aquaculture journal

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Economic Modelling of Mouth Rot in British Columbia Atlantic Salmon Farming

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Abstract

Bacterial stomatitis, or mouth rot (MR), caused by *Tenacibaculum maritimum*, is a persistent health issue for farmed Atlantic salmon (*Salmo salar*) in seawater, leading to elevated mortality and reduced growth during the early months of production. Despite its impact, economic estimates of MR have been lacking. We developed a model to estimate selected direct costs associated with MR at the farm and industry levels in British Columbia (BC), Canada. This model incorporated parameters directly affected by MR, including revenue loss from mortality, and antibiotic treatment costs, while accounting for the feed-cost offset associated with mortality. To address variability across farms, MR-associated mortality, non-MR mortality, smolt weight, the number of treatments for MR, fish sale price, feed price, price of drug, and the proportion of farms affected by MR were simulated (Monte Carlo simulation with 10,000 iterations) using ModelRisk. Results indicated that MR imposed an average farm-level economic burden of USD 0.74 million (SD: USD 0.45 million) per production cycle and an industry-level burden of USD 10.58 million (SD: USD 6.54 million) annually. This study provides model-based estimates of selected direct economic costs associated with MR, based on BC specifications, and highlights the need for improved mitigation strategies and policy prioritization for this disease.

Keywords: mouth rot; Atlantic salmon; economic burden

Academic Editor: Aires Oliva-Teles

Received: 8 May 2026
Revised: 17 July 2026
Accepted: 21 July 2026
Published: 24 July 2026

1. Introduction

Bacterial stomatitis, commonly known as mouth rot (MR) or yellow mouth disease, is caused by *Tenacibaculum maritimum* and primarily affects farmed Atlantic salmon (*Salmo salar*) shortly after their transfer to salt water [1,2], particularly at high salinity sites when temperature is 12 °C or higher [3]. The disease manifests as yellow plaques on the maxilla, mandible, and teeth [3], causing economic losses through increased mortality and antibiotic treatment costs [3]. The causative agent, which has been isolated from clinical fish, tank surfaces, water, and sediments, can be transmitted horizontally within a population [3,4]. Notably, repeated MR outbreaks may occur within the same population during the initial four to five months post saltwater entry, leading to repeated use of antibiotics on affected farms [5].

Economic models for various health issues have been developed to estimate disease burden and evaluate the effectiveness of health management interventions, providing a robust framework for informed decision-making in aquaculture [6,7]. These models help prioritize specific health issues based on cost to the industry and can justify funding initiatives. Aquaculture companies can also leverage digital platforms, such as those developed by AKVA group™, to support health management planning and decision-making [8].

Although many research studies document the biological and production impacts of MR, the economic impact of this disease at both farm and industry levels has not been determined. To address this gap, the primary objective of this study was to develop an economic model to quantify the context-specific direct economic costs associated with MR in the British Columbia (BC) Atlantic salmon aquaculture industry. By establishing this framework, this study aims to provide a baseline estimate of the disease's financial burden, thereby supporting industry stakeholders and policymakers in prioritizing regional research and biosecurity resource allocation.

2. Materials and Methods

2.1. General Model Framework

To estimate the economic burden of MR in Atlantic salmon farming in BC, we developed an economic model using Microsoft Excel (Version 16.107.2) with ModelRisk (Version 8.1.2, © Vose Software) (File S1). The model framework was designed to quantify the direct costs associated with MR. Specifically, biomass loss and treatment expenditures were assumed to constitute the two principal components of direct disease-related costs. The following sections describe the equations used to estimate these components. In addition, the model accounted for the feed-cost offset associated with MR mortality. The corresponding equations are presented in Section 2.3 below. To account for the dynamic nature of the parameters and potential variability across farms, our economic model allows users to adjust key variables for site-specific MR cost estimates. We also provided the model without ModelRisk, enabling users without this software to estimate the costs of MR for specific scenarios (File S2).

2.2. Parameters for the Model

The data for the parameters in our model were obtained from multiple sources, including anonymous data from the industry, publicly available government data, peer-reviewed literature, and a consultation panel of two anonymous salmon aquaculture industry experts from BC, an aquatic veterinarian consultant and a production manager, each possessing over 10 years of regional experience.

Aggregated quarterly reports from a single aquaculture company operating multiple production sites between 2014 and 2025 were used to estimate the average, minimum, maximum, and standard deviation of MR mortality, total mortality excluding MR, and smolt weight, as well as the minimum, maximum, and most likely number of MR treatments. Farms typically relied on a presumptive field diagnosis of MR which was based on gross observations of yellow plaques in the oral cavity of fish.

For market and production parameter estimates, we used information gathered from our industry experts and publicly available online resources, and the final values were confirmed by all authors, who have experience in the salmon industry in Canada, Chile, and Scotland, to ensure they were within industry norms.

