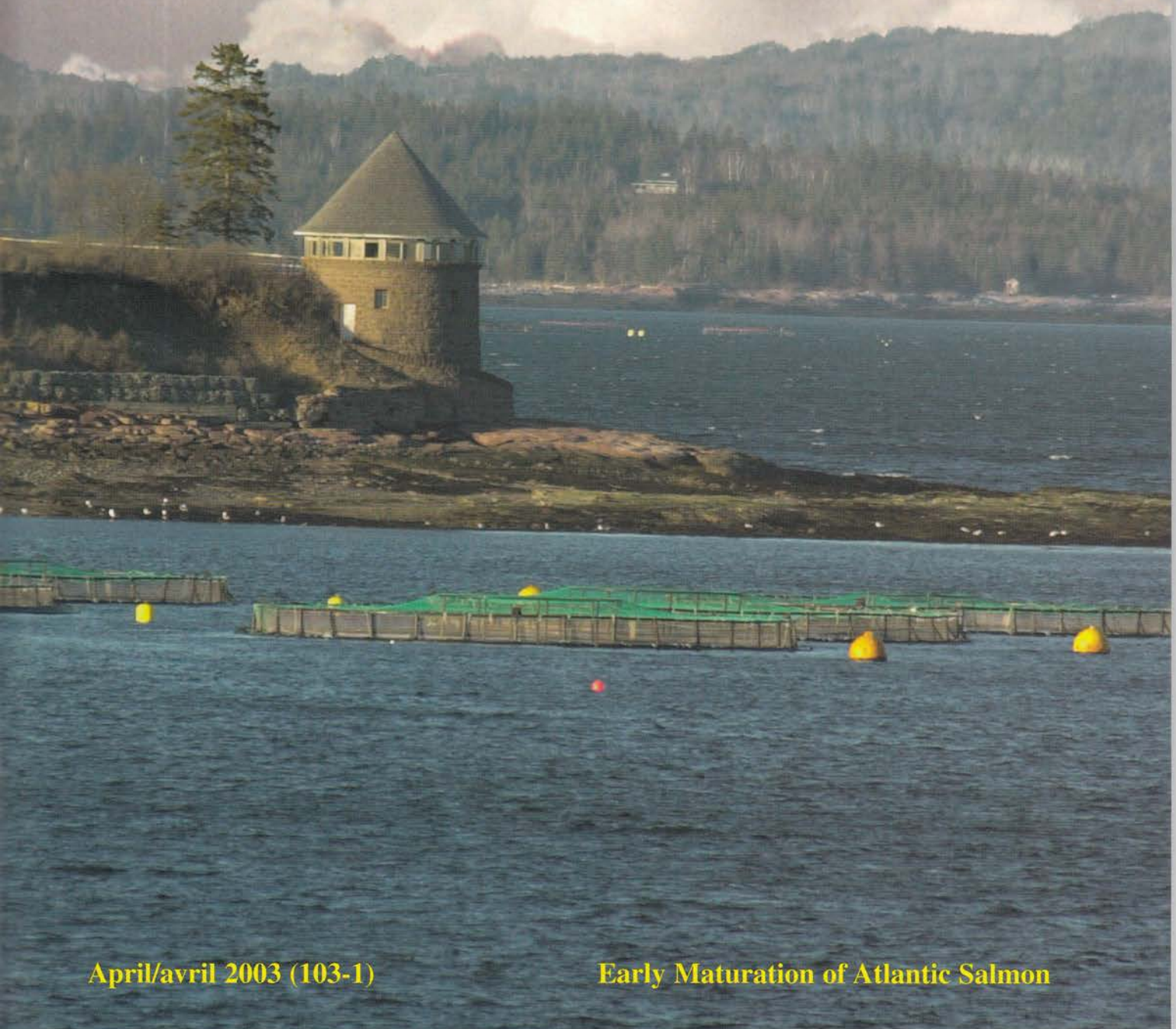


# ***Bulletin***

of the  
**Aquaculture Association of Canada**

de l'  
**Association Aquacole du Canada**



**April/avril 2003 (103-1)**

**Early Maturation of Atlantic Salmon**

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Proceedings of the 2<sup>nd</sup> St. Andrews Biological Station Aquaculture Workshop

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St. Andrews, NB, 6 March 2003

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*Workshop hosted by the Aquaculture Division, St. Andrews Biological Station; DFO's Aquaculture Collaborative Research and Development Program; and the Aquaculture Association of Canada*



# Bulletin de l'Association aquacole du Canada

avril 2003 (103-1)

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**Front cover:** Atlantic salmon farm (Minister's Island Fisheries Ltd.) in St. Andrews, NB. Behind the fish farm is the seaside bathhouse at Covenhoven on Minister's Island, the summer estate Sir William Van Horne built in the late 1890s. The island is only accessible by road by crossing the exposed bar at low tide. Van Horne was largely responsible for building the Canadian Pacific transcontinental railway. He also founded CP Hotels and was heavily involved in the design of the Banff Springs and Chateau Frontenac hotels. His life at Covenhoven was that of amateur architect, gentleman farmer and horticulturist (his head gardener trained at Kew Gardens and developed the nectarine at Covenhoven). He imported a herd of Dutch-belted cattle and built a massive 3-storey barn with turreted silos and a shingled roof. [Dave Aiken photo]

## Introduction

### 2nd SABS Aquaculture Workshop: Early Maturation of Atlantic Salmon

6 March 2003, Department of Fisheries Oceans, Biological Station, St. Andrews

On 6 March 2003, a 1-day workshop *Early Maturation of Atlantic Salmon* was held at the Biological Station in St. Andrews, NB. The event was hosted by the Aquaculture Division of the Department of Fisheries and Oceans (Science Branch) in St. Andrews, the Aquaculture Collaborative Research and Development Program (ACRDP) and the Aquaculture Association of Canada (AAC). Brian Glebe and Paul Harmon co-chaired the organizing committee and AAC staff, Kim Shafer and Vicky Merritt, provided on-site organizational support. AAC funded the publication of these proceedings and ACRDP provided travel support to the two European speakers, Drs. Sunil Kadri and Declan Quigley. Lunch and coffee breaks were generously sponsored by the New Brunswick Department of Agriculture, Fisheries and Aquaculture, Corey Aquafeeds and Shur-Gain Aquaculture.

Sixty-five people planned on participating in the workshop, but a winter storm caused a few last-minute cancellations. The majority of those in attendance were from private sector aquaculture companies (46%), while most of the others were from the Department of Fisheries and Oceans (18%), feed companies (15%), and universities and provincial governments. Most of the participants were from New Brunswick (71%), Prince Edward Island (6%) and Maine (6%).

Grilising (early maturation in seawater) is costing the salmon culture industry millions in lost revenue

each year. With narrow profit margins due to high levels of world production, there is a need to develop mitigating strategies to reduce the grilising problem in Atlantic Canada. An ongoing ISA problem in the Bay of Fundy region and super chill this past winter have also added stress to the industry.

The workshop provided an opportunity for the aquaculture industry and research community to discuss various aspects of grilising. The day began with Dr. David Aiken, Head of the Sustainable Aquaculture Section at the Biological Station in St. Andrews providing the Welcome and Opening Remarks. Dr. Sunil Kadri gave the Keynote Address: *Grilse Reduction and Beyond: Growth Benefits of Photoperiod Manipulation*. A number of other talks were given, including a historical perspective on grilising, the current status of the problem in Canada and Europe, and current methods for control, nutritional aspects, the role of precocious parr, current and future research. The speakers were Vern Pepper, Dick Peterson, Darren Ingersoll, Paul Harmon, Brian Glebe, Declan Quigley, Greg Page, and Larry Hammell.

Current research presented at the workshop has shown that light manipulation can be an effective and economical solution to the grilising problem. As well photoperiod can give added growth. The day ended with a talk by Brian Glebe looking at other ongoing and future areas of research in this field.

— Paul Harmon

Hospitality sponsored by:



NB Department of Agriculture, Fisheries and Aquaculture



## Oyster Industry Sets Example in Its Battle with MSX

**T**he last eight months have been a roller coaster ride of highs and lows as we have watched MSX—a serious disease of oysters caused by a microscopic parasite *Haplosporidium nelsoni*—break out in oyster stocks in Cape Breton. The machinery of over fifteen years of experience working with oyster diseases at the Shellfish Health Unit in Moncton, coupled with our Aquaculture Canada 2002 Honourary Lifetime Achievement Award recipient, Dr. René Lavoie, was booted into action. It did not stop there. Everyone jumped aboard to get a handle on the situation as quickly as possible: provincial colleagues from Nova Scotia, New Brunswick, Prince Edward Island and Québec; shellfish pathologists from around the world (one of the more positive aspects of e-mail!); and last, but most *certainly* not least, industry. Which is where I come to the *View from Here*...

There is a lot of publicity and heated debate over government roles in disease control—from SARS to BSE to ISA to sea lice. Somehow, however, MSX was different. And I think I know why. Having 'grown up' with the oyster industry of Atlantic Canada or in a tip of the hat to Roy Drinnan—who sadly passed away recently—who would say I 'was raised by' the Atlantic oyster industry, it came as no real surprise to see everyone rally together. Despite severe losses, both financial and spiritual, First Nations, commercial oyster fishers, leaseholders, and processors, worked together with federal and provincial governments to track oyster movements and define high priority sites for testing. Bearing in mind this mass of different interests and concerns, however, some people did slip through the communication dragnet. With apologies, best efforts were made to rectify this whenever it was brought to our attention, since the only thing worse than having to deal with a disease outbreak is not knowing what is going on. Any aquatic disease—especially of shellfish—doesn't care if its host is cultured or wild. Likewise, it does not matter if the oyster comes from Cape Breton, Prince Edward Island or Timbuktu. Although often suggested that MSX is a

'Cape Breton' problem, this is definitely not true. Cape Breton is, undoubtedly, the victim, but all provinces recognised that the problem was theirs. First Nations, commercial and aquaculture leaseholders—all equally threatened by the spread of this disease—discussed the pros and cons of control strategies and helped put together harvest protocols to get oysters safely out of affected waters.

In the midst of all this, we were visited by colleagues who have worked with MSX in eastern US waters for the last 45 years. To quote one speaker "if you were going to pick a disease nightmare with respect to control, you could not have picked a worse one than MSX". However, despite this gloomy reality check, our US colleagues made another observation—their *View from There* so to speak—this was a clear admiration of the interest and engagement of the Atlantic oyster industries in actively finding out, questioning and assessing every piece of information they could on the disease. Oyster growers called US genetic researchers; First Nations visited US research shellfish health institutes; industry and government pulled together research funding and sampling protocols; all aimed at getting the most information possible together in the shortest time possible. Notably, the Americans were impressed by the Canadian spirit in jumping into this, literally and figuratively, at the worst time of year to be attempting any field work. We had the worst winter in years, but this did not stop divers and drivers, from getting the samples we needed to the laboratory. Truth be told, this generated a *tsunami* of laboratory work. But, I believe it is safe to say there has never been such a concerted collaborative amalgam of experience ever brought to bear on any other aquatic disease outbreak. We may not win—the odds are certainly stacked against us—but the *View from Here* is that it was a formidable collective effort that stepped up to the plate.

— Sharon McGladdery  
Senior Science Advisor,  
DFO, Ottawa



# Grilse Reduction and Beyond: Growth Benefits of Photoperiod Manipulation in Cages

Sunil Kadri

For the past decade or so, artificial lighting has been increasingly used to illuminate salmon cages as a means of retarding early maturation. However, the results of light use on cages have been mixed, and the reasons for this are several: the implementation of lighting has varied between farms; requirements for positive results can vary between sites, areas and latitudes; and response to lighting and environment can vary between stocks. To achieve sound and reliable results in the use of lights on cages, it is necessary to first establish an understanding of the life history of salmon associated with maturation and how the lighting practices fit into the biology of the fish. Once this is clear, it then becomes important to ensure an understanding of how the technical aspects of lighting cages fit with the theoretical effects. The present paper attempts to shed light on these areas in the hope of helping Canadian farmers begin using lights and develop best practices.

## Introduction

Grilse are defined as salmon which mature after their first winter at sea. In aquaculture, such fish can cause considerable harvest losses as they will cease feeding sometime during the summer prior to spawning<sup>(8)</sup> and subsequently lose colour and condition, reducing their saleability. In order to reduce such losses, considerable research has been devoted to the control and delay of maturation. Approaches to grilse control have included selective breeding, triploidy, restrictive feeding regimes,<sup>(13,19)</sup> and photoperiod manipulation. Of these, the latter has become most widely used and has been found to not only retard maturation but also to improve growth.<sup>(4,9,10,11,15,17)</sup>

The use of lights has produced mixed results, however, both in scientific studies and commercial practice. For producers to increase the chance of successfully using lights to control grilse, it is necessary that they understand some of the biological responses to photoperiod manipulation and the implications these have for technical implementation of such systems. This paper is aimed at providing some of this background.

## Life History of Seawater Maturation in Atlantic Salmon

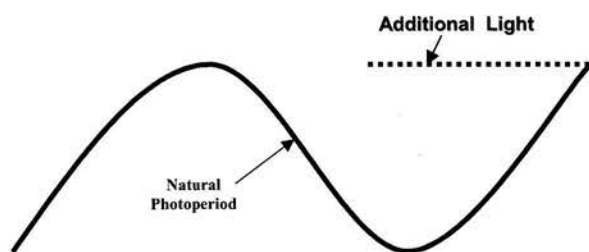
Atlantic salmon are known to use seasonal changes in photoperiod to synchronise their 'internal calendar'. The equinoxes, when photoperiod is changing most rapidly, are of key importance.<sup>(20)</sup> Maturation of

Atlantic salmon in seawater is a process which begins at the onset of the autumn equinox, a year before spawning. Environmental conditions such as temperature, food availability and consequent feed intake, growth rates and accumulation of lipid reserves appear to have a role in determining whether or not a fish will mature the following year. Hence a 'physiological decision' is made at this point to begin (or not) the maturation process. Thereafter the process can be turned off (if, for example, the fish subsequently does poorly in terms of feeding and growth) but cannot be turned on. Since 1999, larger numbers of grilse have appeared in New Brunswick cages than ever before—this may be due to higher energy feeds, improved feeding and subsequently higher growth rates in the autumn.

At the following spring equinox, maturing fish will begin an appetite and growth surge<sup>(7)</sup> which continues until they achieve a threshold level of lipid and protein (fat and flesh) reserves.<sup>(5)</sup> They then cease feeding,<sup>(8)</sup> even if kept in cages where feed is available to them.

This onset of anorexia, or cessation of appetite, is asynchronous among populations, such that more dominant individuals are able to achieve threshold energy reserves earlier and migrate upstream sooner than their subordinate siblings. Kadri et al.<sup>(5)</sup> suggested that this threshold level of energy reserves is related to requirements for completing the upstream migration to the home spawning ground and would therefore be higher for stocks from longer river systems, those with spawning grounds further from the sea, those that have more difficult rivers to ascend,





**Figure 1.** 'Shortening of winter' by use of artificial lights on cages.

and those from more northerly river systems. This hypothesis was supported by the findings of Beacham and Murray,<sup>(1)</sup> working on wild Pacific salmon (*Oncorhynchus* spp.), who showed that fish spawning in the upper portions of long river systems had a reduced fecundity and egg size compared with coastal spawning populations. In addition, Schaffer and Edson<sup>(14)</sup> and Thorpe and Mitchell<sup>(18)</sup> worked with wild Atlantic salmon to show that age and size at first spawning tended to increase with river length and relative harshness of the upriver migration.

### Control of Maturation

Given the life history described above, there are several components of the maturation process which lend themselves to potential for control of maturation.

### Selective breeding

Given that age at first maturity is associated with upriver migration, it should be possible to select for

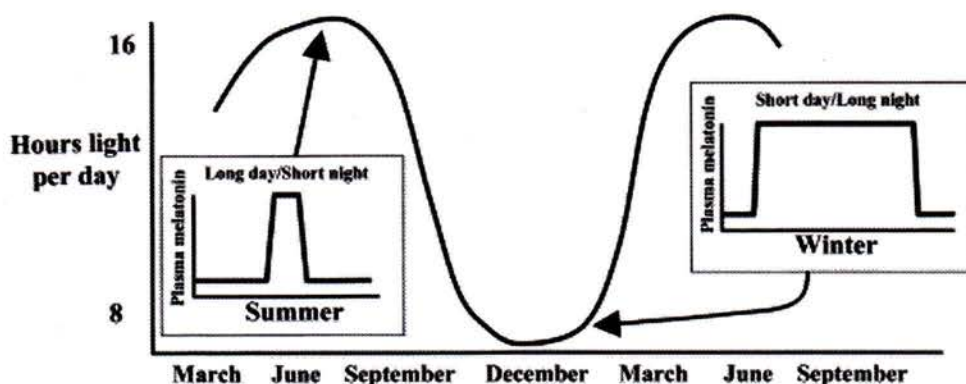
later maturity and thereby 'breed out' grilse. This has already been done successfully in Scotland, where low, medium and high grilse strains exist. The high grilse strains are made up mostly of genotype from the Scottish Western Isles, where rivers are extremely small; low grilse strains have a lot of Norwegian genotype incorporated. Clearly the scope for such an approach would be more limited in New Brunswick where salmon aquaculture stock is confined to Saint John River strains.

