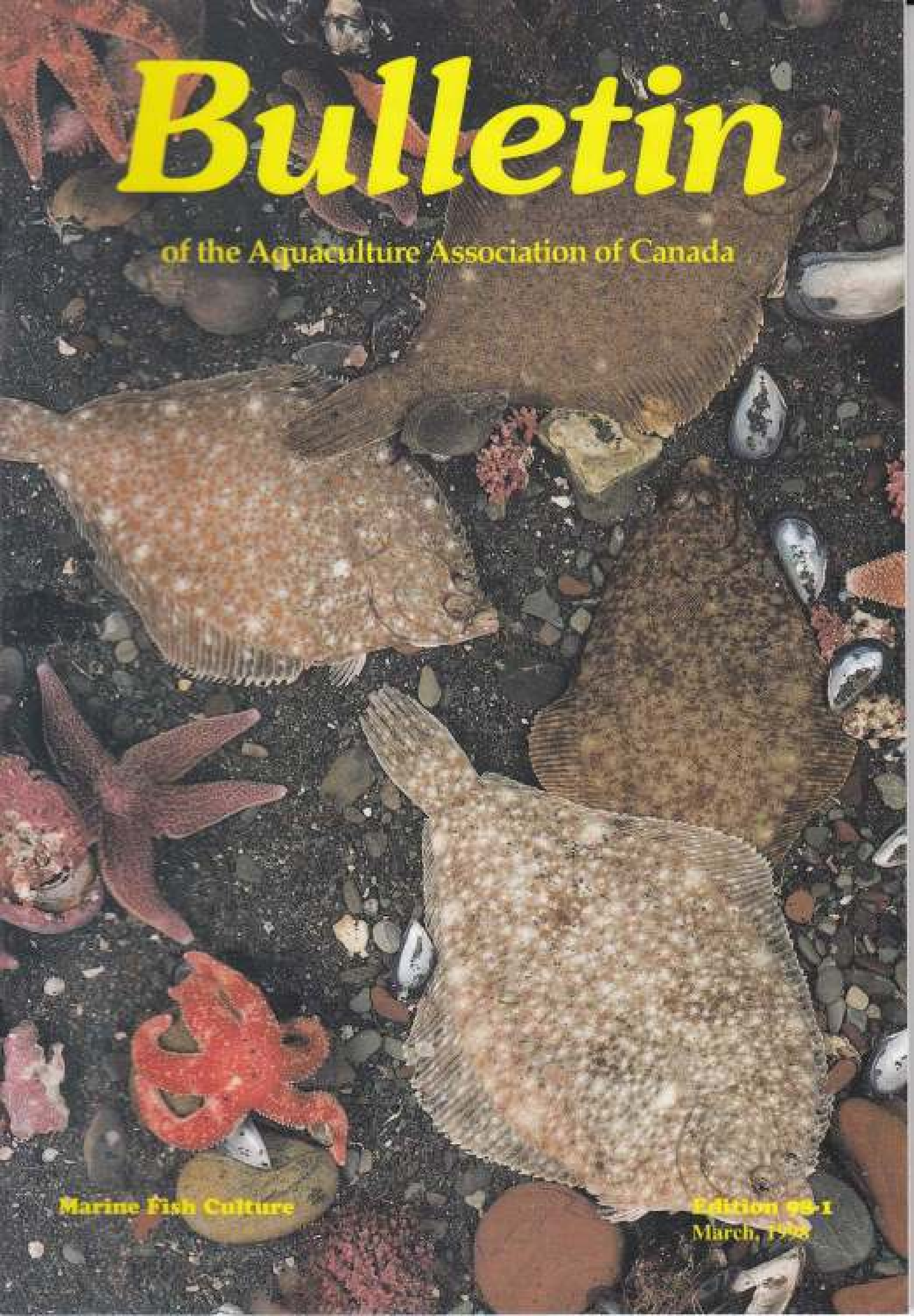
Bulletin

of the Aquaculture Association of Canada



Marine Fish Culture

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of the
Aquaculture Association of Canada

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Cover: Yellowtail founder, Pleuronectes ferrugineus (CCFI photo).

Preface

The premise for the marine finfish session which occurs annually at the Aquaculture Association of Canada (AAC) meeting is to provide an update to the Canadian aquaculture community on the status of marine aquaculture in Canada and the world. At the 1997 AAC meeting held in Quebec City we expanded the scope of the session to provide not only an update on this increasingly important area of aquaculture in Canada but also to bring in some European experts to speak on the history of the marine aquaculture industry in Europe. The session and this issue of the *Bulletin* was made possible through the support of the Canadian Centre of Fisheries Innovation based at Memorial University of Newfoundland in St. John's. Through their support, speakers from Europe, the United States and across Canada were brought to Quebec City to speak on the status of various species. The session was divided into "flatfish" and "roundfish" sections with a keynote speaker for each.

The keynote speaker for the flatfish section was Dr. Bari Howell, Head of Fish Cultivation at the United Kingdom's Centre for Environment, Fisheries and Aquaculture Science located in Conwy, Wales. Bari has been involved in turbot aquaculture since the late 1960s and pioneered the development of rearing techniques for larviculture of this species. In his paper, Bari highlights the history and growth of the turbot industry in Europe. Other papers in this section are on summer flounder in the United States (George Nardi), Atlantic halibut (David Raymond), winter flounder (John Batt) and yellowtail flounder (Joe Brown).

The keynote speaker for the roundfish section was Mr. Richard Prickett, a director and co-founder of Marine Farm Technology Ltd. The company is actively involved in sea bass and sea bream farming in Greece and has a 450 tonne/year operation. In his paper, Richard outlines the history and development of this industry in Europe. He also discusses the problems regarding market saturation and expansion which currently face this industry. Other papers in this section are on Atlantic cod (Jonathan Moir), haddock (Matt Litvak) and wolffish (Joe Brown).

One of the "take home" messages from this session is that marine fish aquaculture is a viable industry but there is a "time frame" associated with developing a species for commercial production. As you will read, the time frame is considerable, commonly more than 15 years from initiation to commercialization. The effort involves directed research and cooperation among government, industry, and researchers. It also requires investment in R&D during the early stages.

At the moment in Canada we are seeing the early stages of this industry involving Atlantic halibut, and soon Atlantic cod. Given you are reading this over a year after the session in Quebec took place, means that another year of R&D on the species mentioned above has been completed. Species such as Atlantic halibut and cod are that much closer to commercialization. Good success has been achieved with haddock and yellowtail flounder, while promising initial results have been realized with new species such as sturgeon and witch flounder (grey sole). Progress towards commercialization moves steadily forward for all the species mentioned above.

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Development of Turbot Farming in Europe

B. R. Howell

The potential of turbot *(Scophthalmus maximus)* as a candidate for farming was first recognized in the early 1970s by researchers in the United Kingdom following laboratory growth trials using wild-caught juveniles. The relatively rapid growth rates achieved, combined with the high market value, stimulated considerable interest among the research and commercial communities. Effort was immediately diverted from other species which had been the subject of pioneering work on marine fish cultivation during the previous decade. Rearing turbot proved more challenging than other species but by the mid-1970s pilot-scale trials were being conducted using hatchery-reared fish. This paper critically reviews the early advances and subsequent developments which have led to a current European production of about 3000 tonnes per annum centered mainly in north-west Spain. There have been some impressive developments during these these two decades, particularly in relation to the industrialization of hatchery techniques. It is suggested, however, that the development of the industry could have been accelerated and its present position strenghtened by greater anticipation of the problems it would have to confront and a more co-ordinated approach to their solution.

Introduction

The turbot, *Scophthalmus maximus* (syn. *Psetta maxima*), is among the most valuable fish of the eastern Atlantic occupying coastal waters to a depth of 80 m from western Norway to southern Spain and throughout the Mediterranean. In the Black Sea it gives way to the equally valuable and closely related species, *Scophthalmus maeoticus*. Though common, turbot does not occur in dense concentrations so that the relatively modest annual European catch of 6,000 to 10,000 tonnes is generated mainly as a by-catch of demersal fisheries for other species. The turbot is one of the top predators of its habitat, feeding on small crustaceans, molluscs and fish in its early juvenile stages but becoming progressively piscivorous during its later developmental stages.(1)

Modern interest in farming the species arose mainly from field(2) and experimental(3) studies of the biology of the species during the late 1960s. This interest was intensified by an exploratory growth trial using wild-caught juveniles which provided a convincing demonstration that the species could attain high growth rates in captivity.(4) This was central to the outcome of an economic analysis which identified turbot as the most promising candidate for farming.(5) Subsequent research effort was consequently focused on this species in preference to the plaice (*Pleuronectes platessa*) and sole (*Solea solea*) which had been the subjects of Shelbourne's pioneering work on the rearing of marine fish larvae.(6)

Early Research

The principal obstacle to the realisation of the perceived potential of the species was that it could not be reared through its larval stages by the methods so successfully developed for other flatfish.(6) The immediate problem was that the larvae were too small to ingest newly-hatched *Artemia*, and would not survive even when fed on cultured rotifers (*Brachionus plicatilis*), an organism which had been shown to support survival of the similarly small larvae of the lemon sole, *Microstomus kitt*.[7] The realisation that these difficulties were due to the nutritional inadequacy of these organisms arose following the successful rearing of a small number of juveniles in a tank to which algae-rich water from an outdoor pond had been added to promote the proliferation of the rotifers which were in short supply.[8] Subsequent experiments suggested that the algae were an important source of long-chain polyunsaturated fatty acids,[9,10] recently found to be essential dietary requirements of turbot.[11] The other significant development at this time was the demonstration that spawning time could be manipulated by photoperiod control, thus allowing a year-round supply of eggs to support both research and commercial activities.[12]

Commercial Developments

Early developments

Industry rapidly took up the challenge of developing commercial systems once these initial advances had been made (Fig. 1). Although in 1972 researchers in the United Kingdom[8] and France[13] had succeeded in rearing only about 50 juveniles at each of three research laboratories, this was sufficient encouragement for two companies in the UK to immediately initiate exploratory on-growing trials. They also became involved in developing hatchery technology, complementing and collaborating in the programmes of the research organisations whose efforts were addressing the key problems of rearing larvae such as egg quality,[14] live food quality[9,10] and weaning onto formulated feeds.[15] The on-growing trials utilised the warm-water effluent from nuclear power stations which was perceived at that time to be a commercially acceptable way of maximising growth. These were supported initially by wild-caught juveniles but dependence on this source of material gradually lessened as rearing competence in hatcheries improved.

By the end of the 1970s, small quantities (about 50 tonnes per year) of fish were being grown to market size from these installations and, though problems remained, the reliability of hatchery techniques was judged to have improved sufficiently to justify the scaling up

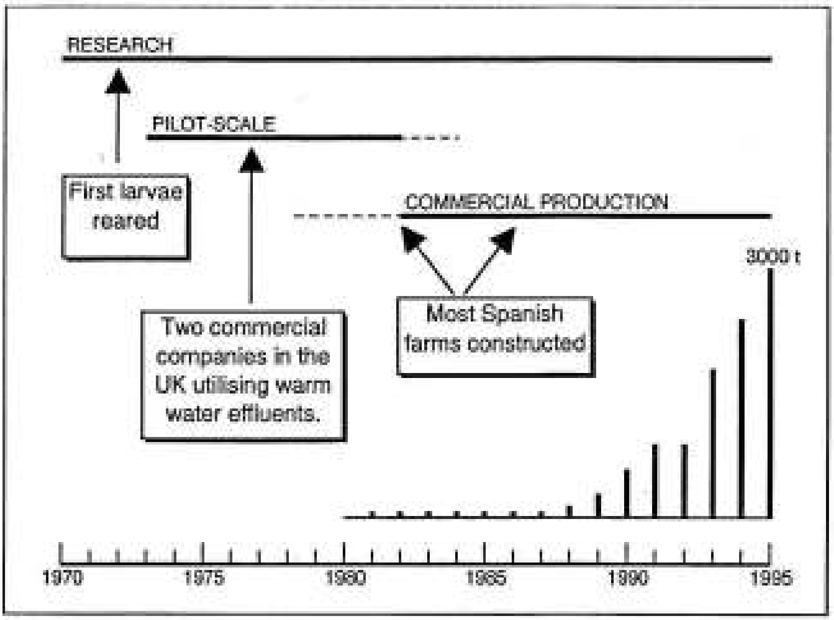

Figure 1. Schematic representation of the development of turbot farming in Europe.

of on-growing units.[16] Hatcheries continued to be developed in northern European countries such as the UK, Norway, and Denmark, where it was considered the cooler climate favoured this phase of production. More southern climes, however, where ambient temperatures were considered to match the requirements of the species were favoured for on-growing operations. The abandonment of nuclear power station sites was largely from concern over the dependence for adequate supplies of water on the good will of power station staff, whose other responsibilities were of much greater economic importance, as well as the potential adverse effect on marketability of the association with nuclear installations. Thus, during the early 1980s the centre of turbot farming shifted to the Atlantic coast of France and Spain, mainly in Galicia.

Commercial production

The majority of existing farms in Galicia were constructed between 1982 and 1986 (Fig. 1). From this time production rapidly increased, reaching about 3,000 tonnes by 1995 with over 90% of this originating from France and Spain (Fig. 2). This compares with a combined production of sea bass and sea bream of more than 30,000 tonnes in the same year despite the almost simultaneous development of rearing methods for these species. This disparity was largely due to the greater difficulty of rearing turbot through the larval stages so that the supply of juveniles did not cease to constrain output until the early 1990s. Marketing considerations were also important. Turbot were more difficult to market because of the lower consumption of that species and the problem was accentuated initially by the poor quality (in terms of pigmentation, flesh texture and fat content) of the farmed product. In Spain, these factors contributed to a greater than 40% decrease in selling price between 1986 and 1992 (Fig. 3). A gradual improvement in juvenile quality and a change from the use of a wet diet of trash fish of variable quality to more precisely formulated dry diets appear to have resolved this problem and resulted in a stabilisation of prices.

