish were determined fresh to the nearest gram, while preserved fry were weighed to the nearest 0.01 g, after damp drying. No length or weight correction factors were used for specimens measured after preservation (originally in 10% formalin, later transferred to 70% isopropyl alcohol).

Sex and state of maturity were determined by gross or microscopic examination of the gonads. Maturity was judged on Kiselevic's six category system (Nordeng 1961).

Scales for aging were removed from the left side of each fish, posterior to the base of the dorsal fin and 2–3 rows above the lateral line. They were mounted on plastic slides (Power 1964) and later examined, without further preparation, at magnifications to 80×. Scale ages were compared, when possible, with otolith age determinations (Jessop 1972).

Measurements along the anterior radius of enlarged scales (50×) were made to the nearest millimeter for back-calculation of fish length at a previous age. Seasonal growth was estimated for age-4 fish by comparing the present years growth with the calculated average increment for 10 year-classes for the fourth year of life.

Totals shown in the tables do not always agree because data on some specimens were incomplete.

Age and growth — The observed lengths overlapped markedly between most age groups, particularly ages 4+ to 8+ (Table 1). The length distribution (excluding age 0) approximates a normal curve with the mode at age 6+. No significant difference ($P = 0.05$) was found in mean length between males and females at any age. Females tended to live longer than males, and thus grow larger.

To avoid bias from the capture of fish during most of the growing season, the analysis of growth rate was based on calculated lengths at the time of annulus completion in each year. Calculations of the time of annulus completion in the study year using the regression method suggested by Backiel (Gerking 1966) indicated that annuli were completed by late June. Observation confirmed this conclusion.

A body–scale relation was determined in order to supply a "time of scale formation" correction factor for use in calculating lengths at the time of completion of each annulus. The equation was

$$Y = 1.0245X - 48.4973$$

where Y is the scale radius and X is the fork length of the fish ($n = 586$). The equation fitted the plotted empirical data well. The positive X intercept value suggests that the round whitefish were 48.5 mm in length when scales began forming. This is in agreement with observations on a number of fry indicating that scales in the area of scale sampling began forming at a length between 45 and 50 mm and were well developed at 55 mm.

The lengths (Table 2) at the end of each year were calculated for the sexes combined, as little difference according to sex was evident. The calculated lengths varied little between age-groups. Lee's phenomenon was not apparent.

Plotting of the relation between the distance from the last annulus to the scale margin and the date of collection for age-group 4+ showed that approximately 16% of the year's growth occurred by the first week of July, 67% by the end of July, and 90% by the first week of September. A pronounced reduction of the growth rate occurred in early August. Similar growth patterns were evident in the scales and otoliths (Jessop 1972) of four other age-groups.

The growth rate decreased progressively with increasing age except after the 10th year and in the second year, when the annual increment was the lowest of the first five years (Table 2).

At a given age, the growth increment varied moderately from year to year. For example, at age 3, the mean was 43.0 mm with a range from 38.7 mm for the 1963 year-class to 49.5 mm for the 1964 year-class. In certain years, the growth made by all ages of round whitefish tended to be consistently high or low.

The calculated growth rates of round whitefish from the Leaf River are similar to those for the Koksoak River, but the Ungava growth rates are much less than those of the Great Lakes fish between ages 0 and 4 and only become similar from age 5 onward (Fig. 1). Since the more northern populations appear to live longer, they ultimately approach the size of their southern counterparts. Round whitefish from the Leaf River and Koksoak River require 4 years to reach about 183 mm and 170 mm, respectively; those from Lake Superior attain the same length in 2 years (Bailey 1963) and those from Lake Michigan in less than 1 year (Mraz 1964).

The length–weight relation was described by the parabola $W = al^n$, where W is weight in grams, l is length in millimeters, and a and n are empirically determined constants. The logarithmic form of the equation was

$$\log W = -4.70466 + 3.2904 \log L.$$

Comparison of the calculated and observed weights reveals that the equation fits the data well except at the higher length intervals where there are few fish samples.

Length–weight data for round whitefish fry (age 0+) were fitted to an equation of the form

$$\log W = -2.23874 + 3.0336 \log L.$$

TABLE 1. Observed length frequencies by age-groups of 807 round whitefish (*Prosopium cylindraceum*) from the Leaf River, 1968.