### Manipulation of feeding or nutrition

Given that salmon require threshold levels of accumulated reserves to begin maturation in the spring and continue the process in autumn, some means of restricting the ability of fish to feed and/or accumulate fat would seem appropriate. Thorpe et al.<sup>(19)</sup> are well known for having attempted to reduce maturation by restrictive feeding regimes during the spring. This approach was met with limited success. The work was in fact carried out at a time when endocrinological evidence led us to believe that maturation began in the late winter or early spring. Now we know that the maturation cycle in fact begins the previous autumn, and hence the period between the summer solstice and autumn equinox is where future attempts should be directed. Potential regimes include not only restrictive feeding, but also the use of low energy diets for some of this period.

### Photoperiod

As maturation is synchronized by change in day length, manipulation of photoperiod is another potential avenue for control of maturation. This has proven very effective when implemented properly and is the most widely used approach today. Not only can



**Figure 2.** Diagrammatic representation of the seasonal changes in diel profile of plasma melatonin. This provides information on daily and calendar time (from Porter et al.<sup>(13)</sup>).

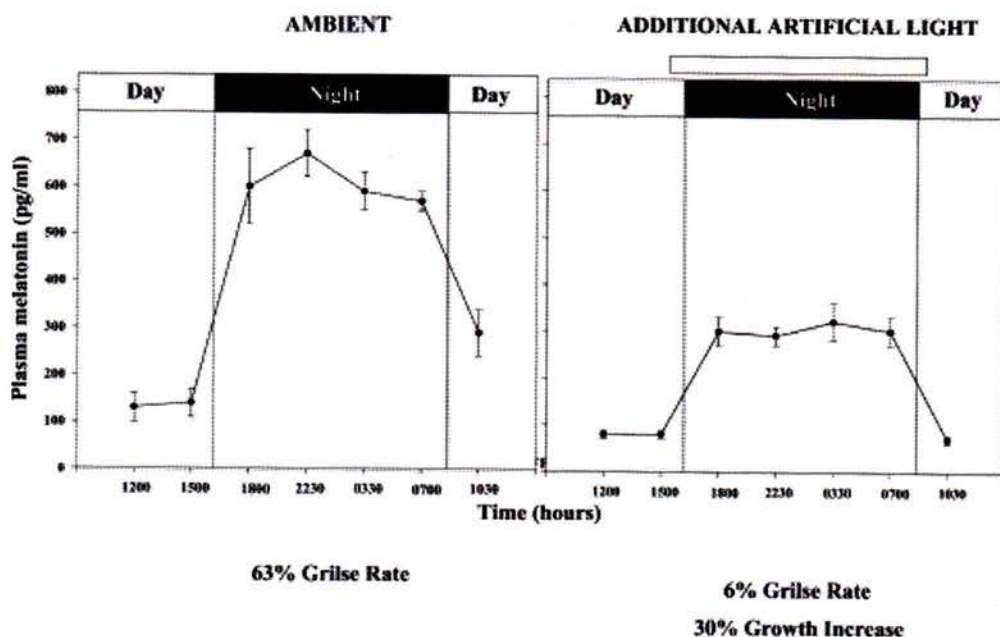


Fig 3: Diel profiles of plasma melatonin level (mean  $\pm$  s.e. pg/ml) of Atlantic salmon maintained in sea cages under ambient day length (left) and ambient + additional light (right). The duration of the night-time illumination is shown as the open bar. Melatonin levels and grilse rates were reduced and growth increased by the additional light (from Porter et al.<sup>(12)</sup>)

photoperiod manipulation reduce grilse rates, but following reduced feeding and growth during the first 6–8 weeks of illumination, it is also known to enhance growth of fish, with lit fish often outgrowing controls before the summer solstice. The basic principle involved in grilse reduction is a 'shortening of the winter' by turning on lights sometime after the autumn equinox (see Fig. 1).

### Harnessing grilse growth as a production strategy

Though the potential for this approach may be more limited in the colder Canadian waters, it is worth noting that grilse are nowadays used as part of the production strategy in some companies; hence the breeding of high grilse strains in Scotland. The extra growth which these fish undergo in the spring is used to maximize their size and they are then harvested prior to the decrease in appetite.

### Photoperiod Manipulation and Physiology

As described above and illustrated in Figure 1, reduction of grilse in salmon cages is achieved by 'shortening the winter' through the use of artificial lighting. In order that the lighting has this effect on the fish, it is important that the fish's physiological sys-

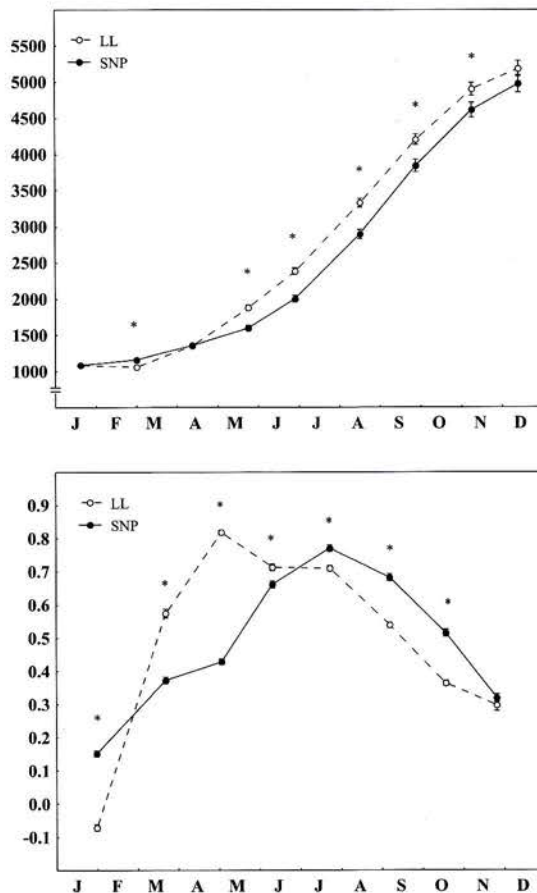
tem perceives the lights as being an extension of the normal day length. As in mammals, the daily photoperiod cycle is perceived physiologically via the pineal gland and is reflected in diurnal variation in the level of plasma melatonin. In all vertebrates investigated so far, plasma melatonin levels rise at night time (see Bromage et al.<sup>(2)</sup>). In addition, variation in melatonin levels, appears to give fish the means of physiologically perceiving season (Fig. 2.).

Hence artificial lighting—if it is to serve as a means of extending photoperiod as perceived by the fish—must be sufficient to dampen the night time increase in plasma melatonin. An example of the desired effect on plasma melatonin levels when using artificial lights on salmon is given in Figure 3.

### How Bright Should Lights on Cages Be?

An understanding of the physiological processes taking place when lights are used on cages brings us to the question of how bright the lights need to be. The lights must sufficiently dampen the nightly rise in plasma melatonin levels such that the fish's physiology behaves as though it is no longer experiencing the long nights of winter. Unfortunately it is impossible to provide any fixed rules on this, as lighting requirements vary between stocks, sites and latitudes. In general, fish grown at lower latitudes require brighter





**Figure 4. Weight increase (A) and specific growth rate (SGR, as % per day) (B) for Atlantic salmon reared under continuous light (LL) or simulated natural photoperiod (SNP). Data are presented as mean  $\pm$  s.e. Statistical differences ( $P < 0.05$ ) among photoregime groups are marked by asterisks(\*). (from Nordgarden et al.<sup>(9)</sup>)**

lights that those at higher latitudes as the contrast between day and night is more pronounced in the former (most areas of salmon cultivation in Canada are considered lower latitudes in the context of salmon farming regions). Water clarity, which affects light penetration, varies between sites and even within a site. The question of light intensity can only be answered by carrying out well designed trials on a per site basis, though there is a rule of thumb by which some users operate: lights should be sufficient to give a luminosity of 10 lux in the darkest part of the cage (N.B. this rule has no scientific basis).

It is worth noting that plasma melatonin levels of fish can be sampled and monitored in order to verify the effectiveness of lights on cages—such services are

available from the Institute of Aquaculture, University of Stirling, Scotland. Please contact the author for further information.

## Lights and Growth

Artificial lighting on cages is known to give a further benefit over and above reduction of grilse rates: accelerated growth is observed, following an initial 6- to 8-week period of reduced appetite and growth. This generally results in lit fish outgrowing comparable unlit fish by about May (Fig. 4). As with grilse rates, the effect of artificial lights on growth has been mixed. To some extent, the variation in growth results can be explained by studies performed in Norway. These have shown that the timing of 'lights on' not only influences the efficacy of grilse reduction, but also affects growth (Fig. 5) and that increasing light intensity gives increased growth. In the latter case Oppedal et al.<sup>(10)</sup> demonstrated a 25% increase in growth rate as a result of a 10-fold increase in measured luminosity within cages.

## General Rules for Use of Lights

Producers and researchers in Norway and Scotland have been using artificial lights in sea cages for some years now. In spite of the accumulated knowledge, results are still not 100% predictable, though several rules by which producers tend to operate have emerged. These include:

- Use metal halogen bulbs, as these are closest to the wavelength of natural daylight.
- It is generally considered best to switch lights on in late October or early November to optimize grilse reduction. Some Norwegian researchers, however, recommend switching on lights immediately before the lowest growth period of the winter, as the first 6-8 weeks following 'lights on' are marked by reduced appetite and growth.
- Lights should remain on until at least May.
- If lights are turned off or breakdown for 2 weeks or more, the lighting process may fail to reduce grilse and may in fact result in increased grilse.

## Using Grilse as Part of the Production Strategy

Having examined means of reducing grilse in cages, it is worth mentioning that some producers use grilse to their advantage and actually produce high grilse populations. This is based on the knowledge that grilse experience a surge in appetite and growth following the spring equinox.<sup>(7)</sup> Hence some producers



use this growth surge to harvest fish in late spring/early summer. Important considerations must be taken when using this approach to grilse in cages:

1. Ensure the immature fish also get fed. The grilse will dominate during feeding, but immature fish may feed below the surface or after the grilse have completed their meal. If fed adequately, immature fish will grow in length while the grilse are 'bulking up'.
2. Harvest fish as soon as possible to avoid the high food conversion ratios (FCRs) which can be experienced in the latter part of the appetite surge when fish are converting energy to gonad<sup>(6)</sup> and subsequently cease feeding.
3. Extend the harvest window by using lights. Very bright lighting (twice as bright as used in winter lighting to reduce grilse) can be used from June onward to give a 4- to 6-week delay in the negative effects of maturation (these include decreased yield, colour loss in flesh, and thinning of belly walls).

## Conclusions

- Grilse and grilse growth can be managed by using methods developed in other salmon industries.
- The timing of the onset of lighting affects the outcome in terms of both grilse reduction and growth.
- Although general rules have been developed, results are still variable. Hence developing best practice is best done through well designed trials being carried out on a per site basis, in order to properly establish relevant parameters.

*The author thanks the following for help in gathering information and data presented in this paper: Dr. Mark Porter, Institute of Aquaculture, University of Stirling, Scotland; Dr. Geir Lasse Taranger, Dr. Ulla Nordgarden & Mr. Frode Oppedal, Institute of Marine Research, Bergen, Norway; Mr. David Mitchell, Huon Aquaculture Pty., Tasmania.*

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# Historical Perspective of Atlantic Salmon Maturation in the Bay of Fundy Aquaculture Industry

R. H. Peterson, P. Harmon, and S. McGrattan

There appears to be a trend towards increased grilising rates in salmon cultured in the Bay of Fundy. Factors that may have contributed to the increase include changes in environmental conditions, genetic composition of the cultured stocks, and composition of the diet. Although surface temperatures have increased over the years, the changes are probably not sufficient to cause the increase in grilising rates that has occurred recently. More work is needed to determine the relationship between grilising rates and broodstock source. Energy levels in salmon diets have increased in recent years and muscle lipid levels are known to be a factor in determining whether or not fish become grilse, so recent changes in the diet may be influencing maturation rates.

## Introduction

Historically, rates of early maturation (= "grilising" which is defined as sexual maturation after 1 year at sea) of caged Atlantic salmon in the Bay of Fundy have generally been thought to have been low in comparison to those elsewhere, but the published data on

the subject are sparse. In view of the fact that early maturation rates in the Bay of Fundy are thought to have increased dramatically in the past few years, it was considered desirable to review relevant publications and compare these data with recent rates of early maturation.

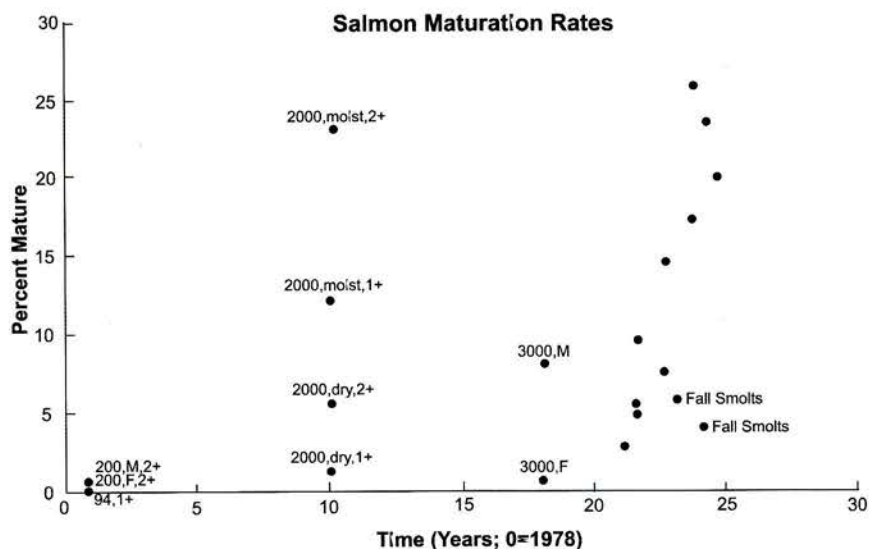


Figure 1. Summary of published accounts on 4 year-classes of percentage of harvested salmon that had sexually matured for 4 year-classes. [M: males, F: females. Numbers preceding commas on figure: sample size. Smolt age indicated by 1+ and 2+]

**Table 1. Summary of mature fish sampled at processing plants. Expected % mature values are based on average % maturities of 8.3% for males and 0.8% for females (Table 17 from Peterson et al. <sup>(3)</sup>)**

|                     | Smolt Class |         |          |           |           |         | Total |
|---------------------|-------------|---------|----------|-----------|-----------|---------|-------|
|                     | 40-60 g     | 60-80 g | 80-100 g | 100-120 g | 120-140 g | > 140 g |       |
| Non-mature males    | 313         | 1012    | 828      | 300       | 342       | 124     | 2919  |
| Non-mature females  | 364         | 1264    | 1089     | 385       | 624       | 71      | 3797  |
| Mature males        | 11          | 130     | 65       | 11        | 41        | 7       | 265   |
| Mature females      | 0           | 10      | 7        | 2         | 11        | 0       | 30    |
| Total males         | 324         | 1142    | 893      | 311       | 383       | 131     | 3184  |
| Total females       | 364         | 1274    | 1096     | 387       | 635       | 71      | 3827  |
| % Males mature      | 3.4         | 11.4    | 7.3      | 3.5       | 10.7      | 5.3     | 8.3   |
| % Females mature    | 0           | 0.8     | 0.6      | 0.5       | 1.7       | 0       | 0.8   |
| % Total mature      | 1.6         | 5.8     | 3.6      | 1.9       | 5.1       | 3.5     | 4.2   |
| Expected % mature   | 4.3         | 4.3     | 4.2      | 4.2       | 3.6       | 5.4     | —     |
| % Males             | 47.1        | 47.3    | 44.9     | 44.6      | 37.6      | 64.8    | 45.4  |
| % Females           | 52.9        | 52.7    | 55.1     | 55.4      | 62.4      | 35.2    | 54.6  |
| % Males as smolts   | 61.5        | 60      | 49       | 44        | 40        | 75      | 49    |
| % Females as smolts | 38.5        | 40      | 51       | 56        | 60        | 25      | 51    |
| Number of cages     | 7           | 20      | 16       | 6         | 7         | 2       | 58    |
| Number of samples   | 14          | 49      | 40       | 14        | 21        | 4       | 142   |

## Review of Maturation Data

The earliest published data on grilising in the Bay of Fundy are that of Sutterlin et al. <sup>(4)</sup> for the first attempt at salmon farming on a commercial scale in this area (Fig. 1). The smolts were placed in sea cages in the spring of 1978 and harvested in November and December of 1979 at an average weight of 3.3 kg. Both 2<sup>+</sup> (mean wt. = 85 g) and 1<sup>+</sup> (unmeasured) smolts were grown. Of 94 harvested fish examined from the group of 1<sup>+</sup> smolts (46 males, 48 females), none were sexually mature. Of 454 harvested fish from the 2<sup>+</sup> smolts (235 males, 219 females), only 3 males (1.3%) and 1 female (0.5%) were mature. The low growth rates in this early trial probably contributed to the low grilising rates.

