Available online at www.sciencedirect.com
ScienceDirect
Aquaculture 268 (2007) 188–194
Aquaculture
www.elsevier.com/locate/aqua-online

Cod juvenile production: Research and commercial developments

Grethe Rosenlund [a,*], Ólafur Halldórsson [b,1]

[a] *Skretting Aquaculture Research Centre AS, P.O.Box 48, N-4001 Stavanger, Norway*
[b] *Marine Harvest, Cold Water Marine Species, Kollsnes Næringspark, N-5337 Rong, Norway*

Abstract

Atlantic cod (*Gadus morhua*) has been a new candidate for aquaculture for some decades in countries around the North Atlantic Ocean. Greatest interest in developing a cod farming industry is found in Norway, Canada and the United Kingdom as well as in Iceland and the USA (north east). Modern hatchery methods for cod using cultivated plankton such as rotifers and *Artemia* were first described in 1984, but it took more than 15 years of dedicated research and development before these efforts now are being translated into up scaled hatchery protocols. Protocols for keeping reproductive stocks of Atlantic cod under different photoperiods have been established resulting in year around production of fertilised eggs. Hatcheries commonly keep 3–5 different stocks to achieve this. The relationship between brood stock nutrition, external cues and reproductive performance is largely unknown and should be studied further. Cod larvae have a very high growth potential (>20% day^{-1}), they are aggressive feeders and can be cannibalistic if food availability is sub optimal. Both temperature and light are found to influence growth in larval cod. Research has addressed cod larval nutrition, both qualitative and quantitative requirements. Also, development of feeds and feeding strategies that would allow early weaning onto inert diets has been a primary objective in cod juvenile production research. Using a diet designed to support larval requirements, weaning can start from 15–20 days post hatch. This strategy has resulted in satisfactory growth and survival without use of *Artemia*, thus reducing the dependency on live feeds. Huge variation in survival and a high incidence of deformities have been reported in hatchery-reared cod juveniles. These observations have been ascribed partly to unfavourable environmental conditions (gas super-saturation) and the problem has to a large extent been solved. Methods to produce large numbers of cod juveniles have been implemented in several Atlantic countries in recent years, and present hatchery capacities can support an annual production of several hundred thousand tons of farmed cod. Common practices in cod hatcheries are presented and future perspectives on cod juvenile production are discussed.

Keywords: *Gadus morhua*; Juvenile production; Feeding; Environmental conditions; Commercial applications

1. Introduction

During the last 30 years there has been a steady decline in the landings of cod from the Atlantic (FAOSTAT at www.fao.org). This together with the successful development of the salmon farming industry in the same area has created an interest for developing commercial farming of cod. The first attempts to develop cod farming was based on fattening of small wild caught fish (Canada, Iceland and Norway) and in Norway also on juveniles produced in natural enclosures on natural zooplankton. However, the instability and lack of predictability in the supply of juveniles, limited the developments.

Production of cod larvae using natural plankton was known in Norway already from 1886 (Hognestad, 1984),

* Corresponding author. Tel.: +47 5188 5514; fax: +47 5188 5501.
E-mail address: grethe.rosenlund@skretting.com (G. Rosenlund).
[1] Present address: University of Akureyri, P.O.Box 244, IS-602 Akureyri, Iceland.

0044-8486/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.aquaculture.2007.04.040

but for nearly 100 years only yolk sac larvae were produced for stock enhancement purposes. Similar release programs were also running in the USA and Canada (Solemdal et al., 1984), but their effect on the cod populations is questioned.

Modern hatchery methods for cod using cultivated plankton such as rotifers and *Artemia* were first described around 1990 (Howell, 1984; Rosenlund et al., 1993). However, the economic environment in the North Atlantic farming industry coupled with the temporary come back in the cod stocks in a period after 1990, slowed down the commercialisation process and it was not until around 2000 that this process again gained speed. In the meantime research programmes related to cod farming were running in many countries, UK, USA, Canada, Iceland and Norway being the most important ones. Supported by the successful developments in the Mediterranean production of marine species, which demonstrated that a predictable year around production of high quality juveniles is a prerequisite for developing a farming industry, a major goal for the research on cod has been to establish good protocols for season independent juvenile production. A more extensive presentation of all aspects related to production of cod and other cold-water fish is found in Moksness et al. (2004).

As for other marine species, juvenile production of cod is a rather complex process where eggs or larvae and food represent the input to the process and juveniles the output. The success of this process can be measured as survival, growth and quality of the juveniles.

A number of environmental factors like water quality, temperature and light are known to affect the process and are therefore necessary to optimise in order to improve the outcome. This paper summarises research important for establishing hatchery methods for cod juvenile production and how research results lately have been translated into commercial developments.

2. Egg availability and quality

Environmental cues like for instance temperature and photoperiod influence the endogenous rhythms resulting in synchronous spawning. Norberg et al. (2004) demonstrated that in cod, photoperiod is of overriding importance as spawning shifted in concordance with photoperiod changes despite significant seasonal variations in temperature. Based on this, protocols for keeping reproductive stocks of Atlantic cod under different photoperiods have been established resulting in year around production of fertilised eggs (Pavlov et al., 2004). Hatcheries typically keep 3–5 different stocks to achieve this. However, there are indications that juvenile production from photoperiod-manipulated brood stock is not optimal compared to normal spring spawning cod. One common observation is that the spawning period is less synchronised, and there is a tendency that males terminate spawning before the females. The reasons for this are not known, but external cues other than photoperiod may improve synchronisation. In Atlantic salmon (*Salmo salar*) it is documented that temperature has such an effect (Taranger et al., 2003).

Brood stock nutrition is another factor known to determine spawning results (Izquierdo et al., 2001) and impoverishment of the brood stock over time due to suboptimal nutrition is of great concern to the industry. Several studies (Kjesbu et al., 1991; Karlsen et al., 1995) have shown that in cod, feed intake during gonadal growth affects fecundity rather than egg quality. However, compared to juvenile fish, brood stock appears to have specific requirements for certain fatty acids and vitamins (Almansa et al., 1999; Bruce et al., 1999; Dabrowski and Ciereszko, 2001; Ishizaki et al., 2001; Izquierdo et al., 2001). Variation in egg quality has influenced production results in Norway in recent years, particularly from off-season populations. The relationship between brood stock nutrition, external cues and reproductive performance is an area that needs further research especially in stocks that will be used in several spawning seasons.

The majority of cod juveniles produced so far come from wild brood stock kept for a shorter time in captivity. However, breeding programs have started in most countries involved in cod farming. Breeding traits include growth, delayed time for first sexual maturation and health related parameters. It is expected that selective breeding will contribute to better productivity in cod farming and fish that are better suited for various environmental conditions.

3. Importance of food

Fish larvae have an incredible growth potential during early life stages. At a given temperature profile, Finn et al. (2002) found that cod larvae increased their body weight about 2000 times within the first 50 days of life. Thus, it is not surprising that starvation at any point during the larval phase has a very negative effect on growth and survival (Jordaan and Brown, 2003). Both the nutritional composition of the food as well as the availability of the food particles is important for larval performance.