During this period of commercialisation, the high initial investment costs associated with pump-ashore installations combined with a declining market value, forced many farms into liquidation. The shortfall in juvenile supply also contributed to the financial difficulties, compelling many of the farms to operate inefficiently at production rates well below capacity. In 1991 for example, farms were operating at only about 30% of their capacity, but as juvenile supplies improved this increased to 68% over the subsequent four years (Fig. 4). This greatly improved profitability was further enhanced by the disposal of

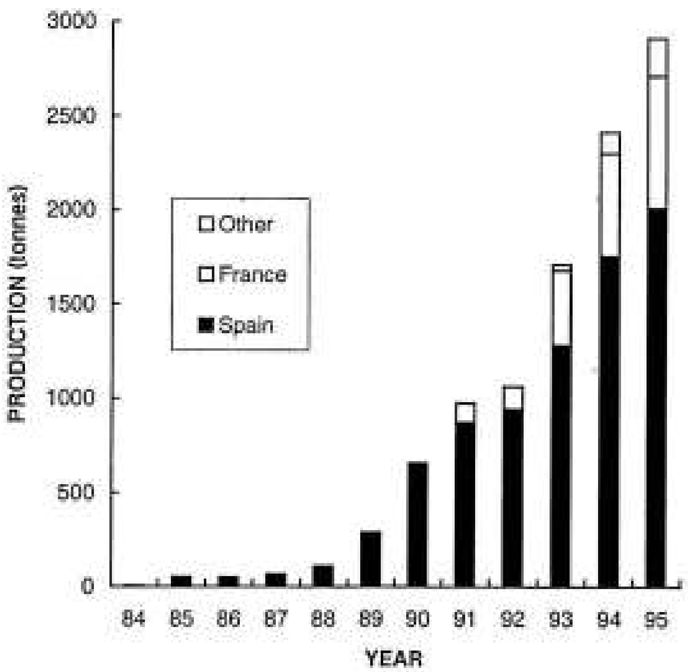

Figure 2. European production of farmed turbot.

liquidated farms at minimal prices, thus relieving the purchasers of the financial burden of high initial investment costs.

A natural consequence of the concentration of on-growing installations in southern Europe was a change in the geographical distribution of hatcheries. In 1986, for example, the UK provided 60% of the total juvenile production (420,000) and France and Spain together provided 32% of supplies. By 1995 the total production of juveniles had increased by almost an order of magnitude to just over four million with France and Spain increasing their share to 80% and that of the UK falling to a meagre 2%. Denmark has been an exception to this trend with their contribution increasing over the same period from 2 to 12%. This is probably attributable to the development of extensive culture methods in that country[17] and the perceived high quality of fish reared in that way.

Current trends

The experience of farming turbot in northwest Spain has shown that conditions are not as ideal as was originally thought. Although the climate prevents the prolonged periods of growth cessation experienced at more northerly latitudes during the winter, summer temperatures have proved to be too high at many locations. This is particularly evident during the second and third years of the production cycle when loss of growth and mortalities may be appreciable. It seems that the decline in the optimum temperature for growth as the fish get older, compounded perhaps by the stress imposed by high density culture, was not anticipated when sites were selected. In this context, a recent re-appraisal of the potential for farming turbot at ambient temperatures in the British Isles concluded that farming may be economic in areas where winter temperatures do not fall below about 8°C. Economic viability may be further enhanced if the loss of growth during the winter is further reduced by the relatively inexpensive measure of artificially extending the long summer photoperiods into the autumn. Such farms have recently been established in both Scotland and Ireland and, in the case of the latter, have already marketed small quantities of fish (Fig. 5).

This recent trend of increased farming activities in northern European countries has also been contributed to by the use of warm water from industrial plants (e.g. in Norway) and the use of recycling systems (e.g. the Netherlands and Denmark). There has been a widespread resurgence of interest in the latter because of the potential advan-

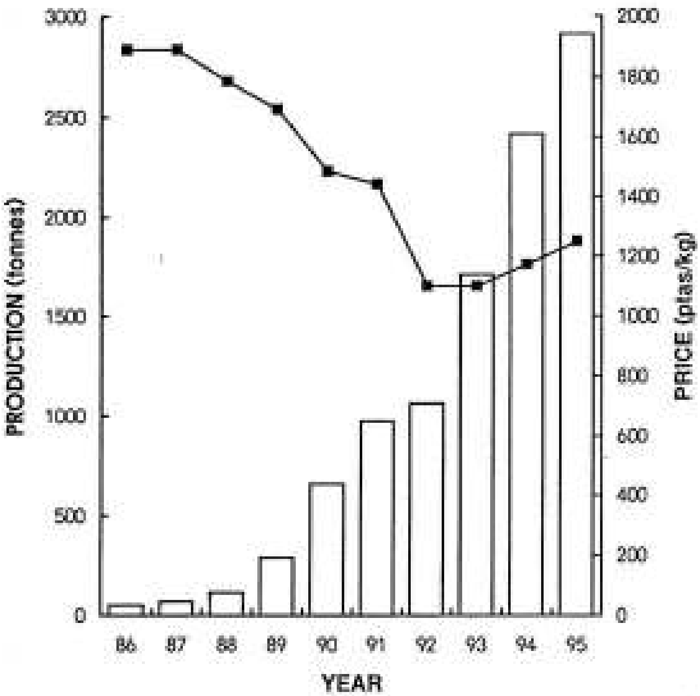

Figure 3. Changes in selling price (line) and production of farmed turbot in Spain.

tages they offer.[18] These include:

1. Greater control over water quality and comparative independence of fluctuations in the quality of the ambient supply;
2. Elimination of seasonal variations in temperature, allowing faster growth rates and therefore higher production in a given volume of tankage;
3. Significant reduction in seawater pumping costs, a major expense in single-pass tank systems;
4. Freedom from the need to acquire prime low-lying coastal sites;
5. A lower level of environmental degradation because of the greater control over effluent quality.

The technical capability of such systems has already been demonstrated and it will be the refinement of these, and economic considerations, that will determine the extent to which they are used commercially. However, current indications are, however, that this technology may provide the means of further extending the geographical range of farming operations.

Overview of Progress

It has taken about 25 years to attain an annual production of about 3,000 tonnes from the initial recognition of the potential of turbot as a candidate for farming in the early 1970s. This is mainly attributable to the profound difficulties encountered in rearing the larvae of this species but it is possible, with the benefit of hindsight, to identify a number of ways by which progress could have been accelerated, even with the same level of investment.

An essential element of the development of a novel industry is the provision of good quality information through systematic research to improve the cost effectiveness of the technology and to permit informed decisions to be made. It is arguable, however, that the emphasis of the research support has not always been well targeted in meeting the immediate or even the longer-term needs of the industry. For example, 70% of the papers published on the larval stages concern feeding and nutrition. This clearly reflects the importance of this subject but it has been at the expense of other areas which may have a critical impact on rearing success. For example, studies of the effects of important abiotic factors, such as light and temperature, have been almost totally neglected and we have only a limited understanding of the role of bacteria in rearing systems. Similarly, of the papers on nutrition, 50% are concerned with lipids and less than 7% on proteins, an imbalance reflecting the early recognition of the importance of lipid quality

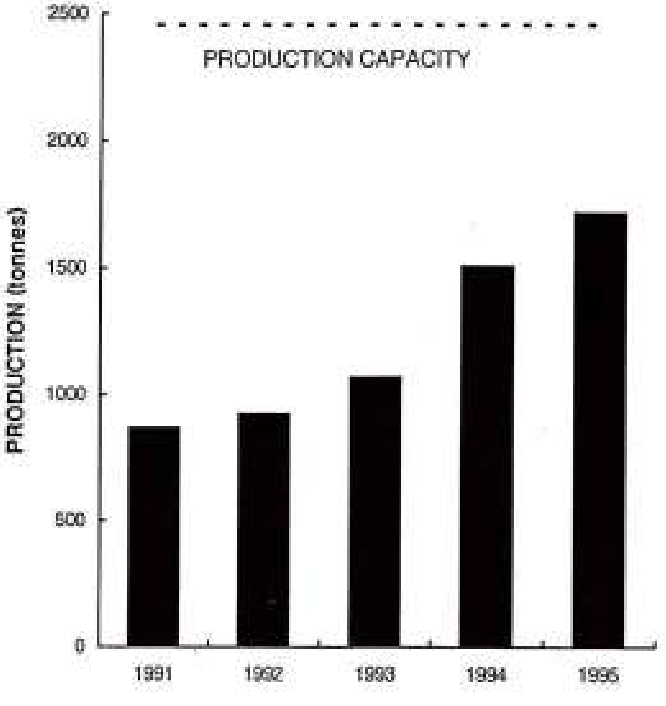

Figure 4. Increase in production of turbot farms in Spain in relation to their capacity.

but nevertheless not entirely justified. With regard to later stages, the lack of comprehensive information on the effects of temperature on growth in relation to fish size is a surprising deficiency. Such information is paramount to the selection of suitable sites. In addition, papers on genetics, a subject of great importance to the longer-term sustainability of the industry, only began to appear in 1993.

This situation may reflect an individualistic rather than a co-ordinated approach to the provision of research support to the industry. A structured and well targeted approach requires close co-operation among all sectors including the researchers, the industry, and perhaps most importantly, the funding agencies. The aim of the latter should be to harness the expertise that exists in academic and applied research institutions to produce balanced programmes which address both the short and long term needs of the industry. It is evident that this has not always been the case.

There are also lessons to be learned by the industry itself. The need to generate a cash flow following considerable investment in on-growing sites without due regard to quality of the product being marketed undoubtedly proved counter-productive in the longer term. The poor image of farmed turbot that this generated resulted in an appreciable price differential between the farmed and wild product which may persist for some time.

Prospects and Priorities

The industry is currently in a period of healthy growth but is unlikely to reach production levels already achieved by the bass and bream industries on the same time scale. Existing installations could support an annual production of 4500 t and this would be achieved by 1997/8 if the recent mean annual growth rate of over 30% is sustained. Further increases would depend on attracting the high investment required to construct new installations and may therefore depend on the development of cheaper on-growing systems. These may include recycling systems, as previously mentioned, or even cages. The feasibility of growing turbot in cages was demonstrated in the UK almost 20 years ago but the poor growth at UK ambient temperatures prevented further developments.

Expansion will also depend on the development of new markets. The turbot is a low volume/high value species and current levels of production, though relatively low, are already having a significant effect on supplies of the species. One encouraging trend is the emergence of a market for fish of 700-800 g in weight. The traditional market demands fish in excess of 2 kg primarily for the restaurant

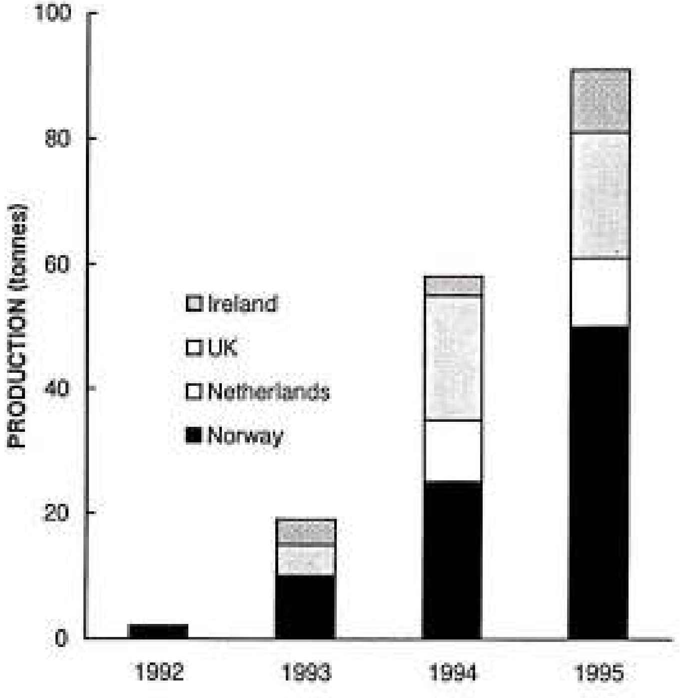

Figure 5. Increase in production of turbot in northern European countries during 1992-95.

trade. Smaller fish suitable for the domestic consumer may be cheaper to produce and may provide a means of significantly expanding the current market.

These developments must be supported by carefully targeted research programmes if the longer-term future of the industry is to be secured. Increasing larval survival and juvenile quality would be a priority to reduce costs. Performance at this stage remains unpredictable due in no small measure to the continued reliance on live foods of variable quality and uncertain availability. The greater use of formulated feeds that could be more readily manipulated to match the requirements of the larvae would be an important advance. The central importance of nutrition, however, should not preclude work in other previously neglected areas such as the effects of the abiotic and biotic environment on rearing success.

Apart from work on the development of cheaper on-growing systems, there is considerable scope for improving performance through the application of genetic techniques which to date have received little attention. Other priorities would include a greater understanding of the effects on growth of abiotic factors, such as photoperiod. Nutrition studies should also have prominence not only to improve performance and reduce costs but as a means of reducing environmental impacts. A sound basis for the prevention and control of disease will of course continue to be important.

The turbot farming industry is now well established and is almost certainly here to stay! Much remains to be done, however, if the progress that has been made to date is to be sustained.

I am greatly indebted to a number of colleagues for discussions on the subject of this paper but especially to Richard Slaski of Mannin Seafarms Ltd (Isle of Man, British Isles) for freely allowing me to exploit his considerable knowledge of the industry based on long experience.

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Winter Flounder Culture

John Batt

For a number of years there has been interest in the winter flounder *(Pleuronectes americanus)* as a potential species for aquaculture. Initially, production of juveniles was a major problem, but that constraint has been overcome. Sambro Fisheries Limited is developing large-scale production systems in anticipation of commercial production. In addition to research on the hatchery phase, work is underway on developing systems for grow-out. University and government groups are also involved in winter flounder culture and have been developing diets and systems for larval culture and conducting research on larval biology and juvenile performance.

