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**Faculty of Veterinary Medicine
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Grazing and farm management of broodmares as an exposure to leptospirosis on commercial equine properties in New Zealand

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Grazing and farm management of broodmares as an exposure to leptospirosis on commercial equine properties in New Zealand

Hästhållning som en exponering till leptospirainfektion hos avelsston på kommersiella hästgårdar på Nya Zeeland

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SUMMARY

Leptospirosis is a worldwide zoonosis endemic in many countries throughout the world. The seroprevalence in Thoroughbred broodmares in New Zealand has recently been studied and the horses were positive to all five serovars tested (Ballum, Pomona, Hardjobovis, Copenhageni and Tarassovi). Little is known about how the broodmares in New Zealand get exposed to *Leptospira* spp. and the aim of this study was to collect horse- and farm management information and evaluate potential risks in the horse management for exposure to *Leptospira* spp. Four stud farms in the Manawatu region on the North Island were visited during five weeks during breeding season and observations about farm-, pasture-, horse- and pest management were recorded. Observations and answers from a farm questionnaire were recorded in Microsoft Excel and compared in between the farms. On each farm three different categories of mares were followed (empty mares, pregnant mares and mares with foals). The management on the farms were similar with co- and cross-grazing with livestock, flooded pastures and pests present. The stud farm with stallions had a high density of mares in the paddocks with low pasture herbage mass while the boutique farms had a lower density and higher pasture herbage mass. Thoroughbred broodmares that were empty were grazing with a low pasture herbage mass at high densities, constantly moving in between paddocks, sorted according to breeding status and mixing with mares from other stud farms with different serostatus to leptospirosis – all factors associated with risks for leptospirosis. Pregnant mares close to foaling were sorted and put together with other mares before and after foaling due to expected foaling date and breeding status *post partum,* also this management is associated with risk factors to leptospirosis. The foaling paddocks were small with decreasing pasture herbage mass and a stressful environment where mares shed urine, blood and placentas containing leptospirosis. The risk factors associated with the management of the Thoroughbred broodmares in New Zealand are areas for future studies to examine where mares get exposed to *Leptospira* spp., how it spreads in between the horses and what impact the disease has on the horses clinically and economically.

SAMMANFATTNING

Leptospiros är en zoonos vilken är spridd över hela världen och endemisk i flera länder. Nyligen studerades seroprevalensen hos engelska fullblodsston på stuterier på Nya Zeeland och av de fem serovarer som testades (Ballum, Pomona, Hardjobovis, Copenhageni och Tarassovi) fanns det ston som var positiva till minst en serovar. Det är mycket som är okänt kring hur avelsstona på Nya Zeeland exponeras för *Leptospira* spp. och syftet med denna studie var att samla in uppgifter kring hästhållningen och information om stuterierna för att utvärdera potentiella riskområden i hästhållningen där stona möjligen utsätts för *Leptospira* spp. Fyra stuterier i Manawaturegionen på nordön besöktes under fem veckors tid under avelssäsongen då information om gårdar, beten, hästar och skadedjursbekämpning insamlades. All information från observationer och enkäter bearbetades i Microsoft Excel och jämfördes mellan gårdarna. På varje gård valdes tre olika kategorier av hästar ut (icke-dräktiga ston, dräktiga ston och ston med föl vid sidan). Själva djurhållningen med sam- och växelbete mellan olika produktionsdjur, historik av översvämmade hagar och närvaro av skadedjur var liknande på de olika gårdarna. Stuteriet med avelshingstar hade en hög densitet av ston och låg torrsubstanshalt i sina hagar medan de mindre stuterierna hade lägre densitet och högre torrsubstanshalt. Icke-dräktiga fullblodsston i avel betade i hagar med låg torrsubstans och en hög densitet, de flyttades mellan hagar, sorterades enligt sin reproduktionsstatus och blandades med ston från andra stuterier med olika serostatus till leptospiros – dessa faktorer är associerade med risker för leptospiros. Dräktiga ston nära fölning sorterades och blandades med andra ston innan och efter fölning beroende på förväntat fölningsdatum och sin reproduktionsstatus *post partum*, även denna hästhållning är associerad med risker för leptospiros. Fölningshagarna var små med minskande torrsubstanshalt och en stressande miljö där många ston utsöndrar leptospiros via urin, placentor och blod. Riskfaktorer som är associerade med hästhållningen av nya zeeländska fullblodsston i avel är ett område i sig som framtida studier får utvärdera för att se var stona utsätts för *Leptospira* spp., likaså hur bakterien sprids mellan hästarna och vad sjukdomen har för kliniska och ekonomiska följder.

CONTENT

List of abbreviations

MAT	Microscopic Agglutination Test
DM	Dry Matter
PDM	Pasture Dry Matter
RPM	Rising Plate Meter
TB	Thoroughbred
TBB	Thoroughbred Broodmare

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1. INTRODUCTION

Leptospirosis is an important disease and a widespread zoonosis caused by the pathogenic bacteria *Leptospira* spp. (Fernandes *et al.*, 2015). Leptospirosis causes disease in all mammals and therefore has a major economic, social and welfare impact on livestock industries (Ellis, 2015). The disease is distributed worldwide with transmission occurring in both industrialized and developed countries (Bharti *et al.*, 2003). In tropical regions leptospirosis is endemic and causes epidemics after heavy rainfall and flooding (Haake & Levett, 2015; Sing, 2015).

The serological evidence of leptospiral exposure in horses has been investigated in several studies and is present, however the clinical signs of disease are rare (Kinde *et al.*, 1996). The serovars affecting horses varies with region and infection source (Hamond *et al.*, 2013). In a study by Hamond et al. (2012b) Thoroughbred horses in Brazil had a seroprevalence of 7.4% with a reactive titre of ≥100[1] against serovar Copenhageni. However, a study from central Italy showed a seroprevalence of only 1.5% with cut off titre of ≥100 which could be due to the dry environment and management of the horses (Ebani *et al.*, 2012). In Sweden the seroprevalence in horses with a titre ≥100 was 16.6% for Bratislava and 8.3% for Icterohaemorrhagiae (Båverud *et al.*, 2009).

