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Development of a method for optimal detection of emerging disease incursions

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

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Abstract

Emerging and re-emerging infectious diseases (ERID) are capable of generating sizable economic loss, and causing loss of life and social instability. To prevent and mitigate the negative impacts of ERID, it is imperative to have a sensitive surveillance system for early disease detection. Furthermore, from the economic perspective, resources are always scarce and have opportunity cost, so investment in surveillance programs has to demonstrate that it can maximize the utility of available resources. The thesis was focused on development and application of a software toolbox, **H**uman and **An**imal **Di**sease **Response** Program (HandiResponse), designed for (i) visualizing the disease risk landscape and representing spatial variation in the expected occurrence of a zoonotic disease both quantitatively and visually; (ii) evaluating economic benefit and costs of a single surveillance activity or a multi-component portfolio; (iii) identifying optimal use of resources for surveillance. It comprises four modules: (i) risk map development – HandiMap; (ii) surveillance portfolio development – HandiSurv; (iii) economic impact assessment – HandiEcon and (iv) surveillance optimization – OptiSurv.

The modules developed were tested on a number of data sets from various countries. The experience demonstrated that using satellite-derived data in combination with national statistical data to produce a disease risk map improved spatial prediction of avian influenza H5N1 outbreaks in southern Vietnam. Development of a risk map from satellite data for Crimean Congo Haemorrhagic Fever for Mongolia guided a field surveillance program which provided the first evidence that this disease is present in both animals and people in Mongolia. Finally an invented disease affecting pigs and people was used to investigate the likely consequences of an incursion of such a novel disease into Australia, involving both domestic and feral pigs and transferring to people. Risk-based and classical disease surveillance options were then tested for disease detection, and modelling work confirmed that a portfolio consisting of different options was the most technically and economically appropriate.

HandiResponse is a practical tool that could promote the implementation of risk-based surveillance approaches, and improve both technical and economic efficiency of surveillance programs for infectious diseases, particularly those affecting both people and animals.

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Table of Contents

Abstract i

Acknowledgements iii

Table of Contents v

List of Figures xi

List of Tables xv

Abbreviations xix

1. Introduction 1

1.1. References 3

2. Review of Risk-based Surveillance for Infectious Diseases 5

2.1. Introduction 5

2.2. Methods 6

2.2.1. Literature search strategy 6

2.2.2. Inclusion criteria 7

2.3. Results 7

2.3.1. General information on the review 7

2.3.2. Definition and objectives of risk-based surveillance 9

2.3.3. Typology of RBS 9

2.4. Discussion: key observations on RBS 33

2.4.1. Key assumptions for RBS 33

2.4.2. Benefits from RBS 34

2.4.3. Challenges related to RBS 35

2.4.4. Evolution in risk-based disease surveillance 37

2.5. Conclusion 39

2.6. References 41

3. From Science to Application: Development of a User-friendly Program to Facilitate Risk-based Approaches for Disease Surveillance -HandiResponse 59
3.1. Abstract 59
3.2. Introduction 60
3.3. Materials and methods 60
3.3.1. Program description 60
3.3.2. Program flow 67
3.4. Implementation 67
3.5. Discussion 68
3.5.1. Program design 68
3.5.2. Risk mapping 69
3.5.3. Models for disease introduction and spread 76
3.5.4. Optimization of surveillance program 77
3.6. Conclusion 78
3.7. References 79
4. Development of a generic system for creating a digital disease risk landscape – HandiMap 87
4.1. Abstract 87
4.2. Introduction 88
4.3. Method 88
4.3.1. Login to HandiResponse 88
4.3.2. HandiMap operation 92
4.4. Results 112
4.5. Discussion 119
4.5.1. Rationale for development of HandiMap 119
4.5.2. Selection of risk layers and environmental descriptors for genuinely novel diseases 120
4.5.3. Standardization of risk values 123
4.5.4. Relative importance of risk factors and environmental descriptors 123
4.5.5. Challenges and limitations 124
4.6. Conclusions 126