Introduction

Winter flounder *(Pleuronectes americanus)* first drew interest as a culture species in the late 1800s in the United States. Recent culture efforts date to the early 1970s with research on spawning, egg handling, larval culture and the use of hormones to induce spawning. Work by Grace Klien-MacPhee and Matthew Litvak led to the involvement of Sambro Fisheries Limited in winter flounder culture and since 1994 the commercial sector has been driving development and research efforts on this species.

Biology

Winter flounder is a common inshore flounder species ranging from Labrador to Georgia.[8] Being from the family Pleuronectidae this species differs from the other popular cultured flounders, turbot and Japanese flounder, in that it is "right-eyed" (lies on its left side with the right side facing up). Winter flounder consumes a variety of foods, but the diet usually consists of small invertebrates, broken sea urchins, clam siphons, etc. This spcies is capable of withstanding temperatures ranging from -1.5°C to 20°C.

Spawning takes place from late April until late June and individual females spawn all their eggs at one time. The eggs are demersal and sticky. In contrast, many other flatfish species, such as halibut and yellowtail flounder, are multiple batch spawners and produce floating pelagic eggs.

Eggs incubate for 7 to 14 days, depending upon seawater temperature. Hatchlings live on their yolk-sac for several days before first feeding begins. The feeding larval stage can last for up to 6 weeks,[6] depending upon temperature,[4] and is followed by metamorphosis. At metamorphosis the left eye migrates to the right side of the head, the body flattens, and the fish begins to lie on its left side.

Aquaculture

The first hatchery work on winter flounder was in the late 1800s when broodstock were held, stripped of their eggs, and the larvae were released to the wild.[5] In the 1970s winter flounder was identified as a candidate for culture, even though for decades it had been considered the "white rat" of marine labs.

Methods for spawning and incubating eggs and larvae were published in the early 1970s[9] and more extensive research took place in the 1980s. Work by AS Smigielski, G Klein-MacPhee, LJ Buckley and GC Laurence looked at a wide variety of larval parameters including growth[1,2] and nutrition.[3]

In 1994, Sambro Fisheries Limited became interested in marine finfish culture and initiated a feasibility study to investigate existing technology and the economics of finfish culture. The study was aimed only at the requirements of Sambro Fisheries Limited and considered the specifics of the local environment, the ability of the company to adapt and afford a new division, and its ability to market various products. In summary, the study found that winter flounder was a species the company could develop for culture. One of the reasons winter flounder was selected was the success achieved by Dr. Matthew Litvak (who at the time was at the Huntsman Marine Sciences Center in St. Andrews) with the hatchery phase. As part of the Sambro Fisheries study, 36 metamorphosed juveniles were produced in three plastic buckets — an encouraging start for the company!

The culture of winter flounder begins with the production of live larval food. The primary live foods for winter flounder larvae are rotifers (*Brachionus plicatilis*), brine shrimp (*Artemia*) and algae, (*Isocrysis* species). Rotifers and the algae must both be cultured continuously and the cultures must be established prior to egg collection.

When winter flounder females begin to show signs of approaching spawning they are separated from the regular population and are placed in shallow isolation pens. This makes them easier to observe and identify exactly when the eggs are ready to be stripped. Prior to the stripping of the eggs, three males are stripped of milt and each milt sample is checked for motility. If motile, the sperm are stored (5 to 10 minutes) until the eggs are ready; if the sperm are not motile, they are discarded. The eggs are stripped in a fashion similar to salmon and are fertilized immediately. After fertilization, the eggs are coated with diatomaceous earth using the method developed by Smigielski.[9] The eggs are incubated for 7 to 14 days depending upon seawater temperature. Upon hatching, the larvae are removed from the incubators by hand and are stocked into larval feeding tanks.

To date, larvae have only been stocked at a density of 20 larvae per liter but have been successfully cultured in 100, 1000 and 2000 liter tanks. The yolk-sac is fully absorbed in 3 to 4 days, but the larvae remain weak swimmers for the first week. First feeding is on rotifers enriched to boost fatty acid content. By day 16, the larvae are developing quickly and becoming stronger swimmers that are able to consume increasingly larger prey. By day 20 to 24, the larvae begin to require larger amounts of feed and are fed both enriched rotifers and enriched *Artemia*. Full metamorphosis occurs by day 30 and the larvae are removed from the first feeding tanks and placed into juvenile rearing tanks.

The on-growing of winter flounder has yet to be accomplished, but on-growing will begin with the increased production of juveniles expected in 1998. It is anticipated that winter flounder on-growing will be similar to that of flatfish species such as Japanese flounder and turbot which are grown in land-based systems. It is conceivable that winter flounder could be grown in cage culture in well-protected areas that have little wave action. However, the effect of water temperature on growth rate may make cage culture difficult in many areas. The utilization of recirculation technology seems to have potential for the culture of this species and experiments are underway both at the University of New Brunswick in Saint John (UNBSJ) and Sambro Fisheries to determine the optimal culture conditions.[2] The results of this work and studies on growth in recirculating systems will prove valuable to the assessment of recirculation technology.

Research to Date

To date, research has been primarily aimed at developing culture systems and larval and juvenile diets. Work at UNBSJ has focused primarily on developing larval and juvenile culture systems with studies on larval tank designs, larval responses to light intensity, use of a "green water" rearing technique, and growth responses of juveniles to temperature and fish density.[7]

Nutrition and diet development research has been undertaken in large part through partnerships. The primary collaborators have been Dr. John Castell and his staff at the Aquaculture Nutrition Lab of the Department of Fisheries and Oceans and the team at Sambro Fisheries. Initial research focused upon larval nutritional requirements through the testing and use of commercial enrichment products and their effects on larval consumption of rotifers. This research has since expanded to include work on the nutritional requirements of juvenile winter flounder (study conducted by Dr. Castell, Sambro Fisheries, Cheryl Hebb, a graduate student at the Nova Scotia Agricultural College, and Melanie Fredette, working with Sambro Fisheries Limited at Dalhousie University).

Future Research

Although much has been done to develop winter flounder culture to its present state, more research is needed. As previously mentioned, little work has been done on the on-growing of this species. The constraint to date has been the low supply of juveniles, but the problems have been overcome and increased production is expected in 1998. Work on the on-growing phase, including determining appropriate culture densities, developing feeds and feeding strategies, determining growth rates, and studying maturity and disease have yet to be performed. Most of this is long-term work that will likely occur as people and companies begin to culture these species. We will be able to use as a basis the work already performed to develop the turbot and Japanese flounder industries. However, it must be noted that these species are from another family and winter flounder will require proper developmental research if it is to reach its full potential in culture.

Conclusion

Winter flounder is a new culture species with strong potential that will only be reached with proper research and development work. With an ever-competitive market and the competitive level of farming aquatic species in other countries, combined with the global marketplace, commercial development must be approached with careful thought. This applies not only to the private sector but to government as well. More and more responsibility for commercial and community development is being left to smaller entities. With provincial and federal governments backing away from aquaculture development and the large corporate agenda being focused only on profit, individuals and small companies have been left to set the agenda. This means the small industries are under increasing pressure to fund "partnerships" with universities and governments to ensure the required research is conducted. The final result is increased risks for small companies trying to lead the way and carry the financial burden of new species development.

I would like to thank all those people who have had input into the Sambro Fisheries Limited aquaculture program. Three groups deserve special mention. First I wish to thank the community of Sambro, including company staff and local fishermen. Next I would like to thank our partners, including the National Research Council's, Industrial Research Assistance Program (IRAP) and the DFO nutrition program led by Dr. John Castell for their support and input. Finally I would like to thank Ron Melanson, Stacy Kirk, Jackie Garrison, Linda Smith, Pauline Whalen and Christina Scarfe for their hard work and commitment. Final thanks go to Sam Elsworth and Doug Garrison for their vison and support of this project as the Directors of Sambro Fisheries Limited.

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Development of Atlantic Halibut Aquaculture in Canada

David Raymond

In 1995 Maritime Mariculture Inc., in a joint agreement with the Department of Fisheries and Oceans and with the support of the National Research Council, the New Brunswick Department of Fisheries and Aquaculture (DFA) and the Atlantic Canada Opportunities Agency (ACOA), established a pilot project at the Biological Station in St. Andrews to develop halibut culture. In 1997 following the completion of the DFO project, MMI moved its operation to the Huntsman Marine Science Centre. A similar project began in 1997 with the Ocean Sciences Centre at Memorial University in Newfoundland. These projects address a variety of technological and biological problems that when solved will lead to the successful implementation of halibut aquaculture in Canada.

Introduction

Maritime Mariculture Inc. (MMI) was established in 1993 with the objective of developing halibut aquaculture in Canada. Between 1993 and 1995, MMI researched the status of aquaculture development in both Norway and Canada and determined that halibut culture was on an accelerated progression to commercialization in Norway. A parallel plan for development in Canada was initiated through a pilot project conducted at the Biological Station, Department of Fisheries and Oceans (DFO), in St. Andrews, N.B.

DFO Pilot Project

In 1996, 11,000 juvenile Atlantic halibut were produced at the Biological Station and the production objective was set at 40,000 juveniles for 1997, based on the following changes in the production protocol.

Broodstock

A pulley-operated spawning table was installed so that broodstock could be hoisted during spawning. This will reduce handling of the fish, and thus stress, and hopefully result in increased egg production.

Egg collectors have been improved to increase the accuracy of detecting spawning times. Temperatures in the broodstock tanks are now maintained with an automated computer-based control system instead of the manual systems used previously. These changes should improve the predictability and consistency of spawning.

In general, egg production is expected to increase over 1996 as a result of these changes and the larger size of the broodstock females due to an additional year of growth.

Hatchery

Three incubators have been added to the system to accommodate the expected increased production of eggs.

Silo larval rearing system

The system controlling salinity has been improved. Previously, salinity fluctuations appear to have caused the halibut larvae to migrate up and down in the silos, resulting in stress and increasing mortality.

An additional silo with a larger cone area was added so that the results obtained in the small cone silos could be compared with those from a larger silo.

A temperature control and water-chilling system has been installed to ensure that constant temperatures are maintained in the silos, thus reducing bacterial loading. A sand filter was also installed to improve water quality and reduce bacterial loading.

Start-Feeding

Artemia. The enrichment protocol has been improved to increase the quality of the live feed. Live feed samples will also be analyzed in an effort to identify the quality of the feed being used and the protocols that produce the best feed quality.

Algae. A vertical cone-bag system has been installed, replacing the horizontal system used previously. This is expected to result in increased production.

Zooplankton. A Unik filter will be used, in addition to a net system, to increase collection of zooplankton.

Ocean Sciences Centre Project

A halbut culture project with an annual production objective of 15,000 juveniles has been established at the Ocean Sciences Centre at Memorial University in St. John's, Newfoundland. This site on Logy Bay does not have the dramatic tidal fluctations that occur in the Bay of Fundy and the salinity is higher than at St. Andrews. Production protocols will be similar to those used in the St. Andrews project, but there will be some differences: rotifers will be produced for use as live feed and large (8,000-L) cone silos will be used.

Juvenile Grow-Out

Of the 11,000 juveniles from the 1996 production year, 8,500 are being used in cage grow-out trials at the Harbour de Loutre (John Malloch) site off Wilson's Beach, Campobello. The remaining 1,500 fish are in land-based feeding trials being conducted by R&R Finfish Development Ltd. at Sandy Cove, Nova Scotia.

The 1997 production of 3,000 fish are being raised in land-based feeding trials being conducted at the Huntsman Marine Science Centre in St. Andrews and will eventually be moved to sea cages. Production in 1998 is expected to be about 20,000 juveniles.

Phase II of the Memorial University Project is being conducted at the Ocean Sciences Centre.

Research and Development Requirements

MMI believes that ongoing research and development should address the following areas:

- Live feed development (*Artemia*, rotifers, zooplankton and dry feed);
- A protocol for hatchery site identification should be developed that includes water quality analysis and engineering requirements;
- Development of land-based grow-out systems;
- Cage grow-out site identification, including a diversification program for salmon sites.

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Progress on the Development of Yellowtail Flounder *(Pleuronectes ferrugineus)* for Aquaculture

J. A. Brown and L. W. Crim

Introduction

Over the past four years we have been working on developing the yellowtail flounder for commercial aquaculture production in Newfoundland. Yellowtail were the focus of a good-sized wild fishery on the Grand Banks off Newfoundland, but stocks have been decreasing steadily since the 1970s. It is a medium-value fish with a high fillet-to-body ratio which makes it a high-yield flatfish. Given the above, plus the fact that yellowtail flounder has market recognition, the aquaculture industry has expressed an interest in determining the feasibility of culturing this species.

Developing any new species for culture requires research into production protocols in a number of areas. The principal areas of work during the first four years on yellowtail culture focused on developing broodstock, larviculture, and juvenile ongrowing protocols. In this paper we will report briefly on the results in each of these areas.

Broodstock Development and Management

Spawning adults were captured from inshore areas by SCUBA or from offshore areas with the assistance of the Department of Fisheries and Oceans in St. John's. Adult fish were placed in tanks, tagged, fed, and monitored for reproductive activity. Adults were found to wean to formulated feed relatively easily.

The blood was monitored to determine seasonal profiles of spawning hormones. This information was then used for monitoring natural, seasonal production of eggs and sperm as well as to improve the success of induced spawning.

Female yellowtail were found to ovulate every 1 to 2 days and females could produce up to 20 separate egg batches during a spawning season. Efforts to manipulate spawning times have been done using both photoperiod/temperature control and hormonal implantation. Future research will be directed towards improving these technologies as well as developing broodstock diets. Currently, broodstock are fed off-the-shelf dry feeds.

Egg and Larval Production

Egg incubation has proven to be rather straightforward and not problematic. Standard, 300-L, conical, upwelling tanks have been used to incubate eggs with good success. Hatching success has varied from 20 to 80% over the years, with some of the variability being due to egg quality problems.