The BC government data on fish health events at marine finfish aquaculture sites between 2023 and 2025 were used to calculate the annual total number of farms with smolts and the annual reported cases of MR. Under licensing conditions in BC, if the cumulative mortality exceeds the regulatory threshold (1% of the stock within 24 h or 2.5% of the stock within five days) [9], a mortality event must be reported to the Fisheries and Oceans

Canada (DFO) within 24 h of discovery. Following this initial report, facility managers and veterinarian(s) must investigate to determine the probable cause of the event.

Table 1 summarizes all parameter values used in the model calculations for this study.

Table 1. Summary of model parameter values used in this study.

Parameter	Parameter Type	Value/Distribution Details	Unit	Reference
Fish stock and grow-out period				
Number of fish at the start of the production cycle	Fixed	1,150,000	Fish	[2]
Initial weight of smolt	Stochastic	[Normal] Average: 0.150 Standard deviation: 0.046 Min: 0.107 Max: 0.286	kg per fish	[Anonymous industry data]
Thermal growth coefficient (TGC)	Fixed	2.45	g $^{1/3}$/degree days	[10]
Average water temperature	Fixed	11	°C	[11]
Average harvest weight per fish	Fixed	4.50	kg per fish	[2]
Unit sale price per kg of fish	Stochastic	[PERT] Min: 7.59 Mode: 8.93 Max: 10.27	USD/kg	[2]
Disease and Mortality				
Number of days from stocking till MR	Fixed	17.50	days	[12]
Mortality associated with MR	Stochastic	[Lognormal] Average: 2.11 Standard deviation: 1.70 Min: 0.21 Max: 7.99	%	[Anonymous industry data]
Total mortality, excluding MR mortality	Stochastic	[Lognormal] Average: 18.53 Standard deviation: 9.41 Min: 2.42 Max: 49.01	%	[Anonymous industry data]
Feed				
Feed price per kg	Stochastic	[PERT] Min: 1.87 Mode: 2.20 Max: 2.53	USD/kg	[2]
Feed conversion ratio (FCR)	Fixed	1.30		[2]

https://doi.org/10.3390/aquacj6030029

Table 1. *Cont.*

Parameter	Parameter Type	Value/Distribution Details	Unit	Reference
Treatment				
Florfenicol premix active ingredient	Fixed	50	%	[13]
Price of florfenicol premix per kg	Stochastic	[PERT] Min: 488.75 Mode: 575 Max: 661.25	USD	[Anonymous industry expert, personal communication, 27 June 2025]
Number of treatments with florfenicol	Stochastic	[PERT] Min: 0 Mode: 2 Max: 7		[Anonymous industry expert, personal communication, 25 July 2025]
Duration of each treatment with florfenicol premix	Fixed	10	days	[Anonymous industry expert, personal communication, 25 July 2025]
Dose of florfenicol drug	Fixed	15	mg per kg of fish	[13]
Industry Farm Count				
Total number of Atlantic salmon farms	Fixed	25	farms	[14,15]
Proportion of farms affected by MR	Stochastic	[PERT] Min: 0.43 Mode: 0.56 Max: 0.72		[14,15]

2.3. Equations

2.3.1. Direct Revenue Loss from MR-Associated Mortality

The direct revenue loss associated with MR mortality (R_{MR}) was estimated by multiplying the MR-associated cumulative percent mortality by the initial number of fish, and then by the average harvest weight and the average unit market price per kilogram of fish (Equation (1)).

$$R_{MR} = (M_{MR} \times N) \times W \times P_h, \quad (1)$$

where:

R_{MR}: Direct revenue loss due to MR-associated fish mortality (USD);
M_{MR}: Cumulative percent mortality associated with MR over the production cycle (%);
N: Number of fish at the start of the production cycle (fish);
W: Average harvest weight per fish (kg);
P_h: Unit sale price per kg of fish (USD/kg).

Because MR-attributable mortality (M_{MR}) varied across production sites, we incorporated stochasticity into this parameter using the Microsoft Excel add-in ModelRisk (Version 8.1.2, © Vose Software). A lognormal distribution was selected to represent uncertainty in M_{MR}. The distribution was parameterized using average, standard deviation (SD), and minimum and maximum values obtained from industry data (Table 1). We also incorporated stochasticity into the unit sale price of fish by applying a PERT distribution, defined by minimum, mode, and maximum values, within ModelRisk (Table 1). To determine direct revenue loss, we conducted a Monte Carlo simulation with 10,000 iterations. The results of this simulation were used to quantify the economic burden of MR (see below).

