Study of the risk and protective factors for severe Septicemia Rickettsial Salmonídea (SRS) outbreaks in Atlantic salmon

This is a working synthesis prepared by Acuaim SpA in order to inform a Consultive Committee and was based on the original Report prepared by the Applied Ecology and Sustainability Centre at the Pontificia Universidad Católica de Chile in February of 2017.

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ABSTRACT

By means of a systematic and structured evaluation process undergone by various experts, it was possible to identify a total of 10 risk factors and 7 protection factors relevant in the development of severe SRS outbreaks. Antiparasitic baths and Cage fouling were shown to be the risk factors with the highest relative risk values, whereas Synchronized fallow periods and Timely diagnostics presented a greater importance for protection against severe SRS outbreaks. Knowing which risk and protective factors influence the development of severe SRS outbreaks is extremely relevant in the decision-making process for SRS sanitary management, especially in Atlantic salmon farming. Based on the results of this study, it was found that different interventions could be implemented and that various practical procedures for risk management could be improved, in order to pre-vent and control the most important infectious disease affecting farmed salmon in Chile.

INTRODUCTION

One of the most important aspects for the control and prevention of the disease is to know which risk and protective factors influence the development of severe SRS out-breaks. The present study seeks to identify, prioritize, validate and communicate a list of risk and protection factors for SRS at farming center level. This information is highly relevant for decision making in SRS sanitary management, especially for Atlantic salmon farming.

In general, the salmon industry has concentrated its efforts on the control of severe SRS outbreaks with the use of antibiotics and vaccines. The use of chemicals has allowed the industry to control the infectious outbreaks; however the use of antibiotics can pro-duce potential side-effects for human and environmental health.

The goal of this research is to identify, prioritize and validate risk and protection factors that help cause or prevent severe SRS outbreaks in Atlantic salmon farming centers, at farming center level. In addition, the goal is to share and diffuse the results of this multi-sectorial research experiment.

METHODOLOGY

An analysis of the qualitative risk for estimating potential impacts was carried out with a panel of experts. The selection of the participants for this panel was based on the following criteria:

1. The composition of a multi-sectorial panel: academia, industry and govern-ment.
2. The expert must have at least 5 years of on the field experience in farming centers concerning SRS management.
3. The expert must be a veterinarian.

Following these criteria, a multi-sectorial panel of 13 experts was formed, with 3 representatives from the academic sector, 3 government representatives (SERNAPESCA) and 7 industry representatives (health department managers from salmon farming companies).

The identification and prioritization of the risk factors was carried out following the Delphi technique. This methodology is based on individual estimations and discussion rounds. The experts discuss their points of view regarding the results obtained in the study, anonymously and afterwards adjusted or maintained their initial values.

Firstly, a set of risk and protection factors for the development of severe SRS outbreaks were pre-identified, as for other salmon diseases, based on a bibliographic review, on previous reports from the researchers of this study and on individual interviews with the panel of experts who incorporated factors that had not been previously considered.

A preliminary list with 47 risk and protection factors was defined and sent to each expert, in order for each expert to select the 20 most important factors for the development of severe SRS outbreaks.

The team of researchers decided to pre-select all of the factors that were selected by at least 4 experts among the 20 most relevant ones. A new list of a total of 17 risk and protection factors was defined.

	Description	Type	Factor category
Cage fouling	Lack of adequate maintenance and/or replacement of fish nets	1	Sanitary
Antiparasitic baths	Number of antiparasitic baths before the first outbreak.	2	Sanitary
Mortality elimination	High biosafety conditions in mortality elimination (stricter than the established regulations)	1	Biosafety
Stock season	Season of the year in which the seeding was carried out (during the summer, the climatological conditions favor the development of diseases)	1	Productive
Proximity to a farming center with SRS	Proximity to a farming center that is going through a severe SRS outbreak (measured in kilometers)	2	Productive
District farming center density	Density of the active farming centers in the district (number of centers in a 5 kilometer ring)	2	Productive
Synchronized fallow periods	Synchronizing the fallow periods in a particular farming center with the break period of the rest of the farming centers in the district.	1	Productive

