DO SALMON HATCHERIES SELECT FOR HIGH METABOLIC RATE? A MODEL AND EVIDENCE FROM OTOLITH MICROSTRUCTURE

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EXTENDED ABSTRACT ONLY- DO NOT CITE

I propose that domesticated behaviour in salmonids (National Research Council, 1996) is caused by selection for elevated metabolic rates in the hatchery environment. I hypothesize that fish with an innate tendency for a higher metabolic rate (MR) are favoured in hatcheries because they develop faster (Metcalfe et al., 1995) start exogenous feeding earlier, and are more aggressive competitors for food (Metcalfe et al., 1995). Thus they may grow faster than low-metabolic rate fish and have higher fitness because of advantages to a larger body size (Fig 1). In the more complex natural environment, several counteracting forces, such as optimal emergence time, elevated predation risk for more active fish and higher maintenance energy demands of high MR fish will stabilize the tendency for metabolic rate at a lower optimum than in the hatchery.

As an indirect test for differences in MR between domesticated and wild salmon populations, I compared the otolith dimensions of domesticated with wild masu salmon (*Oncorhynchus masou*) populations. Growth rate of the otolith in larval fish is a function of basal MR rather than somatic growth rate (Wright 1991). In salmon from different populations raised under identical conditions, the otolith size variation should reflect differences in MR at a given life stage life stage. I compared otoliths of swim-up fry from three populations of masu salmon, one wild, one sea-ranched, and one aquaculture (farmed), all fry being raised from eggs in the laboratory.

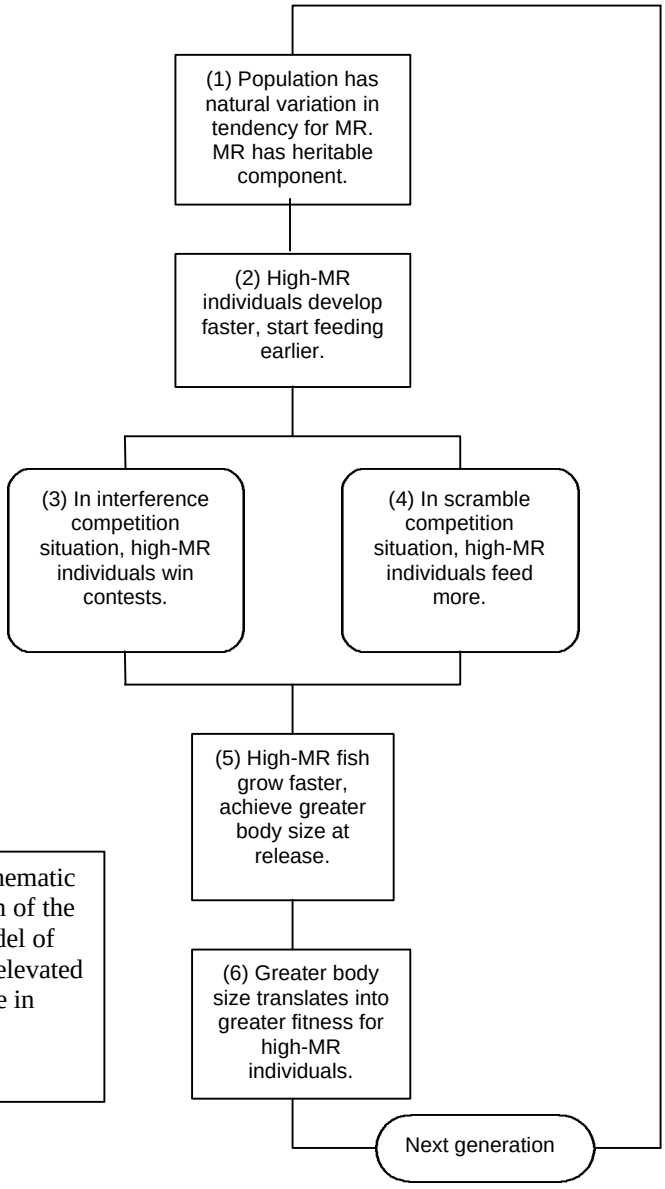

Figure 1. Schematic representation of the proposed model of selection for elevated metabolic rate in salmon

