Closing in on Environmentally Sound Salmon Aquaculture:

A Fresh Look at the Economics of Closed Tank Systems

April 1, 2005

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EXECUTIVE SUMMARY

Open net-pen salmon aquaculture is now an established component of the economy in several regions of coastal British Columbia. Despite the prevalence of salmon aquaculture in these regions, the industry continues to come under scrutiny. Environmentalists and conservation biologists worry about the known and potential environmental impacts of net-pen salmon aquaculture; community leaders and development advocates are concerned about the economic sustainability of salmon aquaculture and its impacts on rural economies, especially those economies that traditionally have depended on the harvest of wild salmon.

Closed tank technology, an alternative to net-pen farming, may offer a solution to a number of important environmental and economic concerns associated with current salmon aquaculture practices. While there is agreement among stakeholders that environmental benefits exist, considerable debate remains over the financial and economic viability of closed tank aquaculture. Specifically, recent studies question whether closed tank salmon aquaculture is:

- Financially viable (i.e. profitable);
- Financially competitive with current net-pen technology; and
- Economically superior from society's perspective.

A careful review, however, finds that reports that specifically assess closed tank salmon aquaculture technologies in British Columbia fall short of providing an accurate and comprehensive assessment of the long-term financial and economic potential of these systems. The following report represents the first stage of an effort to better understand the true economic potential of alternative aquaculture practices in British Columbia. We evaluate existing financial analyses and reports of "proprietary closed tank aquaculture technologies," and assess the degree to which these reports provide a realistic picture of alternative technologies for salmon aquaculture in British Columbia.

We found four principal issues that limit the usefulness of previous analyses:

- Economies of scale and efficiency improvements are not considered;
- Time horizon analyses are not conducted;
- Sensitivity analyses are lacking; and,
- The economic value of environmental and social impacts are not identified or evaluated.

None of the reports we examined provide sufficient data to expand the original analyses to address these shortcomings.

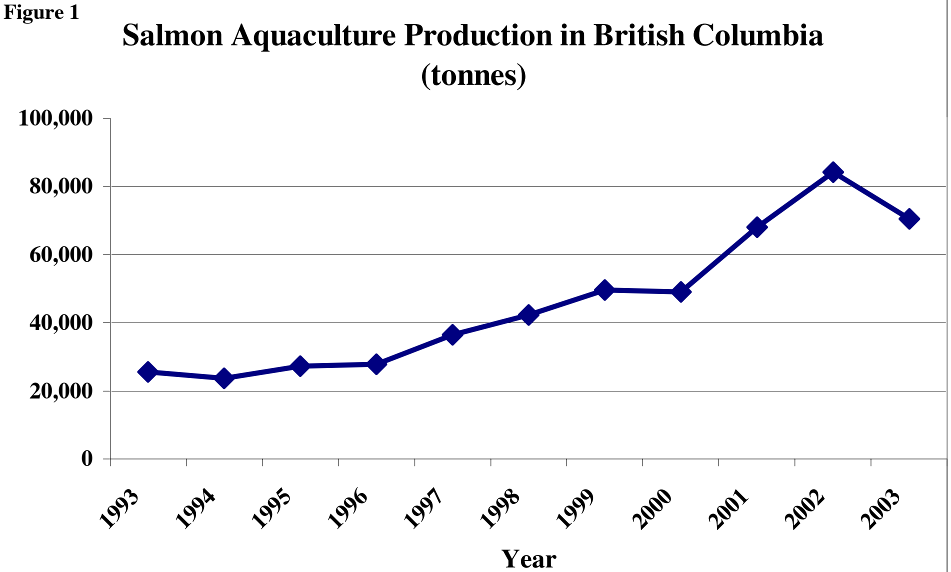
Based on our initial analysis of these reports, we conclude that existing reviews are insufficient to determine the true financial and economic potential of closed tank technologies for salmon aquaculture in British Columbia. Furthermore, shortcomings in these analyses systematically tend to diminish the potential performance of these systems.

More thorough analyses are required so that investors, government, industry, First Nations and other stakeholders can make sound decisions regarding the future of salmon aquaculture in British Columbia. Specifically, stakeholders need a more transparent account of the full financial, economic and environmental costs of net-pens and the actual economic potential of alternative salmon aquaculture technologies.

BACKGROUND

Global salmon aquaculture has grown dramatically in the last 20 years[1]. During this period, worldwide salmon output, including wild catch, grew from just under 800,000 metric tons (mt) to over 1.8 million mt, with virtually all of the growth coming from farms[2]. Today, most farmed salmon is produced in countries with long, protected coastlines and cold ocean water – most notably Chile, Norway, the U.K. and Canada – and is sold to markets in Japan, North America and Europe (Figure 1).

Figure 1



Source: Fisheries and Oceans Canada, Statistics Canada 1993-2003.

For proponents of salmon aquaculture, British Columbia's relatively clean and sheltered coastal waters and proximity to markets in the USA make aquaculture development a logical choice. Furthermore, aquaculture proponents also assert that declines in the wild fisheries and forestry industries make salmon aquaculture a potential source of stable jobs for isolated coastal communities[3]; a benefit that garners strong political support. Salmon farming has become the largest aquaculture sector in British Columbia, with GDP increasing from $0.2 million in 1984 to $87 million in 2001[4] (Figure 2).

