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THE INFLUENCE OF PARENTAL AGE AT MATURITY AND REARING PRACTICE
ON PRECOCIOUS MATURATION OF HATCHERY-REARED ATLANTIC SALMON PARR

by

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ABSTRACT

Matings involving various combinations of precocious parr, grilse and salmon produced 107 family groups. A survey of the incidence of precocious male parr in these groups indicated the rearing of full sibs as 1⁺ smolts and 2⁺ smolts produced similar numbers of precocious parr. The use of precocious parr as sires significantly increased the incidence of early maturation among progeny in a limited number of matings. The incidences of precocious parr resulting from all matings were highly variable (ranging from 0 to 42%) and did not appear to be related to specific sea ages at maturity. The culture implications of these results are discussed.

INTRODUCTION

Precociously mature Atlantic salmon parr produce viable sperm (Shaw 1836; Brown 1862; Jones and King 1950; Thorpe 1975), attempt to spawn with anadromous females (Jones and King 1952) and may be the principle male spawners in certain populations where anadromous males are few or absent (Fritsch 1893, Leyzerovich 1973; Lee and Power 1976). However, little is known of the genetic consequences of matings involving precocious parr. Brown (1862) stated that the use of parr, grilse and salmon sires had no measurable effect on the proportion of progeny smolting at 1 yr. Alm (1943) also concluded that survival, growth and smolting did not differ between the offspring of parr and anadromous males. Thorpe and Morgan (unpublished manuscript) recently compared the growth and smolting in progeny of parents with varying ages at maturity under more rigorously controlled environmental conditions. Their results show a faster development of parr progeny to the smolt stage. The influence of sire age at maturity on maturation of progeny has not been resolved. Alm (1943) suggested that parr progeny matured earlier but environmental influences on his experiments were not assessed. However, this result is consistent with Elson (1973) and Schaffer and Elson (1975), who provide evidence that parental sea age at maturity influences the grilse-salmon component among offspring.

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Precocious parr may have utility in salmon breeding programs. The rate of genetic gain may be increased through reduction in generation time by the use of selected precocious sires. The rate of gain in these male lines would be contingent on there being no deleterious effects of the use of precocious sires. Use of precocious parr sires may be more appropriate for cage culture than for sea ranching. Sea ranched males undergo more rigorous natural selection for survival and homing ability. Precocious parr sires would not have experienced this selection and their use may result in an inadvertent reduction in marine survival and homing ability. This would not be a major consideration in a cage culture program where survival from egg to adult is high and consequently natural selection is not as great.

In this study, we investigated the effect of rearing regime and parental age at maturity on incidence of precocious maturation and size among progeny. Of special interest, were the consequences of using parr sires and salmon and grilse dams. The results are preliminary in nature with the intent of ultimately determining the effect of the various matings on precocious and subsequent maturation.

MATERIALS AND METHODS

Three crossing schemes were utilized in October and November of 1977. The first was a diallel cross involving three two-sea-winter dams from the St. John River stock (Mactaquac hatchery origin) and wild Big Salmon River stock (location map, Friars et al. 1979) and 1⁺ precocious parr sires from Salmon Research Center (SRC) hatchery stocks, F₁ generations from the same salmon stocks as dams (Fig. 1). Fecundity of each female was determined volumetrically and the eggs divided into six lots of approximately 1000. Four lots of eggs from each female were fertilized using the milt of two precocious parr from each stock. Similarly, the milt from each parr was divided and used to fertilize one lot of eggs from a female from each stock (Fig. 1). The remaining two egg lots were fertilized with the milt from a grilse or salmon (depending on availability) from each of the stocks; 34 families were produced by this design. The parr-fertilized families were equally divided and the full sib groups subjected to different rearing regimes. One sib group was initially reared at ambient hatchery temperatures. Incubation of the other sib group was initiated at 4°C in November and the temperature slowly incremented to 12°C by February using auxiliary heating until ambient temperatures rose to this level. The half sib groups (anadromous male sired) were reared at ambient temperatures. All families were maintained in indoor 1-m diameter circular tanks at natural photoperiods until sibs could be marked. In June, the accelerated family groups were branded (Owens and Gebhardt 1968) and combined in an 8-m circular outdoor rearing tank. The length and state of maturity of each individual was determined by family in November. Precocious parr were detected by the issue of milt when gentle abdominal pressure was applied. The groups being maintained at ambient temperatures remained in the 1-m tanks until each could be microtagged (≈7 cm) (Jefferts 1963). The lengths and weights of 20 parr (randomly selected from each family) were measured at this time. Microtagging was completed in December and the parr placed in outdoor 8-m circular tanks at approximately equal densities (≈4000/tank). A random inspection for mature parr was made during tagging. The following November (1979), a random sample of 200 parr was taken from each tank, killed, the sex and state of sexual maturity determined and the length and weight measured. Decoding of the microtags revealed the relative

