Modelling the spread of equine influenza in New Zealand

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Contents

Page

1.	**Executive Summary**	**1**
2.	**Introduction**	**5**
3.	**Project Overview**	**6**
4.	**Movement patterns associated with the live horse imports**	**7**
4.1.	Introduction	7
4.2.	Methodology	7
4.3.	Results	8
4.4.	Discussion	14
5.	**Movements patterns associated with general equine premises**	**15**
5.1.	Introduction	15
5.2.	Methodology	15
5.3.	Results	19
5.4.	Discussion	26
6.	**Movements associated with the Thoroughbred Racing Industry**	**27**
6.1.	Objective	27
6.2.	Overview of industry	27
6.3.	Movements associated with race days	30
6.4.	Movements associated with training	30
7.	**Movement patterns associated with Standardbred training**	**33**
8.	**Movement patterns associated with breeding operations**	**34**
8.1.	Objective	34
8.2.	Overview of Standardbred and Thoroughbred breeding industry	34
8.3.	Methodology	35
8.4.	Results	36
8.5.	Discussion	39
9.	**Modelling Equine Influenza during the silent spread phase**	**40**
9.1.	Introduction	40
9.2.	Data sources	40
9.3.	Model parameters	41
9.4.	Scenarios Modelled	43
9.5.	Statistical analysis	43
9.6.	Results	44
9.7.	Discussion	50
10.	**Control strategies**	**51**
10.1.	Description of control options	51
10.2.	Modelling control options	52
10.3.	Statistical analysis	53
10.4.	Results	54
10.5.	Discussion	60
11.	**References**	**61**
12.	**Appendices**	**63**
12.1.	Appendix A	63

1. Executive Summary

This report summarises the development of a computer model to provide a framework for decision support either prior to or following a disease outbreak. In this project Interspread Plus will be used to model an equine influenza outbreak in New Zealand and likely outcomes from a range of control options. In order to simulate an epidemic, it is necessary to consider how the disease might spread through the population (Stevenson et al., unpublished). In the case of equine influenza, virus introduction is likely to be through the importation of live horses and following the infection of one or more local horses the virus will spread to other properties through a combination of movements and local spread. The period of time from when equine influenza infects the first local horse until it is detected is termed the 'silent spread phase' of an epidemic (Anonymous, 2003). Obtaining an accurate estimate of the distribution of equine influenza at the end of the silent spread phase is dependent on having information to estimate infectivity parameters (e.g. time to onset of clinical signs and susceptibility of local horse population), local spread, the number of movements and background surveillance. In addition, the model requires a realistic "seeding" event that is, description of likely index farm or farms.

Presently, there is virtually no information about movement patterns in any sector of the horse industry, nor are there records of movement patterns associated with imported horses; and as such, determining realistic seeding events and modelling spread is difficult. Therefore the first stage of this project was to conduct a series of surveys to collect horse movement data. The survey data was then used to develop a model of the silent spread phase and determine factors affecting this stage. The information was then used to select a single model to compare control strategies. The control strategies modelled can be divided into: (i) movement restriction and (ii) vaccination.

Movement patterns associated with imported horses

Understanding the movement patterns associated with live horse imports is vital in the development of a realistic seeding event. In order to capture this data, the two main importers were asked to provide information about live horse imports. There were a total of 108 consignments: 100 from Australia, three from Hong Kong and three from North America and two from Europe[1]. A total of 809 live horses entered New Zealand from Australia (n = 809). The most common imported horse breeds were Thoroughbreds intended to be used in the breeding industry. Examination of the data showed that consignments imported from countries other than Australia have more destinations per consignment than those imported from Australia. The majority of consignments (regardless of source country) have a horse, or horses, destined for the Cambridge / Hamilton region. Interestingly, consignments from countries other than Australia appear to be more likely to have horses destined for the South Island (3/9 versus 8/100). The data provided strong evidence that should the equine influenza virus enter New Zealand, the first local horses property to be infected is likely to be in the Cambridge/Hamilton area. The results also suggest that virus could be seeded in one or more regions as a substantial number of consignments had horses destined for more than one location. However, caution is advised when using these results to determine outbreak scenarios because the Australian situation showed that the release scenario could be unrelated to the transport patterns of imported horses.

[1] Source country was unknown for one consignment of horses

Movement patterns associated with local horse population

Owners of equine properties that are not known to be involved in either racing or breeding activities, referred to as general properties or premises were surveyed to determine their movement patterns. The study found that the majority of individuals do not move their horses off the property, although there are seasonal differences. Specifically, the number of movements is roughly the same in spring, summer and autumn but significantly lower in winter. The study also showed that when horses do move that the distances involved can be quite long. For example, 10% of movements in spring, summer and autumn exceeded 200 km.

Analysis of race data from Thoroughbred trainers found that no trainer travelled more than 300 kilometres to attend a trial while 12 % of trainers attending a premier event had travelled more than 400 kilometres. This is not surprising as there is no prize money for barrier trials, and premier race meets have the highest amount of prize money on offer.

The number of times per year that Standardbred trainers attended official events (e.g. trials, race and workouts) was estimated by randomly selecting 100 trainers and obtaining official records for the 2008/2009 racing season from the Standardbred racing industry. The results showed that 13 trainers did not race during the 2008/2009 racing season. In the remaining 87 trainers, the number of race meets attended in twelve months was skewed and ranged from one to 166 with a median of 27.

This project provided the first estimate of movements associated with breeding Standardbred and Thoroughbred horses. Not surprisingly the number of movements was highly seasonal with peak movements corresponding with the breeding season. In the Thoroughbred industry the breeding season begins in August with the arrival of dry mares and concludes in January with the yearling sales; while the breeding season in the Standardbred industry begins in September and ends in February. Like the Thoroughbred industry the end of the breeding season corresponds with yearling sales. In the Standardbred industry the distances travelled were less than for Thoroughbreds. The most likely explanation for this is that Standardbreds allow artificial insemination and as such the semen can be distributed to a number of centres throughout the country.

Modelling the silent spread phase of and equine influenza outbreak

InterSpread Plus was used to simulate the silent spread phase of the epidemic. During the silent spread phase, spread of disease depends on: (1) the frequency and distance of movement of animals, humans and fomites from farm to farm and market to farm (and in the reverse direction), (2) incubation period and virus production for each susceptible species, and (3) local-spread and airborne-spread probabilities. The model also requires information about the location of all farms with horses and coordinates of racetracks (modeled as markets). This section of the report describes the data sources, model parameters used to model the silent spread, results of several scenarios and statistical analysis used to determine the impact of month, type of farm and region on the number of infected premises (IPs) on day 15 of the outbreak that is, the average time to detection.

Results from the analysis show clearly that average infectivity varied significantly between regions. Areas with greater infectivity correspond with regions that have greater horse density and a higher proportion of commercial horse properties (i.e. not general horse properties). Model results also highlight the higher variability in possible outcomes associated with general horse properties (Figure 4). This can be explained by survey results presented previously that found while the majority of properties do not move horses there are some people that regularly move horses large distances.

It is noteworthy that there were no significant differences in model outputs when movement patterns were altered to reflect the seasonal nature of the horse industry. While the result was initially surprising there are a couple of features of movement patterns that could explain this. Firstly, “slow” times in one sector of the industry corresponded with “busy” times in other sectors of the industry. For example, in August the number of movements off Thoroughbred breeding properties increases but the number of movements off general horse properties and Standardbred training operations are at their lowest. Another factor that could have contributed to the results is that movement patterns associated with the Thoroughbred and Standardbred training operations remained constant throughout the year.

Modelling the control strategies

Control strategies can be divided into three categories: (i) movement restriction and (ii) vaccination. The vaccination strategies considered are described in Table 1. The key findings from this study are: (i) Regardless of the control strategy used approximately half of the equine properties will be affected; (ii) Any outbreak is highly likely to affect both the North and South Island; and (iii) Regardless of the control strategy used a nationwide standstill will need to be in place for more than four months. A stop movement of more than four months will result in an enormous economic cost to the industry.

The impact of each vaccination strategy and a nationwide standstill was assessed. The results showed that vaccination of all premises with horses in a 1 km radius around known infected premises reduced the median number of IP’s by approximately 500 but had no significant impact on the area affected and the days to control. In contrast, all other vaccination strategies reduced the median number of IP’s by about 1,000 and also reduced the area infected and the days to control. A seven to ten kilometer ring vaccination and vaccination of all premises with horses in a 3 km radius around known infected premises had the greatest impact on days to control. However, use of the seven to ten kilometer ring required over 10,000 properties to be vaccinated and there was considerable variation around the median time to control. When considering the effectiveness of vaccinations it is important to note that when modeling vaccination we did not include the possibility of vaccinators spreading infection and that the parameters selected for vaccination are based on an immune response occurring within seven days of the first vaccination. Consequently, the model results are the best possible outcomes for vaccination. When these factors are taken into consideration there may be very little benefit to the industry of implementing a vaccination strategy in conjunction with a nationwide standstill.

Table.1: Vaccination strategies evaluated in this project to assess vaccination in the control and eradication of equine influenza (EI).

Type of strategy	Description
Suppressive	Vaccination of all premises with horses in a 1 km radius around known infected premises
	Vaccination of all premises with horses in a 3 km radius around known infected premises
Protective	Vaccination of all premises with horses in a band 7–10km around known infected premises
Targeted	Vaccination of breeding and training operations within 20km around known infected premises

Conclusion

The results of this analysis clearly show that an equine influenza outbreak will be widespread and take a considerable period of time to control. Central to any control strategy will be nationwide standstill of around six months duration. Vaccination used in conjunction with a nationwide standstill did significantly reduce the size of the outbreak. However, the reduction was not substantial and the number of properties, especially when the strategy is to vaccinate all properties within a 7-10 band from known IP's, was substantial. Consequently, the decision as to whether or not to use vaccination is not clear cut and could benefit from some economic assessment of the costs and benefits.

2. Introduction

Equine influenza is an acute, highly contagious viral disease. The virus was first recognised in Eastern Europe in 1956 and was attributed to a subtype of the H7N7 influenza virus referred to as subtype 1 (Daly et al., 2004). The last confirmed outbreak attributable to the subtype 1 was in 1979. In 1963, a different subtype of the EI virus (H3N8) emerged and caused a major epidemic in the USA (Miami). This subtype, called subtype 2, has also caused outbreaks in Newmarket (1976), Britain (1979), Argentina (1985), South Africa (1986), Jamaica (1989), Hong Kong (1992), Dubai (1995), Philippines (1997) and most recently in Japan and Australia (2007) (Daly et al., 2004; Yamanaka et al., 2008; AVMA, 2006). Australia officials successfully eradicated EI and regained their disease free status on the 25th December 2008.

This report summarises the development of a computer model to provide a framework for decision support either prior to or following a disease outbreak. In this project Interspread plus will be used to model an equine influenza outbreak in New Zealand and likely outcomes from a range of control options. In order to simulate an epidemic it is necessary to consider how the disease might spread through the population (Stevenson et al., unpublished). In the case of equine influenza, virus introduction is likely to be through the importation of live horses and following the infection of one or more local horses the virus will spread to other properties through a combination of movements and local spread. The period of time from when equine influenza infects the first local horse until it is detected is termed the ‘silent spread phase’ of an epidemic (Anonymous, 2003). Obtaining an accurate estimate of the distribution of equine influenza at the end of the silent spread phase is dependent on having information to estimate infectivity parameters (e.g. time to onset of clinical signs and susceptibility of local horse population), local spread, the number of movements and background surveillance. In addition, the model requires a realistic “seeding” event that is, description of likely index farm or farms.

Presently, there is virtually no information about movement patterns in any sector of the horse industry. Nor are there records of movements pattern associated with imported horses and as such determining realistic seeding events and modeling spread is difficult. Therefore the first stage of this project was to conduct a series of surveys to collect horse movement data. The survey data was then used to develop a model of the silent spread phase and determine factors affecting this stage. The information was then used to select a single model to compare control strategies. The control strategies modelled can be divided into: (i) movement restriction and (ii) vaccination.

3. Project Overview

The project started with a number of surveys and analysis of existing databases that have been used to describe the following:

- Movement patterns associated with live horse imports;
- Movement patterns associated with general equine premises;
- Movement patterns associated with the Thoroughbred racing industry; and
- Movement patterns associated with Thoroughbred and Standardbred breeding operations.

This information was then used to inform model inputs as depicted in Figure 2.1.

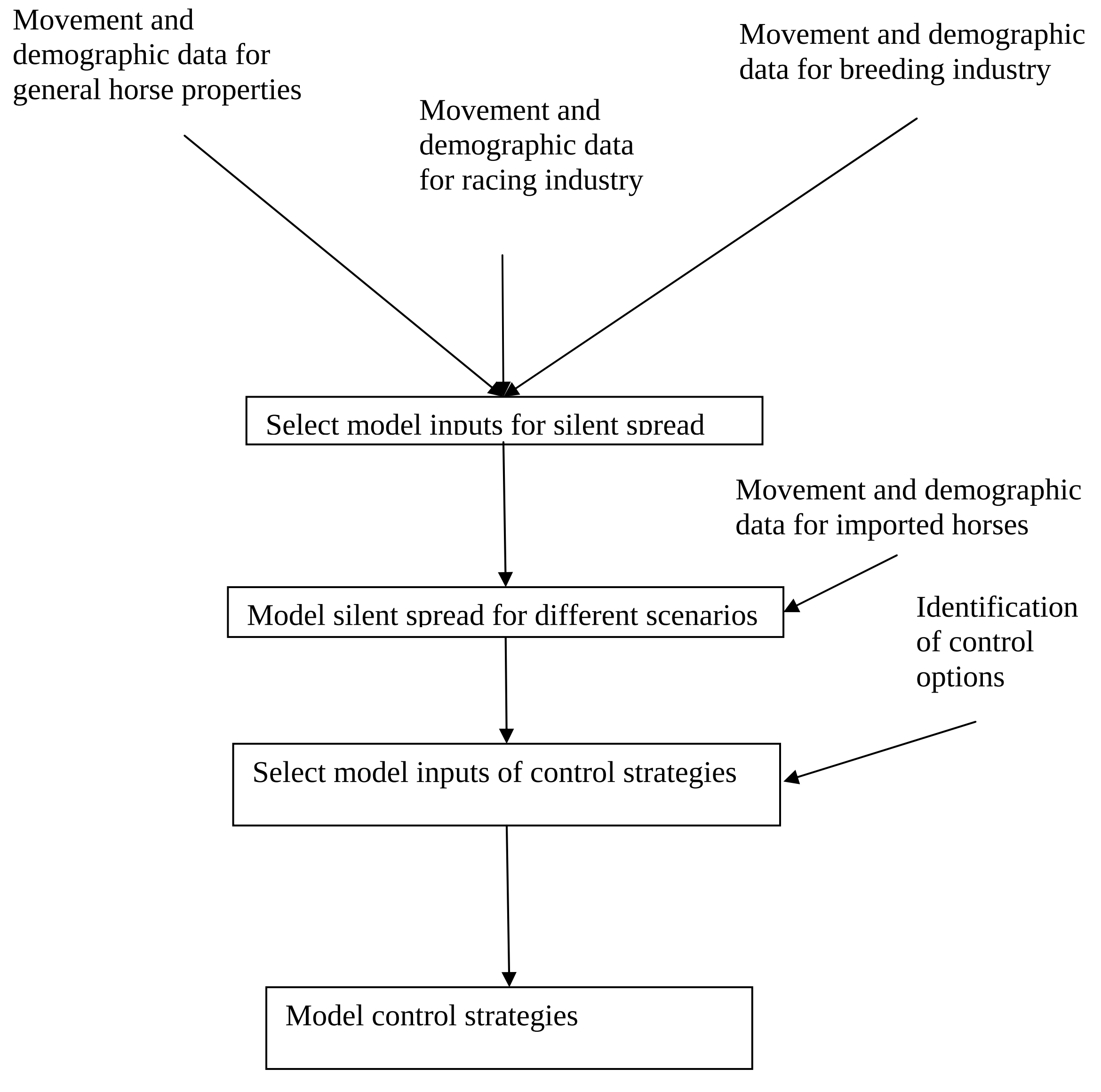


Figure 2.1: Overview of project to model an equine influenza outbreak in New Zealand.

4. Movement patterns associated with the live horse imports

4.1. INTRODUCTION

Understanding the movement patterns associated with live horse imports is vital in the development of a realistic seeding event. This section describes a prospective study to understand the movements of live horses imported into New Zealand.

4.2. METHODOLOGY

4.2.1 Data collection

A questionnaire was sent to companies importing horses into New Zealand. The questionnaire asked the name of the horse, sex, age, breed, reason for importation, country of origin, destination and duration of stay at the destination, overnight stops en route, number of imported horses on the transporter and the number of local horses on the transporter. These questionnaires were sent to the two biggest horse importers in New Zealand, New Zealand Bloodstock (NZB) and International Racehorse Transport (IRT).

4.2.2 Description of data sets

The data collected from the importers was divided into two data sets called the "horse" and "consignment". The horse data set contains the following information for each imported horse: sex, age, breed, reason for importation, New Zealand destination and source country. To assist in data analysis the New Zealand destination was coded as Northland, Auckland, Hamilton / Cambridge, Waikato location other than Hamilton / Cambridge, Bay of Plenty, Lower North Island and South Island. The Hamilton / Cambridge category included all locations less than 50 kilometers by road from either Hamilton or Cambridge. Distances were determined using Google Earth.

The consignment data set contained information about all horses imported by a particular company on the same day. For example, if ten horses were imported on 1st February and six were from NZB and four were imported by IRT these were considered as two separate consignments. For each consignment the following information was recorded arrival date, number of horses in the consignment, number of horses sent to each region in New Zealand and the total number of local horses transported with the consignment. Two additional ordinal variables were created. The first coded the total number of regions that each consignment sent horses to and the second variable coded the number of horse trucks used to transport each consignment.

4.2.3 Statistical analysis

The decision was made to analyse the data consignments from Australia and consignments from countries other than Australia separately. The remainder of this section describes the statistical analysis that was performed on each sub set of data. All statistical tests were performed using SAS Version 9.1 and significance was set at $p<0.05$

Consignments from Australia

The number of horses imported was determined stratified by breed and reason for importation. Results were reported as a count and percentage of all horses imported from Australia. Separate two-way tables were used to describe the relationship between destination and reason for importation and destination and breed. A Fisher Exact Test was used to determine if there were significant association between destination and either reason for importing or breed. To ensure adequate numbers of observations in each cell the destination was converted to a variable with only three categories (upper North Island, lower North Island and South Island), breed was reported as Thoroughbreds, Standardbreds or other and reasons for importing were re-classified as breeding, growing, racing, and other.

The number of horses per consignment was described using a histogram and summarised by the percentiles and maximum. The number and percentage of all consignments sent to each region was determined and the number of contacts with local horses was estimated.

The relationship between number of destinations and number of horse trucks used to transport the consignment was explored and significance assessed using the Chi-squared test statistic.

