State of Salmon Aquaculture Technologies

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In December 2018, Fisheries and Oceans Canada (DFO), in partnership with Sustainable Development Technology Canada (SDTC) and the Province of British Columbia (B.C.), commissioned and funded a study on the state of salmon aquaculture technologies to examine the risks and opportunities of the most promising emerging technologies for salmon farming in B.C. The study explored the financial, environmental and social elements of emerging aquaculture technologies and highlighted some of the ways to incent the adoption of these new technologies, including how other countries have incented adoption. The study explored four technology options: land-based closed-containment; floating closed-containment; offshore technologies; and hybrid systems which combine both land and marine-based systems. The study indicated that all four production technologies have the opportunity to reduce interactions between farmed and wild salmon compared to conventional open net pen aquaculture production, but the assessment against other environmental, economic and social elements varied.

In section 4 of the study, three tables showing the strengths, weaknesses and uncertainties for the four production technologies in relation to environmental, social and economic criteria are presented. These are reproduced below for ease of access.

The tables provide a preliminary, general assessment of these four production technologies and do not include a comparison to open net pens, the primary current production method in B.C., nor do they include the full range of aquaculture production technologies or variations on technologies being used or developed domestically and globally. Some of these technologies are at early stages and thus the tables were developed on a general understanding of how the systems are designed to operate and are not necessarily accurate predictors of how they might operate in real world settings. The State of Salmon Aquaculture Technologies report recognises that this assessment only reflects a point in time, that aquaculture technologies are developing rapidly and that information about performance and capabilities of the systems can quickly become outdated. Moreover, the impacts of each of these technologies will vary depending on various factors including their design, location and the surrounding environment.

The full study can be found at https://www.dfo-mpo.gc.ca/aquaculture/publications/ssat-ets-eng.html.

Table 5 of the State of Salmon Aquaculture Technologies Report. *Environmental strengths, weaknesses and uncertainties for the four new production technologies.*

Land RAS	Hybrid system	Floating CCS	Offshore system
Marine escapes			
• No risk, the system is contained on land.	• No risk during land-RAS stage • Some risk at sea and during transfers, but reduced time at sea and better transfer timing is helpful	• Low risk due to solid containment, and some risk during fish transfer to/from land	• Some risk due to open containment, but built for harsh conditions • Some risk during fish transfer to/from land • Uncertainties need more research
Wild salmon disease			
• No risk, the system is contained on land.	• No risk during land-RAS stage • Some risk at sea, but time at sea is reduced and salmon are larger and healthier	• Low risk due to solid containment, but still some risk as water filtration will not eliminate all concerns	• Some risks, but submerging capability avoids sea lice, and sites may be located away from salmon migration routes
Waste effluent			
• Waste can be composted, used in aquaponics, or to generate energy • Salt content can be a challenge	• Land-RAS waste can be composted, used in aquaponics, or to generate energy • Most waste is released to sea in grow-out, but some capture possible	• Low waste release with collection system and processing on land, but some dissolved nutrients (e.g. nitrogen, phosphorus) released	• Waste is released to sea • Location offshore in deeper high current waters will be better than inshore sites
Chemical release			
• Very low to no release outside the system • Chemicals are used for bacteria, gill diseases, and pH control	• Very low to no release from land-RAS phase • Marine phase releases chemicals to sea, but reduced use due to larger salmon	• Improved fish health will reduce chemical use, but as for waste effluent some will be released to sea	• Improved health will reduce chemical use, but released to sea • Anti-fouling agents on large metal structures are a concern, but this requires research
Wildlife interactions			
• No risk, the system is contained on land	• No risk for land-RAS phase • Some risk for marine phase, but may be improved with longer fallow periods	• Solid wall containment will eliminate risks • Mooring lines and structures may pose some risk to marine mammals	• Some risks with open containment, but integrity is expected to be very good • Mooring lines and structures may pose some risk to marine mammals • These topics require more research
Water use			

• Very low use in 99.5% recirculation systems • Use of aquifers by very large facilities is a concern	• Very low use for land-RAS phase since not used for grow-out • Marine phase only uses seawater flowing through	• The system only uses seawater flowing through, no limited freshwater resources	• The system only uses seawater flowing through, no limited freshwater resources
Energy use and GHGs			
• High energy use in system construction and operation • Grid electricity in BC has low carbon intensity • Location can minimise transport costs for feed to site and products to market	• Medium energy in grid connected land RAS facility since not used for grow-out • Low energy use in marine phase, but petroleum products may be used for boats and feed systems • Transport to/from marine sites adds to energy use	• Medium energy use in system construction and operation • Grid electricity in BC has low carbon intensity, but some sites may not connectto grid • Transport to/from marine sites adds to energy use	• High energy use in system construction • Medium energy in operation, and petroleum products likely needed for remote operation • Transport to/from marine sites adds to energy use • Research needed on these topics

Table 6 of the State of Salmon Aquaculture Technologies Report. *Social strengths, weaknesses and uncertainties for the four new production technologies.*

