

The Impact of Enrichment and Feed Stimulation on the Expression of Net Biting and Escape Behaviour in Atlantic Cod (*Gadus morhua*) and Post-escape Recapture Techniques

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Introduction

During the past five decades, aquaculture has been one of the fastest-growing animal-production sectors in the world (Subasinghe *et al.*, 2009). A constant problem faced by this industry is fish escaping from sea-based facilities. Escapees pose a significant environmental threat to wild populations as well as impacting yields and profitability. Although escapes have been reported for almost all cultured species (Jensen *et al.*, 2010), it is of particular importance to fisheries farming Atlantic cod (*Gadus morhua*). While fish farming in the North Atlantic is typically dominated by salmonids (Naylor *et al.*, 2005), Atlantic cod is also an important farmed species. Atlantic cod are more likely than salmonids to damage nets by biting, then escape via the holes created (Damsgård *et al.*, 2012). This paper examines three recent studies by Zimmerman *et al.* (2012), Damsgård *et al.* (2012) and Serra-Llinares *et al.* (2013) comparing the expression of net-biting behaviours in relation to feed stimulants and net enrichment, and assessing potential recapture techniques.

Discussion

The presence or absence of food stimulation may affect the tendency Atlantic cod have to interact with pen netting (Hansen *et al.*, 2008). Following the notion that well-fed fish have less motivation to escape than those that are starved, Zimmerman *et al.* (2012) examined factors that may mitigate the motivation of Atlantic cod to bite netting, namely feed availability and net enrichment. Four separate trials were conducted, each featuring either food or no food and with or without net enrichment. These combinations were randomly distributed among 20 netted cages in each of the trials. Each netted cage contained five cod and cod in the food cages were offered approximately 1% of their bodyweight in chopped herring daily. Net interactions by individual cod were observed daily via recordings from digital IP cameras. An analysis of the data showed that unfed cod interacted on average 7.5 times more per hour per fish than those that were fed. This figure was higher in those that were unfed in plain cages, indicating that hungry cod with no stimulation were more likely to explore the net in search of food and interact with it more frequently as a result.

Damsgård *et al.* (2012) sought to observe why and to what extent cod bite net walls in relation to feed stimulants. During 4 replicate multi-patch experiments, the cod were placed inside an enclosed tank that featured 6 net panels. Behavioural responses to feed stimulants were observed via underwater video surveillance before, during and after feed was placed outside the net panels. Behavioural event recording showed the greatest number of inspections of the net panel occurred during feed stimulation, which also served as a selection mechanism for net biting. By contrast, the absence of feed stimulants resulted in a significantly lower net inspection frequency and net biting. Both experiments were of short duration compared to commercial aquaculture and with considerably lower stocking densities, which have been shown in recent studies to impact Atlantic Cod movement (Ward *et al.*, 2012). These limitations may have affected the rate at which cod inspected and damaged nets through biting and further studies conducted in conditions truer to commercial aquaculture industries should be conducted to provide a sound basis for understanding this behaviour.

In addition to observing the effect of feed stimulation, Zimmerman *et al.* (2012) and Dansgård *et al.* (2012) simultaneously recorded the effects of net enrichment and net types, respectively, on net biting and escape behaviour, under the same experimental conditions as described earlier. Enriching a net cage with stimulating objects greatly reduced the frequency of net interactions. In particular, the use of hollow tubes stimulated the interest of the experimental cod, possibly because they provided a habitat similar to that preferred by wild populations of cod (Cote *et al.*, 2002). Dansgård *et al.* (2012) presented different findings that revealed alternative net repair types (no repair, long, frayed white thread, short, white thread and black thread) significantly impacted inspection rates and biting behaviour. The repairs made with black thread reflected the greatest biting damage followed by long

white frayed thread. Both sets of findings are encouraging, as they can be easily integrated into net enhancement programs at a relatively low cost in commercial enterprises (Zimmerman *et al.*, 2012).