	Description	Type	Factor category
Productive elimination	Active (daily) elimination of maladjusted and lagging fish, which could act as reservoirs for diseases.	1	Productive
Sea lions	Sea lion attacks in the farming centers (the poor state of the sea lion netting was used as an indicator)	1	Depredation
SRS records in farming centers	The presence of SRS in previous productive cycles (the 2 last productive cycles are considered)	1	Sanitary
Mature fish	Presence of relatively high levels of early mortalities of Mature fish (about 1.5 kg of weight)	1	Productive
Timely diagnostic	The capacity of timely or early SRS diagnosis (clinical-laboratory).	1	Sanitary
Caligus	High caligus re-infestation in a farming center.	1	Sanitary
Current circulation	Marine current conditions and optimal oxygen levels for fish.	1	Oceanographic
Farmed fish	The number of farmed fish, in two cage units with 30x30 meter metallic structures.	2	Productive
Adequate use of vaccines	Rigorous application of the recommendations of vaccine producers concerning accumulated thermal units (ATU) for farming.	1	Sanitary

Table 1: List of identified and selected risk and protection factors for the development of severe SRS outbreaks, among the most relevant factors (in the type column, 1 = nominal variable, 2 = continuous variable).

This list initiated the prioritization process for the different factors, followed 6 steps:

1. **Individual interviews with each expert:** The goals, methodology and the expert's role were indicated and explained to each expert. The questionnaire and the format of the outlined questions were also described.

2. **Individual estimates by means of an email survey:** The experts individually an-swered the questionnaire that was sent to them. The experts indicated the least plausi-ble number for each question, as well as the most plausible number and the best conjec-ture.

3. **Face-to-face group workshop with the panel of experts:** The experts meet face-to-face to debate and analyze the available evidence in order to justify their estimates.

4. **Second round of individual estimates:** The second round of estimates is carried out individually and privately, once the group workshop is finished.

5. **Third round of individual estimates:** The analysis of the estimates of the factors with continuous variables allows for the establishment of a threshold on which the probability of developing a severe outbreak increases (or decreases, depending on the case). Once the threshold value has been determined, probability questions are posed for each factor in a new round of estimates.

6. **Validation:** Individual interviews with 10 of the 13 experts were carried out. A workshop with representatives from SERNAPESCA and SUBPESCA was also realized, where various comments and observations were noted.

   For the analysis and prioritization of the risk and protection factors, 3 measures were used to quantify the impact of each factor on the probability of developing severe SRS outbreaks:

   a. **Odds ratio:** This is a statistical measurement that allows for the identification of the associativity level between the existence of one feature and another in a certain study. In this study, it was used to discover the associativity between a certain factor and the probability of developing severe outbreaks. To calculate it, one compares the quotient of the quantity of severe outbreaks over minor mortalities in the presence of the factor in question, with the same quotient but without the presence of the factor.

b. **Relative risk:** Relative risk helps recognize how much the presence of the factor impacts the probability of the occurrence for a negative scenario. The relative risk has values from 0 to infinite. If its value is higher than 1, then the existence of the factor increases the probability of the occurrence of a negative scenario. Probability increases more as the relative risk is higher. In these cases, the factor is recognized as a risk factor. If the relative risk is lower than 1, then the existence of the factor diminishes the probabilities of the negative scenario from occurring. The lower the relative risk, the greater the decreasing of this probability. In this case, the factor is recognized as a protective factor. If the relative risk has a value of 1, the presence of the factor does not have any relationship with the occurrence of the evaluated scenario.

c. **Absolute Risk Increase/Reduction (ARI/ARR):** This is a measurement derived from relative risk that calculates the percentage change, in absolute terms, that occurs in the number of individuals in the scenario in question when the factor is or is not present.

RESULTS

A set of risk and protective factors were identified at farming center level that have a high relevance in the development of severe SRS outbreaks in Atlantic salmon.