Land RAS	Hybrid system	Floating CCS	Offshore system
Local support			
• Environmental strengths will earn support, but very large facilities using sensitive water resources will likely raise concerns • Economic aspects may be a concern with fewer jobs, but market access and growth potential will build support	• Environmental performance of land-RAS phase will build support, but marine phase will still be a concern • Economic performance will support local jobs, but marine concerns hampering growth may dampen local support	• Environmental performance will build support, but use of marine sites may still be a concern • Economic performance will support local jobs, while market access and growth potential will attract support	• Avoiding near-shore spatial conflicts will gain local support • Jobs will remain in coastal areas, but there may be fewer with increased automation • Growth potential will build support
Global support			
• Seafood labelling will likely support this system as a "best choice"	• Seafood labelling will likely support this system as a "good alternative" since thisalready applies to B.C. farmed salmon	• Seafood labelling does not cover this technology for salmon, but it should garner a "good alternative" rating or better	• Seafood labelling does not cover this technology for salmon, but it may earn a "good alternative" rating
Consumer support			
• Premium prices today are an indication of consumer support • Moves to land-RAS in key markets may mean this system is needed for access • Product quality and fish welfare may be a concern • Higher cost may be a challenge to sell into price sensitive markets	• Products will not be distinguished from conventional netpen salmon • Establishment of land-RAS in key markets may limit market access for products of this system • Product quality and cost is very good, but there may be some concerns with marine contaminants	• Products will be distinguished from those produced by open netpen systems • Product quality and fish welfare will be considered good • Higher cost may be a challenge to sell into price sensitive markets	• Products may be distinguished from those produced by near-shore open netpen systems • Product quality and fish welfare will be considered good, but there may be some concerns with marine contaminants • Research is needed to address uncertainties

***Table 7* of the State of Salmon Aquaculture Technologies Report.** *Economic strengths, weaknesses and uncertainties for the four new production technologies.*

	Land RAS	Hybrid system	Floating CCS	Offshore system
Profitability				
	• Large investments mainly by new entrants to farming are expanding this technology at large commercial scale • A couple years of commercial operations are needed to confirm profitability	• Large investments mainly by existing salmon farming companies indicate this is a profitable technology at large commercial scale	• Some investments by existing farming companies indicate this is a technology of interest at large commercial scale • A few years of commercial operations are needed to confirm profitability	• Investments mainly by new entrants to farming indicate thisis a technology of interest at large commercial scale • A few years of commercial operations are needed to confirm profitability
Capital cost				
	• Cost of 5,000 mt facility is $10 to $14per kg of capacity • Cost of 10,000 mt facility is $7 to $10 per kg of capacity	• Land-RAS for post-smolt costs much less than for grow-out • Marine phase for grow-out uses very low cost netpen systems in use now	• Cost of $5 to $15 per kg of capacity indicates wide range of designs being evaluated	• Cost of 5,000 mt or more facility is about $20 per kg of capacity • Other designs exist, but costs are uncertain
Operational cost				
	• Cost for operations is $5 to $6 per kg of annual salmon produced • New sites are locating near markets to reduce transport costs	• Land-RAS for post-smolt costs much less than for grow-out • Marine phase uses very low cost netpen systems in use now • $3.5 to $4.5 cost per kg needs research	• Cost is lower than land-RAS, but higher than hybrid system • $4.5 to $5.5 cost kg needs research	• Cost may be one of the lowest amongst new technologies given high degree of automation and use of ecosystem services • Research is needed
Financial risk				
	• Biological risks are mortality, high maturation rates, and growth challenges • Market risks are price drops, currency changes, lost price premiums as land- RAS market share increases	• Biological risks are very low since this is an extension of existing technologies • Market risks are those normally associated with salmon aquaculture	• Biological risks are mortality due to system failure • Market risks are price drops, currency changes, lost price premiums as new technology market share increases	• Biological risks are mortality due to high energy environment, system or component failure, growth challenges • Market risks are those normally associated with salmon aquaculture
Supply-chain				

• Feed, fish health, processing, distribution and sales are in BC, but are being developed where new sites are emerging elsewhere • There are limited expertise in BC for construction and operation of land-RAS systems so training and imports are needed	• All elements of the supply chain exist in Canada, although advanced RAS design and expertise draws from other countries • Some additional training are required to expand land-RAS workforce	• All elements of the supply chain exist in Canada including design and operational expertise • Some additional training are required to expand use of this technology	• Most elements of the supply chain exist in Canada, although offshore design and construction expertise draws from other countries • Specialized boats and training for offshore is needed • Research is needed to determine all requirements
Economy			
• Fewer jobs per mt of salmon (26 – 30 direct jobs per 1,000 mt of salmon) and not necessarily in rural areas • High average salaries due to more technical expertise required	• This system keeps most jobs (35 – 40 direct jobs per 1,000 mt of salmon) and largely where they are located now • Some more advanced expertise jobs will command higher salaries	• This system keeps most jobs (35 – 40 direct jobs per 1,000 mt of salmon) and largely where they are located now • Some more advanced expertise jobs will command higher salaries	• There are fewer jobs due to higher amount of system automation • Jobs are still located in rural areas • Some more advanced expertise jobs will command higher salaries
Expansion			
• Several large facilities could double BC salmon production • Site selection takes time to meet requirements, especially discharge permits	• Some expansion can occur at existing marine sites, but grow-out concerns must be addressed for new sites to be allocated	• Some expansion of production can occur by replacing netpens at existing marine sites, and allocation of new sites should be more acceptable due to environmental performance	• BC offers extensive opportunities for expansion once the technology is proven through test sites