Bioeconomic Modeling of Salmon Farming Practices in Southern Chile

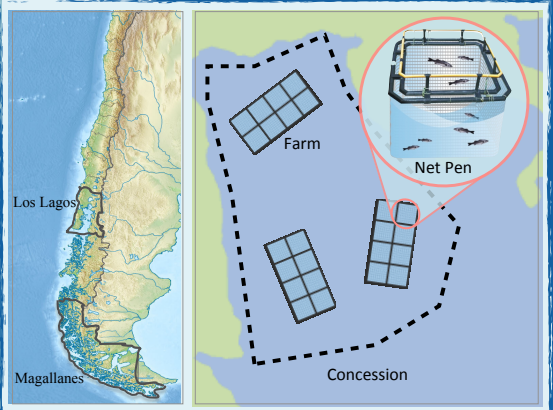
FARMING SALMON IN CHILE: ¿QUE PASÓ?

Chile's salmon farming industry was initiated in the country's Los Lagos region in the late 1970s. Chile quickly grew to become the word's second largest producer of farmed salmon, generating $2 billion in yearly exports and providing over 50,000 jobs.

A lack of science-based management, coupled with weak enforcement of national environmental and labor laws, likely played a role in causing an outbreak of the Infectious Salmon Anemia (ISA) virus in 2007, which swept through the Los Lagos salmon farms, killing entire stocks and driving the industry to a near collapse.

In an effort to rebuild the industry, the Chilean government is allowing its expansion into the country's pristine southernmost region, the Magallanes.

Aquaculture Regions and Components of a Concession



PROJECT OBJECTIVES

Our client, the Wildlife Conservation Society of Chile, is interested in the effects of establishing large-scale salmon farming in the Magallanes.

Our project aims to:

1) Predict how specific salmon farming practices affect environmental and socioeconomic outcomes that are of interest to diverse stakeholders

2) Evaluate the outcomes associated with approved and future Magallanes salmon concessions

3) Identify combinations of farming practices that lead to favorable tradeoffs between outcomes.

A group project thesis for the Bren School of Environmental Science & Management

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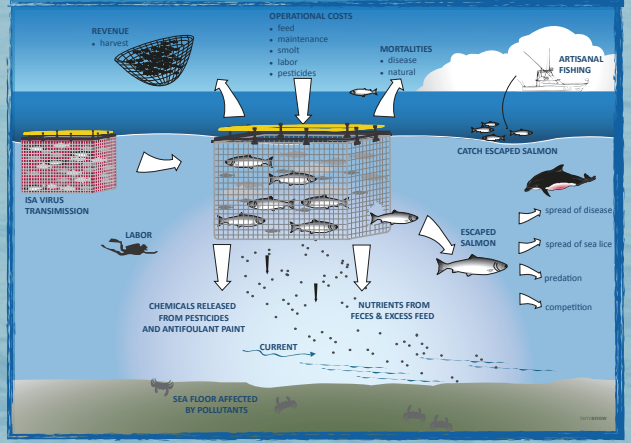
The Inputs and Impacts of Salmon Farming



METHODS

To predict the ecological and socioeconomic outcomes of salmon farming in the Magallanes, we assessed the following five impacts of individual salmon farming concessions: nutrient effluent, chemical effluent, escaped salmon, labor violations, and the threat of ISA virus outbreak. Using a mathematical model describing these impacts, we translated numerical representations of farming practices ("inputs") into their effects on stakeholder interests ("outcomes of interest"). Each run of the model therefore predicts the value of each outcome after one cycle of aquaculture, based on a set of inputs specific to one concession's farms.