Fork length (*mm*)	Age-group															
	0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	Total
20–29	4															4
30–39	85															85
40–49	107															107
50–59	8															8
60–69	1															1
70–79		1														1
80–89		1														1
90–99		6														6
100–109		1	2													3
110–119			10													10
120–129			3													3
130–139			7													7
140–149			11													11
150–159			8	1												9
160–169			–	1												1
170–179			1	7												8
180–189				21	4											25
190–199				21	19	1										41
200–209				6	36	1										43
210–219					24	8										32
220–229					12	13										25
230–239					7	19	4									30
240–249					2	21	13									36
250–259					1	13	28	5								47
260–269					1	5	27	14	1							48
270–279						1	45	23	2							71
280–289						–	24	21	4							49
290–299						–	3	17	8	3						31
300–309						1	2	6	11	2						22
310–319								2	7	–		1				10
320–329								–	4	1	3	2				10
330–339								1	1	–	–	1	2			5
340–349										1	1	1	2	3		8
350–359											1	–		1	1	3
360–369												1		2	1	4
370–379															1	1
380–389															–	0
390–399															1	1
Total	205	9	42	57	106	83	146	89	38	7	5	6	4	6	4	807
%	25.4	1.1	5.2	7.0	13.1	10.2	18.0	11.0	4.7	0.8	0.6	0.7	0.4	0.7	0.4	100.0
Mean length	40.0	93.0	135.0	187.8	209.9	238.9	268.5	281.3	301.3	311.0	333.6	335.7	341.5	354.3	373.5	253.7
95% C.I.[a]	39.3–40.7	87.7–98.3	129.5–140.5	185.1–190.5	207.2–212.6	233.2–244.6	266.1–270.9	278.0–284.6	296.2–306.4	293.6–328.4	317.3–349.9	317.8–355.6	333.3–349.7	345.5–363.1	350.3–396.7	

[a]Confidence interval.

TABLE 2. Mean calculated fork lengths (*mm*) of 586 round whitefish at end of each year of life (sexes combined), Leaf River, 1968.

Age-group	No. fish	Mean length at capture	Year													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	11	92.5	70.2													
2	46	140.0	73.6	104.4												
3	57	188.2	70.2	109.4	155.5											
4	106	209.9	70.2	98.0	147.6	187.1										
5	80	239.5	69.8	98.5	137.2	181.0	217.6									
6	142	267.8	69.2	99.8	141.3	179.1	220.3	250.8								
7	85	281.7	69.1	103.0	143.8	183.4	216.5	248.7	270.0							
8	36	301.8	70.2	100.6	143.8	185.9	219.0	247.6	272.0	289.6						
9	8	312.3	70.3	96.7	140.9	183.7	223.1	249.6	269.2	286.7	299.7					
10	4	336.8	68.0	98.1	141.8	185.8	228.0	259.3	282.0	300.2	318.3	329.9				
11	6	335.7	70.6	100.6	142.9	179.7	223.1	255.1	278.8	296.7	310.8	321.6	331.3			
12	2	340.5	72.3	97.7	143.8	183.1	219.1	253.2	274.8	292.5	306.9	318.9	329.0	338.1		
13	6	354.3	73.9	108.4	149.3	184.8	216.8	250.0	269.6	290.3	308.1	319.8	330.9	342.1	349.9	
14	4	373.5	70.8	105.4	147.1	180.7	218.3	253.0	279.8	297.0	314.7	331.4	341.9	351.4	354.6	369.4
Mean length			70.0	101.2	144.1	182.7	218.8	250.0	271.4	291.1	308.6	324.1	333.3	344.5	354.6	369.4
Annual increment			70.0	31.1	43.0	38.5	36.2	31.2	21.4	19.7	17.4	15.6	9.1	11.2	10.1	14.7

At about 36 mm in length, the fry appear to accelerate their rate of increase in weight relative to length.

No significant difference ($P = 0.05$) was noted between the sexes in weight at a given length where an adequate sample was available. Females age 6 and older tended to weigh more than males, but only at age 6 was the difference significant ($P = 0.05$).

Age and length at maturity and sex ratio — The youngest mature round whitefish of either sex were in their fourth year of life, and all were mature by age 6, with the exception of one male fish at age 7 (Fig. 2). Within an age-group, there were generally

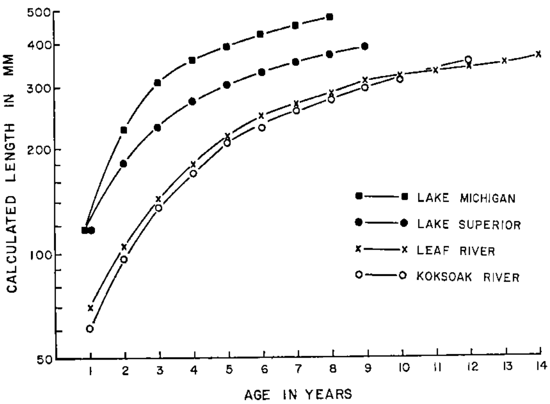

FIG. 1. Calculated lengths at different ages of round whitefish (*Prosopium cylindraceum*) from Ungava and the Great Lakes.

similar percentages of mature and immature fish of both sexes, although at ages 4–5 the proportion of mature fish increased more rapidly for females than for males. The shortest mature males were between 210 and 219 mm, and all were mature at 250–259 mm (with one exception); for females the corresponding lengths were 190–199 mm and 240–249 mm, respectively.