Early maturation data were published by Henderson <sup>(2)</sup> for the 1986 year class of salmon grown at the Atlantic Salmon Demonstration and Development Farm (Fig. 1). Both 2<sup>+</sup> and 1<sup>+</sup> smolts of 94 and 46 gram mean weights, respectively, were grown on 2 diets (a moist and a dry diet). Between 2000 and 2500 fish in each treatment category were examined for grilising. The relatively high grilising rates for fish fed the moist diet was attributed to the higher growth rates attained on moist diets in the mid 1980s. No information on sex ratios was given, but the small mean

weights for both 1<sup>+</sup> and 2<sup>+</sup> smolts may be indicative of the large numbers of males that had been precociously mature as parr. At any rate, the grilising rates for fish fed moist diet were probably higher than the industry norm for that time period.

Of approximately 7000 harvested fish examined from the 1995 smolt year-class (Fig. 1, Table 1), 265 of 3184 males (8.3%) and 30 of 3827 females (0.8%) had matured sexually. <sup>(3)</sup> Salmon from 58 cages, representing 20 farms, were sampled. No apparent trends in percentages of mature fish occurred related to smolt size, although small 1<sup>+</sup> and 2<sup>+</sup> smolts had higher percentages of males.

The percentages of salmon downgraded, due primarily to flesh degradation through anorexia associated with grilising, when harvested from several farms operated by Aqua Fish Farms Ltd. for the years 1998-2002 show a decided trend toward higher grilising rates with time (Fig. 1). Percentages of 20-30% were experienced for the last couple of years. Fall smolts, which experienced only 1 sea summer, had relatively low grilising rates, possibly due to the smaller size when the second winter approached.

## Discussion

If it is assumed that there has been a real trend to-



ward increased early maturation rates in cultured salmon in the Bay of Fundy in the past 5 years or so, then one may speculate as to the reasons for this trend. At least three possibilities come to mind: environmental change, change in the genetic composition of the cultured stocks, and changes in composition of the diet. In view of the lack of solid data available on changes in rates of early maturation experienced in the various geographic sectors of the Bay of Fundy where salmon are cultured, any discussion of the phenomenon is necessarily speculative. The Aqua Fish data presented above includes farms in Limekiln Bay, the Chamcook area, and Grand Manan, so the increase in early maturation may be widespread throughout the industry.

There is insufficient background information to assess the possibility of the involvement of environmental change in the increase in the incidence of grilising. There has probably been some increase in surface temperature of the Bay of Fundy over the past several decades, but this could probably not account for the increase in grilising in the last 5 or 6 years.

Two events coincident in time with the recent increase in grilising rate have been experienced by the salmon aquaculture industry: the appearance of infectious salmonoid anemia (ISA) and the accelerated increase in energy levels of salmon diets.

The ISA epidemic necessitated the slaughter of many fish, including prospective broodstock in infected areas. This loss of select broodstock resulted in the use of fish for broodstock that may have produced progeny with higher inherited grilising tendencies. A more thorough industry-wide review of grilising in relation to broodstock source would be required to adequately assess this possibility.

The energy levels of cultured salmon diets (as expressed by lipid level) have been increasing for the past 20 years or so, but this trend has accelerated in the last 5 years. Two feed manufacturing companies (Skretting and Shur-Gain) have provided us with data on changes in lipid levels in diets over time. For Skretting, the lipid level in the finishing diet (10-mm pellet) was 26% in 1984 and 29% in 1996. The lipid

levels then rose to 31%, 33% and 36% in 1997, 2001, and 2002, respectively. These are maximal levels, as the highest levels are used in winter and the largest pellets have the highest energy levels. For example, for 2002, the lipid levels for 4, 6, 7.5, and 10-mm pellets were 32, 33, 34, and 36%, respectively. Similarly, Shur-Gain has indicated that maximal lipid levels in their diets have increased from 25% to 36%. Since muscle lipid level at certain times of the year has been shown to be critical to determining whether or not fish become grilse (e.g. Duston and Saunders<sup>(1)</sup>), higher dietary lipid levels may well result in higher percentages of caged salmon attaining or exceeding the critical muscle lipid level.

*We wish to thank M. Beatty (Skretting), and T. Taylor (Shur Gain/ Maple Leaf Foods Inc.) for graciously providing information on dietary lipid changes. B. Best typed the final version of the manuscript.*

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# Early and Ongoing Studies on Maturation of Cage-reared Atlantic Salmon in the Bay of Fundy

Brian Glebe, Paul Harmon and Cheryl Quinton

This paper provides an overview of early studies on the maturation of cage-reared salmon in the Bay of Fundy. Since salmon farming began in 1978, maturation rates have steadily increased and the industry has given high priority to research aimed at identifying ways to decrease grilising rates.

## Introduction

Since the establishment of the first salmon farm in the Bay of Fundy in 1978, maturation rates have steadily increased from less than 1%<sup>(1)</sup> to greater than 30%<sup>(2)</sup> in some instances. With the increase in maturation, the industry has given high priority to research to decrease grilising. Fundamental to any research is the need to know what work has already been done in the field. To that end this paper gives an overview of early work which may or may not be ongoing.

## Early Sea Ranching Studies

Saunders et. al.<sup>(3)</sup> reported the results of strain evaluation in two sea ranching trials in the late 1970s at the North American Salmon Research Centre (NASRC) and the Mactaquac Fish Culture Station. The two strains involved were Saint John River and Big Salmon River. As well, a comparison was made between 1<sup>+</sup> and 2<sup>+</sup> smolts. The Saint John River strain produced fewer grilse than Big Salmon River strain and 1<sup>+</sup> smolts produced fewer grilse than 2<sup>+</sup> smolts. The data, summarized in Table 1, were used to recommend the use of the Saint John River stock for aquaculture in the Bay of Fundy.

**Table 1. Variation in grilising rates in sea ranching trials at the NASRC and Mactaquac.**

| Smolt Age                           | Size (cm) | % Grilse |
|-------------------------------------|-----------|----------|
| Saint John River Strain (NASRC)     |           |          |
| 1+                                  | 16        | 32       |
| 2+                                  | 21        | 76       |
| Big Salmon River Strain (NASRC)     |           |          |
| 1+                                  | 15        | 71       |
| 2+                                  | 21        | 98       |
| Saint John River Strain (Mactaquac) |           |          |
| 1+                                  |           | 17       |
| 2+                                  |           | 63       |

## Early Cage Studies

Saunders et. al.<sup>(3)</sup> reported the results of strain evaluation in cage rearing trials in the late 1970s at Deer Island, New Brunswick. The two strains involved were Saint John River and Big Salmon River. As well a comparison was made between 1<sup>+</sup> and 2<sup>+</sup> smolts. The Saint John River stock produced the fewest grilse, and 1<sup>+</sup> smolts produced fewer grilse than 2<sup>+</sup> smolts. Average harvest weight was 3.3 kg. The data would again be used to reinforce the recommendation to use the Saint John River stock for aquaculture in the Bay of Fundy. A summary of this data is presented in Table 2.

**Table 2. Strain variation in grilising rates in seacage rearing trials.**

| Smolt Age                                | % Grilse |
|--|----------|
| Saint John River Strain (Mactaquac 1978) |          |
| 1+                                       | 0        |
| 2+                                       | 0.2      |
| Big Salmon River Strain (NASRC 1980)     |          |
| 1+                                       | 9        |
| Saint John River Strain (NASRC 1980)     |          |
| 1+                                       | 4        |

It was also noted that at Deer Island there are prolonged periods in the winter with temperatures near 1° C. In western Ireland winter sea temperatures seldom fall below 5° C. Cage-reared salmon from the Salmon Trust of Ireland mainly mature as grilse (see paper by D. Quigley in this issue). Based on this information, one could expect to see higher grilse rates in warm winters and lower rates in cold winters.

## Precocious Parr

Glebe and Saunders<sup>(4)</sup> reported the percentage of precocious parr resulting from matings of sires with



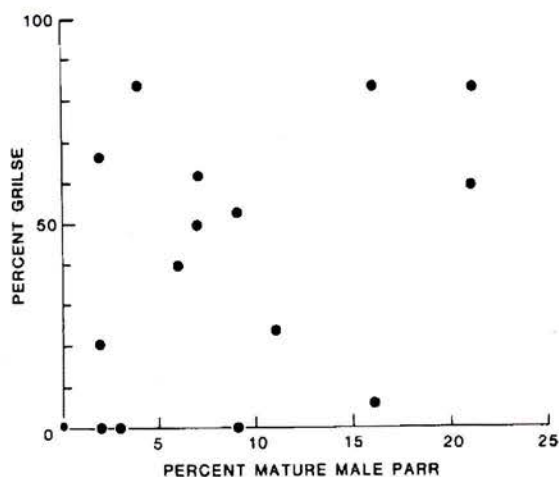
**Table 3. Relationship between sire age at maturity and % grilse in single pair matings.**

| Dam    | Sire   | % Mature Parr |
|--------|--------|---------------|
| Salmon | Parr   | 28            |
| Salmon | Grilse | 12            |
| Salmon | Salmon | 12            |

different ages at maturity. Parr sired by precocious parr were more than twice as likely to be precocious as parr sired by grilse or salmon (Table 3). These authors also showed the relationship between family incidence of mature male parr and the proportion of male grilse among males reared in marine cages (Fig. 1). Analysis indicated there was no significant relationship between family incidence of mature parr and male grilse within the same family.

### Smolt Size

It has been known for some time that post smolts of different sizes grow at different rates in seawater. Austreng et. al.<sup>(5)</sup> in Norway showed Atlantic salmon in sea cages of 30-150 g grew faster in sea cages than those larger than 150 g when reared at the same temperatures. Peterson et. al.,<sup>(6)</sup> using data from cage-reared Bay of Fundy salmon, showed a similar trend in specific growth rate with 130-gram salmon growing 70% faster than 280-gram salmon. Harmon et. al.<sup>(2)</sup> followed post smolts in sea cages in the Bay of Fundy. Between April and November the smallest smolts had the fastest growth rates (>1.35). Smolts over 100 g had growth rates ranging from 1.16-1.22.



**Figure 1. Lack of relationship between family incidence of mature parr and the proportion of mature grilse among males reared in marine cages.**

However, what had not been established was the relationship between smolt size and maturation rates. In 2001, data was collected from approximately 100 sea cages on multiple sites in the Bay of Fundy. This data is presented in Figure 2. Smolts less than 60 grams and over 100 grams produced the highest percentage of grilse.

### Growth

Thermal growth coefficient is commonly used to compare growth rates among cages of fish. The equation for thermal growth coefficient is  $(\text{final body wt}^{0.33} - \text{initial wt}^{0.33}) / (1000/\text{days} * \text{temp}(c))$ .<sup>(7)</sup> Figure 3 presents a comparison between the thermal growth coefficients for salmon cages in the Bay of Fundy in 1995-96<sup>(7)</sup> and 2001-02. The rate has increased from 2.3 to 3.0. This can be correlated with an increase in early maturation from 4.2% to 17.5-21.5% in 2002-03.<sup>(3)</sup>

### ASBDP Breeding Program (formerly the NASRC)

The Atlantic Salmon Broodstock Development Program (ASBDP) is a consortium of 9 major salmon farming companies contributing 1.2 million dollars annually for stock genetic improvement and research. The program was established in 1998. Since that time the ASBDP has completed a one million dollar improvement to the existing hatchery and now is operating as a successful breeding partnership.

Two of the production traits included in this genetic improvement program are harvest weight and grilse rate. These data are partially ranked by family in Table 4. Figure 4 shows the % grilse (families averaged) over the three strains on each of three commercial grow-out sites. Strain 90JC is a synthetic Saint John River strain created in 1990 by the ASBDP. Strain 1 and 2 are commercial strains derived through single pair matings (families) from two New Brunswick salmon farming companies. Strain 1 consistently produced the most grilse. Strain 2 provided the fewest grilse on two of three farm sites. Figure 5 is a graph of % grilse plotted against average family weight. The correlation is not significant and only 5% of the variance in % grilse can be attributed to weight. Figure 6 shows the relationship between mean harvest weight and commercial production site (Site 2 and 3 are considered off-shore (Grand Manan) farms where historically growth has been better. However, better growth

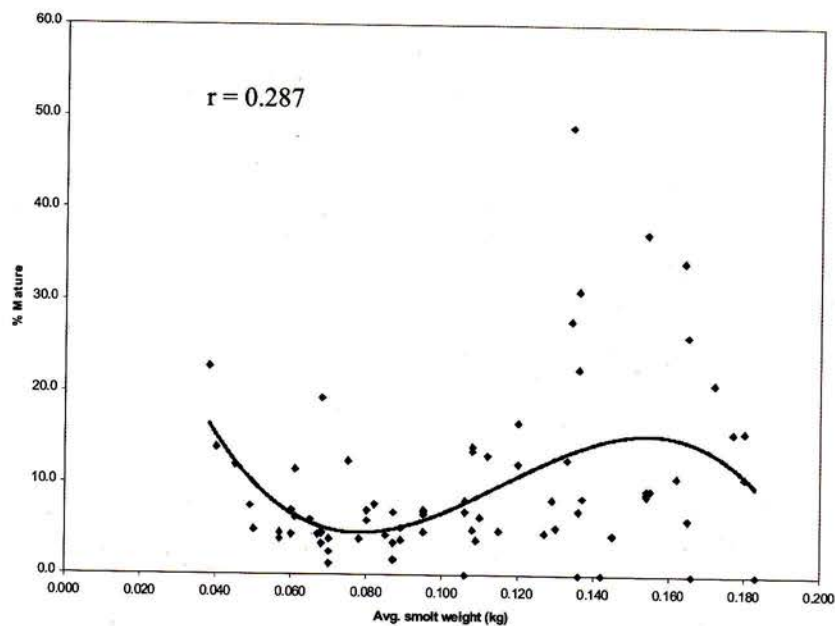


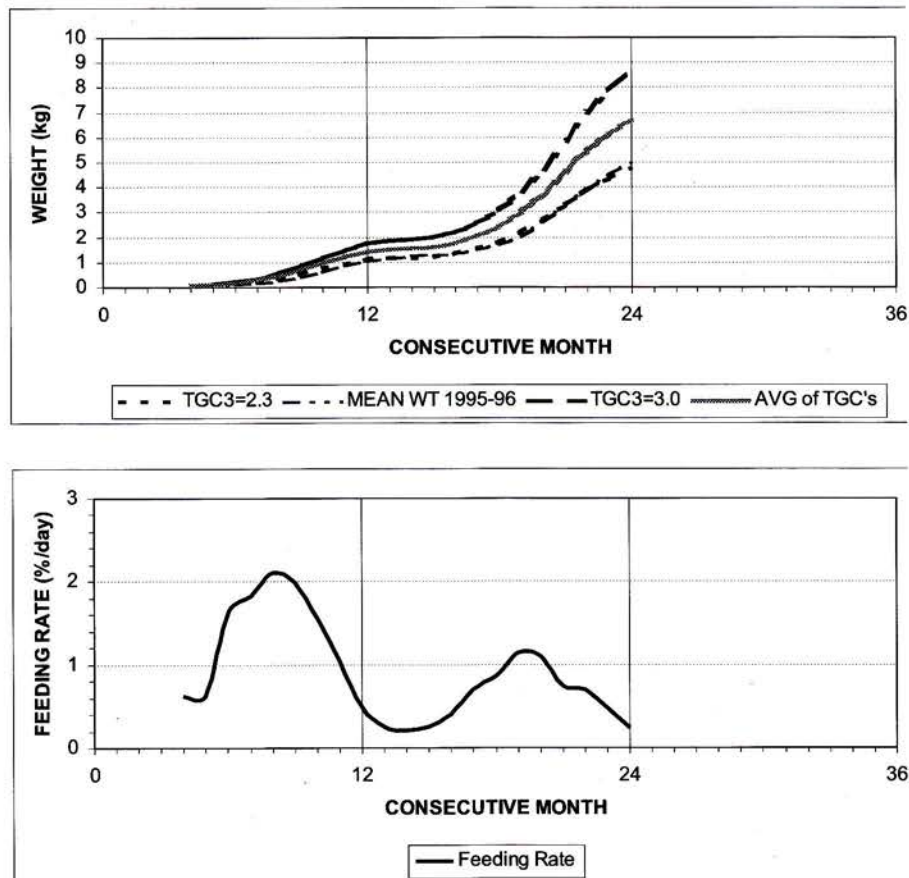
Figure 2. Smolts less than 60 g and over 100 g produced the highest percentage of smolts.

Table 4. Family rankings: Top 10 for high weight and low grilse.

| Rank | Strain | Family Number | Weight (g)<br>(family mean) | Grilse<br>(% immature) |
|------|--------|---------------|-----------------------------|------------------------|
| 1    | 1      | 168           | 12.3                        | 100                    |
| 2    | 90JC   | 125           | 12.2                        | 100                    |
| 3    | 90JC   | 121           | 11.7                        | 100                    |
| 4    | 1      | 140           | 11.6                        | 100                    |
| 5    | 1      | 185           | 11.5                        | 100                    |
| 6    | 2      | 28            | 11.5                        | 100                    |
| 7    | 90JC   | 137           | 11.4                        | 100                    |
| 8    | 1      | 174           | 13.6                        | 86.4                   |
| 9    | 2      | 271           | 11.2                        | 100                    |
| 10   | 2      | 274           | 11.2                        | 100                    |
| 80   | 90JC   | 133           | 10.7                        | 72.2                   |
| 81   | 1      | 155           | 10.2                        | 75.0                   |
| 82   | 1      | 160           | 10.5                        | 70.4                   |
| 83   | 1      | 194           | 11.4                        | 64.3                   |
| 84   | 90JC   | 90            | 10.1                        | 71.4                   |
| 85   | 1      | 138           | 12.3                        | 52.9                   |
| 86   | 1      | 162           | 9.9                         | 65.4                   |
| 87   | 1      | 145           | 11.2                        | 52.6                   |
| 88   | 1      | 158           | 11.9                        | 46.7                   |
| 89   | 90JC   | 117           | 10.9                        | 37.5                   |



## Salmon Size (M) and Feeding Rate (F)



Data Source: Peterson et al. 2001  
Glebe pers comm.

