Best Management Practice - Cod (*Gadus morhua* L.)

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1. Introduction

The Intensive farming of cod (Figure 1) is still a young industry that has had a very rapid growth. One of the major obstacles has been the high degree of malformation within the young livestock. In order to improve the sustainability and profitability of the cod farming industry, the hatcheries aim to produce robust cod juveniles, with low levels of deformities, good growth capacities, and to achieve these characteristics with a high degree of predictability. This BMP has been tested to achieve this and is based on the following procedural components:

- Low temperature on the brood stock during egg production
- Low temperature during the egg stage
- Disinfection of eggs after fertilisation and before hatching
- A moderate pace of temperature increase during the larval stage
- Sufficient water treatment
- Good tank hygiene
- Careful handling and slow moving water
- Fresh live feed organisms

Figure 1: Juveniles of Atlantic cod of +/-15 grams Photo: Nofima Marin AS

2. General remarks

Several studies, both on cod and Atlantic halibut, have shown that better growth and larval development are obtained when the larvae are fed zooplankton harvested from the sea as opposed to feeding *Artemia* and/or rotifers (Næss et al., 1995; Shields et al. 1999).

The specific cause(s) for these superior results, however, has/have still not been ascertained.

The temperature and feeding regime presented here is quite conservative compared to that used by several cod hatcheries. The idea is that, because rotifers and *Artemia* have a nutritional inadequacy in supporting the same growth as that obtained with wild-caught zooplankton, growth should not be stressed at this life stage where so many organs are forming and become functional. Thus, the regime presented below allows a slow development that secures, as much as possible, that the requirements of the larvae are best met, thereby reducing malformation risk and eventual negative impact(s) on later life stages.

Other important factors in reducing deformities for cod larvae, which are discussed in this Best Management Practice, are

- brood stock management
- handling
- water treatment
- water speed
- tank hygiene

This production protocol has been optimised for use by personnel working at the research units at Nofima Marin Sunndalsøra Research Station.

The use of this protocol has resulted in the production of cod juveniles that have low levels of deformities, about 3% at 20g size.

Furthermore, the fish grew similar or better than the information presented in the table of specific growth rates (SGR) provided by BioMar (2008).

3. Some aspects of broodstock management

Broodstock temperature

The earliest steps in the embryonic development are dependant and driven by maternal factors deposited in the oocyte during oogenesis. Very little is known about how these maternal factors influence the embryonic and larval development. However, it is known that exposing cold water broodstock to elevated temperatures affects the reproductive endocrinology of fish (Van der Kraak and Pankhurst, 1997), resulting in increased abnormal cell cleavage in early embryonic stages and to reduced survival (Tveiten et al., 2000, 2001).

It is thus important that the temperature is low and stable during oogenesis and spawning. Normal temperature for cod broodstock is a maximum of 6°C.

Spawning

The most common way of obtaining the cod eggs for production is by communal spawning of broodstock (see Figure 2) and the collection of eggs from the water surface using specially-designed egg collectors.

It is important that the egg collector is designed so that all eggs get an ample supply of well oxygenated sea water and are not damaged mechanically .

Another method used is to strip the eggs and the milt from the broodfish, followed by fertilisation. This technique is used by the professional breeding companies since they need to maintain control of the ancestral history and, of course, it can be used if there are special qualities that one wants to cross in the process.

In any case, it is very important to keep a high focus on hygiene and not to stress the broodstock.

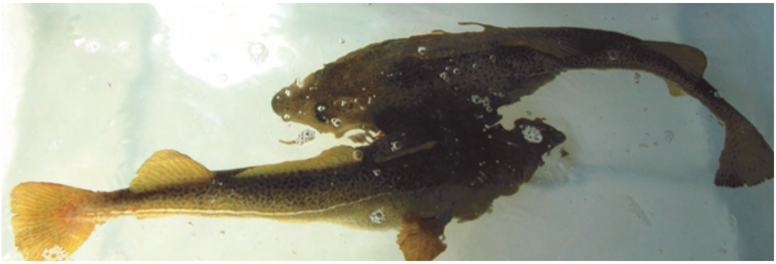

Figure 2: Broodstock of Atlantic cod Photo: Nofima Marin AS

Egg disinfection

A recent study shows that

- one disinfection of the newly fertilised eggs and
- repeated two days prior to hatching

were able to prevent the vertical transfer of the bacteria *Francisella noatunensis* from broodstock to eggs (Midtlyng et al. 2009).

The disinfectant used was glutaraldehyde (25% glutaraldehyde, 8 ml per 10 L sea water, for a duration of 9 minutes).

This disinfection will also remove other microorganisms, and the bacterial load at hatching will be less.

4. Sea water treatment

Temperature

Temperature controls the speed of many biological processes, such as growth and other developmental processes in fish larvae (see separate section on temperature).

Experiments have shown that a constant temperature of 6°C at the egg stage (see Figure 3 below) followed by a gradual increase from 6° to 12° C during a 6 week period, raising the temperature by one degree per week (Figure 4), results in cod larvae with few malformations *(for more information see the section on temperature effects*).