2.3.2. Costs of Antibiotic Treatments

To estimate the expenditure from MR treatments for our economic burden model, we calculated the cost of individual antibiotic treatments. First, we estimated the number of fish treated by subtracting half the population (50%) that died of MR from the initial starting population (Equation (2)). It was assumed that approximately 50% of the fish that died would have been treated [16].

$$N_t = N - [(N \times M_{MR}) \times 50\%], \quad (2)$$

where:

N_t: Number of fish treated (fish);

N: Number of fish at the start of the production cycle (fish);

M_{MR}: Cumulative percent mortality associated with MR over the production cycle (%).

Next, we calculated the amount of medication required per treatment by multiplying the number of fish treated by the average fish weight at the time of MR, then by the antibiotic dose (expressed on an active-ingredient basis), and finally by the treatment duration (Equation (3)).

$$W_{AB} = (N_t \times W_{MR} \times DO_{AB} \times DU_{AB}) \div 10^6, \quad (3)$$

where:

W_{AB}: Amount of antibiotic per treatment (kg);

N_t: Number of fish treated (fish);

W_{MR}: Average weight of fish at the time of MR (kg) (see Equation (4));

DO_{AB}: Dose of antibiotic (mg/kg of fish/day);

DU_{AB}: Duration of treatment with antibiotic (days).

We divided 10^6 to convert mg to kg for the dose of antibiotics.

To estimate the average fish weight at the time of MR (W_{MR}), we used the equation from Jobling (2003) [17] with minor modifications. This equation estimated the weight based on the initial weight of smolts, the thermal growth coefficient (TGC), the average water temperature, and the number of days from stocking to MR (Equation (4)). To capture variation in smolt weight at the time of stocking, we modeled stochasticity in ModelRisk using a normal distribution with a minimum, mean, maximum, and SD obtained from industry data (Table 1).

$$W_{MR} = [\{\sqrt[3]{W_0} + [(TGC \div 1000) \times (Tem \times t)]\}^3] \div 1000, \quad (4)$$

where:

W_{MR}: Average weight of fish at the time of MR (kg);

W_0: Initial weight of smolt (kg/fish);

TGC: Thermal growth coefficient (g $^{1/3}$/degree days);

Tem: Average water temperature (°C);

t: Number of days from stocking until MR (days).

To convert antibiotic premix prices on an active-ingredient basis, we used an industry estimate of the premix cost, modeled via a PERT distribution using minimum, mode, and maximum values (Table 1), and divided it by the premix's active-ingredient fraction. The

https://doi.org/10.3390/aquacj6030029

medication amount per treatment was then multiplied by the unit price (also expressed on an active-ingredient basis) (Equation (5)).

$$t_{AB} = W_{AB} \times P_{AB}, \quad (5)$$

where:

t_{AB}: Cost per treatment with antibiotic (USD);
W_{AB}: Amount of antibiotic per treatment (kg);
P_{AB}: Price of antibiotic (USD/kg of active ingredient).

Total antibiotic expenditure for MR treatment was calculated by multiplying the cost of each single treatment by the number of treatment courses applied on the farm (Equation (6)). Equation (6) illustrates this estimation using two antibiotics commonly used for MR management (i.e., tetracycline and florfenicol) [18,19].

$$T = (t_{FFC} \times n_{FFC}) + (t_{OTC} \times n_{OTC}), \quad (6)$$

where:

T: Total treatment expenditure associated with MR (USD);
t_{FFC}: Cost per treatment with FFC (USD);
n_{FFC}: Number of treatments with FFC;
t_{OTC}: Cost per treatment with OTC (USD);
n_{OTC}: Number of treatments with OTC.

For the purpose of this study, we assumed that only florfenicol treatments were administered to manage MR. This assumption was based on the industry data. To capture the variation in treatment practices across different farms, we incorporated stochasticity into the number of treatments using ModelRisk software and a PERT distribution (minimum: 0; most likely: 2; maximum: 7) (Table 1). To estimate the total antibiotic treatment costs, we conducted a Monte Carlo simulation with 10,000 iterations. The resulting values from these iterations were then used to populate the economic burden of MR (see below).

In addition to the two main disease costs (i.e., forgone revenue and treatment expenditures), our model also accounted for the feed-cost offset associated with not having to feed fish that died of MR.

2.3.3. Avoided Feed Expenditures (F_s)

Having MR mortality would reduce the number of fish requiring feeding. Therefore, we estimated the feed-cost offset attributable to MR-associated mortality using Equation (7). First, we calculated the biomass of fish that died due to MR based on the MR percent mortality, the initial number of fish on the farm, and the difference between the average weight of fish at harvest and the average weight of fish at the time of MR ($W - W_{MR}$). This biomass was then multiplied by an average feed conversion ratio (FCR) to estimate the quantity of feed (kg) that would have been required to produce the biomass lost due to MR. Finally, we multiplied this feed quantity by the average feed price per kg (USD), which was modeled using a PERT distribution based on minimum, mode, and maximum values (Table 1), to determine the avoided feed expenditure (Equation (7)).

$$F_s = [(W - W_{MR}) \times (M_{MR} \times N)] \times FCR \times F_p, \quad (7)$$

where:

F_s: Feed-cost offset associated with MR mortality (USD);
W: Average harvest weight per fish (kg);
W_{MR}: Average weight of fish at the time of MR (kg);

M_{MR}: Cumulative percent mortality associated with MR over the production cycle (%);
N: Number of fish at the start of the production cycle (fish);
FCR: Feed conversion ratio set at 1.3;
F_p: Feed price per kg (USD/kg).

