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SHORT COMMUNICATION

# A PRELIMINARY STUDY ON THE EFFECT OF SOCIAL ENVIRONMENT ON THE GROWTH OF JUVENILE ATLANTIC SALMON (*SALMO SALAR*) AND BROOK TROUT (*SALVELINUS FONTINALIS*)

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## ABSTRACT

The effect of social environment on growth was studied by rearing young-of-the-year Atlantic salmon (*Salmo salar*) and brook trout (*Salvelinus fontinalis*) in kin and non-kin groups for 15 months post hatch. Kin groups were created by fertilizing the eggs of a single female with the sperm of a single male. Non-kin groups were created by fertilizing the pooled eggs of four females with the pooled milt of four males. Juveniles were fed 1% mean body weight throughout the study period. The weight and standard length measurements were taken at 4, 8, 11 and 15 months post hatch. Both weight and standard length were found to be significantly greater in kin groups than in non-kin groups. Also variance in weight and length of the individuals within groups was found to be significantly lower in kin groups than in non-kin groups. These data suggest that the social environment or the relatedness of group members has a significant effect on both the growth rate and variation in growth of juvenile Atlantic salmon and brook trout. Agonistic interactions are known to decrease in the presence of kin or familiar individuals over a broad range of taxa. If individuals in a kin group cooperate among themselves, sharing resources and displaying less agonistic interaction, it may lower mortality and result in higher and less variable growth. The results of this study are consistent with the Hamilton's prediction in his theory on the evolution of social behaviour, that individuals can increase their inclusive fitness by biasing their behaviour towards related versus unrelated conspecifics.

## INTRODUCTION

Salmonids are important species of aquaculture. A variety of environmental factors are known to influence growth and the variability of growth in salmonids (Elliott 1982; Jobling & Baardvik 1994). From an aquaculture perspective it is important to maximize growth and from the marketing viewpoint it is also important that the harvested fish are of uniform size. Reduced variability in size of fish would serve to reduce the need to sort repeatedly or grade fish, a process which can cause stress and is labour intensive.

Salmonids can discriminate kin from non-kin on the basis of water-borne chemosensory cues. Among salmonids kin discrimination was first observed in juvenile coho salmon (*Oncorhynchus kisutch*, Quinn & Busack 1985) and since that report other salmonids shown to discriminate kin include Arctic charr (*Salvelinus alpinus*, Olśen 1989), Atlantic salmon (*Salmo salar*, Brown & Brown 1992), rainbow trout (*Oncorhynchus mykiss*, Brown & Brown 1992) and brook trout (*Salvelinus fontinalis*, Hiscock & Brown 2000). Most salmonids are territorial as juveniles and begin to defend foraging territories soon after emergence from the redd (gravel nest; Scott & Crossman 1973; Dill 1977; Gibson 1981; Scott & Scott 1988). Reduced frequency of territorial defense behaviours reduces the energy expenditure (Puckett & Dill 1985) and risk of physical injuries associated with such behaviours (Abott & Dill 1985). As the fry

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emerge, they may be carried downstream or to the periphery of the stream by the currents (Hutchings 1993). As a result, Brown and Brown (1993) suggest that there is a possibility of having either kin or non-kin as territorial neighbours. In Atlantic salmon and rainbow trout rearing together with kin has been shown to result in reduced aggression and reduced size of defended area (Brown & Brown 1993) and in Arctic char increased growth and reduced size variation among individuals (Brown et al. 1996). Based on Hamilton's (1964) theory on the evolution of social behaviour, individuals can increase their inclusive fitness by biasing their behaviour towards related versus unrelated conspecifics. This theory argues that by either cooperating with or not antagonizing kin, an individual can increase its own genetic fitness (Wilson 1987). Based upon this, Waldman (1988) predicted that individuals are expected to compete more intensely with unrelated individuals rather than with siblings. However, this prediction is contrary to Walls and Blaustein's (1994) suggestion that, patterns of resource utilization would be similar among related individuals or siblings because they are phenotypically similar, leading to intensified competition among close kin.