Consignments from countries other than Australia

The number of horses imported was determined stratified by breed and reason for importation. Results were reported as a count and percentage of all horses imported from a country other than Australia. Owing to the small number of consignments information about the number of horses and destination was presented for each consignment. The number of consignments with transit stops and contact with New Zealand horses was calculated. The small number of data points made it impossible to investigate the relationship between destination and number of horse trucks.

4.3. RESULTS

To date NZB have supplied records from 1st January to 4th August 2009. IRT have provided records from the beginning of the year until the end of March 2009 and provided information about consignments imported from countries other than Australia (i.e. consignments that were quarantined). There were a total of 108 consignments: 100 from Australia, three from Hong Kong and three from North America and two from Europe[2].

4.3.1 Imports from Australian

A total of 809 live horses entered New Zealand from Australia (n = 809). The most common imported horse breeds were Thoroughbreds intended to be used in the breeding industry (Table 3.1). Both the reason for importation and breed were significantly associated with the destination (Table 3.2). The number of horses in the 100 consignments from Australia ranged from one to 45 and the median number of horses was five (Figure 3.1).

Six of the consignments from Australia had incomplete destination data and were excluded from further analysis. Analysis of number of destinations per consignment showed that 56 consignments had horses destined for only one region within New Zealand. Twenty five, six and seven consignments respectively sent horses to two, three and four different regions within New Zealand.

[2] Source country was unknown for one consignment of horses

In total 87 of the 94 consignments sent one or more horse to the Hamilton / Cambridge region. Auckland (n = 37 consignments) was the second most popular destination and the lower half of the North Island (n = 13 consignments) was the third most popular. Eight consignments had horses transported to the South Island. Northland and the Waikato (excluding Hamilton or Cambridge) both received horses from six consignments. The Bay of Plenty only received horses from two consignments.

Information about contact with local horses was missing for 11% of consignments from Australia. In the remaining 89 consignments 83% did not have any contact with local horses (n = 74). Eight consignments had contact with one or two New Zealand horse, four had contact with three or four local horses, a further five had contact with between five and ten local horses and three consignments had contact with more than 10 local horses.

Information about the number of trucks used to transport horses to their destination was available for 84 consignments. Horses from 55 consignments were transported to their New Zealand destination in one truck, horses from 23 consignments were transported in two trucks, three consignments required three horse trucks to transport horses and horses from three consignments require five trucks to transport horses to their destinations. There was significantly positive association between the number of regions each consignment was sent to and the number of horse trucks used ($p = 0.003$).

Table 3.1: Number and percentage of horses imported from Australia stratified by breed and reason for importation.

Breed	Reason for importation	Number	Percentage
Thoroughbred	Breeding	336	41.5
	Grow	321	39.7
	Pleasure	1	0.1
	Race	99	12.2
	Retire	1	0.1
	Show jumping	2	0.2
	Unknown	2	0.2
	Total number of Thoroughbreds	762	94.2
Standardbred	Race	12	1.5
	Total number of Standardbreds	12	1.5
Warmbloods	Competition	2	0.2
	Dressage	1	0.1
	Eventing	1	0.1
	Pet	2	0.2
	Show jumping	5	0.6
	Total number of Warmbloods	11	1.4
Arab	Breeding/Showing	1	0.1
	Competition	1	0.1
	Pet	1	0.1
	Pleasure	3	0.4
	Total number of Arabs	6	0.7
Miniature or pony	Pet/Private	5	0.6
	Unknown	1	0.1
	Total number of miniatures/pony	6	0.7
Quarterhorse	Breeding	1	0.1
	Pet	2	0.2
	Western	1	0.1
	Total number of Quaterhorses	4	0.5
Sporthorse	Breeding	1	0.1
	Pet	1	0.1
	Show jumping	1	0.1
	Total number of Sporthorses	3	0.4
Other	Breeding	2	0.2
	Eventing	1	0.1
	Pleasure	1	0.1
	Unknown	1	0.1
	Total number of horses classified as other	5	0.6
Total		809	100

Table 3.2: Univariable association between an imported horse's destination and the variables reason for importing and breed. Data from 809[a] imported horses from Australia during 2009.

Variable	Level	Destination			P-value
		Upper North Island (n = 725)	Lower North Island (n = 62)	South Island (n = 20)	
Reason for importation	Breeding	310	25	5	<0.001
	Growing	298	18	4	
	Racing	91	12	7	
	Other	102	4	9	
Breed	Thoroughbred	722	57	14	0.021
	Standardbred	11	0	3	
	Other	28	5	4	

[a] Data about destination was unknown for 4 horses

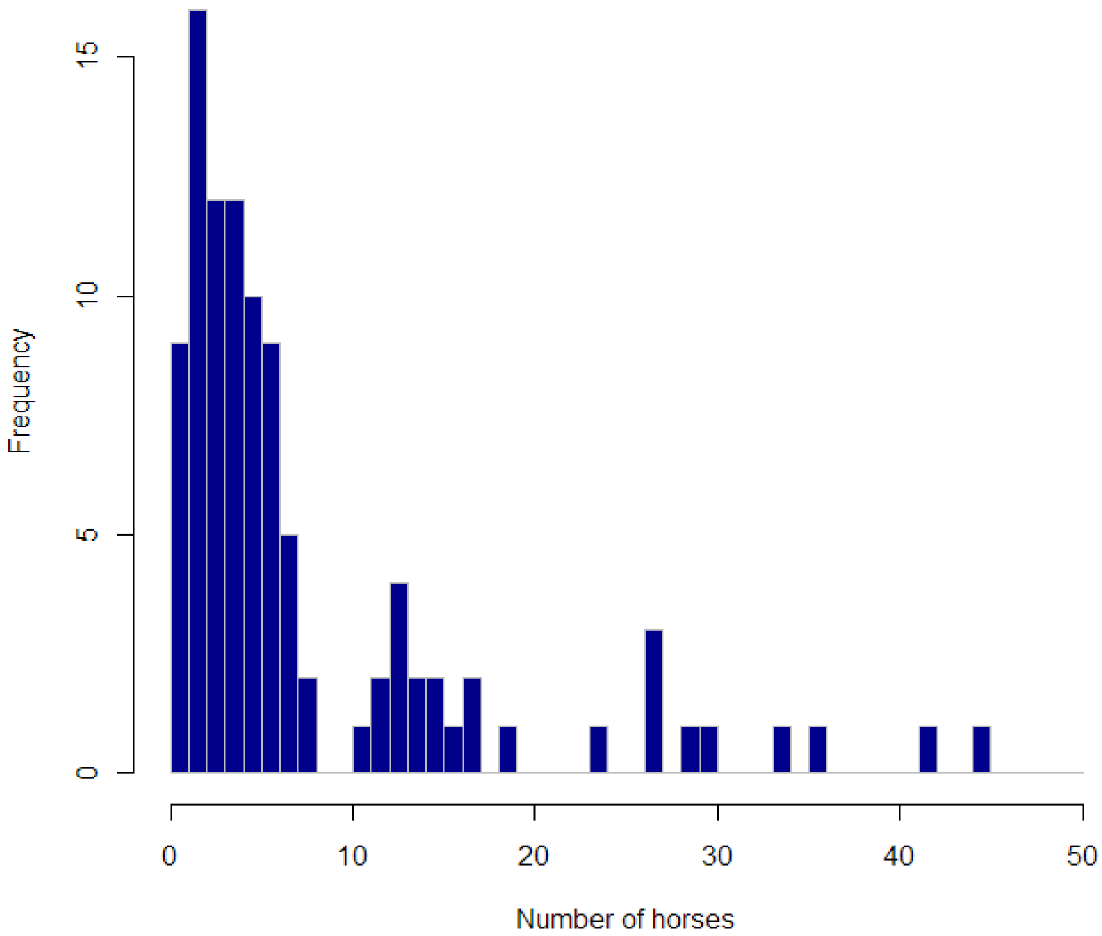


Figure 3.1: Histogram of the number of horses per consignment. Data from 100 consignment imported from Australia between January 2009 and August 2009.

4.3.2 Imports from countries other than Australian

Seventy-five horses were imported into New Zealand from countries other than Australia: 26 from Hong Kong, 20 from North America, 16 from Europe and three from an unknown source country. The majority of horses were Thoroughbreds and the most common reason for importing horses was for breeding (Table 2.3). Only one of the imported consignments did not send horses to the Cambridge area and two of the consignments had horses that were sent onto Australia (Table 2.4). Six of the consignments had a transit stop, even though only three of the consignments sent horses to the South Island. Five of the consignments from countries other than Australia were transported to their final destination using one horse truck, two consignments required two horse trucks and two consignments required three horse trucks. While being transported horses from two consignments were in contact with local horses. The remaining consignments had no contact (n = 6) or insufficient information was provided to determine if imported horses were in contact with domestic horses (n = 1).

Table 4.3: Number and percentage of horses imported from a country other than Australia stratified by breed and reason for importation.

Breed	Reason	Number	Percentage
Throughbred	Breeding	14	19
	Race	8	11
	Retire	21	28
	Total number of Thoroughbreds	43	57
Standardbred	Breeding	13	17
	Race	2	3
	Transit	2	3
	Total number of Standardbreds	17	23
Warmblood	Breeding	1	1
	Total number of warmbloods	1	1
Mini/Pony	Breeding	2	3
	Total number of min/ponies	2	3
Arab	Breeding	4	5
	Transit	1	1
	Total number of Arab	5	7
Other	Breeding	4	5
	Pleasure/Pet	2	3
	Transit	1	1
	Total number of horses classified as other	7	9
Total		75	100

Table 4.3: Destination of horses imported from a country other than Australia stratified arrival data and source country (i.e. consignment).

Arrival date	Source Country	Destination	Number of horses
11-Jan-09	Hong Kong	Auckland	2
		Cambridge	7
		Matamata	2
		Total	**11**
12-Jan-09	Unknown	Auckland	1
		Cambridge	1
		Manwatu	1
		Total	**3**
13-Jan-09	North America	Australia	1
		Cambridge	3
		Christchurch	1
		Matamata	2
		Wellington	1
		Total	**8**
25-Apr-09	Hong Kong	Auckland	1
		Cambridge	3
		Matamata	2
		Total	**6**
04-Jul-09	Hong Kong	Auckland	1
		Cambridge	4
		Matamata	3
		Te Awamutu	1
		Total	9
30-May-10	Europe	Auckland	1
		Cambridge	1
		South Island	2
		Northland	1
		Unknown	1
		Total	6
25-Jul-10	Europe	Auckland	4
		Cambridge	4
		Matamata	2
		Total	10
09-Aug-10	North America	Auckland	3
		South Island	7
		Total	10
13-Sep-10	North America	Auckland	5
		Australia	4
		Cambridge	1
		South Island	2
		Total	12

4.4. DISCUSSION

This is the first time this type of information has been recorded for horses entering New Zealand. Examination of the data shows that consignments imported from countries other than Australia have more destinations per consignment than those imported from Australia. The majority of consignments (regardless of source country) have a horse, or horses, destined for the Cambridge / Hamilton region. Interestingly consignments from countries other than Australia appear to be more likely to have horses destined for the South Island (3/9 versus 8/100). However, the small number of consignments imported from countries other than Australia makes statistical comparisons difficult.

IRT provided additional data for consignments imported from countries other than Australia. However, they did not update information about consignments imported from Australia. Because of the missing data the decision was made not to explore temporal patterns in the importation of horses because the results could not be easily interpreted.

In conclusion, while the data is incomplete it does provide strong evidence that should the equine influenza virus enter New Zealand the first local horses property to be infected is likely to be in the Cambridge/Hamilton area. The results also suggest that virus could be seeded in one or more regions as a substantial number of consignments had horses destined for more than one location. However, caution is advised when using these results to determine outbreak scenarios because the Australian situation showed that the virus can escape from quarantine before the end of the quarantine period. That is, the release scenario could be unrelated to the transport patterns of imported horses.

5. Movements patterns associated with general equine premises

5.1. INTRODUCTION

This section describes movements associated with equine properties that are not involved in either racing or breeding activities, hereafter referred to as general properties or premises.

5.2. METHODOLOGY

5.2.1 Study design

This was a cross-sectional survey of horse properties. Respondents either completed the questionnaire over the phone or were mailed a copy and asked to complete and return it to researchers.

Properties for inclusion in the survey were randomly selected using the statistical software R (Version 2.09). To be eligible for inclusion in the survey properties had to be listed in AssureQuality's AgriBase and classified as horse properties. Horse properties were excluded from the sampling frame if they were classified as partaking in racing, training or breeding activities. Two hundred and fifty properties were selected to participate in the phone survey and the locations of the properties are shown in Figure 4.1. Figure 4.2 shows the distribution of properties selected to participate in the mailed out survey (n = 2,912).

5.2.2 Questionnaire design

The questionnaire contained several parts. The first section required the respondent to verify their address and asked whether they had horses on their property and/or if their neighbours had horses. The second section collected information about the type of horses on the property (e.g. stallion, foals), ownership of the horses and reasons for owning horses. The next section asked people to indicate how frequently and how far they moved their horses and which times of the year these movements occurred. This was followed by a series of questions about visits from horse professionals such as veterinarians, farriers, riding instructors and massage therapists.

5.2.3 Data collection

The addresses of properties selected to receive the postal questionnaire were cross checked against New Zealand Post Rapid Address Finder. Using this method 5% of address in Agribase could be matched. A number of the errors could be explained by differences in how addresses are formatted for example, 'RD4' instead of 'RD 4'. However, even after correcting formatting differences approximately 20% of address could still not be matched. When we could still not match address owner's details were checked against New Zealand Whitepages on line.

When all addresses were verified respondents were sent a survey pack that included the following:

- Introductory letter inviting them to participate and stressing the importance of completing the first section of the survey even if they did not own a horse;

- Questionnaire;
- Return self addressed envelope; and
- Tea bag and a chocolate incentive

Properties selected for a phone interview where called in the early evening and asked to participate in the survey. Those that agreed to participate either completed the survey at that time or nominated a time they would prefer to be contacted.

5.2.4 Statistical analysis

The response rate to the survey was determined stratified by method used to collect data (i.e. phone or mail), region and farm size. When calculating the response rate those not contactable either because the phone was disconnected or the survey was returned to sender were excluded from the denominator. The region category were based on the local government boundaries (Figure 4.3) but owing to small numbers of properties in the Marlborough, Tasman and Nelson regions these were merged into one region called 'Marlborough/Tasman''. Farm size was classified as: < 5 hectares, 5-19 Hectares, 20-199 Hectares and ≥200 Hectares. The Chi-squared test statistic was used to assess the significance of the association between response rate and the variables: region, data collection method and farm size.

The proportion of respondents that owned horses was determined stratified by method used to collect data, region and farm size. Results were presented as counts and percentages. A Chi-squared test was used to assess the significance of the association between horse ownership and each of the stratifying variables.

The relationship between the proportion of respondents that had neighbours with horses was examined stratified by method used to collect data, region, size of property and whether the respondent owned horses. Results were presented as counts and percentages and significance of associations assessed using Chi-Squared test statistic.

For those respondents with horses the number of horses on each property was determined. The Kruskal-Wallis test statistic was used to assess the significance of an association between number of horses on a property and the following variables: method used to collect data, region, reason for owning horses and farm size. The number of horses in each stratum was summarised using minimum, maximum and percentiles.

For each season the number of movements off farm in a week was calculated and summarised using by the percentiles and maximum. Even though the number of weekly movements was non-normally distributed the mean and standard deviation were included because they will be required when selecting input parameters for the Interspread Plus model. The Kruskal-Wallis test statistic was used to determine if the number of movements was significantly associated with the method used to collect data, region, reason for owning horses and farm size.

The distance travelled each time a horse moved was expressed as a categorical variable (0-5 km, 6 to 25 km, 26 to 50 km, 51 to 100, 100 to 200 km and >200 km). A Chi-squared test was used to determine if the distance travelled was significantly different between seasons and results presented as the number and percentage of movements in each distance category.

All statistical tests employed using the statistical software SAS Version 9. Significance was set at $p<0.05$.

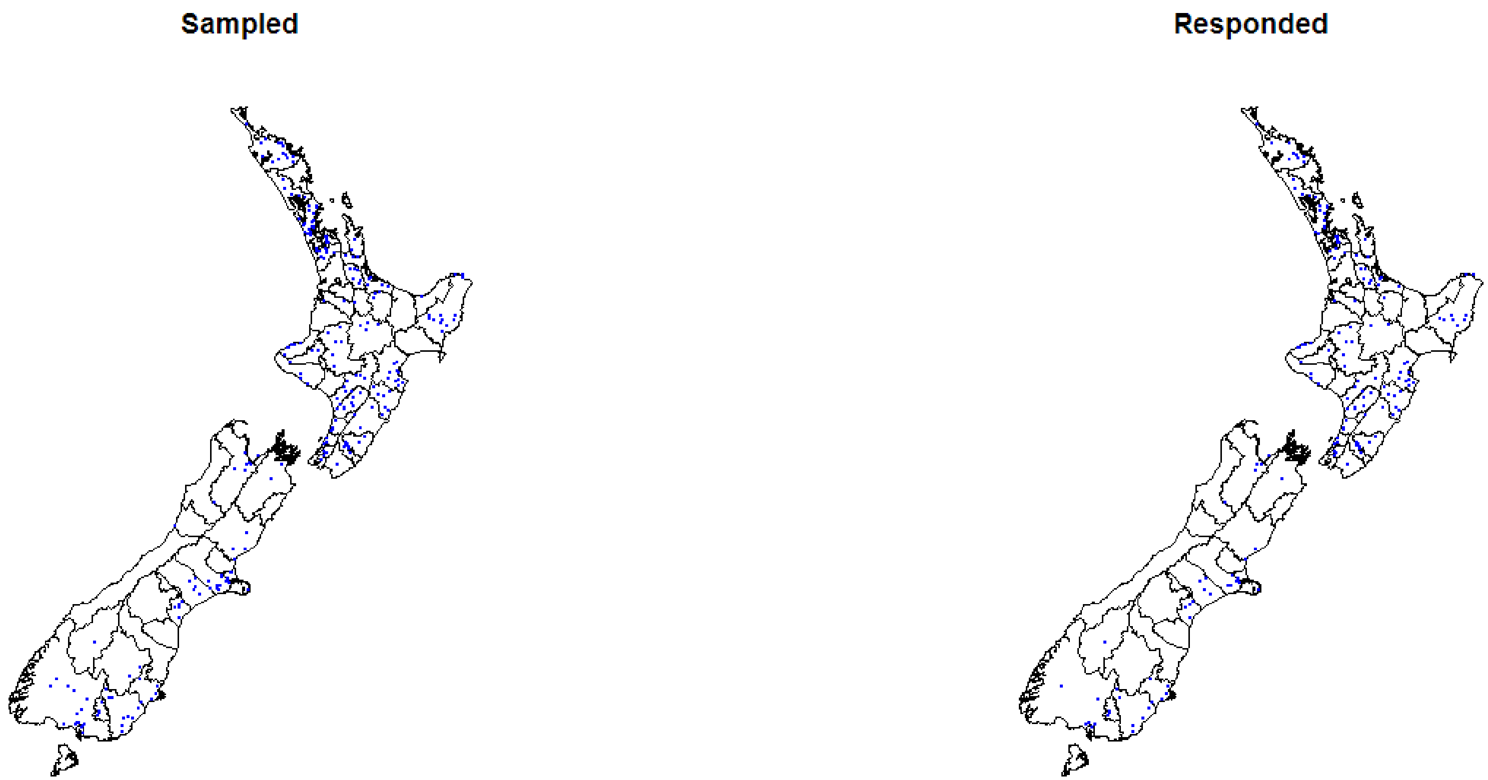


Figure 4.1: Location of properties from Agribase sampled for a phone survey (n = 250) and location of properties that responded (n = 171).