Figures 1 and 2 present the risk and protective factors ordered according to their relative risk value.

Specifically, 10 risk factors with a high relevance were identified, having a high probability that these factors encourage severe SRS outbreaks in Atlantic salmon farming centers, at farming center level. Among them, the factors with the highest strength of association (relative risk > 3) were higher frequencies of antiparasitic baths and cage fouling management in farms.

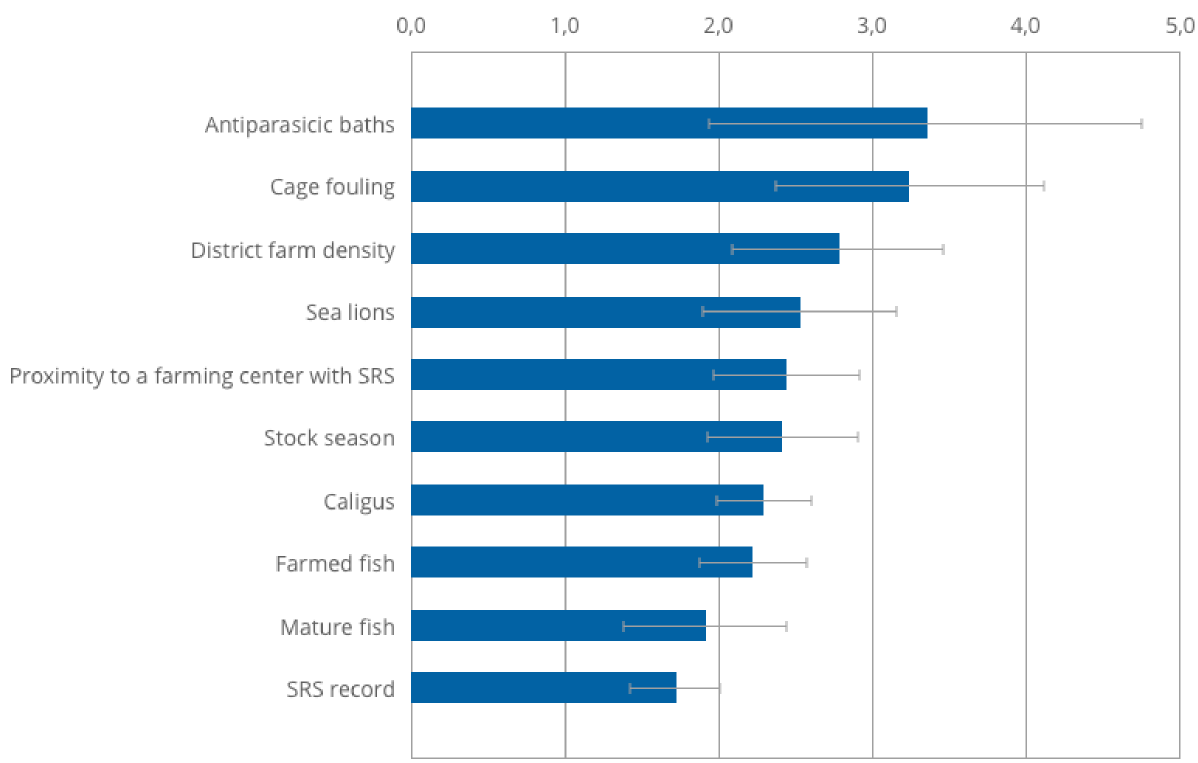

Figure 1: Risk factors ordered according to their relative risk value. Confidence intervals of 95% are shown.

Seven protective factors in severe SRS outbreaks were identified, with relative risk values varying from 0.42 to 0.77. The Synchronized break and Timely diagnostic factors presented the highest significance in terms of protection against severe SRS outbreaks.