proportions of the family groups in the sample. These proportions were used to calculate the numbers in each family from the total number of parr in the tank. Subsequently, the precocious parr were sorted from each tank, killed, the length and weight determined and the microtags recovered. The microtag code was used to assign the parr to a specific family group and the incidence calculated from the estimated family size.

The second crossing scheme was a nested design involving three wild strains and a hatchery stock (Fig. 2). No hybrids were produced. The eggs from each female were divided volumetrically into lots of 1000. Within each strain, 1⁺ precocious parr of SRC origin were mated to two salmon or grilse dams. Due to the random availability of ripe dams, no attempt was made to ensure that the dams mated to one parr were of different sea ages at maturity. Sufficient eggs were available from the Magaguadavic, St John and Big Salmon dams to produce maternal half sib families with randomly selected sires. Forty-one families were produced. The rearing conditions and the methodology for marking and data collection for these lots were identical to those from the first crossing design reared at ambient temperatures.

A diallel cross involving randomly selected grilse and salmon parents (Friars et al. 1979) generated 42 family groups belonging to the same strains but unrelated to families in the aforementioned crosses.

Preliminary statistical analysis of the data included the generation of a correlation matrix for the family parameters including percentage precocious parr, length and weight of female progeny, sire and dam smolt and sea ages and their cross products, a dummy variable to delineate precocious sires from non-precocious sires and, finally, condition factor. A subsequent correlation matrix using the same parameters except for the dummy variable was produced for family data involving only grilse and salmon sires. Mean female progeny size was considered an unbiased estimate of family growth performance and therefore used in the correlation analysis. If males were included, the highly variable incidence of precocious males, their subsequent slower growth, and the suggestion that the larger males have a greater tendency to mature precociously would influence the family mean size calculation.

Analysis of variance was used to assess differences in the mean incidence (arcsine transformed) of precocious males among families segregated by sire types (precocious, grilse and salmon) and dam types (grilse and salmon).

Significant differences in the incidence of precocious maturation between half sib family pairs (both maternal and paternal) and between replicates within crossing designs were investigated using the normal approximation of the binomial distribution (Z statistic). This was used to analyze for the effect of different sires and dams on incidence of maturity among half sibs and to assess the environmental effect on replicates.

RESULTS AND DISCUSSION

Over 2400 precocious parr and 1200 randomly selected parr were taken from among the 20,000 parr reared at ambient temperatures. Among the 2,000 parr reared at elevated temperatures, approximately 200 precocious parr were found. Survival from egg to parr stage was poor. The similar survival rates among half sibs suggested the mortality was associated with culture techniques.

The trends in mean incidence of precocious parr within strains (Fig. 3, 4) are similar to those reported for previous year classes at the Salmon Research Center (Saunders and Sreedharan 1977; Glebe et al. 1978). The Big Salmon and St. John River strains have respectively high and low incidences of mature male parr. Similarly, heterosis for growth and incidence of maturity is evident among hybrids produced by anadromous sires; that is, the hybrid means for these traits are greater than the parental (pure strain) means (Fig. 3c). Inconsistent with previous findings is the lack of heterosis for maturity among progeny when precocious parents are used (Fig. 3a,b). The hybrid mean is intermediate to the mean for the parental strains suggesting a simple additive genetic component. The basis of this discrepancy among hybrids depending on the type of sires used is not known.

