A simulation model of the spread and control of Johne's disease among sheep flocks

ESG Sergeant, AusVet Animal Health Services Pty Ltd, 69 Turner Cr, Orange 2800

Summary
This project was undertaken to develop a simulation model to assist with the evaluation of approaches to the future management of OJD in Australia. Based on the results presented, vaccination in infected flocks is probably the most important contributor to effective regional control of OJD in Australia.

## Introduction

Current regional control measures for ovine Johne's disease (OJD) in Australia are based on surveillance, quarantine of known infected flocks and zoning based on estimated flock-prevalence and level of control in a region. This approach has resulted in considerable producer resistance to the program, and many producers have experienced social and financial difficulties as a result of the stigma and lost trading opportunities associated with the disease. At the same time, the control measures have not been completely effective, with evidence of continued spread within and between regions. Because of the perceived failure of the existing regulatory approach, there is interest in developing an alternative approach based on reduced regulation, increased use of vaccination and producers taking increased responsibility for the management of OJD-risk. This project was undertaken to develop a simulation model to assist with the evaluation of approaches to the future management of OJD in Australia.

## Materials and Methods

A simulation model of the regional spread of Johne's disease among sheep flocks was developed using Visual Basic v6.0®. A specified number of farms (N) were represented as cells on a rectangular grid or lattice structure and a proportion of these farms were identified as having sheep flocks. The model simulated the spread of Johne's disease among the flocks, either through local spread between adjoining flocks (cells), or through movements of replacement sheep between flocks. Progression of infection within individual infected flocks was simulated using a simplified version of a previously reported model for the spread of Johne's disease within infected sheep flocks (Sergeant, 2002).

Simulated control measures to reduce spread of infection could be implemented, commencing in any year specified by the user. Available control options included surveillance, vaccination and movement restrictions.

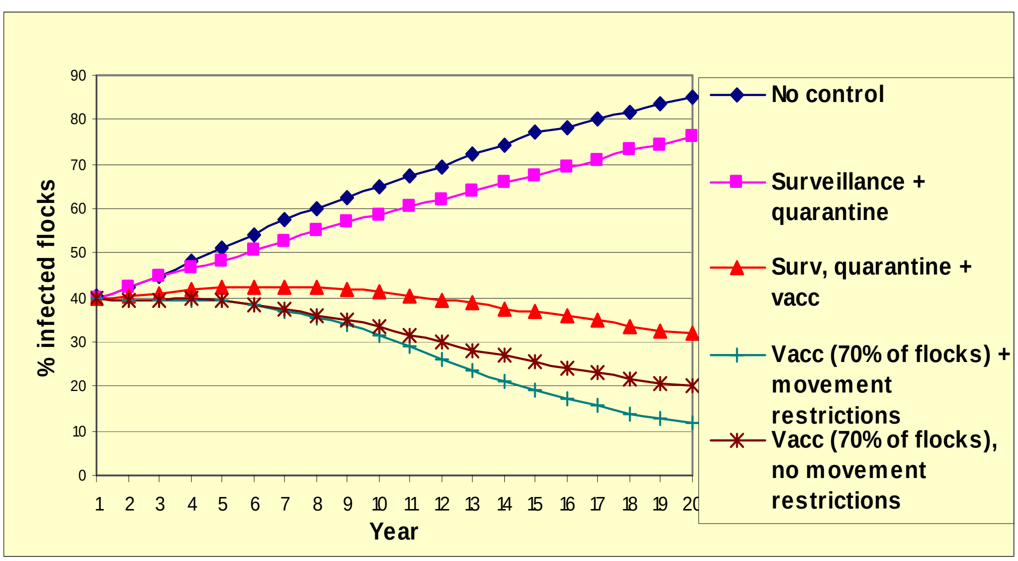
A number of simulations were run, simulating the uncontrolled spread of infection and the impact of various control options in a high-prevalence region. For this scenario, 4,000 farms were simulated, with a starting flock-prevalence of about 40% (comparable to the high-prevalence region of New South Wales). Control measures commenced in year 1 of the simulation, and included: no control (NC); surveillance (500 flocks/year) and quarantine (SQ); surveillance, quarantine and vaccination (SQV); voluntary vaccination of 70% of flocks with vaccination of all purchased replacement sheep (VMR); and voluntary vaccination of 70% of flocks but not requiring vaccination of purchased sheep (V noMR).

Simulations were also run to evaluate control options for a low-prevalence region, with continuing low levels of introduced infection. For this scenario, 10,000 farms were simulated, with a starting flock-prevalence of about 0.5% and assuming that 5% of flocks purchased replacement sheep from a region with a 2% flock-prevalence, while the remaining flocks purchased replacements from within the simulated region. All simulations for this scenario were run for a period of 40 years. Control measures commenced in year 1 of the simulation, and included: no control (NC); surveillance (1000 flocks/year) and quarantine (SQ); surveillance, quarantine and vaccination (SQV); surveillance and vaccination only (SV); and surveillance, quarantine and ring vaccination (SQRV).