In New Zealand little has been reported about the seroprevalence in horses but a recent study by Bolwell et al. (2017) has showed that seroprevalence among commercial Thoroughbred broodmares was widespread with titres ≥100 for serovars Pomona (3.2%), Hardjo (4.6%), Ballum (1.4%), Copenhageni (5.2%) and Tarassovi (0.8 %). How the broodmares are exposed to and affected by *Leptospira* spp. in New Zealand is not fully determined, potentially there might be some on farm association and clustering that increases the risk of exposure for broodmares (Bolwell *et al*., 2017).

Horses are important in New Zealand not only for sport but also as a trading commodity with up to 40% of the Thoroughbred foal crop being exported. The large export focus on the breeding of race and sport horses generates over NZ $2 billion (approximately 2%) of New Zealand's gross domestic product (Rogers *et al.*, 2016).

The temperate climate in New Zealand permits horse breeding and management to be pasture-based with advantages such as reduced production costs and a natural breeding and management of horses (Rogers *et al.*, 2016). This is in contrast compared to Europe where sport horses are commonly fed hay and housed in stalls with a restricted time at pastures (Higgins, 2004; le Jeune *et al.*, 2009).

The aim of this study was to obtain preliminary data on the potential farm-, pasture- and horse level risks for positive *Leptospira* spp. seroprevalence in Thoroughbred broodmares in New Zealand. The potential cross infection routes of pasture management, horse movements and cross-/co-grazing with other livestock was of primary focus.

[1] Using the MAT (Micro agglutination test) and screening serological samples at a 1:100 dilution

2. LITERATURE REVIEW

2.1 *Leptospira* spp

The genus *Leptospira* spp. includes saprophytic (*Leptospira biflexa* sensu latu) and pathogenic (*Leptospira interrrogans* sensu latu) species (Levett, 2015). The species are divided into serogroups and serovars of which the species *Leptospira interrogans* has more than 200 serovars divided into 24 serogroups (Bharti *et al*., 2003). The bacterium is a Gram-negative, obligate aerob and highly motile spirochete with a double membrane and an outer membrane determining the serovars specificity (Frellstedt, 2009). The geography and climate in the environment influence the leptospires in the different parts of the world with the serovars and serogroups adapted to different wild and domestic species, which then become reservoir hosts (Bharti *et al*., 2003; Sing, 2015).

Water plays an important role in the epidemiology of leptospirosis, but the factors involved are poorly understood (Barragan *et al.,* 2011). It is thought that *Leptospira* spp. can persist longer in water with high oxygen and low salt concentrations and another survival strategy is the ability to form a biofilm (Barragan *et al.,* 2011). Climate and environmental conditions such as high humidity and moderate temperature are important for maintaining *Leptospira* spp. in the environment (Favero *et al.,* 2017). Leptospires can persist for months to years if the conditions are favorable such as in freshwater ponds, streams and ground water (Barragan *et al.,* 2011; Bharti *et al.,* 2003; Sing, 2015).

2.2 Epidemiology

Water, soil and rodents (especially after flooding or heavy rains) are important in the epidemiology and transmission of leptospirosis (Perez *et al.,* 2011; Frellstedt, 2009). *Leptospira* spp. spread directly through skin contact, via aerosol and/or ingested food or water contaminated with urine (Sing, 2015). Water contaminated with leptospires from urine of infected animals (Perez *et al.,* 2011; Frellstedt, 2009) penetrates the skin through cuts and lacerations and the leptospires disseminate in the bloodstream and reaches their target organs: lungs, liver and proximal renal tubuli where they are able to survive for months and shed in the urine (Bharti *et al*., 2003).

2.3 Leptospirosis in New Zealand

The temperate climate in New Zealand (cool to warm, not often falling below 0° or rising above 30° Celsius) with high annual rainfall creates a favorable environment for the *Leptospira* spp. to become endemic (Dreyfus, 2013). The two serovars most commonly reported in New Zealand livestock are Hardjobovis (Hardjo) and Pomona (Fang *et al*., 2015). Deer are also a source of infection for human cases of leptospirosis as they are maintenance host for serovar Hardjobovis and accidental/common host to serovar Pomona, see Table 1 (Ayanegui-Alcerreca *et al.,* 2007). New Zealand has a large population of livestock which are kept outside all year – potentially contaminating pastures and streams when shedding urine (Dreyfus, 2013). Livestock are also kept at a high density when they strip-, co-, or cross-graze. These management practices in combination with absent vaccination programs for many classes of livestock may promote a high urine contamination and an endemic situation in New Zealand (Dreyfus, 2013). Commercial vaccines are available globally for cattle, pigs and dogs (Adler & de la Peña Moctezuma, 2010; Sing, 2015). When choosing a prevention program the predominant serovars and local reservoir hosts must be considered for the best effect and most vaccines includes at least two serovars: for bovine it is mostly serovar Hardjo and Pomona, which is also the case in New Zealand (Sing, 2015; Adler & de la Peña Moctezuma, 2010; Heuer *et al.*, 2012). The recommended strategy for livestock is vaccination at one-two up to six months of age, booster the young ones 4-6 weeks later and then revaccinate the whole herd annually (Dreyfus, 2013).

Table 1. *Serovars found in different species, although not New Zealand specific (Adler 2015; Bharti et al., 2013; Dreyfus et al., 2013; Ebani et al., 2012; Favero et al., 2017; Harland, 2015; Mannewald et al., 2015; Shotts et al., 1971; Treml et al., 2003)*

	Maintenance host for	**Exposed to**
Horses	Bratislava	Pomona, Hardjo, Ballum, Icterohaemorrhagiae, Canicola, Copenhageni, Tarassovi
Cattle	Pomona, Hardjo	Ballum, Copenhageni, Tarassovi
Sheep	Pomona, Hardjo	Ballum, Copenhageni, Tarassovi
Human		Pomona, Hardjo, Ballum
Deer	Hardjo, Pomona	Ballum, Copenhageni, Tarassovi
Pigs	Pomona, Australis, Tarassovi	
Dogs	Canicola	Pomona, Hardjo, Ballum, Copenhageni, Tarassovi
Rabbits		Ballum, Canicola, Icterohaemorrhagiae, Australis, Grippotyphosa
Hares		Grippotyphosa, Bulgarica
Possums	Balcanica	
Rats	Icterohaemorrhagiae, Copenhageni, Ballum	
Hedgehogs	Ballum	