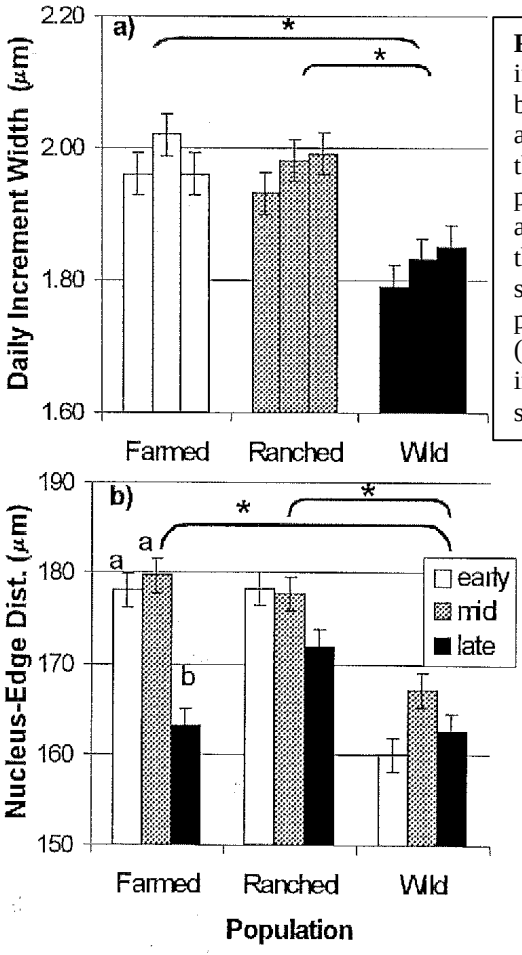

Figure 2. Mean daily otolith increment width (+/- SE) before swim-up (a), and mean age-adjusted distance from the closest nucleus to the posterior otolith edge (+/- SE) at time of fry swim-up (b) in three populations of masu salmon. Shown for each population are values for (from the left to right) early, intermediate ("mid"), and late swim-up fry.

Ninety swim-up fry each (equal numbers from "early", "mid" and "late" emergers) from the three masu salmon populations were sampled for otolith analysis. Two measurements were done on each sagitta : a) the distance between the nearest nucleus and the posterior edge and b) mean width of daily increments in an area formed in the time between hatching and swim-up.

As predicted, the mean increment width of wild fish was significantly smaller than that of the farmed (by 0.14 μm or 7.8 %) and sea-ranched fish (0.13 μm, 7 %) (Fig. 2 a). The mean swim-up date-adjusted distance between nucleus and

posterior edge in wild fish was 9.6 μm (5.8%) smaller than in farmed fish and 12.6 μm (7.7 %) smaller than in ranched fish (Fig. 2 b).

The prediction that early-swim-up fish within a population have relatively bigger otoliths (Metcalfe et al., 1995) was met in farmed fish only (Fig. 2 b). Because wild fish had a lower mean body weight, it was examined whether the smaller otolith dimensions of the wild fish may have been an effect of their smaller body size. Within any of the three populations, neither otolith increment width nor adjusted nucleus-edge distances were significantly correlated with body weight (all correlations $p > 0.1$).

The results from the otolith examination lend preliminary support to my hypothesis of selection for elevated MR through domestication. As predicted, wild fish had smaller otoliths dimensions than either of the two captively-bred populations. Considering the causal relationship between otolith growth and metabolic rate (Wright, 1991), it is likely that the wild fish in this study had smaller otoliths because of lower metabolic rates during egg and alevin development. The mean daily increment widths differed by about 7.5 % between the wild and domesticated populations, which would have been equivalent to an about 30 % difference in weight-specific oxygen respiration rate of resting fish in a different study (Yamamoto et al., 1998).

Further study using pairs of domesticated salmon and their ancestral wild stock are necessary to give conclusive evidence for the hypothesis of selection for high metabolic rates through domestication. Measuring the MR of hatchery and ancestral wild populations may become a way of judging the magnitude of past domestication selection and the effectiveness of new hatchery designs aimed at avoiding domestication selection.

References

Metcalfe, N.B., Taylor, A.C. and Thorpe, J.E. 1995. Metabolic rate, social status and life-history strategies in Atlantic salmon. Anim. Behav. 49: 431-436.

National Research Council. 1996. Upstream: salmon and society in the Pacific Northwest. National Academy Press, Washington, D.C.

Wright, P.J. 1991. The influence of metabolic rate on otolith increment width in Atlantic salmon parr Salmo salar L. J. Fish Biol. 38: 929-933.

Yamamoto, T., Ueda, H. and Higashi, S. 1998. Correlation among dominance status, metabolic rate and otolith size in masu salmon. J. Fish Biol. 52: 281-290.