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Aquaculture Association of Canada

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avril/April 2002 (102-1)

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Cover: Haddock larvae and juvenile hatched and reared at the Marine Fish Culture Facility at the Biological Station in St. Andrews, New Brunswick. Top photo: Hatching larva emerging from the egg. Middle photo: Pre-metamorphic larva, 20 days post-hatch, with rotifers in its gut. Bottom photo: Juvenile haddock, 47 days post-hatch, being fed Cyclop-eese ™, a replacement for *Artemia*. The orange coloration in the gut is the Cyclop-eese ™. [Photos by Steve Neil and Rick Rideout; photocomposition and editing by D.E. Aiken]

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From the Guest Editor

Progress in Cod Farming: Research to Commercialisation

Proceedings of a special session held at Aquaculture Canada 2001, in Halifax, NS

There is a high level of interest both within Canada and internationally on cod aquaculture. In the past year alone, there has been significant discussion on cod farming on listservers such as Aqua-L, in articles in trade publications in Canada, the United States, and abroad, and in research papers in aquaculture-related journals. Many of the discussions and articles have highlighted the fact that market demand for cod far exceeds the supply. Thus, a significant opportunity exists for the development of a cod aquaculture industry, as catches from the commercial fishery have been greatly depressed for the past decade.

Thus, convening a special session on cod culture at the Aquaculture Canada 2001 conference in Halifax was a timely event in the development of cod aquaculture in Canada. The session focussed on several key areas: larviculture, nutrition, health, grow-out and ranching, harvesting quality, and marketing. Most of the speakers invited to present papers in the session have contributed to these proceedings.

The key developments in the evolution of the cod culture industry in Norway are highlighted by Grethe Adoff. Larviculture and hatchery production in Newfoundland and New Hampshire are discussed by Joe Brown and Nicholas King. Santosh Lall presents the current status of cod nutrition, Harold Murphy discusses cod ranching, Michelle Thompson highlights the impact of harvesting practices on flesh quality, and Chris Frantsi discusses the development of haddock culture in the Canadian Maritimes, a marine white-fleshed finfish with many similarities to cod.

Progress is being made in cod culture in Canada. Several key cod research and development programs are underway, a commercial hatchery is being built in Newfoundland, hatchery-reared juveniles are being grown in sea cages, and sea ranching continues to develop and expand. Hopefully, the special session held at Aquaculture Canada 2001 and these proceedings will contribute towards the ongoing progress.

The session speakers and proceedings were sponsored by the Canadian Centre for Fisheries Innovation, an important organisation that supports the development of key sectors of the Canadian aquaculture industry. I thank Marc Kielley and Joe Brown for their assistance in organising and chairing the session.

— G. Jay Parsons

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CANADIAN CENTRE FOR FISHERIES INNOVATION

The Aquaculture Association of Canada acknowledges the Canadian Centre for Fisheries Innovation (CCFI) for funding the Special Session on Cod Culture held at Aquaculture Canada 2002 and the publication of the proceedings.

Development of Atlantic Cod Larviculture in Newfoundland

Joseph A. Brown and V. Puvanendran

Cod farming is not new to Atlantic Canada; small cod taken in the commerical fishery were grown in pens in Newfoundland in the mid 1980s. However, the moratorium imposed on the wild fishery in 1992 prohibited the capture of small cod, so interest developed in the hatchery production of cod for grow-out in sea pens. The "egg to plate" approach to cod aquaculture requires that hatchery production protocols be improved and scaled up to commercial levels. Over the years, our laboratory at the Ocean Sciences Centre has conducted research aimed at optimising the hatchery production of cod. The research has involved the cod farming industry and has depended on the industry to identify "bottlenecks" in production. We have conducted research on a number of factors critical to hatchery production and, most recently, have examined the performance of different stocks of cod under farming conditions. This paper reviews the research that has been conducted and presents updated protocols for the hatchery production of Atlantic cod.

Introduction

Interest in the intensive production of Atlantic cod, *Gadus morhua*, has increased dramatically over the past couple of years. As with most instances of efforts to develop new species for aquaculture, the renewed interest in cod has been driven primarily by market considerations.[1] The market for fresh cod has improved due to the fact that about 60% of the major world fish resources are mature or senescent[2] and the North Atlantic cod fisheries are either in decline or being fished to their limit. The outlook is for a continued scarcity of wild cod. As a result, there is a supply imbalance and very strong demand for cod, which has placed upward pressure on cod prices in Europe and the United States, especially for high quality fresh cod. This situation has made the intensive culture of cod feasible from an economic perspective. In addition, intensive production of cod has become more feasible as research in Canada, Norway, and Scotland has resulted in improved production protocols and in increased numbers of juveniles being produced. The hatchery production of cod has been underway in Norway for awhile and small numbers of cod are being produced in Scotland, Newfoundland (Canada), and New Hampshire (USA).

In Newfoundland, two approaches to cod aquaculture have been taken: seasonal on-growing of wild "trap" cod caught by fishermen (in trap nets) and grown for 5 to 6 months, and full-cycle or "egg to plate" cod aquaculture. In the mid 1980s, a private company in Newfoundland established sites for the ongrowing of trap cod and trained hundreds of Newfoundland fishermen in cod growout techniques. Development of this business was hampered by the onset of the cod moratorium. A private company initiated research on full-cycle cod aquaculture in 1993, during the moritorium, and operated a cod hatchery that unfortunately was lost to fire.

With the recent resurrection of small cod quotas, the past three years has seen a resurgence of interest in the ongrowing of trap cod. A small group of fishermen have been successfully catching, holding and growing cod to double their initial size on a seasonal basis. Market acceptance has been good for this product but harvesting and processing techniques still require refinement. At the same time, research is being conducted on the hatchery production of cod in Newfoundland and in 2001 it is likely that a pilot-scale project will result in the production of between 75,000 and 100,000 cod juveniles for cage trails. This production has benefitted from research conducted on cod larviculture over the past 10 years in Newfoundland and elsewhere, which has resulted in the development of basic hatchery production protocols.

In the rest of this paper, we outline differences among cod populations in the northwest Atlantic (NWA) and what this means for intensive production. We then present research that has been conducted in Newfoundland on cod larviculture protocols and how the results of this research have improved production efficiencies.

Biological Differences among Cod Populations

Atlantic cod is a widely distributed species, extending from northern Arctic waters to as far south as Georges Bank and the Celtic Sea. Genetic differences among the various NWA stocks were reviewed by Ruzzante et al.[3] Genetic differences in growth among the NWA stocks have been reported by Hunt von Herbing et al.[4] and Purchase and Brown.[5,6]

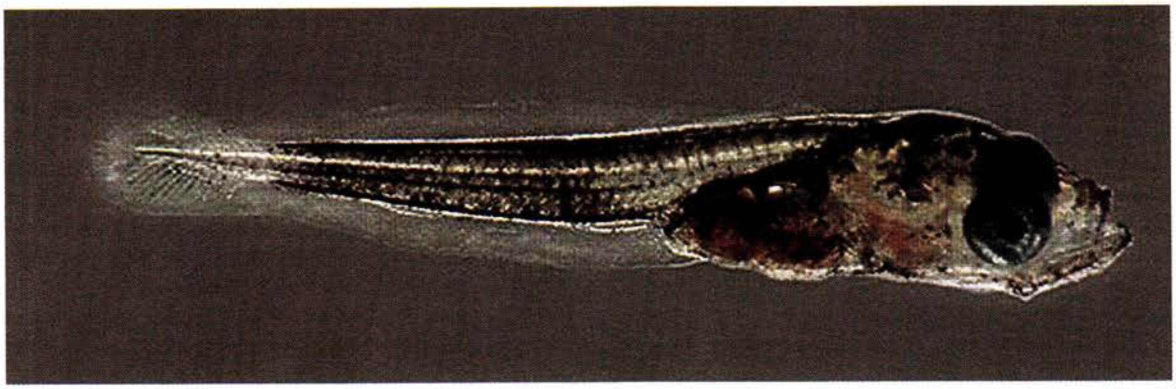
Puvanendran and Brown[7] conducted the first behavioural study documenting stock differences in foraging behaviour in relation to light intensity for NWA stocks. Larvae were found to grow and survive best under the light intensity which most closely resembled the local conditions from which they originated. At least two independent studies have found that under culture conditions cod from the Grand Banks outperform cod from the more southern areas of Nova Scotia and Maine.[4-6] The implications of these results for aquaculture are that the response of individuals from different populations to environmental factors such as temperature and light may vary between populations.

Research on Intensive Cod Production in Newfoundland

Interest in the intensive production of cod began shortly after the 1993 total moratorium on fishing the northern cod stock (NAFO Divisions 3JKL). The development of production protocols for culture of a new species is a process that takes many years. However, because of the existence of established production protocols for marine species in Europe, the process can be shortened by "borrowing" techniques developed for warm-water species and adapting them to the cold-water rearing of cod.

Using an appropriate prey density during larviculture is critical for a number of reasons. Marine fish larvae have evolved specific foraging strategies under intense selection pressure in the sea. Mortality is extremely high during the larval stage of marine fish[8] and it is widely held that starvation is a major contributor to the high mortality.[9] Thus, it is important for larval survival and growth that optimal prey densities be determined. Another reason for determining the best prey density is that producing live feed is an expensive process and wasting live feed is not economical. Determining prey densities at which larval performance is maximised reduces waste and cost. Light is another critical factor in the culture of cod larvae and work by Puvanendran and Brown[7] provides the background for the current research on the effect of light. The results from a series of studies on prey density[10] and light intensity[11] indicate that cod larvae perform best with a prey density of at least 4000 prey/L, a 24-h photoperiod, and a light intensity of 2400 lux. Using this information, and adjusting the production protocols accordingly, has resulted in a dramatic improvement in the growth rate of cod larvae. The size of larvae at approximately 5 weeks of age post-hatch has increased over 50% between 1993 and 2001 (13.5 mm vs. 8.5 mm). This is a dramatic increase and is primarily due to adjustments made in rearing protocols as a result of new information generated from research.

Over the past five years, production protocols have been put in place for cod larvae. These protocols are based on research results or have been "borrowed" from work on other marine species. The work to date, and modifications made to the protocol during the scale up to commercial level has resulted in a fairly complete rearing protocol, which forms the basis of hatchery production in Newfoundland. Work is still



Two-week-old cod larvae capturing a live rotifer (Adrian Jordaan photo).

required to “fine tune” this protocol with regard to changes in certain parameters (i.e., light intensity, photoperiod) that need to be made as the cod larvae develop. However, this protocol forms a good foundation from which to begin commercial-scale production of cod in Newfoundland.

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Experience and Prospects of Norwegian Cod Farming

Grethe Adoff, Finn Christian Skjennum and Rolf Engelsen

Cod is the only species thought to have the same potential for large volume fish farming as salmon and rainbow trout. There is the potential to produce more than 500,000 tonnes of cod per year in Norway alone, far surpassing the wild catch. Large-scale production of cod juveniles started in the mid 1980s at the Austevoll research station and continued with the interest of a few commercial companies until the beginning of the 1990s. Annual production was between 100 and 600 tonnes. In recent years, juvenile production has occurred mainly at research stations and small-scale commercial farms and has become gradually more intensive. Cod Culture Norway (CCN) is one of the largest juvenile farms in Norway and is currently under construction.The first stage has a production capacity of 3 million juveniles using sea bream technology adapted to cod. The production potential is 30 million juveniles.Total juvenile production in 2000 in Norway was 500,000 among 4 farms (2 intensive, 1 semi-intensive, and 1 extensive). Expected production in 2001 is 1 million juveniles. There are plans for 10 intensive production facilities within the next 5 years, but it is unlikely that all of them will be built. There are currently more than 200 applications for ongrowing concessions (leases), but the government will not give concessions without a contract for the purchase of juveniles. The Norwegian Government is promising more money for research and development over the next years, but Norwegian investors are likely to lose in competition with those in European Union countries where investment grants of 40% are obtainable.

Historic Development of Cod Aquaculture

In order to understand Norwegian cod farming today, it is necessary to look at its history and how it started. Norway has a long tradition, not only for cod fishing, but for culturing cod as well. Early experiments were done by the Norwegian biologist G.O. Dannevig who showed that cod would easily spawn in captivity.[(1)] The main purpose of his experiments was to enhance wild stocks and prior to 1971 between 20 and 400 million newly-hatched larvae were released into the sea each year. In the 1970s, trials on the extensive production of juvenile cod started in a lagoon adjacent to the Institute of Marine Research in Austevoll; 75,000 juveniles were produced in 1983. This started interest in cod as an aquaculture species and for the next few years both private industry and research institutions were eager to develop cod into commercial production. The Norwegian coastline has many lagoons and bays, which in the spring and summer produce an abundance of wild zooplankton, considered to be ideal conditions for the extensive farming of cod juveniles.

Juvenile Production

Extensive method

Several private companies started developing the extensive method of culturing cod juveniles in lagoons between 1987 and 1991. They made a considerable financial investment to improve methods for producing large numbers of juveniles, maintain uniform production, and achieve control over environmental conditions. The main goal was to develop strategies to provide sufficient live food for the larvae throughout the season. Eggs (or newly hatched larvae) were released in the lagoon when the production of plankton was most suitable for the larvae. After the release of larvae, management of the lagoon required a lot of attention. Growth and survival of larvae was closely monitored and the pond was fertilised to maintain plankton production. The overall success was not as good as expected and the results were unpredictable.

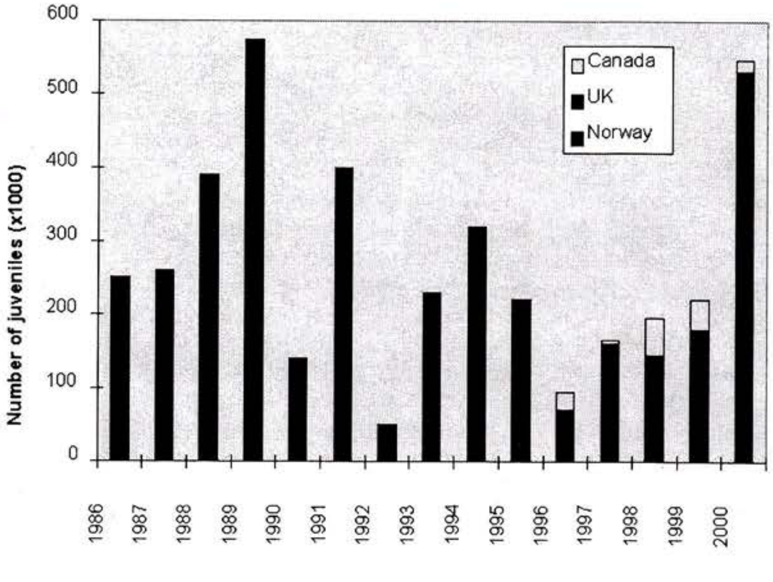

Figure 1. Production of cod juveniles 1986-2000 (source: Kvenseth et al.(3)).