2.4 Horse management in New Zealand

2.4.1 Horse racing in New Zealand

The horse racing in New Zealand has a long history with the first reported Thoroughbred stallion being imported in 1840. Today 40% of New Zealand's foal crop are sold on the international market which is around 4% of the global Thoroughbred foal crop (Rogers *et al.*, 2007 & 2016). The worldwide breeding of Thoroughbreds has restrictions and it is prohibited to use artificial insemination (AI) or embryo transfer (ET) (Rogers *et al.*, 2016; Liljenstolpe, 2009). Natural service is the only option which results in broodmares transported between farms to stallions during the breeding season (Rogers *et al.*, 2009). The stallions move across international borders and this poses a risk for the biosecurity and could possibly spread diseases (Rogers & Cogger, 2010). It is reported that each stallion in New Zealand breeds approximately 50 mares per season (Rogers *et al.*, 2007).

Thoroughbreds are maintained at pasture until preparation for the annual yearling sales when they are approximately 14 months old (Rogers *et al.*, 2016). After the sales the young horses will enter training with most having their first trial or race start as two-year-olds. The majority of horses have a race start as three-year-olds while many horses only have about 8-11 starts in their life (Rogers *et al.*, 2016). Once their racing career is over, the better performing mares and stallions enter the breeding herd and, in contrast to Europe, many horses enter other equestrian sports (primarily eventing) or are used for petfood or human consumption (Rogers *et al.,* 2016).

2.4.2 Pasture-based production system

The temperate climate in New Zealand permits horse breeding and management to be pasture-based with advantages such as reduced production costs and a natural breeding and management of horses (Rogers *et al.,* 2007). Most horses are kept at pasture and grazing all year round since most commercial stud farms pastures meet the horses required nutrition (Rogers *et al.,* 2016). The commercial Thoroughbred farms in New Zealand have a similar management as reported by Rogers et al. (2007). An advantage for the horses in New Zealand is that pastures on the properties mostly consist of perennial ryegrass *(Lolium perenne)* and white clover *(Trifolium repens)* which generally meets the published nutritional requirements of the lactating broodmare and weanling foal (Rogers *et al.,* 2016 & 2017). The period of most rapid pasture growth occurs during the first weeks of foaling - October to November - for most commercial Thoroughbred horses (Rogers *et al.,* 2016 & 2017).

Thoroughbred Broodmares in New Zealand

Broodmares are managed all year round at pastures with a perennial ryegrass/clover sward and during the winter they may be supplemented with hay (Rogers *et al.,* 2016). The sward height on commercial farms is reported to be 10 cm which is approximately equivalent to lawns with a pre-grazing mass of approximately 3500 kg DM/ha (Rogers *et al.,* 2016 & 2017). Pregnant broodmares are usually managed as cohorts of 6-12 mares in paddocks of 2-4 ha (1.5-6 mares/ha) and they are set stocked for 4-6 weeks (Rogers *et al.,* 2017). Even in late pregnancy the pasture should be able to provide all the nutritional requirements of the broodmares, however, during the third trimester most horses are provided with mineral pellets for supplement (Rogers *et al.,* 2016). Empty (non-pregnant) mares tend to be run harder in the pastures during the year with a body condition score 4-5 on a 1 to 9 scale until August and the start of the breeding season, then they are given an increasing amount of nutrition as an attempt to achieve an early onset of oestrus (Rogers *et al.,* 2016 & 2017).

Pasture management

It is important that the species of grass are able to withstand treading during periods of overgrazing as during the breeding season (September-December) when the density of stocking rate is higher (from 1 mare/ha to 2 mares/ha) in the farms. The high density may also force horses to graze near faeces and possibly ingest parasites and other infectious organisms (Rogers *et al.,* 2007 & 2017). The breeding season in New Zealand occurs in spring (September-December) when the pasture growth is greatest and the mares are kept in the same paddock for a long time due to management advantages during breeding season (Rogers *et al.,* 2017). When horses are kept at the same paddock for longer periods they develop preferentially grazed areas (lawns) and non-preferred grazing areas with latrine and faecal piles (roughs) where horses do not want to graze within 1 m radius (Grace *et al.,* 2002a; 2002b). This promotes the growth of weeds and an opportunity for over-grazing of preferred grass species (Rogers *et al.,* 2017). Preferably, maintaining horses' paddocks through cross-grazing with cattle or sheep for a shorter and more intense period where the livestock cleans pastures, redistribute the nutrition, maintain an even sward height and a variety of grass species is an advantage for the horse management (Rogers *et al.,* 2007). In the study by Rogers et al. (2007) the stud farms had policies for maintaining pasture growth and the management included cross-grazing with sheep and cattle, pasture renewal, applying fertilizer and topping the grass.

2.4.3 Estimating pasture dry matter (PDM) / pasture herbage mass

The Rising Plate Meter (RPM) is an instrument used to measure density of grass in pastures (MacAdam & Hunt, 2015) while estimating the dry matter. Basically the plate is placed on the ground and the grass prevents the plate from falling to ground level (see Figures 1 & 2). The plate meter measures the density of the grass/height of the plate from the ground and provides a cumulative measure for that pasture (MacAdam & Hunt, 2015; Earle & McGowan, 1979). The RPM needs to be set after the composition of the grass so the right formula is used to derive pasture dry matter (PDM). Most stud farms in New Zealand have a pasture composition and PDM (kg DM/ha) which is very similar to that observed on dairy farms (Rogers *et al.,* 2017).

2.5 Leptospirosis in horses

Leptospira spp. is associated with four different syndromes in horses: hepato-renal disease, ophthalmological disease, reproductive- and respiratory disorders (Hamond *et al.,* 2013). The acute clinical disorders are associated with serovars Pomona and Icterohaemorrhagiae (Hamond *et al.,* 2013).