**Figure 3. Comparison between the thermal growth coefficients for salmon cages in the Bay of Fundy in 1995-96 and 2001-02.**

did not result in higher grilse rates (Fig. 4). This is consistent with a lack of correlation with between harvest weight at the family level and % grilse (Fig. 5). We hypothesize that the higher grilse rates at the inshore site are due to higher fall water temperature which influence the decision to mature the next year as grilse.

With increasing incidence of Infectious Salmon Anemia (ISA), it has been necessary to move the broodstock to land-based fresh water sites. Not only has this eliminated the possibility of fish being infected with marine diseases but has enhanced biosecurity and reduced the danger of escapes. This has further allowed for a more aggressive genetic improvement program for low grilse since grilse rates among families are significantly higher in freshwater. Recently, Quinton (unpubl. data) has shown a genetic correlation between production traits in full-sib post-smolts cultured in fresh and salt water.

### Triploidy

Sterilisation by triploidy is an effective means to control maturation in Atlantic salmon.<sup>(8)</sup> Figure 7 presents the results of a cohab sea cage trial with Saint John diploid strains and a Gaspé triploid strain. Although two of three Saint John diploid strains showed significantly better growth than the triploid stock, the triploid stock produced no grilse.

### Offseason Smolts

Out-of-season (0+) smolts are derived from eggs laid in the fall, but go to sea cages the following fall, approximately six months ahead of the 1+ smolts.<sup>(9)</sup> Duncan et. al.<sup>(10)</sup> reported the results of a study to examine and compare the performance of out-of-season smolts with in-season smolts. Some of this data is presented in

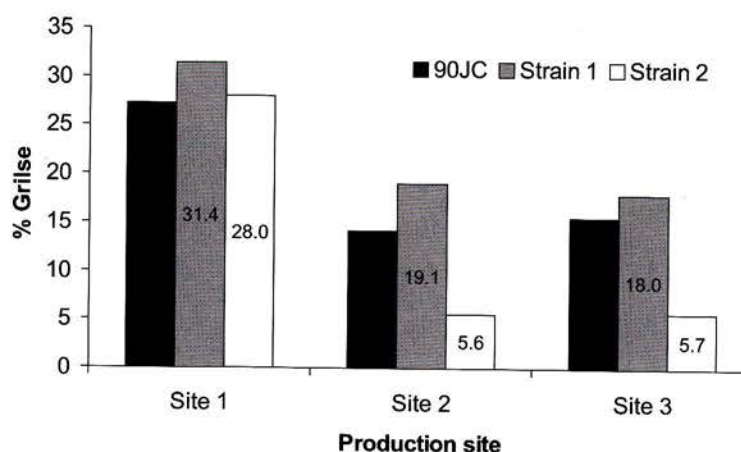


Figure 4. % Grilse from strains grown at three farm sites.

Table 5. Relationship between time of smolt transfer and grilse.

| Transfer Date | % Grilse | Smolt Weight (g) |
|---------------|----------|------------------|
| November      | 35       | 33               |
| March         | 19       | 42               |
| May           | 16       | 43               |
| June          | 12       | 36               |
| July          | 9        | 35               |

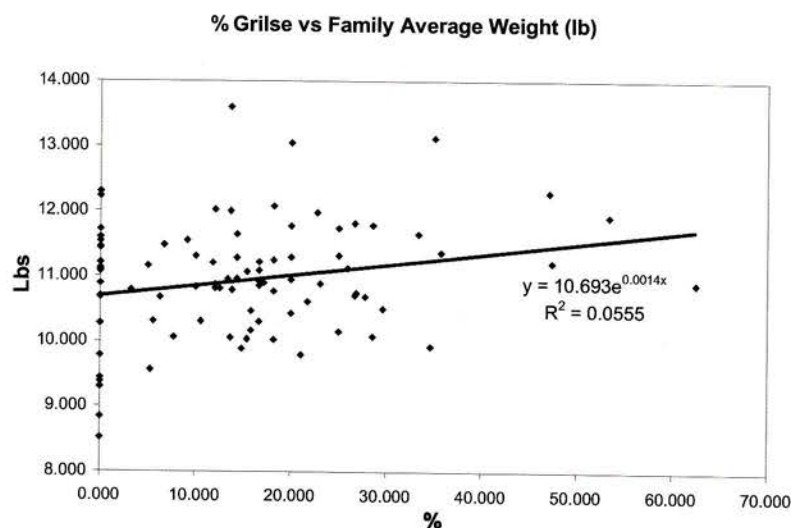


Figure 5. Correlation between % grilse and average weight of the family.



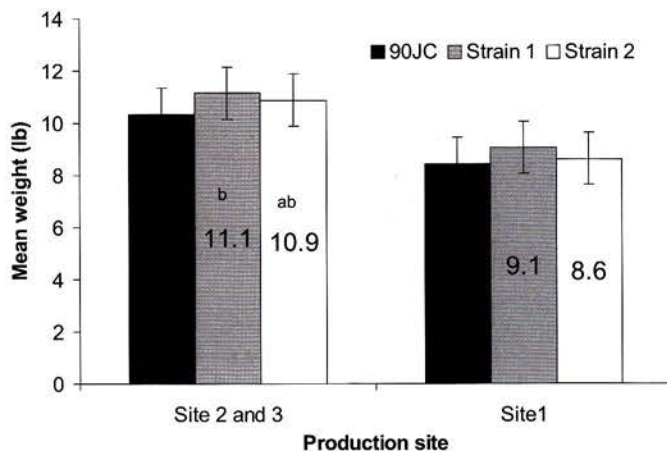


Figure 6. Mean harvest weights by farm site (site 2 and 3 were not significantly different and were combined).

Table 5. Five groups were transferred to the same site during November, March, May, June and July. The percentage of grilse increased with increasing period of time from seawater transfer to final maturation.

#### Ultrasound for Early Detection of Grilse

The ability to identify sex and maturity without sacrificing fish gives farmers a tool in their arsenal to track fish and take pre-emptive measures as necessary. Ultrasound can be used as an effective means to achieve this end. Mattson<sup>(11)</sup> and Reimers et. al.<sup>(12)</sup> have documented the use of ultrasonography for this purpose in Atlantic salmon. The recent development

of Aqua-Scan by Northstar Medical Systems has put this technology into the hands of the industry.

Dr. Fred Page, with the Dept. of Fisheries and Oceans in St. Andrews kindly provided Figure 3.

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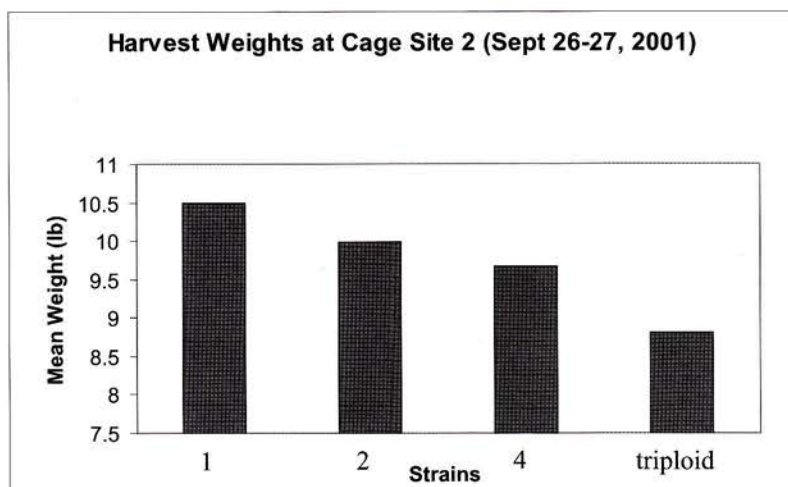


Figure 7. Mean weights at harvest of diploid Saint John strains (1, 2 and 4) and a triploid Gaspe triploid strain in a cohabitation sea cage trial.

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# The Effect of Photoperiod on Maturation of Cultured Salmon in the Bay of Fundy

Paul Harmon, Brian Glebe and Richard Peterson

Continuous illumination of salmon cages significantly reduced maturation rates if the use of lights began in November (1.1% mature fish in the lit cages vs. 21.5% in the control groups). When the onset of artificial lighting was delayed until February, the results were variable (rates of maturation ranged from 2% to 19.4%). The cost of purchasing, wiring and operating the lights was less than \$5,000 per cage, while the increase in the value of the fish exposed to 24-h light from November was greater than \$100,000 per 70-m cage.

## Introduction

The first commercial production of Atlantic salmon in sea cages in the Bay of Fundy began in 1978 at Deer Island, New Brunswick. In 1981, Sutterlin et. al.<sup>(1)</sup> reported that less than 1% of the salmon matured as grilse. In the fall and winter of 1987/88, Henderson<sup>(2)</sup> collected maturation data from the Salmonid Demonstration and Development Farm. He found the maturation rate in harvested fish from 1<sup>+</sup> smolts was 6.9%.

When this result was broken down by feed type, 1.4% of the fish fed on dry food and 12.2% of the fish fed moist feed had matured as grilse. During the fall and winter of 1996/97 Peterson et. al.<sup>(3)</sup> collected data from three cages on each of 20 salmon farms. They found the average maturation rate to be 4.2%. In the study reported here, the average maturation rates on two fish farms were 17.5% and 21.5%. Maturation rates in individual cages were as high as 29.0% and 33.6% on the two farms.

**Table 1. Growth rates in smolts exposed to three lighting regimes: control, 24-h light from November to May, or 24-h light from February to May.**

| Cage | Treatment | Initial Smolt Weight (g) | Mean Weight of Fish in November (g) | Specific Growth Rate (smolt to November) | Mean Weight of Fish in December (g) | Specific Growth Rate (November to December) | Mean Weight of Fish in May (g) | Specific Growth Rate (December to May) |
|------|-----------|--------------------------|-------------------------------------|--|-------------------------------------|---|--------------------------------|--|
| A1   | November  | 123                      | 1586                                | 1.19                                     | 1809                                | 0.365                                       | 3190                           | 0.357                                  |
| A3   | November  | 40                       | 732                                 | 1.36                                     | 966                                 | 0.770                                       | 1810                           | 0.395                                  |
| B3   | November  | 58                       | 1145                                | 1.39                                     | 1496                                | 0.743                                       | 2500                           | 0.323                                  |
| A2   | February  | 88                       | —                                   | —  | —                                   | —   | 2550                           | —                                      |
| B2   | February  | 50                       | —                                   | —  | —                                   | —   | 2420                           | —                                      |
| B1   | February  | 94                       | —                                   | —  | —                                   | —   | 2790                           | —                                      |
| A4   | Control   | 95                       | —                                   | —  | —                                   | —   | 2690                           | —                                      |
| A5   | Control   | 103                      | 1326                                | 1.19                                     | 1652                                | 0.611                                       | 2600                           | 0.285                                  |
| A6   | Control   | 107                      | —                                   | —  | —                                   | —   | 2340                           | —                                      |
| B4   | Control   | 89                       | —                                   | —  | —                                   | —   | 2490                           | —                                      |
| B5   | Control   | 103                      | 1389                                | 1.22                                     | 1816                                | 0.744                                       | 2840                           | 0.281                                  |
| B6   | Control   | 113                      | 1340                                | 1.16                                     | 1762                                | 0.760                                       | 2540                           | 0.230                                  |



**Table 2. Growth rates of fish from May through harvest.**

| Cage and Treatment | Weight in July (g) |               |               |                 | Specific Growth Rate (May to July) |               |               |                 |
|--------------------|--------------------|---------------|---------------|-----------------|------------------------------------|---------------|---------------|-----------------|
|                    | Mature Male        | Immature Male | Mature Female | Immature Female | Mature Male                        | Immature Male | Mature Female | Immature Female |
| A1–Nov lit         | 3394               | 3668          | –             | 3585            | 0.132                              | 0.297         | –             | 0.248           |
| A3–Nov Lit         | –                  | 2401          | –             | 2513            | –                                  | 0.601         | –             | 0.698           |
| B3–Nov Lit         | 3320               | 3165          | –             | 3203            | 0.604                              | 0.502         | –             | 0.527           |
| A2–Feb Lit         | 3469               | 3186          | 3061          | 3164            | 0.655                              | 0.473         | 0.389         | 0.459           |
| B2–Feb Lit         | 2574               | 2781          | 1886          | 2834            | 0.131                              | 0.296         | - 0.530       | 0.336           |
| B1–Feb Lit         | 3629               | 3340          | –             | 3393            | 0.559                              | 0.383         | –             | 0.416           |
| A4–Control         | 3756               | 3047          | 3167          | 2780            | 0.71                               | 0.265         | 0.347         | 0.070           |
| A5–Control         | 3531               | 3386          | 3588          | 2846            | 0.651                              | 0.562         | 0.685         | 0.192           |
| A6–Control         | 3714               | 2710          | 2973          | 2610            | 0.983                              | 0.312         | 0.509         | 0.232           |
| B4–Control         | 3559               | 2524          | 3989          | 2577            | 0.76                               | 0.029         | 1.003         | 0.073           |
| B5–Control         | 3927               | 2449          | 3899          | 2893            | 0.69                               | - 0.316       | 0.674         | 0.039           |
| B6–Control         | 3597               | 2890          | 4346          | 2942            | 0.74                               | 0.274         | 1.143         | 0.313           |

|            | Harvest Date | Harvest Weight (g) |               |               |                 | Specific Growth Rate |                 |               |                 |
|------------|--------------|--------------------|---------------|---------------|-----------------|----------------------|-----------------|---------------|-----------------|
|            |              | Mature Male        | Immature Male | Mature Female | Immature Female | Mature Male          | Immature Female | Mature Female | Immature Female |
| A1–Nov lit | 16 Oct 02    | 5960               | 6080          | –             | 6030            | 0.587                | 0.543           | –             | 0.559           |
| A3–Nov Lit | 4 Feb 03     | 2870               | 4050          | –             | 4160            | –                    | 0.256           | –             | 0.247           |
| B3–Nov Lit | 6 Jan 03     | 2990               | 5690          | –             | 5730            | - 0.060              | 0.335           | –             | 0.332           |
| A2–Feb Lit | 27 Jan 03    | 3880               | 5930          | 3470          | 6150            | 0.057                | 0.317           | 0.064         | 0.339           |
| B2–Feb Lit | 16 Jan 03    | 2730               | 5670          | 4410          | 5480            | 0.032                | 0.385           | 0.459         | 0.356           |
| B1–Feb Lit | 19 Dec 02    | 3970               | 5400          | 2960          | 5240            | 0.057                | 0.306           | –             | 0.277           |
| A4–Control | 9 Sep 02     | 4580               | 3950          | 3880          | 3940            | 0.354                | 0.463           | 0.363         | 0.623           |
| A5–Control | 12 Aug 02    | 4210               | 3450          | 4080          | 3360            | 0.628                | 0.067           | 0.459         | 0.593           |
| A6–Control | 27 Sep 02    | 4200               | 4300          | 3670          | 4390            | 0.166                | 0.624           | 0.285         | 0.703           |
| B4–Control | 9 Oct 02     | 3960               | 4500          | 4090          | 4780            | 0.124                | 0.672           | 0.103         | 0.718           |
| B5–Control | 24 Aug 02    | 4170               | 3510          | 4360          | 3590            | 0.150                | 0.900           | 0.279         | 0.540           |
| B6–Control | 16 Sep 02    | 4500               | 4280          | 4060          | 4300            | 0.356                | 0.623           | - 0.108       | 0.602           |

## Materials and Methods

The study was conducted on two farm sites. Site 1 had twelve 70-m circular cages. Lights were used on 6 of 12 cages. On 3 of the cages, the lights were “turned on” on November 21, 2001. The use of lights on the other 3 cages did not begin until February 15, 2002. On Site 2, four 50-m cages were used for the experiment. On two cages, lights were used from October 31, 2001 and two cages were used as controls. Each

cage was lit using 2 Seebrite® lights which remained on 24 hours a day. All lights were turned off on May 31, 2002.

Growth of the fish was measured using a synchronized dual video camera system.<sup>(4)</sup> Measurements of the fish were taken on November 15, December 21 and May 29.