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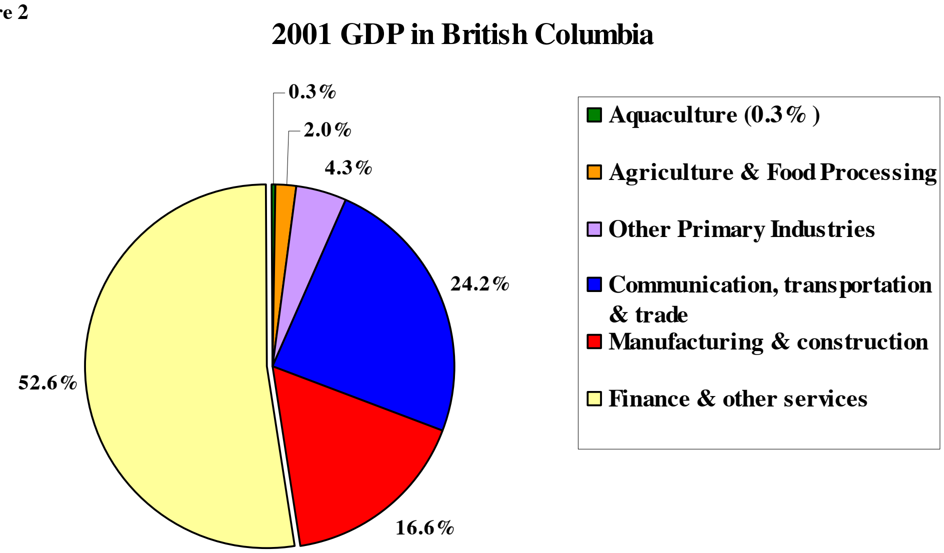
[1] Food and Agricultural Organization of the United Nations (FAO), Fishery Statistical Databases. 2002. *Aquaculture production: quantities 1950-2001*. Accessible via http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp.
[2] Naylor, R. et al. October 2003. *Salmon Aquaculture in the Pacific Northwest*. Environment. Vol 45, No. 8. EBSCO Publishing. New York, N.Y.
[3] British Columbia Salmon Farmers Association. "Fact Sheets." Campbell River, BC, Canada.
[4] British Columbia Ministry of Management Services. September 2002. *British Columbia's Fisheries & Aquaculture Sectors*. Victoria, B.C.

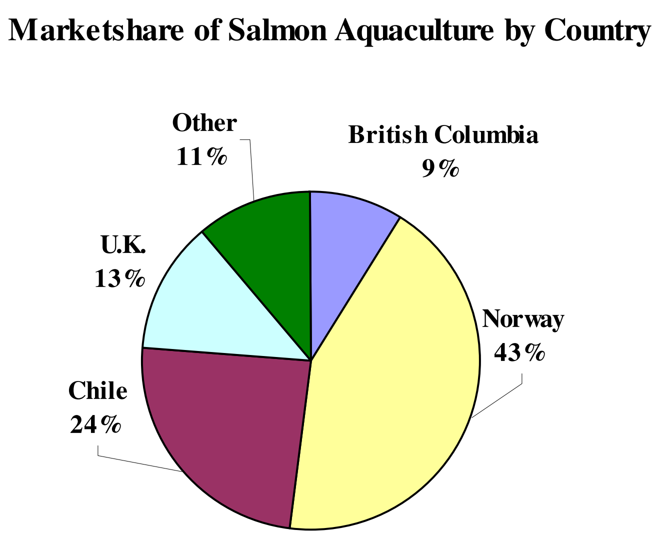
Figure 2



Source: British Columbia Ministry of Management Services 2002.

Despite the rapid growth in salmon production in Canada, total production in Canada's salmon aquaculture industry (9% of global market share in 2000) still trails the world's three major producers: Norway (43%), Chile (24%) and the UK (13%)[7] (Figure 3).

Figure 3



Source: The Register-Guard 2002.

Salmon aquaculture companies operating in British Columbia maintain that farming these carnivorous species is profitable, but decreasing trends in salmon prices may soon put the financial viability of these farms into question[5] (Figure 4). Consolidation and employment-neutral production increases are underway in an effort to keep these farms competitive in a global market.

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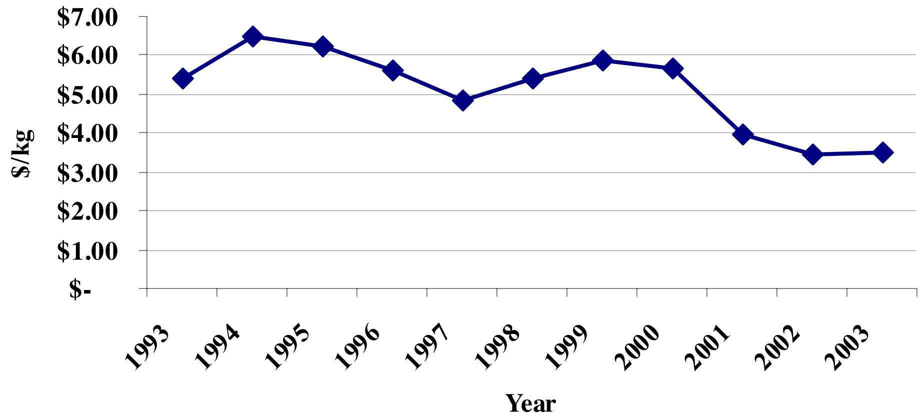
[5] The price of salmon fell $0.58 or 23% from 2000- 2002. See also, British Columbia Ministry of Food, Agriculture and Fisheries. 2002. *The 2002 British Columbia Seafood Industry Review*. Accessible via www.agf.gov.bc.ca/fish_stats/statistics.htm.

Figure 4

Price of Farmed Salmon in British Columbia 1993-2003



Source: Fisheries and Oceans Canada, Statistics Canada 1993-2003.

Information regarding the overall economic costs of salmon aquaculture in British Columbia is seriously lacking. The provincial government and the Department of Fisheries and Oceans Canada only provide aggregated data; an accurate description of the costs and benefits of the industry to the people and environment in British Columbia is nonexistent. Furthermore, industry has generally been reluctant or unwilling to make financial information public.

Environmental risks that are unaddressed, as well as ones that are known but not quantified, point to the possibility that the existing salmon net-pen industry in British Columbia may create economic and environmental liabilities for the province[6]. While the provincial government supports expanded aquaculture, some First Nations, environmentalists, scientists, tourism operators and fishermen warn of an increase in the extent and severity of numerous risks associated with current net-pen salmon farming practices.

Many salmon aquaculture companies operating in British Columbia have suffered substantial decreases in revenue due to international media broadcasts of events such as disease outbreaks,[7,8] as well as from real losses due to on-farm disease outbreaks. This is due primarily to losses in potential fish sales from increased rates of disease and associated operating costs (Figure 5), but also from larger market forces.

