# Enhancing an Evidence-Based Decision Making System for Foot-and-Mouth Disease

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# Abstract

Foot-and-mouth disease (FMD) is a highly contagious disease with significant economic consequences, for which urgent and rational decisions are essential. It is a great concern for countries worldwide where livestock industries are important, regardless of the current FMD status. This thesis addressed the problems in the existing decision support systems used by the current FMD-free countries, with a particular focus on New Zealand.

Because the exact source of infection is uncertain in the spatially and temporally concentrated focus of an FMD epidemic, it is challenging to predict the behaviour of FMD and determine the best control alternatives within a given susceptible population. The studies proposed a new approach for descriptive spatio-temporal analyses of local spread patterns, which was applied to the data from the FMD outbreaks in Cumbria (UK, 2001), Miyazaki (Japan, 2010), and Andong (Republic of Korea, 2010). The analyses identified herd-specific risk factors of local spread: size of a susceptible premises, infectious premises with pigs and susceptible premises with cattle were positively associated with hazard of local spread in all the three epidemics. In addition, the adjusted hazard of local spread varied markedly by outbreak. The UK FMD epidemic in 2001 had the highest hazard of local spread. The findings highlight the needs of care in interpolating the local spread probabilities from one epidemic for use of disease modelling for a different susceptible population.

Detailed investigation of the FMD epidemic in Japan in 2010 illustrated a dynamic change in the patterns of local spread during the epidemic prior to emergency vaccination, suggesting contribution of human activities in addition to purely environmental factors to local spread. A stochastic spatial simulation model, using the local spread parameters derived from the analyses showed a high predictive accuracy, in terms of demographical, temporal and spatial patterns of infection. The model indicated that emergency vaccination played an important role in mitigating potentially unwanted outcomes of an epidemic, such as disease spread outside the prefecture. In addition, the model predicted

that both epidemiological and economic consequences of the epidemic could have been reduced by earlier application of vaccination with a smaller vaccination ring for the epidemic in Japan in 2010.

To enhance contingency planning for FMD, a disease simulation modelling system was developed, by adding an economic module to the existing FMD simulation model for New Zealand. The modelling system allowed estimation of the direct and macroeconomic costs of a simulated FMD epidemic. Analyses of data generated by the disease simulation modelling system indicated that vaccinate-to-die was economically preferred to stamping-out alone or vaccinate-to-live, for a simulated FMD epidemic in the Auckland Region with local spread potential similar to that of the Cumbria outbreak in 2001, which had a high potential of developing into a large epidemic, indicated by a high density of premises, a high cumulative number of IPs, or a high estimated dissemination rate, and local spread patterns similar to Cumbria outbreak (2001). Vaccinate-to-live was economically suboptimal under the current OIE standard regarding recovery of FMD-free status. The results were robust to the uncertainty in the resource capacity, vaccination effectiveness, and the early scale of an epidemic, but sensitive to the choice of vaccination radius. VTL was always economically suboptimal under the current OIE code, but would be advantageous if the OIE's waiting period was shortened by 3 months. Using more refined parameters, future work is required to investigate other potentially more advantageous options, such as vaccination applied to specific species or in alternative prioritisation.

The studies presented in this thesis demonstrated that simulation models that incorporated the current best epidemiological and economic knowledge might enhance contingency planning and decision making for the management of FMD. Simulation models could also be used as the quantitative basis of communication with decision makers and stakeholders, which would then encourage informed discussion around disease control measures.

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# List of Publications

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Wada, M., Stevenson, M. and Morris, R.S., 2011. The principles of farm-level economic decision making. Proceedings of the Epidemiology & Animal Health Management branch of the NZVA. No. 291, p 3.5.1-3.5.10.

Stevenson M, Wada, M., Morris and R.S., 2011. Tools for of farm-level economic decision making. Proceedings of the Epidemiology & Animal Health Management branch of the NZVA. No. 291, p 3.1.1-3.1.7.

# List of Presentations

**2015**

Wada, M., Carpenter, T., Cogger, N. and Stevenson, M.: Optimisation of emergency vaccination for a foot-and-mouth disease outbreak. Oral presentation at the 14th International Symposium on Veterinary Epidemiology and Economics. Nov 2015, Merida, Mexico.

Wada, M., Carpenter, T., Cogger, N. and Stevenson, M.: Economic assessment of alternative eradication strategies against foot-and-mouth disease in New Zealand. Poster presentation at the 14th International Symposium on Veterinary Epidemiology and Economics. Nov 2015, Merida, Mexico.

Wada, M., Carpenter, T., Cogger, N. and Stevenson, M.: Estimation of local-spread transmission probability for foot-and-mouth disease. Poster presentation at the 14th International Symposium on Veterinary Epidemiology and Economics. Nov 2015, Merida, Mexico.

**2014**

Wada, M., Stevenson, M., Cogger, N. and Carpenter, T.: Optimization of control strategies against foot-and-mouth disease in New Zealand. Oral presentation at the Society for Risk Analysis Australia & New Zealand, Aug 2014, Palmerston North, New Zealand

**2012**

Wada, M., Cogger, N., Carpenter, T. and Stevenson, M.: The development of a microeconomic model for the control of foot-and-mouth disease in New Zealand. Oral presentation at New Zealand Veterinary Association annual conference Epidemiology and Animal Health Management, Jul 2012, Palmerston North, New Zealand

**2011**

Wada, M., Stevenson, M. and Morris, R.S.: The principles of farm-level economic decision making. Oral presentation at New Zealand Veterinary Association annual conference Epidemiology and Animal Health Management, Jun 2011, Hamilton, New Zealand

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# Abbreviations

| | |
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| CIP | Cumulative number of infected premises |
| DEFRA | Department for Environment, Food & Rural Affairs |
| DIVA | Differentiating infected from vaccinated animals |
| EDR | Estimated dissemination rate |
| FAO | Food and Agriculture Organization of the United Nations |
| FMD | Foot-and-mouth disease |
| FMDV | Foot-and-mouth disease virus |
| GAM | Generalised additive model |
| GDP | Gross domestic product |
| IP | Infected premises |
| JA | Japan Agricultural Cooperatives |
| MPI | Ministry for Primary Industries, New Zealand |
| NPV | Net present value |
| NSP | Non-structural protein |
| OIE | The Office International des Epizooties |
| RNA | Ribonucleic acid |
| PRCC | Partial rank correlation coefficient |
| SAT | South African Territories |
| SO | Stamping-out alone |
| SP | Structural protein |
| VP | Viral protein |
| VTD | Vaccinate-to-die |
| VTL | Vaccinate-to-live |