A preliminary harvest was taken at site 1 in July 2002. One Xactic tank of fish was examined from each cage (~ 60 fish/tank). Sex, round weight, fork

## GRILSE PRODUCTION IN LIT AND UNLIT CAGES

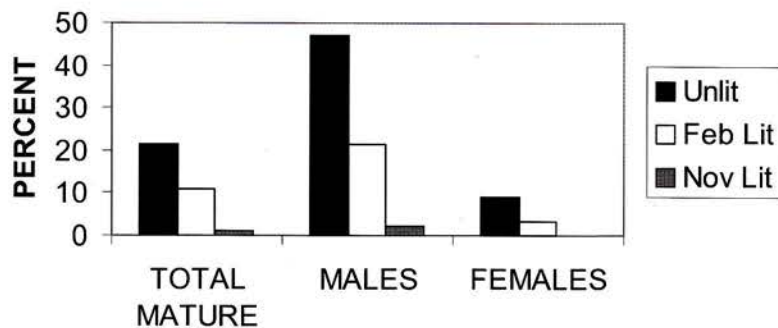


Figure 1. Maturation rates on site 1.

length, girth, dressed weight and gonad weight were recorded. The mean fat content was measured using a Torry fatmeter. Jaw, spinal and gill deformities were recorded. Head shape was noted, particularly elongation and kype. Gonadosomatic index (GSI)<sup>(5)</sup> was calculated for each fish. Males with a GSI of 0.2 and females with a GSI of 0.3 were considered mature.<sup>(6)</sup>

Site 1 was harvested from August 2002 through February 2003. Two Xactic tanks (91 to 153 fish/tank) were sampled from each harvest of the same cage. Length, weight, sex, maturity and deformities were recorded. Site 2 was harvested from August through September 2002. One Xactic tank (98 to 100 fish/tank) was sampled from each cage. Weight, sex and maturity were recorded for each fish.

### Results and Discussion

Initial smolt weights at seawater entry, weights from the 3 camera measurements and specific growth rates for site one are provided in Table 1. Instantaneous specific growth rate expresses the rate of growth as percent per day averaged over a specific period of time.<sup>(3)</sup> From smolt entry through November, the smaller smolts had higher specific growth rates. Peterson et. al.<sup>(3)</sup> found similar results in a study of 20 salmon farms in the Bay of Fundy. In the November to December period, after the initiation of 24-hour daylight, the Novem-

ber-lit cages showed a greater drop in growth rate than the controls (even allowing for differences in smolt size). This initial drop in growth rate after the initiation of increased daylength was also reported by Taranger et. al.<sup>(7)</sup>, Endal et. al.<sup>(8)</sup> and Oppedal et. al.<sup>(9)</sup> Finally, in the December to May period the fish in the November-lit cages had a higher growth rate than the controls. Saunders and Harmon<sup>(10)</sup> reported similar results in an experiment conducted in tanks.

Final weight samples were taken in the processing plant. These data are shown in Table 2. In July, mature fish in

the control cages were growing faster than immature fish. As well, the mature fish were significantly larger than the immature fish. Immature fish caught up to the mature fish by September and, by the beginning of October, the mature fish were smaller than the immature fish. In the lit cages, however, there are no differences in the size of the fish in July. But by December/January, the mature fish in the lit cages had lost between 1 and 2 kilograms in weight.

Figure 1 shows the maturation rates on site 1. The first set of bars are the percentage of mature fish in each of the three treatment groups. The control unlit

## GRILSE PRODUCTION IN LIT AND UNLIT CAGES

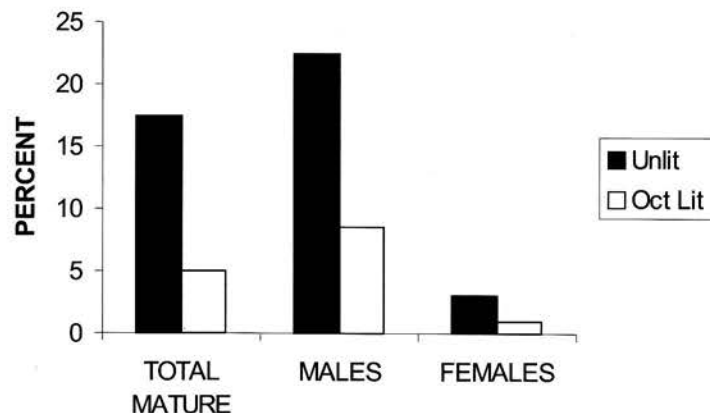


Figure 2. Grilse production in lit and unlit cages on site 2.



cages had 21.5% mature fish, the February-lit cages had 11.1% mature fish and the November-lit cages had 1.1% mature fish. The next two sets of bars break down the total into males and females. In the unlit cages, 47.0% of the male fish were mature, in the February-lit cages 21.5% were mature, and in the November-lit cages 2.1% were mature. With female fish, the unlit cages had 9% mature, February-lit cages had 3.3% and November-lit cages had no mature fish (0%).

Figure 2 shows the maturation rates on site two. The first set of bars are the total percentage of mature fish in each group. Unlit cages had 17.5% mature and October-lit cages had 5.0% mature fish. The next two sets of bars break down the total into males and females. In unlit cages, 22.5% of the males were mature and in October-lit cages 8.5% were mature. In unlit cages, 3.0% of the female fish were mature and in the October-lit cages, 1.0% were mature.

Taranger et. al.<sup>(7)</sup> reported that increased daylength significantly lowers maturation rates in Norway. Our results show the initiation of continuous light beginning in November significantly lowers maturation rates. However, beginning the increase in daylength in February had only a limited effect on maturation (11.1%) and results were unpredictable (2.0 to 19.4% maturation rates).

Table 3 gives a comparison of maturation rates based on GSI and the actual maturation results. GSI on average, using our cut-offs, consistently overestimates the actual rate of maturity. However, using our data a closer estimate could be developed.

The cost of purchasing, wiring and operating the lights was less than \$5,000 per cage. In the November-lit groups, the savings gained were greater than \$100,000 per 70-m cage.

*The authors thank Lloyd Purdy, Mark Moore, Blake Armstrong, Bill Cusack, Darren Ingersoll, Shane Borthwick and Wilfred Young-Lai for their assistance. This research was supported by Jail Island Salmon and ACRDP.*

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**Table 3. A comparison of maturation rates using GSI and actual rates. (SD: standard deviation).**

| Treatment | Cage      | % Mature    |            |
|-----------|-----------|-------------|------------|
|           |           | GSI         | Actual     |
| Control   | A6        | 29.2        | 33.6       |
|           | A4        | 36.9        | 13.8       |
|           | A5        | 36.5        | 26.7       |
|           | B6        | 34.3        | 22.4       |
|           | B5        | 32.8        | 22.4       |
|           | B4        | 8.7         | 9.9        |
| Mean (SD) |           | 29.7 (10.7) | 21.5 (8.6) |
| February  | A2        | 17.1        | 19.4       |
|           | B1        | 10.0        | 11.9       |
|           | B2        | 8.5         | 2.0        |
|           | Mean (SD) | 11.9 (4.6)  | 11.1 (8.7) |
| November  | A1        | 4.3         | 0.5        |
|           | A3        | 0           | 1.0        |
|           | B3        | 1.4         | 1.9        |
|           | Mean (SD) | 1.9 (2.2)   | 1.1 (0.7)  |

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# Bay d'Espoir Atlantic Salmon Aquaculture: Experience with Early Maturation

Vern Pepper

During its 15 years of experience leading up to the 21<sup>st</sup> century, the Newfoundland Salmonid Growers Association (NSGA) documented Atlantic salmon maturation rates typically of less than 10% among its Bay d'Espoir aquaculture farms at the time of harvest. However, there were notable exceptions. At one site in 1997, maturation in three cages exceeded 50%, while the 13 other cages at the affected site had less than 10% incidence of reproductive development. The only incidence of serious early salmon maturation experienced overall by the Bay d'Espoir industry was in year 2000 during harvest of the 1998 year class.<sup>a</sup> Of the salmon smolts placed in the respective cages in 1999, mortality to harvest averaged ~34%. Maturation among cages at time of harvest in a strain-evaluation experiment ranged from 31 to 58%, representing a further 28% loss to the industry (i.e., 62% loss over all). Similar values were reported by many of the Bay d'Espoir industry participants. This extreme level of maturation corresponded with elevated maturation noted elsewhere in Atlantic Canada during that year. Such levels of early maturation have not been repeated in Bay d'Espoir since the 2000 harvest; rates since then again being <10%. There is considerable debate within the industry as to whether early maturation is environmentally induced or a consequence of fish husbandry practices. Either way, the NSGA is anxious to determine alternative means to control incidence of maturation in its salmonid aquaculture operations.

Commercial Atlantic salmon aquaculture in Newfoundland and Labrador has been confined largely to the Bay d'Espoir area of the southwest coast of the island that, historically, has not been adversely affected by arctic ice in the winter months. An estuarine fjord of some 250 km<sup>2</sup>, Bay d'Espoir (Fig. 1) offers some protection from the seasonal violence of the Northwest Atlantic. However, with local-river discharge and a hydroelectric facility at the head of the bay, freshwater input to the inner reaches of the fjord can reach 350 m<sup>3</sup>sec<sup>-1</sup>. Thus, this fjord is subject to considerable physical and chemical water-column variability due to mixing of freshwater at the surface with the underlying marine waters. Superchill conditions within the fjord are not common, though winter water-column temperatures as low as -1.3°C are encountered further seaward from the fjord entrance, usually in the upper 4 m of the water column. Both the subarctic winter-marine conditions and the dynamics of the estuarine-fjord water column have provided many challenges to Bay d'Espoir aquaculture entrepre-

neurs.

Together with industry-development challenges posed by the estuarine-fjord environment, the Newfoundland Salmon Growers Association (NSGA) has been restricted in its development endeavours by stock-transfer regulations. The Bay d'Espoir industry has been constrained both in the numbers of eggs and the salmon strain that it was allowed to import into the province. The NSGA has been working with Saint John strain Atlantic salmon since 1988 and has continued importing eggs from mainland suppliers as well as stripping eggs from brood stock from the local aquaculture cages.

The early years of Bay d'Espoir salmon aquaculture may be characterized as a learning experience. In the last decade of the 20<sup>th</sup> century, the Bay d'Espoir industry faced both husbandry and fish-health challenges. By the turn of the century, these challenges had been met and the industry began to focus more on expansion of its operations and improving its economic performance through refinements to its Atlan-

<sup>a</sup> This paper uses fisheries-biology terminology<sup>(1)</sup> and employs "year class" to refer to the year in which eggs hatched (i.e., January for the Bay d'Espoir hatchery).



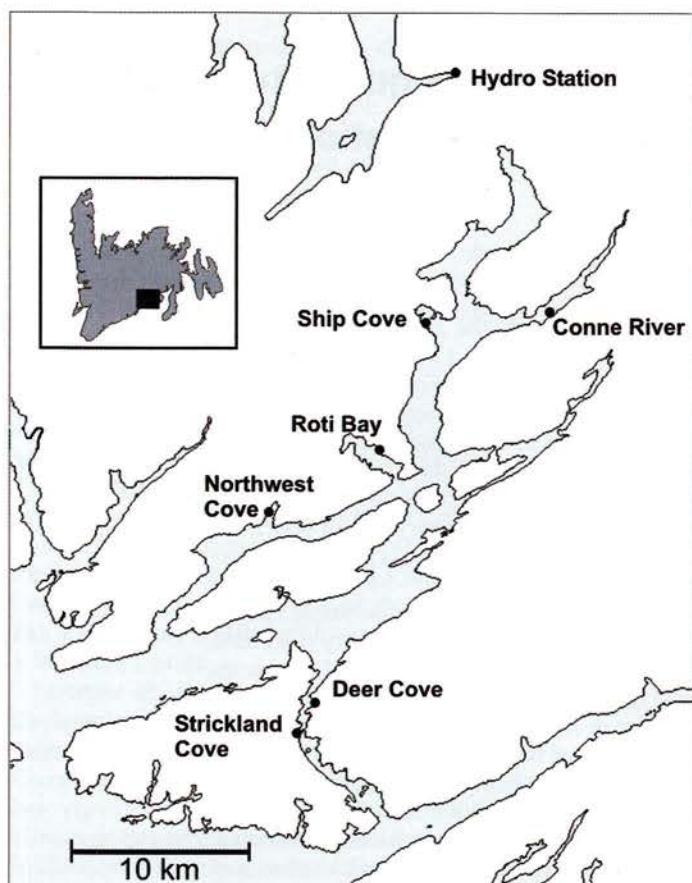


Figure 1. Bay d'Espoir location map and some salmon farm sites.



Figure 2. Winter ice conditions, Bay d'Espoir, Newfoundland.

tic salmon aquaculture strategy.

During the 1990s, the usual practice for the Bay d'Espoir industry was to produce smolts of 30 g to 75 g from its hatchery for on-growing during the first summer in estuarine cages. The smaller size of salmon smolts was typical of the early years of industry development. In order to avoid farm damage due to shifting ice in the winter months, post smolts at the end of their first summer in the estuary were transferred to protected overwintering areas (Roti Bay, Voyce Cove and Northwest Cove; Fig. 1, 2) by towing cages containing the livestock inventory. This process often required six or more hours of continuous towing. Following the first winter in estuarine conditions, the practice was for cages and salmon to be towed to full-salinity marine sites further out the bay (e.g., Little Passage) to complete the production cycle.

It was during these early years of industry experience that the NSGA faced elevated mortality due to fish-health challenges by both *Vibrio* sp. and *Aeromonas salmonicida* subspecies *nova* (atypical furunculosis). Much of the mortality for each year class in the sea-pens took place during early July, leading to speculation that the salmon were made susceptible to fish pathogens due to physiological stress. Reasons for such stress were thought to include estuarine-water adaptation of smolts in their first marine year,

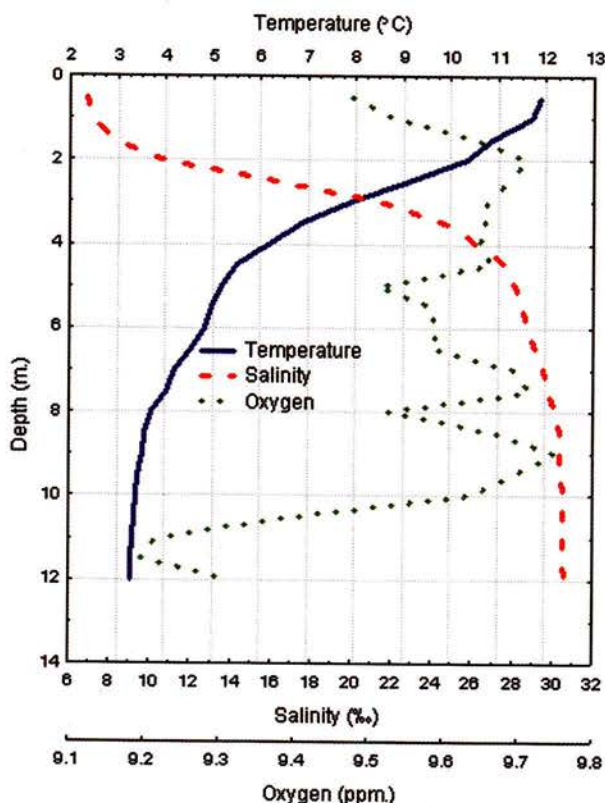
overwintering conditions during their first marine winter (e.g., salmon often are not fed at all for three to four weeks during the coldest months of the winter), or handling practices such as towing. Although the incidence of maturation encountered among harvested salmon at the end of their second summer in the net pens typically was low, it became apparent that many of the fish lost to pathogens in their second year of marine on-growing were in fact maturing at the time they died.

During its 15 years of

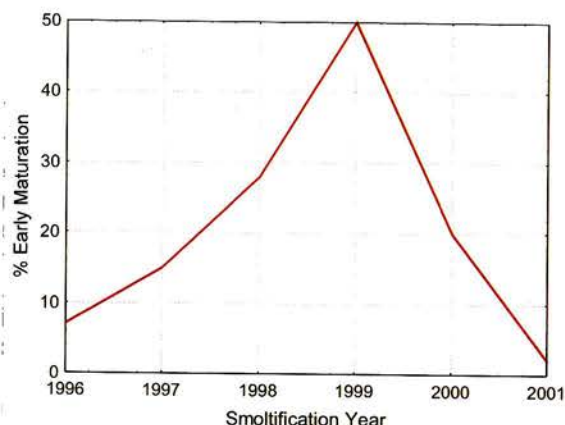


experience leading up to the 21<sup>st</sup> century, the NSGA documented maturation rates typically less than 10% at the time of harvest. However, there were notable exceptions. At one site (Strickland Cove) in 1997, maturation in three cages exceeded 50%, while the fish in the 13 other cages at the affected site had less than 10% reproductive development. The only apparent difference between conditions at the affected cages and all others at the site was much higher water current around those cages with fish exhibiting maturation. Excessive current was apparent visually by billowing of the nets. Such billowing was not observed among other net pens at the site.

The only incidence of serious early salmon maturation experienced overall by the Bay d'Espoir industry was in year 2000 during harvest of the 1998 year class (Fig. 3). The fish processing plant for the Bay d'Espoir industry is located at St. Albans, towards the head of Bay d'Espoir (Ship Cove; Fig. 1), where fish are held for some days until harvest. The staging area immediately adjacent to the fish plant has



**Figure 4.** CTD water-column profile showing evidence of freshwater layering in Ship Cove (close to industry processing plant).