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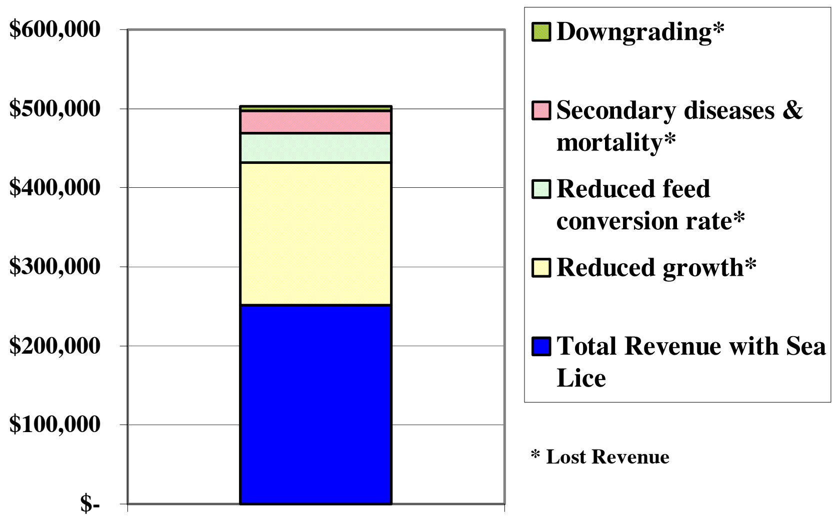
[6] David W. Ellis & Associates. 1996. *Net Loss: The Salmon Netcage Industry in British Columbia*. Prepared for the David Suzuki Foundation. Vancouver, B.C.
[7] The Register-Guard. *Fish Farm Must Kill Diseased Salmon*. February 9, 2002. Associated Press. Eugene, OR. Accessible via http://www.registerguard.com/news/2002/02/09/2b.wst.killsalmon.0209.html. Due to an outbreak of the virus Infectious Hematopoietic Necrosis (IHN), Heritage Salmon's fish farm in Campbell River, BC, had to kill 1.6 million young Atlantic salmon. The company lost $1.9 million in potential revenue.
[8] Dodd, Q. September 4, 2002. *Stolt confirms second IHN outbreak in BC*. Fish Information Services. Accessible via http://www.fis.com. See also Saksida, S. 2002. *Investigation of the 2001-2002 IHNV epizootic in farmed Atlantic salmon in British Columbia*. Victoria, B.C. Accessible via http://www.agf.gov.bc.ca/fisheries/pdf/IHNZ_report.pdf.

Figure 5

Impact of sea lice infestations on estimated costs and revenues in a medium-sized salmon farm



Source: Mustafa et al. 2001.

In addition, evidence exists that open net-pen practices threaten wild salmon stocks. Salmon farms contribute to sea lice infestations[9] like the one that led to a catastrophic collapse (a drop of 98% from 2000 levels) of wild pink salmon runs in the vicinity of the Broughton Archipelago[10]. While there is still disagreement over the causal relationship between the location of nearby salmon farms and the outbreak[11], many scientists have produced evidence in support of this link[12,13]. Scientists advising Fisheries and Oceans Canada concluded that the collapse was unlikely to be explained by any other means than a sea-lice infestation from area salmon farms[14].

While the aquaculture industry has consistently modified production methods in order to increase output and minimize costs, the adoption of environmentally beneficial technology has proceeded more slowly and, as a result, environmental problems continue to exist in the industry.

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[9] The lethal infection limit of post-smolt pink salmon is between 0.75 and 1.6 mobile lice per gram of host mass. Bjorn, P.A. and Finstad, B. 1997. *The physiological effects of salmon lice infection on sea trout post smolts*. Nordic Journal of Freshwater Research. 73: 60-72.

[10] A 2001 study of the Broughton Archipelago found that the number of sea lice averaged 3.73 per fish, whereas the lethal limit is closer to 1.45 lice per fish. *Report to the PFRCC on infestation of the sea louse Lepeophtheirus salmonis (Krøyer) on juvenile pink salmon Oncorhynchus gorbuscha (Walbaum) in the Broughton Archipelago, British Columbia*. Accessible from the Pacific Fisheries Resource Conservation Council (PFRCC) at http://www.fish.bc.ca/reports/pfrcc_broughton_apdx1-annx4.pdf.

[11] British Columbia Ministry of Agriculture, Food and Fisheries, Accessible via http://www.agf.gov.bc.ca/fisheries/faq.htm#killing%20wild%20pink.

[12] Morton, A., Routledge, R. Peet, C. and A. Ladwig. 2004. *Sea lice (*Lepeophtheirus salmonis*) infection rates on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*Oncorhynchus keta*) salmon in the nearshore marine environment of British Columbia, Canada* Canadian Journal of Fisheries and Aquatic Sciences. 61-2: 147-157.

[13] Williams, I., Groot C. and L. Walthers. 2004. *Possible Factors Contributing to the Low Productivity of the 2000 Brood Year Pink Salmon (*Oncorhynchus gorbuscha*) that migrate through the Broughton Archipelago, B.C., Canada*. David Suzuki Foundation,

[14] Pacific Fisheries Resource Conservation Council (PFRCC). *Council issues advisory on the protection of pink salmon in the Broughton Archipelago*. Accessible via http://www.fish.bc.ca/html/fish3200.htm.

CLOSED TANK TECHNOLOGY

Closed tank technology, an alternative to net-pen farming, may offer a solution to a number of important environmental and economic concerns associated with current salmon aquaculture practices. Closed tank production sites use non-permeable barriers that can prevent the transmission of disease, parasites, waste and fish escapes from the pen to the coastal marine environment. Both land-based and floating tank systems have been used in the British Columbia aquaculture industry since the 1980's with varying success, but higher capital costs have discouraged wide-scale adoption by net-pen aquaculture operations.

