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Recent changes in the population of juvenile Atlantic salmon in the Matamek River, Quebec, Canada[1]

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Investigations have been conducted on Atlantic salmon in the Matamek River since 1967. Numbers of juveniles have decreased in recent years and their growth has increased. Two year old smolt were not found in 1967, but in 1976 made up 20% of the run. The majority continue to migrate at three years old. The ratio of male to female smolt in 1967 was about 1:1, but in 1976 was about 1:3. The proportion of precocious male parr appears to have increased. The habitat has remained unchanged, and the fish are unexploited except for controlled scientific sampling. The changes are probably due to a reduced egg deposition. The ratio of two-sea-year salmon: grilse has decreased from 1:1·1 to 1:4·5 and the number of two-sea-year salmon appears to have decreased.

Introduction

Ecological studies have been conducted on Atlantic salmon (*Salmo salar*) in the Matamek River by several investigators since 1967. These studies were undertaken to gain an understanding of the production of salmon rivers in this northern environment and to study the ecological relationships of salmon parr, the juvenile freshwater stage. The adult salmon run consists of one-sea-year (grilse) and two-sea-year (salmon) fish, which enter from the sea from late June to mid-August. The smolt (the stage at which juveniles leave the river for the sea) migrate mainly in June, the majority being three years old (Schiefer, 1969). The area was glaciated up to about 9500 years ago, and the river system has since been invaded by only a small number of euryhaline fish species (Power, Pope and Coad, 1973). The dominant species in the lower reaches of the river are brook trout (*Salvelinus fontinalis*) and Atlantic salmon. This paper describes some of the changes found in the salmon population in recent years.

The study areas

The Matamek River is on the north shore of the Gulf of St. Lawrence, at approximately 50°18′N 65°57′W. The river basin has an area of 684 km^2 overlying Precambrian rock. The vegetation is typical of the boreal forest. The lower river drains a lake of 1620 ha and is 9·6 km long. It has five waterfalls along its course. The fourth from the sea is a barrier to further migration of salmon. This is at the 82 m contour, and presents a nearly vertical drop of 5 m high. The study areas below each falls have areas of rapid water, generally considered to be good parr habitat. The five falls are respectively 0·7 km, 2·4 km, 4·4 km, 5·9 km and 6·7 km from the sea.

Material and methods

Collections of juvenile salmon have been made over several years in many locations, but here data from collections below the second, third and fourth falls are compared. Juvenile salmon were caught by seine net, fyke net, and by angling with small flies. Electro-fishing is unsuccessful in this area as the water is poor in electrolytes. Before 1975 adult salmon were caught by angling, seine net, and trap net below the first falls (Schiefer, 1971). In 1975 adult salmon were obtained at a fish ladder at the first falls. This was built to facilitate trapping and sampling the salmon, which tend to take the easier route. All fish caught here were measured for length, tagged, and released.

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A further sample was taken in a trap net above the second falls.

All fish were measured fresh. Population estimates of parr were made by the Schnabel mark and recapture method in July and August, and estimates of smolt and adult salmon by Petersen's method (e.g., Ricker, 1975). The parr were anaesthetized with MS 222, measured and fin clipped. Year classes were identified by scale reading. Salmon parr wander little, so their populations could be estimated over the relatively small study areas (Gibson, 1973a). Below the second falls the study area was 1·2 ha in 1971, and 0·73 ha in succeeding years. Below the third falls it measured 1·76 ha, and 0·47 ha below the fourth falls. A population estimate was made of the smolt by tagging a number at the second and third falls and sampling the run in the estuary. Smolt were sampled in the estuary through the run for age, sex, and size. Samples of parr for comparative growth studies were taken in August, when growth was minimal. The main growth period is in June (Schiefer, 1969; Gibson, 1973b). Also by August precocious male parr are easily identified by their well developed testes.