2.5.1 Clinical signs

Leptospirosis in adult horses has been considered a subclinical condition although recent studies suggest leptospirosis is an important differential diagnosis of acute respiratory distress in both foals and adult horses (Verma *et al.,* 2013). Other clinical signs that present acutely are haematuria, fever, jaundice, liver and renal dysfunction, anorexia and respiratory distress (Kinde *et al.,* 1996; Hamond *et al.,* 2012a). Subclinical infection with leptospirosis is associated with equine recurrent uveitis (ERU) also referred to as moon-blindness and periodic ophtalmia (Frellstedt, 2009; Verma *et al.,* 2013). Other important conditions associated with leptospirosis in horses are late gestation abortions (predominately after six months of gestation), stillbirth and premature birth due to intrauterine infections and fetal death (Verma *et al.,* 2013; Hamond *et al.,* 2013; Kinde *et al.,* 1996).

2.5.2 Serovars in horses

According to Frellstedt, (2009) leptospiral antibodies are detectable in serum 4-8 days after exposure and may be obtained in serum for at least 7 years. It is possible that serovars adapted to horses, such as Bratislava, might be transmitted via direct horse-to-horse contact (Hamond *et al.,* 2013). In a study by Kinde et al. (1996) where Thoroughbred mares were sampled after a severe flooding incident causing many of the mares to lose their unborn foals, the causing agent was determined to be *L. pomona* and *L. hardjo*. Leptospiral infections are predominantly caused by serovars Pomona, Bratislava, Icterohaemorrhagiae and Grippotyphosa and Båverud et al. (2009) suggested that horses are maintenance hosts for Bratislava.

2.5.3 Horse seroprevalence in New Zealand Thoroughbreds

In New Zealand there has been one study to investigate the seroprevalence in Thoroughbred broodmares and race horses which identified the seroprevalence of Copenhageni, Pomona, Hardjobovis, T-arassovi and Ballum to 9%, 6%, 6%, 6% & 5%, respectively with a cut off titre of ≥1:50 (Bolwell *et al*., 2017).

2.5.4 Risk factors of Leptospira in horses

Risk factors include contact with infected species, environmental and management factors and increasing age (Vallée, 2016; Båverud *et al.*, 2009; Tsegay *et al.*, 2016). It is likely that horses encounter leptospirosis directly from other horses or indirectly from their environment where leptospires are able to persist for a long time (Båverud *et al.*, 2009). Hamond et al. (2012a) suggested that horses can play a role in the transmission of leptospirosis in the environment as the bacterium is excreted in urine from horses.

Presence of water sources, management practices and animals from positive herds are risk factors for infection in horses (Hamond *et al.*, 2013). Studies have shown that higher prevalence is evident in equids with access to surface water and flooded pastures (Oliveira *et al*., 2014; Tsegay *et al.*, 2016; Barwick *et al.*, 1998). Horses with greater access to pasture had a higher prevalence which may be due to exposure to wetlands, wildlife, livestock and surface water (Oliveira *et al*., 2014; Tsegay *et al.*, 2016). Also the stallions may pose a risk if they are carriers of leptospirosis, since leptospires may persist in the genital tract (Hamond *et al.*, 2013). Oliveira et al. (2014) showed that properties with more than 30 equids have a higher prevalence of horses positive to *Leptospira* spp. than properties with smaller numbers. The management of horses influences the seropositivity; horses kept in groups have twice the probability for being seropositive compared with horses kept individually (Lees & Gale, 1994). Horses with an increasing age is significantly associated with seropositivity (Tsegay *et al.*, 2016).

2.6 Leptospirosis in humans

Leptospirosis is a potentially lethal zoonosis, endemic in tropical regions and after heavy rainfall or flooding may become epidemic (Haake & Levett, 2015). The clinical manifestations in humans range from subclinical to febrile illness, jaundice, pulmonary haemorrhage and renal failure (Bharti *et al.*, 2003). Humans get the infection either from direct or indirect exposure to urine from infected reservoir host animals, the reservoirs are carrying the pathogen in their renal tubules and shedding bacteria in the urine (Haake & Levett, 2015). The indirect sources for human infection are contaminated soil and water; contaminated soil washed by rain into water supplies which are used for drinking water, bathing, swimming, fishing and cleaning (Bharti *et al.*, 2003; Schafer, 2016). The incubation phase is reported to range from days to months with an average of 7 to 12 days (Haake & Levett, 2015).

The three most common leptospiral infections occurring in humans are caused by serovar Ballum, Hardjobovis and Pomona (Dreyfus, 2013). According to Thornley et al. (2002) leptospirosis was the most common acquired infectious disease in New Zealand, with the male incidence tenfold that of females. The difference in incidence according to gender is likely due to the male predominance of males in occupations at risk: livestock farm workers, dairy farm workers, meat processing workers and forestry-related workers (Thornley *et al.*, 2002). Farmers and meat workers in New Zealand were reported to be the groups at highest risk of contracting leptospirosis from 2001 to 2010 (Fang *et al.*, 2015). Fang et al. (2015) also proposed that workers exposed to sheep may have a higher risk of leptospirosis compared to workers exposed to cattle since seropositive sheep are more likely to be shedding leptospires. Another group of workers with a risk for leptospirosis are veterinarians and people performing home slaughter (Sanhueza *et al.*, 2015).

2.7 Aim of the study

Due to the gaps of knowledge about transfer of leptospirosis in New Zealand broodmares, the aim of this study was to collect horse- and property information and identify potential risks in horse management for exposure to *Leptospira* spp. in Thoroughbred broodmares in New Zealand. The following questions will be addressed:

- Could the stocking density during the breeding season, in association with the reduced pasture dry matter, provide potential exposure of Thoroughbred broodmares (TBB) to *Leptospira* spp.?
- What aspects of pasture management of TBB during the breeding season pose a risk for exposure and spreading of *Leptospira* spp.?