To estimate the avoided feed expenditure, we conducted a Monte Carlo simulation with 10,000 iterations. The resulting outputs were incorporated into the estimation of the overall economic burden of MR (see below).

2.4. Outcomes of Interest

The following three outcomes of interest were derived using the following formulae and a Monte Carlo simulation with 10,000 iterations, with the parameters calculated and simulated as detailed in the methods above.

2.4.1. Economic Burden of Mouth Rot at the Farm Level

The farm-level economic burden of MR per production cycle was estimated by calculating the potential revenue forgone from MR-associated fish mortality and treatment expenditures. The model also accounted for feed-cost offset attributable to the reduction in fish numbers due to MR (Equation (8)).

$$C = (R_{MR} + T) - F_s, \tag{8}$$

where:
C: Economic burden of mouth rot at the farm level (USD);
R_{MR}: Direct revenue loss due to MR-associated fish mortality (USD) (see Equation (1));
T: Total treatment expenditure associated with MR (USD) (see Equation (6));
F_s: Feed-cost offset associated with MR mortality (USD) (see Equation (7)).

2.4.2. Farm-Level Economic Burden of Mouth Rot per Production Weight

The farm-level economic impact of MR per production cycle was then standardized to a unit cost per weight of fish produced. This unit cost was calculated by dividing the farm-level economic burden of the disease (see Equation (8)) by the total weight of fish produced over one cycle (Equation (9)).

$$C_u = C \div [\{N \times [1 - (M + M_{MR})]\} \times W], \tag{9}$$

where:
C_u: Economic burden of MR per unit weight of fish produced on farm (USD/kg);
C: Economic burden of MR at the farm level (USD);
N: Number of fish at the start of the production cycle (fish);
M: Total farm percent mortality, excluding MR-associated mortality, over the production cycle (%);
M_{MR}: Cumulative percent mortality associated with MR over the production cycle (%);
W: Average harvest weight per fish (kg).

Similar to MR mortality, non-MR mortality was modeled stochastically in ModelRisk using a lognormal distribution with a mean, minimum, maximum, and standard deviation derived from industry data (Table 1).

2.4.3. Economic Burden of Mouth Rot at the Industry Level

To estimate the industry-level economic burden of MR per year, we multiplied the farm-level economic loss due to MR estimate in our model (C from Equation (8)) by the total number of active Atlantic salmon farms (with smolts present) in the year and the proportion of farms affected by MR (Equation (10)). The farm-level burden generated by 10,000 iterations in our model simulations was, on average, representative of farms in BC.

Based on industry data from BC, Canada, during the years 2023 to 2025, there was an average of 25 farms at risk of MR, of which an average of 56% reported MR mortality events (Table 1) [14,15].

$$C_i = C \times (f_{MR} \times f), \quad (10)$$

where:

C_i: Industry-level economic burden of MR per year (USD);

C: Economic burden of MR at farm level (USD);

f: Average total number of Atlantic salmon farms (farms) in one year;

f_{MR}: Proportion of Atlantic salmon farms affected by MR.

2.5. Sensitivity Analysis

A one-way sensitivity analysis was performed using ModelRisk software to assess the influence of MR-associated mortality, total mortality per cycle, number of florfenicol treatments, smolt weight at entry, unit sale price of fish, drug price, and feed price on the model outcomes. A Monte Carlo simulation was executed with 10,000 iterations. The relative influence of the parameters on all three outcomes of interest (farm- and industry-level economic burden, and economic burden per production weight) was quantified and ranked visually using a Tornado chart, which mapped the change in the target output across the full range of each parameter distribution.

3. Results

3.1. Estimated Direct Revenue Loss from MR-Associated Mortality

The estimated forgone revenue from MR in our model simulations ranged from USD 0.10 million to USD 4.03 million, with a mean of USD 0.92 million (SD: USD 0.64 million) (Figure 1A).

3.2. Costs of Antibiotic Treatments

Based on industry data, we assumed that only florfenicol treatments were used to manage MR. For a fish population with an average weight of 0.21 kg (SD: 0.04 kg) (estimated using Equation (4) and the simulated smolt weight at entry), the total treatment costs ranged from USD 0–0.39 million, with a mean of USD 0.10 million (SD: USD 0.06 million) (Figure 1B).