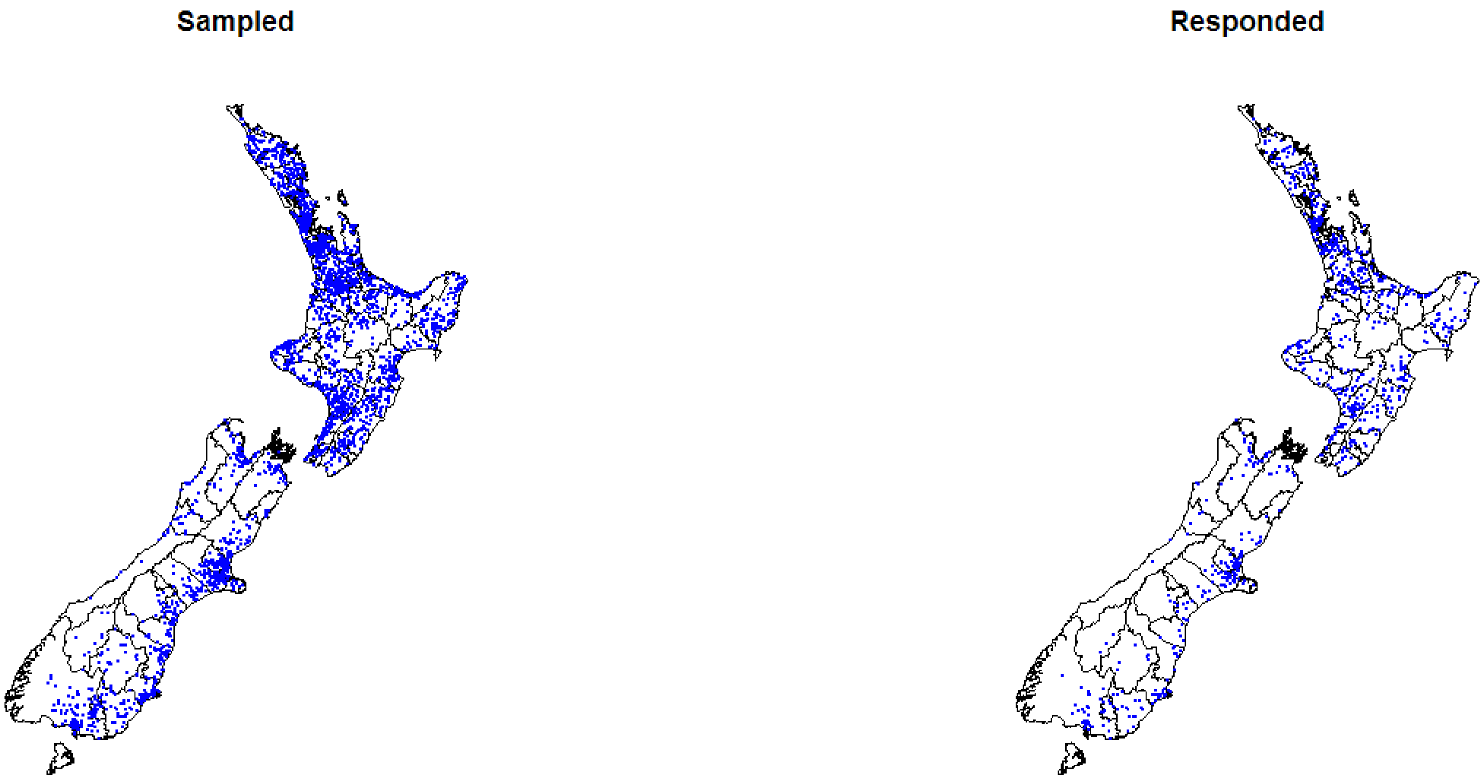
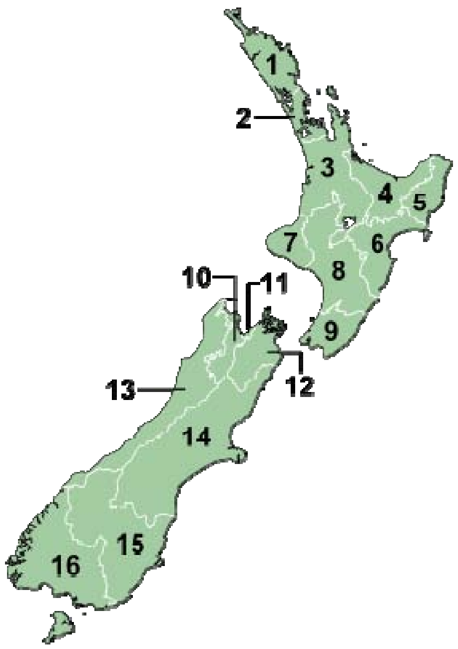


Figure 4.2: Location of properties from Agribase sampled for a mail survey (n = 2,912) and selected properties that responded (n = 860).



Legend

1 Northland
2 Auckland
3 Waikato
4 Bay of Plenty
5 Gisborne
6 Hawkes Bay
7 Taranaki
8 Manawatu-Wanganui
9 Wellington
10 Tasman
11 Nelson
12 Marlborough
13 West Coast
14 Canterbury
15 Otago
16 Southland

Figure 4.3: The 16 territorial land areas in New Zealand that equine premises were assigned to. Owing to the small number of respondents from the Tasman and Nelson areas these regions were combined in analysis of regional differences.

5.3. RESULTS

In total 1,035 people, or 34% of those contacted, responded to the survey. Figure 4.1 shows the location of properties for those that responded to the phone survey and Figure 4.2 shows the location of properties for those that responded to the mailed survey. The response rate for phone surveys (n = 171, 83%) was significantly higher than that for mailed out surveys (n = 860, 31%). There was no significant association between region or farm size and response categories.

Despite being listed in Agribase as horse properties 28% of respondents (n = 288) did not own horses. It is noteworthy that 62% of people contacted by phone owned horses while 74% contacted via mail owned horses. Horse ownership was not significantly associated with region or farm size. The median number of horses on a property was three (Minimum = 1 and Maximum = 493, Figure 3.4) and the number of horses varied significantly with region, farm size and reason for owning horses (Table 4.1). Respondents were more likely to have neighbours that owned horses if they owned horses, lived on the East Coast and had a farm larger than 200 hectares (Table 4.2).

The number of movements off a farm per week varied significantly by season ($P<0.0001$, Figure 4.4, Table 4.3). In each season the number of movements per week was significantly associated with the reason for owning horses (Table 4.4). Not surprisingly those that owned horses for income tended had a higher number of movements off the property per week. In spring there was also a significant association between average number of movements and region ($p = 0.03$). However, this association was not repeated any of the other seasons.

The distance travelled also showed significant seasonal variation ($p < 0.0001$, Table 4.5). In winter the proportion of movements greater than 200 kilometres was 5% while in the other seasons over 10% of movements were greater than 200 kilometres.

Table 4.1: Descriptive statistics for the number of horses stratified by method used to collect data, region, farm size and reason for owning horses and significance of the unconditional relationship between each variable and the number of horse. Data from the 747[a] respondents to a cross sectional survey of horse properties in Agribase[b].

			Percentiles				
Variable	Level	Number	25th	50th	75th	Maximum	P-value
Method	Mail	626	2	3	6	493	0.99
	Phone	104	2	3	6	61	
Region	Auckland	82	2	3	5	493	0.02
	Bay of Plenty	39	2	3	5	66	
	Canterbury	99	2	5	10	50	
	East Cost	32	2	5	8.5	33	
	Hawkes Bay	43	2	3	6	61	
	Manawatu	75	2	3	5	17	
	Marlbourgh/Tasman	30	2	3.5	5	55	
	Northland	58	2	3	8	57	
	Otago	47	1	3	5	16	
	Southland	35	1	3	7	20	
	Taranaki	35	2	3	6	25	
	Waikato	104	2	3	7.5	140	
	Wellington	42	2	5	8	125	
	West Coast	9	2	3	4	6	
Farm size	< 5 Ha	170	2	3	5	25	0.002
	5 -19 Ha	195	2	3	6	50	
	200-199 Ha	185	2	4	9	493	
	>=200 Ha	180	2	4	7	61	
Reason for owning horses[c]	Farming	97	2	3	16	24	<0.0001
	Income (Not primary)	103	5	9	14	60	
	Other	69	1	2	3	49	
	Primary income	20	11	22.5	41	493	
	Riding (recreation or competition)	421	2	3	5	66	

[a] Number of horses was missing from 17 respondents.
[b] Properties classified as either horse breeding or training operations were excluded from the study.
[c] 19 respondents did not record their reason for owning horses.

Table 4:2: Horse ownership of neighbours stratified by method used to collect data, region and farm size. Data from 1,035[a] respondents to a cross sectional survey of horse properties in Agribase[b].

Variable	Level	No neighbours have horses		Neighbours have horses		Total	P-value
		Number	%	Number	%		
Method	Mail	366	45.4	441	54.6	807	0.73
	Phone	68	43.9	87	56.1	155	
Region	Auckland	51	43.2	67	56.8	118	0.02
	Bay of Plenty	27	49.1	28	50.9	55	
	Canterbury	51	41.1	73	58.9	124	
	East Cost	6	17.6	28	82.4	34	
	Hawkes Bay	25	46.3	29	53.7	54	
	Manawatu	44	41.5	62	58.5	106	
	Marlbourgh/Tasman	23	65.7	12	34.3	35	
	Northland	38	48.7	40	51.3	78	
	Otago	35	58.3	25	41.7	60	
	Southland	22	46.8	25	53.2	47	
	Taranaki	24	46.2	28	53.8	52	
	Waikato	66	47.8	72	52.2	138	
	Wellington	18	34	35	66	53	
	West Coast	6	60	4	40	10	
Farm size	< 5 Ha	106	45.5	127	54.5	233	<0.0001
	5 -19 Ha	119	47	134	53	253	
	200-199 Ha	139	53.7	120	46.3	259	
	>=200 Ha	70	32.3	147	67.7	217	
Respondent owned horses	No	135	57.7	99	42.3	234	<0.0001
	Yes	299	41.1	429	58.9	728	

[a] 71 respondents did not know or did not provided information about their neighbours horse ownership.
[b] Properties classified as either horse breeding or training operations were excluded from the study.

Table 4.3: Descriptive statistics for the number of weekly movements off a property in spring stratified by season Data from the 747 respondents to a cross sectional survey of horse properties in Agribase[a].

Season	Percentile			Maximum	Mean	Standard Deviation
	50th	75th	95th			
Autumn	0	0.46	3.44	8.88	0.56	1.35
Spring	0	0.46	3.15	8.31	0.57	1.32
Summer	0	0.5	3.15	10.54	0.58	1.36
Winter	0	0.08	2.31	7.46	0.39	1.13

Table 4.4: Descriptive statistics for the number of weekly movements off a property in spring stratified by season and reason for owning horses and the significance of association between reason for owning horses and number of movements each season. Data from the 747 respondents to a cross sectional survey of horse properties in Agribasea.

Season	Reason for owning horses[b]	Number	Percentiles			Maximum	P-value
			50th	75th	95th		
Spring	Farming	97	0	0	1.2	3.4	<0.001
	Income (Not primary)	103	0.2	0.9	3	7.4	
	Other	69	0	0	0.4	6	
	Primary income	20	0.1	5.8	7.5	7.5	
	Riding (recreation or competition)	421	0	0.8	3.2	8.3	
Summer	Farming	97	0	0	1.3	5.2	<0.0001
	Income (Not primary)	103	0.2	0.7	3.6	8.2	
	Other	69	0	0	0.8	6	
	Primary income	20	0	5	7.5	7.5	
	Riding (recreation or competition)	421	0	0.8	3.2	10.5	
Autumn	Farming	97	0	0	1.7	7	<0.0001
	Income (not primary)	103	0	0.8	3.7	8.9	
	Other	69	0	0	0.4	6	
	Primary income	20	0	5	7.5	7.5	
	Riding (recreation or competition)	421	0	0.6	3.4	7.8	
Winter	Farming	97	0	0	1.8	2.3	<0.0001
	Income but not primary source	103	0	0.3	3	6.5	
	Other	69	0	0	0.4	6	
	Primary income	20	0	5	7.5	7.5	
	Riding (recreation or competition)	421	0	0.2	2.3	7	

[a] Properties classified as either horse breeding or training operations were excluded from the study.
[b] 19 respondents did not record their reason for owning horses.

Table 4.5: Distribution of distance travelled stratified by season. Data from the 747 respondents to a cross sectional survey of horse properties in Agribase[a].

	Spring		Summer		Autumn		Winter	
Distance	Number	%	Number	%	Number	%	Number	%
0-5 km	1014	18.5	954	16.9	830	15.6	652	18
6 -25 km	1252	22.9	1292	22.9	1141	21.4	902	24.9
26 -50 km	977	17.8	1130	20	890	16.7	666	18.3
51 -100 km	779	14.2	798	14.1	1048	19.7	689	19
100 to 200 km	829	15.1	815	14.4	885	16.6	535	14.7
>200 km	623	11.4	659	11.7	543	10.2	185	5.1

[a] Properties classified as either horse breeding or training operations were excluded from the study.

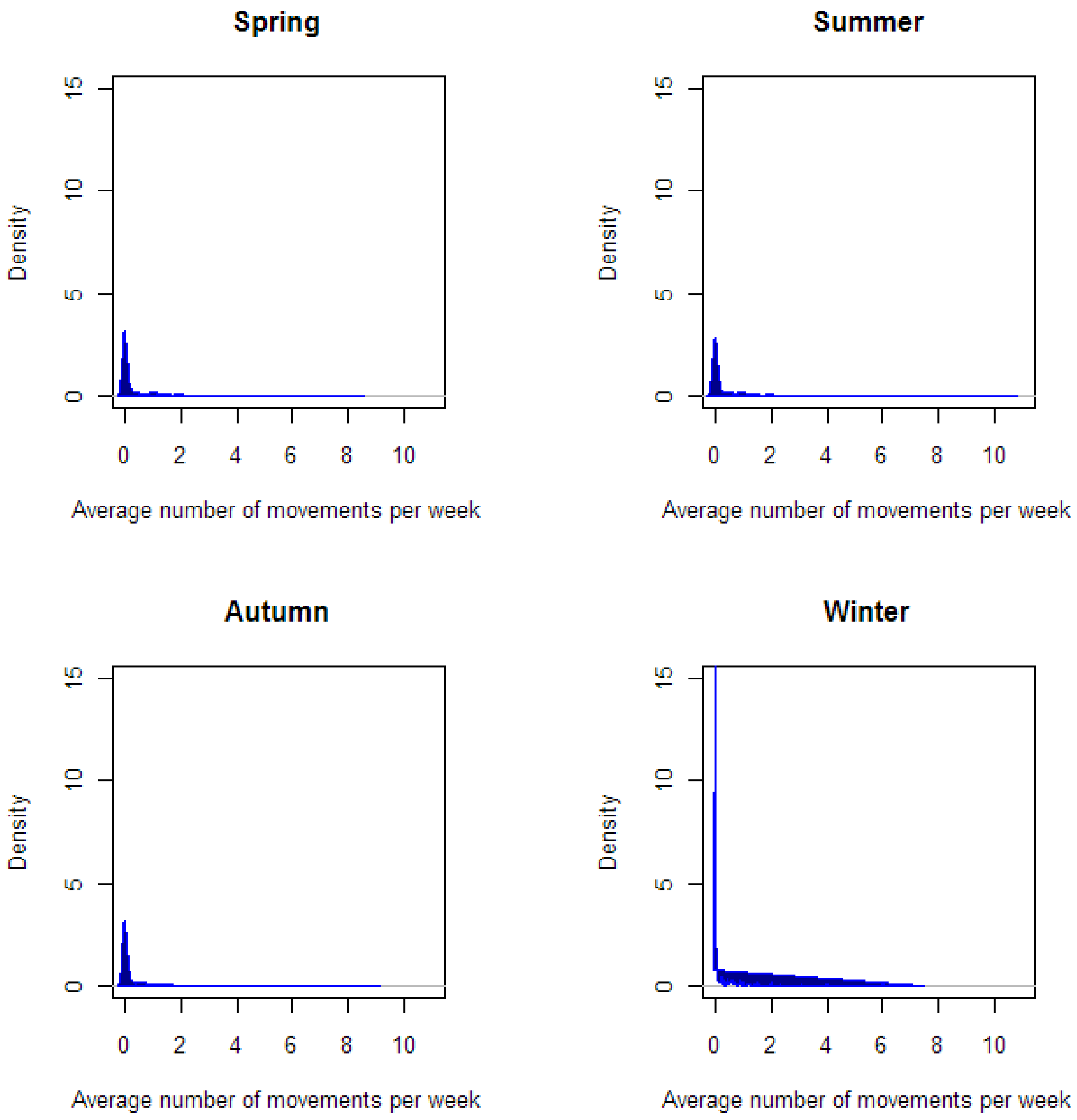


Figure 4:4: Kernel density plot of the number of movements per week stratified by season. Data from the 747 respondents to a mail or postal questionnaire of properties classified as horse properties in Agribase that actually owned horses.

5.4. DISCUSSION

The study found that the majority of individuals do not move their horses off the property, although there are seasonal differences. Specifically, the number of movements is roughly the same in spring, summer and autumn but significantly lower in winter. The study also showed that when horses do move that the distances involved can be quite long. For example, 10% of movements in spring, summer and autumn exceeded 200 km.

Selection bias was reduced in this study by using a random sample of farms. However, the low response rate to mail survey could have introduced some selection bias. In particular those that responded to the mail survey may have been more likely to own horses. This is supported by finding that when ownership was stratified by method used to collect data the proportion of respondents who owned horses was higher for those contacted via mail. This may be a true effect. An alternative is that those who did not own horses saw little value in returning the survey. In contrast, when we phoned people often told us they did not have horses at which point interviewers could complete the survey by asking about neighbours and verify addresses. Regardless of the reason for the difference the results highlight the need to invest resources into updating Agribase if it is to be used to identify equine properties during a disease outbreak.

Collecting data using both phone and mail surveys and could have been a source of information bias. However, with the exception of horse ownership there was no significant differences between data collected over the phone and that collected via a mail out. Therefore, it would seem unlikely that using the two methods to collect data created information bias.

