Global Salmon LCA
CLOSED-CONTAINMENT AQUACULTURE

A primary goal of closed-containment salmon aquaculture is to reduce the ecosystem impacts associated with conventional net pen culture. Potential advantages include reduced escapes and disease transmissions as well as improved waste management. For these reasons, environmental groups, along with a few industry members, have advocated the use of closed-containment systems.

While closed-containment aquaculture may alleviate or eliminate proximate ecosystem impacts, the materials and energy required by such systems have other environmental costs. In this study, we compare a conventional net pen system with three types of closed containment: a marine floating bag system, a land-based flow through system, and a land-based freshwater recirculating system. We quantify environmental costs according to contributions to global warming potential and six other measures of global environmental impacts.

Key Findings

- The energy and material requirements of closed-containment aquaculture can add significantly to the global environmental costs of salmon production.
- The global environmental performance of closed-containment operations in British Columbia benefits from the province's largely hydropower-based electricity mix.
- A floating bag system based in British Columbia outperforms each of the other systems, including net pens, on most global biophysical measures.

Our Analysis

Marine net pens are currently the only form of large-scale, commercially operating salmon aquaculture systems in Canada. Closed-containment salmon systems face a variety of engineering and investment challenges and currently operate only in small-scale, research and development capacities.

Gathering data directly from facility records and interviews with facility managers, we modeled the environmental performance of a conventional net pen salmon system in comparison with three closed-containment systems: floating marine bag, land-based flow through, and land-based recirculating. The net pen, floating bag, and land-based flow through systems were each modeled on saltwater salmon systems in British Columbia. The land-based recirculating system was modeled on a Nova Scotia-based freshwater system in commercial operation for Arctic char.

The land-based systems each utilize concrete tanks, and the floating bag system is similar in structure to a net pen system, with the netting replaced by an impermeable membrane that is suspended in the water. Each of the three closed-containment systems circulates water through continuous pumping, and in each system this pumping is the primary driver of electricity demand. Our analysis found that in the two land-based systems, environmental performance was strongly influenced by total energy demand and the mix of primary energy inputs. Environmental performance in the marine bag system was, as in the net pen system, most influenced by feed provision.

(continued)

FOUR AQUACULTURE SYSTEMS

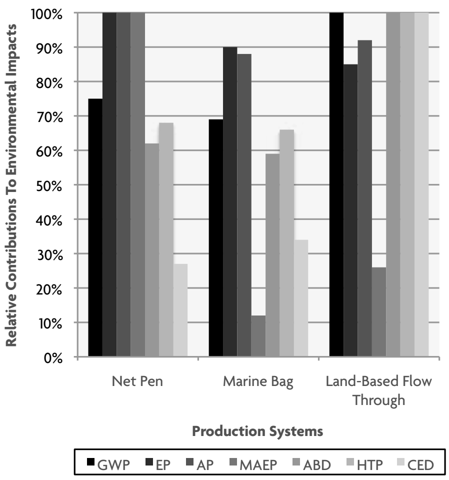
	Marine Net Pen	Marine Floating Bag	Land-Based Flow Through	Land-Based Recirculating
Species	Atlantic salmon	Atlantic salmon	Atlantic salmon	Arctic char
Geographic setting	British Columbia	British Columbia	British Columbia	Nova Scotia
Culture medium	Saltwater	Saltwater	Saltwater	Freshwater
Infrastructure (kg/t)	16	38	391	937
Feed (kg/t)	1,300	1,170	1,165	1,448
Cumulative energy demand (MJ/t)	26,900	32,800	97,900	353,000
Global warming potential (kg CO_2-eq/t)	2,073	1,900	2,770	28,200
Average stocking density (kg/m^3)	20	35	38	73
Total live-weight fish produced during grow-out cycle (t)	3,600	416	96	46

We profiled and modeled system parameters for four salmon aquaculture systems, comparing infrastructure, feed, and cumulative energy requirements on a per tonne of live-weight fish basis. For infrastructure demand, we assessed material inputs of steel, concrete and so on, over the life cycle of the facilities. For cumulative energy demand, we assessed total industrial energy use up to the farm gate. Global warming potential was strongly influenced by both total energy demand and the energy mix used for electricity production. Despite higher stocking densities, the closed-containment systems modeled had much smaller total rearing capacities.

Net pen systems benefit from ecosystem services provided by ocean currents and tidal action. The supply of dissolved oxygen in fresh seawater and the flushing of waste products from the culture environment are two of the ecosystem services that must be technologically replicated in closed-containment systems. Wastewater was not treated in the marine bag and land-based flow through systems modeled in this study.

This study utilized the local energy mix as an input, without accounting for the ecosystem impacts of energy production, which in British Columbia include the potential depression of wild salmon stocks by dams generating hydropower.

GLOBAL ENVIRONMENTAL IMPACTS



We assessed and compared four aquaculture systems according to their relative contributions to global warming potential (GWP), eutrophication potential (EP), acidification potential (AP), marine aquatic ecotoxicity (MAEP), abiotic depletion (ABD), human toxicity potential (HTP), and cumulative energy demand (CED). These comparisons include the impacts of grow-out infrastructure and emissions, on-site fuel use, and smolt, electricity, oxygen, and feed production. The marine bag outperformed the net pen system on six of the seven measures, most significantly on marine aquatic toxicity. The net pen system performed better than the others on cumulative energy demand. The higher energy demand of the land-based recirculating system resulted in significantly higher environmental impacts, and it is not shown here.

Opportunities for Action

Policy Makers, Aquaculturists, Influencers

Weigh the global environmental impacts of closed-containment aquaculture in any decisions about alternative culture systems.

For Further Reading

Ayer, N. and P. Tyedmers. 2009. "Assessing alternative aquaculture technologies: life-cycle assessment of salmonid culture systems in Canada." *J Clean Prod.* 17: 362-373.

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EcoPlan International. 2008. Global Assessment of Closed System Aquaculture. David Suzuki Foundation and Georgia Strait Alliance.

About the Global Salmon LCA Project

The Global Salmon LCA project is the first worldwide life-cycle assessment of a single food product. LCA provides a systematic framework for calculating inputs and outputs at each stage of a product life cycle. Utilizing this framework, we examine the salmon fillet, icon of the global food system, and compare alternative methods of production and distribution. We evaluate global environmental impacts and expand on a traditional LCA to consider additional impacts specific to nearby ecosystems and social welfare. This analysis allows us to identify opportunities for improved performance in both aquaculture and capture fisheries — while building a more robust understanding of sustainable food systems. Please visit www.ecotrust.org/lca to sign up for updates.

Global Salmon LCA Factsheets

A Life Cycle of Foods
Salmon Ecosystems
Capture Fisheries
Aquaculture Production
Closed-Containment Aquaculture
Products and Transport
Social Dimensions
A Globalized Food System

ASTRID SCHOLZ
Ecotrust
www.ecotrust.org
ecotrust

ULF SONESSON
SIK - The Swedish Institute for Food and Biotechnology
engwww.sik.se
Sik

PETER TYEDMERS
School for Resource and Environmental Studies, Dalhousie University
sres.management.dal.ca
DALHOUSIE UNIVERSITY Inspiring Minds

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