Results

There has been an increase in size of the parr since 1970 (Figs 1 and 2). At the second falls (Table 1) 1+ parr were significantly bigger ($P < 0{\cdot}01$) in 1976 than in 1967, and all 2+ parr from 1971 to 1976 were significantly larger than those in 1967 ($P < 0{\cdot}01$ for 1971, 1974 and 1976, and $P < 0{\cdot}05$ for 1973). At the fourth falls (Table 2) there was no significant difference in size of the respective age groups from 1967 to 1970 ($P < 0{\cdot}05$), but in 1975 salmon parr were significantly larger than in the other years ($P < 0{\cdot}01$ for 0+, except $> 0{\cdot}05$ compared with 1970; $P < 0{\cdot}05$ for 1+ and $< 0{\cdot}01$ for 2+). Older age groups showed no significant difference between years, probably due to the small sample sizes. For the missing years in the tables there are no available data.

The parr at the fourth indicated greater growth than at the second falls in 1967, but this was not statistically significant ($P > 0{\cdot}05$). However, in 1975 there was a significant difference between the areas for both 1+ ($P < 0{\cdot}05$) and 2+ parr ($P < 0{\cdot}01$). There was no significant difference between 0+ or between 3+. The sample size of the 3+ was very small (three each at the fourth and second falls).

The numbers of salmon parr below the second falls have decreased at least since 1973 (Table 3), from about 2300/ha, to about 370/ha in 1976. The population in 1971 appeared to be rather low, about 800/ha, but actually was relatively higher than this, as that year the estimate included deep areas of slow water which had few parr. Another indication of fewer parr in 1976 is that angling in the month of

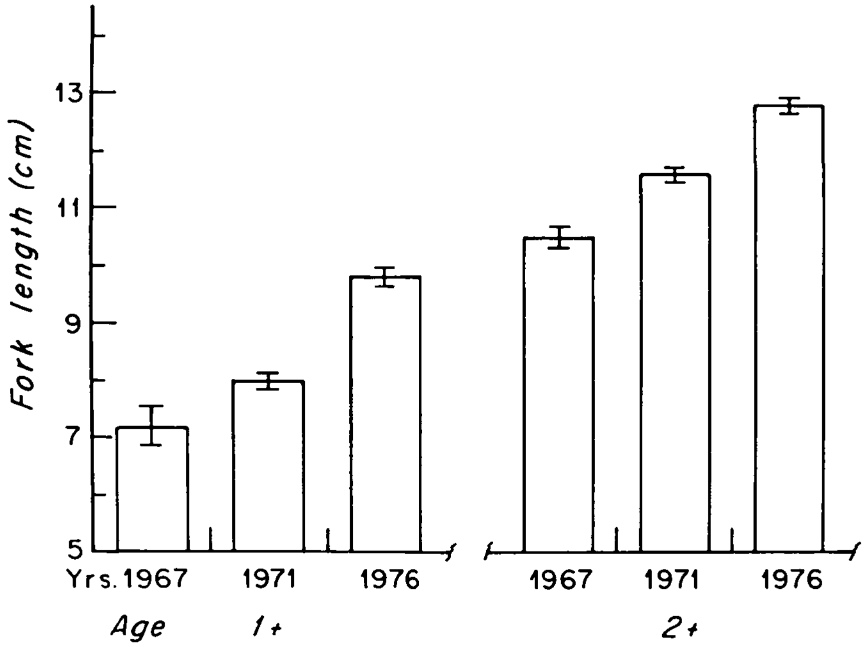

Figure 1. Matamek River: the mean size of salmon parr at the second falls sampled in August of 1967, 1971, and 1976. Each column represents the mean ± S.E.