Checking the addresses in Agribase substantially lowered the number of surveys that were returned undelivered to the researcher. In the authors experience the proportion of surveys that are returned to sender when using Agribase is often around 20% (compared to 5% in this survey). In this survey the use of the additional resources to verify addresses was considered effective as the cost of over sampling to allow for return to senders would have been approximately $2,000. This may not always be the case and as such one would be advised to weigh the savings against the cost of cross checking.

When designing future surveys it would also be worth considering using phone interviews rather than mail out the survey. Firstly, the phone survey in this study had a higher response rate. Secondly, a phone survey has the advantage of allowing interviewers to clarify any issues with the data at the time of collecting information. Phone surveys may also reduce the resources required for data entry if interviewers are issued with headset and log responses directly into a database.

6. Movements associated with the Thoroughbred Racing Industry

6.1. OBJECTIVE

The aim of this section is to provide an overview of the Thoroughbred racing industry, description of movements associated with races and trials and describe a survey of Thoroughbred trainers.

6.2. OVERVIEW OF INDUSTRY

New Zealand Thoroughbred racing industry comprises of 69 Thoroughbred racing clubs that operate 51 race tracks (Figure 5.1 and Table 5.1). Thoroughbred racehorses are trained at these race tracks as well as privately owned tracks and locations such as the beach or river. Privately owned tracks are typically used for slow work only, that is, training at speeds slower than a gallop. Consequently, even if a trainer uses a private track they will normally travel to a local track a couple of times a week to undertake gallop work. Beaches and the like are used to add variety to the training or for rehabilitation following an injury.

Events that are officially sanctioned by New Zealand Thoroughbred Racing include barrier trials and races. Barrier trials are essentially practice races that are classified as either qualifying or non-qualifying trials. Qualifying trials allow horses to gain entry into races and are typically used at the beginning of the two-year-old racing season when horses have no racing history. Non-qualifying trials are held for the purposes of education and training. It is not uncommon for older horses to compete in one or two non-qualifying trials before their first race of the season.

In New Zealand horses compete in flat, hurdles and steeple chase events. Flat racing occurs all year round while jumps races tend to occur during the winter months. Races are classified as group, listed, handicap and maiden. Group races are the very top level of races and attract the best horses. Listed races are just below a group race and used to identify horses with superior ability or as part of preparation for group races. A handicap race is one in which the handicapper decides how much weight a horse will carry and a maiden is a race that is only open to horses that have not won a race previously. Race meetings with listed or group races are referred to as premier race days.

New Zealand Thoroughbred Racing and commercial companies maintain databases for every official barrier trial and race. The databases can be used to determine which trainers attended an event and how many horses they took. Combining this information with programs such as Google Earth it is possible to estimate the distance travelled by each trainer who attended the event.

In addition to running races and trials New Zealand Thoroughbred Racing licenses individuals training horses. Trainers holding a full trainer’s license are those individuals whose primary occupation is training horses. New Zealand Thoroughbred Racing also issues permits to train and owner trainer licenses. A permit to train is issued to individuals that train no more than six horses and maintain an ownership interest in each of the horse. Owner trainer license allow the individual to train:

a) only horses solely owned or leased to him;

b) only horses in respect of which he has an ownership interest of at least 10% with the balance being owned by one or more near relatives; or
c) no more than two horses in respect of which he has an ownership interest of at least 50%;

From a disease control point of view owner trainers and those with a permit to train have parallels with "backyard" producers in the pig and poultry industries. These trainers tended to have horses for multitude of different reasons (e.g. breeding and eventing) and may move in and out of horse ownership. In addition, they train their horses at a variety of locations. Consequently, horses trained by those with and owner trainer license or permit to train have the potential to mix with a variety of different horse populations. In contrast, licensed trainers tend to be more "focused" on racing horses and are less likely to have other types of horses on their property and train at locations other than local or privately owned tracks. Although, unlike owner trainers and those permitted to train, horses trained by a licensed trainer are more likely to be sent to another property for spelling. However, like all industries there is considerable variation between individuals.

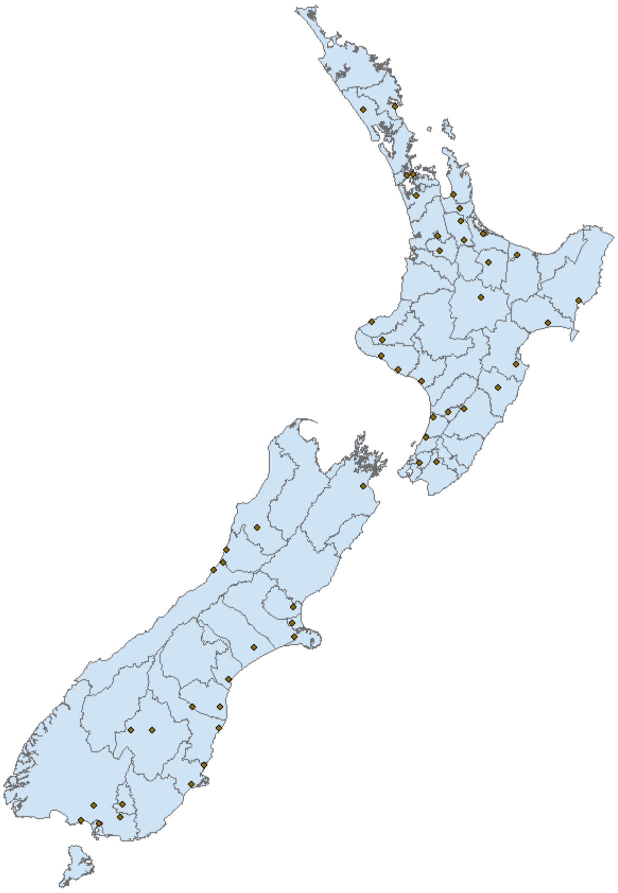


Figure 5.1: Location of the 52 Thoroughbred race tracks in New Zealand.

Table 5:1: Jockey clubs to host races during the 2008/2009 racing season stratified by region.

Northern	Central	Southern
Auckland Race Club	Egmont Race Club	Ashburton Race Club
Avondale Joceky Club	Feilding Jockey Club	Banks Peninsular Race Club
Cambridge Jockey Club	Foxton Race Club	Beaumont Race Club
Counties Race Club	Hawera	Canterbury Racing
Dargaville Race Club	Hawke's Bay Race Club	Central Otago Race Club
Paeroa Race Club	Levin Race Club	Gore Race Club
Pakuranga Race Club	Manawatu Race Club	Greymouth Jockey Club
Racing Matamata	Marton Jockey Club	Kuro Jockey Club
Racing Rotura	Masterton Race Club	Kumara Race Club
Racing Taupo	Popunake Race Club	Marlbourough Race Club
Racing Tauranga	Otaki-Maori Racie Club	Oamaru Jockey Club
Racing Te Aroha	Poverty Pay Turf Club	Otago Race Club
South Waikato Race Club	Rangitikei Race Club	Reefton Jockey Club
Thames Jockey Club	Stratford Race Club	Riverton Race Club
Taumarunui Race Club	Taranaki Race Club	South Canterbury Race Club
Waipa Racing Club	Waipukura Jockey Club	Southland Race Club
Waikato Race club	Wairarapa Race Club	Tapanui Race Club
Whakatane Race Club	Wairo Race Club	Westland Race Club
Whangarei Race Club	Wanganui Jockey Club	Waikowaiti Race Club
	Waverley Race Club	Waimate Race Club
	Wellington Race Club	Wairio Jockey Club
	Woodville Race Club	Winton Jockey Club
		Wyndham Race Club

6.3. MOVEMENTS ASSOCIATED WITH RACE DAYS

Four premier race meetings, 28 standard race meets and eight barrier trials were randomly selected from the racing calendar. Data for each event was grouped by trainer. The number of horses trained by each trainer at the event and the distance each trainer travelled to the event was recorded. Distance travelled was determined using Google Earth and was equal to the road distance rather than shortest distance between points.

Despite using random sampling a disproportionate number of events occurred in May. Furthermore, the premier race category does not include any races from the southern region. Therefore, spatial and temporal associations cannot be investigated.

Distance was categorised as zero to 50 kilometres, 51 to 100 kilometres, 101 to 200 kilometres, 201 to 300 kilometres, 301 to 400 kilometres and greater than 400 kilometres. The proportion of trainers in each distance category was determined stratified by type of race. No trainer travelled more than 300 kilometres to attend a trial while 12 % of trainers attending a premier event had travelled more than 400 kilometres (Table 5.2). This is not surprising as there is no prize money for barrier trials and premier race meets have the highest amount of prize money on offer.

Table 5.2: Proportion of trainers in each distance category for selected racing events (n= 42) stratified by premier, local and trial race meet.

	Premier Race	Local Race	Trial
0-50 km	27	25	44
51-100 km	18	24	33
101-200km	17	23	21
201-300 km	19	16	2
301-400 km	8	8	0
401 km +	12	3	0

6.4. MOVEMENTS ASSOCIATED WITH TRAINING

Two data sources are available to describe the movements around Thoroughbred training establishments. The first was a cross sectional study of trainers conducted in 2009. The second set of data was collected during a longitudinal study of health problems in Thoroughbred racehorses conducted over the 1998/99 and 1999/2000 racing season (Perkins et al. 2004a; Perkins et al. 2004b).

6.4.1 Cross-sectional survey

A cross-sectional survey was conducted on a stratified random sample of individuals licensed by the New Zealand Thoroughbred Racing. The strata were type of license and the sample comprised of 40 individuals licensed to train, 40 with permits to train and 20 with owner trainer licenses. Those selected individuals were then contacted via phone and asked to participate in the survey. Those that agreed to participate either completed the survey at that time or nominated a time they would prefer to be contacted.

Eighty trainers were contacted: 25 refused to participate and seven no longer kept horses. Of those that responded 25 had a license to train and 23 had either a permit to train or an owner trainer’s license. Those with a permit to trainer or an owner trainer license had fewer horses than those with a license to trainer (Table 5.3). This is hardly surprising given that New Zealand Thoroughbred Racing limits the number of horses that those with a permit to trainer or owner trainer license can train.

Twenty three of the 25 trainers with a license to train used their local track daily. In contrast, only 12 of the 23 trainers with either a permit to trainer or owner trainer license used the local racetrack daily. Those trainers that did not use the local racetrack daily visited the track between two and five times a week. Trainers that held an owner trainer license or permit to train kept racehorses all spelled horses on their own property. In contrast, all trainers with a license to train horses sent horses to different locations to spell. However, trainers found it difficult to provide an estimate of how frequently these movements happened. Nor could they provide information about distances horses typically traveled when spelled.

None of the trainers that held an owner trainer license or permit to train had regular scheduled visits from a veterinarian, preferring to use them as required. In contrast six of the trainers with a license to train had schedule visits from a veterinarian. Farrier visits tended to be scheduled into daily operations: 13 out of 23 trainers with a permit or owner trainer license had a farrier visit at least once a week and 24 of the 25 trainers with a license to train had a farrier visit at least once a week. Other horse professionals to visit stables included dentists, horse psychotherapists and chiropractors.

Table 5.3: Minimum, maximum and median number of horses per trainer stratified by type of license and type of horse. Data from a cross sectional study of 48 horses.

Type of license	Type of horse	Minimum	Median	Maximum
License to train	Racehorses in work	0	14	48
	Racehorses spelling	0	6	30
	Broadmare	0	0	50
	Other	0	0	6
Permit or owner trainer	Racehorses in work	1	3	20
	Racehorses spelling	0	2	40
	Broadmare	0	2	30
	Other	0	1	20

6.4.2 Longitudinal study

The data was collected from a number of trainers on the North Island and data collection is explained in detail in Perkins et al. (2004 a; 20004b). Briefly, researchers visited trainers on a monthly basis to collect training and injury information for all horses under the care of the trainer. This data can be used to estimate the number of movements from stables for reasons other than training. Using this data the number of times horses were spelled was determined stratified by month and trainer (Table 5.4). Across each of the trainers the average number of horse spelled each month was six that is, a horse or horses left the stables for spelling every five days.

Table 5.4: Number of months each trainer was observed for and descriptive statistics for the number of horse(s) were spelled each month stratified by trainer.

		Number of times one or more horse was spelled				
Trainer	Number Months	Mean	Standard Deviation	Minimum	Median	Maximum
1	25	6	3	1	5	12
2	20	4	1	1	4	6
3	20	2	1	1	2	3
4	24	9	3	3	9	14
5	17	4	2	1	4	8
6	26	5	3	1	4.5	11
7	25	5	2	1	6	8
8	32	3	2	1	3	7
9	19	5	2	1	6	9
10	24	10	4	1	10	17
11	27	9	3	2	9	14
12	24	10	4	1	10.5	14
13	16	4	2	1	3.5	8
14	24	9	3	1	8.5	14
15	18	5	3	1	5	13
16	16	4	2	1	4	8
17	25	8	4	1	9	16
18	29	5	2	1	5	10
19	22	4	1	2	3	6
20	26	5	2	1	5	8
Mean	23	6	2.5	1	6	10

7. Movement patterns associated with Standardbred training

Standardbreds horses are frequently trained at tracks located on the trainer's property. Consequently, the horses only travel to a racetrack for official workouts, races and trials. The official workouts, trials and races are all recorded in an official database and as with the Thoroughbred racing industry the data can be used to determine which trainers attended an event and how many horses they took. Combining this information with programs such as Google Earth it is possible to estimate the distance travelled by each trainer who attended the event.

Two data sources are available to describe the movements associated with travel to race meetings. The first contained distance data for 43 official events and the second contained information about the number of times 100 trainers had raced in a 12 month period.

The distance data set comprised of data from three premier race meetings, 20 standard race meets, 16 trials and three timed workouts randomly selected from the racing calendar. Data for each event was grouped by trainer. The number of horses trained by each trainer at the event and the distance each trainer travelled to the event was recorded. Distance travelled was determined using Google Earth and was equal to the road distance rather than shortest distance between points. The proportion of trainers in each distance category was determined stratified by type of race. Results showed that trainers were more likely to travel long distances to attended premier races (Table 6.1). In contrast, the majority of trainers at trials and timed workouts travelled less than 100 kilometers.

The number of times per year that Standardbred trainers attended official events (e.g. trials, race and workouts) was estimated by randomly selecting 100 trainers and obtaining official records for the 2008/2009 racing season from the Standardbred racing industry. The results showed that 13 trainers did not race during the 2008/2009 racing season. In the remaining 87 trainers the number of race meets attended in twelve months was skewed and ranged from one to 166 with a median of 27.

Table 6.1: Percentage of trainers in each distance category for selected racing events (n= 43) stratified by type of event.

Distance	Premier Race (n = 3)	Standard race (n = 16)	Trial (n = 16)	Timed workout (n = 3)
0-50 km	42	52	66	71
51-100 km	22	19	21	29
101-200km	9	12	8	0
201-300 km	2	4	3	0
301-400 km	2	5	0	0
401 km +	22	8	2	0

8. Movement patterns associated with breeding operations

8.1. OBJECTIVE

This section provides and an overview of the Thoroughbred and Standardbred breeding industry and describes the movement patterns association with the breeding operations.

8.2. OVERVIEW OF STANDARDBRED AND THOROUGHBRED BREEDING INDUSTRY

The Thoroughbred and Standardbred breeds are primarily breed for flat and harness racing respectively. In New Zealand these two breeds are the largest equine studbooks with ~6,500 and 4,500 active broodmares respectively and are also two of the most important economically. Both the Thoroughbred and Standardbred have a closed studbook. A closed stud book means that the parents of each foal must be registered in the New Zealand studbook or another stud book considered acceptable to the regulating authorities (e.g. Australian Studbook). Close studbooks ensure that the offspring are pure breed. However, depending on the size of the studbook it can result in inbreeding. The structure of the Thoroughbred racing and breeding industry is remarkably consistent across participating countries. In the United Kingdom most fillies leave training and retire to stud when 3 or 4 years old (Wilsher and Allen 2003). In New Zealand approximately 87% of female horses in racing in New Zealand are less than 5 years old (Perkins *et al.* 2005). The opportunities to race and the prize money available decreases as the horse ages, unless it is capable of competing at top level (listed and group races), which effectively means that by 5 years old most mares have been retired to stud and are expected to produce a foal annually.

The use of assisted reproductive technologies such as artificial insemination (AI) and embryo transfer (ET) have been utilised widely by the Sport Horse and Standardbred industries. However, the Thoroughbred industry requires a natural mating (i.e.no AI or ET). In part to counteract the limitation of no AI the Thoroughbred industry has embraced the use of shuttle stallions (the shipping of stallions for breeding from the Northern to Southern hemisphere to breed two seasons in a calendar year) (Pickett and Voss 1998; Pickett *et al.* 1998). In New Zealand from 1993 to 2002 the number of shuttle stallions covering mares increased from 2 to 17, and in 2002 covered 18.7% of the mares bred (Anonymous 2008).

Over the last 20 years there has been a reduction in the effective size of the broodmare herd for both breeds (Table 7.1). The percentage reduction in mares covered has been similar for Thoroughbreds (36%) and Standardbreds (37%), although the relative reduction in live foals has been greater in Thoroughbreds (45%) compared to Standardbred (40%). It is not clear what implications these changes have on movement patterns within the industry.

Table 7.1: Total broodmares bred, exported and live foals in New Zealand from 1989/90 to 2004/05 breeding seasons for the Thoroughbred and Standardbred studbooks.

Year	Thoroughbred			Standardbred		
	Mares Covered	Live Foals	Exported Mares	Mares Covered	Live Foals	Exported mares
1989	10,176	5,882	158	7,261	5,133	176
1990	9,426	5,394	195	6,738	4,712	148
1991	8,451	4,828	118	6,239	4,455	94
1992	8,050	4,828	127	5,610	3,973	97
1993	8,351	4,978	144	5,491	3,978	98
1994	7,987	4,913	121	5,238	3,755	87
1995	7,790	4,918	135	4,813	3,486	94
1996	7,440	4,639	127	4,635	3,427	95
1997	7,172	4,614	123	4,820	3,230	111
1998	6,802	4,454	144	4,197	3,049	115
1999	6,850	4,554	125	3,989	2,808	95
2000	7,357	4,692	158	4,062	2,980	78
2001	7,167	4,625	121	4,629	3,242	79
2002	6,836	4,285	131	4,629	3,218	79
2003	6,458	4,082	172	4,612	3,202	72
2004	6,488	3,181	229	4,512	3,051	62

8.3. METHODOLOGY

8.3.1 Thoroughbred breeding operations

Standardbred and Thoroughbred breeding operations were convenience sampled and contacted by phone to invite them to participate in the survey. If they agreed the researcher organised a time to visit the property and administer a standard questionnaire about movement patterns at different times of the year. The questionnaire was developed in consultation with several post-graduates and staff at Massey University with experience and knowledge of the New Zealand breeding sector and pre-tested with Thoroughbred and Standardbred breeders. The questionnaire took approximately 30 minutes to complete and included questions about movements at different times of the year and current on-farm biosecurity practises.