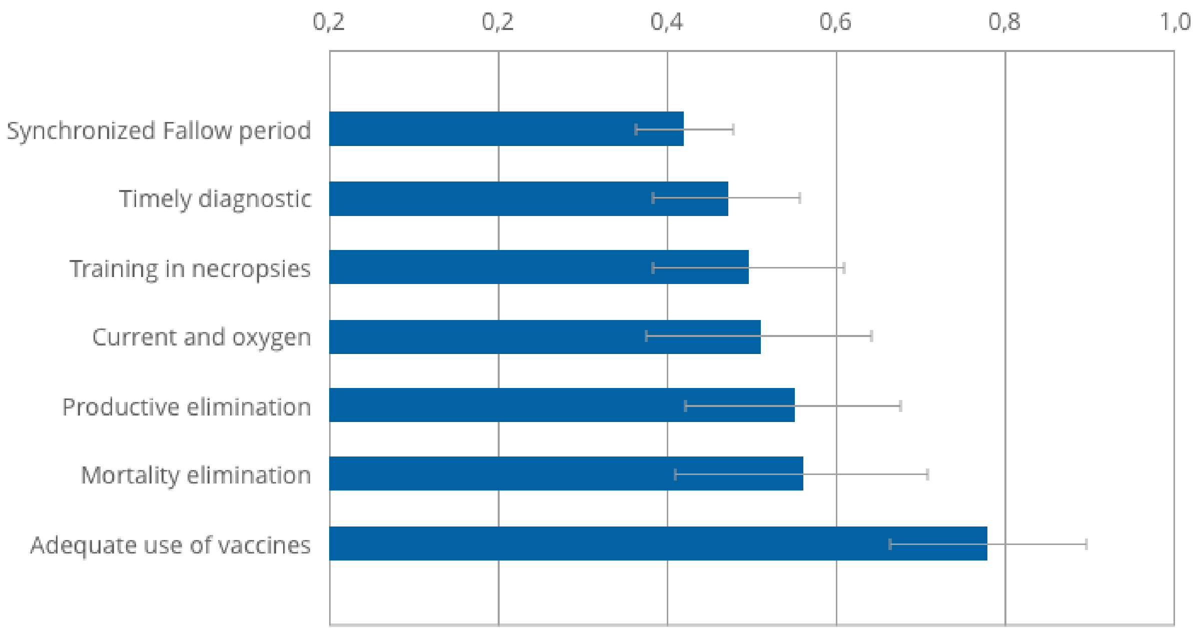

Figure 2: Protection factors ordered according to their relative risk value. Confidence intervals of 95% are shown.

Tables 2 and 3 show the relative risk, odds ratio and ARI/ARR values calculated for each factor based on the goup average in the second round of estimates. The standard deviation is shown between parentheses beside each result.

As was indicated in the methodology, the relative risk value indicated the amount that the probability of the development of a severe SRS outbreak increases in the presence of each factor. The odds ratio indicates the quotient between severe outbreaks and minor mortalities in the presence of a certain factor. Lastly, the ARI/ARR value shows the extent to which the probability of having a severe outbreak increases.

	Relative risk	Odds ratio	Absolute risk increase/reduction (ARI/ARR)
Antiparasitic baths	3,34 (SD= 2,10)	10,71 (SD=10,78)	42% (SD=19%)
Cage fouling	3,24 (SD= 1,45)	11,38 (SD=8,53)	49% (SD=11%)
District farm density	2,77 (SD=1,02)	9,43 (SD=5,57)	46% (SD=13%)
Sea lions	2,53 (SD=1,06)	6,44 (SD=4,45)	38% (SD=14%)
Proximity to a farming center with SRS	2,44 (SD=0,71)	6,63 (SD=4,08)	40% (SD=12%)
Stock season	2,41 (SD=0,77)	6,01 (SD=3,92)	38% (SD=12%)
Caligus	2,30 (SD=0,50)	5,13 (SD=2,31)	36% (SD=10%)
Farmed fish	2,22 (SD=0,52)	5,04 (SD=2,40)	36% (SD=9%)
Mature fish	1,91 (SD=0,88)	4,36 (SD=4,15)	27% (SD=17%)
SRS record	1,72 (SD=0,48)	3,18 (SD=1,61)	24% (SD=14%)

Table 2: Average values for relative risk, odds ratio and absolute risk increase/reduction for each risk factor.