The success of larval culture has improved over the years. Early research focused on determining the best feeding conditions for larvae: prey density and type, loading density, light intensity and photoperiod protocols. Using the "green water" technique and feeding enriched rotifers and *Artemia* under high light intensity and 24-hour photoperiod, a success rate of over 40% has been achieved from hatch through metamorphosis. Optimal temperature requirements are still to be determined.

One area of larval production which needs to be addressed is the size variability which appears during the larval stage. Size differences among larvae from the same batch of eggs become apparent prior to metamorphosis. Research on the first batch of juveniles produced in 1994 indicated that the "small" metamorphs never reach the size of the "large" metamorphs. This was determined by separating the juveniles at metamorphosis into small and large groups. After two years there was no overlap in size between the two groups and the large juveniles were significantly larger than the small juveniles. Research aimed at determining the size at which these size differences first become apparent will be conducted, so that slow-growing, small larvae can be culled early in the production process.

It appears that pigmentation problems occur during the larval stage, but when and how this happens is still not known. Problems with the nutritional value of the cultured feed as well as stress during rearing likely contribute to the pigmentation problem. Work on improving pigmentation will be carried out as required.

Juvenile Ongrowing

Research during the juvenile stage has focused on developing the best culture protocols for juveniles as well as formulating diets for rapid growth. Research on weaning, stocking density, light intensity, photoperiod, and preliminary diet formulation has been completed. Over the years, as the various parts of the juvenile ongrowing process have been studied and the techniques refined, the growth rate of the juveniles has steadily improved. Work on diet formulation is a priority over the next few years.

Currently, a three year production cycle is envisioned, which from a business perspective is a cycle which makes the most economic sense. It is highly likely that this will be achievable over the next few years if we continue work on the production and growth of juveniles.

The one area for which we have no information is the maturity schedule of this species in captivity. Currently a market exists for 500-gram fish, a size that can probably be attained within a two to two and a half year time frame. We need to determine when fish develop gonads as this will influence the production cycle a great deal. Preliminary work is planned on developing the technology to produce triploids which would address problems of early maturity, if they occur.

Prognosis and Update

Since the above research was completed there has been another season of yellowtail culture. During the 1997-1998 production year, we produced approximately 15,000 metamorphosed juveniles. The survival and growth during this last effort was significantly higher then we had achieved previously and was likely due to a variety of reasons.

One major contributing factor was that we had accumulated a lot of experience on egg collecting, incubation, larval rearing and juvenile ongrowing. All the previous research led us to develop production protocols which enabled us to achieve the success we did in 1997/98.

In addition, we also had access to new and better technology in the form of new tanks and temperature-controlled water. The new incubator, start-feeding and juvenile ongrowing tanks provided us with commercial-scale technology. This improved technology, together with the production information, contributed to our successful year.

In addition, research on induced spawning, triploidy production, and growth enhancement using gene biotechnology were all initiated and initial results are very encouraging. Taken together, this work suggests that commercial production of yellowtail flounder is just a few years down the road.

The authors would like to thank the numerous students and research assistants who have contributed immensely to the success of this work. The authors are also extremely grateful to our partners, Fishery Products International and the Canadian Centre for Fisheries Innovation for their financial support over the years.

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Commercial Promise for *Paralichthys*: Summer Flounder Culture at GreatBay Aquafarms, Inc.

George C. Nardi

As catches of marine finfish have declined, an increasing research and commercial focus has been given to farming species such as haddock and flounder in New England. GreatBay Aquafarms began the commercial culture of summer flounder *(Paralichthys dentatus)* in 1995 and over 300,000 juveniles were produced in the first nine months of operation. Expansion into the on-growing phase is planned for 1998. Continued research, particularly in the fields of fish health management and genetics, is essential for continued development of this new aquaculture industry.

Introduction

Since the mid 1980s commercial species of groundfish, particularly haddock, cod and numerous flatfish species have experienced unprecedented stock declines. This decline in commercial fishery landings has changed the industry as we have known it for generations. The under-supplied "white fish" market, traditionally filled with landings from New England or Atlantic Canada, are being increasingly supplied by Alaskan, Russian, Norwegian, New Zealand and Australian products. While seafood buyers procure product more globally, local aquaculturists are looking at filling the void with farm-raised fish, not just salmon, but marine species as well. A decade earlier similar circumstances prompted Asia, and then Europe, to look at commercializing the culture of popular marine species such as Japanese flounder, Atlantic turbot, Atlantic cod, sea bass and sea bream.

Recent Research in New England

Over six years ago, researchers from the University of Massachusetts and the University of Rhode Island began studying the feasibility of culturing summer flounder (*Paralichthys dentatus*). After four years of work it appeared that summer flounder, or fluke as it is often called, had potential as a commercial candidate. However, some very important questions remained, such as replication of spawning success, larval survival, acceptable stocking densities, growth rate, control of malpigmentation, and market value, to name a few. To answer some of these questions and provide additional information on the commercial potential of summer flounder, a research project was initiated with the New England Fisheries Development Association, a regional fisheries and seafood trade association, the University of Rhode Island and the University of New Hampshire. Both of these research efforts were funded by the Saltonstall-Kennedy Industry Grant Program (S-K) administered by the National Marine Fisheries Service through the United States Department of Commerce.

The results from this research further supported the commercialization of summer flounder culture.(1) As a direct result of the S-K research, and commercial success in Europe and Asia with other species of flatfish, commercial efforts to culture summer flounder were initiated and GreatBay Aquafarms, Inc. was formed in 1995.

Commercial Success

In Europe, Atlantic turbot (*Scopthalamus maximus*) and, most recently, Atlantic halibut (*Hippoglossus hippoglossus*) are being commercially cultured. The harvested product is eagerly accepted by the market and for the most part receive premium prices. In Japan, China, and Korea, another *Paralichthys* species, *P. olivaceous* (Japanese flounder) is cultured both for food and stock enhancement. This flatfish is remarkably similar to summer flounder and, as a result, summer flounder exported to Japan or consumed domestically in ethnic markets is readily accepted as "hirame" (Japanese flounder), a highly prized food fish in Japan.

There is indeed great promise for a number of *Paralichthys* species and efforts are underway to commercialize the culture of southern flounder (*P. lethostigma*) in the southeastern and Gulf states, California halibut (*P. californicus*) on the U.S. west coast, linguado (*P. microps*, *P. adsperus*, and *P. woolmani*) in Peru, Chile and Ecuador.

GreatBay Aquafarms

Taking advantage of over a decade of European marine flatfish culture, GreatBay Aquafarms (GBA) transferred their technology and applied recent research findings[1] to provide the company with the best chance of commercial success. In its first nine months of commercial production, GBA produced over 300,000 fully-weaned, 10-gram juveniles.

GBA maintains five stocks of broodfish. Each stock of 50 fish is held under a different photoperiod regime so that egg production is obtained year-round. Rotifers and *Artemia* are cultured to feed the larvae through metamorphosis, which occurs on approximately day 35 at 18°C, at which time the larvae are weaned onto an artificial diet. Three species of micro-algae are used for enrichment of the live feed and "green water" addition to the larval tanks.

From hatch through metamorphosis and weaning, survival ranges from 20 to 40%. After four months at 18°C, the juveniles are between 5 and 10 grams in weight and are ready for transfer to an on-growing operation. Once stocked into an on-growing farm, the flounder are expected to reach one kilogram after 18 months. GBA expects to improve upon this growth rate, perhaps reaching a kilogram within one year of stocking.

Two recirculating systems are used at the GBA hatchery, one for the brood stock and one for the nursery system. Ten percent of the daily volume of water per day is exchanged with new water. The recirculating system allows the hatchery to control the culture environment, ensures economical heating to maintain the optimum temperature for growth, and minimizes the discharge requirements by reducing the volume of water used. The supply of new water and the amount of discharge is controlled directly by a digital system using Windows '95-based software.

The GreatBay Aquafarms hatchery has the capacity to produce between 600,000 and 1,000,000 5 to 10 gram juveniles each year. To date GBA juveniles are being cultured in seven states (New Hampshire, Massachusetts, Rhode Island, New York, Virginia, North Carolina and Texas) in both commercial on-growing and research programs. There has also been significant interest from New Brunswick, Prince Edward Island and Nova Scotia. The hatchery employs the equivalent of eight full-time employees.

Future Plans and Needs

GBA is planning to have an on-growing farm in place in 1998 that is capable of producing 225 tonnes of summer flounder per year. Although only in its infancy, commercial marine fish culture in North America is growing and has great potential. However, this potential will be enhanced through continued research, and better access to capital and regulatory assistance, particularly in the streamlining of the permitting process.

Research, particularly on fish health management, will be essential to the growth of the industry. Commercial success depends upon stocking in tanks, ponds or pens at many times the density found in nature which invariably causes stress, particularly when there are problems due to system malfunction or human error. These periods of stress present opportunities for the lurking pathogens which normally are held in check by a healthy fish not subject to chronic or acute stress. Sooner or later, most farms will have to deal with disease. To avoid a catastrophic loss, the industry needs to understand how to prevent disease and, if present, to treat it in an environmentally sound but effective manner. To be of value, this disease and health expertise needs to develop at the same time as the industry.

In addition to being a hardy culture candidate for rearing as a valued food fish, flounder may also make an excellent candidate for stock enhancement. GBA is committed to assisting in the restoration of the commercial stocks and, where possible, GBA has made a point to hire and train fishermen. GBA looks forward to the restoration of rich fishing grounds and establishing a new reputation in the region as a leader in the production of high quality farm-raised marine fish.

Conclusion

GBA is confident that summer flounder will prove to be a successful candidate for large-scale commercial culture. But more importantly, the field of marine fish culture on a commercial scale in North America is wide open, with numerous promising candidates that are presenting unique and challenging opportunities to culturists and entrepreneurs alike. GBA looks forward to the commercial culture in North America of haddock, black sea bass, tautog, and other flatfish, in addition to halibut and summer flounder.

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European Sea Bass and Sea Bream Industry: Development, Present Status and Prospects for the Future

Richard A. Prickett

Sea bass *(Dicentrarchus labrax)* and gilt-head bream *(Sparus aurata)* are highly rated species in southern Europe. Although they have been produced in limited quantities for several decades using extensive pond systems, most of the production today comes from cage farms in Greece, Italy, Spain, Turkey, and France, with an increasing tonnage from North Africa. Production in 1996 totalled over 40,000 metric tons with an average selling price of about 6.2 ECU/kg (Can$9.70/kg) for sea bass and 5.9 ECU/kg (Can$9.26/kg) for sea bream. Average market size is about 350 g and most of the production is sold fresh, ungutted, and in the round. Most of the research and development phase occurred in the 1970s and early 1980s in France and Italy, and focussed primarily on problems related to large scale fry production. Once fry production problems had been solved, particularly the problem of swimbladder inflation, the industry rapidly expanded using salmonid net-pen technology and financing from generous EU grants. As the industry reaches maturity, sales prices have fallen by 50% since 1990 and the emphasis has shifted to reducing production costs and expanding markets, especially in the supermarket sector. New technical developments such as broodstock selection, disease control, improved nutrition, and the production of related species are only beginning and are still several years behind the salmon industry. Future prospects will depend on learning the lessons of the salmon industry if the same cycle of boom and bust is to be avoided.

General Background

Sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus aurata*) are two of the most highly prized fish in the Mediterranean basin. Although both species naturally occur to the north and south of the region, the main markets are Italy, France, and Spain, where sea bass is generally preferred to sea bream. This is reflected in the prices for each species which are currently about 6.2 ECU/kg (Can$ 9.70/kg; $4.42/lb) for sea bass and 5.9 ECU/kg (Can$9.26/kg; $4.20/lb) for sea bream.

Both species can grow to over 6 kg in weight, but the main market is for fish between 300 and 1000 g. Most of the production is sold fresh, in the round and ungutted. Both species can be classified as eurythermal and euryhaline with an optimum temperature for growth of about 22 to 24°C. At ambient Mediterranean temperatures, ranging from 13°C in winter to 26°C in summer, it takes about 15 months for sea bream and 18 months for sea bass to reach a size of 300 to 350 g from a 1 g juvenile (Fig. 1). Feed is generally pelleted or extruded and contains about 45% protein in the form of fish meal and 12 to 20% fat.

Over 70% of the production is carried out in floating net pens in the Mediterranean Sea. The remaining production comes from land-

Table 1. Sea bass and sea bream production in the Mediterranean region 1990 to 1995 (metric tons per year).