8.3.2 Statistical analysis

The total number of horses was calculated and summarised using percentiles minimum and maximum. Horses on the farm were then classified as stallions, broodmares, weanlings, yearlings, spelled racehorses and other if the horse was not part of either the breeding or racing industry. The number of horses in each category was summarised using percentiles, minimum and maximum. The number of breeding operations that broke, pre-trained or trained race horses and engaged in activities unrelated to racing or breeding was calculated. Results were presented stratified by type of breeding operation (i.e. Standardbred or Thoroughbred).

For each property the number of movements per week was estimated stratified by month and the distribution across all properties summarized using percentiles, minimum, maximum. Even though the number of weekly movements was non-normally distributed the mean and standard deviation were included because they will be required when selecting input parameters for the Interspread Plus model.

For each property and month combination the proportion of movements per week that were 1 to 50 kilometres, 51 to 150 kilometres and 151 to 350 kilometres was estimated. For Thoroughbred studs we also estimated the proportion of movements that were to the South Island. This information was summarised by determining the mean and standard deviation for the proportion of movements in each distance category by month. Results were presented stratified by month and type of operation.

8.4. RESULTS

8.4.1 Thoroughbred breeding operations

Data were collected from 17 Thoroughbred breeding operations in Auckland (n = 2), Waikato (n = 10), central districts (n = 4) and the Wairarapa (n = 1). Three of the Thoroughbred studs did not stand any stallion and five stood one, or more, shuttle stallions. Sixteen of the 17 Thoroughbred breeding operations spelled race horses, 29% (n = 5) broke horses for trainers, seven pre-trained horses and five had training operations on the property. Thirty five percent (n = 6) undertook activities unrelated to breeding or racing Thoroughbred racehorses including show jumping, competing at pony club events and eventing.
The median number of horses on the 17 operations was 231 (Table 7.2). The number of movements off the breeding premises was seasonal with the period of highest activity beginning in August and ending in January (Table 7.3). In each month the majority of movements were less than 50 kilometers (Table 7.4). Although there was a substantial number of long distance movements.

Table 7.2: Descriptive statistics for the total number of horses and number of horses in each category. Data from 17 Thoroughbred breeding operations surveyed during the 2009/2010 breeding season.

		Percentiles			
Horse type	Minimum	25th	50th	75th	Maximum
Stallion	0	1	2	4	7
Broodmare	25	85	120	177	500
Foals	10	30	60	147	250
Yearling	0	20	40	65	110
Racehorses spelling	0	0	6	25	40
Other[a]	0	0	3	11	70
Total	61	123.5	231	433.5	906

[a] Horse not used in the Thoroughbred breeding or racing

Table 7.3: Descriptive statistics for the number of movements per week off Thoroughbred breeding operations stratified by month. Data from 17 Thoroughbred breeding operations surveyed during the 2009/2010 breeding season.

		Percentiles					
Month	Minimum	25th	50th	75th	Maximum	Mean	Standard deviation
August	0	0.31	2.3	7.13	17.5	4.23	5.42
September	0	2.33	3.55	10.42	17.5	6.36	5.73
October	2.3	4.00	7	13.34	24.75	8.85	6.44
November	2.3	5.50	6.78	13.34	32.91	10.22	8.45
December	1.22	5.50	6.78	10	24.75	9.19	6.79
January	0	1.50	3.00	6.78	24.75	5.74	6.92
February	0	0.31	1.22	2.5	7.25	1.73	1.89
March	0	0.31	1.13	2.5	7.25	1.59	1.84
April	0	0.31	1.13	2.54	7.25	1.77	2.08
May	0	0.31	1.13	2.68	8.00	2.16	2.57
June	0	0.54	1.22	2.50	7.25	1.66	1.8
July	0	0.43	1.23	2.52	7.25	1.72	1.84

Table 7.4: The mean and standard deviation (SD) for the proportion of movements off Thoroughbred breeding operations that were 1 to 50 kilometers, 51 to 150 kilometers, 151-350 kilometers or to the South Island stratified by month. Data from 17 Thoroughbred breeding operations surveyed during the 2009/2010 breeding season.

	1-50 km		51-150 km		151-350 km		South Island	
Month	Mean	SD	Mean	SD	Mean	SD	Mean	SD
August	0.66	0.29	0.19	0.21	0.08	0.11	0.07	0.06
September	0.63	0.3	0.18	0.2	0.15	0.23	0.04	0.04
October	0.57	0.25	0.21	0.19	0.15	0.12	0.07	0.07
November	0.56	0.25	0.23	0.21	0.14	0.09	0.07	0.07
December	0.58	0.26	0.21	0.23	0.14	0.09	0.07	0.07
January	0.6	0.32	0.2	0.24	0.11	0.1	0.09	0.09
February	0.67	0.36	0.18	0.33	0.1	0.12	0.05	0.06
March	0.7	0.36	0.16	0.3	0.09	0.11	0.05	0.05
April	0.7	0.33	0.15	0.24	0.1	0.12	0.05	0.05
May	0.7	0.32	0.15	0.24	0.1	0.12	0.05	0.05
June	0.71	0.33	0.13	0.24	0.09	0.12	0.07	0.07
July	0.71	0.33	0.13	0.24	0.09	0.12	0.07	0.07

8.4.2 Standardbred breeding operations

Data were collected from nine Standardbred breeding operations in Auckland (n = 2), Christchurch (n = 6) and Southland (n = 1). Three of the Standardbred operations did not have a stallion on the farm and three stood one or more shuttle stallions. Seven of the operations spelled Standardbred race horses, five broke-in horses, six engaged in some type of pretraining activity and five trainer trained racehorses. Six of the nine Standardbred studs also kept horses for activities unrelated to breeding or racing.

The median number of horses on the 9 operations was 375 (Table 7.5). The number of movements off the breeding premises was seasonal with the period of highest activity beginning in September (Table 7.7). In each month the majority of movements were less than 50 kilometers (Table 7.7).

Table 7.5: Descriptive statistics for the total number of horses and number of horses in each category. Data from nine Standardbred breeding operations surveyed during the 2009/2010 breeding season.

		Percentiles			
Horse type	Minimum	25th	50th	75th	Maximum
Stallion	0	1	2	7	9
Broodmare	30	51	200	250	650
Foals	12	33	70	130	330
Yearling	0	0	8	42	90
Racehorses spelling	0	0	0	3.5	6
Other[a]	0	0	3	30	50
Total	61	128	375	470	910

[a] Horse not used in Standardbred breeding or racing

Table 7.6: Descriptive statistics for the number of movements per week off Standardbred breeding operations stratified by month. Data from nine Standardbred breeding operations surveyed during the 2009/2010 breeding season.

		Percentiles					Standard deviation
	Minimum	25th	50th	75th	Maximum	Mean	
August	0	0	0.41	0.68	3.92	0.89	1.36
September	0	0	0.62	1.25	5.15	1.16	1.68
October	0	0.41	1.25	2.37	12.25	2.9	4.12
November	1	2.17	3.91	7	10.5	4.88	3.49
December	0.5	2.37	3.33	7	14.95	5.32	4.67
January	0.5	3.15	3.91	7	17.89	6.09	5.33
February	0.5	2.17	3.91	7.37	22.54	6.58	6.77
March	0	0.62	1.07	10	11.27	4.39	4.87
April	0	0.62	1.07	7.6	10.5	4.26	4.49
May	0	0.62	1.07	6.37	10.78	3.45	4.39
June	0	0.62	1.5	2.37	10	2.54	3.37
July	0	0	0.63	1.5	2.37	0.75	0.87

Table 7.7: The mean and standard deviation (SD) for the proportion of movements off Standardbred breeding operations that were 1 to 50 kilometers, 51 to 150 kilometers, 151-350 kilometers and >350 kilometers stratified by month. Data from nine Standardbred breeding operations surveyed during the 2009/2010 breeding season.

	1-50 km		51-150 km		151-350 km		>350 km	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
August	0.77	0.27	0.09	0.14	0.13	0.14	0.02	0.04
September	0.77	0.24	0.09	0.13	0.13	0.13	0.02	0.04
October	0.77	0.32	0.14	0.29	0.07	0.08	0.02	0.03
November	0.74	0.3	0.16	0.28	0.09	0.07	0.01	0.03
December	0.74	0.3	0.16	0.28	0.09	0.07	0.01	0.03
January	0.7	0.28	0.2	0.27	0.09	0.07	0.01	0.03
February	0.7	0.28	0.2	0.27	0.09	0.07	0.01	0.03
March	0.74	0.24	0.14	0.18	0.11	0.12	0.01	0.03
April	0.77	0.26	0.11	0.18	0.11	0.12	0.01	0.03
May	0.74	0.26	0.13	0.19	0.12	0.12	0.01	0.03
June	0.65	0.3	0.13	0.19	0.21	0.26	0.01	0.03
July	0.58	0.29	0.17	0.2	0.25	0.3	0.00	0.00

8.5. DISCUSSION

This survey provides the first estimate of movements associated with breeding Standardbred and Thoroughbred horses. Not surprisingly the number of movements was highly seasonal with peak movements corresponding with the breeding season. In the Thoroughbred industry the breeding season begins in August with the arrival of dry mares and concludes in January with the yearling sales. While, the breeding season in the Standardbred industry begins in September and ends in February. Like the Thoroughbred industry the end of the breeding season corresponds with yearling sales. In the Standardbred industry the distances travelled were less than for Thoroughbreds. The most likely explanation for this is that Standardbreds allow artificial insemination and as such the semen can be distributed to a number of centres throughout the country.

Movement estimates may have been measured with some error because we asked the person to estimate the number of movements per month using prompts such as “number of walk-in mares in a week/day?” To reduce bias the prompts were the same for interviewers and single interviewer conducted all the interviews. More detailed data could have been collected using a diary method. However, pre-testing found that stud masters were reluctance to complete the paper work. An alternative of ringing regularly was not considered viable, especially during the breeding season, because stud masters would soon lose interest.

Non-random methods were used to select the breeding operations. Random sampling may have given in a more representative sample. However, we felt that using such techniques was likely to result in low response rates and poor data quality. It is also noteworthy that the studs sampled are responsible for the management of over 80% of Thoroughbred broodmares and 70% of Standardbred broodmares.

9. Modelling Equine Influenza during the silent spread phase

9.1. INTRODUCTION

InterSpread Plus was used to simulate the silent spread phase of the epidemic. During the silent spread phase spread of disease depends on: (1) the frequency and distance of movement of animals, humans and fomites from farm to farm and market to farm (and in the reverse direction), (2) incubation period and virus production for each susceptible species, and (3) local-spread and airborne-spread probabilities. The model also requires information about the location of all farms with horses and coordinates of racetracks (modeled as markets). This section of the report describes the data sources, model parameters used to model the silent spread, results of several scenarios and statistical analysis used to determine the impact of month, type of farm and region on the number of infected premises (IPs) on day 15 of the outbreak that is, the average time to detection.

9.2. DATA SOURCES

9.2.1 Farm types

The farm file that was used to populate the model was derived from the 2009 version of AssureQuality's Agribase. Agribase divided horse properties into a number of property types including, but not limited to, breeding, training, "undifferentiated" and "farming". Farm enterprise types were applied as follows:

1. Equine properties not classified as either breeding or training were coded as General Equine Properties;

2. Equine properties listed as breeding operations that could be matched to a list of Thoroughbred breeders were coded as Thoroughbred breeding operations;

3. Equine properties listed as training operations that could be matched to a list of Thoroughbred trainers were coded as Thoroughbred training operations;

4. Equine properties listed as breeding operations that could be matched to a list of Standardbred breeders were coded as Standardbred breeding operations; and

5. Equine properties listed as training operations that could be matched to a list of Standardbred trainers were coded as Standardbred training operations.

Assure Quality provided the results of work to linked relevant industry databases with the Agribase properties. Examination of the results found that 86% (n = 33) of Standardbred studs, 47% (n = 560) of Standardbred trainers 78% (n = 77) of Thoroughbred studs and 51% (n = 646) of Thoroughbred trainers could be matched to an Agribase property. Having less breeding and training properties that actually exist is likely to result in an under-estimate of the size of an outbreak.

To account for the unmatched properties we randomly selected:

- Five general horses properties in the Canterbury region and recoded them as Standardbred breeding operations;
- 631 general properties within 20 kilometers of a Standardbred race track and recoded them as a Standardbred training operation;
- 22 general properties within 50 kilometers of Cambridge or Hamilton and coded them as Thoroughbred breeding operations; and
- 621 general properties within 20 kilometers of a Thoroughbred racetrack and recoded them as a Thoroughbred training operation.

9.2.2 Markets

Standardbred races and Thoroughbred races are incorporated in the model as markets. Locations and names for each of the Standardbred and Thoroughbred race tracks were derived from the industry web sites and point locations determined using Google earth.

9.2.3 Movements

There is no single robust database of equine movements. Therefore, extensive efforts were made to examine a variety of formal and informal sources and conduct studies to generate model parameters for movement parameters. The results of these studies are presented in Sections 4, 5, 6 and 7 of this report.

9.3. MODEL PARAMETERS

Table 8.1 summarizes the input parameters that are required to model the uncontrolled spread of equine influenza prior to detection and application of control strategies. The remainder of this section describes these parameters in more detail.

Table 8.1 Input data and parameter values used prior to detection of equine influenza.

Item	Details
Farm data	Easting and Northing coordinates of equine farms in New Zealand and farm type
Market data	Easting and Northing coordinates of Thoroughbred and Standardbred racetracks.
Movement – General	Defines the background level of movement of animals off all general equine properties.
Movement – Thoroughbred trainer	Defines movement of animals off Thoroughbred training for training, racing and spelling.
Movement – Standardbred trainer	Defines movement of animals off Standardbred training premises for training, racing and spelling.
Movement – Thoroughbred breeder	Defines movement of animals off Thoroughbred breeding premises.
Movement – Standardbred breeder	Defines movement of animals off Standardbred breeding premises.
Local spread	Defines the spread of disease between locations when there is not clear linkage other than geographical proximity
Incubation period	Defines how quickly clinical signs appear after infection

9.3.1 Time to detection

In the Australian outbreak, infected horses arrived at the Eastern Creek quarantine facility on the 8th August. While, the precise nature on the release mechanism(s) is unknown, the virus is believed to have escaped sometime between the 8th and 15th August and presence of disease was confirmed on the 25th August. Based on this information the background surveillance parameter was selected such that the average time to detection was 14 days.

9.3.2 Infectivity

This variable defines how soon after infection clinical signs will appear. A review of the literature indicated that the time between exposures and clinical symptoms can range from one to five days (Ainsworth and Hackett 2004; Hodgson 2002). Accurate estimates of the incubation period during the Australian outbreak are limited. However, it is known that the index case arrived at Warwick on Friday 24 August 2007 and the first clinical signs in horses occurred on the morning of the 26th August, suggesting an incubation period less than 48 hours. Similarly, the first horses to show signs of infection in Centennial Park Equine Complex had attended the Maitland event on Friday 17 August and the first clinical signs were observed on the afternoon of Wednesday 22 August 2007. Other horses departing the Maitland event were reported as showing clinical signs on 24 August. That is, the incubation period could have been as long as seven days. Information from Thoroughbred breeding studs suggests that on several occasions the incubation period was as short as 24 hours. Based on this information the probability that clinical signs would be present relative to the date of infection was included in the model as a pert distribution with a minimum of one, maximum of seven and a most likely value of two.

Virus excretion by unvaccinated horses may persist for 7–10 days (Geering *et al*., 1995; Hannant and Mumford, 1996) but individual horses are rarely infectious for more than 7 days (Minke *et al*., 2007; Bryant *et al.*, 2008). Therefore, the period of time that an equine property will remain infectious is a function of the number of horses on the property. Garner *et al.* (*In Press)* randomly set infectious periods for each property from the following ranges: one horse (7 days), 2–10 horses (8–12 days), 11–50 horses (13–16 days), >50 horses (17–21 days). Accurate data about horse numbers on equine properties is not available for New Zealand. Therefore, the period of time that a property would be infectious was set to 10 days because the median number of horses on horse properties was one.

9.3.3 Local spread parameters

Garner *et al.* (*in press*) identified 16 regions and estimated separate transmission parameters for each of these regions. Exact details of these parameters were not in the paper but were provided when the author of this report contacted Graeme Garner. Based on these values the local spread parameters were determined (Table 8.2).

Table 8.2: Probability that horses on a property will become infected based on proximity to an infected property.

Distance from a infected premises	Probability of infection
0 to 1000 meters	0.05
1001 to 5000 meters	0.003
5001 to 10,000 meters	0.0007
10,001 – 15,000 meters	0.0003

9.3.4 Movement parameters

In the equine industry the types of movements are closely aligned to the farm type. Movements off Thoroughbred and Standardbred training operations were further divided into three categories: (i) those associated with training; (ii) those associated with racing and barrier trials; (iii) those associated with spelling. Therefore, there was a total of nine different movement types included in the Interspread Plus model. The number of movements per time period, distance probabilities and number of horses contacted for each movement type for each property type are described in the Appendix B.
The probability of transmission varied depending on the type of movement. Specifically, the

probability of transmission was 1 for all movements off breeding operations and those movements off training operations associated with spelling. This value was considered appropriate because in both instances the horse actually remained on the property after the movement. For all other movements the probability of transmission was 0.30. Selection of this value was based on data from the Australian outbreak (Cowled, *personal comms*).

9.4. SCENARIOS MODELLED

Data presented in this report showed that the frequency and distance of movements off general horse properties and breeding operations properties varies by month. Therefore, the size of equine influenza outbreak at the time of detection could vary by month. To explore the effect of time of year equine influenza virus was "seeded" into a randomly selected Thoroughbred breeding operation in the Waikato and movements parameters selected to represent typical patterns in each month (see accompanying spreadsheet for input values). A simulation consisting of 40 iterations with one-day time steps for 15 days was run for each month. The data set from this analysis consisted of the number of infected premises (IP's) at day 15 and because there were 40 iterations for each month the resulting data set consisted of 480 rows.

The location of the first infected property will affect the size of an outbreak. For example, there are some farms that, because of their location and movement patterns, will not cause outbreaks of significance. In contrast, other farms will create large outbreaks due to its proximity to other farms and/or movement patterns. A 'seed model' was run to determine the effect of farm on the size of the outbreak, When running the seed model, infection with equine influenza is "seeded" into a randomly selected property in January and a simulation run to see the number of IP's that would occur. The simulation ran one-day time steps for 15 days and consisted of 20 iterations, that is for the randomly selected property there were 20 possible values for the number of IP's. This process is repeated until the equine influenza had been seeded into each of the 18,410 horse properties listed in Agribase. The output file from the seed model comprised of 368, 200 rows of data (i.e. 18,410 horse properties × 20 iterations). Data from the seed model were aggregated by farm and for each farm the following data recorded: farm id, region, farm class and median number of IP's, herein called the number of IP's.

9.5. STATISTICAL ANALYSIS

All statistical analyses were conducted using SAS Version 9.1 and graphics generated in R Version 2.10. Using the data from the 'month' model the number of IP's per month was stratified by month and assessed for normality. For each month the number of IP's at day 15 of the outbreak was non-normally distributed. Therefore, Kruskal-Wallis test statistic was used to determine if month was significantly associated with the number of IP's. Data from the 'month' model was aggregated into season and again the Kruskal-Wallis test statistic was used to determine if there was a significant association between season and the number of infected premises. Pair wise comparisons between winter and the other three seasons were conducted using the Wilcoxon rank sum test applying the Bonferroni correction for non independent variables. This mean than when making pair wise comparison the level of significance was 0.0125 rather than 0.05.