In the case of protection factors, the relative risk value is inferior to 1. The higher its value, the stronger the protective power of the factor. The value of 1/relative risk indicates how much the probability of not having a severe outbreak increases.

	Relative risk	Odds ratio	Absolute risk increase/reduction (ARI/ARR)
Synchronized Fallow period	0,42 (SD=0,13)	0,18 (SD=0,11)	42% (SD=11%)
Timely diagnostic	0,47 (SD=0,14)	0,21 (SD=0,13)	40% (SD=13%)
Training in necropsies	0,50 (SD=0,24)	0,28 (SD=0,28)	37% (SD=20%)
Current and oxygen	0,51 (SD= 0,2)	0,29 (SD= 0,20)	35% (SD=18%)
Productive elimination	0,55 (SD= 0,21)	0,34 (SD=0,27)	31% (SD=17%)
Mortality elimination	0,56 (SD=0,25)	0,37 (SD=0,29)	32% (SD=21%)
Adequate use of vaccines	0,78 (SD=0,19)	0,62 (SD=0,33)	15% (SD=14%)

Table 3: Average values for relative risk, odds ratio y absolute risk increase/reduction for each protection factor.

Result validation

Hereafter the results of the validation process will be presented, during which 10 of the 13 experts were interviewed, in order to analyze in detail the results for each factor. Some factors did not have any observations during the validation phase.

Antiparasitic baths: An expert brought up a question regarding the possible association between antiparasitic baths and severe SRS outbreaks mediated by the time variable. The expert initiated a discussion on how to establish associations between the caligus factor and the antiparasitic baths factor.

Cage fouling: The experts agree that this factor is very important. The necessity for designing a quantitative indicator concerning what cage fouling comprehends was brought up. There is no consensus regarding the specific impact of the cage fouling fac-tor that encourages severe outbreaks. The following possible impacts are noted:

a. Mechanic obstruction that blocks the marine current circulation, reducing the availability of oxygen.

b. The possibility that the organisms present in cage fouling act as reservoirs for Rickettsia bacteria.

The question regarding which strategy is the most adequate one for reducing cage fouling is considered: in-situ net cleaning or rather changing the nets. During the summer, there are very few days during which the nets stay clean from fouling, in fact every 15 days one can find severe obstructions in these nets. This is an example of a productive management decision that has a direct impact on the sanitary field.

District farm density: The necessity to evaluate all of the factors associated with the loading capacity was discussed. In this sense, the impact of the farm density per district is related to the number of farmed fish in each sector.

Sea lions: The difficulty of correctly evaluating this factor was discussed. Different approaches were proposed, such as the number of attacks, number of sea lions or the distance from the farming center to the sea lion breeding grounds. However, there is no available information for any of these variables.

Another element that was discussed concerned the possibility that the presence of sea lions would generate stress in the fish. This would occur independently, no matter the state of the sea lion nets. Moreover, it was discussed that there would be few sea lion attacks before the first outbreak since the attacks happen in intermediate stages of the productive cycle. Lastly, the inclusion of bird depredation was discussed, which hap-pens early on in the cycle.

Caligus: Some experts considered that the negative impact of the caligus factor was closely related to the bath frequency. The available information did not allow for the quantification of other more direct measurements or continuous variables, such as for example infection density. It is therefore possible that the results are double if this factor is included (Caligus and antiparasitic baths).

Farmed fish: The association between farmed fish and the density of farmed fish was highlighted. The number of farmed fish is considered a more useful indicator in this case. Fish density has a greater effect as the productive cycle advances, but does not have much effect in the first 5 or 6 months.

Mature fish: It is relevant to clarify that an early presence does not refer to post-entry. On the other hand, the appearance of mature fish when the fish weigh approximately 1,5 or 2 kg is relevant, especially because mature fish can be SRS reservoirs when they do not ingest food. This factor is related to smolt quality.

