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The use of a general linear model to identify epidemiological factors affecting the abundance of chalimus stages of the sea louse (*Lepeophtheirus salmonis*) on Scottish salmon farms

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Summary

In this communication chalimus lice numbers in the second, third and fourth quarters of the production cycle are examined in relation to a range of prevailing risk factors using an approach based on that already taken for mobile stages (Revie et al. *in press*). A total of 54 two-year production cycles from 29 farms on the West Coast of Scotland were analysed. Chalimus levels in the second six-month period of the first year of the production cycle were principally explained (adjusted R^2 = 56% of the variation) by: the number of veterinary medicine treatments administered, the site hydrography and current speed characteristics. Sites with a high chalimus abundance attracted more treatments as did fish located in sites with low current speeds and an oscillatory hydrography. In contrast, chalimus levels in the third six-month period of the production cycle were principally explained (adjusted R^2 = 65% of the variation) by: the abundance of mobile and chalimus stages in the preceding six-month period and treatment. It would appear that there are both management and environmental factors which affect the number of chalimus sea lice on fish in Scottish salmon farms and these have an impact on overall sea lice abundance.

Introduction

Sea lice infections are a ubiquitous and continuous threat to the aquaculture industry, and in particular to salmon farming. In recent times, the most damaging species in European waters has been *Lepeophtheirus salmonis*. Most farms now operate lice monitoring programmes to determine when and how best to treat infected fish.

The infective copepodid stage is followed by the attached chalimus stages which then moult to pre-adult and adult stages. Abundance, measured as number of lice observed per sampled fish, changes according to the stage of the production cycle. During a typical two-year production cycle on a Scottish salmon farm low levels of infection are seen in the first six-months of the cycle, followed by a notable increase in abundance in the second and third quarters. For fish not harvested until the final quarter, the number of chalimus and adult lice can increase exponentially. Although control may be achieved using a range of veterinary medicines a better understanding of the management, environmental and biological factors which predispose production sites to elevated levels of infection is required to understand population drivers, to improve control strategies and to develop effective integrated pest management.

In this communication chalimus lice numbers in the second, third and fourth quarters of the production cycle are examined in relation to a range of prevailing risk factors using an approach based on that already taken for mobile stages (Revie et al. *in press*).

Materials and methods

A total of 54 two-year production cycles from 29 farms on the West Coast of Scotland were analysed. Production cycles spanned a period of two years and, for the period 1996 to 2000, the abundance of the chalimus stages was based on counts from 20 to 30 fish, with five fish randomly sampled from each of 4 to 6 cages weekly. Sites were managed by Marine Harvest with detailed information being held on the **SULLepsiS** [**S**trathclyde **U**niversity **L**INK **Leps i**n **S**almon] database (Revie et al. 2002). This database includes information on site environmental factors such as current speed, flushing time for the loch/bay, dominant hydrographical pattern, mean winter or summer water temperature; and site management factors such as presence of bad neighbours, number and types of treatment, stocking density, biomass level, volume of cage and duration of fallowing. Each factor was explored as a potential correlate of risk for high levels of chalimus. A linear modelling approach was adopted with chalimus levels being statistically screened for evidence of any significant differences ($p < 0.20$) between low and high levels of the risk factors. Those factors found to be significant in the screening were included in a multiple regression linear model (Steel & Torrie 1980) along with the mean numbers of chalimus and mobile *L. salmonis* in the preceding six-month period as covariates. This led to the identification and combination of significant factors that accounted for the variation in chalimus levels.

In order to simplify the analysis of repeated measurements over time in production cycles, only the average of the weekly chalimus abundances observed in the second six months of the first year i.e. the period July to December (Chal_1.2), the average abundances in the first six months of the second year of the production cycle (Chal_2.1), and the average abundances in the final six months (Chal_2.2) were used. To address statistical propriety in the regression analyses, the logarithmic transformation of the mean weekly abundance was chosen as the dependent variable.

Results and conclusion

A large number of candidate factors were identified for inclusion in the general linear model. While these varied according to stage in the production cycle, the factors included: presence of bad neighbours, frequency of treatment, type of veterinary medicine, was ‘strategic’ treatment adopted?, cage volume, current speed, dominant hydrographic pattern, summer water temperature, flushing time for entire loch/bay, stocking density, and numbers of chalimus and mobile *L. salmonis* in preceding six month period.

Following stepwise regression a subset of significant risk factors for chalimus levels at each stage of the production cycle emerged, as shown in Table 1.

Table 1 Factors included in stepwise regression of *L. salmonis* chalimus abundance at each stage of the production cycle

Stage of production	Factors identified by model	Adj. R^2
2nd six months of year 1 (Chal_1.2)	Frequency of treatment; Dominant hydrographic pattern; Current speed at farm	56.2%
1st six months of year 2 (Chal_2.1)	Frequency of treatment; Numbers of chalimus and mobile *L. salmonis* in preceding period; Type of veterinary medicine	64.6%
2nd six months of year 2 (Chal_2.2)	No adequate model was found	

Chalimus levels in the second six-month period of the first year of the production cycle were principally explained (adjusted R^2 = 56% of the variation) by: the number of veterinary medicine treatments administered, the site hydrography and current speed characteristics. Sites with a high chalimus abundance attracted more treatments as did fish located in sites with low current speeds and an oscillatory hydrography.

In contrast, chalimus levels in the third six-month period of the production cycle were principally explained (adjusted R^2 = 65% of the variation) by: the abundance of mobile and chalimus stages in the preceding six-month period and treatment. Once again sites with high chalimus abundance attracted more treatments and fish receiving cypermethrin had lower chalimus abundance. Details of the regression model are shown in Box 1. No risk factors were identified for the final six-month period of the production cycle as no adequate linear model was possible.

Box 1 Results of stepwise regression of log transformed mean weekly *L. salmonis* chalimus abundance in the first half of the second year of production on management and environmental factors and covariate lice counts from preceding periods identified for model entry

Regression Model

$$\ln(\text{Chal\_2.1} + 1) = 1.05 + 0.34\ \text{Treatment frequency} + 0.12\ \text{Chal\_1.2} - 0.07\ \text{Mobile\_1.2} - 0.27\ \text{Veterinary medicine type}$$

Model term	Coeff	Coeff SE	Stand. Coeff	Significance	Adj R^2
Constant	1.05				
Treatment frequency	0.34	0.08	0.47	0.000	35.3%
Chalimus (1.2)	0.12	0.03	0.46	0.000	43.6%
Mobiles (1.2)	- 0.07	0.02	- 0.33	0.002	62.8%
Vet. medicine type	- 0.27	0.17	- 0.16	0.123	64.6%

In conclusion it would appear that there are both management and environmental factors which affect the number of chalimus sea lice on fish in Scottish salmon farms and these have an impact on overall sea lice abundance. It is possible that these can be effectively utilised as a means of reducing sea lice challenge and improving the quality and health of farmed fish.

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References

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