3.3. Offset Effect of Avoided Feed Expenditures

Our model estimated avoided feed expenditure attributable to the reduction in biomass associated with MR-related mortality to be between USD 0.03 million and USD 1.22 million, with a mean of USD 0.28 million (SD: USD 0.20 million) (Figure 1C).

3.4. Economic Burden of Mouth Rot at the Farm Level

The simulated overall farm-level economic burden of MR per production cycle, based on our model which included forgone revenue from MR-associated mortality and antibiotic treatment costs, as well as the offset of avoided feed expenditure, ranged from USD 0.09 million to USD 2.97 million, with a mean of USD 0.74 million (SD: USD 0.45 million) (Figure 2A).

https://doi.org/10.3390/aquacj6030029

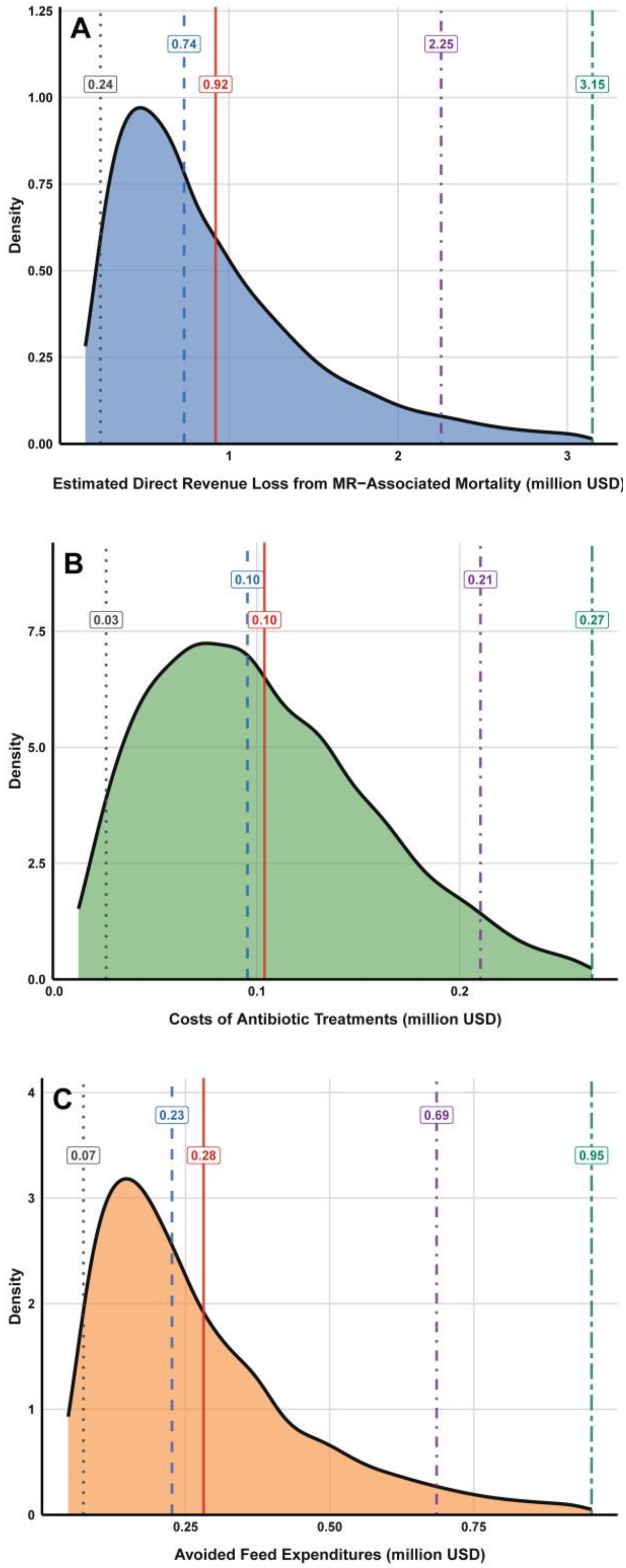

Figure 1. Probability density distributions generated from the Monte Carlo simulation for cost profiles of mouth rot parameters: (**A**) direct revenue loss from mouth rot mortality, (**B**) costs of antibiotic treatments, and (**C**) offset effect of avoided feed expenditures. Within each panel, five distinct statistical indicators from the underlying simulated population distributions are marked with vertical reference lines: the 5th percentile (dark gray dotted line), the median or 50th percentile (blue dashed line), the mean (red solid line), the 95th percentile (purple dash-dot line), and the 99th percentile (green long-dash line).