3. MATERIAL AND METHODS

3.1 Study design and sampling

Four commercial properties in the Manawatu region breeding Thoroughbred broodmares were visited once a week during the spring of 2017. The study period was from September to October 2017 (five weeks). A year before the study period the horses on these farms were included in a cross-sectional survey and were tested for antibodies to the leptospiral serovars Ballum, Hardjobovis, Pomona, Copenhageni and Tarassovi and classified as seropositive or – negative as described by Bolwell et al. (2017). Some mares on the farms in 2017 had not been sampled in 2016 and had an unknown serostatus but were still included in this study. Five farms previously sampled were contacted via phone and informed about the survey to arrange suitable times and days for sampling and interviews. One farm declined participation in the study due to the busy breeding season.

3.2 Farm management

Information regarding risk factors and horse management of each farm was obtained through observations during farm visits using a *pro forma* data collection sheet (Appendix 1) and through interviews with the manager or owner of the farm using a structured questionnaire (Appendix 2).

3.2.1 Observations at the farm visits

During the weekly visits the paddocks were measured and recorded on a Farm data collection sheet (see Appendix 1). During the observation period, other observations noted at the farm included; pasture demography, size and composition, terrain/soil-type, drainage, feeding areas, water sources, contact with other animals, wildlife habitats, presence of pests, location of manure/burn pile, animal movements and weather conditions.

The weather data for 1 September to 31 October 2017 was collected from the New Zealand National Climate Database website (cliflo.niwa.co.nz) and the hourly rainfall (mm), sunshine (h), max, mean and min temperature (°C) was exported into Microsoft Excel. The weather data from 2015 and 2016 were collected from the New Zealand National Climate Database website (cliflo.niwa.co.nz) with reports of weather conditions September to October.

Pasture data collected included pasture dry matter (kg DM/ha), area (ha), physical environment (tall grass, bushes, trees, surface flooding, pasture condition, water source, contact with livestock), stocking density (number of horses/ha), cross grazing history and pasture management.

3.2.2 Farm questionnaire

A questionnaire of 36 open, closed and multiple-choice questions was completed with each farm manager or owner face-to-face, see Appendix 2. The first section included questions on farm management, the second section on pasture and grazing management and the third section on pest management. All sections were arranged to capture the seasonal variation of management in the answers. Alternatives were either all year, spring (September-November), summer (December-January), autumn (February-May) or winter (June-August) to get a seasonal variation. The questionnaire was developed based on a previous survey conducted in 2016 by Bolwell et al. (2017) but with the addition of more thorough questions about seasonal variations and complementary questions about farm-, pasture- and pest- management. The collected data was entered in Microsoft Excel 2013.

The first section (farm management) included a farm map and the manager were asked to show the open drains/streams, manure/burn pile, paddocks with floods the last 12 months, pastures grazed by different categories of horses and indicate the number of horses present on the farm throughout the year. The second section (pasture and grazing management) included questions about crops on farm, livestock and horse rotation in the pastures, kind of livestock grazing horses pastures, time different mobs of animals stay in the same pastures before rotation, sizes of mobs on the pastures, vaccination status of animals on farm and origin of bought animals. The third section (pest management) included questions of kind of pests present at farm, numbers, spots on farm where they were present, how they were fought and average numbers seen.

3.3 Horse management

For each farm, the aim was to select and follow 9 cohorts (groups of mares) with 6-8 broodmares in each cohort: three cohorts of mares with foals at foot, three cohorts of late-pregnant mares and three cohorts of empty/non-pregnant mares.

Definition of cohort

On the first week of visit the cohorts were conveniently identified as the group of broodmares grazing in the same paddock at the start of the study. The stud farm owners/managers showed where the different categories of horses grazed on the farm and were selected according to their breeding status. These mares had both known and unknown serostatus and were prospectively followed in that cohort weekly. When horses moved around, the majority of the mares from the week before (or the mares with known serostatus) determined the identity of the cohort. During the five weekly visits at the farms, the number and identity of mares were observed in each cohort and the original mares were followed as they changed paddocks and cohorts. The presence of livestock in horses' paddocks was also monitored and compared for co-/cross-grazing.

3.3.1 Horse numbers, stocking density and movements

All horses (except foals) in the paddocks within the cohorts, regardless of serostatus, were used to illustrate the movements on and off the farm and calculate the stocking density of the paddocks. The mares were identified using their nametags and/or brands. The number of mares were counted and the density was calculated and presented as number of horses per hectare (n/ha). During each visit, the majority of the mares from the original cohort were followed to their new paddocks if they had been moved. The mares missing in the cohort had either been moved to other cohorts (moved to other category after foaling) or been sent off to another farm for breeding. The studied mares (with known and unknown serostatus) on each farm were mapped diagrammatically to obtain a temporal map to give an overview of the broodmares movements throughout the farms during the weeks of study.

3.3.2 Horse information and breeding record

The horses were identified by their nametags and/or brands and if the horses were previously tested and had records of serostatus from Bolwell et al. (2017) they were included in this part of the study. The included mares were compared according to age, serostatus and breeding records. The breeding records were collected from the New Zealand Thoroughbred racing website (nzracing.co.nz) and exported into Microsoft Excel with information about age, record of foals (not getting pregnant, absorbed, aborted, not serviced, foal dead, foal alive), stallions and regions visited in the past three years.

3.4 Pasture management

3.4.1 Pasture plating

A Jenquip Rising Plate Meter (RPM) was used to derive the pasture dry matter (kg DM/ha) of the monitored paddocks, See Figures 1 and 2. The total pasture herbage mass was estimated applying an inverted L shaped transect in the middle of the paddock every four to five steps (not considering measuring lawns or roughs) doing 40 readings. If the paddock was too small to do an inverted L a transect C was used instead. The pasture herbage mass of lawns and roughs were estimated separately by doing 30 readings spread around the paddock within the roughs and then the lawns. The number shown on the RPM before first reading and the number after all 30-40 readings were used to get the difference between all readings (see Appendix 1 – Farm data collection sheet, pasture plating). This number was then divided by the number of readings (30-40) to generate the average compressed pasture height per sample. This value was entered in the following equation used for measuring dry matter in dairy cows (Manual Jenquip- Electronic platemeter model EC09 User Manual and Jenquip equation and formula):

Figure 1. *RPM used to derive pasture dry matter.*
Photo: Private

Figure 2. *RPM with counter to monitor the number of readings.*
Photo: Private

$$kg\ DM/ha\ = average\ compressed\ pasture\ height\ \times 158 + 200$$

3.5 Data handling and statistical analysis

The data collected were entered in an Excel data sheet with information about previous serostatus for the five serovars (Ballum, Pomona, Hardjo, Tarassovi and Copenhageni), farm background collected in the survey, pasture data, horse information, movements and breeding records. A farm was considered positive if at least one broodmare on the property was positive with the cut-off titre value of 1:50.