While there is agreement among stakeholders that environmental benefits exist with closed tank aquaculture, considerable debate remains over its financial and economic viability. Specifically, recent studies question whether closed tank salmon aquaculture is:

- Financially viable (i.e. profitable);
- Financially competitive with current net-pen technology; and
- Economically superior from society's perspective.

Rigorous financial and economic comparisons[15] are needed to provide investors, government, industry, First Nations and other stakeholders with a transparent account of the full financial and economic costs of open net-pens and the economic potential of alternative salmon aquaculture technologies.

During a 1995-2002 moratorium on farm expansion in B.C., two companies were allotted new tenures in exchange for participating in a pilot program for closed tank technology[16]. Marine Harvest, a subsidiary of Nutreco (one of the largest net-pen operators in the world) opened a pilot study facility on Saltspring Island using an enclosed bag system from Future SEA Technologies. A small aquaculture technology firm based in Washington State, Mariculture Systems, tested their floating tank system in Puget Sound. At the same time, AgriMarine Industries Inc. submitted a proposal to the Ministry of Agriculture, Food, & Fisheries to renew operations at a pre-existing land-based salmon farm on Vancouver Island to produce Atlantic, Chinook and Coho salmon.

The report that follows reflects the findings of a qualitative review of the reports on these pilot projects to determine whether existing studies are sufficient to evaluate the economic potential of closed tank technologies for salmon aquaculture[17,18,19]. The examination includes a determination of the degree to which these analyses accurately reflect actual operating conditions, gains in efficiency of operation from learning and experience, the consideration of economies of scale, and the societal benefits of improving the environmental performance of aquaculture operations in British Columbia.

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[15] Economic analysis differs from financial analysis in that it looks at the overall impacts of a project on society, excluding taxes and subsidies and including external costs and benefits such as those caused by environmental degradation or improvements.

[16] The deployment and testing of alternative technologies by established net-pen industries creates a potential conflict of interest: if the pilot projects prove financially feasible and environmentally superior, government regulators could force net-pen operators to adopt these new technologies, perhaps at substantial private costs.

[17] Hatfield Consultants Ltd. November 2002. *Pilot Project Technology Initiative: Future Sea Closed Containment Units. Monitoring Report Draft: First Production Cycle. Saltspring Island, Marine Harvest Canada.*

[18] California Environmental Associates. June 2003. *Due Diligence on Mariculture Systems Inc. SARGO Technology.* Conservation and Community Investment Forum. July 17, 2003. *Due Diligence on Marciulture Systems Inc. (MSI).*

[19] British Columbia Ministry of Agriculture, Food and Fisheries. June 2003. *Performance Evaluation of a Pilot Scale Land-Based Salmon Farm.*

Of the three systems reviewed here, sufficient data were available only for Future SEA Technologies and Mariculture Systems. The next phase of work requires estimating financial and economic models for Future SEA Technologies, Mariculture Systems and AgriMarine Industries Inc. aquaculture systems.

KEY FINDINGS

Existing financial analyses that compare closed tank systems to open net technologies for salmon aquaculture are based primarily on pro forma projections or preliminary one-year pilot test studies. These analyses were prepared by independent consulting firms, the provincial government, or by the individual technology companies. Collectively, the reports show performance based on dollars per kilogram of salmon produced and focus on short-term financial returns.

These studies highlight potential difficulties encountered in the development and deployment of closed tank aquaculture, but they fall short of providing an accurate assessment of the long-term financial and economic potential of closed tank systems. By focusing on closed tank operations of unusually small scale and short duration, they fail to consider potential cost savings from economies of scale and improved operational efficiency that result from learning over time.

We found four principal issues that limit the usefulness of previous analyses:

- Economies of scale and efficiency improvements are not considered;
- Time horizon analyses are not conducted;
- Sensitivity analyses are lacking; and,
- The economic value of environmental and social impacts are not identified or evaluated.

None of the reports we examined provide sufficient data to expand the original analyses to address these shortcomings.

> **Cost/kg** of fish produced is the measure used in existing reports. These figures represent the total cost of operation during a year divided by total output, rather than the marginal cost for each additional unit of output. Many input categories, like labour or capital costs, do not vary with the quantity of fish produced from a given number of tanks or bags. As a result, these cost figures cannot be used to estimate the profit gains from increasing scale and other efficiency improvements.

Extrapolation: Exploring economies of scale and efficiency improvements

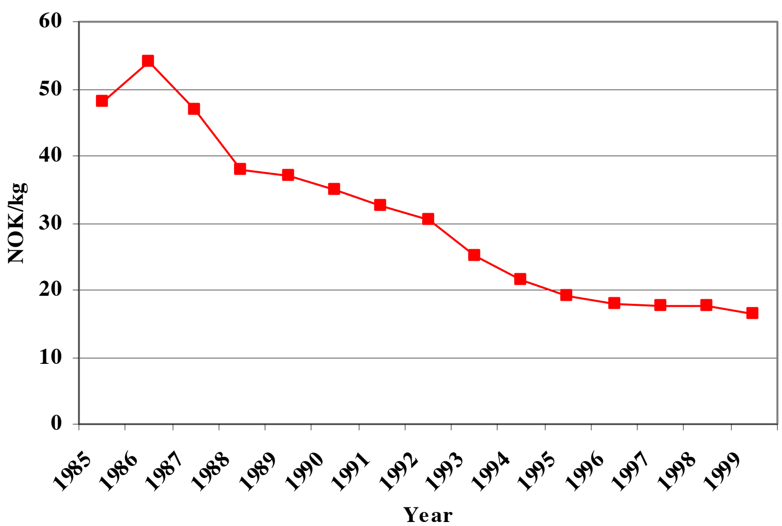
One of the key limitations of each report has been the presentation of all costs in dollars per total kilograms of fish produced ($/kg, found by dividing the total costs of the operation by the weight of fish produced). In order to evaluate accurately the financial and economic viability of appropriately scaled closed tank technology, 1) the marginal cost for each additional unit of output must be known, and 2) costs must be provided in the units that reflect the inputs with which they are directly associated. Average cost figures in dollars per kilogram of fish produced are valid only for the operation or scenario that was examined. Further analysis is needed to explore how economies of scale, improvements in production efficiencies and costs savings will affect the ultimate profitability and economic viability of closed tank technologies. The average figures provided in previous reports do not allow for this type of analysis.