Country	1990	1991	1992	1993	1994	1995	Number of Farms	Tonnes per farm
Greece	1600	3000	6000	8500	13000	17000	220	77
Italy	1900	2500	2900	3400	4000	5500	55	100
Spain	700	1100	1850	2600	3200	4000	31	129
France	370	750	1250	2300	3000	3000	60	50
Portugal	90	300	400	500	650	700	3	233
EU Total	**4660**	**7650**	**12400**	**17300**	**23850**	**30200**	**369**	**82**
Turkey	350	400	800	1500	2000	2200	90	24
Croatia	165	300	150	300	1200	1500	18	83
Malta			200	300	1100	1300	3	433
Morocco		200	300	470	650	900	2	450
Cyprus		60	70	200	500	600	6	100
Tunisia	250	450	500	650	700	400	3	133
Others			100	200	300	500		
Non-EU Total	**765**	**1410**	**2120**	**3620**	**6450**	**7400**	**122**	**48**

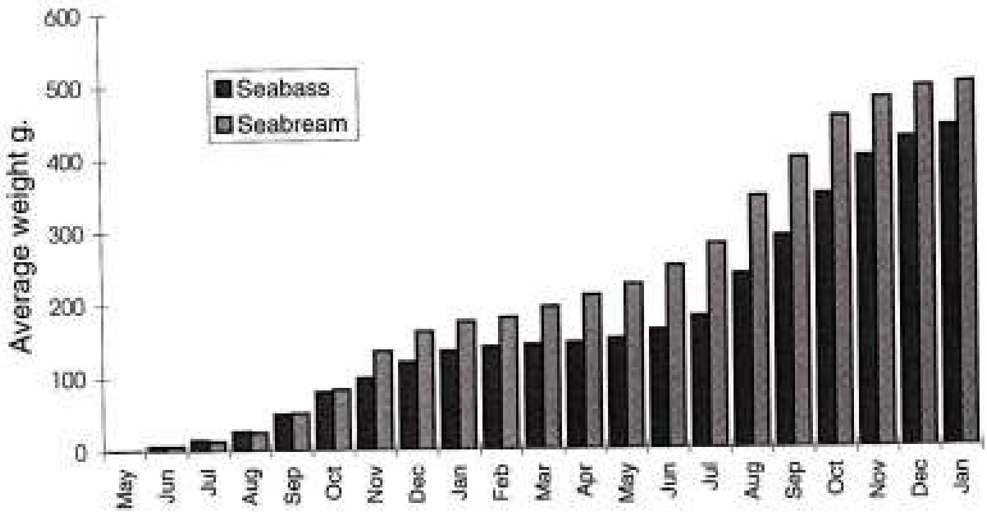

Figure 1. Comparative growth of sea bass and sea bream batches stocked at 1 g in May.

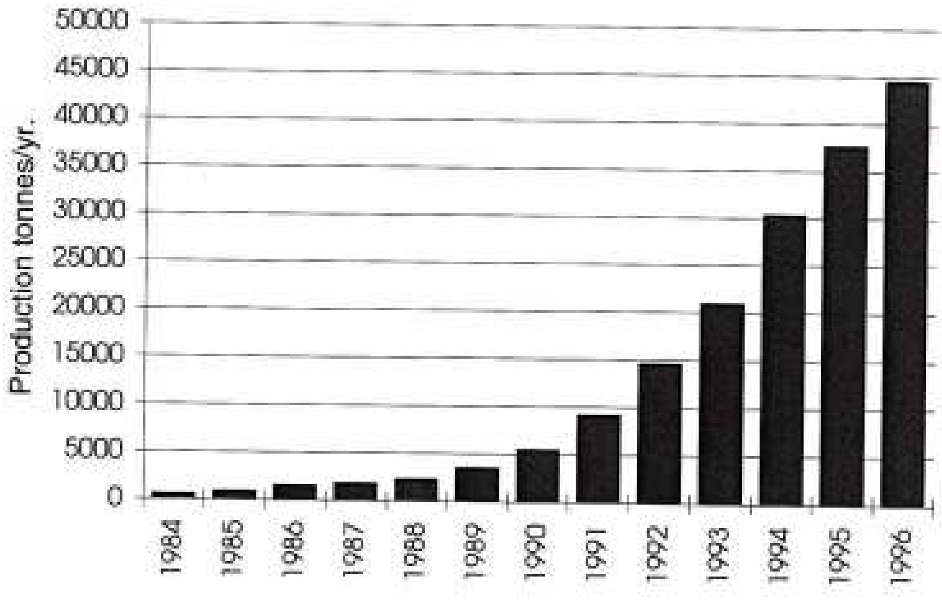

Figure 2. Sea bass and sea bream production in the Mediterranean region 1984-1996.

based tank farms (e.g. Canary Islands, southern Portugal, Italy, and northern France) and earth-pond, semi-intensive farms (e.g. the valli culture in Italy and salinas in southern Spain).

Following over a decade and a half of research and development, which focused primarily on hatchery technology, the industry developed rapidly in the late 1980s. By 1996, total production had reached an estimated 44,000 tonnes, maintaining the exponential growth of the previous years (Fig. 2). This production is composed of approximately 50% sea bream, 48% sea bass, and a small but increasing percentage of new species, mainly from the sea bream family (Sparidae).

Nearly half the production comes from Greece where there are 220 farms, but virtually all the countries surrounding the Mediterranean basin are producing varying quantities of both species and it is estimated that there are over 500 production units in the region (Table 1).

For every kilogram of market-sized fish produced approximately 4 to 5 juvenile fish are required. There are about 70 hatcheries in the Mediterranean region producing a total of over 200 million fry, and most of these are part of an integrated farm. As would be expected, most of the fry production is from Greece, followed by Italy, Spain, and France in more or less equal amounts (Table 2).

Sea bream spawn naturally from November to February at temperatures of 16 to 20°C, and sea bass spawn from January to March at 12 to 14°C. Sea bream produce more eggs than sea bass (500,000 compared to 250,000 per kilogram of female), but sea bass eggs are larger (1.2 mm compared to 1 mm in diameter). By manipulation of the photoperiod and temperature, most hatcheries manage to obtain an egg supply virtually all year round.

Early larval stages are reared at a temperature of about 20°C. "Green water" techniques are used to culture larval sea bream (and its relatives), with rotifers and *Artemia* being fed until weaning onto artificial feeds at 40 days or a length of 12 mm. Sea bass are usually reared in clear water, with *Artemia* nauplii being offered as a first feed and weaning started after 25 days. The minimum size for sale or transfer to the net pens is about 1 g, which is reached in about 90 days for sea bass and 100 days for sea bream.

Table 2. Sea bass and sea bream fry production in the Mediterranean region 1990 to 1995 (millions per year)

Country	1990	1991	1992	1993	1994	1995
Greece	14	23	33	53	65	86
Italy	6	10	14	23	23	32
Spain	13	18	20	23	28	34
France	10	14	14	19	23	26
Portugal	2	2	3	3	3	4
Others	1	1	2	2	3	3
EU Total	**46**	**68**	**86**	**123**	**146**	**185**
Turkey	2	3	3	4	4	6
Croatia	3	3	1	2	4	5
Morocco		1	2	2	2	3
Cyprus	2	4	5	6	6	8
Tunisia	1	3	3	4	3	3
Others	1	1	1	1	2	2
Non EU Total	**9**	**15**	**15**	**19**	**21**	**27**
Total	55	83	101	142	166	212
Fry/kg	6.1	5.7	4.8	4.7	4.4	4.6

Commercial prices for juveniles are about 0.33 ECU/fish (Can$0.51) for sea bream and 0.28 ECU/fish (Can$0.44) for sea bass, and vary depending on size, quantity and payment terms. Most juveniles are stocked in the period from April to July in order to benefit from the summer temperatures. The industry is now reaching the first stages of maturity, and prices have already halved since 1990, putting pressure on the farmer to reduce production costs and to adapt to market forces.

Development Phase of the Industry 1970-1986

Most of the initial research and development on sea bass and sea bream was carried out by public research institutes in France and Italy and to a lesser extent in Spain and Israel. This work was primarily stimulated by the high value of these species in the European market and the progress made on red sea bream (*Pagrus major*) culture in Japan.

After several trials in the early 1970s showed that wild-caught juveniles could be on-grown to market size at reasonable densities in a variety of systems, research began to focus on the hatchery production of juveniles, the major block to the development of the industry.

Broodstocks of both species were successfully spawned in captivity using hormone injection techniques. This was followed by the establishment of the first larval protocols for sea bass and later for sea bream. Near the end of the decade, successful spawning of broodstocks "out of season" enabled research work to continue over a longer period of the year.

By the early 1980s, batches of several thousand fish had been achieved, but larval quality was extremely variable and there was a high incidence of spinal deformities and poor resistance to stress. Work then focussed on two main areas: larval nutrition, in particular the levels of polyunsaturated fatty acids (PUFAs) in the diet of broodstocks and live feeds, and the reasons for the poor rates of swim bladder inflation which had been observed in young larvae.

Analysis of this swimbladder inflation problem showed the main reason to be the presence of a surface film on the rearing tanks which prevented the larvae from gulping air during the first 10 days of life. The problem was ultimately solved by using the Japanese system of blowing air across the water surface using a skimmer. This somewhat simple discovery removed the last bottleneck to the production of large numbers of healthy juveniles. With the removal of this block to commercialisation, other factors came into play to help stimulate the growth phase of the industry.

From Research to Exponential Growth 1985-1996

The initial stimulus to the industry was the formation of MEDRAP (Mediterranean Regional Aquaculture Programme) which co-ordinated information and ran seminars on the emerging technology which helped to attract the necessary attention of the private sector. Fuelled by European Union grants of between 40 to 60% for capital investments in aquaculture projects, several companies and individuals rapidly invested in the industry, particularly in Greece, which because of its indented coastline and water quality was particularly well suited to the cage culture of both species. Once the major feed companies saw the potential of the new industry, specific diets were developed for sea bream and sea bass which resulted in noticeable improvements in feed conversion rates (FCRs). However, it should be noted that these were still inferior to those achieved for salmonids (2.4:1 compared to 1.2:1).

Equipment suppliers experiencing a recession in the salmon industry were also attracted to the new market and Mediterranean farmers suddenly had access to the latest technology, including steel and plastic cages, purpose-built boats, fish pumps, graders, automatic feeders, etc. With an undersaturated market prepared to pay high prices for either species, the industry boomed during the late 1980s and early 1990s, a period that could be described as the "producer-led" phase of the industry's history.

Problems of Maturity

In recent years, several commentators have voiced concern about the continued rapid expansion of the industry and the lack of focus on market needs. The significant price reduction of over 50% for both species during the 1990s (Figs. 3,4) should have sounded a further warning, but the fear still prevails that the industry is generally unprepared for the next stage of maturity.

Traditional markets in the Mediterranean region have been showing signs of saturation in recent years, with cheap fish entering the major markets from outside the EU, particularly from Turkey, Croatia, Malta, and North Africa. Penetration of new markets, particularly in northern Europe, has been slow and confined primarily to ethnic groups and businesses such as Mediterranean and Chinese restaurants and their communities.

The emerging domination of the supermarkets as the main outlets for fresh and processed fish products is also a problem which the industry is facing and there is no doubt that further pressure on prices will continue into the foreseeable future unless marketing becomes the main focus of the industry. Although production costs have fallen in recent years to compensate for lower earnings, the profitability of many farms is now marginal, and the initial returns on capital employed of 30-40% have been severely reduced. Scaling up the production capacity is one of the most common responses to this problem, but if not co-ordinated with thorough market research, this will only put further pressure on prices.

Environmental pressures are also now increasing with new EU legislation demanding that farms are subject to full environmental impact assessments. The continuing conflict with tourism for space has also severely restricted the expansion of the industry in countries such as France, Italy, and Spain. With the increase in production comes the problem of disease which has had a significant negative impact on the industry in recent years. Worryingly high levels of mortality have been

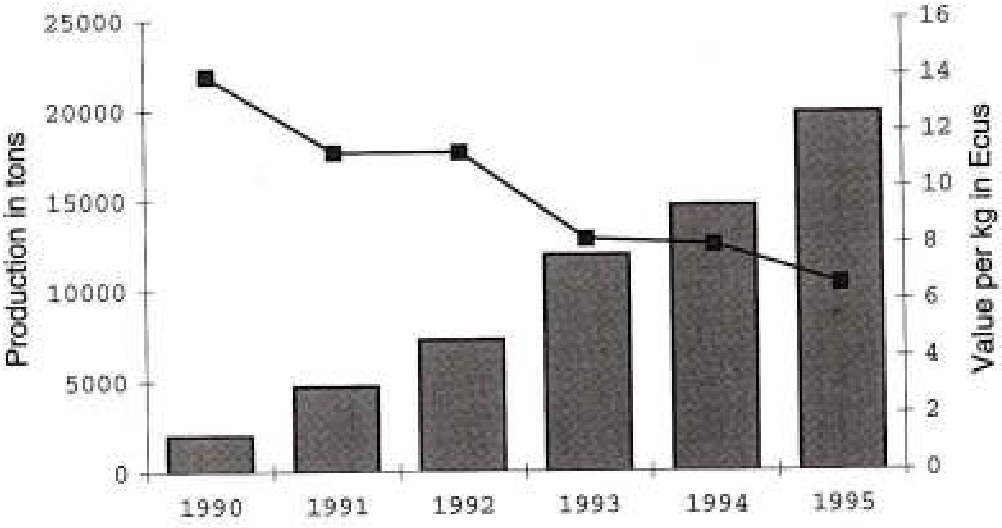

Figure 3. Sea bass production and price evolution.

observed both in hatcheries and in the on-growing units caused by a variety of pathogens, most notably pasteurellosis in the case of sea bream and the recently reported nodaviral infections in sea bass.

No industry can reach its full potential without support from government and the public authorities. In this respect, many Mediterranean fish farmers feel that governments should view aquaculture as a major export earner as well as providing a much needed source of employment in rural areas, a fact often overlooked in the past. This attitude may be attributed to the lower status that private companies have in the Mediterranean states compared to those of northern European countries, and many farmers are envious of the support enjoyed by their colleagues in countries like Norway.

Future Prospects and Strategies

Penetration of new markets

Most marketing in the industry is carried out by individual companies or jointly through associations with neighbouring farms. Although most producer states have formed their own fish farming unions, there is little co-operation at this level. Subsequently, it is the larger companies with the necessary financial muscle who are pioneering the new market strategy.

In Greece, for instance, several of the larger companies have been independently developing links with the major supermarket chains in Europe as well as trying to penetrate the potentially lucrative markets of northern Europe such as Germany. Whilst this may go some way to solving their own problems, it does not offer much comfort to the industry as a whole and to the smaller farmer in particular who must either risk selling his fish into the volatile local markets or become a producer working for the larger companies.

In the absence of any collective marketing effort, therefore, it is almost inevitable that this will lead to the industry being dominated by a few multi-national companies who will expand by the acquisition of smaller farms. This process is already underway not only in the case of sea bream and sea bass but also in the turbot industry.

