Surveillance for Diseases of Poultry with Specific Reference to Avian Influenza

A dissertation presented
in partial fulfilment of the requirements
for the degree of Doctor of Philosophy
at Massey University

Caryl Yolanda Lockhart
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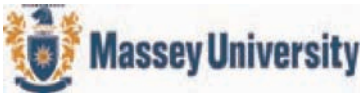

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— Abstract —

This thesis addresses issues related to surveillance for disease in commercial and non-commercial poultry populations. The motivation for this work has largely arisen from the unprecedented outbreaks of highly pathogenic avian influenza (HPAI) H5N1 that have occurred in 52 countries in Asia, Africa and Europe since 2003. A series of studies are presented using data derived from two countries, Vietnam and New Zealand. The two Vietnamese studies provide in-depth epidemiological analyses of the outbreak of HPAI H5N1 from December 2003 to March 2004. The three New Zealand studies deal with issues related to the development of effective surveillance strategies for HPAI — informed both directly and indirectly by the findings from the Vietnamese studies. This approach provides an example of how 'lessons' learnt from countries that have experienced large scale infectious disease epidemics can be used to assist in the design of surveillance activities in (as yet) unaffected countries.

The descriptive analyses of the 2003 – 2004 outbreak of HPAI H5N1 in Vietnam indicate that the epidemic was seeded simultaneously in the north and south of the country in the later part of 2003 with 87% of provinces affected by February 2004. HPAI risk was concentrated around the Mekong and Red River Deltas. The broad scale spatial distribution of disease is likely to have been associated with regional differences in the poultry farming, trade in poultry, and environmental conditions such as the presence of bodies of water which would support reservoir species for the virus. A Bayesian zero-inflated Poisson regression model was used to quantify the influence of environmental and demographic factors on the spatial distribution of HPAI positive communes. In areas where disease was reported, our results show that HPAI risk was positively associated with the presence of irrigation and negatively associated with elevation. After controlling for these fixed effects, a single large area of elevated risk in the Red River Delta area was identified, presumably arising from similarities in the likelihood of reporting disease or the presence of factors increasing disease transmission and spread. Further investigations to elucidate likely transmission mechanisms, targeting this area of the country, would be a profitable area of future research.

The second part of this thesis presents three studies that address issues related to the development of effective surveillance strategies for HPAI in New Zealand. The first was a cross-sectional study to enumerate the prevalence of backyard poultry ownership in two areas (one urban and the other rural) close to a large provincial city in the North Island of New Zealand. The prevalence of poultry ownership was 2% (95% CI 1% – 4%) in the urban area and 19% (95% CI 12% – 30%) in the rural area. The relatively low numbers of land parcels where poultry are present indicates that these areas, in the event of an infectious disease incursion, would be unlikely to pose a risk for spread of infectious agent.

A cross-sectional survey of all members of the Poultry Industry Association of New Zealand was conducted in the later half of 2007. Respondents were asked to document contacts made with other enterprises related to feed, live birds and hatching eggs, table eggs and poultry product, and waste litter and manure. Patterns of contact were analysed using social network analyses. Each of the four networks had scale-free properties, meaning that for each movement type there were small numbers of enterprises that had contacts with large numbers of enterprises (potential 'super-spreaders' of disease). The presence of an undetected infectious disease in enterprises with super-spreader characteristics increases the likelihood that an epidemic will propagate rapidly through the population, assuming there is a directly proportional relationship between the number of contacts an enterprise makes and the probability that disease will be transferred from one location to another. While the finding that feed suppliers had large numbers of poultry farm contacts in the feed network came as no surprise, what was of greater interest was that there were small numbers of poultry farms that reported off-farm movements of feed. This should serve as an important reminder for disease control authorities: movement (and other) restrictions applied during the course of an animal health emergency should be applied across a range of industry sectors, recognising that some industry participants may practice activities that are not entirely typical for their enterprise type (e.g. poultry farms on-selling feed to other farms). In the absence of perfect and up-to-date network data, knowledge of the characteristics of individual enterprises that render them more likely to be atypical (e.g. size, type, and geographic location) would be of value, since this information could be used to inform a risk based approach to disease surveillance and control.