Time horizon analysis

Existing reports focus on a short time horizon in order to examine the financial viability of closed tank systems over a payback period of one to five years. For example, Marine Harvest's Saltspring pilot study presents the results of its first year of data and does not account for any efficiency gains. These financial costs do not consider changes in long-term costs and revenues and cannot be extrapolated to examine how capital costs are paid back over a period of time. Furthermore, existing studies compare a nascent, first-year closed tank aquaculture operation against a fully mature net-pen industry. The reports' findings offer no way to project whether or not a fully mature closed tank industry can be financially competitive with a comparable net-pen operation. Figure 6 shows an overall decline in operating costs for Norway's salmon farming industry over a 15-year period.

Figure 6

Operating Costs: Norwegian Farmed Atlantic Salmon 1985-99 (1997 NOK/kg)

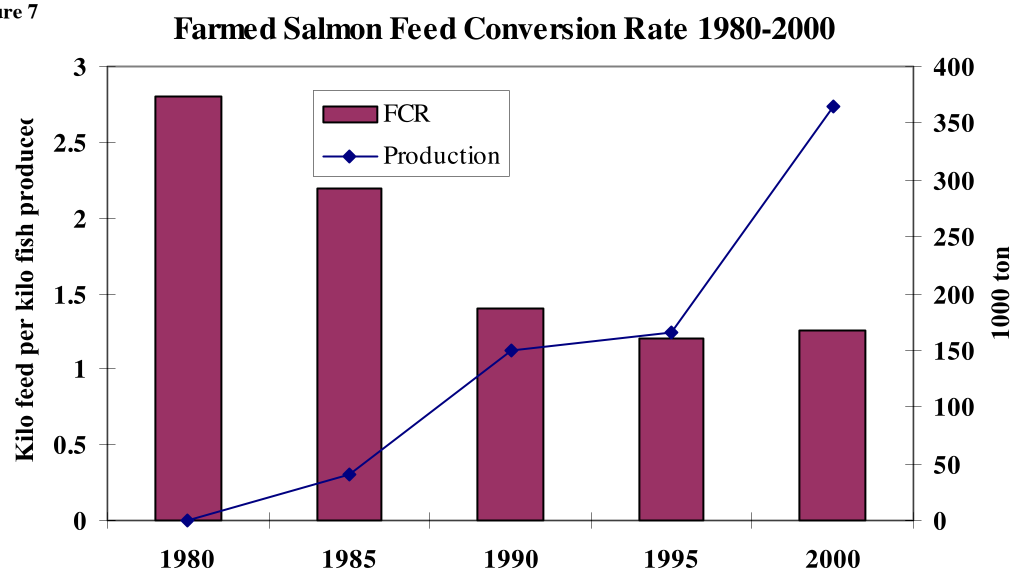


Source: Anderson 2002 Marine Res Econ (Norwegian Directorate of Fisheries 2000).

Sensitivity analysis

A significant limitation of each of the existing reports is the lack of sensitivity analyses for the financial results. If these reports are to be used as a way to assess the performance of closed tank technology, they need to include an analysis of key assumptions on which their projects are based. A more appropriate analysis would factor in numerous realistic scenarios to assess the overall strength and competitiveness of closed tank systems under a variety of economic conditions. Sensitivity analyses should include increases in efficiency over time, increases in actual production and changes in the price of salmon. For example, improved oxygen performance or feed conversion ratios could significantly improve the net revenues of closed tank aquaculture (Figures 7 and 8).

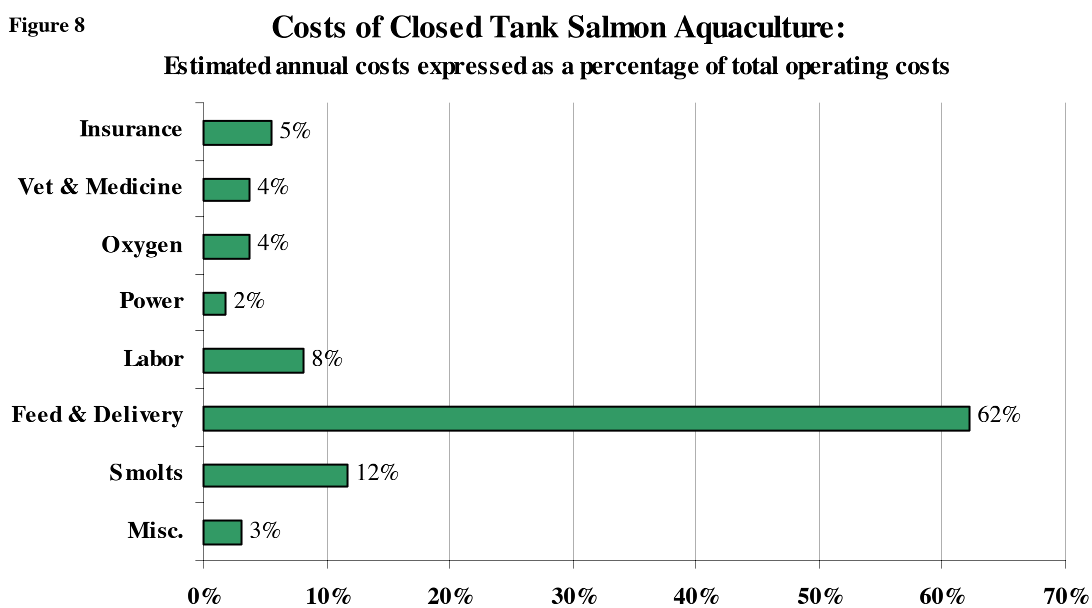
Figure 7



Source: Tveteras 2002 Marine Res Econ (Austreng 1994 and Directorate of Fisheries, various years).