Of the 593 specimens for which sex was determined, 40.6% were males. Females outnumbered males in all age-groups where the sample size was large. Males were only slightly less frequent than females up to age 4 but, as the age increased, so did the proportion of females. Of 32 fish age 9 and older, 23 were females.

Spawning frequency — Of 147 mature females, 84.3% were ripening spawners. Of the 26 nonspawners, seven appeared to have undergone some development, then regressed. Spawning is apparently not an annual event for all mature fish.

Discussion — The results of this study generally support or extend the conclusions reached by Mackay and Power (1968) concerning round whitefish from Ungava. Ungava round whitefish have a slower growth rate, are older at maturity, and attain a smaller maximum size and weight than do Great Lakes populations. However, the separation of environmental effects on their life history attributable to latitudinal differences and river versus lake habitats is not presently possible.

The extensive overlap in empirical lengths between age-groups appears typical for the species wherever it is found (Bailey 1963; Mraz 1964; Mackay and

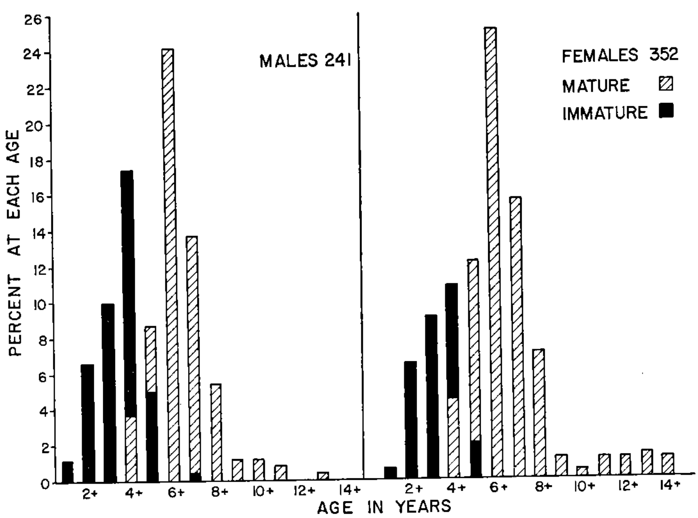

FIG. 2. Age distribution of mature and immature round whitefish, by sex.

Power 1968). The normal distribution of the catch curve for length for this unexploited northern population is in agreement with Johnson's (1972) hypothesis that such population structures are characteristic of northern regions and may be likened to a forest climax condition.

The time of annulus completion is interesting in that, if the period of annulus formation was 3–4 weeks (Hogman 1968) or less, then the initiation of annulus growth closely coincided with the time of ice breakup in the river and subsequent rising water temperature.

The body–scale intercept values for Leaf River round whitefish is greater than those calculated by Bailey (1963) and Mackay and Power (1968), which are similar. It might be expected that the intercept values for Ungava populations would agree more closely between themselves than with the Great Lakes value. A relatively small sample size, with a restricted range of fish lengths such as used by Mackay and Power (1968), might make it difficult to obtain a realistic body-scale equation. Alternatively, the two Ungava populations may actually have dissimilar lengths at the beginning of scale formation.

Assuming that scale growth reflects body growth (Van Oosten 1929), the growing season for round whitefish in the Leaf River is estimated to extend from about mid-June to about mid-September, with the greatest growth occurring in July. Bailey (1963) suggests that the growing season for round whitefish in Lake Superior is at least from the beginning of June to late October.

Leaf and Koksoak River round whitefish decrease in growth rate with age as do more southern populations (Mackay and Power 1968; Bailey 1963; Mraz 1964), but only the Ungava populations showed the atypical decrease in second year growth. This decrease was present in less marked form in the Koksoak River populations, but Mackay and Power (1968) make no note of it. Nebish Lake rock bass (*Ambloplites rupestris*) also showed a second year decrease in growth increment (Hile 1941), but no explanation was offered.

The sexes matured at similar ages in the Leaf River, while Koksoak River females reportedly matured a year earlier than males although this result may be in error (Mackay and Power 1968). All females of both populations were mature at the same age and, also, matured at a smaller size than did males. Why Ungava females mature before or at the same age as males is uncertain; usually males mature before females, as they do in the Great Lakes (Bailey 1963; Mraz 1964). The relation between maturity, size, and age are similar for Leaf and Koksoak River populations and, while the age at maturity is higher for Ungava populations, they reach maturity at a size similar to that of the Lake Superior populations.

The sex ratios of Leaf and Koksoak River fish are identical (41% male). Females outnumber males in virtually every age-group, which is quite unlike the Great Lakes situation.

The reason for late summer gonadal regression in some mature, ripening females is unknown, but it is common for northern freshwater fish not to spawn annually (Kennedy 1953; Vladykov 1956).

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