4.7. References 127
5. Evaluating the benefit of risk mapping to predict temporal and spatial distribution of Highly Pathogenic Avian Influenza (H5N1) outbreaks in southern Vietnam 133
5.1. Abstract 133
5.2. Introduction 134
5.3. Methods 136
5.3.1. Overall technical approach 136
5.3.2. Risk map development 136
5.3.3. Development of avian influenza H5N1 outbreak model for Southern Vietnam 137
5.3.4. Statistical analysis 140
5.3.5. Identifying good fit model(s) 140
5.4. Results 140
5.5. Discussion 150
5.5.1. Rationale for the selection of Wave II HPAI H5N1 outbreak in Southern Vietnam 150
5.5.2. Identification of the best fit model(s) 151
5.5.3. Relative importance of risk factors and environmental predictors 152
5.5.4. The benefit of using a risk map for modelling H5N1 avian influenza 152
5.5.5. Future direction 154
5.6. Conclusion 154
5.7. References 155
6. HandiMap Assisted Risk-based Survey on Crimean Congo Haemorrhagic Fever in Mongolia 159
6.1. Abstract 159
6.2. Introduction 160
6.3. Methods and Data 161
6.3.1. Study area 161
6.3.2. Investigation approach 161
6.3.3. Development of CCHFV suitability map 162
6.3.4. Field investigation 164
6.3.5. Concordance analysis 164

6.4. Results 165
6.5. Discussion 169
6.5.1. CCHF infection exists in Mongolia 169
6.5.2. Selection of risk factors 169
6.5.3. Selection of sheep for the CCHF survey 170
6.5.4. Inconsistency in CCHF occurrence between people and animals 170
6.5.5. Timing for field investigation 172
6.5.6. Interpretation of the risk landscapes 172
6.5.7. Limitation of the study and future directions 173
6.6. Conclusion 173
6.7. Reference 174
7. Modelling alternative surveillance methods to detect incursion of an exotic zoonotic disease 179
7.1. Abstract 179
7.2. Introduction 180
7.3. Methods and data 181
7.3.1. The example disease - Austeria 181
7.3.2. Data needed for modelling 182
7.3.3. Surveillance components for the disease 193
7.4. Results 196
7.4.1. Temporal and spatial distribution of Austeria 196
7.4.2. Number of days taken for Austeria detection 197
7.4.3. Number of infected properties by the time of detection 199
7.4.4. Number of Austeria outbreaks detected 202
7.5. Discussion 204
7.5.1. Selection of disease and location for modelling 204
7.5.2. Epidemiological performance of surveillance approaches 206
7.5.3. Contributions and limitations of our approach 209
7.6. Conclusion 210
7.7. References 211

8. Selection of optimal surveillance portfolios for detecting the incursion of an emerging zoonotic disease affecting pigs and human beings 215
8.1. Abstract 215
8.2. Introduction 216
8.3. Method and materials 217
8.3.1. Details of the disease and populations 217
8.3.2. Surveillance components 217
8.3.3. Simulation modelling of Austeria and surveillance components/sub-components 218
8.3.4. Estimation of economic effect of an Austeria outbreak and benefit of surveillance 219
8.3.5. Surveillance optimization approach 224
8.4. Results 226
8.4.1. Portfolios with the shortest expected 'number of days to detection' 226
8.4.2. Portfolios with the highest net benefit 227
8.4.3. Portfolios with the highest benefit cost ratio 230
8.4.4. Portfolios with both early detection and high net benefit 232
8.4.5. Portfolios with speedy detection and high benefit cost ratio 234
8.4.6. The final set of optimal surveillance portfolios 236
8.5. Discussion 238
8.5.1. Feasibility of optimizing zoonotic disease surveillance 238
8.5.2. Comparison of a surveillance portfolio with a single surveillance component 240
8.5.3. Practical consideration of different criteria for surveillance decision making 240
8.6. Conclusions 244
8.7. References 245
9. General discussion 247
9.1. Goal of the thesis 247
9.2. Studies undertaken in the thesis 247
9.3. Classification of diseases 250
9.4. Steps in the HandiResponse surveillance planning process 251
9.5. Development of a risk map 251

9.6. Using risk mapping to inform surveillance 256
9.7. Development of optimal surveillance portfolios 257
9.8. Practical value of HandiResponse 260
9.9. Limitations and future direction 261
9.10. Conclusion 262
9.11. References 263