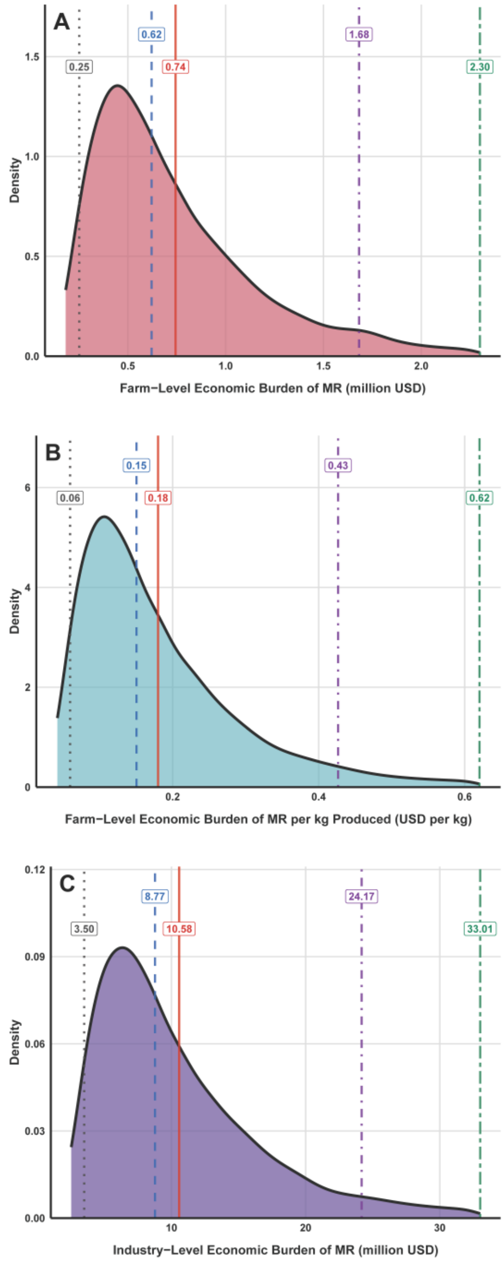

Figure 2. Probability density distributions generated from the Monte Carlo simulation for the overall economic impacts of mouth rot: (**A**) total farm-level economic burden, (**B**) farm-level economic burden per kilogram produced, and (**C**) industry-level economic burden. Within each panel, five distinct statistical indicators from the underlying simulated population distributions are marked with vertical reference lines: the 5th percentile (dark gray dotted line), the median or 50th percentile (blue dashed line), the mean (red solid line), the 95th percentile (purple dash-dot line), and the 99th percentile (green long-dash line).

3.5. Farm-Level Economic Burden of Mouth Rot per kg Produced

The economic burden of MR standardized to the unit cost per kg of fish produced during one cycle ranged from 0.02 USD/kg to 1.05 USD/kg with a mean of 0.18 USD/kg (SD: 0.12 USD/kg) (Figure 2B).

3.6. Industry-Level Economic Burden of Mouth Rot

The annual industry-level economic burden associated with mouth rot was estimated based on the farm-level selected direct cost burden generated from our model simulations and ranged from USD 1.39 million to USD 49.09 million, with a mean of USD 10.58 million (SD: USD 6.54 million) (Figure 2C).

3.7. Sensitivity Analysis

The sensitivity analysis revealed the primary parameter driving uncertainty across our economic outcomes was MR mortality (Figure 3). The other parameters also influenced our outcomes; however, their impact was far less than the MR mortality.

