Provincial Pilot Technologies Initiative

Land-based Salmon Farm at Cedar, B.C.
AgriMarine Industries Inc.

2004 Final Report (2nd Generations)

British Columbia Ministry of Agriculture & Lands

Introduction

In 1995 the Province of British Columbia placed a moratorium on the issuance of new salmon farm tenures while the Environmental Assessment Office conducted a two-year study of the overall sustainability of the aquaculture industry (referred to as the 'Salmon Aquaculture Review,' or SAR). In 1997 the SAR's final report concluded salmon farming - as it was then practiced and at production levels of the time - posed a low overall threat to the environment. It also offered 49 recommendations aimed at reducing aquaculture's ecological impact, and all were accepted by government and industry.

One of the SAR recommendations was to initiate pilot projects for closed marine systems. Subsequently, in 2000, the Province requested proposals from companies interested in developing and testing closed containment and "green" technologies that might lead to continuous aquaculture production improvements. Under this initiative (the 'Provincial Pilot Technologies Initiative', or PPTI) five proposals were approved, with successful applicants receiving new aquaculture licenses contingent upon their completion of comprehensive trials of the green technologies. Operators were required to ensure 50% of their licensed production was supported by such technologies over a 5 year period. If the trial systems proved unviable after that time, sites could revert to conventional production methods.

One of the successful PPTI applicants was AgriMarine Industries, whose proposal involved utilizing an existing[1] land-based facility in Cedar BC to:

- determine if salmon could be grown to harvest size in the facility;
- determine if salmon could be grown at economically-viable densities;
- understand the physical systems needed to create and maintain an optimum rearing environment;
- understand the economics of closed containment farming; and
- assess the feasibility of commercial closed containment salmon farming.

Since the completion of site preparations in 2001, two production cycles of Atlantic, Chinook, and Coho smolts have been ponded in four of the Cedar facility's eight tanks. Harvests occurred in 2002 and 2003, and the fish were marketed as environmentally-friendly "eco-salmon" through an exclusive agreement with a regional grocer. In accordance with the provisions of the PPTI program, AgriMarine was required to submit environmental, biological, and economic information on both production cycles. The Ministry of Agriculture, Food and Fisheries (now the Ministry of Agriculture and Lands) reported on data from the first production cycle in June 2003, and data from the second production cycle was submitted in early 2004. This document summarizes the findings from the first production cycle, and reports on new data from the second production cycle.

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[1] The facility in Cedar consists of eight 18 foot deep concrete tanks, each holding 750 m^3 of sea water brought in from the adjacent Stuart Channel. The bottoms of the tanks are situated above the high-water mark and pumps must constantly bring seawater in at a positive head. The facility was constructed in the 1980's by Hagensborg Resources, but closed mid-way through its first production cycle. A shellfish producer later purchased the facility from Hagensborg.

First Generation Production Characteristics

Biological Performance

Coho

The overall performance of the first generation Coho stocks was comparable to that of salmon raised in open-mesh marine cages. Atlantic salmon generally reach 10 to 12 pounds about 15 months after saltwater entry, and the Cedar Coho were grown at a comparable rate. Survival to harvest rates of 87% compared favourably to industry standards for Coho, as did feed conversion rates (1.2). Peak densities for first generation Coho were 42 kg/m^3, which significantly exceeded typical net-pen density maximums of 20 kg/m^3. Mortalities were somewhat inflated due to difficulties of initial harvesting methods from the concrete tanks.

Chinook

First generation Chinook performance was negatively affected by two factors. First, 66% of the smolt died during transport to the facility. Second, the remaining fish suffered significant mortalities due to outbreaks of chronic Bacterial Kidney Disease (BKD) caused by transport stress. These high mortality levels were not directly attributable to the land-based means of production.

Atlantic Salmon

Poor stock performance resulted in the early termination of first generation Atlantic salmon. As with the Chinook stocks these difficulties are largely unrelated to the closed system itself, and therefore the data does not represent what can be achieved through land-based production of Atlantic salmon. As such, the remaining first generation commentary does not include these fish.

Economic Performance

The experimental nature of the project and start-up expenses resulted in substantial costs over-and-above those that could be expected in a larger scale commercial production setting. However, economies of scale could also be realized through expanding the operation from four to all eight tanks at the site.

Retail markets for the Cedar product were positive. Consumers indicated some willingness to purchase Eco-Salmon at a premium price based on individual environmental and health concerns, and personal value systems.

