

INTRODUCTION OF *GYRODACTYLUS SALARIS* TO THE TANA RIVER : A QUANTITATIVE RISK ANALYSIS

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Gyrodactylus salaris est un monogène ectoparasite des Salmonidés d'eau douce qui provoque d'importantes pertes chez le saumon atlantique, tant en milieu naturel qu'en élevage. Reconnu en Norvège pour la première fois en 1995, le parasite a été détecté à ce jour dans 40 cours d'eau et 37 piscicultures. On a pu montrer une association entre le repeuplement des rivières par des saumons provenant de fermes infestées et la dynamique d'apparition du parasite. Du fait de la gravité économique et de l'impact en milieu naturel de cette parasitose, des méthodes de lutte et des réglementations destinées à limiter sa propagation et assainir les rivières ou les établissements infestés ont été instituées. D'ores et déjà, 22 des cours d'eau et 36 des élevages atteints ont pu être assainis.

La rivière Tana, au nord de la Norvège, l'une des plus belles rivières à saumons d'Europe, est indemne de *G. salaris*. Il n'existe actuellement qu'un seul élevage de saumons dans le fjord, mais une nouvelle implantation est en projet. Compte tenu de la liaison évoquée entre le repeuplement par des saumons d'élevages infestés et la propagation de *G. salaris*, on pouvait craindre que l'une ou l'autre de ces fermes puisse favoriser l'introduction du parasite dans le fjord de Tana, entraînant des pertes dans les populations naturelles et les effectifs d'élevage. Une analyse de risque a été entreprise pour tenter d'apporter des réponses à ce problème.

Les résultats montrent que la faible prévalence du parasite dans les eaux norvégiennes et dans les populations de smolts, ainsi que les mesures de surveillance actuellement instaurées, se combinent pour minimiser très fortement les risques d'introduction de *G. salaris* dans la rivière Tana. Les types de scénarios possibles, le modèle d'analyse et les résultats des simulations sont présentés et commentés.

INTRODUCTION

Gyrodactylus salaris (Monogenea) is an ecto-parasite of the salmonids that if introduced causes significant losses in both wild and farmed Atlantic salmon presmolt stocks. The parasite was first reported in Norway in 1975 and to date it has been found in 39 Norwegian rivers and 37 salmon farms. An association between the stocking of rivers from infested farms and the geographical distribution of the parasite has been demonstrated (Johnson and Jensen, 1986). Because of the serious economic and environmental impacts of the parasite, several procedures and regulations have been instituted in efforts to prevent the further spread of the parasite and to eradicate the parasite from infested rivers and farms. As a result, 21 of 39 infested rivers and 36 of 37 infested farms are now not infested.

The Tana river in northern Norway is free of *G. salaris*. Currently, there is one salmon farm in operation on the fjord but one additional farm is contemplated. Because of the association between new infestations with *G. salaris* and the stocking of rivers with salmon from infested farms, there is national and international concern that the existing farm or the planned farm might lead to the introduction of the parasite to the Tana river. In response to these concerns a quantitative analysis of the risk of introduction of *G. salaris* to the native Tana river salmon was undertaken.

