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The incidence and genetic implications of sexual maturity in male Atlantic salmon parr

by

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ABSTRACT

There were differences in the incidence of sexually mature (dwarf) males among purebred and hybrid strains of Atlantic salmon reared in a hatchery with spawn taken from wild salmon collected in several New Brunswick rivers and fertilized according to a diallel mating scheme. Dwarf males developed in both young-of-the-year, which had been hatched and reared at elevated temperatures during the winter, and those in their second year following hatching and rearing at prevailing ambient temperatures. Mature males were usually smaller than immature males and females and grew more slowly during August - November. Total lipid decreased and moisture content increased in dwarf males during late summer and autumn; immature parr had increasing lipid and decreasing moisture during this period. Consideration is given to the energetic effects of this early sexual maturation and the genetic implications.

INTRODUCTION

Male parr of Atlantic salmon commonly mature sexually before reaching the smolt stage and migrating to sea (Orton, Jones & King, 1938). These mature parr are referred to as paedogenic or precocious males (Jones and Orton, 1940) or dwarf males (Österdahl, 1969). Sexually mature parr are functional males and take part in the spawning act in competition with large, anadromous males (Österdahl, 1969).

Jones and King (1952) suggest that the precocious males provide a safeguard in case the milt from large males is swept away. Österdahl (1969) argues that the dwarf males are the principal male spawners in some salmon stocks. Leyzerovich (1973) describes a salmonid stock in which the females are anadromous while most of the males mature and spawn without going to sea. Whatever the significance of dwarf males, they have been frequently observed in both natural and hatchery reared salmon stocks.

The incidence of dwarf males varies among stocks of Atlantic salmon (Schiefer, 1971; Schaffer and Elson, 1975). Similar variation has also been reported among chinook salmon, *Oncorhynchus tshawytcha* stocks (Flain, 1970).

The purpose of our study was to compare the incidence of dwarf males among several Atlantic salmon stocks reared under similar conditions in a hatchery. We compared growth rates and lipid-moisture dynamics between sexually maturing male parr and immature males and females.

MATERIALS AND METHODS

Random samples of broodstock were collected from four New Brunswick rivers. Eggs and milt were stripped and combined artificially according to either a three-by-three or four-by-four diallel crossing scheme. A diallel cross involving n strains produces n^2 combinations of which n are pure strains (like their parents) and n (n-1) are hybrid strains including reciprocal crosses.

The fish were hatched and reared as separate families (10-12 per strain) for about six months, after which they were combined according to strain.

Two sets of observations were made, one from parr from the 3 x 3 crosses in their second year and the other from young-of-the-year parr from the 4 x 4 crosses. The former were hatched and reared at ambient temperatures. Only a small percentage of these had reached the smolt stage at one year of age. Smolts were released in May and the remainder of the year class retained for a second year. The young-of-the-year parr were only slightly smaller since they had been hatched and reared at elevated temperatures.

Sampling of the purebred strains of 1+ parr began in mid August and continued twice monthly through November. Approximately 100 parr were taken at random and killed for determination of length, weight, and state of maturation and sex. The six hybrid strains of 1+ parr were similarly sampled only in October. The carcasses were frozen and later used for determinations of moisture content by drying to a constant weight at 80°C (for about 48 hrs.); lipid determinations were done by column extraction as described by Korn and Macedo

(1973) using monofluortrichloromethane (MF Freon, refrigerant - 11). The young-of-the-year parr from all 16 strains of the 4 x 4 crosses were sampled, at the rate of *ca.* 100 per strain, in mid November when it was possible to identify mature males by their distended bodies and the issue of milt when they were gently squeezed. These fish were anesthetized, weighed and measured but not killed.

RESULTS

Samples in mid-August revealed well developed testes in some males. Twice monthly sampling showed further increase in testis size with running milt in most mature individuals by early November. No mature females were found. Differences in the incidence of mature males among the three purebred and six hybrid strains of 1+ parr were apparent (Figure 1). One purebred strain had a low incidence of matures; the other two had high incidences. A test comparing mean percentage matures between pure strains and their respective hybrids indicated heterosis or hybrid vigor (Figs. 1, 5) in each comparison.

A relationship between sexual maturity and reduced growth rate was found. Mature males were usually smaller than immature males and females. In one purebred strain the matures were consistently smaller than immatures (Figure 2). In the other two purebred strains the mature parr were generally but not consistently smaller.