Notably, the costs of production at the Cedar site significantly undervalue the costs of land-based production for new facilities. AgriMarine's rent for four of the tanks was $97,880. The original cost of the facility was $500,000 for the land and $7 million for construction. In 1997 the Salmon Aquaculture Review estimated that the capital costs for a 1000 tonne land-based facility with full water re-use systems were approximately $21 – $27 million. Standard accounting practices would depreciate such a facility over a period of several years. For example, a 20 year depreciation period would result in an annual cost to the producer of $1 – $2 million, or 10 – 20 times the rental fee. This additional cost would then have to be applied to the product.

Coho

The cost of production for Coho harvested in August 2002 was $3.22/pound[2] (round weight[3]), and AgriMarine received $3.25/pound for the fish (dressed, head on, gill in). This price did not include the cost of boxes or transportation from the processor to the distributor in Victoria, estimated to be another $0.15 per dressed pound, which raised AgriMarine's total production/distribution cost for the Cedar Coho to approximately $3.40/pound. Given that market prices for regular farmed Coho in 2002 were around $2.25 per dressed pound, the fish were likely sold at a loss. However, market feedback indicates that there may be future opportunities to retail these fish at levels that generate profit.

Chinook

Mortalities incurred during transportation and the outbreak of BKD among Cedar's Chinook populations elevated production costs ($10.90/lb, round weight) and rendered this species' production cycle unprofitable. Introductory retail prices for fresh Cedar Chinook were $2.98/lb (dressed, head on), extending up to $5.98/lb (skin on, pin-boned fillets).[4]

Environmental Performance

The environmental issues that surround salmon farming, as identified by the Environmental Assessment Office's Salmon Aquaculture Review (1997), include genetic and fish health interactions between farmed and wild stocks/marine mammals, and the impacts of waste products. Fish at the Cedar site are held in land-based concrete tanks, thus reducing the likelihood of escapes and, therefore, interactions with wild fish. Also, the potential for interactions between marine mammals and farmed stock is also very low, if not eliminated.

The Cedar site was not constructed with waste collection systems or water reuse systems, and effluent is discharged untreated into Stuart Channel. High flow rates and low waste loads at the facility combine to meet or exceed waste discharge requirements specified under the *Land-based Finfish Aquaculture Waste Control Regulation* (surveys of the marine environment surrounding the diffuser outfall indicate no residual bio-materials from the Cedar operation).

Conclusions – First Generation

The environmental performance of the Cedar facility might be considered an improvement over that of marine net-pens, largely due to the inability of fish to interact with wild species. Biologically, fish performance was in some areas (ie: mortality rates, feed conversion rates) comparable to fish produced in open marine net-pens. In other areas (ie: peak densities) production parameters exceeded typical marine net-pen densities.

[2] All prices in Canadian dollars.
[3] Round weight refers to the whole, unprocessed weight of the fish.
[4] Prices quoted were for the week of June 12-18, 2002.

Initial market reaction to the Cedar product was favourable, with consumers indicating some willingness to purchase the fish at a premium price. Identified economic performance limitations might be overcome through incremental improvements achieved through economies of scale, reduced oxygen costs, enhanced survivability, and refined husbandry techniques. However, it must be acknowledged that production cost at the Cedar site are significantly undervalued when compared to the financial outlays typically associated with new land-based production facilities. This renders it unlikely that a new land-based operation could be economically viable. Nevertheless, there is a possibility that land-based production may fill a sectoral niche by increasing the diversity of products available to consumers.

Second Generation Production Characteristics

Biological Performance

Coho

Coho stocks demonstrated good biological performance over the second generation production cycle. Mortality rates were 13.1% over the rearing period (an average of 0.037% per day), and the average weight of Coho mortalities was 1.58 kg, indicating these fish were more likely than the Atlantic stocks to perish later in their lifecycle. The survival to harvest rates (across 2 tanks) were:

- 94% after 360 days;
- 91.5% after 390 days;
- 88% after 420 days;
- 84% after 450 days.

First-harvest Coho had a growth coefficient of 2.54 over 3546 degree days and an average round weight of 2.7 kg. Final-harvest Coho had a growth coefficient of 2.92 over 4834 degree-days and an average round weight of 3.8 kg. The highest round weight average was 4.23 kg after 433 days.

The feed conversion rate for second generation Coho was 1.6, which was notably higher than the rate for the first generation production cycle (1.2). AgriMarine believes that the second generation Coho, which were grown much longer than first generation fish, were likely overfed during the latter part of their grow-out. As such, the feed inputs likely went into gonadal growth and fat storage rather than muscle, which affected the conversion rate.

