PHYSIOLOGICAL EFFECTS OF BEHAVIOURAL INTERACTIONS IN ARTIFICIAL AND NATURAL ENVIRONMENTS

Katherine A. Sloman
University of Glasgow, Graham Kerr Building,
University of Glasgow, Scotland, G12 8QQ
Phone: (0141) 330 5985; Fax: (0141) 330 5971;
E-mail: 9707573s@udcf.gla.ac.uk

Kathleen M. Gilmour*, Neil B. Metcalfe and Alan C. Taylor
University of Glasgow, *Carleton University, Ottawa

EXTENDED ABSTRACT ONLY - DO NOT CITE

Social interactions and aggression among salmonid fish are known to induce stress responses, particularly in subordinate fish, and the physiological effects of these stress responses have implications for both aquaculture and fish in natural environments. The physiological responses exhibited by subordinate fish vary depending on the nature and extent of the social interaction and can also be influenced by the environment of the fish. Artificial environments generally elicit a larger stress response in the subordinate fish due to fish being held in close confinement. A time course study investigating the effects of social stress in rainbow trout, *Oncorhynchus mykiss*, and brown trout, *Salmo trutta*, confined in pairs demonstrated that after 48 h of confinement subordinate fish exhibited elevation of the stress hormone cortisol. In the more aggressive rainbow trout cortisol elevation was apparent after 4 h of confinement (Sloman *et al*., unpublished a), demonstrating that the amount of social interaction and aggression has an effect on the cortisol response and can vary between salmonid species.

An increase in stress may also cause an elevation of metabolism. When brown trout were confined in pairs, the subordinate fish showed a significant increase in standard metabolic rate (Sloman *et al*., unpublished b). The potential of the increases in blood plasma cortisol concentrations associated with subordinance, to elicit chloride cell proliferation in the gill epithelia was also investigated,

since artificial elevation of cortisol concentrations is known to induce proliferation of chloride cells. However, when trout were confined in pairs no chloride cell proliferation was observed, although cortisol elevation occurred in subordinates (Sloman *et al*., 2000a).

Dominance hierarchies do not always lead to stress responses in subordinates. In a study carried out under semi-natural conditions (in stream tanks), the formation of dominance hierarchies amongst groups of four brown trout did not elicit plasma cortisol elevation in subordinate fish. However, dominant fish still appeared to have a physiological advantage over subordinate fish in terms of growth; the growth of subordinates was significantly higher than in the other three ranks of fish (Sloman *et al*., 2000b; Fig. 1).

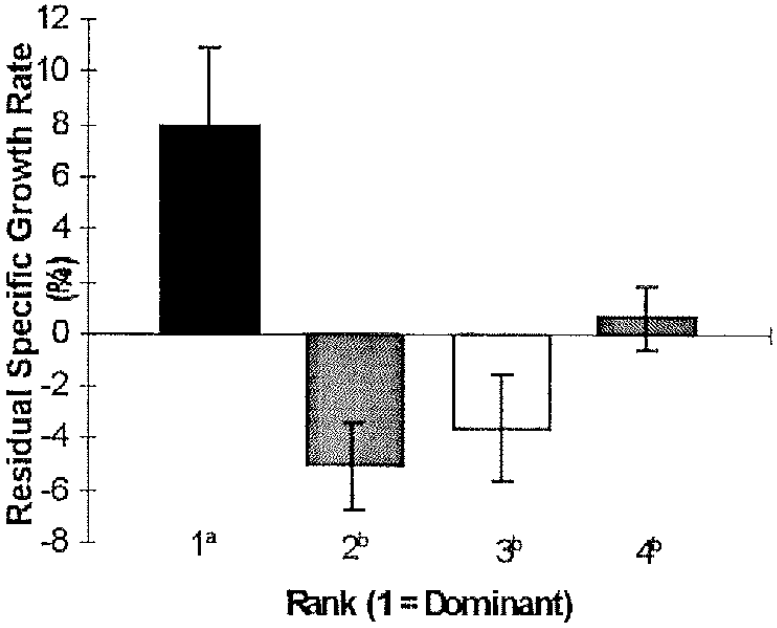

Figure 1: Residual specific growth rates (% change in weight per day) for four ranks of brown trout (1 = Dominant) taken from Sloman *et al*., (2000b). Those groups sharing the same letter are not significantly different from each other (ANOVA; Scheffé post-hoc test).