METHODS

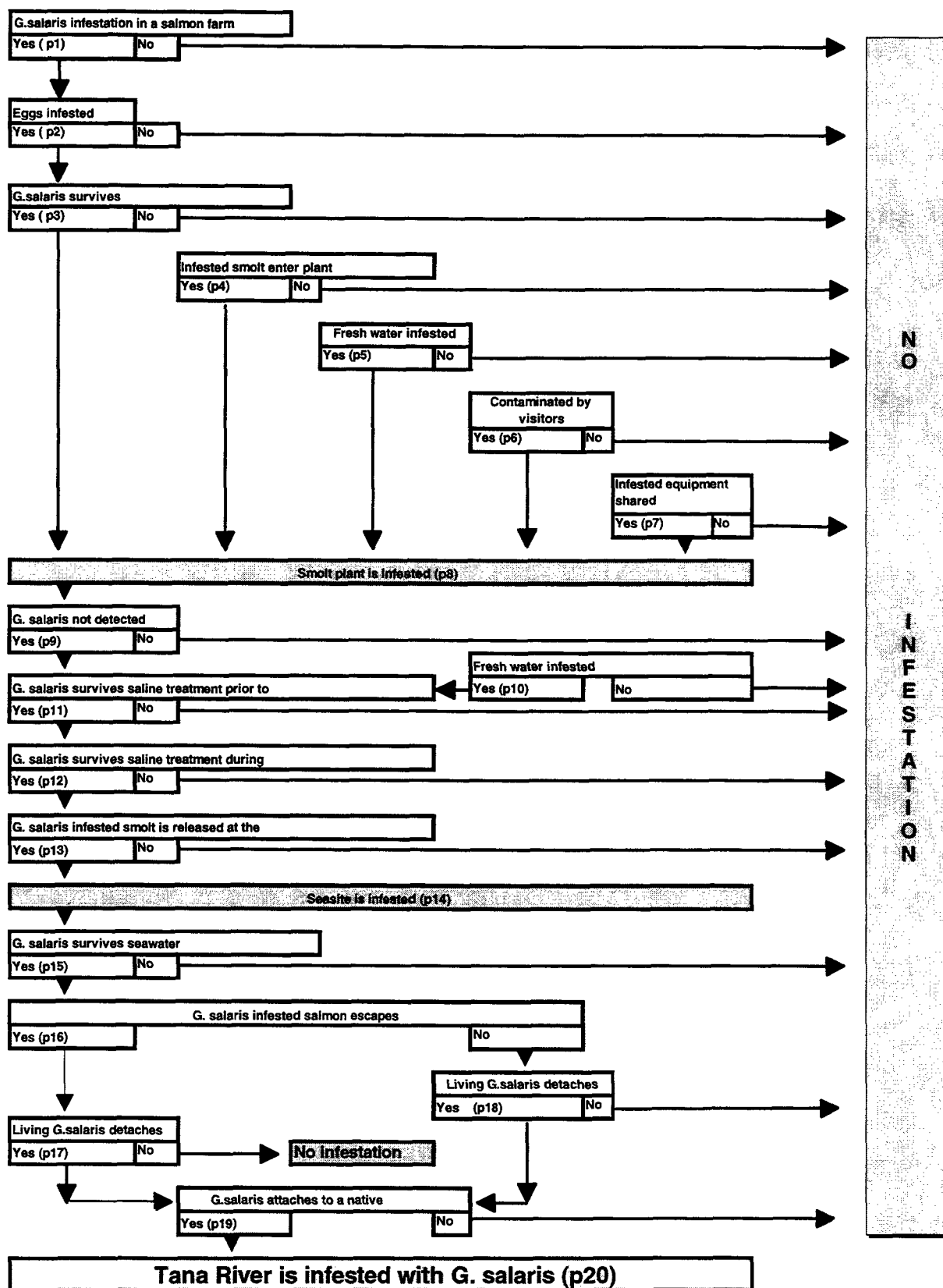
A scenario tree depicting the events that would have to occur in order for *G. salaris* to be introduced to the Tana River was constructed (Figure 1). The following variables and probabilities were used to construct a spreadsheet Monte Carlo simulation model: (Vose, 1996; Winston, 1996)

- p1 = the probability of a *G. salaris* infestation in a salmon egg or smolt source farm.
- p2 = the probability that *G. salaris* infested eggs enter the smolt plant.
- p3 = the probability that *G. salaris* survives disinfectant treatment in the smolt plant.
- p4 = the probability that *G. salaris* infested smolt enter the smolt plant.
- p5 = the probability that *G. salaris* infested fresh water enters the smolt plant.
- p6 = the probability that visitors contaminate the smolt plant with *G. salaris*.
- p7 = the probability that equipment contaminates the smolt plant with *G. salaris*.
- p8 = the probability that the smolt plant becomes infested.
- p9 = the probability that *G. salaris* is not detected during routine health control in the smolt plant.
- p10 = the probability that fresh water used for saline treatment is infested.
- p11 = the probability that *G. salaris* survives saline treatment in the smolt plant.
- p12 = the probability that *G. salaris* survives saline treatment during transport to the sea site.
- p13 = the probability that *G. salaris* infested smolt are released at the sea site.
- p14 = the probability that the sea site is infested by *G. salaris*.
- p15 = the probability that *G. salaris* survives the salinity of sea water at the sea site.
- p16 = the probability that *G. salaris* infested salmon escapes from the net.