It was impossible to control factors such as temperature, wild production of zooplankton, and rainfall, all of which strongly influence production. Cannibalism was also a serious threat and was inevitable if food became scarce and larvae were too abundant or too small (or unwilling) to eat formulated feed. Predators such as larger fish and jellyfish preyed upon the fish larvae and were hard to control. And in the end, catching the cod grown in the lagoon was difficult.

Semi-intensive method

To increase control of production and produce larger numbers of juveniles, some companies changed their production method to using floating bags in the lagoon (semi-intensive production). Larvae were released into the bags and each bag was continuously supplied with zooplankton filtered from the lagoon or elsewhere. This provided better control and if wild plankton became scarce, *Artemia* were produced. This method improved cod survival, but success was still dependent on environmental factors. A lot of experimenting was done to determine the optimum size of the bags, feeding strategy, and methods to keep the water quality acceptable. Improved development of the method continued throughout the 1990s, but the results were not as good as expected and production was restricted to the summer season. As interest in cod production decreased, the bags were used for turbot and, most of all, for halibut culture, which is a higher value species.

Intensive method

In the mid 1990s, trials for intensive production were conducted by both private producers and research institutions, often in collaboration. Diseases like VER, IPN, bacterial diseases, and parasites had been causing problems in bag culture, and intensive production was considered by many to be a better alternative. Intensive culture methods had been successful in southern Europe with sea bass, sea bream and other species, where juveniles were being produced by the millions. This led to the belief that large-scale production would justify significant investments in land-based facilities.

Recent increases in demand for cod have contributed to the interest in intensive production of cod. Declines in wild stocks have led to lower yearly fishing quotas. Several farmers are therefore looking into cod culture and the demand for juveniles is increasing. The production of juveniles was more than 500,000 individuals in 1989 (Fig. 1), but from 1990 to 1999, yearly production was between 100,000 and 300,000. In 2000, production was about 500,000 juveniles and the projection for 2001 is 1 million juveniles.

Ongrowing

The production of marketable farmed cod has been limited to a few producers undertaking cod grow-out as a supplementary activity. Yearly production has been between 100 and 500 mt.[2] The farmers have

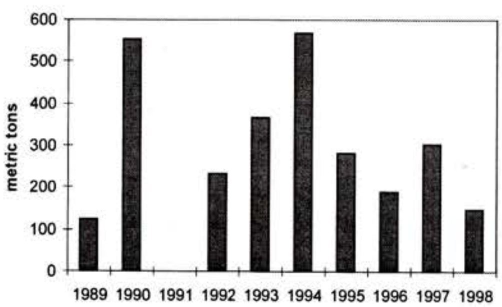

Figure 2. Harvesting of farmed cod in Norway 1989–1998 (source: Fiskeridirektoratet(2)).

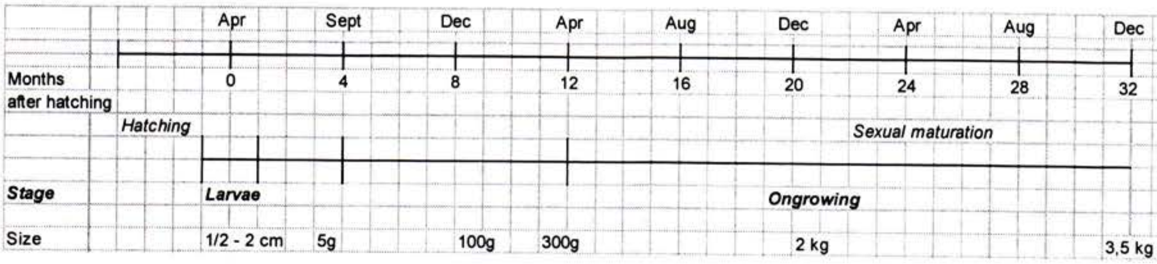

Figure 3. Developmental stages of cod (source: Kvenseth et al.[3]).

aimed their production at specific markets like Christmas, when fresh fish consumption is a tradition in Norway. With increasing interest in cod, the applications for concessions (leases) have escalated and in 2000, 10 farms were in operation. Expected harvesting of cod is 300 mt in 2001 and 1,500 mt in 2002.[3]

The level of farmed cod production has until now been low (Fig. 2). Juveniles are released in pens in the autumn at a size of 50 to 100 g (Fig. 3). In the second winter, growth slows because of sexual maturation in both males and females (Fig. 4), Since maturation occurs before the fish are large enough to be harvested (<2.5 kg), they have to be kept for at least another year in production. The quality of cod are not affected by maturation and gonad products also fetch a good price. But the onset of sexual maturation is one of the most important problems that will have to be solved if aquaculture of cod is going to be profitable.

Experimentation with photoperiod manipulation has shown that sexual maturation can be postponed by at least 6 months using supplemental light (Fig. 4).[4,5] Further testing is necessary to determine how light can be used in large-scale production to avoid problems with sexual maturation.

On-growing of cod will benefit from the technological developments that have occurred over the past decade in salmon farming. Experience developing efficient production routines and reducing production costs will also be useful in the production of cod.[6] Profitability in cod farming is dependent on low cost production and it is therefore necessary to use large production units (economics of scale) to keep the cost down.

Broodstock

So far, egg production has not presented any problems. Cod spawn on their own and each fish spawns 15 to 20 times over a period of 40 to 60 days. The fish spawn easily in a tank or a bag in the sea and the eggs are collected from the surface of the water. Eggs are placed in an incubator (< 7°C) and hatch after 12 to 14 days. The larvae are ready for start feeding within the next 2 to 3 days. A female fish will produce a total of 1 kg of eggs (ca. 500,000 eggs) per kg of body weight.

For intensive production of cod to be profitable, however, eggs will have to be produced year-round which requires that broodstock spawn throughout the year. Recent trials at Austevoll have shown that light manipulation and controlled temperatures can be used to postpone the time of spawning by 6 months. These are promising results, which can be implemented by commercial producers who want year-round production of eggs.[7]

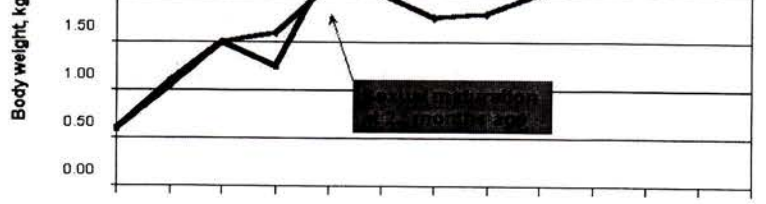

Figure 4. Growth of cod showing the effect of light of sexual maturation (source: Taranger et al.[5]).

Potential for Cod Farming

The first significant effort in cod farming was during the years 1986 to 1994. Although it did not result in any significant production of cod, it provided us with a lot of experience to build on. The conditions for success are far greater today than they were previously. Most importantly, cod farming will benefit from the developments made in salmon farming, such that production costs will be much lower than in previous efforts. In addition, the market price of cod has increased 2-fold due to the reduction in the supply of cod from the wild fishery and a general increase in demand for white fish species.

The potential for cod farming on Norway was described in a report by KPMG[3], financed by the Norwegian Research Counsel and the SND, which provides government funding to private industries. The report points out that:

- The production of Norwegian farmed cod could be as high as 400,000 mt in 15 to 20 years.
- In 20 years, cod production is likely to have the same value as salmon does today (NOK 10 billion).
- There is a large world market for cod. In Europe, there is demand for high quality fresh fish, which can be met through the supply of farmed products.
- Norway has a competitive advantage for cod farming because of its geography, infrastructure, and experience with aquaculture.
- The chances of succeeding with cod farming today are considerably higher than in previous years.
- Cod is the species most likely to reach production volumes similar to salmon, and Norwegian R&D institutions have the necessary knowledge and experience to support and develop cod farming.
- There is great interest in the private sector for cod farming on a large-scale and considerable private capital is being invested in cod farming. Farming cod is, however, still considered high risk.
- Private investors are of the opinion that funds available from the government for research and development for both the industry and research institutions is inadequate.

Challenges for Future Success in Cod Farming

Before cod aquaculture can become a commercial success, there are constraints that must be overcome, both within research institutions and among the private producers. The most important issues are:

- Intensive large-scale production of juveniles has to be achieved.
- Knowledge of disease and health issues in cod production needs to be improved.
- Breeding programs are required to improve growth and other selected qualities.
- Early sexual maturation needs to be reduced or eliminated.
- Better feed and feeding routines are needed to improve growth.
- Increased focus on quality aspects in regards to specific market requirements is required.
- Market development for farmed cod must be examined.

Summary

Given the right conditions, cod seems to have the potential for becoming the next significant aquaculture species in Norway. The combination of previous experience producing cod in extensive production systems and of developing other marine fish for culture in the southern part of Europe will help improve the prospects for cod aquaculture. Large production facilities will lower production costs, thus allowing farmed cod to compete in existing cod markets.

On-growing of cod to market size will benefit from experience gained from salmon farming, both in management and technology. The high demand for cod in the market will be a benefit and the fresh fish market in Europe should be the first market to be tested.

Although prices of cod are increasing and there is great interest from investors, there are still constraints to be solved in both juvenile production and on-growing, indicating that cod aquaculture should still be considered a high risk business.

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Hatchery Production of Atlantic Cod: Addressing Nitrogen, Oxygen, and Total Gas Pressure During Larviculture

Nicholas J. King and George C. Nardi

GreatBay Aquafarms (GBA), a commercial marine fish hatchery and farm, produces summer flounder (*Paralichthys dentatus*) and, most recently, black seabass (*Centropristis striata*). As a project participant in the University of New Hampshire (UNH) Open Ocean Aquaculture Project, GBA is evaluating the potential for commercial production of Atlantic cod. The goal in 2001 was to stock 20,000 juvenile cod (3 g) from the hatchery into intermediate-stage net pens. When the fish reach 20-30 g they will be transferred from the intermediate pens into offshore net pens and grown to market size. The two batches of fish produced in 2001 (productions 2001-1 and 2001-2) were from eggs supplied from the NOAA-NMFS Narragansett Laboratory (Great South Channel cod) and Memorial University of Newfoundland, respectively. Larvae were reared in a 5-tank (4 m^3/tank) coldwater recirculating system and fed rotifers (for 20 days), *Artemia* (to day 40), and formulated weaning diet (from day 30). Nitrogen, oxygen, and total gas pressure were monitored in each tank twice daily, and samples of larvae from each production were measured for length, weight, and swim bladder diameter. At day 56, juveniles were graded, and on-grown to an average size of 3 g. Sources of significant mortality included over-inflated swim bladders, failure to wean, cannibalism, and grading-related handling stress. In 4 months of production, GBA plans to supply approximately 30,000 juvenile cod (3 g) for stocking into the UNH open ocean net pens.

Background

The University of New Hampshire's Open Ocean Aquaculture (UNH OOA) demonstration project, started in 1997, has been involved with site selection and permitting, finfish and shellfish production, offshore cage development, environmental monitoring, and outreach activities. The first finfish species produced was summer flounder (*Paralichthys dentatus*), chosen for its high market value, aggressive feeding behaviour, and the commercial availability of juveniles.The experience with summer flounder came from two groups of fish grown in net pens over two successive years. Results from this work, as well as some laboratory studies, indicate that summer flounder is a promising candidate for open ocean aquaculture. However, because summer flounder ceases to grow during the coldest part of the year in northern New England, open ocean aquaculture of this species is most suited to "finishing" the fish for market.

Interest in developing other, more cold-tolerant finfish for year-round offshore culture in net pens has led to the selection of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), and Atlantic halibut (*Hippoglossus hippoglossus*) as species of interest. Each of these species has several positive features in addition to cold tolerance. There are active research programs and pilot-scale commercial production facilities for all three species. All have good value and have been grown successfully in inshore net pens. The University of New Hampshire (UNH) and GreatBay Aquafarms (GBA) have been involved with the development of cod for commercial fingerling production. Cod production began in the spring of 2000, with the goal of producing 12,000 juveniles. Juvenile production was lower than expected, however, because of supersaturation problems in the hatchery. Only 3,000 fish were transferred to the offshore pen during the summer of 2001. This small group of fish did provide an opportunity for the project to collect information on growth, survival, food conversion ratios, and health maintenance.

2001-2002 Objectives

The hatchery production objective for GBA was to provide the UNH OOA project with 20,000 juvenile fish to stock one Ocean Spar "Sea Station" net pen (diameter 15 m). Because tank space at GBA is limited, it was planned that fish would be moved out of the hatchery when they reached an average size of 3 g and stocked into intermediate-stage, small mesh net pens located in the protected coastal waters of New Hampshire. In addition to providing needed space, these pens allow the fish to acclimate to extensive culture conditions (pen dynamics, currents, tides, photoperiod, temperatures, etc.). When the fish reach 20-30 g (length 10-15 cm) they will be transferred into a nursery small-mesh pen within the offshore cage. Once they attain a length of 20 cm, they will be released from the nursery pen into the large pen.

At the offshore site, cod will be fed a high protein (~50%), low fat (~14%) formulated pellet to satiation 4 times per week using an automatic feeder. Twice per week, divers will inspect the pens for damage, and biweekly samples of fish will be weighed, measured, and given health inspections.

Past Experience

During 2000, GBA reared a small batch of cod in four 1-m^3 tanks. This experience highlighted several issues that resulted in poor survival. The fish experienced high mortalities during the larval stage (Fig. 1). Samples sent to an aquatic veterinarian revealed no symptoms of infectious disease, but there was evidence of gas bubble disease caused by supersaturation. The hatchery had been monitoring total gas pressure and levels of dissolved oxygen, but nitrogen saturation had not been calculated. The high level of mortality is believed to be the result of nitrogen supersaturation which resulted in a high incidence of over-inflated swim bladders. It is believed to have been caused by intermittent periods of supersaturation during the swim bladder inflation and growth period (5 to 12 mm total length). Larval cod also exhibited a high degree of mouth gaping and sensitivity to handling at this stage. Survival to a fully-weaned juvenile was less than 2%.

Protocol for Cod Production in 2001

To improve survival, changes in the larval rearing system were needed. While the algal, live feed, and egg incubation systems required little modification, changes were required in the seawater recirculation system used during the larval and juvenile stages of cod production to maintain cold temperatures, stable salinity, and alleviate gas supersaturation associated with the heating and pumping of seawater. For production 2001-1, which occurred during the early spring (March and April) when the temperature and salinity of the local seawater was relatively stable, the larval culture water was degassed, chilled to 7°C (if necessary), injected with oxygen, and allowed to flow through the tanks. However, production 2001-2 occurred later in the spring (April and May) by which time the temperature of the air and seawater had increased dramatically and the salinity was more variable, so a recirculation system was utilised during larval and juvenile production. In this system, water was returned from the culture tanks across a swirl separating tank, pumped through a 1 to 5 µm bag filter, a UV disinfection unit, and into a plastic media upwelling biofilter. From the biofilter, water entered an oxygenated chilling reservoir, and returned to the culture tanks. New water input to the recirculating system (approx. 5 to 15% per day) entered into the chiller reservoir through a degassing column. Oxygen flow valves were installed at each culture tank, in addition to the general injection at the chilling reservoir. Culture tanks (4 m^3) were set up with a perforated standpipe and upwelling air at the center.