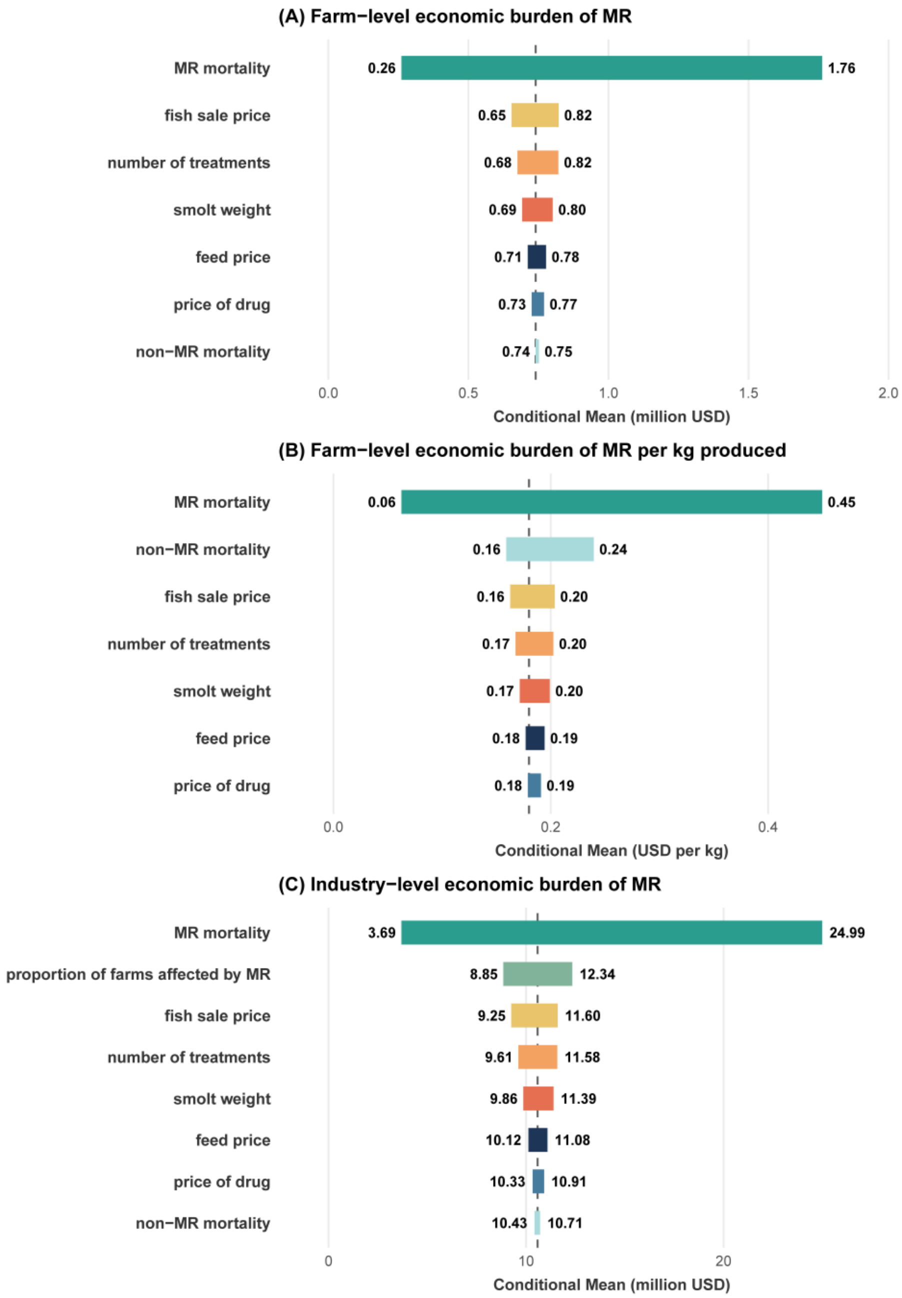

Figure 3. Tornado charts illustrating the sensitivity analysis across the three primary economic indicators: (**A**) total farm-level economic burden of mouth rot, (**B**) farm-level economic burden of mouth rot per kilogram produced, and (**C**) industry-level economic burden of mouth rot. The length of each horizontal bar represents the range of the conditional mean of the outcomes for the respective input parameter, with the upper and lower numerical bounds displayed at the margins of each bar. The vertical dashed lines denote the baseline mean estimates for each economic model, and the parameters are ordered hierarchically from highest to lowest influence on model variance.

https://doi.org/10.3390/aquacj6030029

4. Discussion

Mouth rot remains a significant challenge in Atlantic salmon aquaculture, particularly during the initial months following saltwater transfer. This disease is the primary driver of antibiotic use in the Pacific Northwest salmon industry. Substantial economic losses result from direct mortality and treatment costs [20]. To minimize antimicrobial use (AMU), effective disease prevention strategies are essential; however, identifying these requires a comprehensive understanding of the factors associated with the condition [1,21], which is costly.

Bridging the gap between scientific necessity and practical application requires a clear financial justification. As such, the economics of biosecurity and prevention strategies to address this issue are a key driver of individual behavior; therefore, economic modeling is an important component of behavior-change initiatives [22]. As little is known about the financial impact of mouth rot, we developed an economic model to simulate the economic burden of the disease. Our goal was to provide stakeholders with a user-friendly tool for estimating the cost of this disease at a farm and industry level for informing disease prevention and research resource allocation.

By quantifying economic losses, the model serves as an applied decision-support tool for different aquaculture stakeholders. For farm managers, it provides a means to estimate the return on investment of mitigation or prevention strategies against the expected disease burden. For veterinarians, the tool offers an empirical basis to support long-term antimicrobial reduction planning. Finally, policymakers and industry bodies can use the tool to prioritize research funding.

