

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

# Epidemiological Studies of Highly Pathogenic Avian Influenza in Vietnam

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

Phan Quang Minh  
2010

# **Epidemiological Studies of Highly Pathogenic Avian Influenza in Vietnam**

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

at Massey University

Phan Quang Minh

Institute of Veterinary, Animal and Biomedical Sciences  
Massey University  
Palmerston North, New Zealand

2010

(Submitted 20 August 2010)

Institute of Veterinary, Animal and Biomedical Sciences

Massey University

Palmerston North, New Zealand

2010

---

# Abstract

---

This thesis utilises data on highly pathogenic avian influenza (HPAI) subtype H5N1 from the Vietnamese national surveillance system and purpose-designed field studies to enhance the understanding of the epidemiological features of HPAI H5N1 in Vietnam.

The findings obtained from the first study show that the presence of a HPAI H5N1 human case was associated with an increase in the likelihood of disease being detected in poultry one and four weeks later, indicating that the occurrence of clinical disease in poultry is not a useful predictor of subsequent human cases in the same locality. The analyses from the second study demonstrate that the epidemiology of HPAI H5N1 in poultry in Vietnam has changed over time and the infection transmission occurs by a combination of local and long-distance spread. The findings from a cross-sectional survey of management practices of itinerant grazing ducks suggest that surveillance strategies for this type of duck management should focus on both layer and larger flocks as they are more likely to be moved outside of their home district, facilitating long-distance disease spread. The results from a matched case-control study in poultry identify factors associated with the presence of HPAI H5N1 and provide evidence that disease control strategies should emphasise the reduction of household-level, rather than village-level, risks for disease. In the last study, spatio-temporal interaction of disease risk in poultry was observed within a distance of 10 kilometres and 12 days following the detected onset of clinical signs. Household-to-household infection rate within a commune was approximately 50 times greater than the household-to-household infection rate between communes. These findings show that the predominant mechanism of HPAI H5N1 infection transfer was local spread.

The lessons learnt from the series of studies presented here should assist Vietnamese animal health authorities to implement the necessary systems and infrastructure that will allow novel and emerging disease syndromes to be investigated promptly and efficiently.



---

## Acknowledgements

---

I am heartily thankful to my kind supervisors Mark Stevenson, Roger Morris, and Ron Jackson who have provided guidance for my study. To my chief supervisor, Mark Stevenson, words cannot entirely express my appreciation for the enthusiasm and support you have given me. To Roger Morris and Ron Jackson, you have not only taught me about science but also life.

I am truly indebted to Dirk Pfeiffer, John Hellstrom, and John Egan for their encouragement and support during the initial stages of my studies. I wish to express my appreciation to Birgit Schauer who has selflessly assisted by coordinating the field work in Vietnam. Special thanks to Nigel French and Jackie Benschop from the EpiCentre, Geoff Jones and Alasdair Noble from the Statistics Department, Hoang Van Nam and Tran Dien Quy from the Vietnamese Department of Animal Health, and Chris Jewell from the University of Warwick for working alongside me on Chapters 3, 4, 5, and 7 of this thesis. I am grateful to Nguyen Thanh Chung from the Vietnamese Ministry of Health for providing data for Chapter 3.

I thank New Zealand's International Aid and Development Agency for financial support for this work. This thesis would not have been possible without the assistance provided by colleagues from the Vietnamese Department of Animal Health, and the Regional Office of Animal Health No.7. I am forever grateful to them.

I would like to acknowledge all the help I received from past and present colleagues from the EpiCentre — Cord Heuer, Eric Neumann, Naomi Cogger, Daan Vink, Christine Cunningham, Wendy Maharey, Simon Verschaffelt, Bryan O'Leary, and Colleen Blair. I also offer my regards to all of those who supported me in any respect during the completion of this thesis.

Finally to my dear wife Hoa and son Hung, and my extended family — this study is immeasurably enhanced by your tremendous love and support.





---

## Nomenclature

---

AHW	Animal Health Worker
AI	Avian influenza
AIC	Akaike Information Criterion
CI	Confidence interval
DAH	Department of Animal Health, Vietnam
DVS	District Veterinary Station
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FRD	Field running duck
GIS	Geographic Information System
GLEWS	Global Early Warning and Response System
HA	Haemagglutinin
HPAI	Highly pathogenic avian influenza
HPD	Highest posterior density region
IQR	Interquartile rage
LabNet	National laboratory network
LPAI	Low pathogenic avian influenza