The effect of different rearing environments (designed to produce 1⁺ and 2⁺ smolts) on the proportions of precocious parr was negligible. The strain mean incidences of mature parr was similar for full sibs reared under the two temperature regimes (Fig. 3a,b). The slightly greater length of the parr reared to be 2⁺ smolts was not associated with an increase in proportion of precocious males as predicted (Glebe et al. 1978). At the family level, the Z statistic showed a significant difference in only four out of 17 comparisons of full sibs reared under the two conditions. In these instances, the accelerated group had a higher incidence of mature parr. The incidences of maturity within full sib replicates reared under ambient water temperatures (Fig. 2,4) were significantly different in four out of nine comparisons. The reasons for the significant differences are unknown. However, it must be noted that the proportions of mature parr in replicates from both crossing designs were consistently high or low proportions. The most significant Z value was 4.0 for a comparison of the incidences 29% and 17% (sample size in excess of 400 in each case), both of which are relatively high values yet statistically different. Similarly, the low incidences of 0% and 0.5% were significantly different when the sample size approached 400 ($Z = 2.8$).

Except for the St. John strain, the mean incidence of mature parr within pure strains was higher when precocious parr rather than anadromous males were used as sires (Fig. 3,4). However, analysis of variance indicated there was no significant difference among the mean incidences of precocious maturity among all maternal half sibs grouped by sire type (precocious, grilse and salmon) ($F(2,89) = 2.18, p > 0.05$) and between paternal half sibs separated by grilse and salmon dams ($F(1,92) = 0.3, p > 0.05$). Similarly, correlation analysis did not show any significant relationships between the family incidence of precocious maturity and the parental age at maturity. We believe the variation resulting from strain specific incidences of precocious males may have precluded the detection of significant differences using these statistical methods. In contrast, the binomial analysis (Z statistic) indicated that eight out of 16 comparisons of the proportions of precocious parr in maternal half-sib families were significantly different. The precocious parr sires produced more precocious offspring than salmon and grilse sires in three comparisons within the Magaguadavic strain and in five comparisons within the Big Salmon strain. The mean incidence was 16.1 (SD = 7.0) among progeny of these precocious sires and 4.4 (SD = 4.1) among progeny of the compared anadromous sires. Where the compared incidences were not significantly different, the precocious and anadromous sires (both grilse and salmon) produced equally low numbers of precocious offspring (2.0%, SD = 2.0).

The proportions of precocious parr from paternal half-sib families were significantly different in five out of nine cases. The dams mated to a single male were, except for one mating set, of the same sea age at maturity. Therefore, the significantly different half-sib groups included two salmon pairs, two grilse pairs and a salmon and grilse. The random nature of occurrence of significant differences in the maternal and paternal half-sib analysis suggests that, in terms of the proportion of precocious parr among offspring, there appears to be no genetic difference between many precocious parr, grilse and salmon. Freshwater and marine growth may be factors determining maturation. Ritter (1975) found a relationship between smolt size (freshwater growth) and age at first maturity. Schaffer and Elson (1975) associate rapid growth at sea subsequent to the grilse stage with delayed maturity. Therefore, the genetic component in growth may be associated with age of maturity both in the sea and among parr in freshwater. However, the interaction between the genotype and environment may explain the lack of correlation between parental age at maturity and the incidence of precocious male parr among their progeny. Ongoing sea ranching and cage rearing of the progeny produced by the study crosses may provide further insight into the influence of parental traits on sea age at maturity.