Regardless of the structure of the industry, the producers are still faced with the problem of presenting the market with a larger variety of acceptable products. Portion-size sea bass and sea bream which have been the main

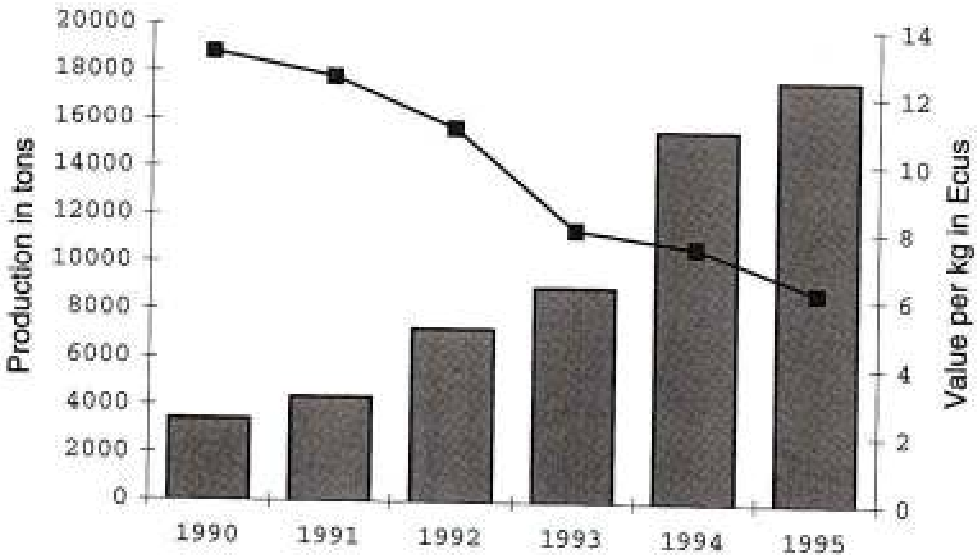

Figure 4. Sea bream production and price evolution.

product to date, do not lend themselves to processing into the type of products preferred by many northern Europeans. This is in sharp contrast to salmon which is now sold whole, filleted, steaked, smoked, and marinated, as well as in a variety of pre-prepared meals. In recent years, market demand has obliged producers to supply gutted fish as a first move to processing on-site, and some are now asking for fillets.

For the industry to follow these trends, further investments in packaging and processing units will need to be made, together with an improvement in hygiene standards and conformation to industry standards such as ISO 9001 and adoption of HACCP (Hazard Analysis Critical Control Point) systems. These demands will further reduce the number of small independent farms and lead to a large scale rationalisation of the ownership of the industry.

Production of new species

One alternative for the farmer in the struggle to improve his product range is the production of new species. Members of the sea bream family are particularly attractive in this respect and several species such as *Dentex dentex, Pagrus pagrus, Puntazzo puntazzo, Diplodus sargus,* etc., have been produced and sold in small quantities by some producers. The attraction to the producer is that the technology and facilities needed to produce these species in the hatchery and on-growing units are similar to those used for sea bream and sea bass, thus avoiding the need for new investments.

There is a danger, however, with this producer-led strategy. These other species occupy the same market niche as sea bream and sea bass, which will inevitably suffer as a consequence. An overlooked and potentially more lucrative alternative for producers is to concentrate on producing larger fish, which generally fetch premium prices, and extend the scope for processing into value-added products. Although simple selection of fast growing fish during grading is a first step, there is a need for more research into methods of preventing maturation and improving the growth of fry through genetic selection of broodstocks.

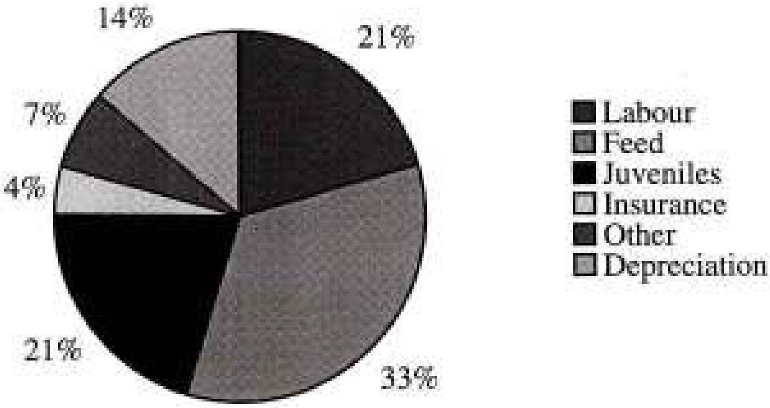

Figure 5. On-growing production costs.

Reducing production costs

Whatever the pressure of the market, the producer must continually attempt to reduce production costs. At present, the average Mediterranean farm produces about 75 tonnes per year and has a production cost of about 4.5 ECU/kg (US$4.00) before financial costs. Figure 5 illustrates the main components of this cost.

Feed is the largest single cost with present feed prices ranging from 600 ECU/t (Can$ 935) for pelleted feeds to 860 ECU/t (Can$ 1,340) for extruded feed. Further improvements in feed quality and subsequent potential savings are largely in the hands of the major feed producers and out of the control of the average farmer. There is a trend developing among the medium and larger sized farms to produce their own feeds, partly in an attempt to reduce costs and partly in order to control the ingredients in the feed. This is particularly common in Greece and other countries where there is a shortage of locally-based feed suppliers.

Fry are also a major cost and most farms are forced to purchase from the integrated larger farms as there are few independent hatcheries. After an early decline, fry prices have remained reasonably constant in recent years and have been the main reason why integrated farms have tended to be more profitable than independent on-growing units. Many small farmers enter into arrangements where they purchase fry and pay for them by selling back market fish, which does not always work in their favour. More recently, some farmers have invested in small hatcheries (1 to 3 million fry/year) which directly use saline groundwater at 20°C, producing fry for as little as 0.09 ECU/fish (Can$ 0.11) thus presenting a major reduction in costs.

Labour is the other significant cost which the farmer must control and in this respect much can be learnt from the salmon industry, even though the sea bass and sea bream farmer has more fish to tend for a given tonnage. Many Mediterranean farms operate at an efficiency of less than 15 tonnes per man year, compared to 35 tonnes per man year for farms of a similar size in Scotland. In Norway, production efficiency is even higher, but the figures are not directly comparable because many farmers contract out activities such as net cleaning, food delivery, and harvesting, that are performed by Scottish and Mediterranean workers

Indirect cost savings can be achieved by improving fish health, quality and growth performance, and in this respect there is still a vital need for continuing R & D support from the public and private sector. Stock enhancement programmes, though slow to start, are now becoming a focus of attention and although many years behind the salmon industry, selected strains of fish which are proven fast growers are beginning to make their mark. One such "Spanish strain" fish introduced into Greece by our own sister company is now developing a similar image to the "Mowi" strain of Atlantic salmon.

With vaccines becoming available to protect against vibriosis and pasteurellosis, the use of antibiotics has decreased considerably. The appearance of the nodaviral infections in sea bass is somewhat alarming, as there is no known cure available at the present time. It has had the benefit, however, of focusing attention on the need for better veterinary support within the industry.

Expansion through exploitation of exposed sites

Salmon farmers have for many years resorted to using large area plastic cages with net volumes of up to 10,000 m^3, while in the Mediterranean there has been a reluctance to change from the original square cages with net volumes of only a few hundred cubic metres. Now that farms are being forced to expand in order to survive, these larger cages are becoming more popular, especially as they allow the farmer to move away from the sheltered inshore sites which have caused so much conflict with tourism and local communities in the past. In countries with few natural protected cage sites such as Spain, France and Italy, this is the only way for the industry to develop, and several companies have invested in the more robust open sea cage systems now available on the market.

Research and support from governments

European support from Brussels has been forthcoming with EU capital investment grants greatly assisting the industry in the early years, and more recently, with funding aimed at helping organisations such as FEAP (Federation of Aquaculture Producers), to collate and analyse market data.

Apart from marketing, further research should be undertaken in areas of common interest to the industry, such as disease, nutrition and genetics, all of which are beyond the resources of the producer. Proper co-ordination of such research would also help to reduce the duplication often seen in Europe and there is therefore a major role to be played by producer/research organisations such as the European Aquaculture Society (EAS) and other such bodies.

Conclusions

The future of the sea bass and sea bream industry is difficult to predict at the present time, but what seems likely is that more fish are going to be produced in the next few years and the market is going to get tougher. This will inevitably lead to a streamlining of the industry with the smaller producers who are unable to meet the demands of the market being replaced by larger companies with lower production costs and the ability to adapt.

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The Development of Haddock Culture in Atlantic Canada

Matthew K. Litvak

There is considerable interest in developing haddock *(Melanogrammus aeglefinus)*, for culture in Atlantic Canada. Haddock grow rapidly and can be reared in salmon cages. Capital costs for grow-out will therefore be low and feed will be less expensive than for salmon because pigments are not required. As with many marine fish, the obstacle to development are the difficulties in rearing larvae through metamorphosis. This paper discusses some possible approaches to the development of haddock culture in Canada.

Introduction

Canadian aquaculturists have long recognized the importance of diversification to stabilize the industry and provide opportunities for future growth. There are a number of species currently under research and development. Haddock, *Melanogrammus aeglefinus*, with its historical demand on the east coast of North America, is one of the most attractive candidates for culture in this region. In this section, I will briefly discuss the positive and negative attributes of this species and will highlight some of the differences between culture of haddock and Atlantic salmon (*Salmo salar*).

Commercial Supply and Price

Landings of haddock have decreased and the value of the fishery has increased in North America during the past 46 years (Figs. 1, 2). The existing market for haddock is for fresh dressed and fresh and frozen fillets. Fillets are sold as combinations of skin-on, skinless, pinbone in, and boneless. Prices vary with season and year, but generally the products are sold in the following price ranges: fresh dressed \$2.60 to \$3.70/kg; fresh fillets \$8.80 to \$15.40/kg; frozen fillets \$7.70 to \$9.35/kg. Competition for haddock will be with other white fish including cod, hake and flatfish.[1] However, along the eastern seaboard there is potential for niche market development of a fresh premium-grade haddock fillet.

R-selected Marine Finfish and the Salmon Model

The goal in the development of haddock is to help stabilize the existing finfish aquaculture industry. Haddock, like many marine finfish, are highly fecund (r-selected) batch spawners, producing many small eggs with limited yolk reserves. The evolutionary argument for this strategy is clear: produce as many eggs as possible to ensure a few survive to reproduce. This lottery approach, although successful in the wild (when the stock is not overexploited), brings with it difficulties for culture that are not experienced by salmon growers. Haddock eggs are small (1.3 to 1.6 mm in diameter), numerous (can be in the millions per female) and buoyant.[7]

The following is a brief description of haddock aquaculture research and potential modes of culture.

Broodstock

Unlike salmon, haddock eggs are collected from fish allowed to spawn in tanks. Broodstock under the care of Debbie Martin-Robichaud at the Department of Fisheries and

Oceans in St. Andrews, have produced millions of eggs over the past few years. Her team has also been able to advance the breeding season using photothermal manipulation.

A major problem with haddock broodstock has been the death of fish at or around the time of spawning (January to June). Unfortunately, the proximate cause of death is unknown, although in almost all cases hyperinflation of the swim bladder was observed. Currently, the broodstock being used are wild fish and may have been damaged during capture. Mortality may be related to tank depth and stress, because it has not been observed in haddock held in cages on John Malloch's aquaculture site on Campobello.

Wild broodstock, which do not normally occur in shallow water, may have difficulty regulating their buoyancy in shallow tanks, particularly during stressful periods such as spawning. Fish may become more tolerant as they become domesticated, or we may need to use deeper tanks and/or collect spawn directly from fish held in cages. Collection of spawn from caged fish will be considerably less expensive for the farmer and more like the salmon model. However, successful extension of the breeding season will be more difficult under these conditions.

Hatchery

Eggs are disinfected with glutaraldehyde (400 ppm for 5 to 10 minutes) following a protocol developed for cod.[5] Eggs are incubated in a variety of systems: static, recirculation, and flow through (upwelling and downwelling). Eggs have been reared in a variety of light regimes and although all conditions have resulted in larvae, there are no data on the effect of light on the viability of the larvae. Effects of photoperiod and light intensity on egg development are just now being studied by Gavin Downing, a PhD student at the University of New Brunswick in Saint John.

Depending on temperature, the 3 to 4 mm larvae will hatch in 2 to 3 weeks (5 to 8° C). Currently, larvae are reared in intensive land-based systems utilizing either flow-through or recirculation systems. Larval tanks are best stocked with eggs to minimize handling damage.[7] Initially, stocking density was set at the standard cod model of 20 larvae/L. However, Linda Kling and her co-workers at the University of Maine, Orono, recently demonstrated that gaddids experience higher survival and growth when reared at very high densities (150 to 300 larvae/L). They attribute this response to the high clearance rates of live food (rotifers) placed in the tanks. The rotifers are typically enriched with Culture Selco (Artemia Systems NV, Belgium) and the quality of the rotifers decreases with time spent in the tanks. Therefore, high clearances rates ensure that the food ingested is of high quality and that there is little or no detrital build-up in the tank. Larvae are reared under continuous illumination at 250 to 1500 lux.[2]

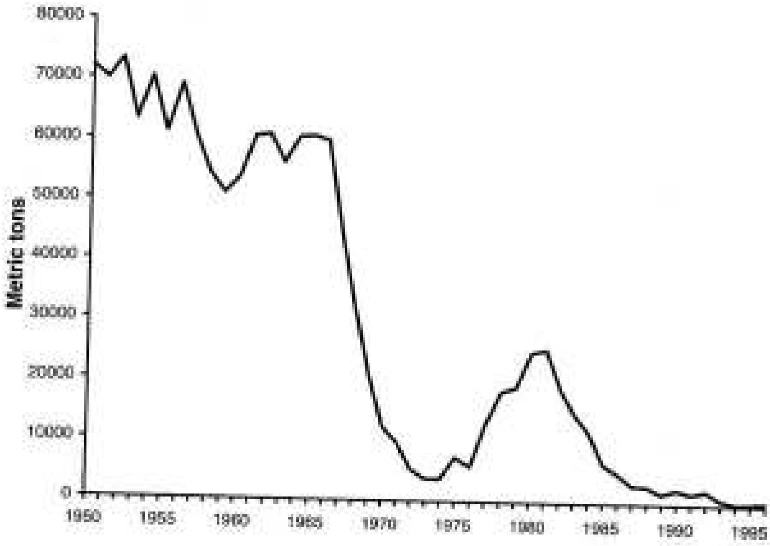

Figure 1. Landings of haddock in the United States. Data acquired from FAO Department of Fisheries Resources website (www.fao.org).

