Effects of water speed on lordosis & heart ventricle weight in cod

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Introduction

The intensive farming of Atlantic cod is a growing industry in several of the countries bordering the North Atlantic. One of the major obstacles in the intensive production of cod has been the high degree of malformation. This study addresses **lordosis**, a condition which encompasses the abnormal ventral curvature of the vertebral column—see Figure 1.

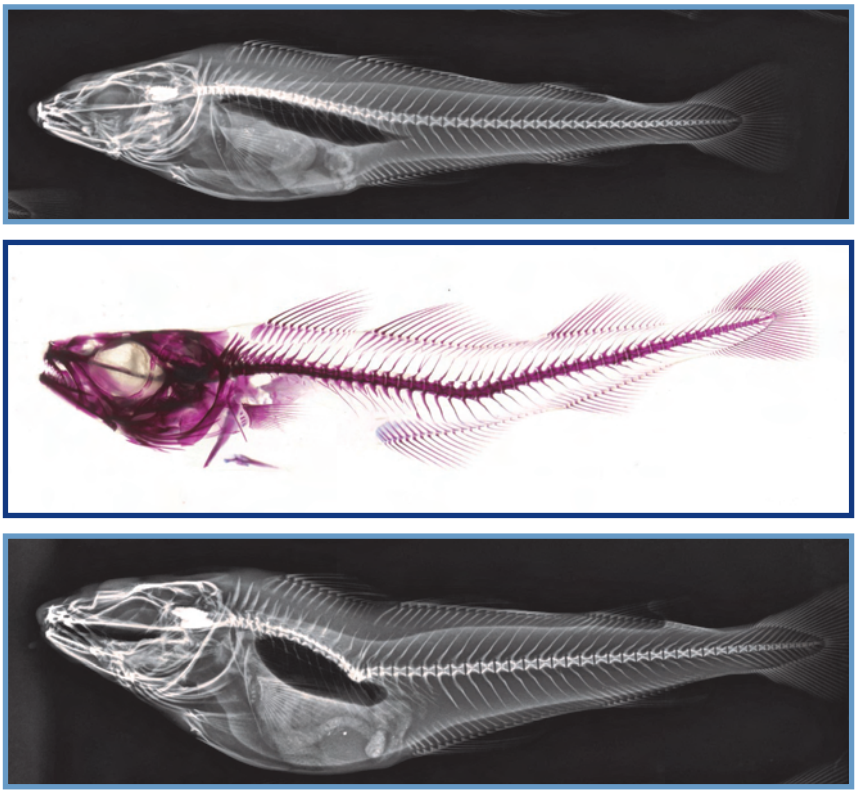

Figure 1. Cod juveniles (Gadus morhua) with Photos: Nofima Marin AS

a) normal vertebral column (radiographic image),

b) lordosis (Alizarine staining) and

c) severe lordosis (radiographic image).

The motivation for choosing this approach to establish causative factors of lordosis was based on the findings from some of the researchers, working within FINEFISH, and their experiences with sea bass and sea bream.

The combined effect of early rearing temperature and swimming speed of European seabass (*Dicentrarchus labrax*) was studied in the EU-funded project entitled "Optimisation of rearing conditions in sea bass for eliminated lordosis and improved musculoskeletal growth" (ORCIS— EU project QLRT-2000-01233).

Eggs and larvae of European seabass had been reared at either 15 or 20ºC—until metamorphosis. After metamorphosis, they were reared at the same temperature. The researchers found that lordosis was more frequent in fish from the 20ºC protocol, independent of the water current applied (Sfakianakis et al., 2006). Furthermore, they found a clear effect of water current velocity on lordosis development in populations coming from both developmental temperatures.

The objective of the present study was to test if high water speed would also induce lordosis in the skeleton of cod juveniles.