The similarity in incidence of precocious maturity among many half-sibs families irrespective of parental age at maturity suggests precocious parr may be useful in selective breeding programs for reducing generation time and accelerating genetic gain without adversely influencing the age of maturity of the offspring. However, to do this, the size of the genetic components and the environmental and physiological effects controlling precocious parr development must be more fully elicited and the genetic correlation between precocious parr and large salmon traits must be determined before male parr can be used effectively. Furthermore, this study has indicated that age of maturity of individuals per se may not be an appropriate selection consideration. Rather primary selection should be for stocks with characteristically high or low mean age at maturity (depending on what is most appropriate for the program) and secondary selection would involve specific families within the stocks. The family average performance will provide a true indication of the genetic potential.

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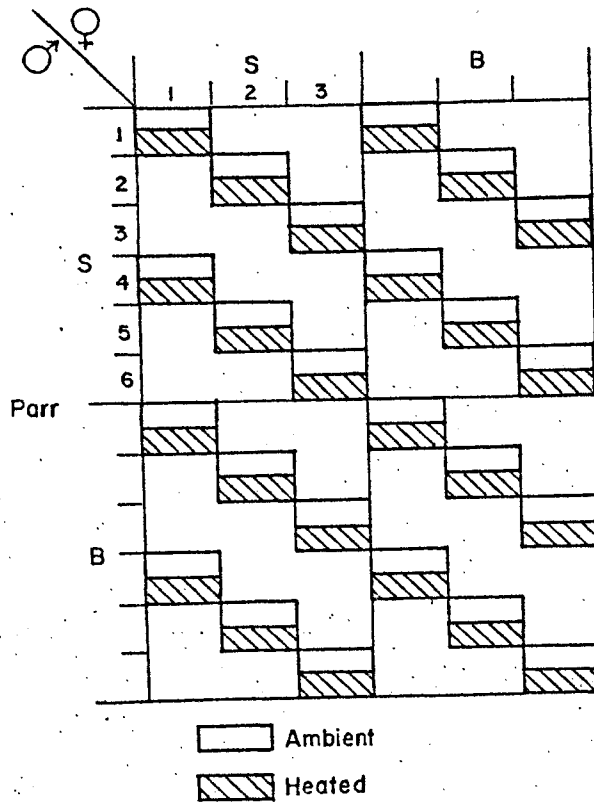


Fig. 1. Diallel crossing scheme involving precocious parr and salmon females. S, Saint John River stock; B, Big Salmon River Stock.

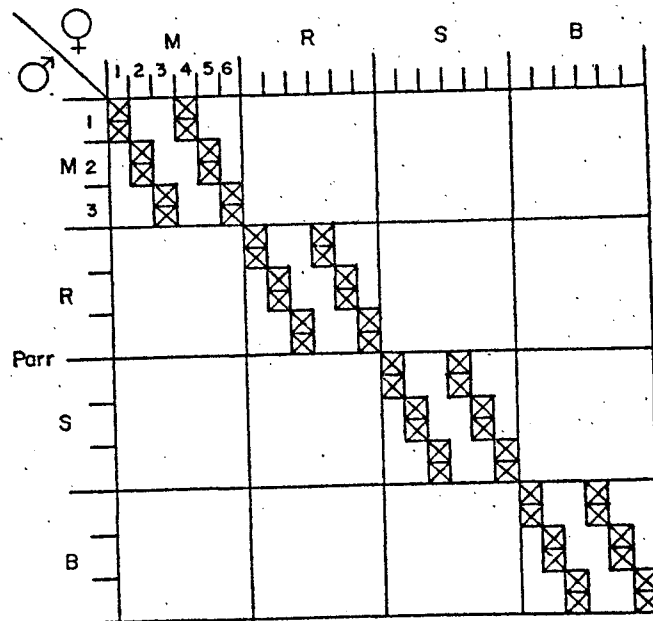


Fig. 2. Nested crossing design involving precocious parr and salmon and grilse females. M, Magaguadavic River stock; R, Rocky Brook stock; S, Saint John River stock; B, Big Salmon River stock. Replicates within families indicated by "X".