Building on our experience with gas saturation during larviculture, we implemented a rigorous monitoring program to insure an increased level of control over oxygen, nitrogen, and total gas saturation. Using a Tensionometer 300E® (Alpha Designs Ltd., Victoria, BC), the local barometric pressure (BP, mm of Hg) and the differential gas pressure (ΔP) were measured twice daily in each larval rearing tank. These parameters, along with the dissolved oxygen (mg/L), temper-

1) $TGP\ (\%) = [(BP + \Delta P) / BP] * 100$

2) $N_2\ (\%) = [[BP + \Delta P - 0.5318\ (DO/B_{O2}) - P_{H2O}] / [0.7902\ (BP - P_{H2O})]] * 100$

3) $O_2\ (\%) = [[0.5318\ (DO/B_{O2})] / [0.20946\ (BP - P_{H2O})]] * 100$

where,

B_{O2} = Bunsen coefficient for oxygen as a function of temperature and salinity

P_{H2O} = Vapour pressure of seawater as a function of temperature (mm Hg) ature (°C), and salinity (ppt), were used in Equations 1, 2, and 3 to calculate the total gas pressure (TGP), the saturation of nitrogen, and the saturation of oxygen in each tank, respectively.[1]

Low levels of supersaturation (< 110% TGP) are associated with hyperinflation of the swim bladder, as well as extravascular emboli in the gastrointestinal tract, eyes, and mouth. Supersaturation also leads to secondary effects such as skeletal deformities, opportunistic infections, and high mortality.[2] Generally, saturation levels >110% are considered dangerous for fish, but the critical saturation level varies with species and life stage. Nitrogen gas is considered the problematic component since oxygen is assimilated metabolically and less likely to form persistent bubbles. However, it is not advisable to increase oxygen saturation beyond 125%.[2] In 2000, we experienced high levels of mortality believed to be the result of nitrogen supersaturation when total gas pressure exceeded 102%. Because of the apparent hypersensitivity of cod to total gas pressure and nitrogen gas supersaturation, effective degassing must be coupled with nitrogen gas removal from the system. Free nitrogen gas can be stripped from seawater by increasing dissolved oxygen as shown in Equation 2, and was, therefore, our strategy in controlling nitrogen supersaturation. Along with degassing and temperature control, the following criteria were regulated through general and local tank control of oxygen concentration: TGP <102%, O_2 <125%, and N_2 <100%.

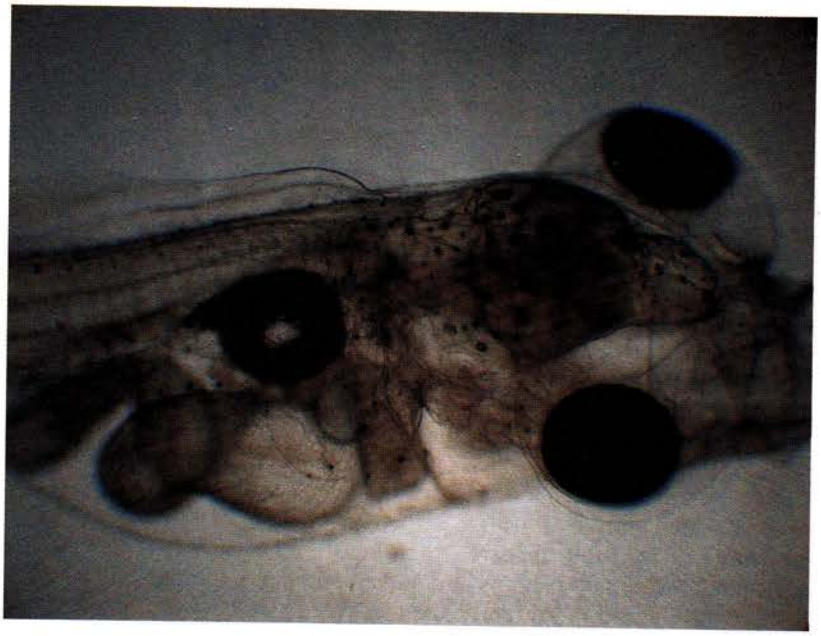
Cod production in 2001 (2001-1 and 2001-2) came from two sources of eggs. The first batch of embryos was received from broodstock cod that were caught with set line on the western side of the Great South Channel (GSC) on the southern end of Georges Bank and landed in Chatham, Massachusetts. The broodstock were maintained at the Narragansett Laboratory in Rhode Island and were fed frozen fish (her-

Table 1. Basic protocols for cod productions 2001-1 and 2001-2.

2001-1 Great South Channel cod		2001-2 Newfoundland cod
397,000	**EGGS**	1,400,000
Iodine (50 ppm)	disinfection	Perozan®
5 dpf	transport	9 pdf
+ 13 days @ 6° C	incubation	+10 days @ 7 °C
286,000	**LARVAE**	635,000*
18/L	density	32/L
12 days	greenwater	7 days
20 days (to 9 mm TL)	rotifers	20 days (to 8.5 mm)
to 40 dph (14 mm)	*Artemia*	to 39 days (13 mm)
from 30 dph (12.5 mm)	weaning nursery	from 30 dph (11 mm)
		from 50 dph (100 mg)
	TEMPERATURE/SALINITY	
4-9°C/35 ppt	incubation	6-9°C/35 ppt
9-12°C/21-33 ppt	0-45 dph	9.5-13°C/29-32 ppt
13-16°C/18-21 ppt	45+ dph	13-16°C/27-32 ppt
	SATURATION (mean to day 30)	
101%	total gas	101%
126%	oxygen	114%
95%	nitrogen	98%

* does not represent hatching success, as not all hatched larvae were stocked into the larval rearing system.

Figure 2. An abnormal cod larvae exhibiting the effects of exposure to supersaturation.



ring, mackerel, butterfish, hake) and squid, and provided with supplementary vitamins. These brood stock were designated Narragansett Laboratory GSC cod. The second batch of embryos was received from Memorial University of Newfoundland. These broodstock came from NAFO Division 3L, off the east coast of Newfoundland. The cod were first held in sea pens for 6 months and then at the Ocean Sciences Centre in St. John's from December 2000 onwards. They were fed a broodstock sausage diet, supplemented with herring and capelin.

The eggs were disinfected with either iodine (@50 ppm) or Perosan (Zep® Manufacturing) prior to transportation from Narragansett and St. John's, after 5 and 9 days of incubation, respectively. Eggs from both sites were incubated at temperatures ranging between 6° and 9°C in 100-L conical tanks at densities of up to 1,700/mL. After hatching was completed, the yolk sac fry were transferred to the larval rearing tanks. Continuous addition of algae (*Tetraselmis chuii*) was used for green water conditoning of the culture tanks. Larvae were fed four times per day a combination of rotifers enriched separately with microalgae (*C. isochrysis* or *T. chuii*), and Algamac 2000® (Bio-Marine Aquafauna Inc., Hawthorne, California). After 3 weeks, *Artemia* enriched with DC DHA Selco® (INVE Aquaculture, Salt Lake City, Utah) were fed four times per day to larvae before weaning them to microdiet Biokyowa B400/700 (0.25-0.4 mm, 0.4-0.7 mm). Following weaning, juveniles were transferred to DanaFeeds (cod diets 0.6-2.0 mm) during the nursery stage. Table 1 shows the basic protocols for both cod productions.

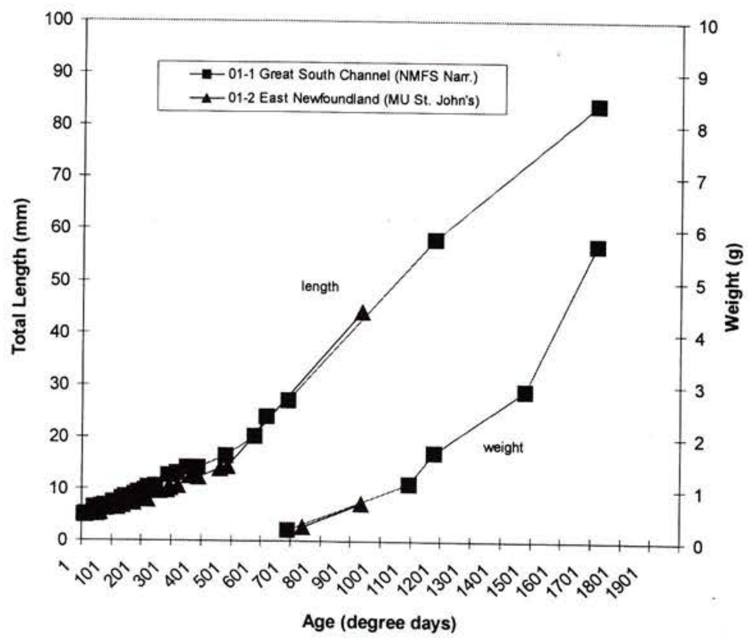


Figure 2. Growth of cod during two productions in 2001. Source of embryos for productions 2001-1 and 2001-2 were Great South Channel (NMFS-Narragansett) and east Newfoundland (Memorial University, St. John's), respectively.

Results of the 2001 Cod Production

Larvae were sampled for length, weight, and swim bladder diameter during production. Initial growth of larvae during production 2001-1 was slightly less than during production 2001-2 (Fig. 2). However, after metamorphosis and weaning was complete (500-600 degree-days), growth in length and weight of fish in production 2001-2 was similar to those in 2001-1. For production 2001-1, the hatchery goal of a 3 g average size was attained in 1500 degree-days (4 months post hatch), and although they were only 1000 degree-days at the last measurement, production 2001-2 appeared to have a similar growth rate.

Swim bladder diameter was measured from initial inflation through metamorphosis and correlated with fish body size (total length). Initial inflation of the swim bladder (100% of fish) occurred by 5 days post-hatch (dph), and appeared to follow similar growth and elongation patterns through both productions. Figure 3 shows the correlation between fish body size and swim bladder diameter during three stages of larval growth: 5-8 mm, 8-12 mm, and 12 mm+ (post-metamorphosis). After initial inflation, the swim bladder diameter grew at a very similar rate relative to body length (up to 8 mm) during both productions (slope=0.17 in both cases). During the second period of larval growth shown in Figure 2 (8-12 mm), the slope of the regression for both productions increases (slope=0.28 and 0.26), illustrating a rapid increase in swim bladder diameter relative to body size. Coincidentally, during production in 2000 and 2001-1, we observed a high degree of floating larvae and eventual mortality (50% in 2000, and 20% in production 2001-1) during this same larval growth period, presumably due to supersaturation. Total gas, nitrogen, and oxygen saturation during the 5-12 mm growth stage for productions 2001-1 and 2001-2 averaged 101, 95, 126%, and 101, 98, 114%, respectively. Although most of these saturation levels fel within into our predetermined gas saturation criteria (<102%, <100%, <125%), oxygen saturation during production 2001-1 exceeded our limits and may have contributed to the observed mortality. In production year 2001-2, gas saturation levels were within our limits and we observed a much lower incidence of

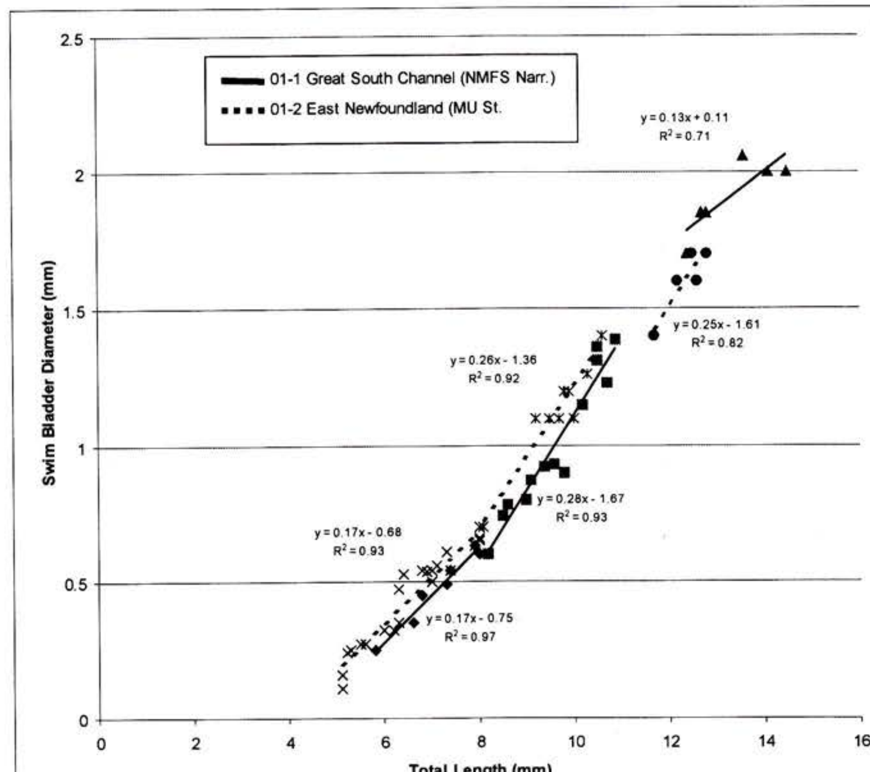


Figure 3. Correlation between total length and swim bladder diameter of cod during three stages of growth: 5-8 mm, 8-12 mm, and 12 mm+ (post-metamorphosis). Source of embryos for productions 2001-1 and 2001-2 were Great South Channel (NMFS-Narragansett) and east Newfoundland (Memorial University, St. John's), respectively.

mortality related to swimbladder inflation (<10%). It seems likely that cod larvae are sensitive to increased supersaturation levels during the larval growth period (8-12 mm) when the swim bladder is undergoing a rapid rate of growth relative to body size.

Over-inflated swim bladders, failure to first feed, and failure to wean may have accounted for up to 50% mortality through metamorphosis to 18 mm TL. Survival to this stage was 165,000 and 315,000 fish for productions 2001-1 and 2001-2, respectively. As already discussed and shown in Table 2, mortality due to swim bladder complications during the growth period from 8-12 mm was much lower in production 2001-2 than it was for 2001-1, probably as a result of reduction of oxygen saturation to within critical limits. Weaning mortality, however, was increased during production 2001-2 to approximately 25% possibly a result of smaller-sized fish at the initiation of weaning (see Table 1). Cannibalism became prevalent once fish reached approximately 15-20 mm (70-200 mg), which necessitated the need for grading. Production 2001-2 was graded through a floating bar grader at 56 days post-hatch; however, high water temperature (16°C) and excessive handling resulted in high mortality for several days following the grading event.