Lipid content steadily decreased (Figure 3) and moisture increased (Figure 4) during maturation. These parameters followed opposite trends in immature parr from those in mature parr. Trends in lipid and moisture content were similar in immature males and females.

Pronounced differences in percentages of mature male parr were found among the four purebred strains of underyearlings (Figure 5). Two strains had low and two had high percentages of matures. Here again, there were consistent indications of heterosis when percent maturity was compared between purebreds and their respective hybrids.

DISCUSSION

Schiefer (1971) suggests that rapid growth rates in juvenile, stream dwelling Atlantic salmon leads to production of dwarf males and that these, in turn, mature and return from the sea as grilse. He describes some river stocks of salmon, from the North Shore of the Gulf of St. Lawrence, which support his hypothesis. Schaffer and Elson (1975) list rivers in Maine in which the parr have rapid growth in freshwater, many dwarf males but few grilse in their spawning

Percent mature males

♂ \ ♀	B	D	S
B	33	87	50
D	62	50	47
S	52	72	14

BB 33	DB 62	BB 33	SB 52	DD 50	SD 72
DD 50	BD 87	SS 14	BS 50	SS 14	DS 47
83/2	149/2	47/2	102/2	64/2	119/2
42	75	24	51	32	60
33		27		28	

Figure 1. Percentages of sexually mature (dwarf) males in three purebred and six hybrid strains of Atlantic salmon parr. B = Big Salmon River, D = Dennis Stream and S = Saint John River. Means of two purebred and their reciprocal hybrids are compared to give measures of heterosis, e.g., BB + DD = 83, X = 42; DB + BD = 149, X = 75; 75 - 42 = 33, the indication of heterosis.

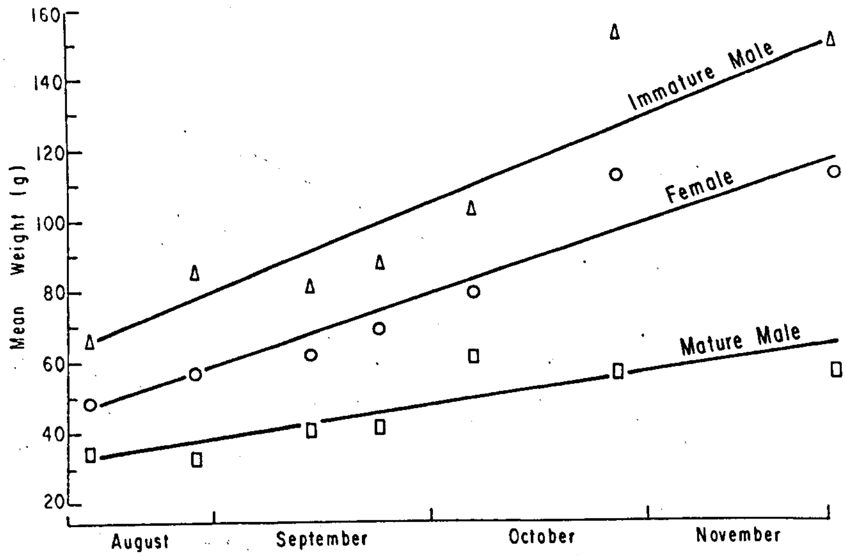

Figure 2. Weights of mature and immature parr during late summer and autumn. Points represent means of 10-30 individuals; the three means for a given date total *ca.* 100 individuals, all the fish sampled on that date.

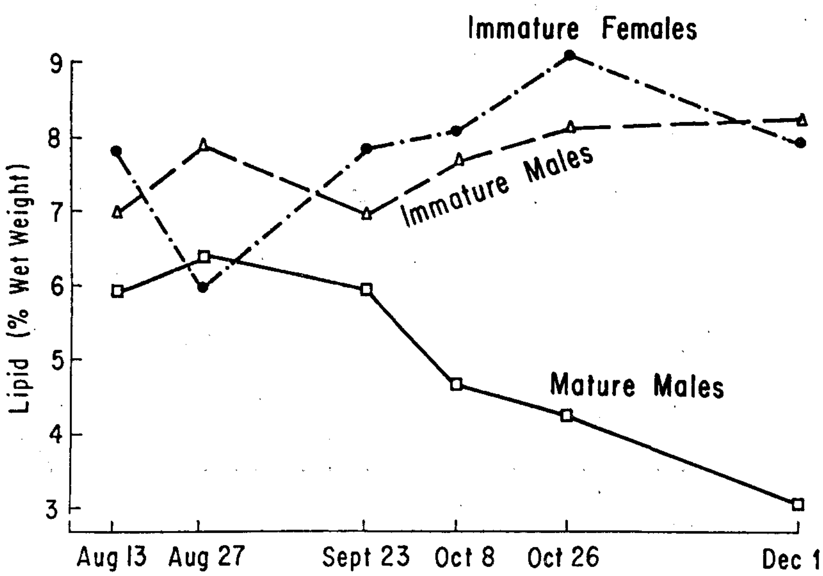

Figure 3. Lipid composition of mature and immature parr during late summer and autumn. Points represent means as in Figure 2.