The descriptive analysis of number of horses, pasture size, horse density, pasture dry matter (PDM), horse movements and seropositivity was compiled using STATA 2012 (StataCorp LP, College Station, Texas, USA).

4. RESULTS

4.1 Farms in the study

4.1.1 Background

During 8 September – 17 October 2017, four farms in the Manawatu region situated within 20 km of the city of Palmerston North were visited, see Figure 3 and 4. The farms are situated 4 to 13 kilometers from each other and in this period the weather conditions were wet with unusually high rainfall, see Table 2. According to the farm managers and owners the past year had been unusually wet in this area, the grass was growing slowly and livestock and horses were pugging the paddocks.

Figure 3. *Location of farms in New Zealand*

Figure 4. *Location of the farms in Palmerston North*

Table 2. *Weather conditions 8 September – 17 October Palmerston North*

	Rainfall (mm)	**Temp average (°C)**	**Temp max (°C)**	**Temp min (°C)**	**Sunshine (h)**
Study period 2017	160.9	12.1	20.1	1.2	136.4
2016	82.5	12.6	20.6	0.8	105
2015	76	11.3	18.3	-0.1	141.5

(Source weather data New Zealand National Climate Database: http://www.niwa.co.nz/climate/monthly collected 2017-11-20)

4.2 Farm description

Table 3 provides an overview of the four farms. The farms have a similar occupation, pasture demography, water source and are situated close to each other (see Figure 4) but the extent of operation ranged from a small boutique stud/race farm of 20 ha to a large commercial stud farm of 160 ha. Farm 1 and 3 had the largest area, but farm 1 had the lowest rate of annual pasture renewal (8.3%). In contrast, the smallest farm (farm 4) aimed to re-sowing 30-35% of the pastures each year. The soil-types on the farms were of a similar character (loam and profile/contour) due to close geographical proximity. Despite this both farm 2 and 4 were characterized with poor and slow drained soil. All farms have had floods (either the creeks and rivers or surface floods in the paddocks) during the past 12 months.

Table 3. *Comparison of farm background and pasture management*

	Farm 1	**Farm 2**	**Farm 3**	**Farm 4**
Size (ha)	121+40	86	160	20
Occupation	Stud	Stud	Stud	Stud + Race
Pasture demography	Flat, free-draining	Flat, free-draining	Flat, free-draining	Flat, free-draining
Resown each year (ha)	10 (8.3%)	8-12 (9.3-14%)	20 (12.5%)	6-7 (30-35%)
Soil-type*	Kairanga silt loam, Karapoti brown sandy loam, Te Arakura sandy loam	Kairanga silt & fine sandy loam	Kairanga & Parewanui silt loam	Kairanga silt loam
Exposure to natural water	River and creek runs through	River	Creek through property	River and creek
Flooded past 12 months	Yes	Yes	Yes	Yes
Water source in pastures	Trough, creek	Trough	Trough	Trough

* Reference Cowie, 1978

4.2.1 Livestock and pest management

Table 4 compares the farms according to categories of livestock and pests present. All four farms co-/cross-graze with either sheep or cattle with a similar number of livestock present and originating from the same source (sale yards). Two of the farms have vaccinated cattle for leptospirosis while the other two have not. The presence and management of pests are similar throughout the farms. For more background information of the farms see Appendix 3.

Table 4. *Comparison of livestock and pests present at the four studied farms*

	Farm 1	**Farm 2**	**Farm 3**	**Farm 4**
Co-/cross-graze	Yes	Yes	Yes	Yes
No beef cattle <1 year old	26	0	100-200	0
No beef cattle >1 year old	19	10-30	100-400	0
No dairy cattle >1 year old	0	10-30	0	0
No sheep mixed	0	0	0	1000
No sheep lambs	0	200-300	1000-1500	0
Origin of beef	Sale yard	Sale yard	Sale yard/agent	-
Origin of dairy	-	Neighbor	-	-
Origin of sheep	Sale yard	Sale yard	Sale yard/agent	Own
Livestock vacc Leptospirosis	Yes	Yes dairy and dogs	No	No
Pests present at farm	Rats, mice, possums, rabbits, hares, ducks	Rats, mice, possums, rabbits, hares, ducks	Rats, mice, possums, rabbits, hares, ducks, ferrets	Rats, mice, possums, rabbits, hares
Pests location	Feed storage, stables, pasture	Feed storage, stables, pasture	Stables, pasture	Stables, pasture
Pest management	Poison, bait station refilled once a month	Poison, bait station refilled once a year	Poison, bait station refilled once a year	Poison, bait station refilled once a year
Disposal of burn pile	Burn once a year	Burn once a month	Burn once a year	Save for compost

4.3 Horse management

4.3.1 Horse numbers and density

In Table 5 the different categories and numbers of horses on the farms are presented. The total number of horses varies depending on season (breeding season in spring is the busy period for all farms when mares are sent on and off stud farms). On farm 1 during the year there are large fluctuations in the number of horses on the property since large groups of mares were coming for foaling and covering with the three stallions present. Farms 2-4 sent their mares off to other studs for covering during breeding season (either during the day to stud farms in the nearby area or further to stay for several weeks to make sure they are bred and pregnant before returning to home stud). Farm 1 aggists mares and foals from other stud farms for just a couple of hours (mares come and see the stallions and are brought back to their resident stud farm) up to 8-10 weeks (to foal down, get covered and checked for pregnancy before going back to the resident stud farm). Farm 1 also sends about 20 of their resident mares off to other stud farms to be bred by other stallions. Farm 2 sends resident mares off for covering but also take about 20 mares in for surveillance when they foal down (stay at the farm for about three weeks).