In salmonid juveniles, the effects of kinship on growth remain controversial and the available data support both of the above predictions (Beacham 1989; Quinn et al. 1994; Brown et al. 1996). In Atlantic salmon and rainbow trout a significant reduction in aggressive behaviour was observed when their neighbours were kin compared with when the neighbours were non-kin (Brown & Brown 1993; 1996b). Arctic char being reared with kin has been shown to result in increased growth and reduced size variation (Brown et al. 1996). However, Beacham (1989) found the opposite results. He compared the mean and variance of growth rates in juvenile coho salmon reared as full sibling and mixed sibling groups and observed a higher variation in growth rates in full sibling groups with no overall difference in growth rate. Quinn et al. (1994) also reported similar results from a study conducted in an experimental stream channel using coho salmon. These results (Beacham 1989 and Quinn et al. 1994) suggest that fish from a fast growing and competitive family may grow faster or show less variation in growth when reared with members of other, comparatively less competitive families than when reared with highly competitive siblings. This study was designed to examine the effect of social environment or kinship on growth in juvenile Atlantic salmon and brook trout. Based upon previous studies of salmonids we tested the null hypothesis that 'kinship has no effect on the growth in the two species'.

## METHODS

### Experimental Animals

Eggs and sperm were collected from males and females of laboratory held brook trout and wild caught Atlantic salmon. Kin groups were created by fertilizing the eggs of a single female with the sperm of a single male. Non-kin groups were created by fertilizing the pooled eggs of four females with the pooled milt of four males (standard hatchery mix) according to well established protocols (Olsen 1987, 1989; Brown & Brown 1992, 1993, 1996; Hiscock & Brown 2000). The kin group comprised all full siblings and the non-kin group comprised unrelated, half-siblings and full sibling individuals. Fertilized eggs of both kin and non-kin groups were placed in separate trays in an incubator with a continuous fresh water supply. After yolk absorption the fry were transferred into 40L tanks, one for kin and one for non-kin in both species.

After one month, fry were transferred to cylindrical $1m^3$ rearing tanks. The fish were fed with salmon/trout starter feed (Vextra) and continued with the same feed until the start of the experiments and during the experiments. Two separate kin groups and one non-kin group of Atlantic salmon and one kin group and one non-kin group of brook trout were maintained. Each Atlantic salmon tank contained 120 fry while the brook trout tanks contained 90 fry (initial stocking density of $0.75\ kgm^3$). Juveniles were fed 1% mean body weight once per day. A sub-sample of 20 fish from each tank was selected arbitrarily. Fish were anaesthetized lightly using MS222 and were weighed (to the nearest 0.05g) and measured the length (to the nearest 1.0mm). The measurements were taken at 4, 8, 11 and 15 months post hatch. The water temperature ranged from 2-18$^0$C during the study period. Mortality was recorded daily. Ambient fresh water was provided with a flow rate of 3L/min. Fish were raised under a natural photoperiod.

Means of both weight and length data were analyzed using one-way ANOVA (Sokal & Rohlf 1995). Individual comparisons between groups were done using Welch's approximate *t*-test for unequal variances (Zar 1984). Variance data were compared using a Bartlett's test of homogeneity of variance (Snedecor & Cochran 1989).

## RESULTS

Both mean weight and mean standard length (Figure 1) were greater in the kin groups than in non-kin group both species but no significant differences were observed during the first eight months in both species. In Atlantic salmon between kin group 1 and non-kin group significant differences were observed in mean weight ($F_{1,38}$= 15.244, $p<0.001$; $F_{1,38}$= 10.413, $p<0.005$) and length ($F_{1,38}$=9.535, $p<0.005$; $F_{1,38}$=6.241, $p<0.05$) at 11 and 15 months respectively. Similarly significant differences were observed between the kin group 2 and the non-kin group (weight $F_{1,38}$=35.381, $p< 0.001$; $F_{1,38}$=22.007,$p< 0.001$; and length $F_{1,38}$=30.031, $p<0.001$; $F_{1,38}$=16.258, $P<0.001$) at 11 and 15 months respectively. A significant difference in mean weight was observed between the two kin groups at 11 months ($F_{1,38}$=5.804, $p<0.05$) and at 15 months ($F_{1,38}$=7.831, $p<0.05$) and in mean length at 11 months ($F_{1,38}$=4.762, $p<0.05$) and 15 months (F=$_{1,38}$4.341, p,0.05). In brook trout a significant difference in mean weight was observed only at 15 months ($F_{1,38}$ = 4.855, $p<0.05$). Mean length differed significantly at 11 months ($F_{1,38}$= 4.267, $p<0.05$) and 15 months ($F_{1,38}$= 8.668, p#0.05). A higher variance in both weight and standard length (Figure 2) was observed in the non-kin groups in Atlantic salmon and brook trout throughout the experiment. Variance in weight and length between kin and non-kin groups were significantly higher in the non-kin group from 4 months in brook trout (Figure 2). Similar differences were observed in the variance of Atlantic salmon length and weight starting from 8 months (Figure 2). However, no significant differences in length and weight variances were observed between kin group 1 and kin group 2.