To conduct sensitivity analyses, cost data need to be examined for each individual cost category. Cost categories in existing financial analyses are exceedingly broad. For example, the categories 'capital' and 'operating' costs do not provide enough resolution to explore cost savings or over-runs in specific areas of operation. Explicitly defined costs within 'capital' or 'operating', such as system and installment costs or maintenance costs, are necessary to create a realistic picture of closed tank costs.

Figure 8



Source: Conservation Strategy Fund 2004, California Environmental Associates 2003, and Hatfield Consultants Ltd 2002.

Oxygen supplementation is a cost category unique to closed tank systems. During Marine Harvest's Salt Spring Island pilot study using the Future SEA System, the costs associated with transporting bottles of oxygen and the costs of the liquid oxygen itself were prohibitively high, comprising nearly 17% of the total cost of production. In Future SEA Technologies' subsequent analysis, they reported that once the technical issues regarding oxygen are resolved, costs are expected to decrease by more than 65%. Nevertheless, previous analyses failed to further examine how this change in costs would affect the overall operating revenue. Using preliminary figures to account for the line item cost component of oxygen in production, we find that a 30% reduction in the cost of oxygen could increase the project's long-term profitability by 20%, an outcome that may be obtainable with on-site oxygen generation.

Feed is the largest cost component of farmed salmon. One potential benefit of closed tank aquaculture may be that it requires less feed per unit of output (known as the feed conversion ratio, FCR), thus reducing overall feed expenses. Existing studies indicate a range of FCRs, but none of the reports show how a lower or higher FCR would affect profits. A preliminary analysis indicates that if the FCR is decreased by 5%, the long-term profitability of closed tank operations could increase by up to 40%.

The economic value of environmental and social impacts

To date, short-term financial analysis has been the only method used to assess the competitiveness of closed tank salmon aquaculture, a technology developed specifically to address the current industry's environmental management issues. Environmental costs and benefits associated with open net and closed tank technology are not included in existing analyses.

It is necessary to consider a range of economic and environmental factors including the effects of government subsidies and taxes and the impact of disease outbreaks, escapes, waste management, tourism development and commercial and recreational fisheries. Only a more complete economic analysis, including environmental costs and benefits, can accurately account for these issues and capture the true economic performance of closed tank aquaculture technology.

Such an analysis would:

- Determine whether closed tank aquaculture would be likely to produce "normal" or better financial returns for potential investors;
- Examine the degree to which closed tank aquaculture would represent a sound economic investment from society's perspective, including an analysis of the potential "savings" to society if closed tank can overcome many of the environmental concerns posed by net-pen aquaculture; and,
- Determine if there are market failures that have prevented the adoption of closed tank systems.

A comprehensive analysis of closed tank and net-pen technologies for salmon aquaculture is required to inform all stakeholders, including the investment community. Government aquaculture policies must include these factors if they aspire to sustainable and environmentally sound aquaculture practices.

CONCLUSION

Existing reviews of closed tank technologies for salmon aquaculture are insufficient to determine its true financial and economic potential in British Columbia.

1. These analyses fail to account for economies of scale and efficiency improvements over time, or the full impact of closed tank systems on the overall economic welfare of society, especially with respect to the environment.
2. Taxes, subsidies and environmental impacts are likely to play a significant role in the ultimate determination of the economic feasibility of closed tank aquaculture.
3. Shortcomings in these analyses systematically tend to diminish the potential performance of these systems.

More thorough analyses are required so that investors, government, industry, First Nations and other stakeholders can make sound decisions regarding the future of salmon aquaculture in British Columbia.

1. Closed systems offer solutions to many of the problems associated with open net-pen aquaculture.
2. Stakeholders need a more transparent account of the full financial, economic and environmental costs of net-pens and the actual economic potential of alternative salmon aquaculture technologies.
3. The results of these analyses can be used to compare the overall economic performance of current and alternative technologies for salmon farming and discuss implications for industry strategies, government policies and environmental health.

NEXT STEPS

STEP 1. A critical next step is to conduct financial (private) cost-benefit analyses of traditional open net-pen and three closed tank salmon aquaculture technologies: Future SEA Technologies, Mariculture Systems and AgriMarine Industries.

- Fixed and variable costs for each technology need to be estimated using existing pilot study results, estimates from engineers involved in aquaculture production, projected costs and financial returns, and average open net-pen industry figures.

- These estimates would be used to create base case scenarios and perform sensitivity analyses to determine specific parameters that affect the project's financial viability.
- Risk analysis should be conducted to incorporate uncertainty and evaluate financial viability under a range of scenarios.
- Finally, these analyses should present a variety of indicators to assess the estimated performance of aquaculture methods, including annual costs and revenues, net present value of operations (a criterion that estimates the value of a long-term activity in present value terms), and internal rates of return.

STEP 2. In addition to financial analysis, an economic analysis that fully explores the impacts of the salmon aquaculture industry on society as a whole is required.

- Financial analyses only assess the private profitability of business ventures and do not include external costs and benefits associated with closed tank and net-pen aquaculture practices.
- External impacts represent costs and benefits incurred by society and the environment, but not necessarily borne by the aquaculture firm.
- External impacts represent real changes in environmental health and societal well being, and must be considered when evaluating whether an aquaculture system is good for society as a whole.
- Incorporating all of these costs and benefits is likely impossible, but there are accepted methods to assign economic value to external impacts that
    a. have been scientifically verified, and
    b. have the potential to result in large impacts to other sectors of British Columbia's coastal environment.
- Economic valuation techniques can help put differences in the financial performance of net-pen and closed tank aquaculture in the context of social and environmental impacts resulting from the deployment of the different methods.

STEP 3. The economic, financial and technological potential of closed tank systems needs to be informed by larger, commercial scale demonstration projects spanning typical business cycles of four to eight years.

- Existing studies evaluate nascent, pilot projects over short time frames of one year.
- A lack of data on commercial-scale performance is one of the biggest limitations in conducting rigorous and realistic analyses of the financial and economic viability of closed tank systems.
- Data from these demonstration projects will help evaluate the overall economic potential of a fully mature closed tank industry compared with a fully mature net-pen industry.