Although the overall survival was low in 2001, it was better than in the previous year of production and we were able to raise 30,000 juvenile cod during 4 months of production for stocking into the UNH open ocean net pens at 3 g. The hatchery successfully developed a recirculating system and monitoring program that reduced to insignificant levels (<10%) the complications involving gas supersaturation. This year again highlighted issues resulting in reduced survival, in particular, larval weaning, juvenile cannibalism, and grading. However, we feel these productions have provided us with the experience to move forward with commercial production of cod fingerlings, and GBA aims to produce between 100,000-200,000 fingerlings in the coming season.

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Table 2. Percent mortality of cod during critical stages of fingerling production in 2001 (two groups produced: 2001-1 (from broodstock from the Great South Channel, Georges Bank) and 2001-2 (from Newfoundland broodstock obtained from NAFO Division 3L).

2001-21 Great South Channel cod		2001-2 Newfoundland cod
	SWIM BLADDER	
5%	Initial inflation (5 mm TL)	5%
20%	Growth phase (8-12 mm TL)	10%
5%	Post-metamorphic (12+ mm TL)	5%
	NUTRITION	
5%	Failure to first feed	5%
15%	Failure to wean	25%
50%	Total mortality through weaning (18 mm)	50%
	CANNIBALISM/GRADING	45%
	Survival to 3 g	5% (30,000 fish)

Status of Cod Growout in Newfoundland

Harold Murphy

The wild cod resource in Newfoundland provides an opportunity for the integration of the wild resource and aquaculture technology. Cod that move inshore in early summer can be harvested live with the use of traditional cod traps. Cod are size selected, transferred to sea cages, and fed capelin, herring, and mackerel. Following a 4- to 6-month period of feeding, the cod can double their weight and become a premium quality product. As a result, cod farmers/fishers can obtain greater returns than if the cod are processed at the time of capture. In addition to the weight increase, the cod can be sold at times of the year when market demand and prices are highest. In 1997, 8 farms produced 32,930 kg of head-on, gutted (HOG) cod and by 2000 ranching had developed to 18 sites producing about 189,000 kg of head-on, gutted cod with a farm gate value of $578,677. Research and development required to support the industry includes: development of feed alternatives to reduce the cost of feeding fish, techniques for size-sorting, and studies on fillet texture, fish health, and overwintering. Quality considerations and marketing development are also important issues in the further expansion of this industry.

Introduction

The feasibility of cod grow-out or "ranching" using cod from wild stocks has been demonstrated in various areas of Newfoundland and Labrador. Fish caught in cod traps during May and June can be held in cages and fed a diet of herring and capelin. Their weight will double in approximately 100 days.

The Opportunity

The cod resource in Newfoundland offers a unique opportunity for the integration of the wild resource and aquaculture technology. Cod move inshore in early summer and are harvested live in traditional cod traps. The catch can be size graded, in accordance with any commercial and conservation requirements. For example, small fish and spawning fish can be released live, while others can be held for farming/growout purposes.

Cod captured in traps (Fig. 1) are transferred to sea cages and fed capelin, herring, and mackerel. Following a 4-month feeding period, a 100% weight increase can be achieved and a premium quality product realised. Cod farmers/fishers can obtain greater returns than if their cod quota is sold at the time of capture. In addition, fish can be sold at times of the year when market demand and price are at their highest.

The main advantages to fishers/farmers of ranching can be summarised as follows:

- Cod ranching provides an alternative to rearing cod from the juvenile stage;
- Fishers can utilise their existing skills, fishing vessels and equipment to harvest the fish and service the cage sites;
- Cod double their weight and are ready for market in approximately 100 days, providing a rapid return on investment;
- Food supplies of capelin, herring, mackerel, and squid are readily available;
- Fish can be held for the best market price;
- Cod ranching helps conserve the wild stocks as small cod are released and the value-added weight of ranched cod provides opportunity for wild fishery enterprises to remain viable with reduced allocations.

Harvest

The cod trap is a traditional means of harvesting cod in Newfoundland (Fig. 1). The cod trap fishery normally coincides with the inshore spawning of capelin and herring in the spring and early summer. Cod follow the schools of capelin along the shore and thus can be caught live in traps. In the past, these cod were harvested and sold directly to processing plants. Cod selected for grow-out are moved from the traps to a holding cage attached to the back of the trap (Fig. 1). The headline of the holding cage and the back of the trap are sewn together.

Traps are hauled in the traditional way by drying-up the fish in the back of the traps, but instead of being brailled into the boat for slaughter, cod are forced to swim over the submerged headline into the holding cage. Daily catches can accumulate in the holding cage until there are sufficient fish to be transferred to the holding site.

Transfer

Cod are kept off feed for at least 4 days before they are transferred to the towing cage. The towing cage can vary in size but normally measures 4 m by 4 m by 3 m deep. At relatively high densities, a 50-m^3 cage will hold up to 10,000 kg cod during transfer. The tow cage is fitted with a buoyant rigid polypropylene pipe collar sufficiently weighted on the bottom to hold its shape while towing at about 1 to 2 nautical miles per hour to the growout site (Fig. 2). The growout sites are normally in close proximity to the harvest site; however, cod have been towed up to 15 km. The fish are graded by a grid in the towing cage and are weighed into the growout cage. The weight is used to determine the stocking density and for other farm management purposes. It is also required by the federal Department of Fisheries and Oceans (DFO) to determine the weight to be deducted from the fisher's cod quota.

Stocking Density

The stocking density used by most fishers is 6 kg/m^3 and finishing density is about 12 kg/m^3. The standard cage of 800 m^3 is stocked with 4,500 kg of cod.

Growout Cages

Two types of cage systems are used: the buoyed net cage and the plastic circle cage. The buoyed cage is the most popular with fishers. It is less expensive, easier to construct and maintain, and can withstand rough sea conditions, which is important in more exposed grow-out sites. Figure 3 shows a typical buoyed net cage of approximately 800 m^3, which is designed to hold a starting stock of 4,800 kg.

Feed

After 3-4 days in the grow-out cage, cod are introduced to a diet of capelin or herring or a mixture of

Table 1. Feed conversion ratios obtained when fish were fed to ranched cod.

Year	Herring	Capelin	Mixed
1998	2.0-3.1	3.6	3.5
1999	2.2-3.5	3.8	3.4
2000	2.5-3.5	4.1-6.0	4.8-6.0

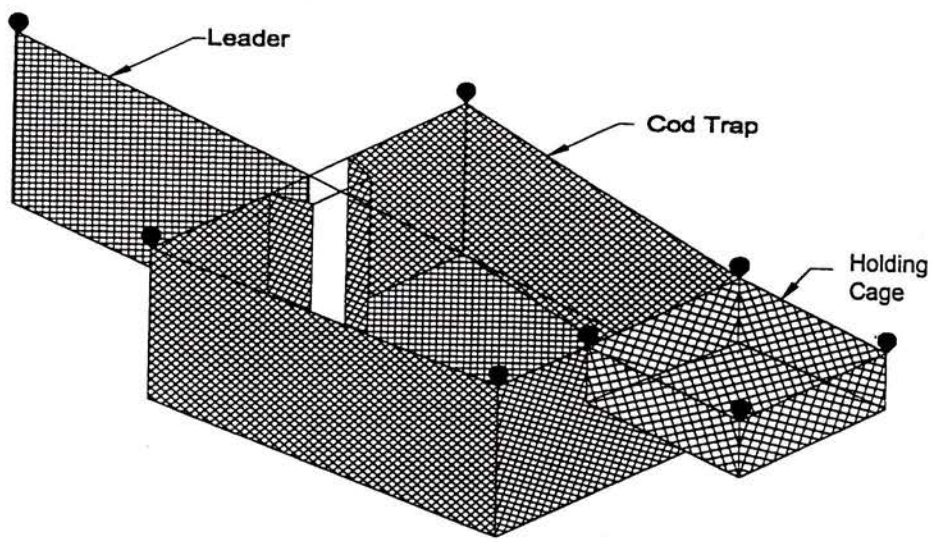

Figure 1. A schematic of a cod trap with holding cage attached (with permission of the Department of Fisheries and Oceans, St. John's, NF).

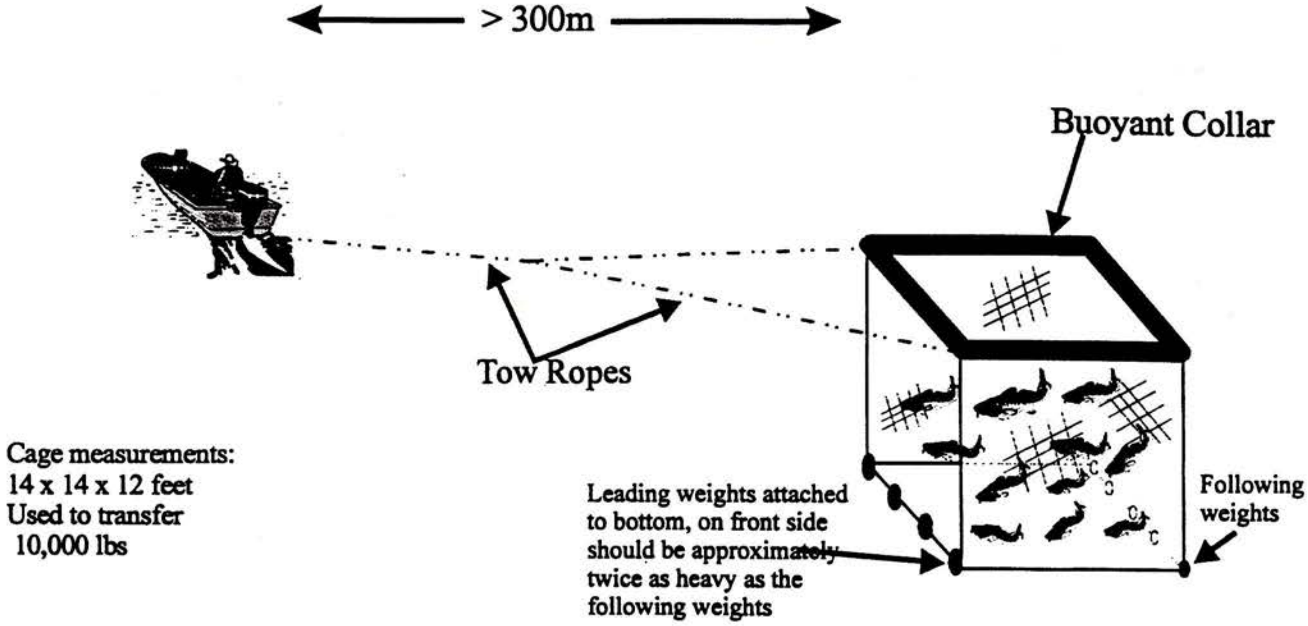

Figure 2. A schematic of a cage used to tow cod from the harvest site to the grow-out site(1) (with permission of the Department of Fisheries and Oceans, St. John's, Newfoundland).

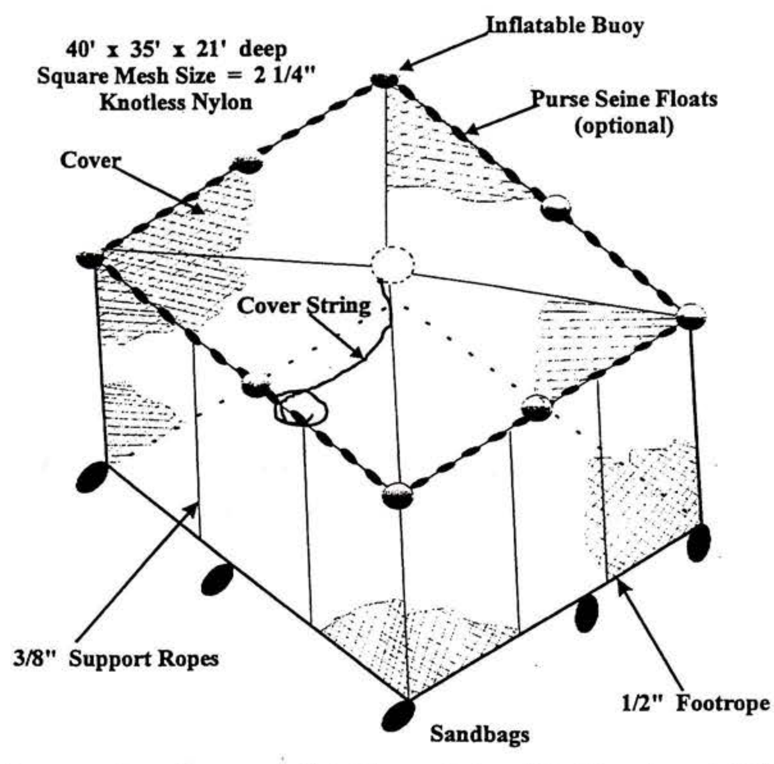

Figure 3. A buoyed net cage for cod growout.(1) (with permission of the Department of Fisheries and Oceans, St. John's.

Table 2. Number of farms in operation and the total production of head-on gutted (HOG) cod, 1997-2000.

Year	Number of Farms Operating	Production HOG (kg)	Production HOG (lb)	Farm Gate Value ($)
1997	8	32,930	72,600	72,500
1998	4	30,935	68,200	92,775
1999	7	106,800	235,400	344,500
2000	18	189,000	416,300	578,677

both. The capelin are used whole and herring is chopped into 5 or 6 pieces. Mackerel is sometimes used, but only in limited quantities due to its high oil content. A diet of herring provides the best feed conversion ratio (FCR) (Table 1).

Cod Growout

The technology for cod growout was developed in the 1980s; however the various cod moratoria in 1992 prevented commercial development until 1997 when there was a limited reopening of the fishery. A pilot project was carried out in 1997 and 1998 to set up a number of farms to demonstrate the technology.

In 1998, four cod farms operated in the province (Table 2). Three of the four farms were located in NAFO Fisheries Management Area 3Ps, near the communities of Burgeo, Rushoon, and Southern Harbour. One other farm, located in Area 3L, near New Harbour, Trinity Bay purchased fish from Placentia Bay and was transferred to the site by tank truck. A total starting stock of about 20,000 kg produced 40,800 kg.

In 1999, 7 farms were operating, with a total starting stock of 71,895 kg which resulted in a total production

Tending a buoyed net cage of cod in Trinity Bay, Newfoundland

of 132,900 kg. In 2000, 18 farms were operating with a starting stock of 139,000 kg, which resulted in a production of 235,800 kg. Table 2 shows the number of farms in operation and the total production of head-on gutted (HOG) cod for the years 1997 to 2000. In 2000, there was 189,000 kg HOG worth a farm gate value of $578,677.

Development Factors

Available stock

A major consideration for cod grow-out is a reliable supply of wild cod from April to June. The low state of cod stocks in recent years has been a constraint to the development of cod ranching. Cod migrations in some areas have been inconsistent and fishers have experienced difficulty harvesting sufficient quantities of cod. The scarcity of cod, however, has increased the importance of grow-out operations in increasing the value from the fishery.