## DISCUSSION

Due to lack of tank space we were unable to run adequate replicates for treatments in this study. The lack of replication compromises the generality of the results. However, as will be discussed, the results are in general agreement with previous studies. A higher and a less variable growth was observed in the kin tanks compared to those of non-kin group in both Atlantic salmon and brook trout. Agonistic interactions are known to decrease in the presence of kin or familiar individuals over a broad range of taxa from mammals (e.g. Fuller & Blaustein 1990; Ylonene and Viitala 1990) to sea anemones (Francis 1973; 1988). If individuals in a kin group cooperate among themselves, sharing resources and displaying less agonistic interaction, it may lower mortality and result in higher and less variable growth. The results of this study and those of Brown et al. (1996) are consistent with this prediction where in juveniles higher mean and lower variance in growth was observed in kin tanks.

The less variable growth of the kin groups compared to the non-kin group do not support the Beacham's (1989) and Quinn et al.'s (1994) finding that the growth of coho salmon reared in single families was more variable than the growth of the same families in tanks containing mixed families. Their findings support the prediction that more genetically similar individuals experience higher competition and are similarly efficient at obtaining resources, resulting in lower and more variable growth. In studies on anurans carried out to determine how relatedness influenced individual performance in growth and development produced conflicting results. In some species growth is reduced in kin groups compared to that of non-kin group. Conversely, growth is enhanced in some species while in other it is unaffected when individuals are reared with kin. In two species (*Rana arvalis* & *R. cascadae*) growth is reduced in kin groups, compared to that of in non-kin group (Shvarts & Pyastolova 1970; Hokit & Blaustein 1997). However, growth is enhanced in kin groups of *Pseudacris triseriata* (Smith 1990) and in *Rana sylvatica* (see Walls & Blaustein 1994). Results with *Bombina variegata* and *Bufo americanus* are variable with growth either enhanced, inhibited or unaffected when individuals are reared with kin. Tadpoles of *Bombina variegata* grew more in kin groups than in groups of non-kin (Jasienski 1988). However, later studies on the same species showed opposite results (Hokit & Blaustein 1994; 1997; Walls & Blaustein 1994).