Using the aggregated data from the seed model the number of IP's per property was stratified by region and farm class and assessed for normality. For each region and farm class the number of IP's per property was non-normally distributed. Therefore, Kruskal-Wallis test statistic was used to determine if region or farm class had a significant effect on the number IP's.

9.6. RESULTS

Figure 1 describes the distribution of IP's on day 15 when using movement parameters for January and August. In both instances the iteration displayed is that with the median number of IP's. Analysis of data found that the number of IP's did not vary significantly from month to month ($p = 0.73$). However, there was a significant difference in the number of IP's when data was aggregated by season ($p=0.05$, Figure 8.2). Comparison of winter with each of the seasons only found significant difference between winter and summer. Specifically the median number of IP's in summer was 193 (Minimum = 34, Maximum = 766). In contrast the minimum, maximum and median number of IP's in winter was 38, 632 and 153, respectively. Analysis of the data from the seed model found that the number of IP's varied significantly by region ($p <0.0001$, Figure 8.3). With the number of IP's being highest for properties in Auckland (median = 1,243) and Waikato (Median = 504) and lowest for the East Coast of the North Island (median = 56), Otago (median = 64) and the West Coast of the South Island (median = 64). The number of IP's also varied between the farm classes ($p <0.0001$, Figure 8.4) with the highest number of IP's in Thoroughbred breeding operations (median = 351) and the lowest number of IP's in Standardbred training operations (median = 178).

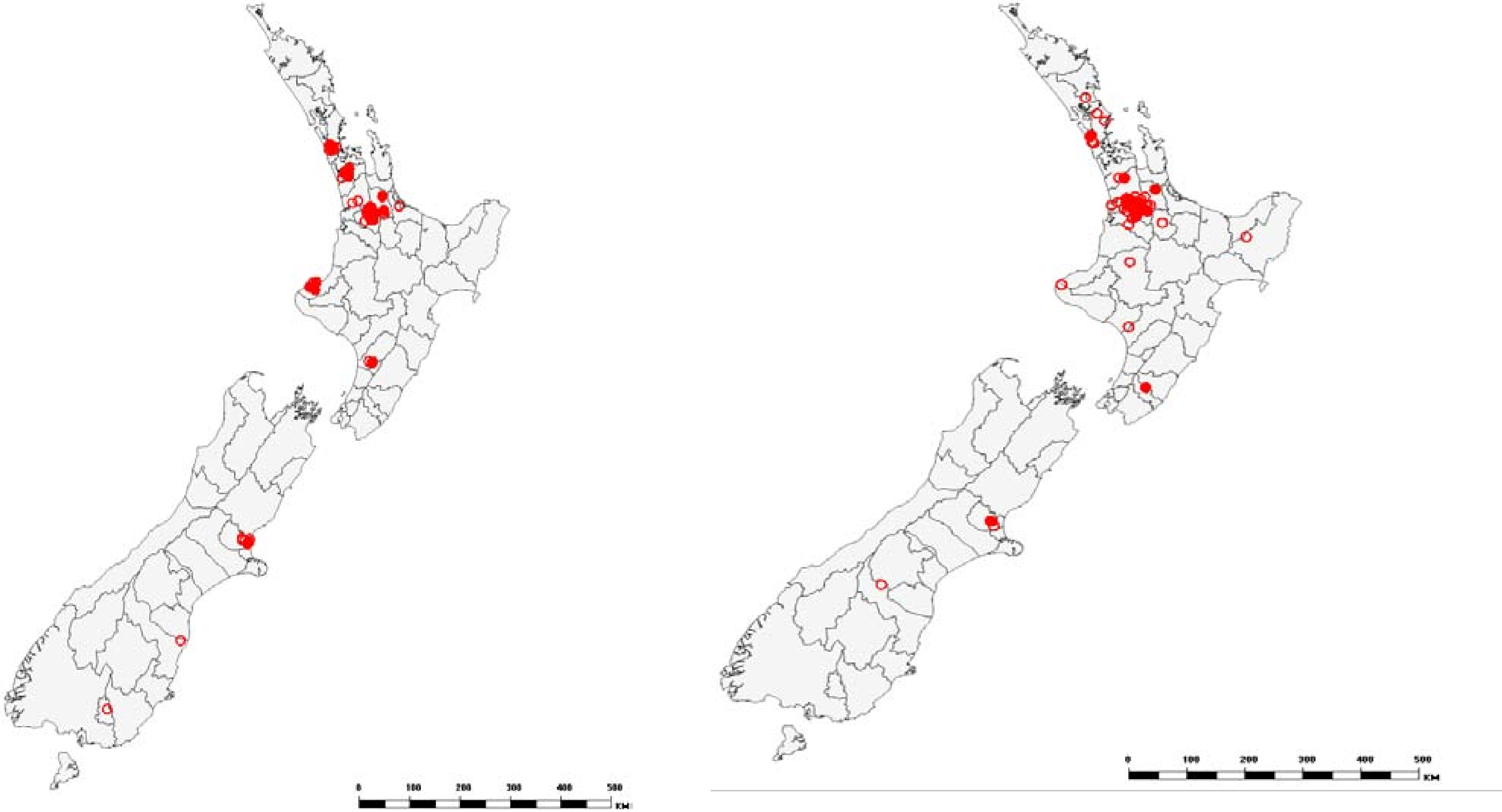


Figure 8.1: Distribution of infected properties on day 15 of an outbreak in January (Left) and August (Right). Data from a model in which disease was seeded into a randomly selected Thoroughbred breeding operation located in Waikato.

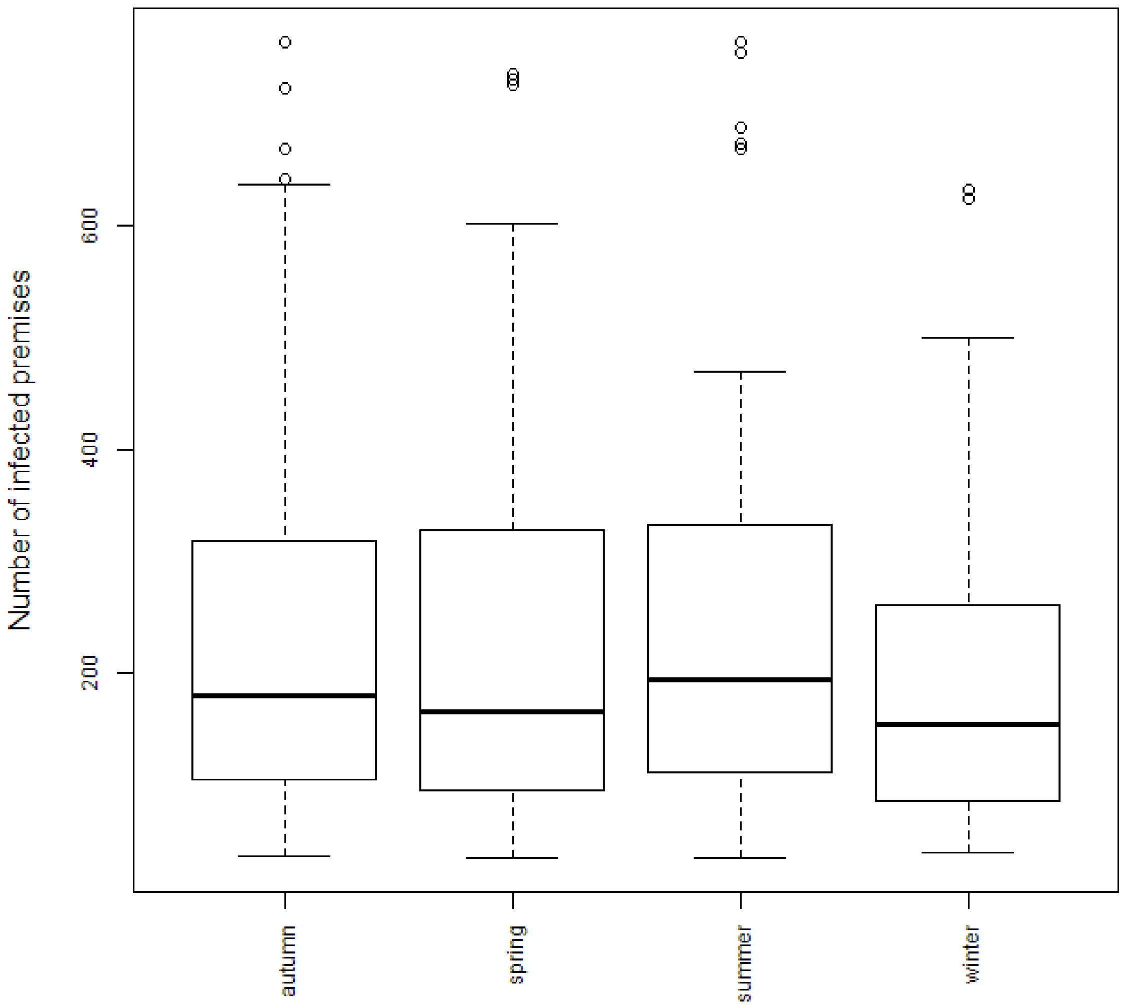


Figure 8.2: Box-and-whisker plot showing the effect of season on the number of properties infected by equine influenza 15 days after an incursion, from a model with disease seeded into a randomly selected Thoroughbred breeding operation in the Waikato.

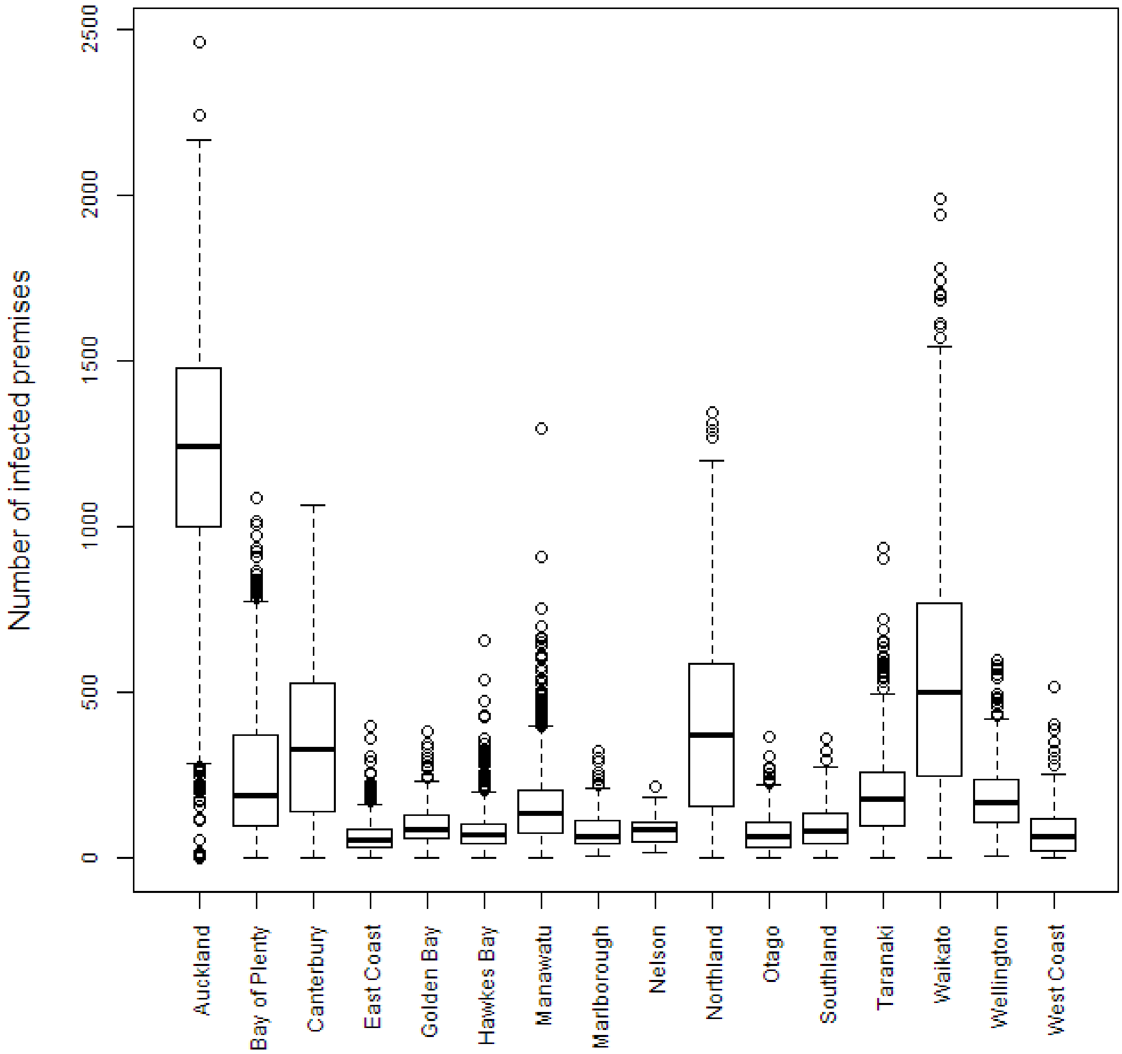


Figure 8.3: Box-and-whisker plot showing the effect of region on the number of properties infected by equine influenza 15 days after an incursion, from a seed model run using parameters representing movements in August.

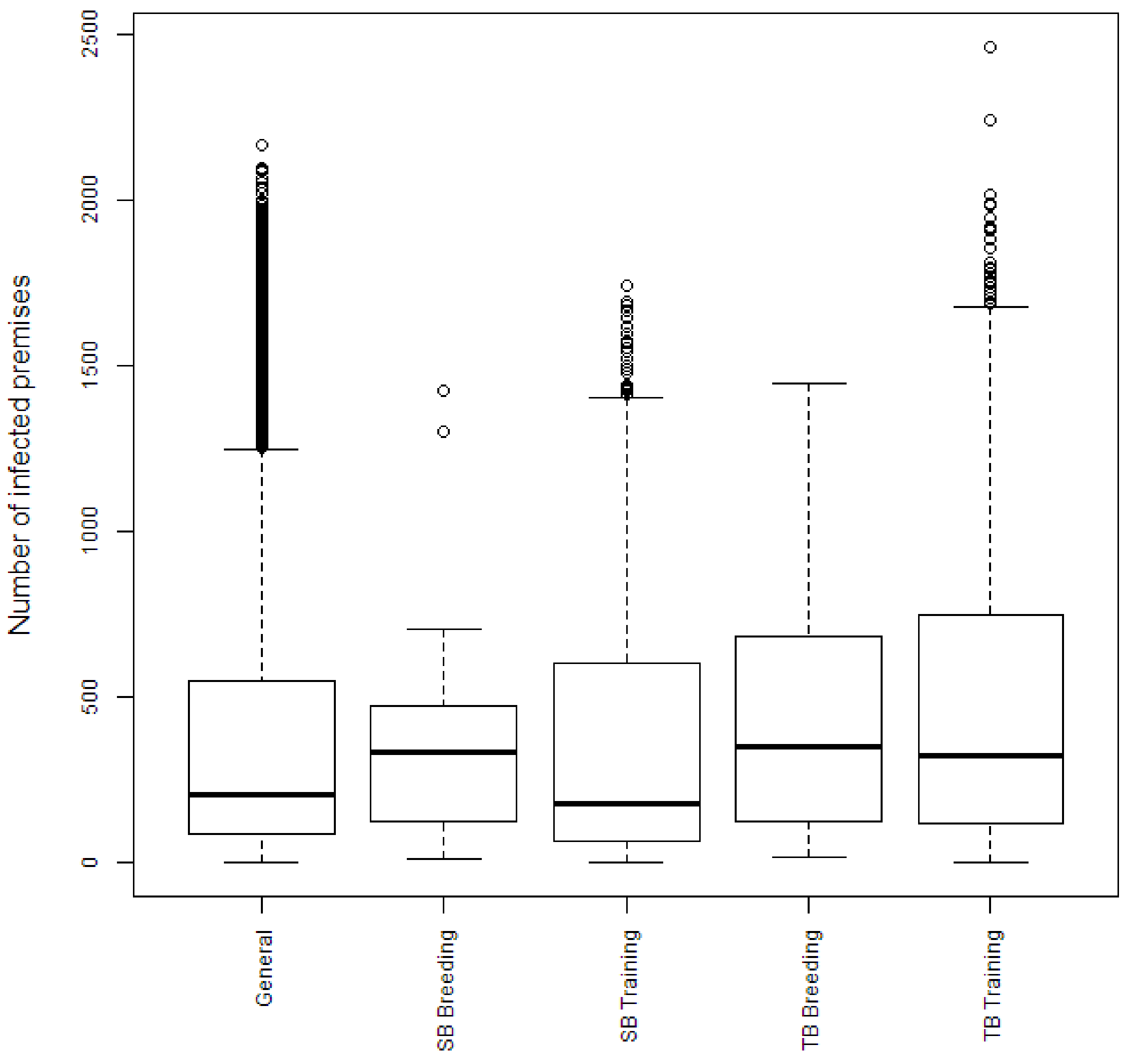


Figure 8.4: Box-and-whisker plot showing the effect of farm class on the number of properties infected by equine influenza 15 days after an incursion, from a seed model run using parameters representing movements in August.

9.7. DISCUSSION

Results from the analysis show clearly that average infectivity varied significantly between regions. Areas with greater infectivity correspond with regions that have greater horse density and a higher proportion of commercial horse properties (i.e. not general horse properties). Model results also highlight the higher variability in possible outcomes associated with general horse properties (Figure 4). This can be explained by survey results presented previously that found while the majority of properties do not move horses there are some people that regularly move horses large distances.

It is noteworthy that there were no significant differences in model outputs when movement patterns were altered to reflect the seasonal nature of the horse industry. While the result was initially surprising there are a couple of features of movement patterns that could explain this. Firstly, “slow” times in one sector of the industry corresponded with “busy” times in other sectors of the industry. For example, in August the number of movements off Thoroughbred breeding properties increases but the number of movements off general horse properties and Standardbred training operations are at their lowest. Another factor that could have contributed to the results is that movement patterns associated with the Thoroughbred and Standardbred training operations remained constant throughout the year.

There are countless other combinations that could have been explored, such as running the seed model for each month. However, running the seed model takes at least seven days and the baseline model when disease is seeded in a single property takes 12 to 24 hours. Therefore, running a number of combinations would be computationally demanding and would not in the author’s opinion add significant value to this project as the overriding aim is to compare control strategies.

In order to run these models several adjustments had to be made to Interspread-Plus: (i) Allowing multiple market types; (ii) Allowing temporal movement patterns in movement patterns; and (iii) Enhancements to memory capabilities. These changes are available to all Interspread Plus users, including MAF employees. Consequently, the improvements made in the current project will have flow on effects to other MAF projects using Interspread Plus. For example, the addition of multiple marketplaces will be useful when modeling Foot-and-mouth disease because it allows users to enter markets that sell only one type of animal as well as allowing for one off markets that differ in size and movement patterns to normal markets. Enhancement of Interspread-Plus memory management will ensure that larger models run more efficiently.