The peak density for second generation Coho was 32.5 kg/m^3. Although this level is lower than that for the first generation, it is still significantly higher than density levels for open marine net-pen systems (usually not greater than 20 kg/m^3). Moreover, at 1.2% the level of “low performance” Coho (ie: survivors too small for market, measured by round weight of culls to total round weight produced) is another positive indicator. These are important criteria for land-based operations, which must grow fish at higher densities to compensate for production costs.

Atlantic Salmon

The mortality rate for Atlantic salmon was 11.39% over the rearing period, an average of 0.032% per day. The average weight of mortalities was 1.43 kg, revealing that these fish were more likely to perish earlier in their lifecycle than Coho. Survival-to-harvest rates were:

- 84% after 480 days;
- 83% after 510 days;
- 82% after 540 days.

First-harvest Atlantic salmon had a growth coefficient of 2.49 over 4686 degree-days and an average round weight (at harvest) of 3.6 kg after 477 days. Final-harvest fish had a growth coefficient of 2.24 over 5685 degree-days and an average round weight (at harvest) of 4.46 kg after 546 days. The highest average was 5.2 kg after 530 days.

At 1.34, the feed conversion rate was favourable compared to fish grown in marine net-pen systems. Peak density levels of 36.0 kg/m^3 were also favourable in comparison to net pen systems, which hold stock at approximately 16 kg/m^3. There was a minimal number (0.2%) of low performance fish among the Atlantic stocks.

Chinook

Second generation Chinook were in the grow-out stage at the time of AgriMarine's report. These fish were harvested in the summer-fall 2005 (data was unavailable at the time of this report).

Environmental Performance

Again, because fish at the Cedar site are held in land-based cement tanks, the likelihood of interactions (through escapes) between farmed and wild stocks is virtually non-existent. This is also true with regard to potential interactions between marine mammals and farmed fish, the risk of which is low (if not eliminated). Also, there were no major disease out breaks or lice infestations among the 2nd generation fish, and only incidental levels of Kudoa in the Atlantic stocks.

The absence of integrated filtration or waste collection systems at the Cedar facility results in untreated effluent being discharged into Stuart Channel. Financial and logistical considerations relating to the design of Cedar's outflow pipes impede the installation of drum filters for waste collection due to the high flow rates. Nevertheless, the facility consistently met or exceeded waste requirements specified under the *Land-based Finfish Aquaculture Waste Control Regulation*.

Economic Performance

Overall, the economic performance of the Cedar operation continued to be constrained by the (comparatively) higher operating costs associated with this production facility. It also appears market prices were largely unable to offset the elevated costs of production, particularly as they relate to the system's ongoing energy requirements and marketing/processing factors.

As with the first generation, costs of production at Cedar were significantly undervalued in terms of the financial expenditures typically associated with operating new land-based production facilities. Annual rental fees are considerably below capital costs that would be incurred at a new land-based site, and these would be applied to the product, further reducing the already narrow margins. Again, it is unlikely that these significant cost variations could be absorbed while maintaining profitability (this remains an important challenge for the Cedar farm).

Coho

The cost of production for second generation Coho was $3.07/lb (round weight). As with the first generation, this figure is higher than that for marine net-pen farmed Coho. The approximate price AgriMarine received for Cedar Coho was $3.22/lb (dressed). However, costs of production rise considerably when expenses for packaging and delivery to market (estimated to be $0.41/lb) are accounted for, which elevates total costs of production to $3.48/lb. Moreover, one must consider how mass-loss due to dressing – estimated to be 15% for Coho (depending on the size of fish) – negatively affects margins. All the available information indicates AgriMarine's second generation production cycle at Cedar was most likely unprofitable.

Atlantic Salmon

The cost of production for second generation Atlantic salmon was $2.72/lb (round weight). As with the Coho, this figure rises when packaging and delivery expenses are included, which are estimated to be $0.33/lb, bringing the total cost of production to $3.05/lb. The fish were sold as "Eco-Salmon" by the retailer for $4.49/lb (dressed), and it therefore appears that the grocer profitably retailed these fish. Again, however, one must consider how mass-loss due to dressing – estimated to be 7-10% for Atlantics – negatively affects profit margins.

Technical Performance

AgriMarine conducted various research studies on the technical performance of the Cedar farm throughout the second generation grow-out phase. The findings of these studies are outlined below.

Hydraulic Flow

Rearing water exchange is important not only for water quality, but also in terms of economics. This is because supplemental oxygen costs are reduced through the introduction of fresh seawater, but the costs of pumping are increased. An analysis of the site's water supply system can determine optimum water flow rates at a variety of temperature and density levels.