List of Figures

Figure 2-1. Publications on RBS by year 8
Figure 2-2. Publications on RBS by source 8
Figure 2-3. Publications on RBS by continent 8
Figure 2-4. Publications on RBS by approach 8
Figure 2-5. Focus of Risk-based Surveillance 8
Figure 2-6. Algorithm for Prioritization of Disease Surveillance 11
Figure 2-7. Primary steps and key considerations in the collection and analysis of animal social networks 14
Figure 2-8. A schematic overview of the process of predicting spatial disease risk 19
Figure 2-9. The Sentinel Framework in Context 24
Figure 2-10. Stylized scenario tree 26
Figure 2-11. Standardized approach for demonstration of freedom from disease by using scenario tree modelling 27
Figure 3-1. Structure of HandiResponse and linkage between different modules 62
Figure 3-2. Algorithm for constructing a surveillance portfolio 65
Figure 3-3. Results of weight elicitation by different methods 75
Figure 3-4. Example: AHP result of weight elicitation by risk component and layer for HPAI in southern Vietnam 76
Figure 4-1. Login to IRIS 89
Figure 4-2. Entering HandiResponse 91
Figure 4-3. HandiResponse main screen 93
Figure 4-4. Report details on the risk map of HPAI H5N1 outbreak for southern Vietnam 95
Figure 4-5. Selection of risk groups, layers 97
Figure 4-6. List of risk layers for selection under affected species 98
Figure 4-7. Results of standardization of duck density layer 103
Figure 4-8. Risk layer weight assignments of M-Map for HPAI H5N1 outbreak, southern Vietnam 105
Figure 4-9. Group weight assignments of M-Map for HPAI H5N1 outbreak, southern Vietnam 106
Figure 4-10. A sample of risk level categorization 109
Figure 4-11. Selection of map presentation 111
Figure 4-12. Kernel smoothed P-Map for HPAI H5N1 outbreak, southern Vietnam (open street map) 113

Figure 4-13. Non-kernel smoothed P-Map for HPAI H5N1 outbreak, Southern Vietnam (open street map) 114
Figure 4-14. Options for map presentation by HandiResponse 115
Figure 4-15. Selected individual risk layers for HPAI H5N1 outbreak in southern Vietnam 116
Figure 4-16. E-Map for HPAI H5N1 outbreak in southern Vietnam 117
Figure 4-17. M-Map for HPAI H5N1 outbreak in southern Vietnam 118
Figure 4-18. The structure and content of a sample risk file produced by Handimap 119
Figure 4-19. Comparison of results from weight elicitation methods for M-map 124
Figure 5-1. Approach for Screening best fit model for HPAI H5N1 outbreak in southern Vietnam . 136
Figure 5-2. Adjustment procedure for transmission probabilities based on risk level 137
Figure 5-3. Plan of risk-adjusted disease modelling process 138
Figure 5-4. Comparison of four base models with the actual cumulative epidemic curve 142
Figure 5-5. Kernel smoothed E-map 143
Figure 5-6. Kernel smoothed P-Map 143
Figure 5-7. Kernel smoothed M-map 143
Figure 5-8. Comparison of spatial distribution of the good fit risk adjusted model with the actual outbreak in southern Vietnam, 2004/5 145
Figure 5-9. Comparison of daily cumulative number of infected communes of model 4-m-r-3-10 with that of the actual outbreak in Southern Vietnam, 2004/5 146
Figure 5-10. Comparison of number of daily infected communes under model 4-m-r-3-10 with that of the actual outbreak in Southern Vietnam, 2004/5 147
Figure 5-11. Result of Kolmogorov Smirnov Test 148
Figure 5-12. Epidemic Waves of HPAI H5N1 in Mekong River Delta, Vietnam 151
Figure 6-1. Habitat suitability map for tick distribution (CCHFV I map) 165
Figure 6-2. Risk map for CCHF occurrence (CCHFV II-1 map) 165
Figure 6-3. Risk map for CCHF occurrence (CCHFV II-2 map) 166
Figure 6-4. Number of sheep by district in Mongolia, 2013 166
Figure 6-5. Districts selected for field investigation of CCHF in Mongolia, 2013 167
Figure 7-1. Estimated relative density of feral pigs in Queensland, Australia 186
Figure 7-2. Infection transmission routes between herd types for pigs in Queensland, Australia 187
Figure 7-3. Number of daily cumulative infected farms of an uncontrolled Austeria outbreak in Queensland, Australia 196
Figure 7-4. Spatial distribution of Austeria infected pig herds in a median outbreak overlaid on top of the feral pig zones in Queensland, Australia 197
Figure 7-5. Number of days taken for Austeria detection by surveillance approach 199
Figure 7-6. Median number of herds infected by the day of detection, by surveillance approach 201