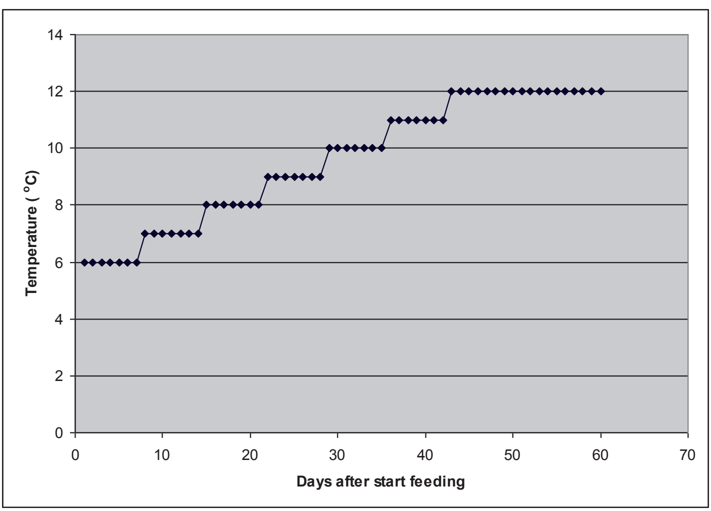

Figure 3. The control temperature regime from start feeding (day 0) used at the Nofima Marin Research station at Sunndalsøra.

Water exchange/water flow

An ample supply of water is important in order to keep the level of dissolved gasses and excretory products within the biological levels for good growth and welfare of the fish larvae.

An unnecessary high rate of water exchange may be expensive if the water is temperature regulated, and also algae and live feed may be removed from the tank too fast.

A too low water exchange may result in poor tank hygiene and an accumulation of live food organisms with a reduced nutritional status.

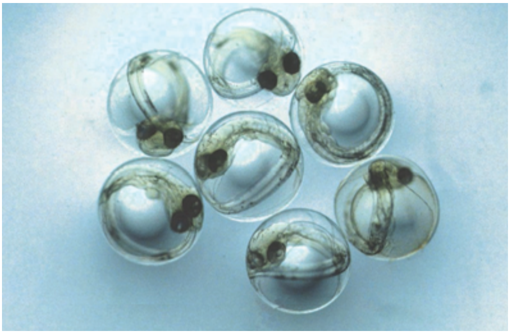

Figure 4: Eggs of Atlantic cod, prior to hatching.
Photo Nofima Marin AS

At an initial larval density of 150 larvae per liltre, a tank water exchange rate —before hatching - of 10 to15 times per day works well BUT it is important to reduce the flow when the first signs of hatching appear. The preference is that one day prior to expected hatching exchange rate is reduced to the same level as used during the start feeding with rotifers— this is about 7 times (exchanges) per day.

However, one should consider increasing the flow up to 10 exchanges per day if there is a reduced O_2 level during the *Artemia* feeding period.

During weaning: 10 exchanges per day is recommended.

After weaning the flow is to be regulated according to the O_2 levels in the tanks.

Filtration, protein skimming, degassing and UV

Depending on the quality of the intake water, there are several methods that can be used to treat the water. Most cod hatcheries are based on flow-through (no recirculation) and it is common to filter the intake water to various degrees, depending on the life stages.

The technique used at the research station, and also common in the cod culturing industry, is to filter the sea water to 1 µm during the egg, hatching and often also the start feeding stages.

It is also common to use a protein skimmer, with or without ozone, to remove particles, a vacuum degasser, eventually with O_2 addition for adjusting the dissolved gas saturation, and UV radiation before the water enters the fish tanks.

As the fish grows, the required amount of water increases substantially and the fish is also more robust. The level of water treatment, and type of treatment needed changes and is seasonally dependent.

At the research station we commonly use 10 µm filtered sea water in the formulated feed phase, and continuously evaluate whether the sea water needs to be oxygenated.

Oxygen saturation

One study has been done that showed a positive effect on growth in cod raised in hyperoxic conditions (140 to 150% saturation) compared to cod raised in normoxic conditions (85 to 95% saturation) (Helland et al., unpublished data).

The fish from the hyperoxic tanks had a larger ventricle (heart) size, and it appeared that hyperoxia was not a causative factor for lordosis.

More studies are needed however before any safe conclusions on tank oxygen level can be made. Until further studies are done, the tank oxygen level should be adjusted to just below 100% saturation in the outlet.

Nitrogen saturation

Even a small supersaturation of nitrogen has a strong impact on cod larvae and juveniles.

The larvae will position themselves in the upper or lower areas of the tank and the appetite will be strongly reduced.

In case of higher nitrogen saturation the cod larvae and juveniles will die.

Total gas saturation must be checked regularly, and it is important to be very careful in mixing two water sources of different temperatures.

In case of N_2 super saturation all the sea water or a part of the water can be vacuum degassed, preferably with addition of oxygen. If a part of the total water flow is vacuum degassed make sure that the water is well mixed before it enters the fish tanks.