Currently, there is no artificial food that can be used to feed newly hatched haddock. The earliest time that larvae can be switched to an artificial diet and/or initiate co-feeding is still under investigation in a number of the laboratories. Thus, haddock, like many marine species being developed for aquaculture, depend on the production of live rotifers, *Brachionus plicatilis*. Fortunately, unlike many other species, haddock do not require algae for green-water culture or food.[4] Larvae are often fed rotifers (10-20/mL, 2 to 3 times daily) until day 14 to 21 and are then co-fed *Artemia* (1 to 2/mL) and an artificial diet until metamorphosis. The production of rotifers requires space, supplies and highly qualified personnel trained in growing live feed. Unlike salmon hatcheries, a haddock hatchery must produce both fish and the food to feed them.

Alternatively, a lower intensity culture model could be used. Haddock larvae could be fed wild zooplankton, although the temporal variability in zooplankton abundance can make this a risky venture. Ken Waiwood successfully grew haddock larvae in large fabric mesocosms in the Biological Station's (Department of Fisheries and Oceans) tidal pool. These enclosures are a good prototype and his results indicate the potential for a large bag system to be used in lower intensity larviculture.

The weaning process has not yet been refined, and many larvae die during swimbladder inflation and at weaning. Larvae with hyperinflated swimbladders are often found struggling on the surface prior to death. Surviving larvae reach metamorphosis at approximately 25 mm standard length and after metamorphosis resemble the adult. Although there has recently been a quantum leap in production of juvenile haddock (particularly at Centre Marin in Shippegan), the optimal tank design, flow regime, and water quality parameters have not yet been clearly identified, and growth rates have not been analyzed.

Juvenile growth

Growth during the juvenile stage is now under investigation at the Department of Fisheries and Oceans (Ed Trippel and John Castell) and Centre Marin (Carole Lanteigne). Early results indicate that juvenile haddock do well in tanks and grow quickly. However, little data has been collected to date. Waiwood[7] indicates that haddock could be placed in sea cages by early fall. With the advancement of spawning, it might be possible to place juveniles in cages in the late summer.

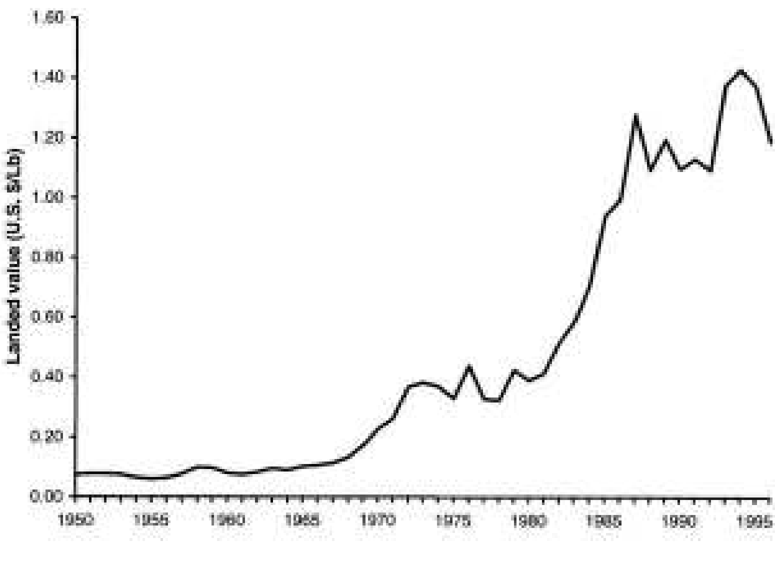

Figure 2. Historical landed value of haddock in the United States. Data acquired from FAO Department of Fisheries Resources website (www.fao.org).

Grow-out

As mentioned previously, haddock can be grown in systems currently used for salmon. Haddock has already been successfully held in salmon cages by John Malloch of Campobello. In early development, the growth rates are rapid and the weight of an average wild fish at 36 months is 1.4 kg (Fig. 3). If we can shift the growth trajectory a minor amount, growth rates will be similar to those of salmon. If the feed conversion efficiency of haddock is the same or better than salmon, the farmer will save on the cost of feed because pigments are not needed for this white fish.

Future Prospects

The potential benefits in developing haddock culture are great. The value of haddock and its ability to be used in existing grow-out systems are excellent. Additionally, the benefits extend beyond the direct cash crop. Crop rotation is often used in agriculture to defeat epizootic outbreaks and a similar strategy may be necessary with the cage systems used for salmon culture. To accomplish crop rotation, more fish species such as haddock must be made available to farmers.

The future development of haddock depends on a clear and focused research and development strategy. Little is known about haddock, so an understanding of the basic biology of this fish is essential. The success of the salmon industry today can in large measure be attributed to the tremendous amount of information collected over the past 100 years on this fish. Highly qualified personnel are needed to continue the push towards development and run the high-tech marine finfish hatcheries of the future.

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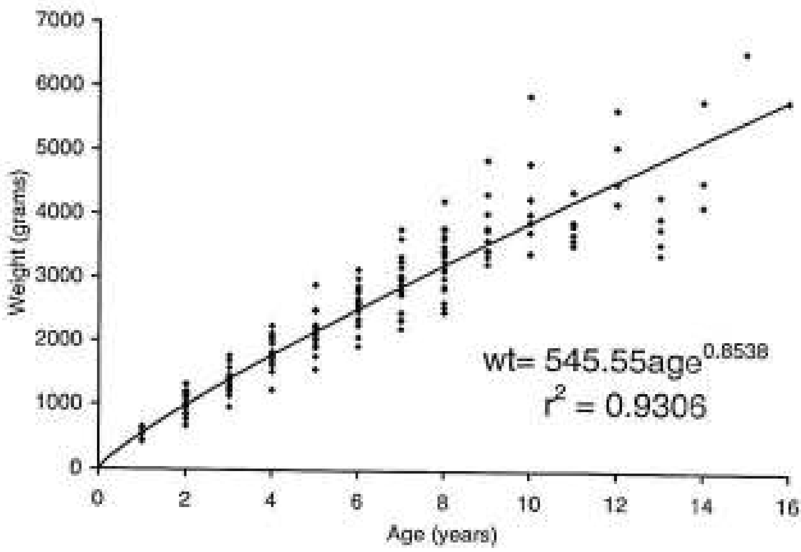

Figure 3. Regression of weight on age of wild haddock. Data was collected from Department of Fisheries and Oceans annual reports from fish in Canadian and US waters (1983-1991).

Wolffish Aquaculture: Where to Now?

J. A. Brown[1]

Introduction

There has been active interest in Atlantic wolffish (*Anarachius* spp.) aquaculture in Newfoundland since the late 1980s. Although most of the work has centered on the stripped wolffish *(A. lupus)*, adult spotted wolffish *(A. minor)* have recently been collected and held in captivity. The spotted wolffish is the preferred species for culture as growth rates are reported to be much higher than in the stripped wolffish.

The interest in wolffish as an aquaculture species is due to several factors. Wolffish larvae hatch at a well-developed state and larval survival is high relative to other marine species. Coupled with this is the observation that wolffish larvae will wean to dry feed early in development, which makes the larval period much less troublesome. They are also a cold-water species and produce blood "antifreeze" which has value for the biotechnology industry and also enables the fish to survive periods of low water temperature.

It is felt that the technological requirements for wolffish culture will be less than for other marine finfish species. Much of the research on this species has been done in Norway, but work has also been conducted in Newfoundland over the past 10 years. In this paper I will summarize the results of our efforts and those from Norway

Broodstock Management

The area of broodstock management presents one of the major challenges to the commercialization of this species. Wolffish are fertilized internally and spawn in the fall, which makes them different from all other North American marine finfish species currently being cultured. Techniques for efficient management of this style of reproduction have been developed in Tromsö, Norway, and work on another internally fertilizing species, the ocean pout *(Macrozoarces americanus)* has been successfully carried out at the Ocean Sciences Centre (OSC) in Newfoundland by L. Crim. Spawning should not be a problem with wolffish, but differences between wolffish and ocean pout must be taken into consideration. As far as I am aware, no work has been done on manipulating the time of spawning in wolffish, an area worth investigating.

A general technique for controlling spawning and fertilization is to collect sperm from a male with a pipette and squirt the sperm into a female that has eggs at the correct stage of development. Within 16 to 24 hours, the female wolffish deposits the fertilized eggs in a sticky mass which must be removed and incubated. The number of eggs produced by each female varies, but between 5,000 to 10,000 eggs can be expected, depending on the size of the fish.

Egg Incubation and Larval Rearing

Eggs are large (approximately 6 mm in diameter) and adhesive after release from the female. The cluster of eggs needs to be broken into small egg masses so that they can be incubated in standard incubators used for salmonids. Incubation time is prolonged, 7 to 9 months at ambient Newfoundland seawater temperatures. Incubation time can be shortened, however, by increasing the water temperature. Periodically the eggs require disinfection which can be easily done in flow-through systems.

Newly hatched larvae are large, 20 mm in length, and have very small yolk-sacs. They can be fed *Artemia* at the onset of start-feeding. In my laboratory, survival of over 80% through the larval stage has been achieved by providing prey densities of around 1,000 *Artemia*/L and offering dry feed from the second week onwards.[2] Larvae will self-wean at an age of about 4 wk and *Artemia* can be discontinued by 6 to 7 wk post-hatch.[3] Temperatures of between 6 to 8°C and light intensities of about 2000 lux result in survival of over 80% through the larval stage.

Juvenile Ongrowing

The majority of work on juvenile ongrowing has been conducted in Norway. Juveniles have been successfully ongrown in shallow raceways at high stocking densities. Reports of successfully growing juvenile wolffish at stocking densities of over 80 to 90 kg/m^3 have been made (Oiestad, pers. comm). Growth rates of between 0.37 to 0.50% per day have been reported for fish up to 3 kg. Survival during ongrowing is greater then 97%. These results have been achieved at low water temperature, another favorable attribute for wolffish culture.

An area that is receiving attention in Newfoundland is diet formulation for juvenile ongrowing. Currently, various lipid/protein ratios are being tested in diets to determine the best levels of these components for the optimum growth of juveniles.

Thus, juvenile wolffish appear to have a number of positive attributes: fast growth, high survival, and tolerance of high stocking densities. In addition, the fish are not aggressive and appear to be hardy with regard to stress and disease. Juveniles have attained a weight of between 2.5 to 3 kg after 3 years in culture.

Market Considerations

Wolffish produce a long, white, lean filet with high consumer acceptance. In Tromsö, Norway, a group consisting of Akvaplan -niva, the Norwegian College of Fishery Science and Troms Steinbit AS are working to establish the commercial production of wolffish. In addition to the flesh, by-products, such as the skin which is used to make leather and the blood which contains antifreeze proteins, are valuable products which add to the value of the species.

In North America, the commercialization of wolffish has suffered because the value of the product is low. This is due to the fact that wolffish are a "by-catch" and there is no directed fishery for these species. This results in the impression that wolffish filets are of low quality and the fish are not worth culturing. However, anyone who has eaten fresh wolffish will attest to the fact that it is a high quality filet, that with the proper marketing would command a decent price in the market.

Prognosis

From a biological perspective, wolffish show great promise as a culture species. The only problem which requires major work is broodstock development and management. Work on diet formulation is required for juveniles, but that is not as pressing a problem as the broodstock issue. With proper funding, the commercialization of wolffish in North America could be achieved very quickly. Given the advances made by Norwegian researchers, efforts in eastern Canada should attempt to involve the Norwegian expertise in order to reduce the time to commercialization. This is especially true for the development of broodstock protocols.

It is likely that wolffish aquaculture could be advanced with technology transfer from Norway and that commercialization realized along the same time scale as other marine species such as halibut, yellowtail flounder and Atlantic cod or haddock.

Thanks are due to the many students involved in projects over the years. The Wesleyville Marine Finfish Hatchery staff, and especially John Watkins, were industrial partners during the early years of the project. Thanks to the Canadian Centre for Fisheries Innovation for financial support.

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From Research To Commercialization: Progress of a Cod Hatchery

Johnathan Moir

Introduction

Sea Forest Plantation Ltd. (SFP) commissioned its hatchery in February 1996 and spawning began shortly after the hatchery opened. Spawning continued until the end of June when, with increasing water temperatures, all the remaining broodstock spawned. The company successfully raised 20,000 fry from 150,000 metamorphosed larvae using intensive green-water production techniques originally developed for sea bass and bream. Significant problems were experienced with bacterial infections during early larval rearing. Survival from each tank was 2,000 to 4,000 fry, regardless of the number of larvae stocked, suggesting that survival was food limited.

To overcome these problems, researchers at SFP developed a series of protocols which, it is postulated, will significantly improve survival through improved sanitation, optimal lighting, improved enrichment and feeding regimes, and alterations to the physical holding systems. The protocols are being evaluated under experimental production-scale conditions.

The changes to the production protocols required extensive renovations of the hatchery to accommodate both the new protocols and the projected increases in production. Correct sizing of the feed and rearing systems are critical to the survival of larvae. The facility requirements were calculated from projected monthly production quotas. Major design considerations were:

- Annual production target of 2 million juveniles,
- Target weight of 10 g,
- Three production cycles per year,
- Operating temperature of 12°C,
- Recirculation or heat stripping of most water,
- Separation of rearing systems.