A Conceptual Look at the Model

Inputs
Stocking Density
Length of Cycle
Number of Net Pens
Equipment Quality
Number of Chemical Treatments
Current Speed
Water Depth
Hours Law Violations
Wage Law Violations

→ The Model (7 sub-models) →

Outcomes of Interest
Ecosystem Health
Concession Profit
Area Affected by Pollutants
Probability of ISA Infection
Artisanal Fisheries Profit
Tourism Profit
Expected Cost of Labor Violations

CONCLUSIONS

As the salmon aquaculture industry grows to meet rising demand, it will need to be carefully managed to achieve favorable tradeoffs between ecological and socioeconomic impacts. Our model provides a tool that can be used to predict the extent of these impacts and inform management decisions. Models such as ours will be crucial as this industry grows in the Magallanes and worldwide.

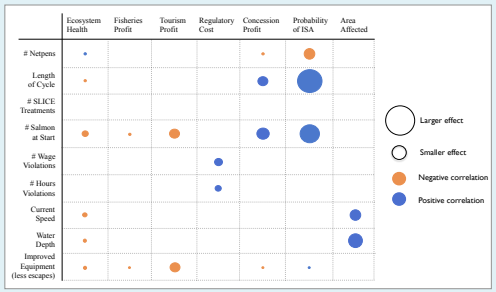
RECOMMENDATIONS

- We recommend that industry leaders, aquaculturists, and environmental groups use our model to evaluate current concessions and future concession applications. Managers can rank applications to determine which should be accepted based on their performance on particular outcomes.
- We recommend that Magallanes industry leaders and aquaculturists use our model to help maximize the benefits of individual concessions. Our model can be used to identify the farming practices that, when adjusted, have the greatest impact on the outcomes of interest. Aquaculturists can target these practices over others to improve the overall benefits from the industry.
- We identified model parameters that, if certainty about their values were greater, would most improve the reliability of the model's results. We recommend that the scientific community conducts more research on these values, which include the following: nitrogen content in feed, mortality due to disease, and distance between farms.
- Our model serves as a framework. Enhancing it with greater breadth and detail would expand the model's scope and lead to more accurate results.

ANALYSIS AND RESULTS

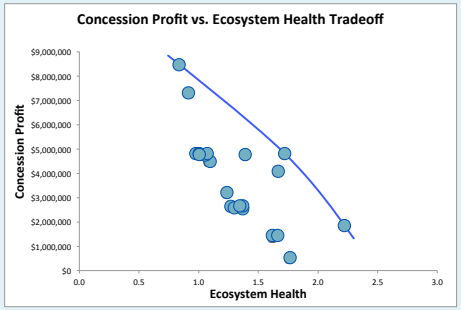
We carried out three main analyses: an assessment of the strength of inputs' effects on outcomes, an evaluation of the currently approved and potential Magallanes salmon farming concessions, and a sensitivity analysis to identify areas of future research that would most improve the accuracy of our model.

Which practices have the strongest influence on stakeholder interests?



We systematically increased the value of each input by 10% and measured the resulting percent increase or decrease in each outcome. Comparing these two values reveals the farming practices that, when adjusted, have the greatest impacts on corresponding outcome values. For example, increasing the stocking density leads to greater Concession Profit. However, increased profit for aquaculture comes at the expense of Ecosystem Health, Artisanal Fisheries, and Tourism, and also increases the probability of ISA infection.

How are approved Magallanes concessions expected to perform?



We ran the model once for each of the 21 concessions that the government has already approved for operations in the Magallanes, with each run predicting the ecological and socioeconomic outcomes from one concession. This analysis can be used to highlight important tradeoffs between outcomes, like that between Ecosystem Health and Concession Profit. The concessions that make the most efficient tradeoffs between these two outcomes fall along the outer bound of the distribution, the "efficiency frontier"; all others could be improved to reach the frontier. Importantly, further research suggests that different combinations of farming practices could enable future concessions to achieve even better outcomes than the best approved concessions - that is, they could push the efficiency frontier outward.

Which parameters are most important for future research?

We performed a sensitivity analysis to identify which of the model's parameters have the greatest effect on each outcome. For example, we found that the parameter describing feed conversion ratio has a large impact on Ecosystem Health, and the parameter describing mortality rate due to disease has a strong effect on Concession Profit. Increased certainty about these two parameters will lead to more reliable model results.