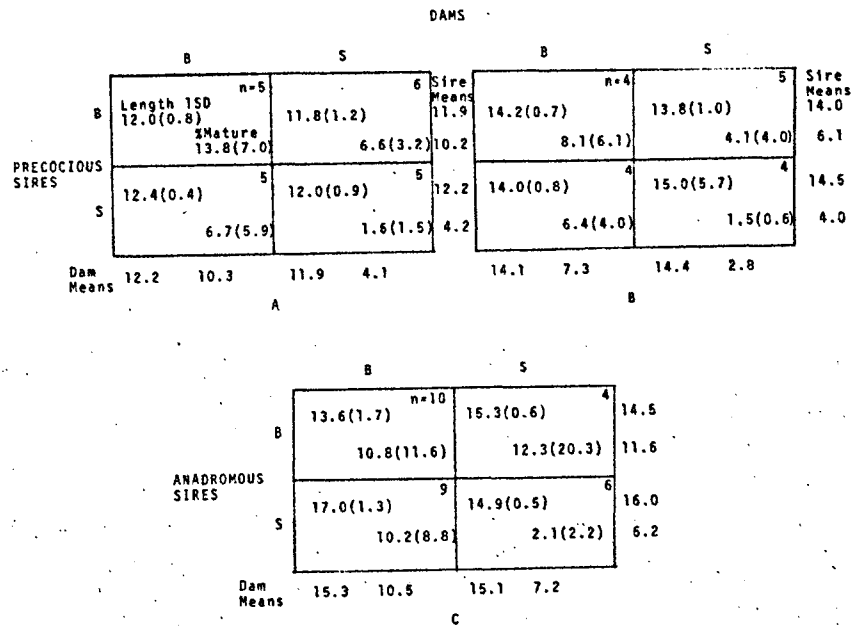


Fig. 3. Family mean incidence of precocious males (expressed as a percentage of the total family size, both sexes included) and mean length for strains produced by the diallel cross. The families are segregated by sire type (precocious and anadromous which includes salmon and grilse). The sire and dam means indicate relative paternal and maternal effects on size and incidence of maturity. A, parr sired families reared at ambient temperatures; B, parr sired families reared at elevated temperatures; C, anadromous male sired families reared at ambient temperatures. n, number of families included in the mean.

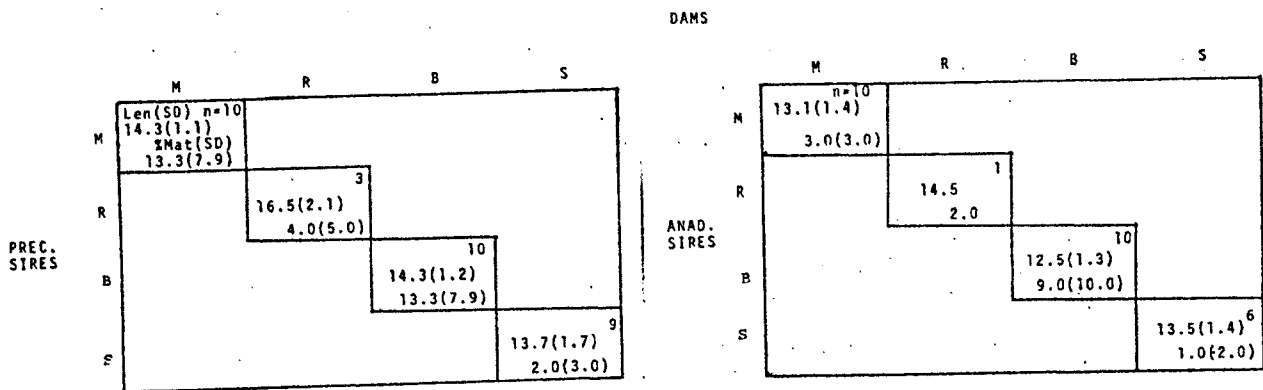


Fig. 4. Family mean incidence of precocious males and mean length for strains produced by the nested mating design. Families are segregated by sire type (precocious and anadromous). n, number of families included in the mean.