In Table 5, the median density and inter quartile range (IQR: 25-75%) is presented for the cohorts on the four farms. Pregnant mares on farm 1 were kept at a high density (5.9 n/ha), more than twice as high as farm 3 (2.8 n/ha) and four times higher than farm 2 (1.4 n/ha). Also, the density of the empty mares on farm 1 was highest (2.6 n/ha), twice as high as farm 3 (1.3 n/ha). Overall the density of mares on farm 4 was higher compared to farm 2 and 3, especially for the mares with foals (3.3 n/ha) that were kept in small foaling paddocks during the study period. The variation of the density for the different categories of broodmares during five weeks of study is also illustrated in Figure 5. Farm 1 has the highest median density for the pregnant mares and the empty mares (5.9 and 2.6 n/ha). The densities on farm 2-4 had the same distribution of pregnant and empty mares but was not as high as in farm 1. For all farms, the density was decreasing over time (except farm 2 which increased during week 4-5 due to new mares arriving for foaling) as mares are sent off the studs to be bred and then comes back to home stud and moves to larger paddocks in the stud farm.

In Table 5 the median time the different classes of horses and livestock are grazed in the same paddock before moving to a new one is presented. On farm 3 the horses were set stocked (kept in the same paddock) for as long as possible without running out of grass. All farms keep their empty mares for a long time at the same pasture (1-6 months) except farm 4 that moved their horses every 2-4 weeks. Farm 1 and 2 have a similar management where mares with foals at their sides are moved every 2-4 weeks and pregnant mares were intermediate. Table 5 also show the different numbers and categories of horses kept at the four farms.

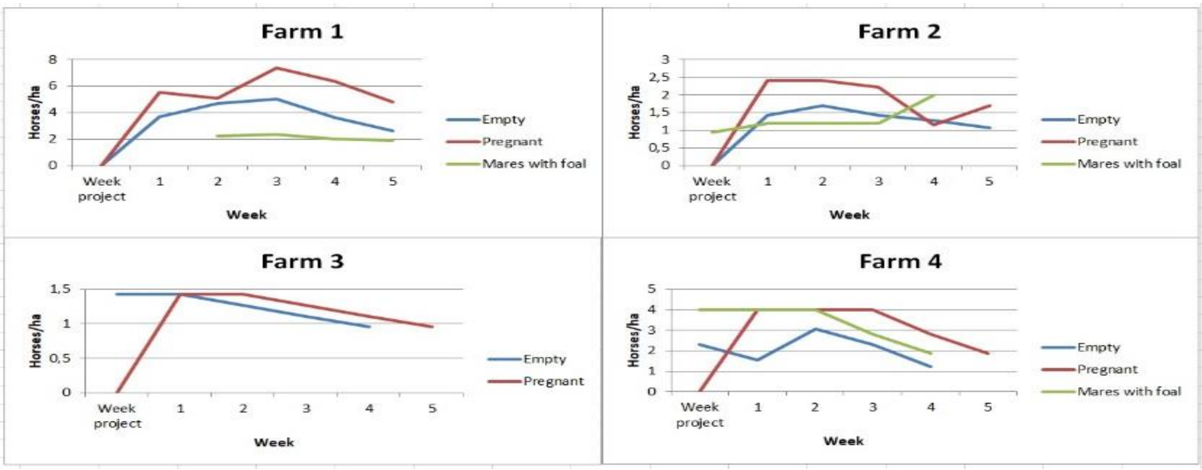

Figure 5. *The density (number of horses per hectare) for the three studied categories of broodmares in the four farms showed weekly*

Table 5 Comparison of number of horses (n) present at the farms with the paddock size in hectares (ha), density (n/ha) and average time cohorts spend in the same paddock

		Farm 1	Farm 2	Farm 3	Farm 4
Resident mares (n) *		100-130	28	20	12
Outside mares on farm for foaling (n) *		120-200[2] (breeding 9 weeks)	20[3] (3 weeks)	0	0
Resident mares sent to other studs (n) *		20	24	20	12
Total mares on property during spring (n) *		250-300	4-48	0-20	0-12
Empty mares per paddock	**n(IQR)**	4 (4 – 8)	10 (9-10)	8 (7-9)	3 (3-3)
	ha(IQR)	1.9 (1.5-2)	7(6.5-7)	6 3 (6.3-6.3)	1.3 (1.3-1.3)
	n/ha(IQR)	2.6 (2.4-5.8)	1.4(1.3-1.4)	1.3 (1.1-1.4)	2.3 (1.5-2.3)
Pregnant mares per paddock	**n(IQR)**	8 (6-19)	8 (7-8)	3 (2-4)	6 (4-8)
	ha(IQR)	1.4 (0.8-5)	6 (1.9-7)	2.7 (0.35-4)	1.5 (1.5-1.5)
	n/ha(IQR)	5.9 (4 -7.5)	1.4 (1.1-3.2)	2.8 (1.4-6.2)	4 (2.8-4)
Mares with foals per paddock	**n(IQR)**	3 (2-4)	3 (2-3)	-	1 (1-2)
	ha(IQR)	3 (1-3.4)	2.5 (2.1-2.5)	-	0.43 (0.3-0.48)
	n/ha(IQR)	1.7 (0.6-3)	1.2 (0.9-1.2)	-	3.3 (2.0-4.6)
Mares in foaling paddocks	**n(IQR)**	2 (2-2)	-	-	-
	ha (IQR)	0.8 (0.8-0.8)	-	-	-
	n/ha(IQR)	2.5 (2.5-2.7)	-	-	-
Empty mares time in same paddock *		1-6 months	1-6 months	Set stocked	2-4 weeks
Pregnant mares time in same paddock *		2-4 weeks	1-6 months	Set stocked	2-3 weeks
Mares with foals time in same paddock *		2-4 weeks	2-4 weeks	Set stocked	2-3 weeks
Livestock time in same paddock *		Co- and cross-graze horses	1-6 months/ co-graze horses	Set stocked/co-graze horses	2 weeks-6 months/co-graze horses
Stallions (n) *		3	0	0	0
Racing horses (n) *		0	0	0	20
Spelling horses (n) *		30-60	2-3	0	6
Weanlings (n) *		60	20-22	15	7
Yearlings (n) *		40	6-8	7-8	5

*This data is from survey and stud manager

[2]Mares are coming for surveillance during foaling, stay for covering and are checked for pregnancy before going back to the stud farm, up to 9 weeks

[3]Mares are coming for surveillance during foaling and are then sent off for covering, up to 3 weeks

4.3.2 Farm serostatus to Leptospira spp.

In Table 6 the serostatus of *Leptospira* spp. at a titre of ≥1:50 is shown on the four studied farms with a total of 57 mares with known serostatus for five *Leptospira* serovars. Most of the mares (123 out of 180 mares on the farms) had unknown serostatus and were included in the study to demonstrate horses' density and movements on the farms.