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APPENDIX A:

PROJECT PARTNERS

With financial assistance from the Gordon and Betty Moore Foundation, Tides Canada and the Packard Foundation, the California-based Conservation Strategy Fund and Canada's Coastal Alliance for Aquaculture Reform will work together with Dr. Linwood Pendleton from the University of California Los Angeles to produce analyses and reports comparing the economic costs and benefits of open net-pen to closed tank salmon farming in British Columbia.

Dr. Linwood Pendleton, University of California Los Angeles

Dr. Pendleton is currently an Associate Professor in the Program in Environmental Science and Engineering in the Department of Environmental Health Sciences at UCLA. His current research focuses on the economics of environmental goods and services, especially those in the coastal zone. He received an M.A. in Biology from Princeton University, a Masters in Public Policy from Harvard's Kennedy School of Government, and a Ph.D. in Natural Resource Economics from the School of Forestry and Environmental Studies at Yale University.

Conservation Strategy Fund

The Conservation Strategy Fund (CSF) uses economics and strategic thinking to help conserve natural ecosystems around the globe. CSF's approach is to help local conservationists use analytical tools to find smart, efficient solutions to the most urgent environmental problems. They train environmental professionals in a focused package of practical skills, and also work with groups directly in the field. Since its creation in 1998, CSF has concentrated on areas where extraordinarily high levels of biological diversity are found. To maximize the reach and quality of their work, they involve leading experts and conservation organizations in all of their projects. CSF is a non-profit, tax-exempt organization.

The Coastal Alliance for Aquaculture Reform (CAAR)

The Coastal Alliance for Aquaculture Reform is a coalition of nine conservation and First Nations groups in British Columbia working to educate the public on the environmental and human health risks associated with farmed salmon. CAAR is working to reform industry practices and believes salmon farming will be safe when the industry employs technology that:

- Eliminates fish escapes
- Eliminates disease and parasite transfer
- Guarantees no waste is released into the ocean
- Ensures contaminants in farmed fish don't exceed safe levels
- Develops fish feed that doesn't deplete global fish stocks
- Labels their fish as "farmed" so consumers can make informed choices
- Ensures wildlife is not harmed
- Prohibits use of genetically modified organisms
- Eliminates the use of antibiotics, biocides, and chemicals in fish farming
- Stops locating fish farms in areas opposed by aboriginal groups or other communities

Raincoast Conservation Society

Founded in 1990, Raincoast Conservation Society is a non-profit research and public education organization. A member of CAAR, they work in partnership with scientists, First Nations, local communities and non-governmental organizations to build support for decisions that protect marine and rainforest habitat on British Columbia's central and north coast. Raincoast has made significant gains towards protecting the Great Bear Rainforest and attracting the attention of millions of people to its rare beauty and threatened status. Their on-the-ground approach fosters a deep-rooted understanding of this vast coastline and has also enabled them to bear witness to many environmental tragedies that otherwise would have gone undocumented.

David Suzuki Foundation

The David Suzuki Foundation (DSF) works through science and education to protect the balance of nature and our quality of life, now and for future generations. Also a CAAR member, DSF focuses on four program areas – marine and freshwater, forests and wild lands, climate change and clean energy, and the web of life. DSF seeks out and commissions quality, up-to-date research to help reveal ways we can live in balance with nature, and supports the implementation of ecologically sustainable models for political and economic decision making at local, Canadian, and international levels-. DSF also works to ensure that solutions developed through research and application reach the widest possible audience and help mobilize broadly supported change.

Friends of Clayoquot Sound

The Friends of Clayoquot Sound (FOCS), the third CAAR member group working on this project, was established as a non-profit society in Tofino, British Columbia, Canada in 1979. As a grassroots, community-based organization, they work to protect the biological diversity of ancient temperate rainforests and the wild oceans of British Columbia. FOCS are strongly opposed to logging of ancient temperate rainforests and the export of raw (unprocessed) logs. They support small-scale, community-based forestry in second growth forests, promote the reduction of wood and paper consumption, and endorse the use of ecologically sustainable, tree-free alternatives to wood and wood-fiber products. They also advocate the removal of all open net-pen salmon farms from the ocean and work to drive consumer demand towards sustainable alternatives.

APPENDIX B:

AQUACULTURE TECHNOLOGIES

Most of the world's production of freshwater fish occurs on land, in closed tank systems. This is essential for many freshwater aquaculture systems where over-nitrification is a serious concern, as there are no ocean currents to carry waste and pathogens away from the farm. Since 1994, closed tank systems have been evolving on the Pacific coast. The technologies employ tanks either in the water or on land and in part separate the farm from the wild environment. Capital costs for closed tank systems are higher than for open net-pen systems and incur additional operating costs, such as energy to fuel the pumps and oxygen to maintain optimal growth, that are not incurred by open net-pens. To compensate for the higher costs, these farms have more control over the environmental parameters of the system, and many have achieved better growth, lower feed conversion rates, and improved survival. Further, waste collection is feasible, which prevents dumping directly into the ocean environment and could potentially translate into a secondary source of income for the farms.

In closed tank systems, fish can be grown at higher densities: upwards of 35 kg/m^3 are common compared to ~10-15 kg/m^3 open net-pen systems. All three saltwater salmonid species typically grown in open net-pens (Coho, Chinook, and Atlantic) have been grown successfully in closed tanks. Three companies are currently exploring alternative technologies on the Pacific coast: Mariculture Systems, AgriMarine Industries Inc., and Future SEA Technologies. Future SEA sells their bag systems throughout the world. AgriMarine's land-based pilot is currently in its third grow-out season and is searching for support to build two commercial-scale farms on Vancouver Island. Mariculture Systems ran a small pilot with closed tanks in Washington State and has received approval to build a new farm on Quadra Island.

It is important to note that many of the pilot projects were basic in feature. New systems are envisioned to bring a series of innovations including ultraviolet treatment or filtration of water for disease pathogens and parasites, waste processing, and methane generation.