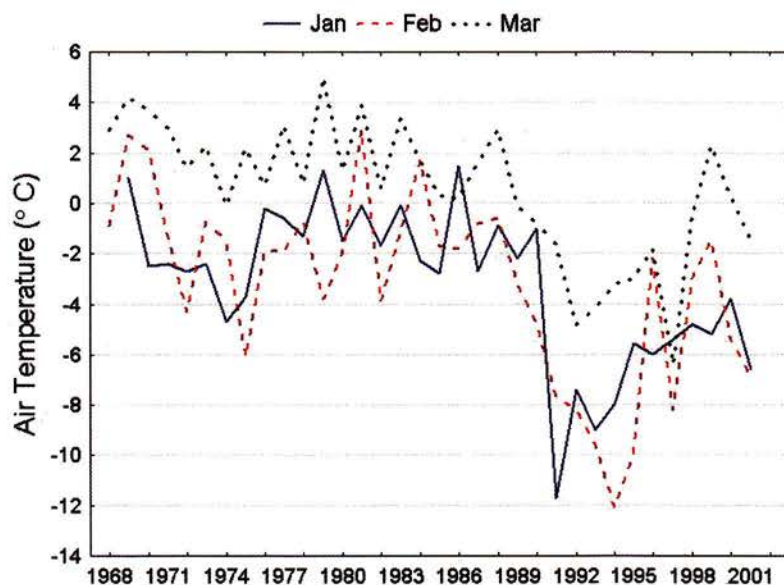
**Figure 3.** Incidence of early maturation among Atlantic salmon harvests from Bay d'Espoir aquaculture.

a pronounced layer of low-salinity water in the upper water column (Fig. 4). Hence, during final preparations for harvest, salmon readily segregate naturally into those that are maturing (i.e., upper water column) and those that are marketable (i.e., lower part of the net pens). While it is standard Bay d'Espoir industry practice to cull maturing salmon from the fish plant at the time of harvest, for occasions in which maturation is sufficiently elevated as to require excessive processing labour, maturing salmon are seined from the surface waters and eliminated from the marketable inventory. The harvest of 2000 presented such conditions.

Of the smolts placed in the respective cages in 1999, mortality to harvest averaged ~34%. Maturation among cages at time of harvest in a strain-evaluation experiment (Deer Cove) ranged from 31 to 58%, representing a further 28% loss to the industry (i.e., 62% loss over all). Similar values were reported by many of the Bay d'Espoir industry participants. Some Bay d'Espoir growers attribute the unusual mortality and maturation rate to husbandry deficiencies (i.e., insufficient net depth, warm upper-water column temperatures, too much handling). However, experience elsewhere in Atlantic Canada<sup>(2)</sup> suggests, at least for the maturation component of the losses, environmental cues of a much broader geographic context (e.g., El Niño/North Atlantic Oscillation).

In anticipation of the need for salmon-strain performance improvements for the environmental conditions of Bay d'Espoir, the NSGA undertook several initiatives in collaboration with the Newfoundland and Labrador Region of Fisheries and Oceans Canada (DFO) and with the provincial Department of Fisheries and Aquaculture, starting in 1989 and proceeding through 2000. These initiatives included





**Figure 5.** Historical air temperatures for Bay d'Espoir winters (recordings from the Bay d'Espoir hydroelectric generating station).

evaluation of alternative strains of Atlantic salmon and rainbow/steelhead trout, gender manipulation, reproductive control, pedigree breeding and refinements to husbandry practices. None of these initiatives served to counter the incidence of early maturation documented at harvest in 2000. However, in the interval since the 2000 peak in incidence of maturation among harvest salmon, significant gonad development by time of harvest again has diminished to levels considered acceptable by industry. The reasons for this improved harvest performance are uncertain but are thought, again by some within the industry, to be due to recent changes to industry practices. Foremost among these practices are the following:

- supplemental importation of Atlantic salmon from a New Brunswick pedigree program (2000 year class) in addition to historic reliance on whatever is available from commercial mainland hatcheries;
- cages containing livestock are not towed between sites;
- smolts (80g +) are introduced directly to full-salinity marine conditions;
- salmon are overwintered at full-salinity marine sites (i.e., further out the bay); and,
- winter-water temperatures are lower in February and March at marine overwintering sites and climb more slowly in the spring than in previously used, estuarine overwintering locations.

Observations germane to the early-maturation topic are:

- smolts introduced directly to full-salinity seawater have demonstrated improved fish health;
- increased handling in the spring has corresponded with elevated grilising;
- incidence of grilising is positively correlated with the length of the growing season in the 2<sup>nd</sup> year in marine cages; and,
- lowest mortality and grilising rates took place during the early years of industry activity. This corresponds with the smallest of the juvenile salmon produced for estuarine on-growing and, at least prior to the winter of 2002/03, the coldest winters experienced in the Bay

d'Espoir area (Fig. 5).

Present consensus among the Newfoundland salmon growers seems to be that fish-health status now is much better than for previous year classes of Bay d'Espoir aquaculture salmon. While the industry remains cautiously optimistic that this will translate into improved economic performance, it still maintains interest in structured salmon-breeding programs geared towards improved economic performance under Bay d'Espoir aquaculture conditions.

*I wish to thank North Atlantic Sea Farms (Malcolm Cox), the Department of Fisheries and Aquaculture (Elizabeth Barlow), Markland Seafoods Ltd. (Clyde Collier) and the Newfoundland Salmonid Growers Association for providing data and their insights regarding the early-maturation rates seen in their Atlantic salmon operations.*

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# Early Maturation in the Irish Salmon Farming Industry

Declan T. G. Quigley

In the early years of salmon farming in Ireland, the industry used native strains which had a naturally high level of early maturation ("grilising"). During the 1980s and 1990s the industry experimented with at least 21 different genetic strains, including Irish, Scottish, Icelandic and Tasmanian strains with varying degrees of success. The industry is now using as few as 5 strains based on MSW Mowi and/or Bolaxs broodstock lines, but is still very dependent on imported ova. To reduce the incidence of early maturation and to increase growth, the majority of farmers use 24-hour lighting regimes on S0s from their October input through to the end of April (first winter only). Some farmers use lights on S1 smolts from mid December to mid May, with the exception of fish intended for use as broodstock. Two 400-watt bulbs, submersed at a depth of 3 to 4 m, are commonly used in 80-m cages (1.5 to 2.0 watts/m<sup>2</sup>). Although the incidence of early maturity in cultured salmon in Ireland now appears to be relatively low (5%), it still represents a significant cost to farmers. In 2002, the estimated economic loss due to downgrading because of early maturity was 900,000 euros.

## Introduction

The Irish salmon farming industry is relatively small in comparison with its European neighbours such as Norway and Scotland. Despite many obstacles, Irish production increased from a base of 21 tonnes in 1980 to an estimated 22,294 tonnes in 2002 (Fig. 1). In common with salmon farming worldwide, the Irish industry has been struggling to maintain its economic survival during a period of rapidly increasing production and falling prices (Fig. 2). Nevertheless, Irish production is expected to increase to 35,000 tonnes by 2006. Although the Irish industry rightly claims to produce high quality salmon and to achieve above average prices because of its "green image" in niche markets, like everybody else

in this game it needs to continually focus on reducing production costs and developing value-added products in order to compete effectively in what is now a worldwide commodity market. Early maturation is obviously only one of the many problems that needs to be addressed if the industry is to survive. In this presentation I have attempted to examine the maturation issue from an Irish perspective.

Figure 1. Irish Atlantic Salmon Production 1980 - 2002

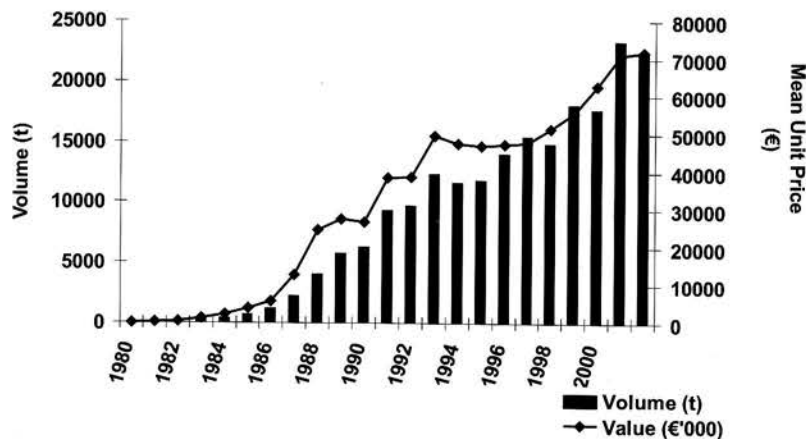
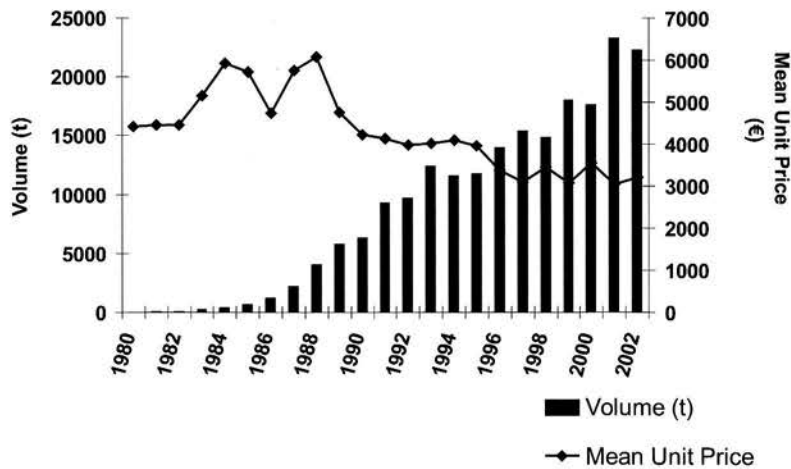




Figure 2. Irish Atlantic Salmon Production 1980 - 2002



During its early years of development, the Irish industry largely depended on native strains of salmon which had a naturally high level of early maturation or "grilising" (e.g. Shannon and Lee). These native strains were acceptable while the industry was in the enviable position of high consumer demand and high prices. However, as global competition increased, it was clear that early maturation, along with many other factors (e.g. biological, technical, political and economic), was severely impeding the development of the industry.

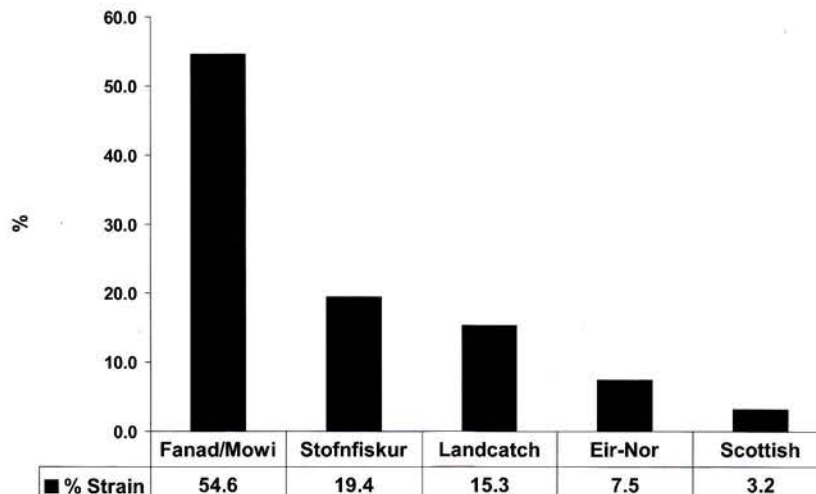
Following the EU ban on the importation of Norwegian ova during the late 1980s, a few short-lived attempts were made by individual Irish companies (e.g.

part of a national salmon broodstock programme.<sup>(1-5)</sup> During the 1980s and 1990s, the industry "experimented" with at least 21 different generic strains (Table 1), including 8 Irish, 9 Scottish/UK, 3 Icelandic and 1 Tasmanian,<sup>(1)</sup> with varying degrees of success, and sometimes with disastrously high grilising levels (up to 99% in one particular strain).

However, in recent years, the Irish industry has consolidated the number of relatively low grilising strains in use. For example, only 5 strains of ova were laid down in Irish hatcheries this winter (Fig. 3). Three of these strains are based on MSW Mowi and/or Bolaxs pedigree broodstock lines operating in Ireland (Ma-

Salmara Fisheries Ltd. and Bradan Mara Teo) to develop their own in-house broodstock programmes based on the mass selection residual Norwegian multi-sea-winter (MSW) strains (e.g. Mowi and Bolax) within the country. At the same time, increasing public concern about the perceived environmental impact of the industry led to political intransigence regarding repeated proposals by the industry for the selection and development of lower grilising native MSW strains as

Figure 3. % Salmon strains used by Irish industry in 2003





**Figure 4.** ISPG currently represents 15 different finfish companies operating in 29 sites along the western sea-board from Donegal in the northwest to Cork in the southwest.



**Table 1. Salmon strains used by the Irish industry (1980-2003)**

| Strain          | Country  | Genetic Origin        |
|-----------------|----------|-----------------------|
| Fanad           | Ireland  | Mowi                  |
| Salmara         | Ireland  | Mowi                  |
| Bradán Mara     | Ireland  | Mowi/Bolax            |
| Eir-Nor         | Ireland  | Mowi/Bolax            |
| Northern Salmon | Ireland  | Scottish/Mowi         |
| Shannon         | Ireland  | Native ISW            |
| Lee             | Ireland  | Native ISW            |
| Curraun         | Ireland  | Native ISW            |
| Landcatch       | Scotland | Scottish/Mowi         |
| Joseph Johnson  | Scotland | Namsen/Mowi           |
| Wester Ross     | Scotland | Namsen/Mowi           |
| McConnell       | Scotland | Scottish/Mowi         |
| Stolt           | Scotland | Scottish/Mowi         |
| Highland        | Scotland | Scottish/Mowi         |
| North Uist      | Scotland | Scottish/Mowi         |
| Lakeland        | Scotland | Mowi                  |
| Salar           | Scotland | Mowi                  |
| Laxalon         | Iceland  | Icelandic             |
| Saga            | Iceland  | Mowi/Bolax            |
| Bolax           | Iceland  | Bolax                 |
| Tasmanian       | Tasmania | Canadian (Saint John) |

**Table 2. Variation in % grilising in salmon strains grown at seasites with different salinities.**

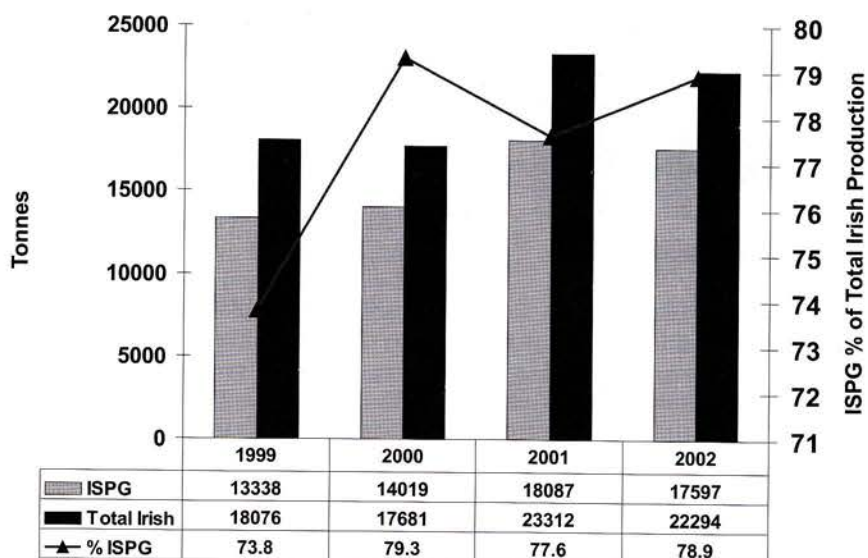
| Producer     |                 | Marine Harvest 1988 |            | Gaelic Seafoods 1997 |           |             |
|--------------|-----------------|---------------------|------------|----------------------|-----------|-------------|
| Seasite      |                 | Lough Swilly        | Mulroy Bay | OBB                  | Sealax    | Ballinakill |
| Salinity (‰) |                 | 33                  | 33         | 34                   | 29-30     | 15-34       |
| Strain       | Highland        |                     |            | 2.5%                 |           | 13.6–14.1%  |
|              | Landcatch       |                     |            | 0.4%                 | 0.8%      |             |
|              | McConnell       |                     |            | 7.3%                 | 5.8–20.0% |             |
|              | Fanad/Mowi      | 4.0–5.0%            | 10.0–12.0% |                      | 0.9–7.0%  |             |
|              | Northern Salmon |                     |            |                      |           | 0.5–1.1%    |

rine Harvest, 55%), Scotland (Landcatch, 15%) and Iceland (Stofnfiskur, 20%). Nevertheless, the Irish industry is still very vulnerable in terms of its dependence on imported ova. While it is encouraging to note that Stofnfiskur is currently developing its own pedigree broodstock lines in Ireland and Scotland, it will

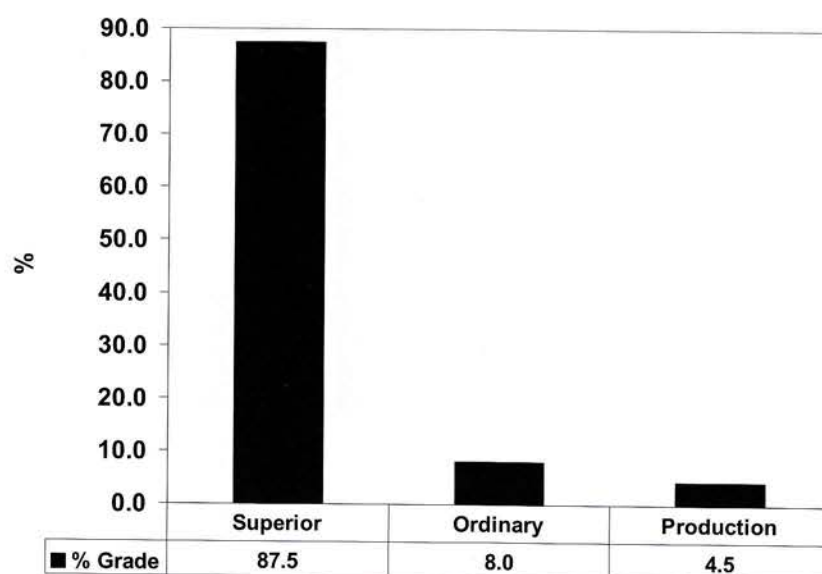
be interesting to see what future opportunities arise following the relaxation of the EU ban on Norwegian ova imports in January 2003.