Governments have been supportive of cod ranching and consequently some provisions are being made in implementing the cod management plans to provide appropriate time frames to harvest cod for grow-out. Although to date no special quota has been assigned to cod growout.

Feed

Availability of feed has not been a constraint to date. Some fishers catch supplies of herring and capelin and these are used fresh or stored frozen at local processing plants. Others purchase fish directly from a processing plant or bait supplier. The costs have ranged from 13 to 20 cents per pound ($0.29-0.44/kg).

A substantial increase in cod growout could place increasing pressure on the availability of raw fish supplies and consequently growers are interested in using formulated feed as an alternative. The use of dry pelleted feed has been tried on an experimental basis, including a project in 2000 sponsored by the Newfoundland Cod Growers Association. The results of these tests demonstrated that further work is needed to develop an alternative feed for wild stock cod.[2]

Quality Assurance

The objective of the cod growers is to produce a top quality product that can be sold at a premium price. Handling practices during capture, grading and transfer to grow-out cages are being refined to minimise injuries and mortalities. Husbandry practices, specific to wild cod, are being established and specific harvesting, processing, packaging, and transporting practices are being developed and adopted to provide a good quality product from capture-based, farmed cod production.

Marketing and Sales

Presently, all farmed cod is ready for market between October and December. The fish are sold to local processors who normally ship the cod HOG to markets in the eastern United States. To date, the product is not necessarily presented to the consumer as a farmed cod product and there is no specific promotion of this premium farmed fish as a distinct product. Increasing production will require a market development plan and a sales schedule that extends beyond the autumn season. In this regard, two growers in 2000 have held fish over the winter as an experiment to determine the feasibility of an extended harvest and market supply period.

Increased production of fillets and other value-added forms, prior to export, will also have to be addressed as the industry becomes established. By-products such as liver, roe, and cheeks have potential value in the market place as the industry grows.

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Nutrition of Atlantic Cod

Santosh P. Lall and Dominic Nanton

Although our understanding of the feeding and nutrition of cod has been expanding steadily in the past decade, information on the quantitative nutrient requirement of this species is very limited. A diet containing high amounts of protein (48-60%), low carbohydrate (10-15%), and low lipid (< 15%) with a sufficient amount of n-3 long chain polyunsaturated fatty acids (1-1.5% eicosapentaenoic and docosahexaenoic fatty acids) and well fortified with vitamins and trace elements is recommended for initial feed formulations of cod growout diets. Preliminary brood stock and larval nutrition studies have revealed the role of essential fatty acids, certain amino acids, and trace elements in successful reproduction and larval survival. Recent findings on the effects of dietary lipid on hepatosomatic index and feed utilisation, as well as the practical problems associated with the feeding of cod, are discussed.

Introduction

Aquaculture of cod (*Gadus morhua)* and several other marine fish species, including haddock (*Melanogrammus aegelfinus*) and halibut (*Hippoglossus hippoglossus*), is expanding in Atlantic Canada. Cod and haddock are carnivorous and are situated at the top of the marine food chain. A paucity of information exists on their quantitative nutrient requirements, efficiency of feed utilisation, and the feeding strategies necessary at various stages of their life cycle such as larval, juvenile, growout and sexual maturation. Initial feed formulations for cod were based upon the chemical composition of gadoids and their diet in the wild, along with the estimate of nutrient requirement values derived from salmonids and other marine fish.

Recent data on the diet of wild cod ranging from 64 g to 13.8 kg caught from the Scotian Shelf of Atlantic Canada show their major stomach contents to be fish (45%), crustaceans (33%), echinoderms (4%) and molluscs (3%). Other species of marine organisms and organic material constitute the remaining portion of the stomach contents.(1) However, echinoderms constituted the major portion (38%) of haddock stomach content indicating that feeding habits of gadoids may vary considerably. Capelin, which may contain 10 to 35% lipid on the dry matter basis,(2) has been reported to be the most important fish species in the diet of cod.(3,4) A shift in the prey composition with the size of the fish has been also observed. In the stomach of small cod (<25 cm), the major food organism was krill (73-94% of total weight), whereas capelin or shrimp (*Pandalus borealis*) were the main components in larger cod (27-72 cm).(4) It appears that the diet of wild cod is rich in protein. Krill and other crustaceans consumed at early stages of cod development can provide a low level of lipid with a moderate amount of chitin. The intake of ash (total minerals) and vitamins may vary significantly. A brief review of the nutrition and feeding of cod is presented and several analogies are drawn from other marine fish to plan strategies for development of efficient diets for this species.

Nutrient Requirements

Cod feeds formulated from feed stuffs of fish or plant origin must contain optimum levels of nutrients (protein, amino acids, essential fatty acids, vitamins, and minerals) and energy (supplied by protein, carbohydrate, and lipid) for growth, reproduction, and health. Deficiencies of these nutrients can reduce growth rates and affect health and reproductive performance. In some cases, excesses can also cause reduction in growth rate and possibly toxicity. Limited research efforts have been directed at determining the quantitative nutrient requirements of most marine fish including gadoids.(5) However, some generalisations are possible on the basis of information available on other species. The protein requirement of most marine fish species(5) ranges between 50 to 60% and the requirement for juvenile haddock has been estimated to be 49.9%.(6) A diet containing 52% protein, 11% lipid and 17.5% carbohydrate was suitable for cod where 60%, 25%, and 15% of available energy was supplied by protein, lipid, and carbohydrate, respectively.(7)

Atlantic cod has a limited ability to utilise carbohydrate and an increase in the amount of starch causes excessive accumulation of glycogen in muscle and liver.[8] Essential fatty acid (EFA) requirement of most marine fish can only be met by supplying the long-chain highly unsaturated fatty acids (HUFA), eicosapentaenoic acid (EPA), 20:5 (n-3), and/or docosahexaenoic acid (DHA), 22:6 (n-3). These fatty acids, required for normal cellular function, cannot be synthesised *de novo* and must be supplied in the diet. A high concentration of HUFA occurs in cod tissues;[9] however, the quantitative EFA requirement and deficiency signs in gadoid fishes have not been reported.

The quantitative vitamin and mineral requirements of cod have not been investigated, but the distribution of most water and fat-soluble vitamins in tissue have been reported.[10] A significant amount of vitamin A and D has been detected in gadoid livers.[11] At least part of the requirement of cod and other marine fish for certain minerals such as calcium, cobalt, iron, magnesium, potassium, sodium, zinc and others can be obtained directly from the seawater. Haddock require 9.6 mg P/g of diet for optimum growth, feed utilisation and bone mineralisation and their requirement is much higher than salmonids.[12] Although the importance of broodstock nutrition in gonadal development, egg quality, and the survival of larvae is widely recognised, few studies have been conducted to define the role of key nutrients in reproduction of gadoids.

Larval Nutrition

Larval feeding and nutrition continue to be a critical area for the aquaculture development of cold water marine fish species. A proportion of amino acids in the more available free form, similar to that found in their copepod prey (*Pseudocalanus* sp.),[13] is required by first-feeding gadoid larvae. At the first-feeding stage, their digestive system is not fully functional.[14] The high amount of the EFA DHA in gadoid eggs, larvae, and wild prey suggests a high requirement for DHA in the diet. Cod larvae (*Gadus macrocephalus*) fed enriched *Artemia* high in DHA (1.6-2.1%) showed the best growth performance.[15] Phospholipids are also indispensable for sustaining growth and survival of fish larvae.[16] A phospholipid-rich diet containing a DHA:EPA ratio of *ca.* 2:1 along with the EFA arachidonic acid may be optimal for marine fish larvae.[17]

Gadoid eggs are rich in phospholipid with a DHA: EPA ratio of 2:1 and free amino acids.[18,19] Therefore, gadoid eggs/roe have been incorporated as a major component in feeds to meet the nutritional requirements of gadoid larvae.[20,21] Although not reared through metamorphosis due to high mortality, cod larvae fed formulated diets containing cod roe had higher growth rates than those fed other prepared diets.[20,21]

Cannibalism can be a major source of mortality for the fry of gadoids weaned from live to formulated diets, accounting for 3 to 76% of the total mortality in cod.[22] Therefore, gadoids require a highly digestible diet of the desirable organoleptic properties during the weaning period with a similar composition to their wild copepod prey or larval diets, as described above. Moist diets gave better survival rates than dry diets during weaning of cod.[22]

The larval feeding procedure used for culturing haddock and cod on a pilot scale at the National Research Council Aquaculture Research Station (Sandy Cove, Nova Scotia) involves the use of DHA-rich algae to green the water (*ca.* 11°C) in rearing tanks. The first-feeding larvae are fed algae-enriched rotifers from 0 to 7 days post-hatch (PH), enriched (commercial product high in DHA) rotifers from 7 to 25 days PH and enriched (commercial product high in DHA) *Artemia* from 25 to 37 days PH. At *ca.* 37 to 45 days PH, the haddock are weaned from the live food onto a formulated diet. This is achieved by gradually dropping the *Artemia* concentration in the tank to zero, while co-feeding the formulated diet over a 4 to 10 day period. Cannibalism can be a major source of mortality during this weaning period. The weaned haddock juveniles are then fed a standard (high protein, low lipid) marine fish diet.

Lipid Utilisation

In contrast with salmonids, the main energy storage organ in cod and haddock is the liver, and the lipid content of the muscle rarely exceeds 1.0% of the wet weight.[23,24] The hepatosomatic index of cod is directly related to dietary lipid level and feed intake.[7,25] The hepatosomatic index of farmed cod fed formulated diets has ranged from 6.2 to12.7% and total liver lipid from 49.7 to 70%.[25-28] A dietary lipid level of about 9% dry mass (DM) or less was necessary to produce a hepatosomatic index in juvenile haddock similar to that of wild gadoids (7%).[29] An increase in the liver lipid of cod and haddock is associated with a high intake of dietary fat but it is not reflected in muscle lipid,[23,30] which remains approximately 1%. Very low density lipoprotein (VLDL) is a major transporter of lipid out of the liver through the blood to other tissues including muscle. Haddock serum contained low levels (< 50 mg/dL serum) of VLDL. These observations suggest that the transport of lipid out of the liver to the muscle for storage in gadoids is limited.[24]

Feeding of Cod

Large sexually mature cod have a lower optimal temperature for growth than smaller cod (50-1,000 g). The optimum temperature for growth of large cod may lie within the range of 9° to 12°C, which is 2° to 3°C lower than the temperature range (11° to 15°C) found to promote optimum growth in smaller cod.[31,32] Attractiveness or palatability of the feed for cod is of particular importance at lower water temperatures. Food rejection rate increased with decreasing temperature for cod fed formulated feeds; however, it remained constant for cod fed capelin.[33]

Due to the high level of energy (lipid) storage in the liver of gadoid fish fed formulated diets, less frequent feeding may improve feed utilisation and reduce fatty liver. Feeding cod three times per week may be better than feeding six times per week or one day per week.[34] Feeding cod juveniles *ad libitum* once every three days compared to once a day reduced the hepatosomatic index and liver lipid levels. However, weight gain was also reduced in cod fed once every three days.[7] Growth rate has been positively correlated with hepatosomatic index in gadoids,[23] thus attempting to reduce the abnormally high hepatosomatic index or liver lipid storage levels by reducing feeding frequency can negatively affect growth in gadoids fed formulated diets.

Growth, feed utilisation efficiency, protein efficiency ratio and fillet to body weight ratio was highest in cod fed a combination of chopped herring and wet feed compared with moist or wet diets. The level of lipid in the liver of cod fed a mixed diet of coarsely chopped herring for four days and a formulated wet diet three days per week was relatively high (70.3%). However, these cod had a slightly lower liver lipid level compared to those fed seven days per week on moist diets (72.6-75.6%).[25]

Practical Feeds

On the basis of current knowledge of the nutrient requirement of gadoids and other fish, a diet containing a high amount of protein (48-60%) and low levels of carbohydrate (10-14%) and lipid (<15%) with sufficient amount of n-3 long chain HUFA (1-1.5% EPA and DHA for juvenile fish) as well as being fortified with vitamins and trace elements would be suitable for initial feed formulations of cod growout diets. Our recent research on juvenile haddock (50-250 g) suggests that high energy diets containing 15% to 24% lipid result in a lower feed conversion ratio but growth rate was not improved. There was no real advantage of incorporating more than 15% lipid. However the growth rate declined when dietary lipid was reduced below 12%. A recent study on cod suggests that extruded feed containing 48% protein and 16% lipid would be desirable in terms of growth, feed utilisation and overall cost of the diet.[27]

Several forms of moist and dry commercial and experimental feeds have been used for feeding cod. Dry extruded pellets have several advantages because they ensure continuous availability and uniformity of feed, ease of transport, storage, and feeding. The processing and production of moist feeds show wide variations. Moist pellets contain a variable amount of fish tissue (ground whole fish, and fish and crustacean waste) or fish silage. Dry ingredients (fish and crustacean meal, wheat by-products, corn gluten meal, soybean meal, etc.) mixed with vitamin and mineral supplements and a binding agent, etc., can be extruded through meat grinders or more elaborate cold extruders. Raw fish and fishery-products must be pasteurised to destroy pathogens and thiaminase enzyme found in fish tissues. Improper and/or long-term storage of these diets can adversely affect the stability of vitamins, cause oxidation of lipid and increase bacterial and fungal contamination. The overall acceptability of moist diets by cod and haddock remains high as compared with dry extruded feeds for fish reared in Eastern Canada, where average annual seawater temperature is between 6° to 8°C (range 0° to 18°C). Clearly, there is a need to further improve the weaning, growout and broodstock diets for cod and other gadoids.

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AAC Donates Aquaculture Prize to NSAC's Final Year Project Conference

AAC donated a 1-year membership and subscriptions to Northern Aquaculture and Fish Farming to NSAC's (Nova Scotia Agriculture College) Final Year Project Conference as the prize for the best aquaculture project.

The winner was Andrea Dicks, shown on the right being presented the award by NSAC facility manager Peter Harvey. Andrea is from St. John's, NF, and the title of her prject was *Gonadal Enhancement of Green Sea Urchins Using Alfalfa-based diets.*

Evaluation of Flesh Quality in Ranched Cod

M. Thompson, K. Rideout, R. Trenholm and B. Gillett

Excessive levels of gaping in the fillets of ranched cod have constrained the market development of this product. The Newfoundland Cod Growers Association initiated research to investigate the effect of drying-up (crowding) time in the holding pounds prior to slaughter and the effect of stunning, using carbon dioxide (CO_2), on fillet quality. The following characteristics were evaluated: degree of rigor, fillet texture, gaping, drip loss, temperature, and pH. Extended periods of drying-up time (2 to 4 hours) in the pounds prior to slaughter had no negative effect on fillet quality. There was no significant effect of stunning using CO_2 on fillet quality. Total rigor time in ranched cod ranged from 96 to 120 hours. Ranched cod filleted 3 and 4 days postmortem were of the lowest quality in terms of fillet texture and gaping.