A scenario tree model was developed as an approach for evaluating the effectiveness of New Zealand's passive surveillance system for HPAI. The model was developed in two stages. In the first, factors thought to influence the geographic distribution of NAI risk of introduction and spread (and therefore surveillance strategy) were combined to create a spatial risk surface. In the second stage, a scenario tree model of the passive surveillance system for NAI was developed using the spatial risk surface and the HPAI surveillance

strategy prescribed by Biosecurity New Zealand. The model was most sensitive to farmers reporting the presence of suspected cases of disease. This implies that the sensitivity of the system as a whole stands to increase if the importance of reporting suspicious clinical signs is reiterated to poultry producers.

The studies presented in this thesis have presented a range of techniques and methodological approaches that are sufficiently generic to be used in any country to inform the design of surveillance strategies for a variety of animal diseases, not just those of poultry. Although epidemiology, as a discipline, is endoured with a vast range of analytical techniques that can be used to enhance the understanding of factors influencing the spread of disease among animal populations, the quality of data used to support these techniques is often lacking. The challenge in the years ahead, for both developed and developing countries, is to set in place the appropriate infrastructures to collect details of animal populations consistent in quality over time and space.

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Nomenclature

AC-EIA	Antigen-capture enzyme immunosorbent assays
AGID	Agar gel immunodiffusion
AHSM	Animal Health and Surveillance Management system
AIDS	Acquired immune deficiency syndrome
AMLS	Animal Movement Licensing System
ASF	African swine fever
BOSSS	The Bovine Syndromic Surveillance System
BSE	Bovine spongiform encephalopathy
CIRAD	The French Agricultural Research Centre for International Development
CSF	Classical swine fever
CTS	Cattle Tracing System
DAH	Department of Animal Health (Vietnam)
DCS	Disease Control System
Defra	Department for Environment Food and Rural Affairs (United Kingdom)
DIVA	Differentiating Infected from Vaccinated Animals
DP-DCS	The Diseases of Poultry Disease Control System
DSM-4	The Diagnostic and Statistical Manual of Mental Disorders
ELISA	Enzyme linked immunoabsorbent assay
EMPRES	Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FMD	Foot-and-mouth disease
GLEWS	The Global Early Warning and Response System
GPHIN	The Global Public Health Intelligence Network
GOARN	The Global Outbreak Alert and Response Network
HA	Haemmaglutinin

HI	Haemmaglutinin inhibition test
HPAI	Highly pathogenic avian influenza
ICAHMS	Computerised Animal Health Monitoring System (Israel)
INRA	The National Institute for Agriculture Research (France)
LAMP	Loop mediated isothermal amplification
LPAI	Low pathogenic avian influenza
MAF	Ministry of Agriculture and Forestry
NA	Neuraminidase
NASBA	Nucleic acid sequence-based amplification
NAHIS	National Animal Health Information System (Australia)
NAI	Notifiable avian influenza
ND	Newcastle disease
NI	Neuraminidase inhibition test
NLIS	National Livestock Identification System for Cattle
OIE	World Organization for Animal Health
OR	Odds ratio
POC	Point-of-care
RADAR	Rapid Analysis & Detection of Animal-Related Risks
R_0	Basic reproductive ratio
RRT-PCR	Real-time polymerase chain reaction
RT-PCR	Reverse transcriptase polymerase chain reaction
RSVP-A	The Rapid Syndrome Validation Project – Animal
SARS	Severe acute respiratory syndrome
SGS	El Sistema de Gestin Sanitaria
Sisbov	The Bovine Identification and Certification System (Brazil)
SND	Scrapie Notification Database
SNIG	El Sistema Nacional de Información Ganadera (Uruguay)
SPS	Sanitary and phytosanitary measures
TVD	The National Movement Database Tierverkehrsdatenbank (Switzerland)
vCJD	variant Creutzfeldt-Jakob disease
VetPAD	The Veterinary Practitioner Aided Disease system
WAHID	World Animal Health Information Database

WHO	World Health Organization
WNV	West Nile virus
WTO	World Trade Organization

List of Publications

Lockhart CY, Stevenson MA, Hoang Van Nam, Lai Thi Kim Lan, Jackson R, Morris R, French NP (2006) Descriptive epidemiology of the outbreak of highly pathogenic avian influenza in Vietnam, December 2003 to February 2004. In: *Proceedings of the 14th FAVA Congress and the Food Safety & Biosecurity, and Epidemiology & Animal Health Management Branches of the New Zealand Veterinary Association*, Foundation for Continuing Education Publication Number 253, VetLearn Foundation, Palmerston North, New Zealand, 179 – 192.

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