It is well known that early maturation is influenced by both genetics and the environment and this is well illustrated in Ireland (Table 2). Some strains (e.g.

**Figure 5. % Total Irish Farmed Salmon Produced by ISPG (1999-2002)**



**Figure 6. ISPG Production 1998-2003: % Quality Grades**





Highland) appear to have a high genetic propensity for grilising in sites affected by low salinity, while others (e.g. Landcatch) appear to perform relatively well in both high and medium salinities. In recent years there has been a significant increase in the number of S0 smolts put to sea: from 14% of total smolt input in 1999 to 34% in 2001. In order to reduce early maturation problems and increase growth, the majority of farmers use 24-hour lighting regimes on S0s from October input through to the end of April for the first winter only. Some farmers use lights on S1 smolts from mid December to mid May with the exception of potential broodstock. Two 400-watt bulbs, submersed at 3-4 m, are commonly used in 80-m cages (1.5-2.0 watts/m<sup>2</sup>).

In an attempt to determine the current overall importance of early maturation in the Irish salmon farming industry, it was decided to examine what is found at the end of the production line.

### Irish Seafood Producers Group

The Irish Seafood Producers Group (ISPG) was established by a consortium of salmon farmers in south Connemara (Kilkieran) in the west of Ireland in 1986 and has since grown to become the main farmed finfish marketing, sales and distribution company in Ireland. ISPG currently represents 15 different finfish

companies operating in 29 sites along the western seaboard from Donegal in the northwest to Cork in the southwest (Fig. 4). The company's product range includes farmed salmon, organic salmon, sea-reared rainbow trout and freshwater-reared arctic charr. Over the last four years, ISPG has handled between 75% to 80% of Ireland's total farmed salmon production (Fig. 5).

ISPG's production database from July 1998 to January 2003 was examined in order to assess the relative importance of early maturation in the Irish salmon farming industry. The database, which represents a total production of 63,040 tonnes, includes monthly details on size and quality grades and factors affecting downgrading, including maturation levels. Almost 88% of the production was classified as *superior quality* (Fig. 6), while 12.5% was downgraded for various reasons (described below) as either *ordinary* (8%) or *production quality* (4.5%).

Almost 97% of ISPG's production was marketed as gutted fish and over 70% was sold as 2-3 kg (25%), 3-4 kg (28%) and 4-5 kg (19%) fish (Fig. 7). Significantly more of the smaller grade and production quality fish was sold round. Similarly, a greater percentage of smaller grade fish were downgraded to *ordinary* and *production* grades while the percentage of *superior* quality fish increased with size (Fig. 8). The peak months of production (Fig. 9) were May

Figure 7. ISPG Production (1998-2003): % Size Grades - Round & Gutted

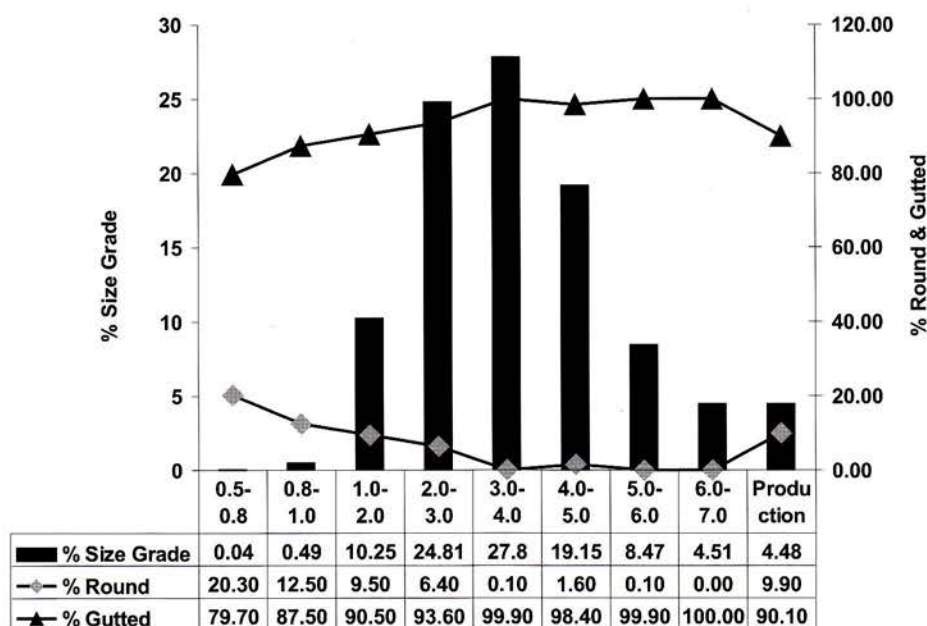


Figure 8. ISPG Production (1998-2003):  
% Superior & Ordinary Quality Grades per Size Group

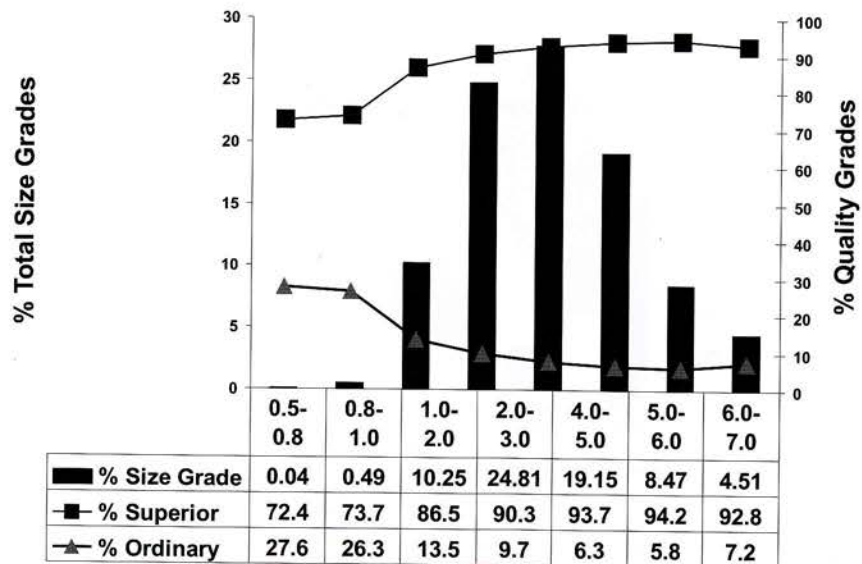
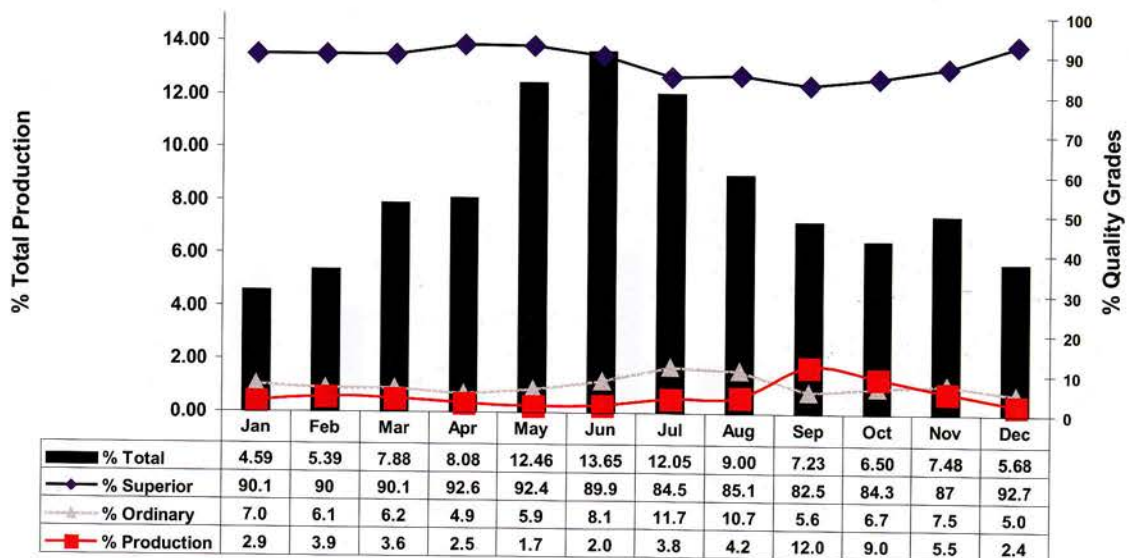


Figure 9. ISPG Production (1999-2002):  
% Monthly Total Production & Quality Grades



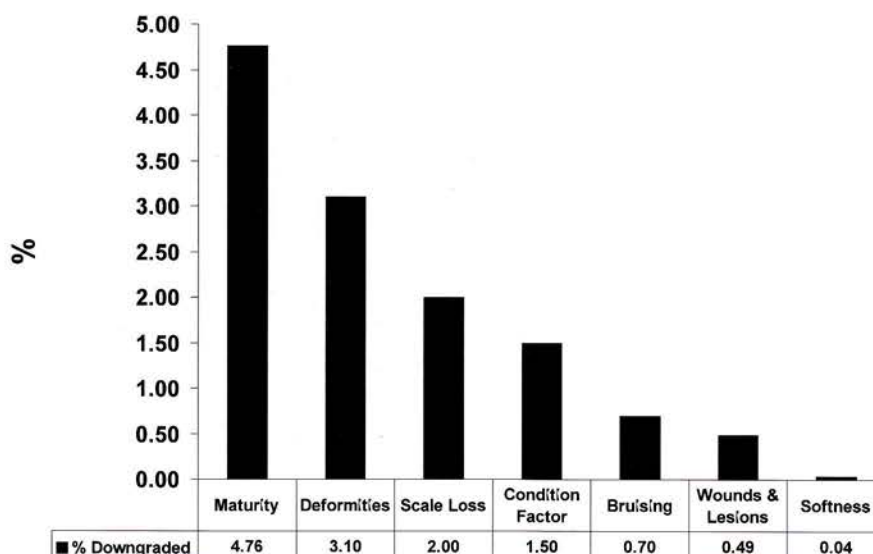


(12.5%), June (13.6%) and July (12%) and the highest level of downgrades (represented by *ordinary* and *production* grades combined) occurred between July and October; the mean level of downgrades was 16% during this period.

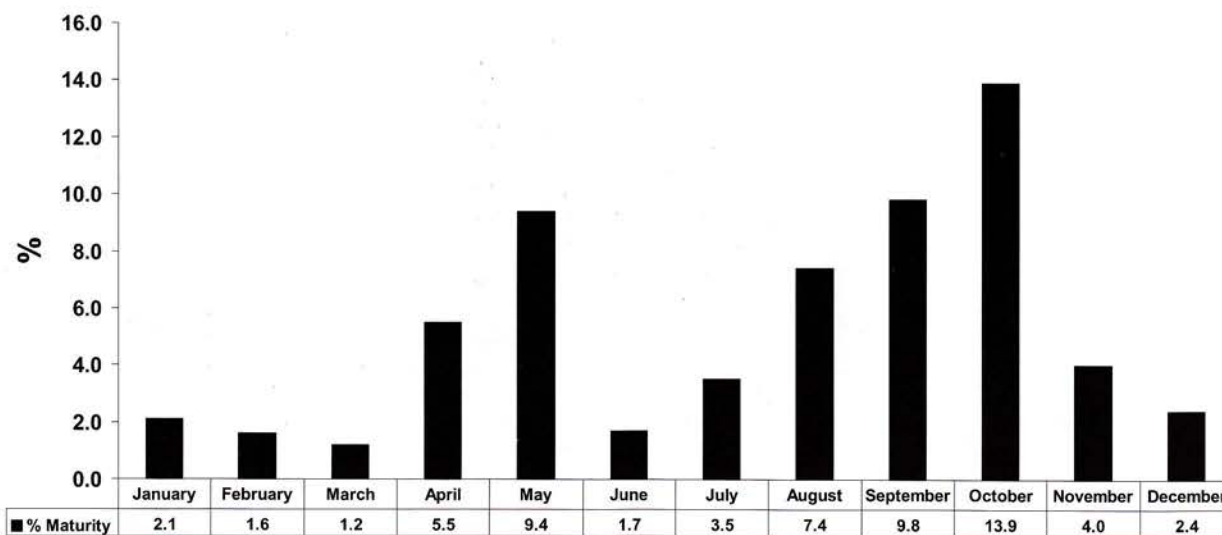
### Downgrading Factors

Figure 10 shows the relative importance of the various factors that led to 12.5% of total production being downgraded into *ordinary* and *production* grades dur-

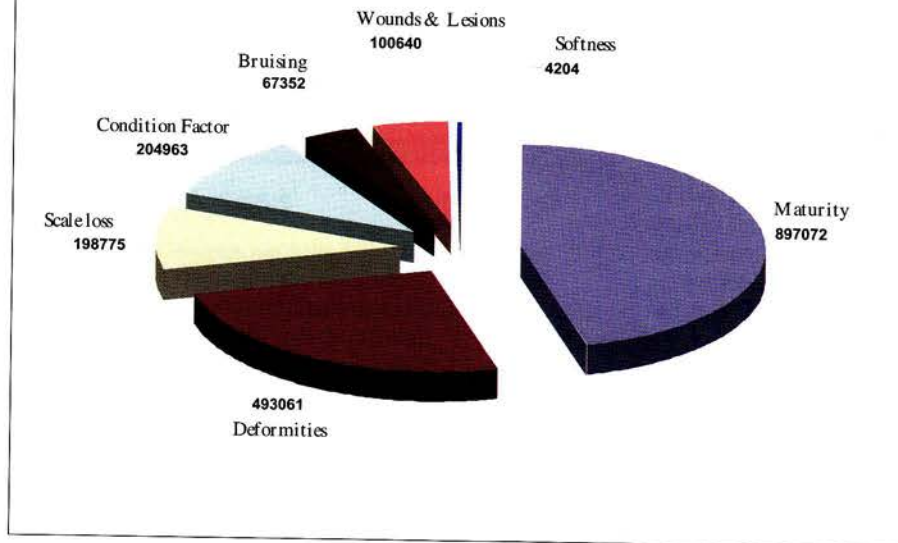
**Figure 10. ISPG Production 2002:  
% Downgrading Factors (Ordinary & Production Grades)**



**Figure 11. ISPG Production 2002:  
% Monthly Distribution of Maturity**



**Figure 12. ISPG Production 2002:  
Estimated Cost of Downgrading Factors  
(Total = 1,966,066 Euro)**



ing 2002. Almost 5% was downgraded due to early (1%) and advanced maturity (4%). The combined effect of maturity and deformities was significant (8%); both of these factors are influenced to some degree by genetics which is largely outside the farmer's control. Other factors, such as scale loss, condition factor, bruising, wounds and softness, which together represented 4.7% of total production, were associated with production and harvesting problems, which were largely under the farmer's control.

Figure 11 shows the level of maturity in downgrades on a monthly basis during 2002. Significant levels of maturity were recorded during late spring (April 5.5%), early summer (May 9.4%) and throughout the autumn (August 7.4%; September 9.8% and October 13.9%). The April/May fish matured the previous winter and were in the process of recovery, while the autumn fish were in the process of maturing.

Although the overall incidence of maturity (5%) appears to be relatively low, from an economic point of view it represents, along with other downgrading factors, a significant cost to the Irish salmon farmer (Fig. 12). In 2002, the estimated economic loss due to downgrading was almost 2 million euro. Maturity problems alone accounted for 45.6% (900,000 euro) of this loss.

It is clear that there are significant savings to be made by minimizing maturity problems. The farmer needs to select strains that have the lowest possible ge-

netic propensity for early maturation along with management techniques appropriate to the environment in which the fish are grown.

*I wish to thank Richard McNamara, John Folan, Maggie O'Flaherty & Willie Pepper (ISPG), Jonathan Clarke (BIM) and Joe Gibbons (Marine Harvest) for their help.*

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## Historical Perspective on Aquaculture Development and Commercialization—The Case for R&D

Cyr Couturier

### R&D Funding and the Need for Coordination

There are a variety of funding groups and agencies across Canada with a mandate for aquaculture **research** and development (R&D). I emphasize the "R" as most of the criteria for accessing funding are aimed at this component of the research to commercialization continuum (see below). A partial listing of agencies and programs that spend at least part of their budgets on R&D or provide direct or indirect access to R&D funds includes the Canadian Customs and Revenue Agency, the National Research Council of Canada (core and Industrial Research Assistance Programs), the Atlantic Innovation Fund (administered by ACOA), the Natural Sciences & Engineering Research Council of Canada, Fisheries & Oceans Canada (core and ACRDP programs), various provincial governments, Industry Canada, AquaNet, the Canadian Centre for Fisheries Innovation, BC Science Council, Atlantic Canada Opportunities Agency (via administration of federal funds for R&D) and, of course, the aquaculture industry itself.