Introduction

Aquaculture provides an opportunity for cod harvesters to increase the value of fish landed in the traditional Newfoundland trap fishery in May and June. When cod held in sea cages are fed a diet of fresh or frozen pelagic fish, they increase in size by up to 100% of their original weight in a few months. The Newfoundland Cod Growers Association, an organisation of local cod ranchers, approached the Centre for Aquaculture and Seafood Development at the Marine Institute of Memorial University of Newfoundland to evaluate the impact of handling procedures on the quality of cod flesh. The Association identified several handling practices they felt might be negatively affecting flesh quality in ranched cod: the use of carbon dioxide to stun cod, the length of the drying up (crowding) period in pounds prior to slaughter, and the pre-harvest holding temperature.

Materials and Methods

The project was carried out as three separate experiments at three different times and locations. A standardised harvest method was developed and incorporated into each experiment. It consisted of a starvation period of 14 days and stunning using CO_2 (except for the non-stunned group). The fish were live bled for 30 minutes at the cage site in seawater chilled with ice. Fish were then iced (1:1 ratio of ice to fish) in tote pans. At the wharf, the fish were tagged, measured, weighed (whole weight), gutted, re-weighed (head on gutted (HOG) weight), and re-iced in tote pans. They were transported to the Marine Institute in the back of a covered vehicle.

Three fish were removed from each treatment upon arrival at the Marine Institute (time 0) and at 24, 48, 72, 96, 120, and 144 hours post-harvest. A number of tests and quality evaluations were conducted on the fish. Each head-on gutted (HOG) fish was examined for rigor and assigned a grade based on the 9-point scale developed by Curran et al.[1] and modified by Sigholt et al.[2] (1 = pre-rigor, recently slaughtered; 5 = full rigor; and 9 = post-rigor, fish is limp). HOG fish were hand filleted by an experienced filleter. For consistency, one person did all the filleting. Fillets were mechanically skinned using a Baader 51. Two criteria were used to evaluate the fillets for dockside grade: fillet texture and the percent gaping. A single qualified dockside grader was used to ensure consistency among samples. A numerical score was assigned in the evaluation of fillet texture: 5 = firm and resilient, 3 = slightly soft, and 1 = soft. The percentage of the surface area of the fillet showing gaping was recorded. The temperature of the fillets was recorded using a digital thermometer with a steel probe inserted into the loin portion of the fillet. For whole and HOG fish, a temperature probe was inserted into the loin portion of the fish through the gills or belly cavity. The pH of the fillets was measured using a Shindengen-ISFET pH meter KS501.

Sample fillets were placed on Styrofoam trays that were indirectly iced and placed in a cold room (0° to 4°C). Three fish from each treatment were sampled each day over a 6-day period. On each sampling day, the fillets were re-iced and retained, and then examined for quality at 10 and 16 days postmortem. For example, fillets produced on day 4 were assessed for quality on days 4, 5, 6, 10 and 16. Proximate analysis of samples was carried out by taking the loin portion

Table 1. Comparison of rigor times in cod stunned with CO_2 prior to slaughter and cod that were not stunned.

State of Rigor	Ranched Stunned Cod	Ranched Non Stunned Cod	Wild Cod
Pre-rigor*	> 8 h	> 8 h	< 8 h
Full rigor	by 24 h	by 24 h	< 24 h
End of rigor	120 h	12 h	insufficient data

* sampled at 8 h upon arrival at the Marine Institute

of the fillet and analysing it for moisture, protein, fat, and ash according to modified AOAC methods.[3] Samples were analysed in triplicate, with results reported as the average of three determinations ± standard deviation. Differences in the means were quantified by analysis of variance and the post hoc test used was Tukeys Honestly Significant Difference Test (SPSS 9.0). Statistical differences were achieved where $P < 0.05$. The data were compared for days 4, 6, 10, and 16 days postmortem.

Stunning Experiment

The use of carbon dioxide to stun cod prior to slaughter was adopted from the salmon farming industry and is used to ease the handling of fish and to reduce stress on the fish. Stunning is labor intensive and slows the harvest process, so during the 1999 season several cod ranchers eliminated the process. The stunning experiment was carried out 16 October 2000 to determine if stunning has any effect on flesh quality.

Treatments and Handling

Ranched cod used in the experiment were captured during the summer fishery, held in a holding pound, and fed a diet of pelagic fish (mainly capelin) until 2 October.

The wild fish were harvested by a fisher using hook and line in an area within 6 km of the holding pounds. They were caught on the same day as the ranched cod were sampled. The wild fish were bled, gutted, and iced in totes at the time of harvest. At the wharf, the fish were tagged, measured, weighed and then re-iced in totes with a 1:1 ratio of ice to fish. The wild fish samples were transported to the Marine Institute for sampling with the ranched cod samples.

Results

Both the stunned and non stunned ranched cod were harvested in waters of 9.5°C. While the temperature of the water was not measured for the wild fish sample, it is assumed that because the fish were taken from the same bay or area as the cod pounds the water temperature would be similar. The water temperature of the stun tank was -1°C and in both the stunned and non-stunned samples the bleed tank temperature was -1.2°C. At the time of weighing, the internal fish temperature of the stunned/non-stunned samples was 0.2° to 4.5°C and of the wild fish 5.6°C. Table 1 summarises the results in terms of the postmortem rigor times for all treatments.

Overall, wild cod scored lower for texture than ranched cod. Texture scores for the stunned and non stunned fish were the same and there was no significant difference observed in texture scores on the various filleting days. There were no statistically significant differences observed in the precent gaping of fillets in fish that were stunned versus fish that were not stunned. The least gaping in fillets was observed when ranched cod were filleted at time 0 (< 10 h) and 1 day postmortem. Drip loss from the fillets expressed as the percent weight loss was examined. Overall, there were no significant differences reported in the percent drip loss from ranched cod that were stunned versus ranched cod that were not stunned. The highest drip loss (up to 7%) was on filleting day 0 (<10 h postmortem). Wild cod had the lowest drip loss overall. The pH of the fillets was examined and overall the pH of the wild cod fillets was higher than the pH of the ranched cod fillets.

Drying Up (Crowding) Experiment

During the harvesting of ranched cod, fish are dried up in the holding pound which results in crowding of the fish in a small area for extended periods. This experiment examined the effect of drying up time of ranched cod in the holding pound during harvesting to determine if there is any impact on flesh or fillet quality. The drying up experiments were carried out at two ranch sites: Rushoon in Placentia Bay, on 18 October 2000 and Southport in Trinity Bay on 30 October 2000.

Table 2. Rigor times in the drying up experiment.

State of Rigor	Rushoon Ranched Cod Drying Up 0 h	Southport Ranched Cod Drying Up 0 h	Rushoon Ranched Cod Drying Up 2 h	Southport Ranched Cod Drying Up 2 h	Rushoon Ranched Cod Drying Up 4 h	Southport Ranched Cod Drying Up 4 h	Rushoon Wild Cod	Southport Wild Cod
Pre-rigor	> 8 h	> 8 h	> 8 h	> 8 h	> 8 h	> 8 h	< 8 h	< 8 h
Full rigor	by 24 h	by 24 h	by 24 h	by 24 h	by 24 h	by 24 h	< 24 h	24 h
End of rigor	96 h	96 h	120 h	96 h	120 h	96 h	72 h	72 h

Treatments and Handling

In both locations, all fish were initially crowded in the pound. At time 0 hour, sample fish for the 0 h drying up time were harvested using the standard harvest method. Remaining fish were left crowded in the pound for their respective drying up times and harvested at 2 and 4 hours. Wild fish were harvested, using hook and line by a fisher, in the same bay and on the same day as the ranched cod samples used in each experiment. All wild fish samples were bled, gutted, and iced in totes.

Results

Temperature during harvest

In Rushoon, initial water temperatures were 9.3° to 9.8°C. The stun tank temperature was 9.3° to 9.8°C and the bleed tank temperature was -1.2° to -0.4°C. In Southport, the initial water temperature was 7.2°C, stun tank temperature was 7.2° to 7.4°C, and the bleed tank temperature was -1.9 to -0.6°C. Internal fish temperatures during sampling were 0.2° to 1.8°C for Rushoon cod and 2.8° to 3.6°C for Southport cod.

Table 3. Summary of drying up experiments.

Factor	Location	Comparison (wild vs ranched)	Best Filleting Time for Ranched Cod	Effects on Drying Up Time	Worst Filleting Day for Ranched Cod
Texture	Rushoon	wild < ranched	0-2 d	all equal	–
	Southport	wild = ranched	0-2 d	all equal	3-4 days
% Gaping	Rushoon	Ranch < wild	0-2 d	all equal	–
	Southport	Ranch > wild	0-2 d	all equal	3-4 days
% Drip Loss	Rushoon	Ranch > wild	–	all equal	3-4 days
	Southport	Ranch > wild	–	all equal	0-3 days
pH	Rushoon/ Southport	Ranch < wild	–	–	–

Table 4. Summary of proximate analysis. Results are reported on a wet weight basis and represent the mean of 3 determinations ± standard deviation.

Source	Moisture (% w/w)	Fat (%w/w)	Protein (%w/w)	Ash (%w/w)
Wild cod – Southport	82.80 ± 0.58	0.26 ± 0.05	18.60 ± 0.43	1.15 ± 0.05
Ranched cod – Southport	78.73 ± 0.44	0.23 ± 0.02	20.63 ± 1.15	1.21 ± 0.06

Rigor

Table 2 summarises the results obtained from the rigor analysis of all treatment types for the drying up experiment at both the Rushoon and Southport ranch sites. There were significant differences in the rigor time, for the various drying up times and between wild and ranched cod.

Table 3 provides a summary of the results obtained from texture, percent gaping, percent drip loss, and pH for both drying up experiments. There were differences in drying time between wild and ranched cod.

Proximate Analysis

There was a significant difference in the percent moisture and percent protein in wild and ranched cod taken from the Southport site (Table 4). This difference might explain some of the flesh quality differences between wild and ranched cod.

Conclusions and Recommendation

There was no impact of stunning with carbon dioxide on the fillet quality, so if carbon dioxide is not used during the harvesting of ranched cod there is no noticeable impact on the quality of the fillet produced. Stunning may be used to ease handling of the ranched cod. Drying up (crowding) time of 2 to 4 hours in the holding pound prior to harvesting did not have any negative impact on the quality of fillet produced. It may be beneficial to dry up the fish for a period of 2 to 4 hours prior to slaughter to allow the fish to adjust to their surroundings. The results obtained in this experiment were based on small numbers of fish. To ensure the validity of these results from a commercial harvesting perspective, it is recommended the experiment be repeated during a regular commercial harvest operation. There were significant differences observed in the results between the two sites in the drying up experiments. Handling practices for both sites were identical and the differences appear to be a result of environmental influences. At this time, we are unable to conclude that water temperature is a contributing factor.

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Haddock Culture in Atlantic Canada

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Heritage Salmon Limited, in partnership with regional government laboratories, has advanced the culture of haddock *(Melanogrammus aeglefinus)* significantly from its beginnings in 1996. Studies on broodstock holding, manipulation of spawning time, and egg collection and transport are being done at the New Brunswick Aquarium and Marine Centre in Shippagan and at the Fisheries and Oceans Canada Biological Station in St. Andrews. Juvenile haddock are being produced at Shippagan and at the National Research Council, Sandy Cove Marine Laboratory near Halifax. Juveniles (3-5 g size) hatched from eggs collected in early January are transferred in May to sea cages at the Heritage Fairhaven Marine Site, Deer Island, and grown to market size in roughly 3 years. Haddock feeds (weaning, market and broodstock) in both dry and moist forms, are being developed at the National Research Council Institute for Marine Sciences in Halifax. The dry feed is being manufactured by Zeigler Feeds of Gardner, Pennsylvania. The first processing and market trial of fresh cultured haddock fillets was conducted in February 2001. The product was well received in the marketplace, but the exercise pointed out marked differences between haddock and salmon processing and the need to design processing facilities specifically for haddock. Additional work — in particular on the grow-out stages, since haddock grow relatively slowly in Bay of Fundy seawater temperatures — must be done before this species is ready for commercial investment. Current experience will allow us to grow haddock to 2 to 2.5 kg in 3 years from egg collection. A model developed from growth data shows the potential for significant growth improvement with increased water temperature. Growout trials in heated, recirculated tanks are proposed.

Introduction

Heritage Salmon Limited in partnership with a number of government laboratories in the Canadian Maritimes has advanced the culture of haddock significantly from its beginnings in 1996 to the present. The project has benefited from the participation of the federal government, provincial government, and industry representatives in the evolution of the project. This paper outlines the technical progress and administrative framework that has allowed for the efficient and successful development of haddock culture.

In 1996, the then New Brunswick Department of Fisheries and Aquaculture co-ordinated a federal/provincial initiative termed the Alternate Species Co-operative Development Program to address the development of finfish and shellfish aquaculture in the Maritimes. The program was designed to bridge the gap between laboratory research and commercial production and avoid the "entrepreneurial burnout" that commonly occurs when business invests in partially developed technologies.

A committee, with representatives from government, industry, and the research community, developed a list of candidate species, and invited, evaluated and recommended proposals, and provided guidance to funding agencies for the issuance of research contracts. The objective of the initial 5-year program was to commercialise alternate species for aquaculture in the region. Heritage Salmon Limited co-ordinated the development of haddock aquaculture, and with the support of its partners, has advanced haddock culture to what might be termed a pre-commercial level.

Broodstock and Spawning

Haddock in the western Atlantic spawn generally from March through May. The Biological Station in St. Andrews, New Brunswick (SABS) and the Aquarium and Marine Centre in Shippagan, New Brunswick (AMC) hold broodstock and provide eggs to the haddock program as early as late December by advancing spawning time with photoperiod and temperature manipulation. This has allowed stocking of sea cages with 3 to 5 g juveniles in mid-May coincident with seawater temperatures reaching 6°C. The broodstock program hopes to further advance the time of spawning into November to allow the juveniles to reach a size of 50+ g before transfer to sea cages in May.

Haddock broodstock are held at 5-6°C during the spawning season. Haddock spawn on their own under culture conditions and each female releases 15 to 20 egg batches per season. Large, deep circular tanks (> 3 m deep) are used for holding haddock broodstock; deep water appears to support complex mating behaviours.

Females usually spawn with only one male and dominant males frequently monopolise females and reduce the genetic contributions of the broad spawning population. DNA microsatellites are being used to determine the pedigree of individual brood stock to reduce inbreeding. Although wild-caught fish are still used as broodstock, F1 cultured fish are being incorporated into the broodstock programs to improve performance.

Commercial haddock broodstock diets have not yet been formulated. Most facilities feed a moist feed (modified to contain lower fat and higher protein levels than salmon feed), frozen whole shrimp, squid, herring, and vitamin supplements.