The altered rearing environment of captive cod compared with wild populations has given rise to morphological, physiological and behavioural changes (Serra-Llinares *et al.*, 2013). These differences can be maladaptive when captive populations encounter wild populations (Bekkevold *et al.*, 2006). It is therefore important to minimise the likelihood of such interactions from occurring. Serra-Llinares *et al.* (2013) investigated the dispersal of escaped fish from commercial net cages as well as the efficiency of recapture methods. It was apparent that cod dispersed rapidly from the captive grounds and were more likely to be found on offshore littoral areas. The primary focus of this study, which was to investigate the post-escape dispersal of Atlantic cod, was achieved via acoustic telemetry. The efficacy of recapturing these fish was also assessed by releasing four groups of externally tagged cod to be captured either by cod pots, fyke nets or gill nets, with the fourth group serving as a long-term escape or control group. Only 1.73% of cod in this study were recaptured and no method of recapture was favoured. Studies such as this complement the work of Zimmerman *et al.* (2012) and Damsgård *et al.* (2012) as it provides a solid scientific basis from which management strategies can be devised for use at the post-escape stage.

Conclusion

Recent literature has made a valuable contribution in showing how an understanding of animal behaviour can be applied to solve a practical problem in the aquaculture industry. More specifically, these three studies highlight that slight alterations to captive sea cages can mitigate the expression of net biting and escape behaviour, and can be introduced into existing structures with relative ease and minimal cost. Further research in this area can aid in detailing the long-term effectiveness of the inclusion of cage enrichment and feed stimulants to captive cod fisheries around the world.

References

- Bekkevold, D., Hansen, M.M., Nielsen, E.E. (2006) Genetic impact of gadoid culture on wild fish populations: predictions, lessons from salmonids, and possibilities for minimizing adverse effects. *ICES Journal of Marine Science: Journal du Conseil*, 63, 198-208.
- Cote, D., Ollerhead, L.M.N., Gregory, R.S., Scruton, D.A., McKinley, R.S. (2002) Activity patterns of juvenile Atlantic cod (*Gadus morhua*) in Buckley Cove, Newfoundland. *Hydrobiologia*, 483, 121-127.
- Damsgård, B., Hoy, E., Uglem, I., Hedger, R.D., Izquierdo-Gomez, D., Bjørn, P.A. (2012) Net-biting and escape behaviour in farmed Atlantic cod (*Gadus morhua*): effects of feed stimulants and net traits. *Aquaculture Environment Interactions*, 3, 1-9.
- Hansen, L.A., Dale, T., Damsgård, B., Uglem, I., Aas, K., Bjørn, P.-A. (2008) Escape-related behaviour of Atlantic cod, *Gadus morhua*, in a simulated farm situation. *Aquaculture Research*, 40, 26-34.
- Jensen, Ø., Dempster, T., Thorstad, E.B., Uglem, I., Fredheim, A. (2010) Escapes of fishes from Norwegian sea-cage aquaculture: causes, consequences and prevention. *Aquaculture Environment Interactions*, 1, 71-83.
- Naylor, R., Hindar, K., Fleming, I.A., Goldberg, R., Williams, S., Volpe, J., Whoriskey, F., Eagle, J., Kelso, D., Mangel, M. (2005) Fugitive Salmon: Assessing the Risks of Escaped Fish from Net-Pen Aquaculture. *Bioscience*, 55, 427-437.
- Serra-Llinares, R.M., Nilsen, R., Uglem, I., Arechavala-Lopez, P.B.J., P.A., R., C., N. (2013) Post-escape dispersal of juvenile Atlantic cod (*Gadus morhua*) from Norwegian fish farms and their potential for recapture. *Aquaculture Environment Interactions*, 3, 107-116.
- Subasinghe, R., Soto, D., Jia, J. (2009) Global aquaculture and its role in sustainable development. *Reviews in Aquaculture*, 1, 2-9.

Ward, D., Føre, M., Howell, W.H., Watson, W. (2012) The Influence of Stocking Density on the Swimming Behavior of Adult Atlantic Cod, *Gadus morhua*, in a Near Shore Net Pen. *Journal of the World Aquaculture Society*, 43, 621-634.

Zimmerman, E.W., Purchase, C.F., Fleming, I.A. (2012) Reducing the incidence of net cage biting and the expression of escape-related behaviors in Atlantic cod (*Gadus morhua*) with feeding and cage enrichment. *Applied Animal Behaviour Science*, 141, 71-78.