One of the aquaculture industry's main concerns is there appears to be a substantial expenditure of taxpayer dollars but little coordination or strategic approach to using these resources. In fact, the Canadian Council of Fisheries and Aquaculture Ministers has asked a task group to examine the specific question of R&D coordination and to provide recommendations to both levels of government. A workshop led by the Science Branch of Fisheries & Oceans Canada (DFO), and involving several of the major funding/granting agencies, was held in Montréal in early March. A report from the workshop organizers is expected soon with recommendations on who should lead the R&D initiative and where, how, and when it will be done.

Another major concern of the industry has been that while there appears to be ample support for aquaculture *research*, albeit perhaps not as coordinated or strategic as desired, there is little public or private funding for aquaculture *development* in Canada. Unlike a number of other economic sectors important to the Canadian economy, aquaculture has not

been the subject of a national strategic development approach. A national workshop and working group on "Research to Commercialization" was convened in Ottawa in late March by the Canadian Aquaculture Industry Alliance (CAIA) with logistic support provided by DFO ACRDP (Aquaculture Collaborative Research and Development Program). Leading industry experts were invited to present case studies on the research, development and commercialization continuum, and a number of recommendations were made for moving ahead on this issue. A report on the workshop is available from CAIA.

As part of the working group, I provided an historical perspective and some comments on Canadian aquaculture development and commercialization. The following sections summarize that presentation.

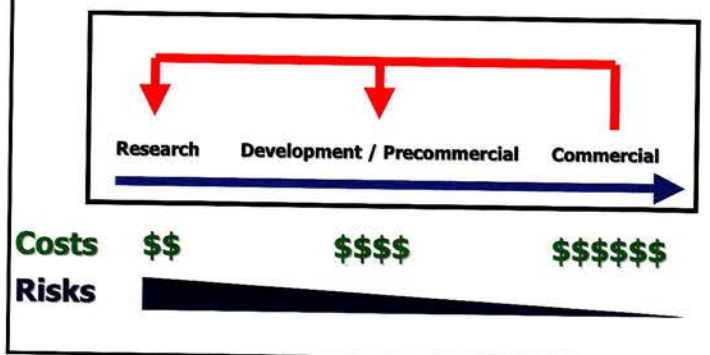
### The Research, Development and Commercialization Continuum

Research, development, and commercialization are essential components of the success of any industry, including aquaculture. There is no clear separation among these three primary components, and they exist on a continuum, ranging from basic and applied research to full commercialization (Fig. 1). A number of key features of the R to C continuum are worth noting (historical examples are given on the following page):

- The *duration* of each phase (research, development, or commercialization) varies somewhat depending on the species or sector and the associated constraints; however the duration generally decreases along the continuum.
- The phases are *interdependent*. Research depends on development and commercialization outcomes, and commercialization depends on R&D.
- There is an *R&D requirement* even after commercialization. This is needed to remain competitive and/or to solve constraints (shown as feedback loops in Figure 1). Thus, once a commercial stage is reached, the industry needs to continuously improve in a variety of ways to remain competitive.
- The level of *risk*, whether financial, technical or



Figure 1 - The Research to Commercialization Continuum

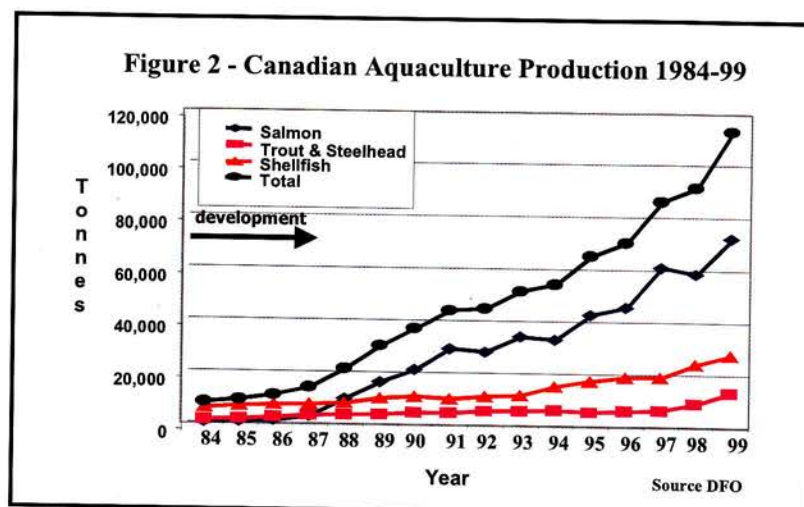


otherwise, diminishes as commercialization is approached. It can be argued that the higher the risk the greater need for public support, particularly in terms of funding and financing.

- Financially, the *cost* increases along the continuum, with research requiring relatively small amounts of money compared to the development/pre-commercialization, or commercialization phases. Examples from Canadian aquaculture or other industries show that a \$1 million research investment, generally means at least \$4 to \$5 million in development/precommercialization effort, followed by another \$5 to \$10 million in commercial financing, which in turn has the potential to contribute \$10 million or more annually to the Canadian economy.

## Historical Overview

Recent Canadian aquaculture production statistics are shown in Figure 2. One feature of this graph is that



growth in any given species group shows major increases, even exponential, once a threshold of about 3,000-5,000 tonnes is reached. These are essentially the same patterns observed in highly successful aquaculture industries elsewhere, including the New Zealand Greenshell® mussel industry in the late 1980s, the Norwegian Atlantic salmon industry in the 1970s, and the Chilean salmon and mussel industries in the 1990s. There are several reasons for these growth patterns following a minimum threshold, but the principal ones are: 1) sufficient technical competency attained for commercial production, including

consistent production; 2) private investor confidence in commercialization; and 3) clear market presence. In fact, these three elements are no different than in any other industry, whether involved with food production or not.

Now let's turn to Canadian examples. The research phase of the continuum for cultured salmon and mussels occurred over a 10 to 15 year span from the 1960s to the late 1970s. Since this was research, and considered high risk, it was conducted primarily in the public sector (by the Fisheries Research Board of Canada and DFO in the case of salmonids, and by provincial governments/university partnerships in the case of blue mussels in Atlantic Canada).

The next phase, *development and precommercialization*, took place over a 5 to 10 year period beginning in the late 1970s with salmon on both coasts and mussels on the east coast. Commercial salmon production began growing rapidly in the late 1980s after a 10 year period of development with levels increasing slowly to 5,000 t by 1988 and rapidly to 70,000 t a decade later in 1998 (Fig. 2). A

similar pattern occurred in blue mussels in PEI where production in the early 1980s was barely 3,000 t, but a decade later had increased more than 500%. Once the 3,000-5,000 t level was reached during the *development* phase, each of these sectors entered a major growth period.

It is important to mention that the *development* period was still considered high risk and therefore occurred principally via public-private partnerships (PPP). In fact, it can be argued that significant industry devel-



opment and commercialization only took place in areas where public policy (mostly from provincial governments) was supportive and development funds were made available from the public sector. For example, the mussel industry in PEI developed rapidly when there was public policy supporting site access, financing support in the form of loan guarantees, market development assistance, and ongoing technology transfer and farm extension programs. Similarly, the New Brunswick salmon industry development phase saw public sector support for loan guarantees, seed capital, site access, technology transfer and extension programs.

The salmon and mussel industries in Prince Edward Island, New Brunswick and British Columbia essentially achieved the *commercialization* stage in the early 1990s, characterized by private sector investment, market and industry growth. However, industry development does not stop there; once commercialization is achieved there is an ongoing need for R&D to further enhance production and remain competitive. Areas such as production technology and stock improvements, development of health and pest management tools, product diversification (including alternate species), etc., need to be ongoing, thus providing a feedback to the continuum from research to commercialization. Current examples include the need for R&D to deal with invasive fouling organisms in the mussel sector and fish health management strategies in the finfish sector. Essentially this is a self-improvement model. Ongoing R&D, particularly the development side of things, still has considerable risk, even for established, sustainable corporations. Therefore it can be argued that public support for PPPs is needed for development, yet there are few, if any targeted funds available for this.

One of the key features of the R to C continuum is the interdependence of the phases. Research precedes development & precommercialization which precede commercialization. Sounds intuitive, but each depends on the others and they are all linked by feedback mechanisms involving the need to continuously improve to remain competitive.

### **Some Thoughts on Aquaculture Development Funds**

As mentioned previously, there are a multitude of R&D funds, each with their own criteria for access. However, it can be argued that most, if not all, are not focused nor are they targeted in a strategic manner to address industry constraints. In fact, there are few, if any, true *development* funds available to the Canadian aquaculture industry. Those that do exist have caps that do not come close to addressing the needs.

Past experience has shown that in regions of Canada

where public policy and initiatives in support of aquaculture have not been supportive over several years, one way or the other, significant private investment has been made in research and development for unproven commercial technology/know-how. In these areas, governments encouraged development risk, yet have not shared the risk adequately. The net result is that the private sector has used up its equity and is not able to reach commercialization owing to lack of investment or access to financing. We need only look at a couple of provinces where aquaculture has been slow to develop in spite of more than two decades of effort by industry. In those regions of the country where governments were willing to share the risk of development and commercialization, vibrant and sustainable commercial finfish and shellfish culture sectors have evolved.

There is currently little in the way of targeted *development* funding for aquaculture. What exists is fragmented, uncoordinated, and not strategic in nature. This is unlike our competitors who have mechanisms to fund aquaculture development because of its strategic importance to the economy. One need only look at the Norwegian or Chilean experience to understand what is meant by this. To my knowledge, there are no national strategic or even regional strategic plans supported fully by policy or public funding strategy in Canada.

Can we afford not to have public policy in support of aquaculture development? One only needs to look at lost opportunities with respect to salmon, mussels, and other species to have the answer. Perhaps more importantly, any policy **must** be supported with funds to implement the *development* framework. There is a definite gap here that has impeded, or slowed progress, in sustainable aquaculture development.

### **How much money is needed?**

That depends on the objective, species, etc. We already know that relatively minor investments of public funds in PPPs for development have yielded significant economic opportunities for aquaculture. Examples include the salmon industry in New Brunswick and the mussel industry in PEI. More recent examples include the development of the cod seed supply system in Newfoundland and the halibut hatchery-nursery systems in Nova Scotia and New Brunswick.

Many of the industry participants at the workshop in Ottawa concluded that federal-provincial agreements with development components have played a significant role in aquaculture development. Examples were given of the ACERA agreement in Newfoundland and Labrador which for an annual PPP investment of \$4 million over 5 years, now generates \$25 million per



year in farm sales and another \$25 million in indirect benefits. The Alternate Species Federal-Provincial Agreement in the Maritimes which provided ca. \$1 million per year in PPP funds over 5 years kick-started the multimillion dollar halibut, scallop and haddock culture sectors. Current estimates are that \$7 million annual development investment over 6 years to commercialize the cod industry in Atlantic Canada will yield up to \$150 million in farmgate sales and \$100 million in spinoffs in 7 years or so. Thus, relatively minor public investment in development has and should yield relatively high returns to the Canadian economy.

And, why not invest in aquaculture development, from a public policy perspective? Models exist already for other industries that are based on technology, and that are both in the realm of renewable and non-renewable resources (e.g., oil and gas, agriculture, etc.). It would seem to me that sustainable food production from aquaculture is a natural fit for all Canadian governments and worthy of public support.

### **Some ideas on funding aquaculture development**

Potential instruments to provide public development funds for aquaculture include:

- Sharing risk via loan guarantees, as is available for other economic sectors;
- Establish targeted federal/provincial R&D funds, as occurred in the past;
- Have a strong and vibrant tax credit system for R&D;
- Sequester mineral and non-renewable resource revenues for sustainable aquaculture development (e.g., oil and gas, nickel, etc.);
- Target human resource transitional funding for collapsing economic sectors, but avoid the TAGS "lesson".

### **Importance of Extension and Technology Transfer**

Extension and technology transfer are critical for initial development and commercialization, but also for ongoing development of the industry. At present there is no overarching national, or in many cases even regional, strategy and commitment for Extension and Technology Transfer (ETT) for the aquaculture sector. There are clear examples of this in the past where ETT has greatly aided and advanced the industry. One of the challenges, however, is for enabler/regulatory agencies such as DFO or provincial fisheries departments to provide extension support unless clearly established in law or regulation. This has rarely worked effectively in our country, but there are models such as

the BIM component of the Ireland Department of Marine (BIM is legislated as an extension and not regulatory function) or the federal-state-university Sea Grant model in the United States.

### **Conclusions**

- The R to C continuum is integrated, interdependent, and can be as long as 20 years in the making. Public and private sectors need to realize this at the outset.
- Public policy needs to be developed and enunciated on aquaculture development. Moreover it needs financial support for implementation.
- There is a need for a national targeted aquaculture development strategy, with regional implementation. Our competitors have them, why not Canada?
- The national strategy must include risk sharing by both public and private sectors, which includes commitment of public funds from provincial and federal sources.
- The "return on investment" for public funding of aquaculture development can be relatively large and there are clear examples of this. Relatively small public investments have been shown to yield substantial increases in GDP and sustainable economic activity. Models already exist (e.g., Fundacion Chile, Norwegian counterpart, EU aquaculture strategic development funding, etc.); there is no need to reinvent the wheel.
- There is a need to consider the holistic approach and address the continuum rather than only the individual phases. Current approaches are piece-meal: R&D funds or just R funds; no real D funds.
- A national R&D council (Canadian Aquaculture Science & Development Council?) that includes industry and has the specific mandate of coordinating and implementing a national R&D strategy is worthy of consideration. This could help to avoid potential duplication and create a more effective and efficient mechanism to foster Canadian aquaculture development.

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# Calendar

conferences, workshops, courses and trade shows

- **Aquaculture 2004 and Marine Ornamentals 04**, 1-5 March 2004, Hawaii Convention Center, Honolulu, HI, USA. Triennial meeting of the World Aquaculture Society, National Shellfisheries Association, Fish Culture Section of the American Fisheries Society, National Aquaculture Association, and U.S. Aquaculture Suppliers Association. Information: John Cooksey (tel 760 432 4270, fax 760 432 4275, e-mail [worldaqua@aol.com](mailto:worldaqua@aol.com), website [www.was.org](http://www.was.org)).
- **Atlantic Universities Aquaculture Conference**, (APICS), 5-7 March 2004, University College of Cape Breton (UCCB). Conference website: <http://discovery.uccb.ns.ca/auubc2004>.
- **4<sup>th</sup> World Fisheries Congress**, 2-6 May 2004, Vancouver, BC, Canada. For information: contact Gary Carmichael (tel 604 688-9655, fax 604 685-3521, e-mail [fish2004@advance-group.com](mailto:fish2004@advance-group.com) or [carmichael\\_gary@yahoo.com](mailto:carmichael_gary@yahoo.com), website [www.worldfisheries2004.org](http://www.worldfisheries2004.org).
- **Aquaculture International 2004**, 19-21 May 2004, Glasgow, Scotland. E-mail [sue.hill@informa.com](mailto:sue.hill@informa.com); website [www.heighway.com](http://www.heighway.com)
- **Atlantic Aquaculture Exposition, Conference and Fair**, 9-12 June 2004, St. Andrews, NB. Trade show produced by Master Promotions Ltd., PO Box 565, Saint John, NB (tel 506 658-0018, fax 506 658-0750, e-mail [show@nbnet.nb.ca](mailto:show@nbnet.nb.ca)).
- **5th International Conference on Recirculating Aquaculture**, 22-25 July 2004. Hotel Roanoke and Conference Center, Roanoke, Virginia. Forum for sharing ideas, opportunities and technologies in recirculating aquaculture. Contact Ms. Terry Rakestraw (tel. 540 231-6805, fax 540 231-9293, e-mail [aqua@vt.edu](mailto:aqua@vt.edu), website <http://www.conted.vt.edu/aquaculture/>
- **US Trout Farmers 50<sup>th</sup> Conference and Trade Show**, 16-18 September 2004, Twin Falls, Idaho. Information: e-mail [ustfa@intrepid.net](mailto:ustfa@intrepid.net); tel Mary Lee at 304 728-2167.
- **2004 Aquaculture Pacific Exchange Conference and Exhibition**, 30 Sept - 1 Oct 2004, Campbell River, BC, Canada. Consists of a 100-booth trade show and 2-day conference. Produced by Master Promotions Ltd., PO Box 565, Saint John, NB (tel 506 658-0018, fax 506 658-0750, e-mail [show@nbnet.nb.ca](mailto:show@nbnet.nb.ca)).
- **Aquaculture Canada<sup>OM</sup> 2004**, 17-21 October, Fairmont Le Chateau Frontenac, Quebec City. Annual meeting of the Aquaculture Association of Canada.
- **Aquaculture Europe 2004**, 20-23 October 2004. Barcelona, Spain. Theme: Biotechnologies for Quality. Plenary sessions will address: 1) Biotechnology and aquaculture policy issues, 2) Biotechnology tools to enhance production, 3) Biotechnology and health management, 4) Biotechnology and quality of food production, 5) Bioactive products through aquaculture. Information: [eas@aquaculture.cc](mailto:eas@aquaculture.cc).

## Aquaculture Canada<sup>OM</sup>

17-20 October 2004

Fairmont Chateau Frontenac  
Quebec City