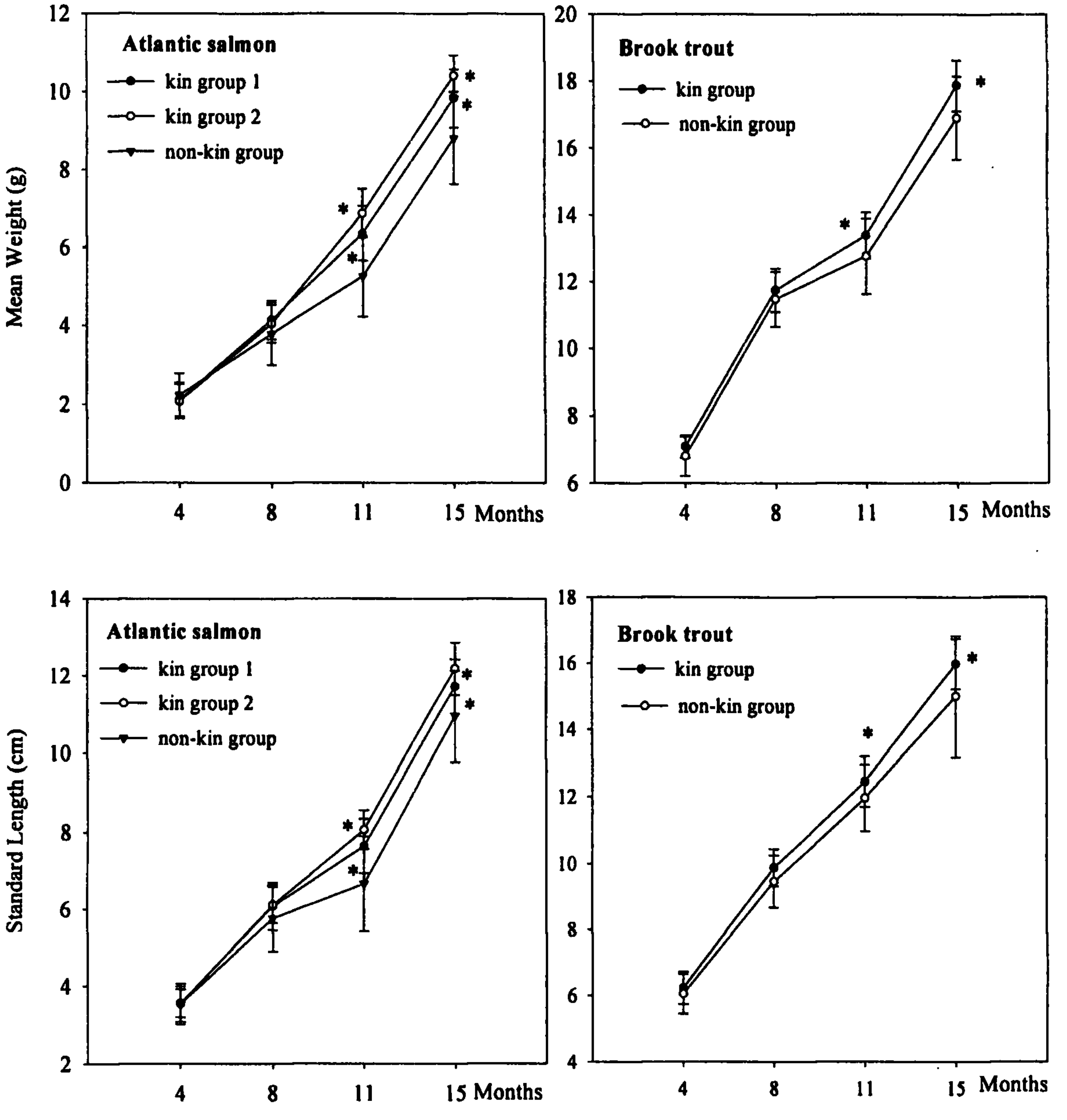


Figure 1 Mean standard length (cm) and mean weight (g) of juvenile Atlantic salmon and brook trout in kin and non-kin groups. Vertical bars = stadard deviation, n = 20, * denotes significant differences at $p<0.05$.