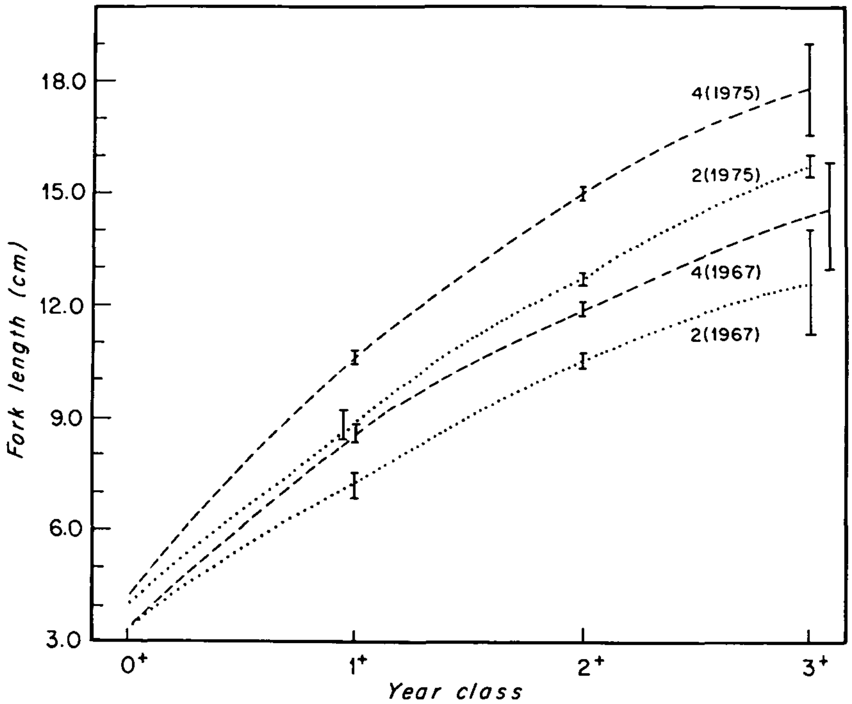

Figure 2. Matamek River: the change in growth of salmon parr at the second falls 2, and fourth falls 4 between 1967 and 1975. Each bar represents a S.E. either side of the mean.

Table 1. The mean sizes of juvenile salmon (fork length in cm, weight in g) from below the second falls in years measured since 1967, sampled in August. The standard error of the mean is given in parantheses. Data in 1967 from Schiefer (1971)

Age		1967	1971	1973	1974	1975	1976
0+	*FL*	3·5 (0·94)	3·9 (0·08)	4·3 (0·18)	4·3 (0·10)	4·0 (0·05)	4·4 (0·06)
	W	–	–	0·7 (0·11)	–	–	–
1+	*FL*	7·2 (0·34)	8·0 (0·10)	7·6 (0·18)	7·6 (0·13)	8·8 (0·45)	9·8 (0·18)
	W	4·5 (0·09)	5·6 (0·11)	4·7 (0·35)	4·8 (0·26)	7·5 (1·16)	10·5 (0·51)
2+	*FL*	10·5 (0·16)	11·6 (0·10)	11·5 (0·21)	11·8 (0·22)	12·7 (0·17)	12·8 (0·14)
	W	12·9 (0·16)	16·4 (0·45)	15·5 (0·49)	17·2 (0·92)	22·0 (0·82)	23·5 (0·78)
3+	*FL*	12·6 (1·40)	15·8 (0·27)	–	–	14·9 (0·41)	15·7 (0·30)
	W	21·5 (1·15)	49·1 (2·70)	–	–	40·7 (2·48)	48·8 (3·33)

Table 2. The mean sizes (fork length in cm, weight in g) of juvenile salmon from below the fourth falls in years measured since 1967, sampled in August. The standard error of the mean is given in parentheses. Data from 1967–1970 are from Schiefer (1971)

Age		1967	1968	1969	1970	1975
0+	*FL*	3·5	3·6	3·2	3·7	4·1
		(0·06)	(0·03)	(0·07)	(0·18)	(0·04)
	FL	8·6	9·2	8·9	8·3	10·6
1+		(0·27)	(0·35)	(0·27)	(0·79)	(0·17)
	W	7·2	9·1	8·4	6·7	14·3
		(0·12)	(0·10)	(0·07)	(0·19)	(0·64)
	FL	11·9	13·0	12·8	12·7	15·0
2+		(0·21)	(0·88)	(–)	(0·27)	(0·17)
	W	19·9	24·9	25·7	23·8	42·4
		(0·09)	(0·34)	(–)	(0·17)	(1·42)
	FL	14·4	–	–	–	17·8
3+		(1·43)	–	–	–	(1·27)
	W	34·4	–	–	–	76·2
		(1·13)	–	–	–	(15·43)
	FL	–	–	–	–	20·0
4+		–	–	–	–	(0·35)
	W	–	–	–	–	105·0
		–	–	–	–	(4·3)

