

**LONG-TERM GROWTH AND ENERGY COSTS OF REDUCED
FOOD AVAILABILITY IN OVERWINTERING SALMON**

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EXTENDED ABSTRACT ONLY – DO NOT CITE

Delayed migrant Atlantic salmon (those that do *not* migrate to sea after their first year in fresh water) show a period of greatly suppressed appetite and growth during the winter known as the anorexic phase. The fish rely heavily on lipid reserves accumulated during the late summer and autumn as a primary source of winter energy. Bull *et al.* (1996) developed a state variable model to predict the daily foraging effort that would maximize over-winter survival of delayed migrant salmon. The model predicted that anorexia should only occur if sufficient, prior lipid accumulation takes place, and that if this were prevented then the salmon should continue to feed until their lipid reserves were normal for the time of year.

In order to test this prediction, we subjected delayed migrant salmon to a six-week period of reduced (weekly) food availability in Sept./Oct., and compared the food consumption, growth and lipid reserves of the food-deprived fish to daily-fed controls over the subsequent seven months (to April). Food consumption was measured by X-radiography (Morgan *et al.* 2000) and whole body lipid reserves (%) were calculated from a regression equation of lipid weight against body weight and length obtained from a separate, sacrificed, group of salmon ($r^2 = 0.935$, $P < 0.001$). The fish were then held together until August when sex, and the incidence of male maturity were determined.

At the end of the experimental treatment, the food-deprived fish were significantly smaller than the controls (Table 1). They also had significantly lower lipid reserves, but whilst larger fish carry proportionately more lipid, the size difference did not explain the difference in lipid. On the resumption of daily feeding, the food-deprived fish responded to their reduced lipid levels with a dramatic increase in food consumption. This compensatory response was sufficient to restore lipid reserves to control levels within two weeks. However, neither the weight nor length of the food-deprived fish returned to control values by December (Table 1).

Table 1. The effect of a six-week period of food deprivation on size and whole-body lipid reserves in delayed migrant salmon. *Indicates a value for food-deprived fish that is significantly different to that of controls ($P < 0.05$).

Measurement/time†		Controls	Food-deprived
Weight (g)	September	3.20 ± 0.11	2.94 ± 0.08
	October	3.77 ± 0.12	2.89 ± 0.09*
	December	4.05 ± 0.13	3.44 ± 0.11*
	April	7.05 ± 0.29	4.79 ± 0.23*
Lipid (%)	September	6.93 ± 0.09	7.07 ± 0.09
	October	7.03 ± 0.10	5.95 ± 0.14*
	December	6.61 ± 0.11	6.43 ± 0.10
	April	8.84 ± 0.16	7.07 ± 0.21*

† Experiment started September, ended April. October = immediately after food deprivation.

We had anticipated that, once any compensation for the temporary reduction in food availability was completed, the two groups of fish would show similar patterns of growth. However, two months after the experimental treatments, from December onwards, the performance of the two treatments began to diverge. The growth rates of the food-deprived fish fell below those of the

controls, so that the post-treatment size discrepancy between the two groups had increased by April (Table 1). The lipid reserves of food-deprived fish decreased from December to March whereas those of the control fish increased, so that by April, the lipid reserves of the controls were some 25% greater than those of the food-deprived fish (Table 1).

The two treatments had a similar proportion of female fish in August. However, only 48% of food-deprived males achieved maturity compared to 74% of the controls. Male maturation in non-migratory Atlantic salmon may be switched off if lipid reserves are not replenished during spring growth (Rowe *et al.* 1991). Maturation may begin as early as November (Simpson, 1993), but by that time the lipid levels of the food-deprived fish had recovered from the experimental treatment. It is therefore probable that the unexpected lipid deficit in the food-deprived fish was a direct cause of the reduced incidence of male maturation.

In conclusion, this study confirmed the prediction that anorexia in delayed migrant salmon would be delayed by a failure to accumulate sufficient lipid reserves in autumn. This delay would reduce the probability of later starvation (Bull *et al.* 1996) but would increase predation risk and could therefore lead to increased short-term mortality. Moreover, the temporary depletion of lipid reserves appears to have deferred, long-term costs. The suppressed growth of the food-deprived fish may cause migration to be postponed for a further year, while a significant decrease in mature males could reduce the reproductive success and subsequent recruitment in Atlantic salmon populations.

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References

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