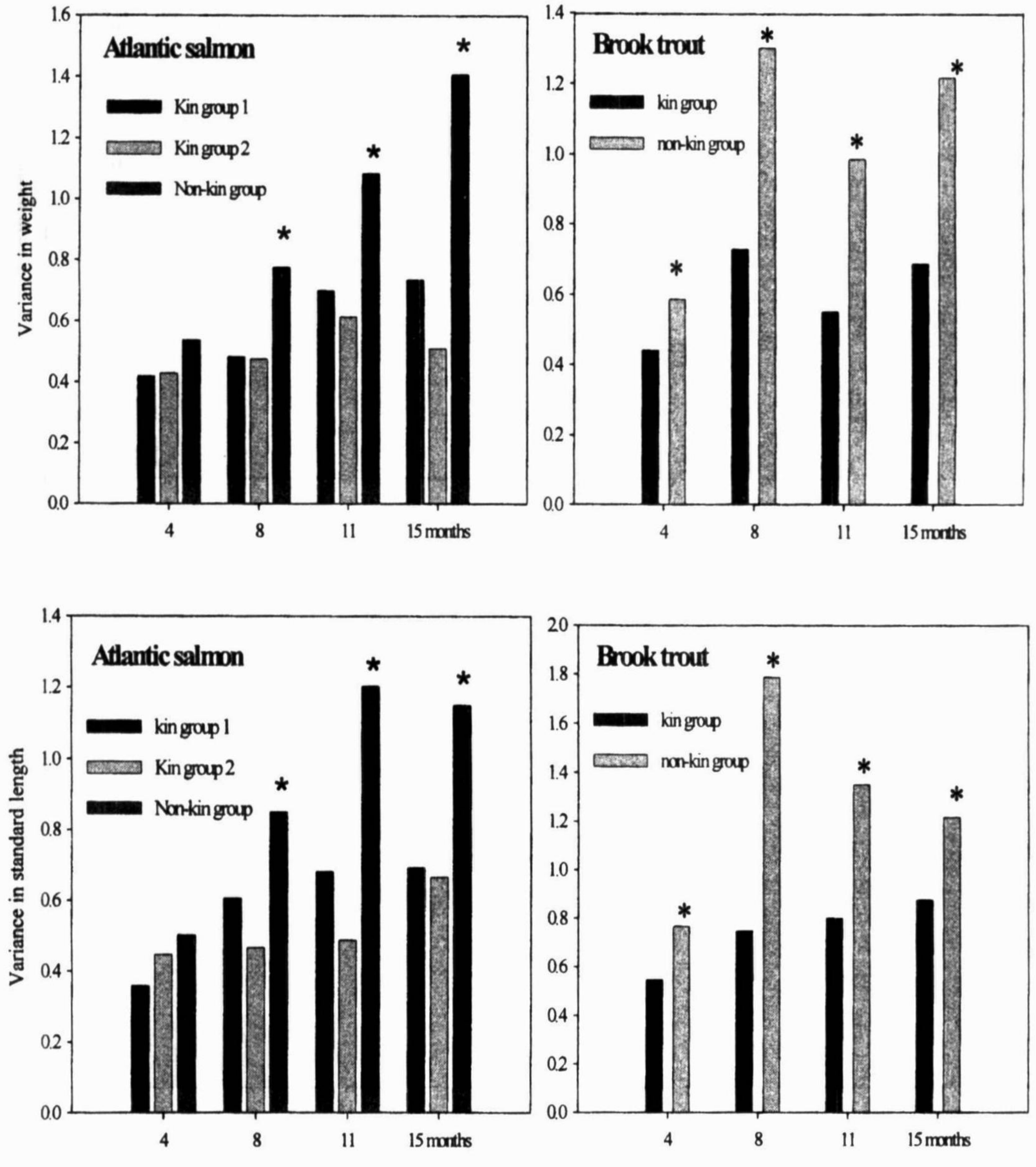


**Figure 2. Variance in weight and standard length for Atlantic salmon and brook trout in kin and non-kin groups. * denotes significant differences at $p< 0.05$.**

Anderson and Sabado (1999) investigated the effects of kinship on the growth of the kelp perch, *Brachyistius frenatus*, which do not exhibit overt aggressive or cooperative behavioural interactions. These authors revealed that average growth rates were similar between kin and non-kin treatments while the variation in growth increased initially in non-kin compared to kin. Based on their results they suggested a third alternative for the kinship effect on growth. These authors (1999) suggest that the equivalent rates of growth between groups of kin and non-kin and lower variation in growth among kin could simply reflect inherent genetic similarities in the absence of aggressive or cooperative behaviours. Absence of cooperative or agonistic behaviours in this species has given these authors an opportunity to explore the effect of genetic relatedness independent from effects due to behavioural interactions.

In an evaluation of the effect of kinship on growth performance, the best method to follow is to have the same kin group reared as one family and individuals from the same family reared communally with unrelated individuals (e.g. Beacham 1989; Quinn et al. 1994). In this method, the expression of the genetic variation could be eliminated. In this study and in the study of Brown et al. (1996) separate males and females were used to create kin and non-kin groups. This rearing method did not allow the analysis of the performance of individuals from one family under the two different social environments (i.e. with kin as neighbours and non-kin as neighbours). We cannot make a generalized conclusion that observed differences in this study are entirely due to the effect of social environment (i.e. kin being more cooperative and less aggressive in a kin group) because we did not have the data to compare the individuals from the same family reared under a non-kin environment. The observed differences in growth between kin and non-kin groups could also be attributed to the genetic differences of the different families. Moreover, aggressive defense of feeding territories is characteristic of stream dwelling salmonids including Atlantic salmon (Stradmeger & Thorpe 1987) and brook trout, but not in standing habitats (Grant & Noakes 1988; Bachman 1984). The constraints on movement imposed by the size and the shape of the tank may have led to less aggressive or less cooperative behaviour than might occur in a natural stream condition.

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