Experimental set-up

Three days prior to hatching, eggs from Atlantic cod (*Gadus morhua*) were disinfected and transferred to a 1200L tank where the eggs hatched and the cod larvae were grown until day 60 after hatching. The temperature at incubation was 6^{o}C and, from start feeding, this was increased to 12^{o}C—during a period of 7.5 weeks. The cod juveniles were then transferred to eight 90L tanks.

At start of the experiment (day 60 post hatch), four tanks were rigged so that there was minimal water speed in the tanks (control) and the fish had arbitrary swimming directions. Four other tanks were rigged so that the fish was able to swim against the water current between 5 and 10 sec., before the fish changed behaviour to again swim against the current (Figure 2).

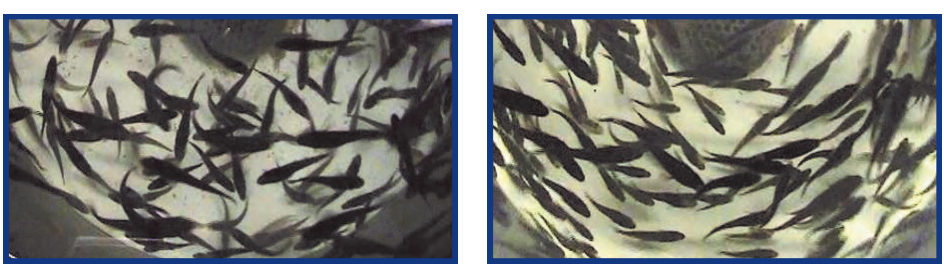

Figure 2. Atlantic cod juveniles in control tanks with arbitrary swimming directions (left image) and high water speed tanks and cod swimming against the current (right image). Photos: Nofima Marin AS

The water speed was based on swimming behaviour, which was checked and regulated twice a week . This meant that with increasing swimming ability, an increased water speed was applied.

The water exchange rates were the same in all eight tanks.

At 4 and 13g average size, 50 and 130 fish, respectively, were sampled for radiographic images. At the last sampling, the heart ventricle was dissected from the fish and weighed for calculation of the cardiosomatic index (CSI= (weight of cardiac ventricle*100/body weight), as an indicator of cardiac development.

Results

The weights of the cod at the end of the experimental period of four months were the same for the control and the high water speed treatments (13.1 g). Water speed did however have an effect on the fish total length, where the cod from the high water speed treatment (22.9 cm) were longer than the control treatment (20.8 cm).

As a consequence, the condition factor differed between the treatments, being highest in the control treatment.

The weight of the heart ventricle was higher in the cod from the high water speed (0,019 g) treatment than the control (0,024 g), and also the calculated cardio somatic index.

There was a higher incidence of lordosis in cod at 13 gram size reared with a high water speed than low water speed (control), and a higher incidence of lordosis at 13 than at 4 gram size within treatment (Figure 3).