Oxygen Supplementation

Improvements to the oxygen injection system helped to avoid problematic spikes and declines in oxygen levels. Enhanced monitoring systems provide more accurate and timely recording of oxygen levels, and further research into the merits of in-line injection systems to optimize oxygen would be beneficial.

Oxygen losses were reduced by the addition of an evaporator and pressure-relief valves. Air stones were also used to improve oxygenation, and indicated that a heightened salination of the stones' pores occurred when, in the absence of gas pressure, seawater was allowed to back-flush through the stones. This reduced the lifespan and overall effectiveness of the stones, but it was corrected through the application of constant gas pressure.

Harvest Methods

Harvest methods were adapted to reduce direct fish handling over extended periods. Staff sized and graded fish in a passive manner using a product called Flexi-Panel®. Graded fish were inserted into a holding pen within the same tank where they remained (unfed) until harvest. This allowed the non-harvest (smaller) fish to continue to grow, and to avoid the handling stress associated with the pre-harvest grading method used in the previous year.

Fish Stress & Biomass

At the beginning of this pilot project there were serious concerns regarding fish stress from overcrowding and corresponding increases in disease outbreaks. However, biochemical indicators revealed no differences in stress levels between the fish raised at the Cedar site and those raised in marine net-pens. AgriMarine's experience indicates that biomass levels between 35-40 kg/m^3 constitute the upper density limits for this system compared to 15-20 kg/m^3 in a net cage.

Conclusions – Second Generation

As was stated earlier in this report, the objectives of the AgriMarine PPTI were to:

- determine if salmon could be grown to harvest size in the facility;
- understand the physical systems needed to create and maintain an optimum rearing environment;
- understand the economics of closed containment farming; and
- assess the overall feasibility of commercial closed containment salmon farms.

Observations from second generation production cycles reveal that salmon can indeed be grown to harvest size in a land-based facility. This reaffirms similar observations from the first production cycle. Overall, AgriMarine observed salmon health to be favourable, and that data for mortality and feed conversion rates compared positively with open net-pen systems. Density levels in the smaller, closed system were forecast to be an issue with regard to fish stress and disease outbreaks, but these initial concerns proved unfounded. In fact, functional density levels exceeded those typically found in open net-pens.

Limitations and problems with the physical aspects of land-based systems were discernable over the trial period. However, most of these limitations were specific to the Cedar site itself, and potential resolutions were identified through trials of design improvements. For example, oxygen flow/concentration issues were addressed through improved monitoring tools, air stones, in-line injection systems, evaporators, and pressure relief values. Difficulties relating to sizing, grading, and harvesting fish were rectified by the application of passive handling procedures/technologies. Overall, observations indicated that salmon can be successfully grown in a land-based system such as the one tested at Cedar, and that the technology itself does not constrain fish performance.

The economic performance of the land-based operation at Cedar revealed very narrow margins, largely due to the higher operating costs associated with this form of production. These costs are incurred as a result of energy requirements for constantly pumping water into the site, and the maintenance of farm infrastructure. Balancing the heightened costs of production with higher prices at the retail level is a challenging issue for land-based farms such as that found at Cedar, and it remains to be seen whether or not consumers would consistently pay a premium for fish grown under this production regime. Refinements to husbandry techniques, inventory systems, and shipping/processing approaches, however, may lead to improvements in economic performance. Similarly, determining optimal hydraulic flow rates for various temperature and density levels could reduce the comparatively higher energy costs. Indications of favourable upper density limits might prove beneficial in terms of offsetting costs with appropriate production output levels.

It is important to underscore that costs of production at the Cedar site are significantly undervalued in terms of the financial outlays typically associated with operating a land-based production facility. In a non-pilot business setting, these additional costs would likely be applied to the product, which would further reduce margins. As indicated earlier, the associated margins are already very narrow, rendering it unlikely that significant cost variations could be absorbed while maintaining profitability. This remains the largest challenge for Cedar and similar farms.

Conclusion

AgriMarine's experience at the Cedar pilot site offers insights into the opportunities and constraints associated with closed containment aquaculture. Ongoing refinements to the physical, economic, and biological aspects of these systems, in conjunction with the development and application of associated technologies, may eventually improve overall viability. Moreover, unique locations and/or existing facilities may exist where entrepreneurs can further explore the viability of closed containment systems. Locating rearing tanks in marine waters, for example, could reduce operating and construction costs, lower energy consumption, and enhance economic viability. Consequently, there remains some optimism for closed containment technologies, particularly in markets willing to bear the increased costs of production. However, rather than viewing land-based production as a competing form of technology, it is more likely it will assume a complementary role by increasing the range of products accessible to consumers.