10. Control strategies

10.1. DESCRIPTION OF CONTROL OPTIONS

Control strategies can be divided into three categories: (i) movement restriction; (ii) vaccination and (iii) movement of horses out of zones to create a horse free buffer.

10.1.1 Movement controls

The draft response plan for equine influenza states a nationwide standstill will be implemented following diagnosis (McFadden, 2007). This will be followed by a controlled area that is subject to movement restrictions for a period of six weeks. Initially, the controlled area will consist of either/or both the North and South Island. When the extent of the outbreak becomes clear it may be possible to remove the North or South Island from the control area. Incorporating the removal of controlled areas into an Interspread-Plus model would be difficult, if not impossible. One option for modelling this option was radial zones to define control areas around locations that are infected. However, initial modelling suggests that using radial zones would not substantially reduce the size of the control areas. Nor would radial zones allow the flexibility to incorporate a so called “purple” zone, that is, an area within which movements of horses are allowed but no movements are allowed outside of the region. Incorporating such flexibility would require Interspread Plus to set control areas dynamically by incorporation of a set of logic rules. Presently this cannot be done in Interspread Plus. Inclusion of such functionality would require considerable substantial modifications to the Interspread Plus source code.

Therefore, modelling of control options was limited to consideration of the impact of nationwide standstills that lasted for six weeks and six months (i.e. duration of time being modelled). Review of these outputs may allow for setting of explicit zones to examine more closely the affect of a “purple” zone on duration and number of IPs.

10.1.2 Vaccination

Vaccination reduces clinical disease, the susceptibility of at-risk horses, severity of clinical symptoms and the level of viral shedding if a horse becomes infected. On the down side vaccination may mask clinical signs and makes serological monitoring difficult. Furthermore, it requires time to import the vaccine, deploy the vaccine and train vaccinators. Despite these drawbacks it is likely that there will be considerable industry and political pressure to use vaccination. Therefore, it is necessary to determine

(i) What vaccination will be used?

(ii) What strategy will be employed when administering the vaccination?

In the case of equine influenza there are three types of commercially available vaccines. These can be categorised as inactivated vaccines, live attenuated vaccines and recombinant canary pox vector vaccines. For inactivate vaccines immunity is not effective until after two vaccinations four to six weeks apart and optimal immunity is not achieved until at least one to two weeks after the second dose. Live attenuated vaccines provide quicker and stronger immunity than inactivated vaccines but they do have potential to introduce other strains of equine influenza virus and for this reason were not used during the Australian outbreak. Like inactivated vaccines the primary course of vaccination with recombinant vector vaccinations involves two vaccines administered four to six weeks apart but the ProteqFlu manufacturer claims that immunity will develop within 14 days of the first infection. This claim appears to be supported by evidence from the Australian outbreak (Garner *et al*., *In press*). Given these considerations the recombinant vector vaccines (ProteqFlu^{TM}) would be most useful for the control of equine influenza in New Zealand.

Generally speaking there are two vaccination strategies: ‘dampening-down’ or suppressive vaccination or protective vaccination (Anonymous, 1999). Dampening down vaccination involves vaccination within the known infected area to reduce the amount of virus circulating and thereby reduce the probability of spread. When using a suppressive vaccination strategy there is a risk that premises that have already been exposed to equine influenza virus will be vaccinated. Alternatively, horses on vaccinated properties could be subject to challenge before sufficient time has elapsed for an immune response.

Protective vaccination aims to contain the disease. Therefore, when using a protective vaccination strategy animals well outside the known infected area are vaccinated. With both suppressive and protective vaccination it is possible to target particular types of properties. In this project we considered two suppressive strategies, two protective strategies and a targeted strategy. These strategies are summarised in Table3.

Table 9.1: Vaccination strategies evaluated in this project to assess vaccination in the control and eradication of equine influenza (EI).

Type of strategy	Description
Suppressive	Vaccination of all premises with horses in a 1 km radius around known infected premises
	Vaccination of all premises with horses in a 3 km radius around known infected premises
Protective	Vaccination of all premises with horses in a band 7–10km around known infected premises
Targeted	Vaccination of breeding and training operations within 20km around known infected premises

10.1.3 Movement of horses to create a buffer

The final option to consider is the movement of horses to create a horse free buffer. The advantage of this option is that it could be applied relatively quickly. In practise owners are unlikely to favour this option. In addition, an equine influenza outbreak is likely to be wide spread so finding suitable grazing for large numbers of horses for an extended period of time would be difficult. Furthermore, transportation of horses could result in the spread of disease and as such, the industry would not support movement of horses. Therefore, movement of horses was not considered as a control strategy in this paper.

10.2. MODELLING CONTROL OPTIONS

10.2.1 Seed farm

The seed farm for comparison of control options was a Thoroughbred breeding operation located in the Waikato. In the seed model the number of IP’s at day 15 ranged from 19 to 1,348 and the median number was 117.

10.2.2 Time of year

The control strategies were investigated using movement parameters representing movements in January. The decision was made to limit comparison to one time period to allow more meaningful comparisons of control strategies. Impact of changing the movement patterns will be investigated during the sensitivity analysis.

10.2.3 Infectivity

Infectivity parameters will not be altered when modeling the movement control strategies. When modeling vaccination an immunity function was added to the model. The immunity function is a number between 0 and 1 that is applied by multiplication to the probability of transmission. In this model if the days since vaccination were:

- < 7 then the immunity function was 1;
- 8-14 then the immunity function was 0.50;
- 15-21 then the immunity function was 0.30;
- >21 then the immunity function was 0.1;

These decision rules are based on those developed by Garner *et al.* (*In press*), which were determined after a review of relevant literature and field experience during the Australian outbreak.

10.2.4 Resource constraints

To provide a realistic assessment of control strategies vaccine was not available until the four weeks after detection of the first infected property. In addition the number of properties that could be vaccinated in a single day was 50 on the first day of vaccination and increased linearly to 250 over a 26 day period. Because the effectiveness of a vaccination program is dependent on available resources the effect of this variable will be investigated in a sensitivity analysis.

It was not necessary to include resource constraints when modeling the movement restrictions.

10.2.5 Surveillance

The model consisted of four different types of surveillance. The first was background surveillance and ran from the start of the model to the time of detection. The probability background detection would detect disease prior to an outbreak was a constant 0.02. This value was selected to ensure that the average time to detection was 14 days. Following disease detection there would be two types of active surveillance. The first is tracing and the second is enhanced surveillance in the zone around infected properties. These activities would substantially increase the probability of detection. The value for this parameter was set to 0.7 for both surveillance systems. However, to ensure a realistic model, tracing was only set to run for the first week after detection and zone surveillance was in place for 21 days following detection. Therefore, after day 21 infected properties are only detected as a result of passive surveillance. This was modeled by increasing the background surveillance so that the probability of detection was:

- 0.25 the day clinical symptoms appeared;
- 0.75 in the 2-7 days after the appearance of clinical symptoms; and
- 0.05 when the days since the appearance of clinical symptoms was >7 days.

10.3. STATISTICAL ANALYSIS

For each control strategy a simulation comprising of 50 iterations was run. The outcome for each iteration was the total number IP's, the size of the affected area measured in hectares, and days until the outbreaks was controlled measured as days until no further IP's were detected. For those control strategies involving vaccination the number of vaccinated properties was determined. Therefore, the final data set for analysis comprised of 300 rows of data (i.e. 50 times seven control strategies).

When movement controls were lifted after six weeks all properties in the country became infected. Therefore, this control option was not considered further in any analysis. Box-and-whisker plots were used to display the variation in model outcomes for each of the control strategies. Results were summarized using the minimum, maximum and quartiles. A Kruskal-Wallis test statistic was used to separately determine if number of IPs, area affected and days to control varied significantly from the six month nationwide standstill. All statistical analyses were conducted using SAS Version 9.1 and graphics generated in R Version 2.10.

10.4. RESULTS

The median number of IP's properties when a nationwide standstill was enforced for six months was 9,720 properties, or 53% of all equine properties (Table 9.2 and Figure 9.1). All vaccination strategies when used in conjunction with a nationwide standstill significantly reduced the number of IP's ($p<0.01$). The affected area (Table 9.3 and Figure 9.2) and the days to control (Table 9.4 and Figure 9.3) were also reduced when vaccination was used in conjunction with a nationwide standstill. The differences for a 1 km suppressive vaccination were not statistically significant ($p = 0.19$). In contrast, the reduction in affected area and days to control were statistically significant for all other vaccination strategies. The number of properties that needed to be vaccinated was less for the targeted surveillance and greatest when vaccinating animals in a band 7 and 10 kilometers from known infected properties (Table 9.5 and Figure 9.3).

Table 9.2: Descriptive statistics for the number of infected properties stratified by control strategy.

		Percentiles			
Control strategy	Minimum	25th	50th	75th	Maximum
Six month nationwide standstill	9,424	9,641	9,720	9,843	10,235
Vaccination of all properties within 1 km of infected properties	8,694	9,033	9,246	9,447	9,894
Vaccination of all properties within 3 km of infected properties	6,519	7,769	8,463	8,874	9,721
Vaccination of all properties 7-10 kilometers of an infected property	3,999	7,661	8,468	8,975	9,765
Vaccination of all commercial properties.	7,265	8,426	8,993	9,371	10,018

Table 9.3: Descriptive statistics for the affected area (Ha) stratified by control strategy.

		Percentiles			
Control strategy	Minimum	25th	50th	75th	Maximum
Six month nationwide standstill	715,764	772,366	820,683	907,473	1,166,830
Vaccination of all properties within 1 km of infected properties	637,971	754,716	812,701	876,005	1,028,688
Vaccination of all properties within 3 km of infected properties	458,990	608,631	714,090	809,026	913,877
Vaccination of all properties 7-10 kilometers of an infected property	234,208	573,648	655,877	747,981	973,226
Vaccination of all commercial properties.	527,469	720,603	789,890	877,072	1,047,322

Table 9.4: Descriptive statistics for the time to control (days) stratified by control strategy.

Control strategy	Minimum	Percentiles 25th	50th	75th	Maximum
Six month nationwide standstill	124	147	158	174	180
Vaccination of all properties within 1 km of infected properties	112	141	152	175	180
Vaccination of all properties within 3 km of infected properties	52	116	130.5	142	180
Vaccination of all properties 7-10 kilometers of an infected property	86	103	118	137	180
Vaccination of all commercial properties.	122	154	171	178	180

Table 9.5: Descriptive statistics for the number of properties vaccinated stratified by control strategy.

Control strategy	Minimum	Percentile 25th	50th	75th	Maximum
Six month nationwide standstill	1,753	2,978	3,847	5,228	6,013
Vaccination of all properties within 1 km of infected properties	4,471	6,193	7,533	9,244	10,593
Vaccination of all properties within 3 km of infected properties	7,883	9,577	10,637	12,409	14,291
Vaccination of all properties 7-10 kilometers of an infected property	992	1,350	1,798	2,253	2,482

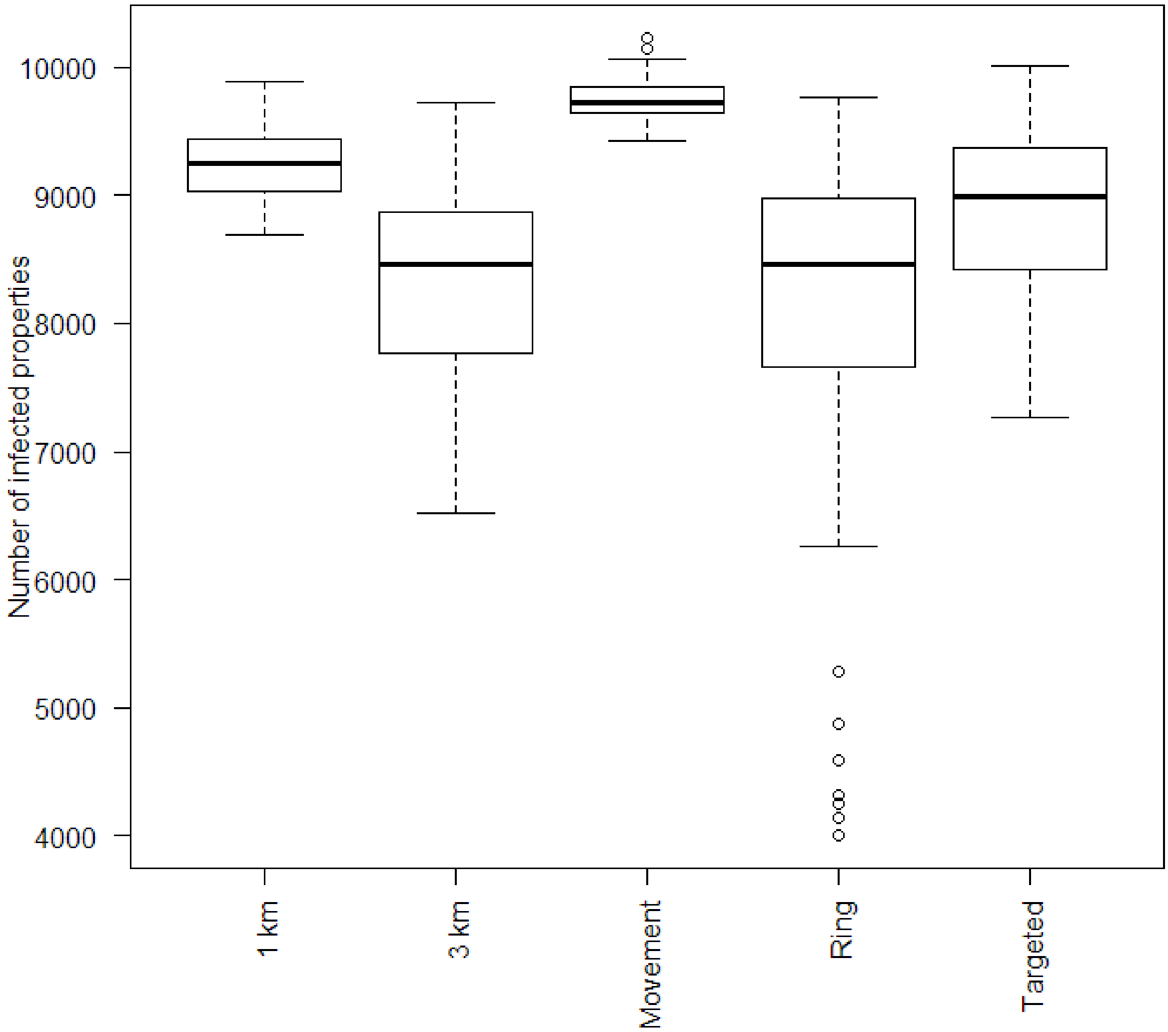


Figure 9.1: Box-and-whisker plots of the number of infected properties when all properties within 1 kilometre of an infected property are vaccinated (1 kilometre), when all properties within 3 kilometres of an infected property are vaccinated (3 kilometres), when a nationwide standstill is in place for six months (movement), when all properties in a 7 to 10 kilometre band of an infected property are vaccinated (Ring) and when all commercial properties within 20 kilometres of an infected property are vaccinated.

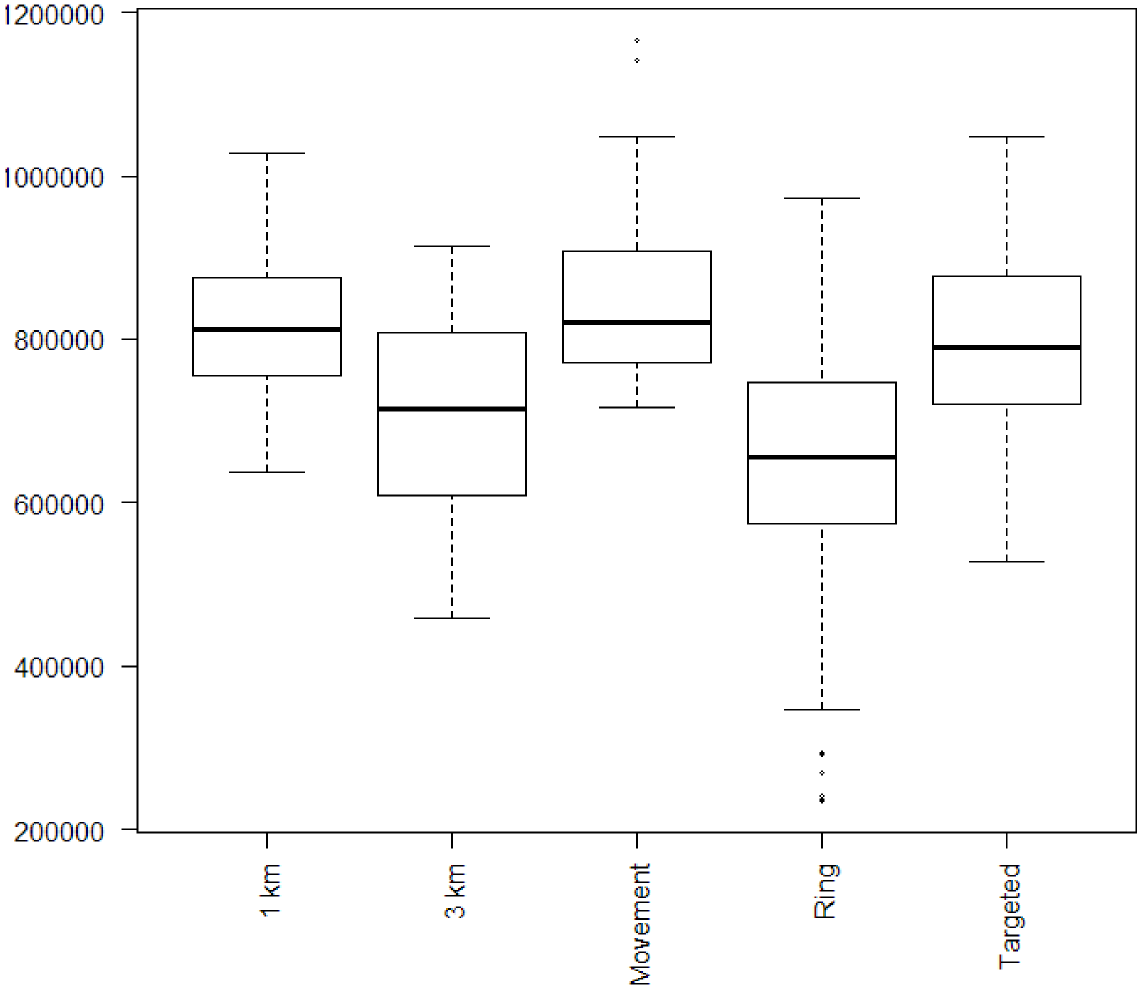


Figure 9.2: Box-and-whisker plots of the affected area (hectares) when all properties within 1 kilometre of an infected property are vaccinated (1 kilometre), when all properties within 3 kilometres of an infected property are vaccinated (3 kilometres), when a nationwide standstill is in place for six months (movement), when all properties in a 7 to 10 kilometre band of an infected property are vaccinated (Ring) and when all commercial properties within 20 kilometres of an infected property are vaccinated.