In this particular study, sub-dominant (second-ranking) fish had the lowest growth rate and it is suggested that these fish adopted a high cost/high return strategy, competing with the dominant fish and therefore expended more energy than the other two ranks of subordinate fish which adopted a low cost/low return strategy. Interestingly, sub-dominant fish demonstrated significantly higher numbers of chloride cells (Fig. 2), but whether the proliferation of chloride cells is related to changes in plasma cortisol concentrations remains unclear.

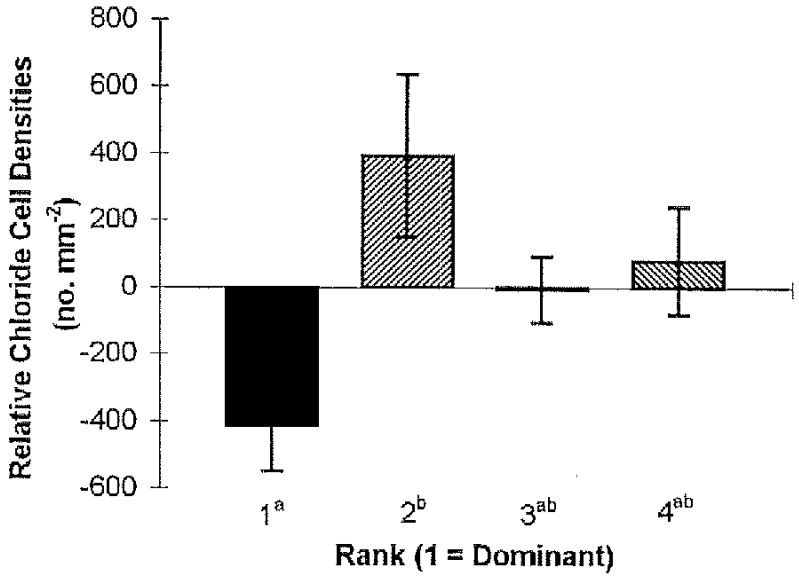

Figure 2: Relative chloride cells densities for four ranks of brown trout taken from Sloman *et al.*, (2000b). Those groups sharing the same letter are not significantly different from each other (ANOVA; Scheffé post-hoc test).

Further studies using semi-natural conditions investigated the effects of environmental perturbations on previously established dominance hierarchies (Sloman *et al*., unpublished c). The environmental perturbation of lowered water levels, simulating drought, was found to disrupt the dominance hierarchy and the social structure of the groups of four brown trout. The normal growth advantages gained by dominant fish under constant semi-natural conditions were lost, and all fish exhibited similar growth rates. No effects of the environmental perturbation on plasma cortisol concentrations were seen suggesting that (a) environmental perturbations may disrupt social hierarchies and (b) these perturbations are not necessarily stressful in themselves so the absence of a higher growth rate of dominant fish in the experimental groups was dependent on changes in social structure.

In conclusion, the physiological responses to social interaction and the formation of dominance hierarchies in salmonid fish are affected by the environment of the fish e.g. whether the environment is artificial or natural, and stable or subject to fluctuations. Known effects of social stress include decreases in growth rate and condition, and increases in plasma cortisol and standard metabolic rate. The potential of social stress to affect chloride cell proliferation is currently being investigated further.

References

Sloman, K.A., Gilmour, K. M., Metcalfe, N. B. and A. C. Taylor (2000a). Does socially-induced stress in rainbow trout (*Oncorhynchus mykiss* Walbaum) cause chloride cell proliferation? J. Fish Biol. 56: 725-738

Sloman, K.A., Gilmour, K. M., Taylor, A. C. and N. B. Metcalfe (2000b). Physiological effects of dominance hierarchies within groups of brown trout, *Salmo trutta*, held under simulated natural conditions. Fish Physiol. Biochem.

Sloman, K. A., Gilmour, K. M., Metcalfe, N. B. and A. C. Taylor (unpublished a). Socially-induced elevation of plasma cortisol concentrations in rainbow and brown trout.

Sloman, K. A., Motherwell, G., O'Connor, K. I. and A. C. Taylor (unpublished b). The effect of social stress on the standard metabolic rate (SMR) of brown trout, *Salmo trutta*.

Sloman, K. A., Taylor, A. C., Metcalfe, N. B. and K. M. Gilmour (unpublished c). Effects of an environmental perturbation on the behaviour and physiological function of brown trout, *Salmo trutta*.

Acknowledgements

KAS was in receipt of a NERC studentship whilst this research was being carried out. We would also like to thank Ms June Freel and Mr John Laurie for technical help.