August, by the same angler, gave 20·3 parr/h (S = 7·77) in 1971, 18·5/h (S = 2·50) in 1972, and 7·6/h (S = 2·33) in 1976. The 1976 figure is significantly different ($P < 0·01$) from 1971 and 1972, but 1971 and 1972 figures were not signficantly different from each other ($P > 0·05$). A population estimate at the fourth falls was made only in 1975. This gave figures of 140 (95% limits 90–280)/ha of 2+ parr and 550 (260–1380)/ha of 1+ parr. An estimate in an area near the third falls the same year gave figures of 270 (210–360)/ha of 2+ parr and 200 (140–290)/ha of 1+ parr.

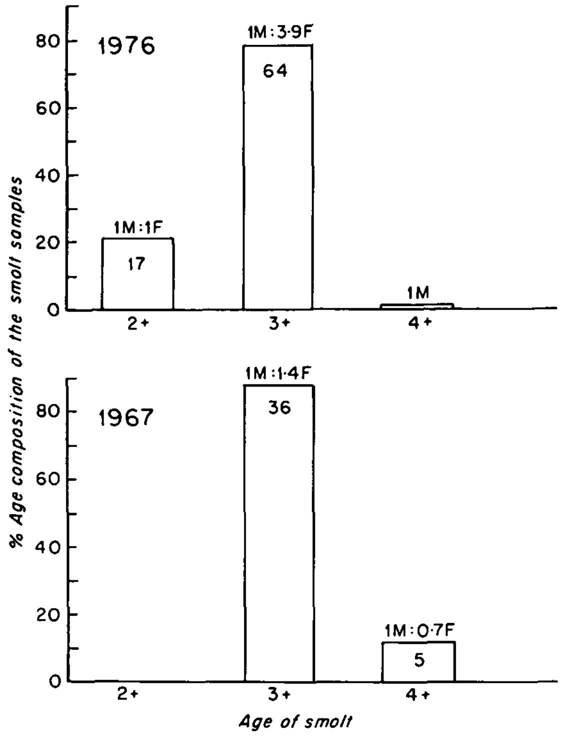

Figure 3. A comparison between the composition of the smolt run in the Matamek River in 1967 and 1976; 1967 data from Schiefer (1969). The smolt run in 1976 was estimated as 2580 (1500–4850) and the overall male to female ratio 1:2·7. In 1967 the overall male to female ratio was 1:1·3. The figures in the columns are the actual sample numbers.

The smolt run in 1976 was estimated to be about 2600 (1500–4850). In 1974 an estimate was made by treating 2+ parr marked at the second falls the previous year as recaptures. This gave an estimate of 8000 (5600–11000). However, this would be high as it does not take into account overwinter mortality. Using this same method with marked 2+ parr from other areas in the river the previous year gives an

Table 3. Population estimates of salmon parr/ha below the second falls (95% confidence limits are given in parentheses)

Age	1971[1]	1972	1973	1974	1976
2+	590	–	1 750	450	230
	(510–700)		(1 420–2 290)	(350–630)	(220–260)
		2 020[2]			
		(1 700–2 500)			
1+	200		510	260	140
	(140–320)		(300–1 660)	(200–360)	(110–200)
Biomass (kg/ha)	10·8	–	29·7	13·1	11·3

[1] Estimate made over 1·2 ha. In other years it was over 0·73 ha.
[2] Total population estimate of both 1+ and 2+ parr.