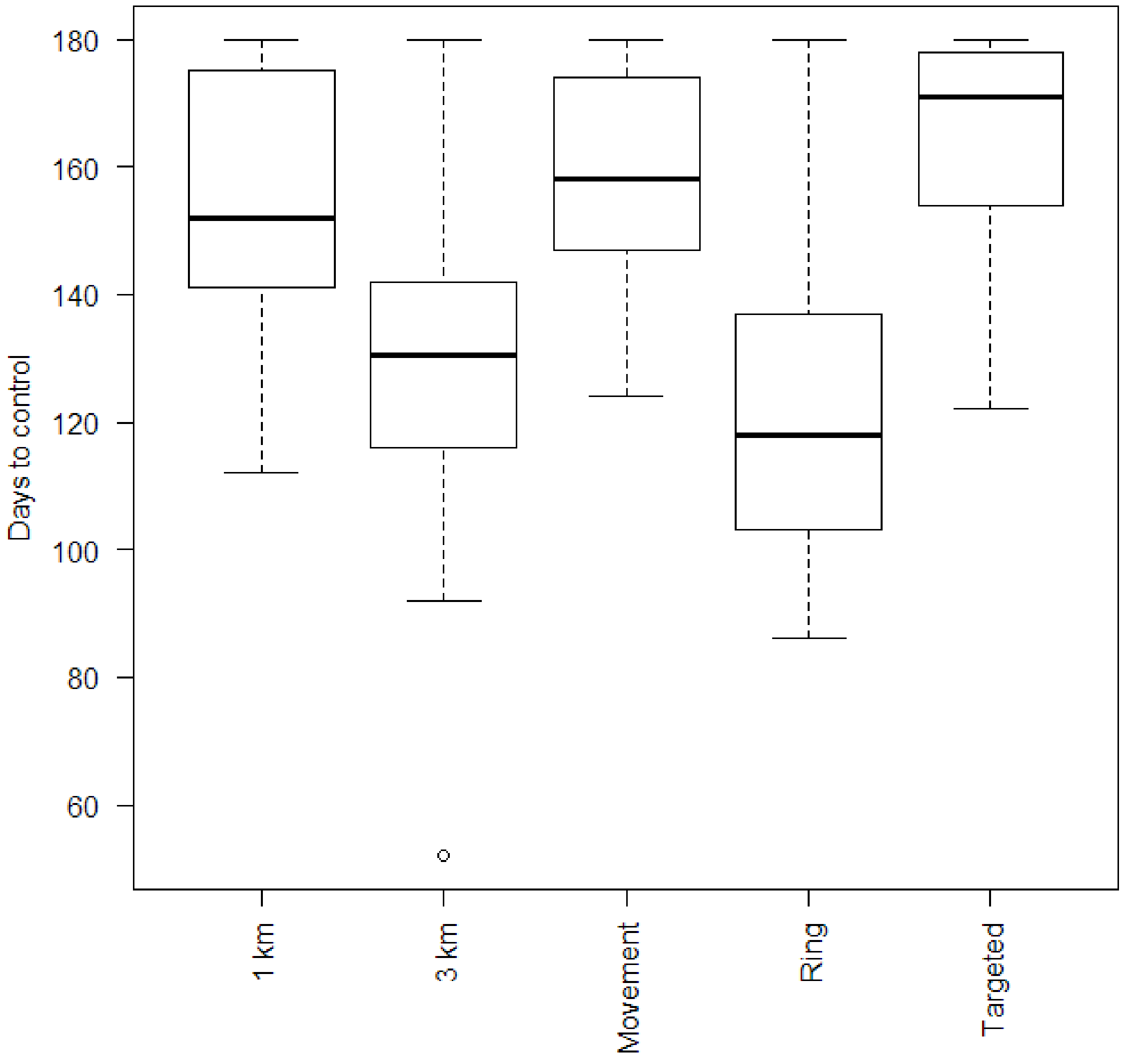


Figure 9.3: Box-and-whisker plots of the days to control (days) when all properties within 1 kilometre of an infected property are vaccinated (1 kilometre), when all properties within 3 kilometres of an infected property are vaccinated (3 kilometres), when a nationwide standstill is in place for six months (movement), when all properties in a 7 to 10 kilometre band of an infected property are vaccinated (Ring) and when all commercial properties within 20 kilometres of an infected property are vaccinated.

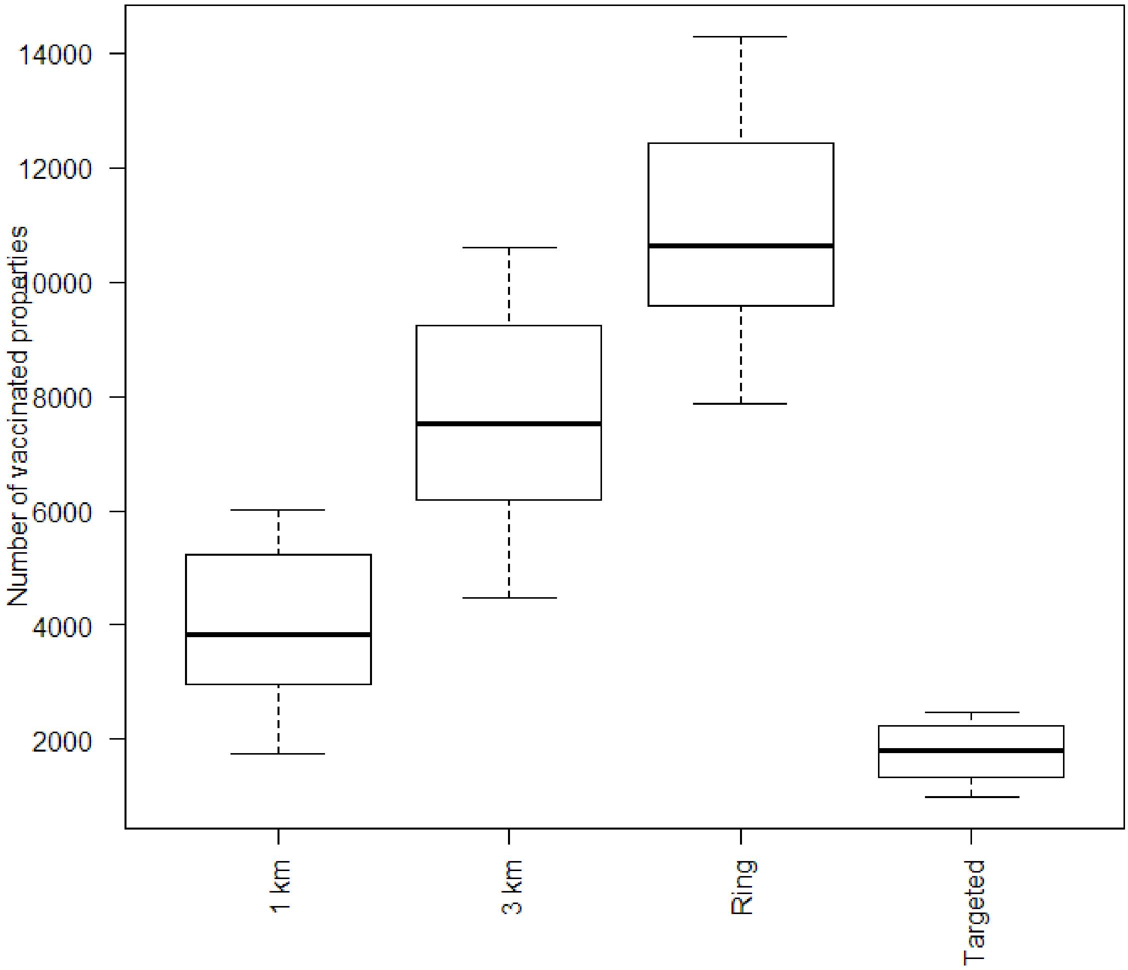


Figure 9.4: Box-and-whisker plots of the number of vaccinated properties when all properties within 1 kilometre of an infected property are vaccinated (1 kilometre), when all properties within 3 kilometres of an infected property are vaccinated (3 kilometres), when all properties in a 7 to 10 kilometre band of an infected property are vaccinated (Ring) and when all commercial properties within 20 kilometres of an infected property are vaccinated.

10.5. DISCUSSION

The key findings from this study are: (i) Regardless of the control strategy used approximately half of the equine properties will be affected; (ii) Any outbreak is highly likely to affect both the North and South Island; and (iii) Regardless of the control strategy used a nationwide standstill will need to be in place for more than four months. A stop movement of more than four months will result in an enormous economic cost to the industry. Therefore, officials may need to consider introduction of a purple zone that is a zone were an area within which movements of horses are allowed but no movements are allowed outside of the region. Incorporating them in a predictive Interspread-Plus model modelling them would be difficult, if not impossible. However, this should not be taken to mean that such strategies would not have a place in an equine influenza outbreak in New Zealand.

The impact of each vaccination strategy and a nationwide standstill was assessed. The results showed that vaccination of all premises with horses in a 1 km radius around known infected premises reduced the median number of IP's by approximately 500 but had no significant impact on the area affected and the days to control. In contrast, all other vaccination strategies reduced the median number of IP's by about 1,000 and also reduced the area infected and the days to control. A seven to 10 kilometer ring vaccination and vaccination of all premises with horses in a 3 km radius around known infected premises had the greatest impact on days to control. However, use of the seven to ten kilometer ring required over 10,000 properties to be vaccinated and there was considerable variation around the median time to control. When considering the effectiveness of vaccinations it is important to note that when modeling vaccination we did not include the possibility of vaccinators spreading infection and that the parameters selected for vaccination are based on an immune response occurring within seven days of the first vaccination. Consequently, the model results are the best possible outcomes for vaccination. When these factors are taken into consideration there may be very little benefit to the industry of implementing a vaccination strategy in conjunction with a nationwide standstill.

In conclusion, the results of this analysis clearly show that an equine influenza outbreak will be widespread and take a considerable period of time to control. Central to any control strategy will be nationwide standstill of around six months duration. Vaccination used in conjunction with a nationwide standstill did significantly reduce the size of the outbreak. However, the reduction was not substantial and the number of properties, especially when the strategy is to vaccinate all properties within a 7-10 band from known IP's, was substantial. Consequently, the decision as to whether or not to use vaccination is not clear cut and could benefit from some economic assessment of the costs and benefits.

11. References

Ainsworth DM, Hackett RP. (2004) Disorders of the respiratory system. In: Reed SM, Bayly WM, Sellon DC, editors. *Equine internal medicine*. 2nd edn. Saunders, St Louis, MO, 312–314.

Anonymous (1999). Strategy for emergency vaccination against foot and mouth disease (FMD). Report of the Scientific Committee on Animal Health and Welfare. Adopted 10 March 1999, 37 pp.

Anonymous (2008) .Historical record - Shuttle stallions. In: *Register of Thoroughbred Stallions of New Zealand 2004*, Ed: N.Z.T.B. Association, New Zealand Thoroughbred Breeders Association Auckland, New Zealand. pp 144-145.

Anonymous, 2003. Epidemiological Modeling Project Report – The Silent Spread Model. (London, Risk Solutions)

Animal Health Australia, 2002. Australian Veterinary Emergency Plan Foot and Mouth Disease Edition 3, version 3

AVMA (2006) Equine influenza backgrounder. http://www.avma.org/public_health/influenza/equine_bgnd.asp American Veterinary Medical Association (AVMA).

Cowled, B., Ward, M.P, Hamilton, S. and Garner, G., 2009. The equine influenza epidemic in Australia: Spatial and temporal descriptive analyses of a large propagating epidemic. Preventive Veterinary Medicine 92: 60-70

Daly, Newton, and Mumford. (2004). Current perspectives on control of equine influenza. Veterinary Research 35:411-423.

Garner, MG, Cowled, B, East, IJ, Moloney, BJ and Kung, NY (In press). Evaluating the effectiveness of early vaccination in the control and eradication of equine influenza—A modelling approach. Preventive Veterinary Medicine

Geering, W., Lubroth J., 2002. Preparation of Foot-and-Mouth Disease Contingency Plans. Food and Agriculture Organization of the United Nations.

Hannant, D, Mumford, JA, (1996). Equine influenza. In: Studdert, M. (Ed.), Virus Infections of Equines. Elsevier Science BV, Amsterdam, pp. 285–293.

Hodgson J. (2002) *Equine exotic disease: A manual for horse owners*. Rural Industries Research and Development Corporation, Kingston, ACT.

McFadden, A (2007). Equine Influenza: Draft operation plan for exotic disease response. Biosecurity New Zealand.

Minke, JM., Edlund Toulemonde, C, Coupier, H, Guigal, P-M, Dinic, S, Sindle, T, Jesset, D, Black, L, Bublot, M, Pardo, MC, Adonnet, J-C.,(2007). Efficacy of a canary-pox vectored recombinant vaccine expressing the haemaglutinin gene of equine influenza H3N8 virus in the protection of ponies from viral challenge. American Journal Veterinary Research 68, 213–219.

Perkins, N, Reid, SW and Morris, R, 2005. Profiling the New Zealand Thoroughbred racing industry 1. Training, racing and general health patterns. *New Zealand Veterinary Journal*. **53**: 59-68.

Pickett, B.W. and Voss, J.L. (1998) Management of shuttle stallions for maximum reproductive efficiency - Part 1. *Journal of Equine Veterinary Science* **18**, 212-+.

Pickett, B.W., Voss, J.L. and Clay, C.M. (1998) Management of shuttle stallions for maximum reproductive efficiency - Part 2. *Journal of Equine Veterinary Science* **18**, 280-287.

Perkins, N., Reid, S.W. and Morris, E. (2004a). Profiling the New Zealand Thoroughbred racing industry 2. Conditions interfering with training and racing. *New Zealand Veterinary Journal*. 53: 69-76.

Perkins, N., Reid, S.W. and Morris, E. (2004b). Profiling the New Zealand Thoroughbred racing industry 1. Training, racing and general health patterns. *New Zealand Veterinary Journal*. 53: 59-68.

Stevenson, M.A., Sanson, RL, Stern, MW, O'Leary, BD, Mackereth, G, Sujau, M, Moles-Benfell, N. and Morris, RS, (unpublished). InterSpread Plus: a spatial and stochastic simulation model of disease in animal populations.

Wilsher, S. and Allen, W.R. (2003). The effects of maternal age and parity on placental and fetal development in the mare. *Equine Veterinary Journal* 35, 476-483.

Yamanaka, Niwa, Tsujimura, Kondo, and Matsumura, (2008). Epidemic of equine influenza among vaccinated racehorses in Japan in 2007. Journal of Veterinary Medical Science 70:623-625.

12. Appendices

12.1. APPENDIX A

Parameters for movements off general horse properties

Number of movements

Month	Number of movements
August	Poisson(0.40)
September	Poisson(0.55)
October	Poisson(0.55)
November	Poisson(0.55)
December	Poisson(0.60)
January	Poisson(0.60)
February	Poisson(0.60)
March	Poisson(0.55)
April	Poisson(0.55)
May	Poisson(0.55)
June	Poisson(0.40)
July	Poisson(0.40)

Number of contacts 10

Probability of transmission Constant(0.30)

Distance of movements

-

Distance category	Probability movement within distance category
0-5 km	0.175
6-25 km	0.24
26-50 km	0.16
51-100 km	0.17
100-200 km	0.16
>200 km	0.08

Parameters for movements off Thoroughbred breeding operations

Number of movement

Month	Number of movements
August	Poisson(0.5)
September	Poisson(0.01)
October	Poisson(1.25)
November	Poisson(1.45)
December	Poisson(1.3)
January	Poisson(0.8)
February	Poisson(0.25)
March	Poisson(0.25)
April	Poisson(0.25)
May	Poisson(0.30)
June	Poisson(0.25)
July	Poisson(0.25)

Distance of movements

Distance category	Probability movement within distance category
1-50 km	0.65
51-150 km	0.18
151-350 km	0.12
South Island	0.05

Number of contacts 1

Probability of transmission 1

Probability of movement to each farm type

Farm type	Probability of movement to
SB Breeding	0
SB Training	0
TB Breeding	0.008
TB Training	0.07
General	0.92

Parameters for movements off Standardbred breeding operations

Month	Number of movements
August	Poisson(0.15)
September	Poisson(0.02)
October	Poisson(0.50)
November	Poisson(0.70)
December	Poisson(0.75)
January	Poisson(0.90)
February	Poisson(0.95)
March	Poisson(0.60)
April	Poisson(0.60)
May	Poisson(0.50)
June	Poisson(0.35)
July	Poisson(0.10)

Distance of movements

Distance category	Probability movement within distance category
1-50 km	0.72
51-150 km	0.15
151-350 km	0.09
>350 km	0.04

Number of contacts	1
Probability of transmission	1

Probability of movement to each farm type

Farm type	Probability of movement to
SB Breeding	0.002
SB Training	0.068
TB Breeding	0
TB Training	0
General	0.93

Parameters for movements of Thoroughbred racing operations

Movements associated with training

Number of movements	Poisson(0.8)
Number of contacts	15
Probability of transmission	0.3
Destination	TB Racetrack
Distance	0-20 km

Movements associated with racing

Number of movements	Poisson(0.10)
Number of contacts	70
Probability of transmission	0.3
Destination	TB Racetrack

Distance

Distance category	Probability movement within distance category
0-20 km	0.15
21-100 km	0.4
101-200 km	0.2
201-300 km	0.15
301-400	0.05
401+	0.05

Movements associated with spelling

Number of movements	Poisson(0.1)
Number of contacts	1
Probability of transmission	1

Destination

Farm type	Probability of movement to
SB Breeding	0
SB Training	0
TB Breeding	0.008
TB Training	0.072
General	0.92

Distance

Distance category	Probability movement within distance category
1-50 km	0.72
51-150 km	0.15
151-350 km	0.09
>350 km	0.04

Parameters for movements off Standardbred racing operations

Movements associated with training

Number of movements	Poisson(0.5)
Number of contacts	10
Probability of transmission	0.3
Destination	SB Racetrack
Distance	0-20 km

Movements Associated with racing

Number of movements	Poisson(0.05)
Number of contacts	45
Probability of transmission	0.3
Destination	SB Racetrack
Distance	

Distance category	Probability movement within distance category
0-20 km	0.55
21-100 km	0.2
101-200 km	0.1
201-300 km	0.05
301-400	0.05
401+	0.05

Movements associated with spelling

Number of movements	Poisson(0.05)
Number of contacts	1
Probability of transmission	1

Destination

Farm type	Probability of movement to
SB Breeding	0.002
SB Training	0.068
TB Breeding	0
TB Training	0
General	0.93

Distance

Distance categorgy	Probability movement within distance category
1-50 km	0.55
51-150 km	0.2
151-350 km	0.1
>350 km	0.15