SRS record: The need for clarifying the association between the SRS record factor and the absence of appropriate sanitary fallow period is brought up. In this sense, if the break is long (longer than 3 months) as is indicated by the current regulations, the factor would not be relevant. In the case that the factor is still relevant despite respecting the break periods, the relationship between this factor and current circulation would have to be evaluated. On this matter, the recurrence of the disease could be related to oceanographic conditions.

Synchronized breaks: This factor does not consider the potential risk of the seed window/ frame, which is included and understood by the Synchronized breaks factor. For example, if seeding is carried out during the two limits of the accepted period according to regulations, it is unclear whether this could increase the probabilities of severe outbreaks.

Current and oxygen: It was suggested to consider the Current and oxygen factor as a given. This is a factor that determines certain conditions that are impossible to manage at farming center level (it is only possible to intensify the control measures). This is rather defined by district selection. The assumption is that optimal conditions do exist, such as good salinity conditions and oxygen circulation.

Communication and diffusion of the results and of the collaborative research experience

The most important points to communicate are the two following points:

1. This study presents the first prioritization of risk and protective factors for the development of severe SRS outbreaks.

2. The research process was based on a collaborative model between academia, the industry and the government.

In order to achieve this goal, a proposal for a brochure of this project was designed. The content of the brochure highlights the methodology, results and future challenges. This material is intended to be distributed to the public related with Atlantic salmon research, production and administration.

DISCUSSION

A total of 17 relevant factors for the development of severe SRS outbreaks were identified based on a systematic and structured evaluation process by experts. Of all of the variables, 10 factors were classified as risk factors and 7 as protection factors.

Some risk factors (SRS background and Mature fish) and protective factors (Adequate use of vaccines) have a moderate association with the development of severe outbreaks. Almost half of these factors increase the risk of severe outbreaks at a structural level, meaning that they are conditions that are inherent to the salmon industry and to the environment, and which would require the development of public and private health policies.

The Proximity to a framing center with SRS, District farm density, Current and oxygen, Caligus and Sea lion factors are related to the location of the farming centers, which could be considered useful for the characterization of salmon regions. It is important to characterize the distribution of the sanitary risk (for example by means of a risk indicator) and to define high and low risk zones. This spatial risk characterization would help the definition of management plans, risk based surveillance and monitoring, leading to a more efficient system.

One of the factors that presented the highest association with severe mortality risk was the antiparasitic bath practice. In addition to the identification of a higher parasitic load as a risk factor and to a higher concentration of farming centers in ACS, these results shed light on density-dependent processes for the SRS-caligus complex. Specifically, the rate of contact between susceptible individuals (salmon, cages or farming centers) and infected ones depends on the density (number of fish, number of farming centers per district), and in this sense the transmission rate increases as the density increases.

Another interesting variable is associated with relatively high early mortality levels for mature fish, at the moment when the fish weigh approximately 1,5 and 2,0 kg. There is evidence in scientific literature that indicates that sexually mature fish are more susceptible to certain diseases than sexually immature fish.

During this study, it was possible to observe that the fish that entered the fattening stage between summer and autumn had a higher risk for an outbreak. This is related to the effect of the water temperature on a higher reproduction rate for the caligus parasite and a greater survival of P. salmonis. Unfortunately, seeding during the summer and autumn is unavoidable because of commercial reasons and because of the species' characteristics; however, fish seeding in geographic zones with lower temperatures could be much more advantageous.

Productive elimination and mortality elimination are two factors that would diminish the probability of developing a severe SRS outbreak.

Productive elimination is related with the elimination of fish that are not productively viable, with a lower performance over time and an abnormal appearance. It was hypothesized that normal salmon have been fed pellets in an optimal way, but that fish that are not productively viable eat anything in order to survive. In this sense, the productively unviable fish could act as SRS reservoirs and their elimination would serve as a protec-tion factor.

For the case of the elimination of mortalities, fish considered as having a higher risk of contracting SRS are discarded, including dying fish. The objective of this is to minimize the infectious population that can spread the infectious agent and to shorten the infectivity period.

