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Social, stocking density and dietary effects on the failure of farmed cod *Gadus morhua*

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ABSTRACT

A large proportion of cod juveniles fail following transfer to sea cages from the hatchery. Failed cod take and then eject feed and are thin and emaciated fish of low weight compared with "normal" siblings. Failed fish comprised 70% of total mortalities and 10% of fish stocked in the first eight months of production on a cod farm in Scotland. Failed cod comprised from 0 to 8% of fish reared in twelve hatchery tanks over 3 months. These failed cod were graded from larger fish in five consecutive grades at four to six weekly intervals and, after being reared separately, over 90% of these fish were "recovered". No significant differences were found in food acceptance of six alternative diets and a standard marine commercial diet by failed cod. Smaller pellets or feed moistened in seawater were offered but this did not significantly increase the rate of feed acceptance. The effects of stocking density on the development of failed cod were assessed by comparing performance at densities of 0.2, 2 and 20 kg m^{-3}. Aggressive interaction was lowest at an intermediate stocking density of 2 kg m^{-3} and highest at a density of 20 kg m^{-3}. Fin nipping was concentrated on the first dorsal fin and was not significantly different between stocking densities, but the other dorsal fins, pectoral fins and tail were also attacked more frequently at the highest stocking density. It is concluded that failed cod can be recovered by grading from the main population and feeding these cod separately. Stocking densities in sea cages should initially be similar to hatchery levels and this may be achieved by holding the cod in small enclosures within the main net.

1. Introduction

Farming of Atlantic cod *Gadus morhua* has been a major development in Norway, Iceland, Scotland and Canada over the last ten years (Kjesbu et al., 2006). The farming of cod is likely to remain of interest, although the economics of cod farming have been difficult recently and there are still some technical issues to resolve to achieve sustainable production (Adoff, 2011). Technical developments include vaccines for diseases such as *Vibrio anguillarum* and atypical *Aeromonas salmonicida* (Bricknell et al., 2006) and control of early maturation which adversely affects growth rate (Taranger et al., 2006). A major economic issue for the industry in Scotland (British Marine Finfish Association, pers. comm.), Norway (Adoff, 2011; Hanche-Olsen and Nilsen, 2009) and Iceland (Kristmundsson et al., 2011) is a condition involving the failure of a high proportion of farmed cod following transfer from the hatchery to sea cages. There is no published information on this condition, possibly due to the relative infancy of the industry and commercial confidentiality. However, there are several industry reports (from former NoCatch Ltd Shetland, A. Bourhill, pers. comm; A. Young, Biomar, pers. comm., Adoff, 2011) of thin and underweight cod compared with "normal" fish and these failed fish represented a high percentage of fish stocked. Failed cod syndrome is also a widespread problem in Norway and the farmers often lose 20–40% of a group of cod within the first 6–8 weeks after transfer to sea cages (Fig. 1) (Hanche-Olsen and Nilsen, 2009).

The failed cod condition has not been formally defined. Histopathology samples were taken of failed cod at Vidlin Voe, Shetland (NoCatch Cod) but these did not reveal a clinical condition, with only anorexia being reported (Prof. H. Ferguson, company health report to NoCatch Cod, October 2004). However, the main feature of the condition is that soon after transfer from the hatchery to sea cages, the fish will take, then reject ('spit out'), formulated feed, even if known to be hungry (A. Bourhill, pers. comm.). The fish thereafter become poor growers, lose condition and probably become more susceptible to disease. The present work focussed first on the influence of food preferences and feeding behaviour of cod as failed cod were reported to ingest and then "spit out" feed pellets.

Failed cod syndrome may also be related to social structure and aggression within the cage population. Cod reared in commercial hatcheries are held at a relatively high density, e.g. in organic production up to 15 kg m^{-3} or up to 30–35 kg m^{-3} in standard systems. Under such conditions, the opportunity for individual fish to create territories is limited. However, when cod are transferred to sea cages of much larger volume, stocking densities can suddenly be reduced to around 2 kg m^{-3}. This may permit cod to establish territories and

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Fig. 1. Failed cod from a veterinary survey of cod in Nordland County, Norway. Photo supplied by Hanche-Olsen and Nilsen, pers. comm., September 2011.

potentially a pecking hierarchy, where the dominant fish might prevent or inhibit the smaller fish from feeding, leading to runting or "failed cod syndrome". The effects of different stocking densities on social hierarchy and interaction of juvenile cod were assessed as a possible initiator of the failed cod syndrome.

However, there are widely conflicting accounts of aggressive behaviour in cod. Hoglund et al. (2005) showed that juvenile cod are highly aggressive, whereas Salvanes and Hart (2000) did not find indicators of aggression nor territorial defence among juvenile cod competing for feed. Other experimental studies have shown that cod do not defend a feeding territory (van Duren and Glass, 1992), whereas wild juvenile cod have been observed to show territorial behaviour (Tupper and Boutilier, 1995). In contrast, there have been several other reports of feed deprivation and restricted feeding without evidence of typical aggression related fin damage (Foster et al., 1993; Hawkins et al., 1985). Other studies have shown that juvenile cod compete for food in a scrambling manner without physical aggression (Hart and Salvanes, 2000; Salvanes and Hart, 2000).