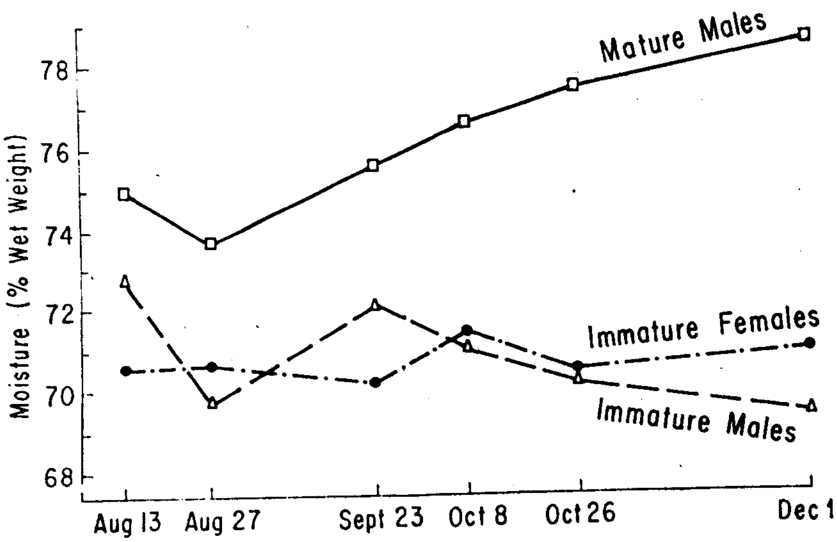

Figure 4. Moisture composition of mature and immature parr during late summer and autumn. Points represent means as in Figure 2.

Percent mature males

♂ \ ♀	M	S	R	B
M	4	19	11	13
S	19	20	14	22
R	17	14	6	23
B	22	35	25	18

M-S		M-R	M-B	S-B	R-S	B-R
4	19					
20	19					
24/2	38/2					
12	19					
+7		+9	+6.5	+9.5	+1.0	+12

Figure 5. Percentages of sexually mature males in whole sample (males plus females) in four purebred and 12 hybrid strains of Atlantic salmon parr.
M = Magaguadavic R.
S = Saint John R.
R = Rocky Brook
B = Big Salmon R.
Measures of heterosis are indicated and were calculated as in Figure 1.

populations. Schaffer and Elson reason that life cycle patterns, like morphological patterns, are inherited. Our observations suggest an important genetic component in the development of sexually mature male parr and that genetic dominance is indicated because of the consistent, strong heterosis.

It is possible, indeed likely, that the differences in incidence of dwarf males among the various purebred strains were owing to the hatchery environment and that the expressions of parr maturity observed would not resemble those in the donor streams. Similarly, between year differences in hatchery environment may have been responsible for the low incidence of dwarf males between Saint John 1+ parr (Figure 1) and Saint John underyearling parr (Figure 5). We suggest that the difference in incidence of dwarf males between those two year classes was owing to different developmental and growth rates. However, it should be noted that in the between year class comparisons of the Big Salmon River strains, incidences of dwarf males were of similar magnitude.

Leyzerovich (1973) reports that male parr which mature are the faster growing ones and that the immature fish overtake the matures in size during late summer and autumn. Although our observations were not started early enough to record the beginnings of sexual maturity, most mature males were smaller than immatures by the end of the study.

Reduced lipid levels found in dwarf males in our study may be a possible cause of the higher winter mortality rate reported among dwarf males (Mitans, 1973). If stored lipids are important in the survival of overwintering juvenile salmon, reduced levels in dwarf males are likely a handicap.

This preliminary study is being followed by more detailed investigations of the genetic and environmental control of sexual maturation in male parr, the fate of dwarf males, the energetic consequences of maturation and the possible genetic role of dwarf males in salmon stocks.

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