In both cases, it is important to determine at which level of this associated practice would the effort of controlling SRS in terms of time, human resources and eventual costs associated with the loss of biomass be justified.

Finally, the experts recognized the benefit of timely diagnostics and the personnel training in the evaluation of necropsies in the field. As shown in Figure 3, at a secondary intervention level these protection factors follow a fundamental principle, being that an early detection allows for a more efficient treatment and therefore allows for an increase in the probability of the recuperation of the specimen to an overall healthy state, with a reduc-tion in productive losses.

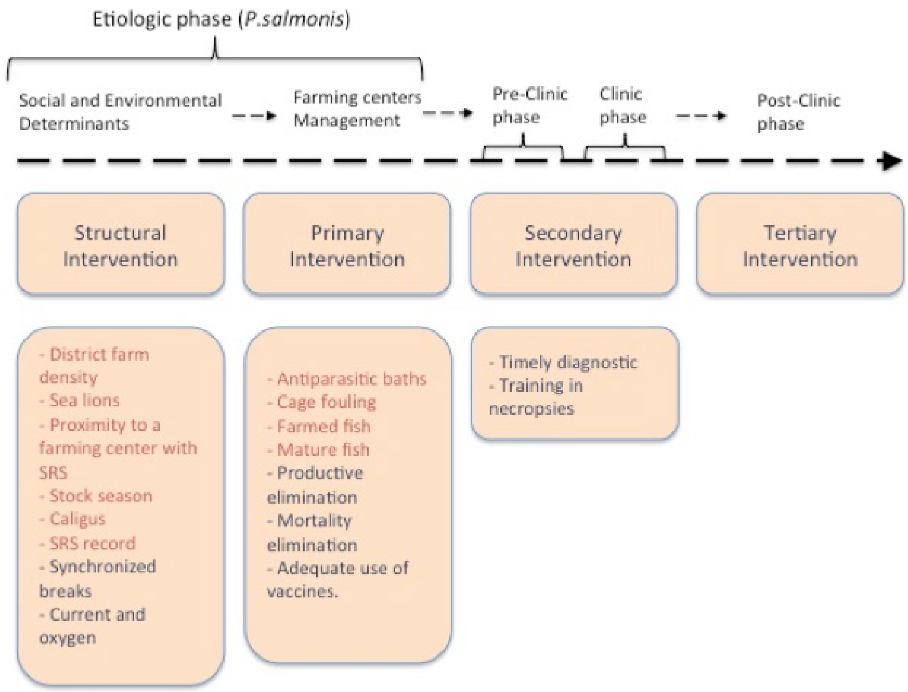

Figure 3: Risk factors (red) and protection factors (black) according to the different intervention levels for P. salmonis.

RECOMMENDATIONS

The fundamental recommendation from a decision-making point of view is to consider the results of this Project as part of a risk management cycle. When reviewing the results obtained in this study, it is important to apply certain techniques and protocols for risk management.

Various points should be addressed as a continuation of the present study:

- Analyzing the interactions between risk and protective factors.
- Promoting new studies in epidemiology and risk management for identifying and evaluating management strategies.
- Establishing indicators such as risk score or risk ranking per geographic area, district or center.
- Evaluating the interaction and causal link of the risk and protection factors by means of regression analysis and data modelling.

CONCLUSIONS

Through expert opinions and scientific literature, this study has identified 17 risk and protective factors, in addition to a series of recommendations for establishing management mechanisms that could increase the quantity and quality of new information, as well as improve practical procedures for health management in order to prevent and control the most important infectious disease affecting farmed salmon in Chile.

The recommendation is implement a risk management phase, during which other types of strategies could be applied. These initiatives are developed at a local scale, such as pilot experiments that are afterwards used to define management policies. Once the re-sults of the study are satisfactory, it will be possible to continue and implement a second management level for districts or for a set of farming centers.

It is necessary to develop pilot experiments that demonstrate innovative ways of manag-ing farming centers.

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PROGRAMA
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