The purpose of the present study was to establish the extent of the failed cod condition, and the relative importance of feed type and consistency, and social and behavioural factors in influencing the development of failed cod through antagonistic behaviour. The value of recovering failed fish by segregation from the rest of the cod and feeding them separately was investigated further.

2. Materials and methods

2.1. Proportion of failed cod in total mortalities of juveniles in Scotland and Norway

The numbers of failed cod in Scotland in the first year of stocking in sea cages were obtained from stock records of the former company NoCatch Ltd, Shetland (A. Bourhill, pers. comm.). The company classified losses under six categories: Failed, deformities, predation, transport, *V. anguillarum* and unclassified. The cumulative mortality of cod juveniles under each of these categories was calculated as a percentage of total mortalities and as a percentage of the total stock. Data from Norway were sourced from a study by fish veterinarians of mortalities on five cod farms in Nordland County (Hanche-Olsen and Nilsen, 2009). Weekly mortality figures in the first year of the production cycle were classified under a more detailed scheme than in Shetland with nine headings but "failed cod" was a common identification in Norway and Shetland: Failed fish, cadevorosis, ulcers, mechanical trauma, predation, egg bound females, intestinal lesions, Atypical furunculosis, unclassified mortalities (unidentified).

2.2. Frequency of failed cod in hatchery tanks

An assessment was made of failed fish in hatchery tanks to determine if this mirrored the reported "failure" of cod in sea cages. The fish were stocked in 12 tanks of 1.5 diameter and 1 m depth, of 900 l water capacity. The flow rate was 5 l min^{-1}, temperature in the range 8 to 11 °C, and salinity varied from 32.2 to 33.1 ppt, aeration was provided and lighting of 1600 lx was continuous. The fish were feed twice each day to satiation with 3 mm Biomarine Pearl diet. 100 fish of 12 g mean weight were stocked in each tank. After 12 weeks all fish were removed from each tank, anaesthetised in 150 ppm phenoxyethanol (Ross and Ross, 2008), and measured to fork length (mm) and weight (g). The numbers of "failed cod" were recorded and these were classified as thin fish, of low weight, and with a relatively large head compared with the body. These features were not on a numeric scale but were instantly recognisable as "runt" fish by trained farm technicians and veterinarians (Figs. 1 and 2). These elements were quantified in the tank trials reported here in Section 3.2. and, in the farm situation, these fish were typical runt fish as immediately recognised as fish that were emaciated and did not feed. With the three elements of emaciation (over thin), low weight, and thus large head relative to body, categorisation of failed fish was unmistakable.

2.3. Recovery of failed fish by grading

Attempts were made to "recover" failed cod in isolation from larger fish and to determine whether they would accept feed. 39 failed fish were stocked in a 1.5 m diameter tank of 1300 l volume with a flow rate of 5 l min^{-1}. The temperature was in the range 8 to 12 °C, salinity varied from 32 to 34 ppt, and the fish were maintained in continuous light. The fish were fed 4 to 5 times each day with standard Biomar Pearl Marine diet of 2 mm pellet size. The feed composition is shown in Table 1. The measure of the trial was the number of fish that was recovered and identified by length and weight measurements. Fish that did not recover did not increase in weight from Time zero and in many cases weight declined further. Interaction between fish was recorded as fin nipping or "flight" response.

The trial continued for 6 weeks and then the fish were removed, anaesthetised in phenoxyethanol, the length and weight were measured, and the numbers of failed cod were recorded. This experiment was repeated on three further occasions with durations from 4 to 6 weeks by removing the recovered cod from the tank and repeating the trial with the remaining failed fish, while the recovered fish were transferred to stock tanks. Occasional fish were removed for internal examination but were replaced with failed fish of similar weight from stock tanks.

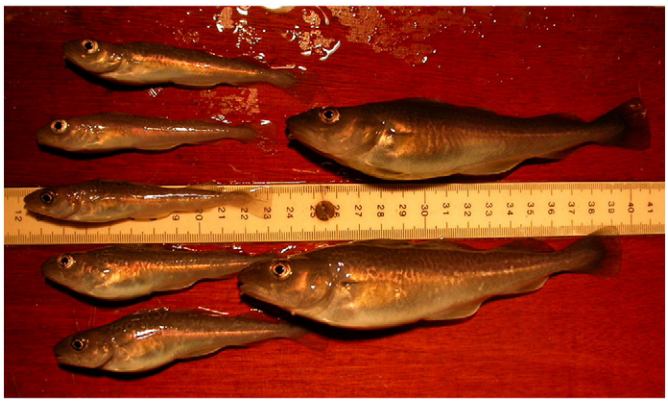

Fig. 2. Failed (mean weight 11 g) and normal cod (48 g) of the same age (250 days post hatch) from tank rearing.