Impact of stress on the welfare of rainbow trout (*Oncorhynchus mykiss*)

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Introduction

The welfare of farmed fish is causing increasing concern (Conte, 2004; North *et al*., 2006). Capture, handling, crowding, confinement and transport may affect the physiological stress responses and welfare of fish, with negative consequences on performance and disease resistance (Conte, 2004; Lefrancois *et al*., 2001). Recent studies have reported developments in welfare of teleosts by examining factors responsible for stress in rainbow trout (*Oncorhynchus mykiss*).

Discussion

North *et al*. (2006) studied the impact of stocking density on welfare by measuring a range of indicators in juvenile trout (n=100), housed in different densities (10, 40, 80 kg m^{-3}). Physiological indicators of welfare (such as plasma cortisol concentrations), growth and mortality were not significantly affected by stocking density. However, lower mean body condition and increased size variation were observed at lower densities. Size heterogeneity is an indicator of social environment within fish populations, suggesting competition among individuals. The formation and maintenance of hierarchies may become more difficult at higher stocking densities. Also, food supply is more defensible at low stocking densities, which would explain food acquisition disparity among individuals.

At low stocking densities, plasma cortisol concentrations increased and lysozyme activity was reduced. High cortisol level was attributed to increased size variability, dominance and establishment of territories at low densities. However, reports on the relationship between stocking densities and cortisol concentrations in trout are inconsistent (Jentoft *et al*., 2005; North *et al*., 2006). The authors suggest that the lower cortisol concentrations found at higher densities may be an adaptive response to chronic stress.

Fin condition was significantly affected by increasing densities, with fins being smaller and eroded. The exact cause remains unknown. Factors likely to contribute to poor fin condition include handling, poor water quality, pathogenic infections, abrasion against sides of rearing unit, aggressive conspecifics and accidental nipping during feeding. The extent of fin damage varied between different fin types, the pectoral fins being more susceptible to contact with tank surfaces. Asymmetric lesions suggest both stocking density and direction of flow contributed to damage, possibly related to sub-optimal position of fish in the tank. Stronger dominance hierarchies at lower densities illustrates that low density also has the potential to adversely affect trout welfare.

This study suggests that, provided water quality is good, rainbow trout can be reared at densities up to 80 kg m^{-3} without negative effect on growth or mortality. The presence of higher concentrations of cortisol, lower condition scores and lysozyme activity at low stocking densities suggests that there may be adverse effects on welfare at both low and high densities. This highlights the difficulty of specifying acceptable levels of welfare indicators.

Distinct behavioural and physiological stress-coping styles exist in teleost fish. Overli *et al*. (2006) aimed to establish whether sex differences in stress-coping style were present in rainbow trout. Immature fish (n=250) were used to study feeding and growth in a new environment, locomotor activity and plasma cortisol concentrations under acute stress, as well as the correlation between behavioural and endocrine measures.

A negative correlation was observed between locomotor and feeding activity following transfer to a novel environment. Despite previous studies reporting increased locomotor activity in salmonidae following cortisol treatment (Overli *et al*., 2002a), cortisol response did not differ between sexes. However, a significant sex variation in behavioural response to novelty and stress emerged despite there being no differences in glucocorticoid concentrations. Females resumed feeding faster than males and spent less time moving under stressful conditions. The reasons for such differences in coping styles could not be determined. It was suggested that females might be bolder, as boldness and motivation to feed are closely linked through common neuroendocrine signals. Alternatively, stress factors may wear off faster in females than in males. Lastly, variation in cognitive abilities is possible, since there is an association between stress responsiveness and learning.

The ability to cope with stress is essential for quality of life (Huntingford *et al*., 2006). Previously, lines of low-responsive rainbow trout have been generated by selection for consistently low post-stress cortisol concentrations. These fish would resume feeding faster after transport and had reduced locomotor response to territorial intrusion, despite displaying dominance over more responsive lines of trout (Overli *et al*., 2002b; 2005).

These studies suggest that selecting animals better equipped to cope with stressful conditions generated by intensive farming will improve welfare. This approach should be complimented by managemet strategies. Olsen *et al*. (2005) studied the effect of stress on trout intestinal functions (n=160). Acute stress caused gastrointestinal cellular alteration, mainly observed in midgut. Cortisol and lactate plasma concentrations were higher in food-deprived fish but glucose concentrations were lower. Stress did not cause tissue damage (measured by cellular leakage of transaminase enzyme into the blood), nor did it affect the lipid and fatty acid composition of intestinal membranes. This suggests minor free radical production due to stress in salmonids.

Ultra-structural damage was observed in the midgut but most changes were transient, returning to normal levels within 48 hours. Stress caused widening of tight junctions between enterocytes, with more damage experienced by fed fish. Intestinal paracellular permeability increased post-stress in food-deprived fish but was not observed in fed trout. The composition and level of adherent microbial population in the hindgut were reduced post-stress, while their levels increased in faeces. Substantial amounts of mucus seem to peel off from the intestinal mucosa following stress.

Increased intestinal paracellular permeability may be responsible for an increased susceptibility to bacterial infections as suggested by changes in level and composition of adherent intestine microbial biota following acute stress. This study suggested that active feeding might have a protective role, having implications for trout farming management and welfare since social stress is known to reduce fish appetite (Overli *et al*., 2002b).

Conclusions

Although it is still argued whether fish are sentient beings able to experience pain, fear and stress, an increased interest has developed in the welfare of farmed fish due to the ever-growing demands placed on aquaculture (Chandroo *et al*. 2004; Huntingford *et al*., 2006). Factors causing stress in teleosts are complex but greatly influence welfare.

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