Floating tanks

Mariculture Systems has developed a hard-walled, in-water tank system for finfish aquaculture called SARGO. Their system is a hard plastic tank with a waste collection system and all associated pumping and oxygen infusion equipment. Water is pumped through the tank from depth. Solid waste is collected using the centrifugal action of the water current and then processed via treatment and release, composting or methane generation.

In 1997, Mariculture tested their first tank during a trial in Washington State. This first trial was viewed as a success and maintained good biological parameters (low feed conversion ratio, low mortality, high growth) when compared to an adjacent conventional net-pen, which was plagued by a toxic algae bloom resulting in the death of thousands of salmon and the largest escape in the history of salmon farming on the Pacific coast. The SARGO system was not affected by the bloom and incurred no escapes.

COMPANY IN SHORT

Mariculture Systems Inc.
Head Office: Edmonds, WA
Countries of Operation: USA, Canada
Corporate Status: Public
Number of Trial Systems: One in Washington State
New systems: Under Construction, Quadra Island
Environmental highlights:

- Mandatory waste collection
- Little to no risk of tank breakage
- Experimental physical filtration system
- Experimental methane regeneration
- Three types of waste treatment

Mariculture has partnered with Yellow Island Aquaculture Ltd. to begin a new trial at their Quadra Island facility and they have secured partial funding for this new and particularly innovative system. The company is considering composting and methane regeneration of waste to power a portion of the pumping costs (~25%) and is currently developing a filtration system for the tanks. The goal is for the system to be operated under Yellow Island's unofficial organic standards.

The cost to purchase the SARGO system is around 1.7 million USD. Mariculture's initial calculations showed that the increased growth and survival as well as improved feed conversion ratio resulted in a financial performance comparable to a conventional farm, even in the short term. The California Environmental Associates, funded by the Packard Foundation, conducted an economic analysis of Mariculture's system that found the company's reports of financial viability to be an overestimate, and key missing variables such as depreciation and insurance were added. The conclusions of the report noted the need for a price premium to pay back the initial capital investment and higher operating costs of the SARGO system.

Flexible bag systems

Future SEA Technologies develops and patents alternative technology for aquaculture. The private company has been in operation since 1994 and has some investment through Provincial venture capital. Future SEA's primary system is a semi-contained thick plastic polymer bag that expands and contracts according to water flow. The basic setup includes the tanks and associated pumping and oxygen infusion equipment. The bag allows water to pass through and be injected, untreated, into the environment through a screen at the bottom. Waste collection technology is available, though optional, on the system, and allows for primary treatment of wastes for later composting and sale as fertilizer or feed.

> **COMPANY IN SHORT**
> **Future SEA Technologies Inc.**
> *Head Office*: Nanaimo, British Columbia
> *Countries of Operation*: USA, Canada, Chile, Australia
> *Corporate Status*: Private with some venture capital investment
> *Number of Trial Systems*: Many in a variety of locations
> *Current systems*: Saltspring Island and others throughout the world (mostly salmon ranching and freshwater smolt production); a saltwater system in Japan planned for 2004.
> *Environmental highlights*:
> Waste collection system optional
> Some risk of tank breakage
> No biological filtration system

The Future SEA system has been tested throughout the world in a variety of other applications. In Alaska, the bags are used for ocean ranching. In British Columbia, they are used in freshwater sites for smolt production and as lensing bags in the ocean. In 1997, the Canadian Department of Fisheries and Oceans tested the Future SEA bags for salmon farming in Nanaimo at the Pacific Biological Station. In addition to increased growth, the bags had up to ten times less sea lice than the adjacent open net-pen system. Most recently, through the British Columbia government's pilot project program, Marine Harvest (subsidiary of Nutreco, the world's largest salmon farmer) purchased a Future SEA bag system for a site on Saltspring Island. The cost of production at this most recent trial was 39% higher than the adjacent open net cage system, although Future Sea stressed that the full potential benefits of the system were not realized because the net-pen fish did not experience any challenging environmental conditions such as hazardous algal blooms, low dissolved oxygen, disease or lice outbreaks that are mitigated or completely avoided by the SEA system. The study concluded that improved oxygen performance and maintenance schemes should bring operating costs onto par with open net-pen.

Land-based aquaculture

AgriMarine Industries Inc operates Cedar Farm, one of the only saltwater land-based facilities in North America. AgriMarine is a private company in operation since 1983 and has been involved in open net cage finfish farming, fish processing, hatcheries and consulting. The Cedar Farm system is comprised of eight 15-metre wide concrete tanks south of Nanaimo, B.C. Water is pumped into the tanks from one-quarter mile offshore at depths of 20 metres. Various parameters including temperature, oxygen and salinity are monitored electronically.

Cedar Farm is in its third grow-out cycle and has tested Chinook, Coho, and Atlantic salmon on site. The 2004 season will consist of five tanks of Chinook. AgriMarine has successfully grown both Atlantic and Pacific species in high densities. During the first season, the company granted a Canadian retail exclusive to Thrifty Foods, which in turn marketed the product under the label "Eco-salmon", a first for a closed-tank product. Although Cedar Farm was potentially profitable when built in 1989, declining salmon prices have rendered it uneconomical. By utilizing modern, low-head pumps, improved oxygen separation technology, and greater economies of scale, AgriMarine plans to apply their technology at two proposed new sites. One will be an in-water floating concrete tank structure in Campbell River; the other is exploring the use of recirculation technology, utilizing equipment at abandoned pulp mill sites, technology that is similar to freshwater systems. Recirculation technology has rejuvenated potential for land-based systems, once thought to be uneconomical due to high capital and pumping costs. These new systems will also employ waste recuperation and processing (likely composting for resale) and filtration or UV sterilization of outgoing water.

COMPANY IN SHORT

AgriMarine Industries Inc.
Head Office: Campbell River, British Columbia
Countries of Operation: Canada
Corporate Status: Private
Number of Trial Systems: One in Cedar BC, ongoing
New systems: Under Construction, Gold River; Proposed: Campbell River
Environmental highlights:
- Proposed waste collection
- Little to no risk of tank breakage
- Experimental ultraviolet filtration system
- Strong predator control
- Little to no risk of escape – no transport risk in new sites next to land transport