Figure 7-7. Percentage of the 99 simulated Austeria outbreaks detected by each surveillance approach within 365 days 203
Figure 7-8. Estimated density of backyard pig herds in Australia [1] 205
Figure 7-9. Estimated density of feral pigs in Australia based on habitat 205
Figure 7-10. Weekly cumulative Austeria epidemic curves by pig production sector 207
Figure 8-1. Optimization process under OptiSurv Program 224
Figure 8-2 Summary screen of OptiSurv 226
Figure 8-3. Optimal performance of a surveillance strategy 241
Figure 8-4. The weekly count of infected farms caused by a medium sized Austeria outbreak in Queensland, Australia 242
Figure 8-5 Generic form of economic analysis of zoonoses being developed -beyond the scope of this project 243
Figure 9-1 Thesis structure 248
Figure 9-2. Structure of HandiResponse and linkage between different modules 249

List of Tables

Table 2-1. Key vectors, relevant environmental/climatological predictors and diseases 20
Table 2-2. Contextual factors for evaluation of methods for space-time analysis of disease surveillance 25
Table 2-3. Suggested framework for simplified sampling scheme for Trichinella in European Union 30
Table 2-4. Summary on when likelihood and consequence need to be used for different RBS 32
Table 2-5. Summary on technical efficiency improvement by RBS 34
Table 2-6. Summary on economic efficiency improvement by RBS 35
Table 2-7. Development of output based surveillance for demonstration of freedom from disease 38
Table 3-1. Essential Steps for Risk Mapping by Using HandiMap 63
Table 3-2. Key Parameters Used for Estimating Performance of Surveillance Subcomponent 65
Table 3-3. Typology of risk map 70
Table 3-4. Epitypes of Zoonoses 72
Table 3-5. Categorization of risk factors related to emerging infectious diseases 73
Table 3-6. Selected key risk factors, environmental predictors and their proposed relationship with HPAI H5N1 outbreaks in South East Asia 74
Table 4-1. Summary of selected putative risk factors, environmental predictors and their relationship with HPAI H5N1 outbreaks in South East Asia 100
Table 4-2. Selected putative risk factors and environmental predictors for HPAI H5N1 Outbreaks in Vietnam 101
Table 4-3. AHP for weight assignment for risk layers for the P-Map estimating the risk of HPAI H5N1 outbreak, southern Vietnam 104
Table 4-4. Final weight assignments for selected risk factors and environmental descriptors 107
Table 5-1. Key parameters needed for HPAI H5N1 outbreak model 139
Table 5-2. Criteria for assessing fit of HPAI model(s) to actual epidemic data 140
Table 5-3. Summary of goodness of fit of models to actual epidemic 144
Table 5-4. ROC association statistics for Model 4-m-r-3-10 149
Table 5-5. Weight assignments under three additional hypotheses 152
Table 5-6. Average AUC under three additional hypotheses 152
Table 5-7. Epidemiological contribution of different transmission routes under m4-m-r-3-10 153
Table 6-1. Putative environmental and climatological factors for CCHFV suitability mapping 162
Table 6-2. Selected putative environmental/climatological predictors for CCHF mapping in Mongolia 163

Table 6-3. Assumed relationship between a selected environmental and climatological descriptor and tick distribution, human CCHF infection risk 163
Table 6-4. Weight assignment for selected environmental/climatological descriptors for CCHF mapping in Mongolia 164
Table 6-5. Anti-CCHFV IgG prevalence among human and sheep by district surveyed 168
Table 6-6. Districts in disagreement in CCHF status between human and sheep 171
Table 6-7. CCHFV antibody test results for sheep samples in selected districts by ELISA and IFA 171
Table 7-1. Number of feral pig and commercial pig herds in Queensland, Australia, 2013 183
Table 7-2. Estimated distribution of feral families by risk zone in Queensland, Australia 185
Table 7-3. Number of owned herds of each type in the feral pig density zones 185
Table 7-4. Movement type 1: Simulates routine movements within and among the types of commercial and backyard pig holdings 188
Table 7-5. Movement type 1: distance matrix 188
Table 7-6. Movement type 2: Simulates movement of commercial and backyard pig holdings to sale yards 189
Table 7-7. Movement type 2: movement distance matrix 189
Table 7-8. Movement type 3: simulates movement from sale yards to commercial and backyard pig holdings 190
Table 7-9. Movement type 3: distance matrix 190
Table 7-10. Movement type 4: Long distance movements among feral pigs 191
Table 7-11. Movement type 4: distance matrix 192
Table 7-12. Local spread 1: probability of transmission 192
Table 7-13. Adjustment in probability of transmission for specific farm class destinations 192
Table 7-14. Local spread type 2: probability of transmission 192
Table 7-15. Local spread type 2: adjustment in probability of transmission for specific farm class destinations 193
Table 7-16. Local spread type 3: probability of transmission 193
Table 7-17. Local spread type 3: adjustment in probability of transmission for specific farm class destinations 193
Table 7-18. Subjects for each Austeria surveillance component 194
Table 7-19. Description of surveillance components for Austeria 195
Table 7-20. Two examples of defining surveillance intensity and probability of detection for the high intensity sub-component 195
Table 7-21. Mean number of days taken for each surveillance component to detect Austeria over up to 99 iterations, Queensland, Australia (summarized for 9 sub-components) 197
Table 7-22. Mean number of farms infected by the day of detection over up to 99 iterations, ... 200