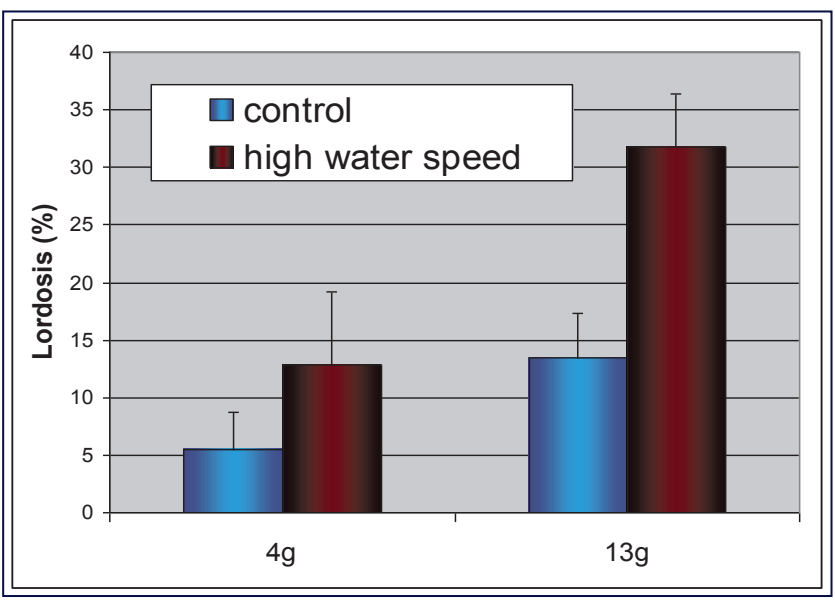

Figure 3. Incidence of lordosis in Atlantic cod (*Gadus morhua*) at 4 and 13 grams size (radiographic evaluation) reared with low water speed (control) or high water speed.

The vertebra in the centre of the lordosis axis break was calculated (average of all fish that were diagnosed with lordosis), and this was vertebrae number 18 counted from the cranial end.

Normal fish were randomly selected and the angle was measured from the centre point of vertebrae number 18 and four vertebrae towards the cranial and caudal ends.

Similarly, the angle from the lordotic centre in fish with lordosis was measured.

The average backbone angle was 174 and 143 degrees of normal and lordotic cod, respectively.

Neither platyspondyli, fusions, nor axis deviations in the neck of the cod were affected by high water speed.

Conclusions/practical recommendations

The systems used for cod rearing are partly based on knowledge and experience obtained from the salmon and the sea bass/bream industries. This knowledge transfer has given a head start for the development of the intensive cod aquaculture industry. Nonetheless, such transfer of knowledge from other species not only has advantages but, also, limitations.

It is common in studies of the Mediterranean fish species to differentiate between pre-haemal and haemal lordosis since these seem to have different causal factors.

The pre-haemal lordosis is associated with the lack of a functional swim bladder, and is thought to be an effect of a compensatory swimming behaviour due to a lack of buoyancy (Chatain 1994; Chatain and Dewavrin, 1989). The cod in the present study had no problem with non-inflated swim bladder or pre-haemal lordosis.

Haemal lordosis is attributed to the swimming effort of sea bass *Dicentrarchus labrax* juveniles and of red sea bream *Pagrus major* with inflated swimbladder (Divanach et al. 1997; Kihara et al., 2002).

An effect of early developmental temperature on the severity of deformity, both in respect to the angle of the lordosis and the number of affected vertebrae, was found by Sfakinanakis et al. (2006) in *Dicentrarchus labrax*. From the same experiment, the allometric studies revealed that an inappropriate force results in vertebral adaptations in the form of lordosis (Kranenbarg et al., 2005).

Similarly to the studies made on sea bass, the present study shows that high water speed induced lordosis in cod.

Lordosis appeared in the present study at a higher degree at 13g than at 4g size,. Thus it is likely that lordosis can be induced at quite a late developmental stage (i.e. after 4g size). It may also be that ‘damage’ made at an early stage manifests itself at a later stage.

The main reason for having a high water speed is to increase self cleaning of the fish tanks. Therefore, the safe water current velocity at the various life stages of cod should be tested further , since self cleaning in the tanks strongly reduces the labour needed for manual tank cleaning , the stress that this may cause on the fish and improves the tank water quality.

Increased exercise is one of several long term environmental parameters that are known to alter the fish cardiac physiology and anatomy (Gamperl and Farrell, 2004). In their review, the hypothesis is put forward that training-induced cardiac growth occurs predominantly in the compact myocardium, receiving oxygen-rich coronary arterial blood. The increased CSI found in the present study is likely to be an effect of increased exercise/swimming activity in the tanks with high water speed.

It is concluded that high water speed in the rearing tanks induces lordosis, reduced condition factor and increased cardio somatic index in Atlantic cod juveniles.

Therefore, swimming speed must be controlled through the control of water speed in tanks for juvenile Atlantic cod. Until further knowledge is available, water speed should be reduced as much as possible while allowing for the water speed that is required for obtaining the self-cleaning properties desired in the tanks.

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