## Results

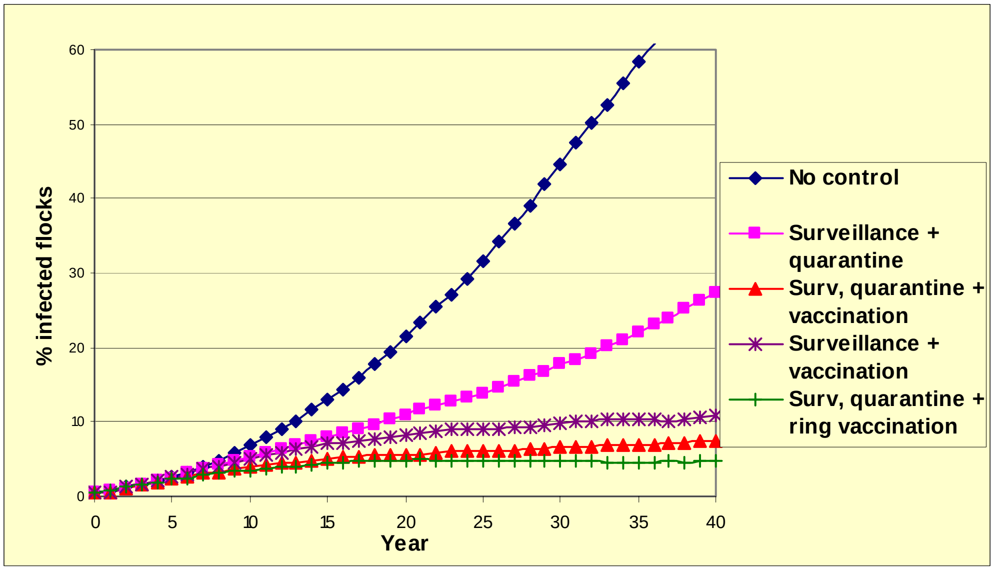
Results for the high-prevalence scenario are summarised in Figure 1. Briefly, the NC simulation resulted in a continued rapid rise to >80% over the simulated 20-year period. For the SQ simulation, prevalence continued to rise, but more slowly than for the NC scenario. For the SQV scenario, spread slowed further, and prevalence started to decline slowly after about 10 years. The rate of change in these simulations varied considerably, depending on the level and effectiveness of surveillance (results not shown). Voluntary vaccination simulations resulted in a progressive decline in prevalence over the 20-year period. Restricting purchases to sheep from vaccinated flocks only, with random vaccination of 70% of flocks (VMR), resulted in a decline in flock-prevalence from about 40% to 11% after 20 years. This decline was more rapid if the percentage of flocks vaccinating was increased and was slower if purchases were not restricted to vaccinating flocks only (V noMR), or if fewer flocks were vaccinated (results not shown).

**Figure 1: Mean flock-prevalence for high-prevalence scenarios, assuming a 40% flock-prevalence at the start, a 20-year simulation period.**



Results for the low-prevalence scenario are summarised in Figure 2. Flock-prevalence increased rapidly under the NC simulation, reaching 71% after 40 years. The SQ simulation provided limited control, with flock-prevalence continuing to increase steadily over 40 years. All other simulations considered provided a reasonable level of control, with flock-prevalence about 8-10% after 40 years. SQV and SQRV simulations both provided a slight decrease in flock-prevalence compared to SV alone, but the difference was small compared to the difference between SV and SQ.

**Figure 2 Mean flock-prevalence for low-prevalence scenarios, assuming a 0.5% flock-prevalence at the start, 5% of flocks introducing sheep from an area with a flock-prevalence of 2%, a 40-year simulation period.**




## Discussion

Based on these results, vaccination in infected flocks is probably the most important contributor to effective regional control of OJD in Australia. In the high-prevalence areas this could be achieved by compulsory vaccination of flocks selling replacement sheep, or voluntary vaccination of flocks with some additional incentives for flocks to vaccinate before OJD-losses become obvious. In the high-prevalence area, surveillance and quarantine or ring vaccination would provide some additional benefit, but at significant additional cost. Surveillance and quarantine without vaccination is unlikely to provide effective control, even with high levels of surveillance, because no action is being taken to control infection in infected flocks and to reduce prevalence.

For low-prevalence regions, the most important measures are prevention of ongoing introductions (results not shown) and vaccination of infected flocks. In this situation, because flock-prevalence is low, effective surveillance is important to identify infected flocks, but quarantine of detected flocks is not necessary for effective control.

## Acknowledgment

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**References**

Sergeant ESG, 2002. Modelling the spread of ovine Johne's disease in infected flocks. In: Trengove C, Larsen J, Marshall J (Eds.), *Proceedings of the Australian Sheep Veterinary Society*. Australian Sheep Veterinary Society, Indooroopilly, Qld. pp 10-13