Egg collectors secured at the surface of the spawning tanks are used to collect the 1.5 mm pelagic eggs. Newly fertilised eggs are removed from the collectors daily, egg volumes are recorded and fertilisation rates determined. Eggs are disinfected in 400 ppm glutaraldehyde for 6-10 minutes before allocation to egg incubators.

Low survival of egg lots has been a problem. This has been attributed mainly to handling and shipping eggs while in a "tender" stage, analogous to that seen in salmon culture. Early survival ranges from 0 to 90+%. Eggs should be transported only after incubation for 55 degree-days (dd), when gastrulation is complete. Transporting eggs prior to this developmental stage can result in poor egg survival. Application of this procedure has resulted in predictable levels of survival and hatch rates exceeding 90%.

Eggs are shipped from SABS and AMC to hatcheries at AMC and the National Research Council Institute for Marine Biosciences (NRC-IMB) for incubation and juvenile production.

Egg Incubation

A variety of incubators and regimes have been evaluated for the incubation of haddock eggs. The incubators currently in use have a volume of 100-300 L, are conical to near-flat-bottomed, and have up-welling water flow, air flow and a banjo filter outlet.

Approximately 0.5 L of eggs (175,000 eggs) are incubated in each 100-L incubator. The seawater sup-

One of the wild haddock that has been held for several years in the broodstock facility at the Biological Station in St. Andrews and used to produce eggs for the industry.

ply is filtered to 5-µm, UV-treated and supplemented with oxygen to prevent nitrogen saturation. Water exits via banjo filters and eggs are prevented from accumulating on the outflow filters by directing mild aeration towards the filter. Dead eggs are removed daily by shutting off the water and air flow; viable, buoyant eggs accumulate at the surface, while dead eggs sink to the bottom and are purged. The volume of dead eggs removed provides an estimate of overall egg survival. Eggs are incubated at 6-8°C and hatch in 70 to 80 degree-days.

Larval Culture

After hatching is complete, larvae are transferred to larval tanks. Larval tanks have a volume of 2000 to 3000 L, are close to being flat-bottomed, and have upwelling water, aeration, and banjo filter outlets. Temperature in the larval tanks initially matches that of the egg incubators and is gradually increased to 10° to 12°C through the larval period. Larvae are initially fed rotifers that are enriched using a variety of diets ranging from dense microalgae to commercial formulations. Feeding rates are determined from the behaviour of the larvae and are adjusted depending on how quickly prey items are eaten. Generally, larvae are fed twice per day. By day 15 (100 to 150 degree-days), larvae are good hunters and need not be overwhelmed with feed items to ensure they receive adequate nutrition. By about day 25 (200 degree-days) larvae are started on *Artemia* nauplii and by day 40 (300-350 degree-days) weaning to a formulated diet can begin.

Weaning and Grading

Weaning can begin when larvae attain a size of 18 mm, usually coinciding with external signs of metamorphosis. This period also marks the beginning of cannibalism within the tanks. Improvements in survival rates have been made using high quality diets, and by improving hygiene and grading techniques. A better understanding of starvation and gill disease have allowed for much greater success and survival through the weaning and nursery period.

The production of juveniles for transfer to sea cages increased from 1,000 in 1997 to over 150,000 in 2001.

Transfer to Sea Cages

Haddock juveniles are transferred to sea cages at the Heritage Salmon Limited, Fairhaven Marine Site, in late May and June at the 3 to 5 g size. The fish are starved for 48 hours before transport. To date, the fish have been transported using 1- and 2-m^3 insulated tanks at stocking densities of 15 to 20 kg/m^3 (4,000-5,000 fish/m^3 tank). Oxygen is maintained in the range of 110-150% saturation. Periodic increases in oxygen levels to 200% saturation do not appear to severely impact the fish. Of note is that haddock will not recover from even short exposure to low oxygen; the result is almost certain death either immediately or shortly thereafter. Transport temperatures are set to approximate the receiving waters, generally 5-6°C in May and up to 8°C in June.

Initial transfers are made into 6 x 6 x 3 m deep cages of ½ inch (1.27 cm) stretch nylon treated mesh. Caution should be exercised to insure that nets are soaked on location for a few days prior to stocking with juveniles, since the net treatment can be toxic to juvenile haddock in a restricted-flow situation.

All haddock nets have a top net of treated nylon 1 3/8 inch (3.5 cm) stretch mesh that is tightly sewn in.

Feeds and Feeding

Haddock nutrition and feed development research have been carried out at the NRC Institute for Marine Biosciences in Halifax. Initial studies on the protein requirement of juvenile haddock found that 50% protein was essential for maximum growth. Lipid levels above 15% in the diet cause excessive fat accumulation in the liver resulting in a relatively high hepatosomatic index (HSI). Unlike salmonids, the main energy storage organ in gadoids is the liver, whereas the lipid content of the muscle rarely exceeds 1% of the wet weight. Dominic Nanton, a PhD student (supported by Heritage Salmon) at the University of Prince Edward Island, in collaboration with NRC, is investigating the effects of dietary lipid intake on lipid metabolism in the liver of haddock. His preliminary results indicate that levels higher than 12% dietary lipid cause an increase in liver growth and HSI, and also affect somatic growth. The liver function of fish with enlarged livers, however, is not affected.

Dry and moist grower feed formulations based on marine fish by-products have been developed by NRC-IMB and the specifications provided to commercial manufacturers. Dry expanded feed is currently produced by Zeigler Bros., Inc. and moist feed by Heritage Salmon. The fish are weaned onto dry feed and held on dry feed in the cages until the following spring, at which time moist vs. dry feed trials commenced. A number of feed trials have been conducted. At this point, the moist feed provides better growth than the dry feed. This may be related to better acceptability of moist feeds at low seawater temperatures and also a higher digestibility of fish protein in moist feed. Fish on moist feeds show a consistent dark skin colour and firmer texture of the anterior muscle than those on dry feed. Additional studies are planned to further investigate the effects of diet composition on growth, feed utilisation and fish quality.

Ongrowing in Sea Cages

Fish transferred into 6 x 6 x 3 m cages in May are moved into 12 x 12 x 6 m cages in mid to late July at which point they are contained by the standard 1 3/8 inch (3.5 cm) 210/80 mesh used for salmon smolts. A top predator mesh of similar twine is used. This top predator mesh is necessary as otter and mink show a marked preference for haddock when salmon and haddock are grown at the same site. It is necessary to tie the predator net securely to the main net. We use electrical ties at roughly 6-inch (15 cm) intervals. The selection of cage size for these trials was based on the availability of salmon cages that were small enough for experimental use and replication.

In the current program, haddock grow to about 180 g within 12 months from egg (December) to roughly 1 kg by the following December, and to 2 to 2.5 kg (4.4 to 5.5 lb) by the following year end, at which point harvest begins.

A growth curve is under development and confirms the relatively slow growth of haddock in the ambient temperatures of the Bay of Fundy. The curve also shows a distinct relationship between growth and with temperature and points the way to improved growth for haddock in the area.

Processing and Marketing

Over the last year a number of trials were conducted to determine the procedures for harvesting and processing and to test the product in the market place. To date about 3 tonnes have been handled. The fish were processed mainly during the period January through February 2001. There still remains much work to be done on issues such as pre-starvation strategies, effect of maturation on product quality, timing of filleting in relation to the onset of rigour, and timing of fish to market since haddock appear to stay in rigour up to 5 days post-harvest.

Fish were harvested for the trials by seine and dip net. The average size of the fish was roughly 1.4 kg. These fish were smaller than the eventual market size, but represented the 1998 year-class which were no longer required for the on-going trials. The fish were bled by slicing across the front of the isthmus region; this appeared to provide a better bleed than slicing a gill arch, as is used for salmon. The fish were bled in iced seawater and transported to the processing plant.

The fish were filleted, J-cut to remove the bones, skinned and layered with cello separation, and iced in 10 lb. (4.5 kg) Styrofoam boxes. Fillet sizes were 6-8, 8-10, and 10-12 oz, (168-224 g, 224-280 g, and 280-336 g), smaller than future targets but fully marketable. Fillet yields for this size and group of fish were roughly 34%, similar to that of wild haddock. Expectations are for higher yields in subsequent lots of fish since the larger fish in the lot, over 1.8 kg, exceeded 38% yield.

Market acceptance of the haddock fillets, without exception, has been excellent. The processing trials clearly showed the need to automate the haddock filleting operation not only to reduce cost, but because hand filleting is a disappearing art.

Commercialisation of Haddock Culture

The main constraints to commercialisation of haddock in Atlantic Canada include:

1. *Sea cage growth rates.* A number of issues must be addressed including: a) testing haddock growth at elevated temperatures in a land-based system using heated and re-circulated seawater; b) incorporation of technology under study, including advancement of spawning from the current December/January period to early November, allowing juveniles to grow to 50-100 g before entry to sea cages in May; and 3) incorporation of F1 and subsequent generations into the system to evaluate benefits of selective breeding.
2. *Cage site availability.* There are currently severe restrictions on the issuance of new leases for cage sites in Atlantic Canada. In order for this species to become a significant component of aquaculture in this region, new sites need to be allocated for new species, or haddock must be demonstrated to be a preferred alternative to salmon on existing sites, or culture must take place in a controlled land-based system.
3. *Availability of new investment money for haddock.* New investment dollars for aquaculture, in particular for a new and untried species, are not readily available. Thus, the focus of this program was on demonstration of the commercial feasibility of the species. Progress is being made in this area, but more needs to be done by bringing additional lots to market and improving the technical performance of the species to justify the confidence of investors.

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Role of Extension Services in Aquaculture Development

summary of a special session held at Aquaculture Canada 2001, Halifax, Nova Scotia

One of the primary mandates of the Aquaculture Association of Canada (AAC) is to act as a bridge between those involved in aquaculture research and development and the users of the information, the aquaculture industry. To fulfill this role, the AAC holds an annual conference (Aquaculture Canada) that brings together students, academics, and industry and government stakeholders, all of whom share a common objective of improving the industry through the dissemination of information. At Aquaculture Canada 2001, held in Halifax, Nova Scotia, a special session was organized on the role of extension services in the development of Canadian aquaculture. Presentations were given by six well-respected professionals, representing five Canadian provinces, actively involved in providing technical or extension service support to growers in the industry.

The speakers were Bill Heath (British Columbia), Richard Moccia (Ontario), Maurice Gaudet and Claude Forest (Quebec), Richard Gallant (Prince Edward Island), and Karen Coombs (New Brunswick). Each speaker was asked to present an overview of their experience as extension specialists, their perception of their role, and the constraints they face in doing their work, and to provide suggestions for increasing interaction among extension officers in Canada.

Context

While the AAC annual conference plays a key role in enhancing the exchange of information between science and industry, the daily efforts of extension officers in each of the provinces have largely been overlooked. The AAC recognizes that a large part of the growth and success of the industry is due to the extensive, yet subtle, support provided by a network of experienced professionals who work closely with growers to solve problems, transfer and adapt new technologies, and follow up on farm-based research and development. Extension services are critical to ensuring that aquaculture R&D is transferred to the industry. Although extension services in agriculture have a long history, it is a relatively recent support mechanism for aquaculture producers, and the method of intervention, as well as the type of services provided, vary widely between regions.

Extension officers in both the freshwater and marine sectors of aquaculture are dealing with a higher level of complexity and an increasing number of problems as both species and technologies evolve and become part of the aquaculture framework. Their schedules are becoming more demanding as the number of farms expand in number and size. How are extension officers coping with the demand and what are the mechanisms for them to access the knowledge and solutions they require to support the industry? This special session was a first step in linking their expertise with that of their peers. The input and participation of the six speakers was very rewarding to all who attended, not only because of their enthusiasm and frankness, but because they demonstrated the complexity of their responsibilities and the intricate nature of their relationships with growers, as they struggle with limited time and resources.

Extension services are critical to the improvement and development of aquaculture. In many cases, significant funding has been allocated to maintain this service. However, unlike scientists who have a multitude of venues for information exchange, there has never been a national aquaculture extension service workshop or conference of note in Canada.

The special session on extension services held at Aquaculture Canada 2001 provided a unique opportunity for extension officers to share their knowledge and expertise and develop a network of contacts.

Presentations

I have listed a description of the responsibilities carried out by extension officers and an overview of the type of services offered throughout the country. The intent is to initiate an information database that reflects the responsibilities and issues that relate to the provision of aquaculture extension services in Canada.

The presentations given by the 6 speakers were based on their practical experience. The titles of their talks reflect the different issues and concerns presented by each speaker:

W.A. Heath: Shellfish aquaculture extension through collaboration with industry in British Columbia

M. Gaudet and **C. Forest**: Technical support to Quebec mariculture businesses

R. Moccia: A pedagogical paradox: How to do more with less in extension education

R. Gallant: PEI's experience in providing technical advice to the aquaculture sector

K. H. Coombs: Changing roles of extension officers in a changing industry

Issues and Concerns

Roles of extension officers

- Technical guidance
- Organize industry workshops
  - Best management practices
- On-site monitoring and advice
- Completion of evaluation forms (fact sheets) for growers
- Veterinary services
  - Clinical/diagnostic
  - Advice and assistance
  - Practical information
  - Monitoring
- Information transfer
  - Technical transfer and outreach
  - Prepare and distribute publications on topics of interest to the industry
  - Trouble-shooting/certification
  - Assistance via telephone
  - On-site assitance and sampling
- Human resources and lab space provided
- Travel support for clients to attend workshops
- Technical duties include helping to develop government programs.

Problems and challenges encountered by extension officers

- Difficult to respond to increased demand for services
- Challenge to gather all the required information related to the increased number of species being cultured
- Extension is not the only information transfer required; education of clients (uptake/assimilation/use of information) also takes time and energy
- Rate of pay not a function of the expertise of the technical officer — this needs to change in order to maintain the level of expertise required to support the industry
- College and university specializations could be better utilized
- Difficult to separate regulatory enforcement duties and the technical help needed by industry; extension officers are occasionally placed in conflicting situations with negative long-term consequences

What does the industry want or need from extension officers?

- Need for a better understanding of clients
- Need to stay current, which is often difficult
- Need to be more efficient in passing along information to clients
- Need to enlarge the R&D information base
- Want a single management program so that all services are available from one source
- Need to examine how to complement extension services with educational support provided by colleges and universities
- Need annual list of action items — this would structure service provided to clients
- Want industry-driven programs
- Want technical outreach — this requires providing deliverables to the private sector (fact sheets & talks, which forces extension officers to get out into the field)
- Want more student involvement in the industry
- Want to foster a teacher/learner relationship between extension officers and farmers

Recommendations

Most of the extension officers either come from industry, were once entrepreneurs or have postgraduate experience, but in all cases they have learned the trade through the fulfillment of their responsibilities within their government office or institution. The six speakers represent decades of field experience and interaction among their peers, and this portfolio of valuable expertise is recognised and appreciated by industry stakeholders. As such, the extension officers were asked to present proposals to better structure the extension services within and among provinces, and propose ways to strengthen ties.