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Figure 1
Scenario tree for the introduction of *G. salaris* to the Tana River



p17= the probability that a living *G. salaris* detaches from an infested escaped salmon.

p18= the probability that a living *G. salaris* detaches from an infested captive salmon.

p19= the probability that a living *G. salaris* attaches to a native salmon.

p20= the probability that Tana River is infested with *G. salaris*.

The total probability (risk) of infestation of the Tana River by *G. salaris* was calculated as follows:

Risk that the smolt plant will be infested (p8)=(p1*p2*p3)+p4+p5+p6+p7.

Risk that the sea site will be infested (p14)=(p8*p9*p11*p12*p13)+(p10*p11*p12*p13).

Risk that the Tana River will be infested (p20)=(p14*p15*p16*p17*p19)+(p14*p15*(1-p16)*p18*p19).

The model was developed with @Risk software (Palisade Corporation, Newfield, NY). The probabilities were represented in the model by estimates or probability distribution functions based on values obtained from the literature, experimental data and expert opinion. The sampling method was latin hypercube and the Standard Recalc was set to Monte Carlo. One of the critical assumptions in the model was that the smolt would be treated in saline prior to transfer to the sea site. However, since the saline treatment might not be done, this possibility was incorporated into the model. In Simulation 1, the smolt were treated in saline. In Simulation 2, the smolt were not treated in saline. Each Simulation was run 10,000 iterations.

RESULTS

The results are presented in Table I. Simulation 1 is with saline treatment of the smolt prior to transfer and Simulation 2 is without saline treatment.

Table I
The total risk of Introduction of *G. salaris* to the Tana River

	Minimum	Mean	Maximum	Standard Deviation
Total risk per year: Simulation 1.	0	1.23E-07	4.50E-06	3.88E-07
Total risk per year Simulation 2.	0	1.70E-07	6.00E-06	5.30E-07

The results show that the risk of infestation of the Tana River by *G. salaris* via introduction of salmon smolt to a sea site is extremely low. In Simulation 2, when saline treatment was not done, the maximum risk calculated in any of the 10,000 iterations was 6.0 E-06. This is equivalent to the expectation of 1 outbreak per 166,667 years.

DISCUSSION

A stochastic simulation model of the risk of introduction of *G. salaris* to the Tana River was constructed. The data used in the calculations were derived from the literature, unpublished experimental and expert opinion. Where possible, probability distribution functions were substituted for fixed probabilities. The advantage of using probability distribution functions, in lieu of fixed probabilities, is the ability to utilize the uncertainty inherent in any estimate to better represent the situations found in nature.

The variables with the highest correlation with the overall risk, in rank order, were the number of infestations per year, the salinity at the sea site, the probability of an outbreak in an egg source farm and the probability that a living *G. salaris* detached from an infested, escaped salmon.

Treating of the smolt in saline prior to transfer to the sea site, or not, one of the risk reduction measures that has been put into practice, was modeled as 2 simulations. All other variables in the model changed according to their respective probabilities or probability distributions. Sensitivity analysis of the effect of saline treatment suggests that it did not greatly reduce the overall risk.

This model incorporated measurements of the salinity of the sea water in the Tana Fjord during the period when the smolt are normally released. The salinity data were combined with data on the maximum survival time of *G. salaris* at various water temperatures and salinity levels to generate probability distributions of the survival times of *G. salaris* in relation to the time of escape from the net or detachment and falling to the bottom and the likelihood of living parasites at those times. The salinity of the sea water had the second highest rank correlation with the total risk in both simulations.

The results of this analysis suggest that the risk of introduction of *G. salaris* to the Tana River via the transfer of smolt from this specific smolt plant is very small.

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