Improvements in the Welfare of Atlantic Salmon (*Salmo salar*) in Aquaculture Systems through Advances in Husbandry Practices

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Introduction

Atlantic salmon is the most economically important farmed fish in Europe, especially in the coastal areas within the north, including Norway and Scotland (Stewart *et al*., 2012). In recent years, the issue of fish welfare in production systems such as Atlantic salmon farming, has become a topic of increasing concern and interest to the scientific community and the general public (Noble *et al*., 2012). Although there are scientific discrepancies about whether fish have cognitive capabilities and can respond physiologically to noxious stimuli, it is now widely accepted that fish can sense pain (Jones *et al*., 2012). As a result, production strategies for improving fish welfare, such as by changes in husbandry practices, are being researched and implemented (Noble *et al*., 2012). This paper examines the recent advances in husbandry practices within Atlantic salmon production and their welfare benefits to fish in aquaculture systems.

Discussion

In tank-based aquaculture systems such as those used in the freshwater smolt stage of Atlantic salmon production, elevated levels of ambient dissolved CO_2 can greatly compromise fish welfare. This increase in dissolved CO_2 occurs as a result of inefficient husbandry practices and monitoring (Noble *et al*., 2012). In a study to clarify this problem, Noble *et al*. (2012) modelled the welfare and bio-economical implications of deploying CO_2 stripping technology for Norwegian smolt production systems after quantifying the detrimental effects of increasing CO_2 levels on the Atlantic salmon smolts. The smolts were held in tanks (n=320 fish per tank) for 42 days prior to their seawater transfer and allocated one of four different levels of CO_2 (Noble *et al*., 2012). Smolt growth, feed conversion ratio (FCR) and mortality were measured to determine the effects of elevated CO_2 – a change in feeding behaviour in response to environmental stressors has been identified as an indicator of reduced welfare in fish (Martins et al., 2012). Stress imposed on the salmon in situations where its homeostasis is threatened, elicits a biological response through behavioural and physiological changes (Martins *et al*., 2012). Atlantic salmon showed increased growth and feeding efficiency at lower levels of ambient dissolved CO_2 compared to elevated levels, demonstrating stress reduction on the animal through improved feeding behaviour. Although CO_2 can be reduced through alternative methods, such as increasing specific water flow and reducing stocking density, CO_2 strippers directly impact fish welfare and are a practical option for farmers (Noble *et al*., 2012).

Another relevant advance in aquaculture husbandry practice is the change in feeding method to demand feeder systems that deliver food based on the current appetite of the fish. Stewart *et al*. (2012) investigated the welfare and economic advantages of changing from a fixed to a demand feeding regimen to reduce fin damage in Atlantic salmon smolt production in Scotland. Salmon smolts were held in six cages (each 61847±2620 fish) for 35 days; three groups were fed via demand feeders and three via automatic systems delivering food every 10 minutes. Dorsal fin damage is a reliable indicator of poor husbandry and welfare, due to the presence of nociceptors that enable fish to perceive pain (Cañon Jones *et al*., 2011). Fin erosion, as recorded by Stewart *et al*. (2012) when greater than 50% of tissue was eroded, was significantly lower in the demand feeder cages.

This result was confirmed by a study conducted by Jones *et al*. (2012), in which Atlantic salmon subjected to predictable feed delivery exhibited higher aggression, which can result in fin damage. These results demonstrate an improvement in the welfare of salmon smolts through decreasing injury caused by aggressive competition for resources and preventing susceptibility of pathogenic infection through damaged tissue (Stewart *et al*., 2012). The subjective measurement of dorsal fin damage was a major limitation of this study, however, as resource aggression was the likely cause of the fin damage. Studies have shown that an increase in dorsal fin biting leads to more severe fin damage in Atlantic salmon, supporting the measurement of fin erosion (Cañon Jones *et al*., 2011).

Prevention and control of disease in aquaculture systems is an important aspect of fish husbandry and welfare. Using modelling systems, Groner *et al*. (2013) investigated the effects of cleaner fish, such as the wrasse species, on sea lice (*Lepeophtheirus salmonis*) infestations of farmed Atlantic salmon in a variety of treatment scenarios. The model developed in this study incorporated parameters on sea lice, wrasse factors, chemical treatments and environmental effects, and these parameters were varied to simulate different scenarios on Atlantic salmon farms (Groner *et al*., 2013). The results of the simulations illustrated that wrasse can effectively control sea lice and the increase in wrasse densities dramatically reduced the number of chemical treatments required to control sea lice infestations.

As a result of reduced need for chemical treatments, stress on salmon decreased. Also reduced were environmental and human hazards from these chemicals. The findings of this study demonstrate the positive welfare implications of cleaner fish as a method of control, as they do not cause severe stress to salmon and reduce the effects of parasitic infection, such as morbidity and potential mortality (Groner *et al*., 2013). Although the use of experimental data, which could test the efficiency of utilising cleaner fish as pest management, was not incorporated into this model, wrasse species are used frequently in Atlantic salmon production in Norway, and previous studies have demonstrated their effectiveness in controlling sea lice (Torrissen *et al*., 2013).

Conclusion

The use of improved husbandry technologies and practices in aquaculture production systems, such as those outlined in the three studies, present promising advances in fish welfare and farm management. CO_2 stripping technology significantly improved feeding efficiency, and deployment of demand feeder systems additionally demonstrated welfare benefits through a reduction in fin damage. The effective use of wrasse in controlling sea lice reduced the requirement for chemical treatments, thereby reducing overall stress from treatments and infestations. Further research into fish welfare and advances in husbandry practice are essential to ensure that the wellbeing of fish is conserved in production systems.

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