estimate of 4720 (3050–7670) smolts for 1976, but still less than the 1974 estimate. This also provides evidence of a decrease in the juvenile salmon population. The proportion of 2+ smolt has increased, an indication of faster growth in recent years. No 2+ smolt were caught by Schiefer in 1967, but about 20% were 2+ in the 1976 sample (Fig. 3). The majority still migrated as three year olds. The mean fork length in 1976 of a sample of 70 was 14·9 cm (range 12·0–17·9) and weight 33·9 g (range 15·9–54·5) similar to those sampled in 1970 and 1971 (15·0 cm–33·0 g) (Schiefer, 1971). The ratio of male to female smolt had changed. In 1967 there was no significant difference from the 1:1 ratio, but in 1976 the ratio was 1:2·7, which was significantly different ($P < 0{\cdot}01$). The previous year a sample of 80 two year old parr gave a ratio of 1·2 males to 1 of females. As the majority of these would normally become smolts the following spring, this suggests that there was a relatively greater overwinter mortality of the male parr. This may be related to the characteristic of some male parr becoming mature, and there is some indication that the proportion of precocious male parr has increased (Table 4). The decrease in numbers of parr has allowed more space and food to become available to the fewer number of fish, so that more parr could be fatter than in previous years, possibly allowing a greater number of male parr to mature. The precocious males have a higher condition factor (see Table 5). The condition factor of parr was higher at the fourth falls than further downstream, and this appears to have allowed the proportion of mature male parr to be higher there.

The relative proportions of salmon to grilse are shown for the years of 1967 and 1968 and for 1975 in Figure 4. The proportion of salmon: grilse sampled in 1975 was 1:4·5 (22:100) but was 1:1·1 in 1967 (43:47). A population estimate was made of 130 grilse (95% limits 70–180) in 1975. Too few two-sea-year salmon were recaptured to make an accurate population estimate of them, but using the ratio of salmon: grilse, there would have been about 30 two-sea-year salmon. As can be seen from Figure 4, the relative proportion of two-sea-year salmon in the 21 June–15 July period was considerably less than in the 1967 and 1968 samples.

Table 4. The percentage of precocious males among male parr sampled in the autumn during 1967 and 1975; 1967 data from Schiefer (1971). Numbers of males in the samples are given in parentheses

	1967 Age			1975 Age		
Location of falls	1+	2+	3+	1+	2+	3+
2nd	0	19	34	0	40	100
	(36)	(33)	(9)	(1)	(12)	(3)
3rd	8	57	100	38	89	100
	(71)	(55)	(3)	(8)	(18)	(6)
4th	45	75	100	100	100	100
	(8)	(19)	(11)	(3)	(16)	(2)

Table 5. Condition factors ($c = 100\,(W\,FL^{-3})$ where W weight in g and FL fork length in cm) of two year old salmon parr at three locations in 1975. Standard error of the mean is in parentheses

	Fourth falls	Third falls	Second falls
Immature males	–	–	1·01
	–	–	(0·03)
Immature females	1·17	1·04	1·06
	(0·10)	(0·02)	(0·02)
Mature males	1·28	1·11	1·15
	(0·11)	(0·04)	(0·03)

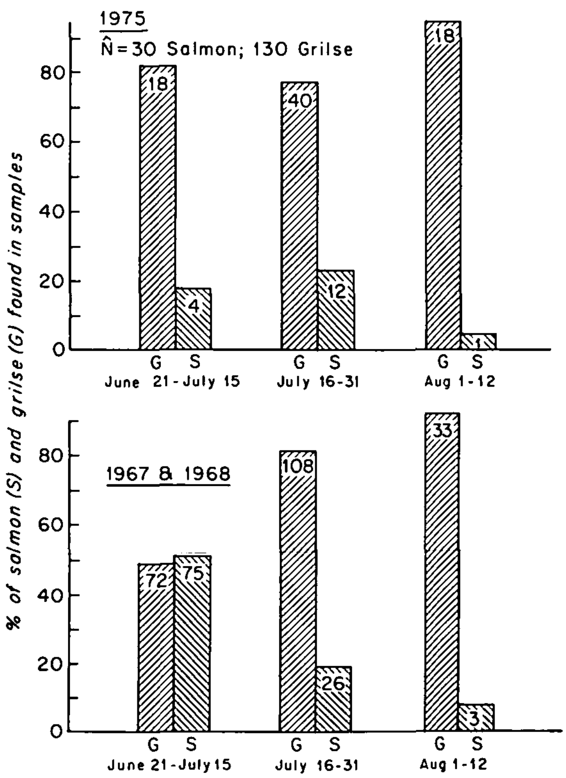

Figure 4. The composition of the adult salmon run in 1967 and 1968, (from Schiefer, 1969), and in 1975, from samples taken below or at the first falls. The figures in the columns are the actual sample numbers.