MARD	Ministry of Agriculture and Rural Development, Vietnam
MCMC	Markov chain Monte Carlo
MRD	Mekong River Delta
NA	Neuraminidase
NIVR	National Institute of Veterinary Research, Vietnam
NVDC	National Veterinary Diagnostic Centre, Vietnam
OIE	World Organization for Animal Health
OR	Odds ratio
PDSR	Participatory disease surveillance and response
RAHO	Regional Animal Health Office
ROC	Receiver Operating Characteristic
RRD	Red River Delta
RRT-PCR	Real time Reverse Transcriptase Polymerase Chain Reaction
SDAH	Sub-Department of Animal Health
SE	Standard error
SEIR	Susceptible-Exposed-Infected-Recovered
SIR	Susceptible-Infected-Recovered
SIVR	Sub-Institute of Veterinary Research
TADinfo	Transboundary Animal Disease Information System
WHO	World Health Organization

---

## List of Publications

---

Minh, P. Q., Schauer, B., Stevenson, M. A., Jones, G., Morris, R., Noble, A. (2009). Association between human cases and poultry outbreaks of highly pathogenic avian influenza in Vietnam from 2003 to 2007: A nationwide study. *Transboundary and Emerging Diseases*, **56**, pp. 311 – 320.

Minh, P. Q., Morris, R. S., Schauer, B., Stevenson, M. A., Benschop, J., Nam, H.V., Jackson, R. (2009). Spatio-temporal epidemiology of highly pathogenic avian influenza outbreaks in the two deltas of Vietnam during 2003 – 2007. *Preventive Veterinary Medicine*, **89**, pp. 16 – 24.

Minh, P. Q., Stevenson, M. A., Morris, R. S., Schauer, B., Quy, T.D. (2010). A description of the management of itinerant grazing ducks in the Mekong River Delta of Vietnam. *Preventive Veterinary Medicine*, **94**, pp. 101 – 107.

Minh, P. Q., Stevenson, M. A., Morris, R. S., Schauer, B. (2010). Risk factors associated with outbreaks of highly pathogenic avian influenza H5N1 in the Mekong River Delta of Vietnam. Submitted to *Preventive Veterinary Medicine*.

Minh, P. Q., Stevenson, M. A., Jewell, C., French, N., Schauer, B. (2011). Spatio-temporal analyses of highly pathogenic avian influenza H5N1 outbreaks in the Mekong River Delta, Vietnam, 2009. *Spatial and Spatio-temporal Epidemiology*, **2**, pp. 49 – 57.



---

# Contents

---

<b>Abstract</b>	<b>iii</b>
<b>Acknowledgements</b>	<b>v</b>
<b>Nomenclature</b>	<b>vii</b>
<b>List of Publications</b>	<b>ix</b>
<b>1 Introduction</b>	<b>1</b>
<b>2 Literature review</b>	<b>5</b>
2.1 Introduction . . . . .	5
2.2 Avian influenza . . . . .	6
2.2.1 Aetiology . . . . .	6
2.2.2 Epidemiology . . . . .	7
2.3 The emergence of HPAI . . . . .	12
2.3.1 Worldwide situation . . . . .	12
2.3.2 Outbreaks of HPAI H5N1 in Vietnam . . . . .	16
2.4 HPAI control and prevention . . . . .	19
2.4.1 Control and prevention strategies in other countries . . . . .	20
2.4.2 Control and prevention strategies in Vietnam . . . . .	22
2.5 HPAI surveillance . . . . .	24
2.5.1 Surveillance programmes in other countries . . . . .	28

2.5.2	Surveillance for HPAI in Vietnam . . . . .	31
2.5.3	Participatory approaches for HPAI surveillance . . . . .	37
2.6	Conclusion . . . . .	41
<b>3</b>	<b>The association between human cases and poultry outbreaks of HPAI</b>	<b>43</b>
3.1	Introduction . . . . .	44
3.2	Materials and methods . . . . .	45
3.2.1	Study population . . . . .	45
3.2.2	Data sources and case definition . . . . .	45
3.2.3	Analytical methods . . . . .	46
3.3	Results . . . . .	49
3.4	Discussion . . . . .	56
3.5	Conclusions . . . . .	59
<b>4</b>	<b>The spatio-temporal epidemiology of HPAI outbreaks in the two deltas</b>	<b>61</b>
4.1	Introduction . . . . .	62
4.2	Materials and methods . . . . .	63
4.2.1	Study area and study population . . . . .	63
4.2.2	Data sources and case definition . . . . .	63
4.2.3	Analytical methods . . . . .	64
4.3	Results . . . . .	66
4.4	Discussion . . . . .	75
4.4.1	Affected species . . . . .	75
4.4.2	Temporal patterns . . . . .	75
4.4.3	Spatio-temporal patterns . . . . .	76
4.5	Conclusions . . . . .	78