Table 7-23. Mean Percentage of Austeria outbreaks detected over 99 iterations for each surveillance component in Queensland, Australia (summarized for 9 sub-components) 202
Table 7-24. Comparison of HCR and RB2 by the day of onset and the day of detection 208
Table 7-25. Comparison of number of infected farms under different surveillance approaches 209
Table 8-1. The nine surveillance components evaluated in the study and the populations in which they were applied 217
Table 8-2. Description of surveillance components and sub-components for Austeria 218
Table 8-3. Terminology and definitions used in the economic evaluation of surveillance components/sub-components 219
Table 8-4. Diet specifications and ingredient costs for Australian pig budgeting model 220
Table 8-5. Key performance metrics influencing cost of production and net revenue per pig in herds with and without Austeria 221
Table 8-6. Economic net loss per pig due to Austeria under different production systems in Australia 223
Table 8-7. Top ten surveillance portfolios for Austeria in Australia with the shortest days to detection 228
Table 8-8. Top ten surveillance portfolios for Austeria in Australia with the highest net benefit 229
Table 8-9. Top ten surveillance portfolios for Austeria in Australia with high benefit cost ratio 231
Table 8-10. Top ten surveillance portfolios for Austeria in Australia with fast detection and high net benefit 233
Table 8-11. Top ten surveillance portfolios for Austeria in Australia with fast detection and high benefit cost ratio 235
Table 8-12. A summary of the best surveillance portfolios for Austeria in Australia 237
Table 8-13 Comparison of the optimal surveillance portfolios with single components for two different surveillance decision rules 240
Table 9-1. The purpose and output of different modules of HandiResponse 250

Abbreviations

Abbreviation	Explanation
ACF	Autocorrelation Function
AHP	Analytic Hierarchy Process
ARIMA	Autoregressive Integrated Moving Average
AUC	Area Under Curve
bTB	bovine Tuberculosis
CAC	Codex Alimentarius Commission
CCHF	Crimean Congo Haemorrhagic Fever
COS	Consequence of spread
CV	Coefficient of Variation
CWD	Chronic Wasting Disease
DALY	Disability Adjusted Life Year
DR	Direct Rating
EBL	Enzootic Bovine Leucosis
ELISA	Enzyme-linked Immunosorbent Assay
ERID	Emerging and Re-emerging Infectious Diseases
GARP	Genetic Algorithm for Rule-set Prediction
GIS	Geographic Information System
GLM	Generalized Linear Model
HandiEcon	Human and Animal Disease Economic Module
HandiMap	Human and Animal Disease Mapping Module
HandiResponse	Human and Animal Disease Response Program
HandiSpread	Human and Animal Disease Spread Program
HandiSurv	Human and Animal Disease Surveillance Module
HandiView	Human and Animal Disease View Program
HIV	Human Immunodeficiency Virus
HPAI	Highly Pathogenic Avian Influenza
IFA	Indirect Immunofluorescence Assay
IPPC	International Plant Protection Convention
LOS	Likelihood of Spread
MADM	Multi-Attribute Decision Making
MARP	Most at Risk Population
MCDA	Multiple-criteria Decision Analysis
NDVI	Normalized Difference Vegetation Index
OIE	World Organization of Animal Health
OptiSurv	Optimal Surveillance Module
PA	Point Allocation
PACF	Partial Autocorrelation Function
PCR	Polymerase Chain Reaction
POE	Probability of Exposure
PRRS	Porcine Reproductive and Respiratory Syndrome

RBS	Risk-based Surveillance
RDS	Respondent Driven Sampling
ROC	Rank Order Centroid
ROC	Receiver Operating Characteristic
RS	Remote Sensing
SNA	Social Network Analysis
SPS	Sanitary and Phytosanitary Measures/Agreement
SSC	Surveillance System Component
TLS	Time Location Sampling
WHO	World Health Organization
WLC	Weighted Linear Combination
WTO	World Trade Organization
WTP	Willingness To Pay