5. Tank rigging

Tank water speed/water velocity

Resent research shows that high water speed in the tanks induces lordosis in cod *(see section on abiotic factors, water speed for more information).*

One way to regulate the water speed is by regulating the water inlet. There are water inlet systems that have been specially developed to reduce the water speed.

Another technique is to reduce the water speed by adjusting the positioning and shape of the water inlet.

The water speed should be kept to a minimum during the egg, larval and early juvenile stages. However, it is very important also to maintain good tank hygiene, and the minimum water speed necessary to facilitate a good tank environment ought to be set for each rearing facility.

Surface skimmers

Surface skimmers are to be used from the start of rotifer feeding until weaning. It is important that any eventual bio-film on the water surface is broken for the cod larvae to be able to fill the swim bladder with air.

Aeration

Use an aeration rod or a centre aeration ring from egg transfer until weaning so as to keep the eggs, larvae and the live feed organisms in the water column.

Use only sufficient aeration, aeration that is too strong may easily damage the larvae and malformation or mortality may occur.

Light

A pilot study has been done showing that light regimes (e.g. light:dark, 18:6) or the use of a single light source on the tank edge had no effect on skeletal deformities (Lein et al., unpublished data).

However, growth rates were reduced when introducing a night period, and weight was more affected than length. Growth was also reduced by the single light source.

Until further information is available, it is recommended to use standard ceiling light 24h a day.

This will also help to maintain good tank hygiene, rapid spotting of filamentous bacteria and facilitates good observation conditions of the state of the cod larvae and juveniles.

Algae

The addition of algae in the diet of Atlantic halibut larvae (*Hippoglossus hippoglossus* L.) has been shown to have a positive effect on feeding incidence, survival and growth rates during *Artemia* feeding.

No direct nutritional value of the algae on the halibut larvae was found (Naas et al. 1992), but it appears that these positive effects may be linked to factors such as turbidity and effects on the light regime, and also the eventual leaking of feed attractants like free amino acids.

Most cod hatcheries use algae paste that has been mixed with sea-water and then added to the tanks. Normally this is done three to four times a day, resulting in clearing of the tank water in some periods during the day facilitating tank cleaning and observation.

6. Feeding regime

Live feed phase

Cod larvae are start fed when the yolk sac is almost empty (3 or 4 days after hatching). The following feeding regime is currently the control protocol used at the research station (Figure 5).

The cod larvae should be fed solely on rotifers until day 25 (4 rotifers per ml).

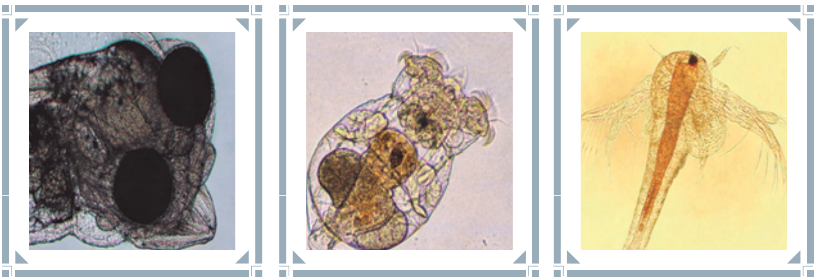

Figure 5. Atlantic cod larvae at start feeding (left), *Brachionus spp.* rotifer (middle) and *Artemia franciscana* (right) Photo: Nofima Marin AS

It is important to observe the appetite and adjust the feeding strength accordingly.

It is important to remember that old prey have a lower nutritional level that fresh prey, so avoid congestion of rotifers in the tank. Also, think about tank hygiene. After day 25, the cod larvae are co-fed rotifers and *Artemia* 50/50 (2 rotifers and 2 *Artemia* per ml), and after day 32 they are fed only *Artemia* (4 per ml) for one week.

Weaning phase

After day 39, co-feed *Artemia* and formulated feed for 1 week, during which the amount of *Artemia* is gradually reduced and the amount of formulated feed is increased.

Do look at the larvae regularly to check that they are eating the formulated feed.

Growth expectancy

In 2008 ,Nofima Marin produced cod families for MarineBreed, a commercial breeding company in Norway (F2 generation). The growth of these families has been followed for more than one year from 1.4 gram size, and the SGR is similar or above that of the BioMar SGR table of 2008. The fish have been given commercial diets and have been reared at ambient temperature.

Bjørnsson et al (2007) made a growth model for cod, showing the effects of temperature and body weight on growth rate. These models are based on wild fish, while most Norwegian hatcheries use fish from one of the two breeding programs. This growth model tends to underestimate the growth obtained in some of the cod hatcheries.

7. Concluding remarks

For all animals, there are biological constraints to physical development and crossing these limits may lead to malformation, malfunction, and may even be lethal.

In the rearing of cold water marine fish larvae, the mortality rate is still high and the predictability of results is low.

This implies that the production is on, or crossing, the biological tolerance limits. With the rather easy measures described in this BMP for Atlantic cod, one remains within the biological limits that we know of today for the prevention of malformation .

Development of the Best Management Practice is, however, a continuous process, where new technology, new feeds etc.. would necessitate an ongoing revision.

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