<b>5</b>	<b>The management of itinerant grazing ducks in the Mekong River Delta</b>	<b>79</b>
5.1	Introduction . . . . .	80
5.2	Materials and methods . . . . .	81
5.3	Results . . . . .	83
5.3.1	Village information . . . . .	83
5.3.2	Household information . . . . .	84
5.4	Discussion . . . . .	90
5.5	Conclusions . . . . .	92
<b>6</b>	<b>Risk factors for HPAI outbreaks in the Mekong River Delta</b>	<b>93</b>
6.1	Introduction . . . . .	94
6.2	Materials and methods . . . . .	95
6.2.1	Study design . . . . .	95
6.2.2	Definition and selection of cases and controls . . . . .	95
6.2.3	Sample collection of control flocks . . . . .	97
6.2.4	Questionnaires . . . . .	97
6.2.5	Data collection . . . . .	98
6.2.6	Data analysis . . . . .	98
6.3	Results . . . . .	100
6.3.1	Descriptive analyses . . . . .	100
6.3.2	Bivariate analyses . . . . .	101
6.3.3	Multivariable analyses . . . . .	101
6.4	Discussion . . . . .	105
6.5	Conclusions . . . . .	107

<b>7</b>	<b>Spatio-temporal analyses of HPAI outbreaks in the Mekong River Delta</b>	<b>109</b>
7.1	Introduction . . . . .	110
7.2	Materials and methods . . . . .	111
7.2.1	Study area and study period . . . . .	111
7.2.2	Outbreak definition . . . . .	111
7.2.3	Data collection . . . . .	112
7.2.4	Data analysis . . . . .	113
7.3	Results . . . . .	117
7.3.1	Spatio-temporal interaction . . . . .	117
7.3.2	Full epidemic model . . . . .	117
7.4	Discussion . . . . .	125
7.5	Conclusions . . . . .	129
<b>8</b>	<b>General discussion</b>	<b>131</b>
8.1	The use of routine surveillance data . . . . .	134
8.2	Epidemiology of HPAI . . . . .	135
8.3	Surveillance strategies . . . . .	136
8.4	Disease control and prevention . . . . .	137
8.5	Conclusion . . . . .	138
	<b>Bibliography</b>	<b>141</b>
<b>A</b>	<b>Appendix 1</b>	<b>A-1</b>
<b>B</b>	<b>Appendix 2</b>	<b>B-1</b>



---

## List of Figures

---

2.1	Monthly number of HPAI H5N1-affected countries, 2003 – 2010. . . .	15
2.2	Daily number of HPAI H5N1-infected communes in Vietnam, 2003 – 2007.	17
2.3	Locations of of HPAI H5N1-infected communes in Vietnam, 2003 – 2007.	18
2.4	Map showing the areas administered by each of the seven RAHOs. . . .	32
2.5	The information flow for routine reporting of HPAI in Vietnam. . . . .	33
3.1	Locations of the eight geographic regions in Vietnam. . . . .	53
3.2	Maps showing the number of reported poultry outbreaks and human cases of HPAI H5N1. . . . .	54
3.3	Epidemic curves of human cases and poultry outbreaks of HPAI H5N1.	55
4.1	Location of the Mekong River and Red River deltas in Vietnam. . . . .	69
4.2	Epidemic curves in the two deltas . . . . .	70
4.3	Kernel density maps of HPAI H5N1-infected communes in the Red River Delta . . . . .	71
4.4	Kernel density maps of HPAI H5N1-infected communes in the Mekong River Delta . . . . .	72
4.5	The spatial autocorrelation of HPAI H5N1-infected communes in the Red River Delta . . . . .	73
4.6	The spatial autocorrelation of HPAI H5N1-infected communes in the Mekong River Delta . . . . .	74
5.1	Locations of surveyed districts. . . . .	88
5.2	Bar plots showing the percentage of field running duck flocks. . . . .	89

7.1	Map showing locations of the four studied provinces. . . . .	119
7.2	SIR diagram. . . . .	120
7.3	Spatio-temporal interaction of HPAI H5N1 risk among household-level outbreaks. . . . .	121
7.4	Graphs showing the probability density functions of the parameters of full epidemic model. . . . .	122
7.5	Map showing the mean predicted epidemic size in each commune. . . .	123
7.6	Map showing the posterior mean of the commune level random effects.	124

---

## List of Tables

---

2.1	Sources and contributing factors for HPAI outbreaks. . . . .	8
2.2	Details of the national and regional laboratories in Vietnam. . . . .	35
3.1	Results of logistic regression model for the same district. . . . .	52
3.2	Results of logistic regression model for the same or neighbouring districts. . . . .	52
4.1	HPAI H5N1-affected species in the Red River Delta. . . . .	68
4.2	HPAI H5N1-affected species in the Mekong River Delta. . . . .	68
5.1	Surveyed village information. . . . .	86
5.2	Percentage of field running duck flocks running outside. . . . .	86
5.3	Logistic regression model for duck movement. . . . .	87
6.1	Results of bivariate analyses of potential risk factors for HPAI H5N1. . . . .	103
6.2	Results of the multivariable regression for risk factors for HPAI H5N1. . . . .	104