Discussion

The response of the parr to a reduced population has been a faster growth rate, with some fish migrating to sea a year earlier. The proportion of precocious male parr also appears to have increased. The relatively larger size of parr and their better condition factor at the fourth falls could be due to either or both of two factors: 1) the density was sparse; 2) the food was more plentiful near the lake. Gibson and Galbraith (1975) have found that the filter feeding insects were abundant near the lake, but were sparser downstream. The richer environment has also allowed a greater proportion of male parr to mature at the fourth falls than further downstream. The higher proportion of two year old parr to one year olds at the second falls may have been due to the fact that the major spawning grounds are below the third falls, 1·5 km upstream, and the larger parr may migrate downstream in greater numbers than the smaller ones. Parr are found down to the estuary, 3·7 km from the nearest spawning grounds. At the third falls area also there was a disproportionate number of two year olds. This was near the spawning grounds, but the population estimate was done in an area which included relatively deep pools. Just upstream was an area of shallow fast riffles with cobble and rubble substrate, and here one year olds were numerous but not two year olds. This was tested in August 1976 by Mr. P. Lamarque, who demonstrated that with a 700 V electro-shocker fish could be caught in this shallow rapid water, although it was unsuccessful in the slower deeper water, where parr could be caught by seining.

Female smolt are frequently more numerous than males (Jones, 1949), but this unequal representation has only recently become apparent in the Matamek. It has been suggested that female smolt are usually more numerous than male smolt because there may be a greater mortality of the precocious male parr after spawning (Power, 1969). If this is so, the increase in the proportion of precocious male parr would explain the higher proportion of female smolt in 1976. A small proportion of male parr at Matamek remain in the river, but they are not numerous and it is not known if they have increased recently. These large male parr have been caught up to 25·3 cm fork length (Gibson 1973b; 1975). The important segment of the migratory stage is the females, as it is the female gametes that have to obtain a large size, and mature male parr are able to adequately fertilize eggs (Jones, 1959). The smolt size does not appear to have changed, but this can be fairly variable, depending on how long they take to leave the river in the spring. In 1975, due to the weather, the smolt run was bimodal, so that during the last part of the run between 30 June–4 July the mean fork length was 16·2 cm (range 13·2–19·6). Between 16–24 June that year it was 15·3 cm (12·5–21·4) (Gibson, 1975).

The Matamek basin is "undeveloped" and has no history of logging or spraying. Only since 1975 has a highway along the coast allowed easy access. The whole basin is protected as a Quebec government fish and game reserve, so it remains unexploited and virtually in its original pristine condition. Changes in the fluviatile populations, therefore, have not been caused by human interference in the river itself, but are probably caused by either natural factors or increased exploitation at sea. In 1975 it was possible to estimate the population of adult salmon for the first time, but there is little doubt that the run of two-sea-year salmon has decreased. In 1967 Schiefer took a sample of 47 grilse and 43 two-sea-year salmon, more two-sea-year salmon than were estimated for the total run in 1975; also, the early July run of predominantly two-sea-year salmon, found in previous years, has almost disappeared. In 1976 it was not possible to make a good population estimate of the adult salmon, as exceptionally low water in July allowed the fish to ascend the first falls without difficulty, and few were caught in the fishladder. However, samples from the trap net allowed a rough estimate of the ratio to be made, of one salmon: three grilse (Gibson, 1977). The potential egg deposition in 1975 would have been about 160000 (6% of 130 grilse – the proportion of females = 7·8. Average weight of grilse = 3·2 lbs. 65% of 30 salmon = 19·5. Average weight of salmon = 8·8 lbs. Fecundity = 800 eggs/lb., these proportions are from Schiefer, 1969). The adult salmon population was unknown in previous years. In the Matamek River it is now apparently below its carrying capacity for salmon, a situation similar to rivers further south (Paloheimo and Elson, 1974), and which may also apply to other salmon rivers on the North Shore of the Gulf of St. Lawrence.

Acknowledgements

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