BEHAVIORAL AND NEUROENDOCRINE CORRELATES

OF SOCIAL STRESS IN FISH

Svante Winberg
Evolutionary Biology Centre, Dept. Animal Developmment & Genetics,
Uppsala University, Norbyvägen 18A, SE-752 36 Uppsala, Sweden
Phone: +46-18-4712649 Fax: +46-18-4712683
e-mail: svante.winberg@devbiol.uu.se

Paul H. M. Balm
Department of Animal Physiology, Faculty of Science, University of Nijmegen
Toernooiveld 1, 6526 ED Nijmegen, The Netherlands

Erik Höglund
Evolutionary Biology Centre, Department of Limnology, Uppsala University
Norbyvägen 20, SE-752 36 Uppsala, Sweden

Øvind Øverli
Evolutionary Biology Centre, Dept. Animal Developmment & Genetics,
Uppsala University, Norbyvägen 18A, SE-752 36 Uppsala, Sweden

EXTENDED ABSTRACT ONLY – DO NOT CITE

Salmonid fish often develop strong dominance hierarchies, especially at juvenile life stages when they are highly aggressive and territorial in nature. Socially subordinate fish are characterized by a general behavioral inhibition, including suppressed aggressive behavior, an inhibition of appetite and feed intake, and lowered spontaneous locomotor activity (Øverli *et al*., 1998). In addition, subordinate fish usually display chronically elevated plasma levels of cortisol (Winberg and Lepage, 1998; Øverli *et al*. 1999).

Behavioral and neuroendocrine stress responses are to a large degree controlled and integrated by control mechanisms within the brain, and the central monoaminergic systems appear to play important roles in these control mechanisms. We have observed that escalated fights for social dominance in pairs of juvenile rainbow trout (*Oncorhynchus mykiss*) results in a rapid

activation of the norepinephric, dopaminergic and serotonergic systems in the brain, of both winners and losers, e.g. future dominant and subordinate pair members (Øverli *et al*., 1999). However, in the dominant fish brain monoaminergic activity as well as plasma cortisol levels rapidly returns to baseline levels following the settlement of the fight for social dominance, whereas in subordinates brain serotonergic activity and plasma cortisol levels remain elevated. Especially the stress-induced activation of the brain serotonergic systems shows very weak signs of habituation, and brain serotonergic activity remains elevated in subordinate fish even after long-term social interaction in established dominance hierarchies (Winberg and Nilsson, 1993).

Social subordination also results in a rapid and chronic elevation of pituitary pro-opiomelanocortin (POMC) mRNA levels in rainbow trout (Winberg and Lepage, 1998). In recent experiments we have shown that socially subordinate Arctic charr (*Salvelinus alpinus*) display an elevation in plasma levels of melanocytestimulating hormone (MSH) (Höglund *et al*., in press). In Arctic charr, social subordination also results in skin darkening, an effect that appears to be mediated by a MSH, and that may serve as a social signal decreasing aggressive behavior in established dominance hierarchies (Höglund *et al*., in press).

Serotonin (5-hydroxytryptamine, 5-HT) has been suggested to inhibit aggressive behavior, locomotor activity and feed intake, and also to stimulate the hypothalamic-pituitary-adrenocortical axis in mammals. We have obtained results demonstrating that 5-HT has similar effects in teleost fish, and that brain 5-HT may be involved in mediating both the behavioral and endocrine effects of social subordination in salmonids. In subordinate rainbow trout the ratio of 5-hydroxyindoleacetic acid (5-HIAA, the major 5-HT metabolite) to 5-HT in the hypothalamus, an index 5-HT activity, correlates with plasma levels of cortisol (Winberg and Lepage, 1998). Futher, 8-OH-DPAT, a specific 5-HT_{1A} agonist, elevates plasma levels of cortisol in cannulated rainbow trout in a dose dependent manner (Winberg *et al*., 1997). Using receptorautoradiography with ^{3}H-8-OH-DPAT as the radiol ligand we have been able to show that 5-HT_{1A} receptors are present in the rainbow trout brain, including the hypothalamus. The stress-induced elevation of plasma MSH, and thus skin darkening, may also, at least in part, be mediated by 5-HT. Plasma levels of MSH correlates with brain 5-HIAA/5-HT ratios (Höglund *et al*., in press), and 8-OH-DPAT (i.p.) induces skin darkening in Arctic charr.

Pharmacological stimulation of the brain 5-HT system inhibits spontaneous locomotor activity and general behavioral responsiveness in Arctic charr, whereas pharmacological inhibition of the brain 5-HT system has the opposite effects (Winberg and Nilsson, 1993). Serotonin is synthesised from the amino acid L-tryptophan (TRP), and the rate of 5-HT synthesis *in vivo* appears to be restricted by TRP availability in both fish and mammals. In a recent experiment we observed that dietary supplementation of TRP elevates brain 5-HT activity and suppresses aggressive behavior in juvenile rainbow trout.

In conclusion, our studies have shown that social subordination results in chronic stress, a stress that initially is related to losing aggressive interactions but that later on when the hierarchy is established seems to be more related to lack of control and the constant threat imposed by dominant fish. Socially subordinate fish are characterized by a chronic activation of the brain 5-HT system. This monoaminergic neurotransmitter system appears to play a key role in controlling and integrating behavioral and neuroendocrine stress responses. A stress-induced activation of the brain 5-HT system may mediate several other behavioural and physiological effects of social subordination in salmonid fish, e.g. activation of the hypothalamic-pituitary-interrenal axis, elevation of plasma MSH levels causing skin darkening, inhibition of aggressive behavior, and a general suppression of behavioral responsiveness to environmental stimuli.

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