Based on the above discussions and presentations, three principal recommendations were proposed and supported by all the speakers and the audience:

- To establish a **National Network of Extension Specialists (NNES)**. The interaction could be maintained through gatherings at the AAC annual meeting. A list of contacts could be drawn-up (who/where) and cross-pollination between jurisdictions could enhance the knowledge base of individuals and the capacity for information transfer among extension officers.
- To establish a **Center of Training for Extension Service Officers,** so that they can keep abreast of information and learn the techniques for reaching clients and improving the teacher/learner relationship.
- To provide a **Professional Certification** (as is done in British Columbia) for extension officers.

The details of each proposal will have to be worked out during the next session on extension services, being held in Charlottetown, PEI, at Aquaculture Canada 2002, in September. It is our intention that this annual session take on a life of its own!

Discussion Period

The meeting ended with a general discussion and participation from the audience. Several questions related to the support of extension services merit additional consideration, including:

- Should government remain involved in extension services, especially since aquaculture is still a relatively young, developing industry? Many participants felt that governments have a role and responsibility for providing extension services.
- Should industry pay for extension services and should there be a fee for service?
- How should intellectual property issues be resolved or protected in the course of duty?
- What is the role of private consultants in extension services?
- Should there be specific non-disclosure agreements between extension officers for services provided and the client? Are there currently problems and are such agreements needed?

For the short term, there was general consensus to promote the following:

- To establish an e-mail discussion list for technical support staff across the country. Several venues are presently available or possible. These include the use of Aqua-L, or perhaps the creation of an Extension-L! There is also the Recirculation Technology list.
- To define the role and responsibilities of Extension Officer positions. What is the technical expertise required for the position in today's aquaculture sector ?

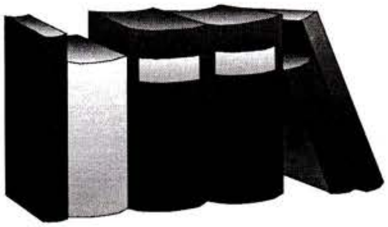
Conclusion

I have summarized the issues and discussions from the May 2001 special session on the role of extension services in aquaculture development. This paper is intended to be a guide for future meetings and is limited to the facts of the presentations; I have attempted not to stray from the essence of the meeting. I would like to extend my congratulations to all the speakers who made the effort to tell their story, and to the members of the audience who openly discussed their views.

This special session emanated from discussions of an *ad hoc* membership committee of the AAC, composed of Stephen Lanteigne, Chris Hendry and myself. Our intent was to look at ways to increase AAC membership. Although many venues are still to be explored, it was recognised at the time that one of the key stakeholders in the aquaculture industry was poorly represented at AAC annual meetings. By exposing the extraordinary role of extension officers, who are so intimately part of the fabric of aquaculture development, we hope that AAC can help facilitate the transfer of information between science and industry, through a network of Canadian extension officers. This in turn may serve to bridge the information gap for their clients, the aquaculture producers.

— John C Bonardelli, PhD

Session chair



New Publications

Recirculating Aquaculture Systems, by MB Timmons, JM Ebeling, FW Wheaton, ST Summerflet and BJ Vinci, December 2001, US$70 plus shipping and handling, ($6 per book USA, $12 other countries), quantity discounts available. Contents include: recirculating aquaculture technology, water quality, fluid mechanics and pumps, mass balances and loading rates, culture units, biofiltration, waste management and disposal, fish health management, fish nutrition and feeds. The book also includes a CD-Rom of software packages to calculate a wide variety of aquaculture type problems, e.g. CO_2 removal, oxygen addition, production economics, pipe friction losses, etc. For more information, contact Brenda Marchewka at Cornell University, e-mail: BLS19@cornell.edu (tel 607 255-2495, fax 607 255-4080).

Natural Resources Engineering, by EW Tollner, June 2002, Iowa State University Press. 512p., hardcover, ISBN 0-8138-1847-8, US$124.95. This practical text and reference examines physics and engineering aspects related to water, soil and air quality preservation. It covers a diverse range of topics on the forefront of natural resource engineering. Iowa State University Press (website isupress.com).

European Water Management, the official journal of the European Water Association (EWA), has started a free e-mail news service. Older issues of the news are available at www.riza.nl (click on European Water Management News). Visit the site to get an idea of what you will get and if this is useful for you. To subscribe, e-mail jan.van.de.kraats@kabelfoon.nl with "Subscribe European Water Management News" in the subject line.

An Illustrated Dictionary of Fish and Shellfish CD-Rom, by C Frimodt, October 2001, Iowa State University Press. CD-Rom 87-980974-90, US$141.99. Includes over 770 commercially important species of fish and shellfish. Each entry has several distinguishing features, including: color illustration, detailed map of where the species is found, optimum size and weight, catching method, and grading of eating quality. Easy-to-follow directions will help even the novice computer user access the information with ease. Iowa State Press. (website isupress.com).

Sea Fish, by BJ Muus and JG Nielsen, drawings by P Dahlstrom and BO Nystrom, October 2001, Iowa State University Press. 340p., hardcover, ISBN 87-90787-00-5, US$63.95. The book includes an overview of fish physiology, life cycles, and includes all common fish of Europe. Iowa State Press (website isupress.com).

Phytoplankton Productivity, edited by P Williams, D Thomas, and C Reynolds. June 2002, Iowa State University Press. 400 p., hardcover, ISBN 0-632-05711-4, US$94.95. Includes: approaches to the measurement of phytoplankton production, assessment of primary production on a global scale, origins and causes of interannual varability of freshwater phytoplankton, regional-scale influences on the long-term dynamics of lakes, and other topics. For more information, check the website www.plankton-productivity.org.

Carp and Pond Fish Culture, 2nd ed., by L Horath, C Seagrave, and G Tamas. April 2002, Iowa State University Press. 208p., hardcover, ISBN 0-85238-282-0, US$79.95. This book describes the full cycle of fish culture, from selection and spawning of broodstock through techniques of early fry rearing, growing, and harvesting. Included is information on the historical background of carp husbandry, fish feeding, and health, and guidelines for pond planning, stocking, and maintenance. Iowa State University Press (tel 515 292-0140, fax 515 292-3348, website isupress.com).

Responsible Marine Aquaculture, edited by RR Stickney and JP McVey, June 2002, CABI Publishing. 416p., hardcover, ISBN 0-85199-604-3, US$120. This book was developed from a meeting of the World Aquaculture Society, held in Florida in January 2001, with additional contributions commissioned. It focuses on minimal net utilization of natural resources, production of healthy products for food, and appropriate regulations and policies, illustrated by case studies from various areas including North and Latin America, Asia and the Pacific. CABI Publishing (website www.cabi-publishing.org/bookshop).

Calendar

conferences, workshops, courses and trade shows

- **Aquaculture Canada 2002, 19th Annual Meeting of the Aquaculture Association of Canada,** 17-20 September 2002, Delta Prince Edward, Charlottetown. Theme: *Finding Solutions, Creating Sustainable Wealth.* Co-hosted by the PEI Aquaculture Alliance and the PEI Department of Fisheries, Aquaculture and Environment. Information: AAC Office (tel 506 529-4766, e-mail aac@mar.dfo-mpo.gc.ca, website www.aquacultureassociation.ca).

- **Bordeaux Aquaculture 2002,** 18-20 September 2002, France. For more details: contact Bordeaux Evénements Congrès, Allé Louis Ratabou, BP 105, 33030 Bordeaux Cedex, France (fax +33 556 11 88 22, e-mail bxaqua@bordeaux-expo.com, website www.bordeaux-aquaculture.com).

- **Aquafest Australia 2002**, 19-22 September 2002, Wrest Point Convention Centre, Hobart, Tasmania. Information: Tom Lewis (TAGA), 73 Lansdowne Crescent, West Hobart 7000 Australia, (tel (03) 6231 9230, e-mail tom_lewis@ biodevconsult.com).

- **Littoral 2002 "The Changing Coast",** 22-26 September 2002, Porto, Portugal. Information: email fpinto@fe.up.pt website: www.eucc.nl/ littoral2002

- **100th Anniversary Meeting of the International Council for the Exploration of the Sea (ICES) 2002**, 1-5 October 2002, Copenhagen, Denmark. The theme of the science conference is *Aquaculture: New Trends and Developments* in recognition of the important work being done in the North Atlantic region. If you are interested in participating, please contact the convenor by e-mail: I.R.Bricknell@marlab.ac.uk

- **Aquaculture Pacific Exchange Conference and Exhibition,** 3-4 October 2002, Strathcona Gardens, Campbell River, Canada. Consists of a 100-booth trade show and 2-day conference. Produced by Master Promotions Ltd. (tel 506 658- 0018, e-mail show@nbnet.nb. ca).

- **Aquaculture Europe 2002,** 16-19 October 2002, Verona, Italy. Organized by the European Aquaculture Society. Theme: *Placing Aquaculture in Rural and Coastal Management.* Workshops: Applied solutions to health management in Mediterranean aquaculture, new technologies for Mediterranean aquaculture, and certification in aquaculture (HAACP, ISO standards, ecolabelling and organic). Information: EAS (e-mail ae2002@ aquaculture.cc).

- **Aquaculture Pacific Exchange Conference and Exposition,** 3-4 October 2002, Strathcona Gardens, Campbell River, BC, Canada. Managed and prodcued by Master Promotions Ltd. Information: http://www.masterpromotions.ca/ fisheries/pacificexchange.html.

- **The Society for Underwater Technology Conference,** 29-31 October 2002, Den Pasar, Bali, Indonesia. Focus of the conference will be on sites that > 30 km from shore. Information: website www.sut.org.uk, e-mail jeansut@sstg. demon.co.uk, tel +44 (0) 1224 823637. Website: www.sut.org.ul.

- **5th International Symposium on Flatfish Ecology 2002**, 3-7th November 2002, Port Erin Marine Laboratory, Isle of Man (UK). Symposium will address the role of flatfishes in benthic ecosystems under three themes: patterns, processes and management. For information, contact Richard Nash, Port Erin Marine Laboratory (e-mail flatfish@liv.ac.uk, website www.liv.ac.uk/peml/ flatfish).

- **International Workshop on Restoration of Benthic Invertebrate Populations: Genetics, Diseases and Ecology,** 9-12 November 2002, Coquimbo, Chile. Program will include thematic sessions, invited key speakers, and oral and poster presentations. Papers and posters are invited on topics related to the restoration of invertebrate populations. Workshop will be in

English with simultaneous translation into Spanish. For information, e-mail: restoration@ucn.cl, telephone (56) 51-209813,or fax (56) 51-209910.

- **Second International Seafood By-Products Conference,** 10-13 November 2002, Anchorage, Alaska. Information: J. Babbitt, tel. +1 907 486-1518, e-mail akfishfound@aol.com

- **Effects of Fishing Activities on Benthic Habitats: Linking Geology, Biology, Socioeconomics, and Management,** 12-14 November 2002, Doubletree Westshore Hotel, Tampa, Florida, USA. E-mail: lori@esa.org

- **Fish at EuroTier 2002,** 12-15 November 2002, Hanover, Germany. For more details contact DLG, Eschborner Landstr 122, D-60489 Frankfurt am Main, Germany (fax +49 69 247 88 113, e-mail u.hausmanns@digfrankfurt.de, website www.eurotier.de).

- **Caribbean Aquaculture Association,** 12-17 November 2002. Allegro Hotel, Providenceiales, Turks and Caicos Islands. Offshore cage culture in the Caribbean will be featured. Information: Daniel Benetti at dbenetti@ rsmas.miami.edu.

- **Acuicultura 2002**, 20-23 November 2002, Santiago, Chile. Information: contact Sue Hill at sue.hill@informa.com

- **Aquaculture America 2003**, 18-21 February 2003, Commonwealth Convention Center, Louisville, Kentucky. US National Aquaculture Conference and Exposition of the US Chapter of the World Aquaculture Society in conjunction with the National Aquaculture Association and the US Aquaculture Suppliers Association. Information: Director of Conferences (tel +1 760 432 4270, fax +1 760 432 4275, e-mail worldaqua@ aol.com).

- **Sea Urchins: International Conference on Fisheries and Aquaculture 2003**, 25-27 March 2003, Puerto Varas, Chile. Aquaculture portion of the program will feature open ocean and land-based operations, reproduction, stocking, nutrition and disease. For more details, visit website www.ifop-acuicultura.cl/SeaUrchin2003/index.html, or contact Mrs. Soledad Toledo, Balmaceda 252, Puerto Montt, Chile, (tel. +56 65 25 99 96, fax +56 65 26 29 61, e-mail lseaurchin2003@ifop.cl).

- **World Aquaculture 2003,** 19-23 May 2003, Bahia Convention Center, Salvador, Brazil. Annual meeting of the World Aquaculture Society in conjunction with other associations, industry and government sponsors. Information: Director of Conferences (tel +1 760 432 4270, fax +1 760 432 4275, e-mail worldaqua@ aol.com).

- **3rd International Percid Fish Symposium,** 20-24 July 2003, Madison, Wisconsin. Program will cover the current status of percid fisheries, pecid biology, and rcent breakthroughs in the aquaculture of percids. Contact: Terence P. Barry (tel 608 263-2087, e-mail tpbarry@ facstaff.wisc.edu). Website: www.seagrant.wisc.edu/percids.

- **Aquaculture Canada 2003 and Aquaculture and Pacific Exchange Conference and Exhibition,** 28 Oct - 1 Nov 2003, Victoria Conference Centre, Victoria. For Aquaculture Canada information, contact Shawn Robinson (e-mail robinsonsm@mar.dfo-mpo.gc.ca, fax 506 529-5862). Trade show information, contact Master Promotions Ltd., (tel 506 658-0018, fax 506 658-0750, e-mail show@nbnet.nb.ca).

- **Aquaculture 2004**, 29 February - 4 March 2004, Hawaii Convention Center, Honolulu. Triennial meeting of the World Aquaculture Society, the National Shellfisheries Association, and the Fish Culture Section of the American Fisheries Society. Information: Director of Conferences (tel +1 760 432 4270, fax +1 760 432 4275, e-mail worldaqua@aol.com).

- **2004 Aquaculture Pacific Exchange Conference and Exhibition,** Campbell River, October 2004. Consists of a 100-booth trade show and 2-day conference. Produced by Master Promotions Ltd., PO Box 565, Saint John, NB (tel 506 658-0018, fax 506 658-0750, e-mail show@nbnet.nb.ca).

- **AQUA 2006,** 9-13 May 2006. Florence, Italy. Annual conferences of the World Aquaculture Soceity and the European Aquaculture Society. Information: Director of Conferences (tel +1 760 432 4270, fax +1 760 432 4275, e-mail worldaqua@aol.com).