The annual production target of 2 million juveniles is based upon a survival rate of 10% from hatched larva to 10-g individual. There are three main phases in the hatchery cycle: egg incubation (20 days at 4 to 5 °C), larval rearing (50 to 70 days at 12 °C), and nursery rearing (approximately 90 days).

To meet the annual production projection, 2 million larvae must be hatched each month, which requires 3.3 million eggs (approximately 7 litres) based on a hatch rate of 65%. Nine hundred liters of incubation space is required for the eggs (three 300-L incubators). Larvae are initially stocked at 60 larvae/liter and four 8 m^3 larval rearing tanks are required. Water flows were calculated based on a maximum of 2 changes/day and starting with 1 change/day in the larval tanks.

In 1996, SFP used both rotifers and *Artemia* as food sources with a minimal supplementation of zooplankton collected in a UNIK filter. As a rule of thumb, prey densities are maintained at 5 rotifers/mL and the density of prey items is checked every two hours. For adequate feed production, the following requirements were determined from the 1996 feeding rates:

- Rotifers maintained at a density of 200 million/larval tank,
- Total rotifer requirement is approximately 1 billion/day,
- Green water is supplied by 100,000 cells/mL of algae/day (*T. isochryis*),
- Algal requirement is 40 to 60 L of algae/tank or a total of 250 to 300 L/day, depending on algal counts,

- For rotifer culture, an additional 300 L of *Nannochloropsis*/day is required based on an estimated cell density of 45 x10^6 cells/mL,
- *Artemia* are fed on demand based on residual *Artemia* in larval tanks.

In order to meet the feed demands, significant modifications to both algal and rotifer production systems were required. The batch algal system was increased to a standing volume of 10 m^3 of algae in plastic bags. Light intensity was 20,000 lux at the bag surface and air was enriched with 1% CO_2. These conditions yielded cultures of *T. isochrysis* with cell densities between 12 and 15 x 10^6 cells/mL, and *Nannochloropsis* cultures of 45 x10^6 cells/mL. Approximately 10% of the total volume could be harvested on a daily basis.

A similar exercise for rotifer production was undertaken to arrive at the design criteria for the facility. SFP uses a standard 6-day cycle for rotifer production in which the population increases 3-fold over the 6 days. The following criteria were used to define the size of the rotifer facility:

- Requirement to harvest 1 billion/day for feed and approximately 1 billion for restocking culture tanks,
- Stocking density in culture tanks of 500 rotifer/mL,
- Rotifers cultured on a 6-day cycle,
- Rotifers grown in six 5 m^3 tanks.

Production Protocols

To ensure adequate egg collection, the broodstock facility was increased 60% by the addition of two new 30 m^3 tanks. Daily egg collection increased to 8 liters per day during the peak spawning season.

Eggs are collected daily during the spawning season and a decision is made whether or not to retain the eggs, depending upon the number of eggs currently in the hatchery and expected timing of the next hatch.

It is important to ensure that there are no large size discrepancies within each monthly cohort as this would require an excessive number of nursery tanks once grading is initiated after metamorphosis. It is also important to ensure there is sufficient time available between the stocking of tanks to ensure that work can be adequately completed on one tank before the next tank must be filled. In order to accomplish this, each month's eggs are collected over the period of a week. Collection then ceases, unless there is a problem with egg quality or the loss of eggs in some incubators.

Egg collection and disinfection procedures are as follows:

- Eggs are collected in 1000 µm bags in an external collector,
- Eggs are removed once or twice daily, disinfected in 3% gluteraldehyde for 10 minutes, rinsed in filtered salt water, and placed in downwelling incubators,
- Dead eggs are removed daily, measured and discarded, and the remaining numbers noted,
- A second disinfection is undertaken in the incubator at 70 degree-days,
- Hatched larvae are transferred to larval culture tanks at 100% hatch.

Once transferred to the larval tanks, larvae are closely monitored to ensure they are feeding and developing well. Larvae are measured on a regular basis to determine when the feed can change from rotifers to *Artemia* and ultimately to dry food. For the first 20 days, the tanks are siphoned to remove debris and dead algae every 5 days. As *Artemia* are introduced, water flows are increased to remove excess *Artemia*.

For the first 10 days of a production cycle larvae are fed rotifers enriched only with algae. As the larvae grow, some of the rotifers are enriched with Algamac and eventually all are enriched with Algamac. *Artemia* are enriched on a mixture of Algamac and DHA Selco. Larval rearing protocols are as follows:

- Larval tanks are filled the day before transfer and the water is greened with algae,
- Water flow is set at 1 tank volume/day,
- Larvae are transferred to the tanks at a density of 60 to 70 larvae per liter,
- Algae is added daily for the first 3 weeks,
- Rotifers are fed beginning 1 to 3 days after transfer, once there is algae in the gut,
- Rotifer density is maintained at 5/mL,
- Tanks are illuminated for 24 hours per day with light intensity greater than 2000 lux at the water surface,
- Rotifer numbers are gradually increased as required,

- Enriched *Artemia* are added once larvae reach 6.5 mm,
- Dry food is introduced once 50 % of the larvae are 12 mm or greater,
- Larvae are graded once the cohort reaches a minimum size of 13 mm.

Once graded from the larval tanks the larvae are introduced to the nursery where weaning onto dry food is completed by gradually removing *Artemia* from their diet. Once fully weaned, the light intensity is reduced.

Summary

- Rearing marine fish is very challenging.
- The biological responses to culture conditions and systems have been complicated by using systems, particularly in research environments, unsuitable for rearing marine fish.
- Production goals should be planned, even for research projects, as this will highlight critical points in the cycle.
- The relationship between production goals and facility size are intrinsic to the success of the project.

Jonathan Moir was the General Manager, Sea Forest Plantation Ltd, St. John's, NF. Canada.

16th Annual Meeting of the Aquaculture Association of Canada

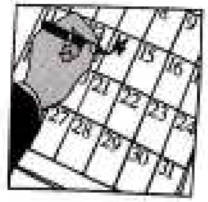
October 26-29, 1999, Victoria Conference Center, Victoria BC

Special Sessions include:

- Regulatory Constraints
- Economic and Social Change From Traditional to Cultured Fisheries
- New Technology of Aquaculture
- Biotechnology: Its Application in Aquaculture
- Recirculation Systems
- Aquaculture Vendors Session
- Marketing Shellfish
- Mussel Culture: The Potential
- Sturgeon Culture: Synergy with Resource Management
- Feed for an Expanding Industry
- Fish Health

This event will combine the annual AAC meeting with the Aquaculture Pacific Exchange Trade Show. For information contact: Linda Townsend, Fisheries and Aquaculture Department, Malaspina University-College, 900-5th St. Nanaimo, BC V9R 5S5 (Fax 250 755-8749, Email: townsdl@mala.bc.ca)

Calendar



•**Great Atlantic Shellfish Exchange,** 15 – 17 April 1999, Charlottetown, PEI. Organized to coincide with the NSA meeting in Halifax. Information: PEI Aquaculture Alliance (tel 902 368-2757, fax 902 368-3598, e-mail peiaqua@pei.sympatico.ca).

•**World Aquaculture '99,** 26 April – 2 May 1999, Sydney, Australia. Annual conference of the World Aquaculture Society. Conference theme: *Bridging the Gap.* Contact: John Cooksey, Conference Manager, 21710 7th Place West, Bothell, WA USA (tel 425 485-6682, fax 425 483-6319, e-mail worldaqua @aol.com). Website: http:// www.was.org).

•**12th International Pectinid Workshop,** Bergen, Norway, 5 – 12 May 1999. Program includes thematic sessions, keynote speakers, special topic working groups, and plenary discussions. Preregister by contacting Mr. Gunnar Eiken, 12th IPW, Hordaland Fykeskommune, N-5020 Bergen, Norway (fax 47 55 23 93 16, e-mail gunnarek@online.no).

•**Course on Diagnosis and Treatment of Warmwater Fish Diseases,** 17 – 28 May 1999, Tropical Aquaculture Laboratory, Ruskin, Florida. Course to provide instruction in diagnosis and treatment of parasitic, fungal, bacterial, viral, nutritional and environmental diseases. Cost US$550. Information: Dr. Ruth Francis-Floyd, Dept. Fish. Aquatic Sciences, University of Florida, 7922 NW 71st Street, Gainesville, FL 32653 (tel 352 392-9617, fax 352 846-1088, e-mail rff@gnv.ifas.ufl.edu, website http://www. ifas. ufl.edu).

•**12th Annual Atlantic Aquaculture Exposition, Conference and Fair,** 16 – 20 June 1999, St. Andrews, NB. Theme: *Opportunities in the New Millenium.* Information: Shelia Washburn or Elain Haun, P.O. Box 1169, 205 Water Street, St. Andrews, NB E0G 2X0 (tel 506 529-4011, fax 506 529-4056, e-mail sheilaw@nbnet.nb.ca, website www. caughey.on.ca/hdt).

•**Conference on Sea Lice Control and Biology,** 28 – 30 June 1999, Dublin, Ireland. Information: Dr. Mark Costello, 7 Glennalure Park, Rialto, Dublin 8, Ireland (e-mail mcostello@ecoserve.ie, website http://www. ecoserve. ie).

•**Aquaculture Europe '99,** 7 – 10 August 1999, Trondheim, Norway. Topics: larviculture, with focus on quality of offspring, fish health, genetics, interactions of farms with the environment, marketing of aquaculture products, and harvesting and market quality. Information: EAS Secretariat (tel +32 59 32 38 59, fax +32 59 32 10 05, e-mail eas@unicall.be, http://www. easonline.org).

•**ICES Symposium on the Environmental Effects of Mariculture,** 13 – 16 September 1999, St. Andrews, NB. Forum to share research results and enhance international cooperation and collaborative research on 1) the environmental effects of bivalve and fish farming in the coastal zone, and 2) the influence of local environmental factors on mariculture productivity. Abstract deadline 1

Annual Meeting of the National Shellfisheries Association

18 – 22 April 1999, Halifax, NS

Special sessions: Modelling Shellfish Ecosystems; Science, Business, and the Future of the Shellfisheries Industry; Physiological Ecology of Shellfish: Applications and Future Directions.

Information:
Dr. Jay Parsons, Aquaculture Unit, Fisheries and Marine Institute, Memorial University, Box 4920, St. John's, Newfoundland, A1C 5R3 (tel 709 778-0307, fax 709 778-0535, e-mail jparsons@ gill.ifmt.nf.ca).

April 1999. Information: Dr. D. Wildish, DFO, Biological Station, St. Andrews, NB E0G 2X0 (tel 506 529-5894, fax 506 529-5862, e-mail wildishd @mar.dfo-mpo.gc.ca).

•**Marketing & Shipping Live Aquatic Products '99,** 14 – 17 November 1999. DoubleTree Hotel, SeaTac Airport, Seattle. Agenda: improved handling technologies, resource management, regulatory concerns, unwanted introductions of non-indigenous species, economics, and animal welfare issues. Information: JB Peters, 5815 NE Baker Hill Road (fax 360 394-3760, e-mail JohnBPeters@compuserve.com).

•**2nd South American Aquaculture Congress,** 17 – 20 November 1999, Puerto La Cruz, Venezuela. Contact: J. Cooksey, Conference Manager, 21710 7th Place West, Bothell, Washington, USA (fax 425 483-6319, e-mail worldaqua@ aol. com).

•**Aquaculture America 2000**, 1 – 4 February 2000, New Orleans. Meeting of the US Chapter of the World Aquaculture Society. Contact: John Cooksey, Conference Manager, 21710 7th Place West, Bothell, Washington, USA (telephone 425 485-6682, fax 425 483-6319, e-mail worldaqua@ aol.com).

•**International Conference on Risk Analysis in Aquatic Animal Health,** 8 – 10 February 2000, Paris, France. Sessions: the need for risk analysis; risk analysis methodology; areas of application to aquatic animal health including problems, research needs and environmental concerns, case histories and field studies; and recommendations and future prospects. Information: Dr. K. Sugiura, Office International des Epizooties, 12 Rue de Prony, 75107, Paris, France (tel 33 (0)1 44 15 18 88, fax 33 (0)1 42 76 09 87, e-mail k.sugiura.oie.int, web site http://www.oie.int).

•**AQUA 2000,** 2 – 6 May 2000, Nice, France. Annual meetings of the World Aquaculture Society and the European Aquaculture Society. Information: John Cooksey, Conference Manager, 21710 7th Place West, Bothell, Washington, USA (tel 425 485-6682, fax 425 483-6319, e-mail worldaqua@ aol.com).

AQUATECH '99

University of New Brunswick,
Fredericton, 27-30 July, 1999

The 1999 meeting of Aquatech will be integrated with the larger BioAtlantech 1999 and bring together an international audience focusing on the development of genomics and nutraceuticals for agriculture, aquaculture and forestry.

Invited speakers include:
Dr. Bob Devlin: Application of molecular genetics for aquaculture;
Dr. Steve Griffiths: Diagnostics and DNA profiling in aquaculture;
Dr. Joel Heppell: DNA vaccines in fish;
Dr. Tom Kocher: Genomic approaches to selective improvement in tilapia;
Dr. Jim Wright: Transgenic fish in the treatment of diabetes;
Dr. Charlie Yarish: Seaweed cultivation and biotechnology — from food to phycocolloids to nutraceuticals and bioremediation.

There are openings for oral and poster presentations; contact Dr. Tillmann Benfey, University of New Brunswick (e-mail benfey@unb.ca). Registration information, telephone 506 444-2444, fax 506 444 5662, e-mail jgartley@fundy.net. Website: www.bioatlantech.nb.ca

Aquaculture Canada '99

Annual Meeting of the Aquaculture Association of Canada

26 – 29 October 1999, Victoria Convention Center and Empress Hotel, Victoria

For information, contact Linda Townsend
(fax 250 755-8749, e-mail townsdl@ mala.bc.ca)