Based on our model simulation, the mean revenue loss from MR-associated mortality on a typical Atlantic salmon farm in BC was estimated at USD 0.92 million. The average costs of antibiotic treatments (mean: USD 0.1 million) and the offset costs of avoided feed expenditures (mean: USD 0.28 million), the total selected direct costs of MR per production cycle was estimated at USD 0.74 million. The most influential parameter in our model for the economic burden of MR was the MR mortality (Figure 3). The profound impact of this parameter on overall costs underscores the need for the industry interventions specifically targeted at reducing mortality from MR. This mortality can be impacted by a complex interplay of factors, including fish age and size, management practices, water quality (e.g., temperature at the time of susceptibility and salinity), and microbial dynamics, that influence the severity and progression of *T. maritimum* infections [1]. Not all these factors could be included in our basic economic model, but we added stochasticity around several parameters, including MR mortality, to capture some of this variation.

We also estimated the annual total economic burden of MR for the Atlantic salmon farming industry in BC. Utilizing active farm data from 2023–2025 [14,15], the mean provincial loss was estimated at USD 10.58 million. Relative to the CAD 513.82 million (USD 375.04 million, based on an exchange rate of 0.73 USD, retrieved from Google Finance on 25 April 2026) total value of BC salmon culture in 2024 [23], this would represent an annual loss of approximately 2.8%. This loss is significant in terms of overall industry profits, and validates research expenditures to improve the control of this disease.

While originally designed to estimate the costs of MR, this model could be adapted to other diseases. However, its framework is most robust for conditions like MR, where pathogen-related mortality is concentrated at the beginning of the seawater grow-out period rather than distributed across the entire production cycle. The latter would require estimations of losses over time and feed consumption during different parts of the grow-out period, and although these estimates could be modeled, it would complicate the tool.

Our model has a few limitations. While the primary direct costs of aquaculture diseases generally encompass biomass loss and expenditures on prevention, treatment, and non-veterinary resources, such as labor [6], this model did not account for the latter. Another limitation of this model was the assumption of uniform growth over the course of the grow-out period. In practice, infectious diseases in aquaculture often lead to reduced growth rates and impaired feed conversion efficiency, which increase production costs. As an example, our model subtracted the avoided feed expenditure due to MR mortality under the assumption that dead fish would have otherwise grown to harvest weight at a baseline FCR. This assumption may not hold if infected fish suffered from reduced growth or an altered FCR before dying, which could have skewed the calculated feed-cost offset associated with mortality. Mortality was also assumed to be uniform over the grow-out period; however, in reality, infectious diseases cluster in time. Consequently, the current economic estimates may represent a conservative baseline that does not fully account for the multifaceted biological impacts on farm-level productivity. However, in the case of MR, which occurs early in the saltwater grow-out cycle, this limitation may not be as significant as with other diseases that occur later in the production cycle. Furthermore, the treatment component of our model was simplified; due to a lack of empirical data on treatment outcomes, intervention was modeled solely as a direct financial cost and did not modify mortality rates, disease duration, or severity. Consequently, while the model captures the expenditure of treatment courses, it cannot quantify the corresponding economic benefits or clinical effectiveness of these interventions, representing an additional conservative boundary in our estimates. Additionally, applying an assumption that 50% of the dead fish had received treatment introduces a limitation as the actual proportion of treated mortalities can fluctuate between outbreaks.

Lastly, our industry-level extrapolation must be interpreted with caution. Although parameters like farm size and harvest weight tend to remain relatively fixed, uncertainties inherently exist for any modeling input. To capture this, we introduced stochasticity around several operational parameters to provide a larger range of possible costs. However, due to limited empirical data, we were unable to incorporate uncertainty across all dynamic variables, such as variations in FCR, production timing, and farm size. Consequently, our simulated typical farm may not be entirely representative of all affected BC farms, rendering the industry-level estimate an approximation. Furthermore, our estimate of the industry cost could have underestimated the true burden, as the prevalence of this disease was based on the DFO threshold reporting data, and not all MR outbreaks may have met this criterion.

Despite these limitations, a key strength of this model is its flexibility, allowing users to input site-specific data and customize parameters to their unique production environments. Given the results on the selected direct costs of MR under BC-specific assumptions, research should focus on quantifying the costs of preventive and control strategies for MR. This could be incorporated into the existing model to assist in estimating the return on investment for stakeholders.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/aquacj6030029/s1, File S1: Model with ModelRisk; File S2: Model without ModelRisk.

Author Contributions: Conceptualization, L.Y.Y., D.M.G., M.C. and S.S.-H.; methodology, L.J., L.Y.Y. and S.S.-H.; validation, L.J., L.Y.Y., D.M.G. and S.S.-H.; resources, S.R.; data curation, T.A.D.; writing—original draft preparation, L.J., L.Y.Y. and S.S.-H.; writing—review and editing, D.M.G., M.C. and T.H.C.; supervision, S.S.-H. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: As this manuscript does not involve any research on animals or human subjects, ethical approval from an Institutional Review Board was not required.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Acknowledgments: The authors have reviewed and edited the output and take full responsibility for the content of this publication.

Conflicts of Interest: The authors declare no conflicts of interest.

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