Farm 4 was negative, farm 1 had the lowest seropositivity (15.6%), farm 2 slightly higher (18.8%) and farm 3 had the highest seropositivity (66.7%), see Table 7.

Table 6. *Number of mares (n) followed with known and unknown serostatus for five Leptospira serovars. The serostatus (%) on the farms studied of the 57 mares with known serostatus*

	Seropositive all serovars		**Seronegative all serovars**		**Horses with known serostatus**	**Horses with unknown serostatus**	**Total horses**
	n	**%**	**n**	**%**	**n**	**n**	**n**
Farm 1	5	15.6	27	84.4	32	77	109
Farm 2	3	18.8	13	81.2	16	22	38
Farm 3	2	66.7	1	33.3	3	13	16
Farm 4	0	0	6	100	6	11	17
Total	10	17.5	47	82.5	57	123	180

Table 7. *Number of mares (n) seropositive (%) for five Leptospira serovars on the four farms studied. Some horses were positive to several serovars (n=57)*

	Ballum		**Hardjo**		**Pomona**		**Tarassovi**		**Copenhageni**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Farm 1	3	9.4	0	0	1	3.1	0	0	3	9.4
Farm 2	0	0	2	12.5	0	0	1	6.25	0	0
Farm 3	1	33.3	0	0	0	0	1	33.3	1	33.3
Farm 4	0	0	0	0	0	0	0	0	0	0
Total	4	7	2	3.5	1	1.7	2	3.5	4	7

4.3.3 Horse serostatus and ages

The mares had an average age of 11 years (range 5-20 years old) and the broodmares were split into two age groups of younger (age 5-11) and older (age 12-20) mares. Figure 6 shows there is a high seropositivity among the older broodmares compared to the younger mares. Older mares are exposed to and have a higher proportion seropositive (and are potential carriers) of leptospirosis. The mares 5-11 years old were 32 mares of which one mare (7 years old) was positive to leptospirosis (seropositivity 3.1% in this age group). Of the mares 12-20 years old there were 25 mares, of which 9 mares were positive to leptospirosis (36% seropositive).

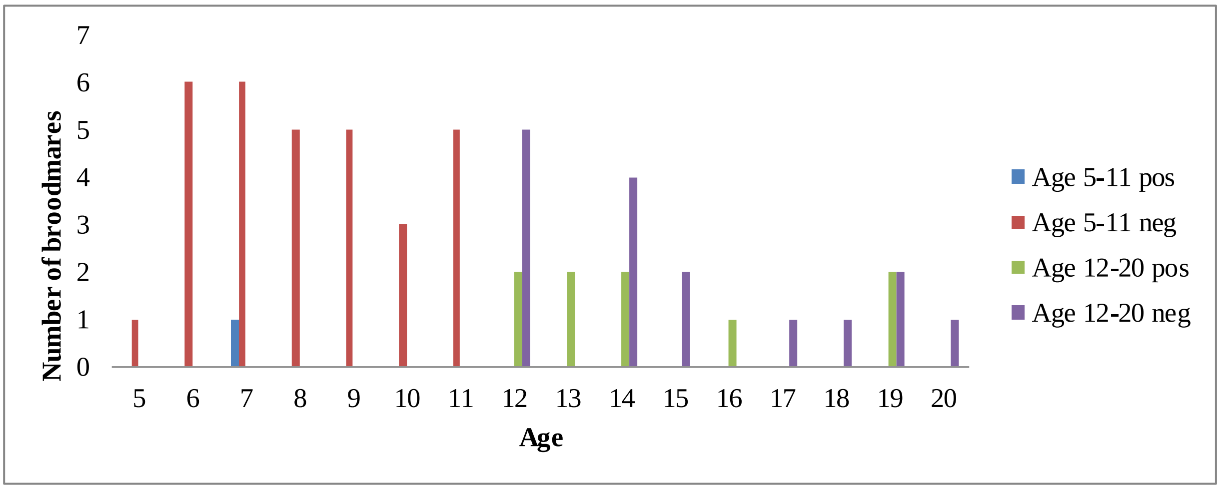

Figure 6. *Number of horses positive and negative to leptospirosis in different age groups for all farms*

4.2.4 Horse movements

In Figures 7 and 8 the two main types of stud farms are shown, commercial and boutique stud farms, and the median number of movements a mare makes in the different cohorts of the same category (pregnant, foaling paddock, mares with foals and empty) throughout the same farm during the five weeks of study. The squares and circles are the cohorts, the numbers in the squares are the median number of movements within the cohort and numbers in brackets are inter quartile range (IQR) of movements.

In Figure 7, farm 1 has several mares, both empty and pregnant mares, arriving to the farms and staying for 2-3 months before they leave the stud with a 42 ppt (42 days positive pregnancy test). The empty mares are arriving and moving around continuously to arrange them according to breeding status, average 3 times/mare. The mares for covering are arriving pregnant close to foaling or with their foals at the side, arranged according to expected foaling date with an average movement of 2 times, enter the foaling paddocks and are moved twice before put together with other mares with foals and sorted according to foal age/breeding status.

In Figure 8 the three other studied farms (farm 2-4) are represented, the management here compared to the commercial stud farm with stallions is different hence the mares are kept in the same cohorts at a higher extent than of farm 1 and do not move as much in between cohorts on the resident farm. The mares are sent off from the studs to get covered and then coming back to other cohorts on the same farm.

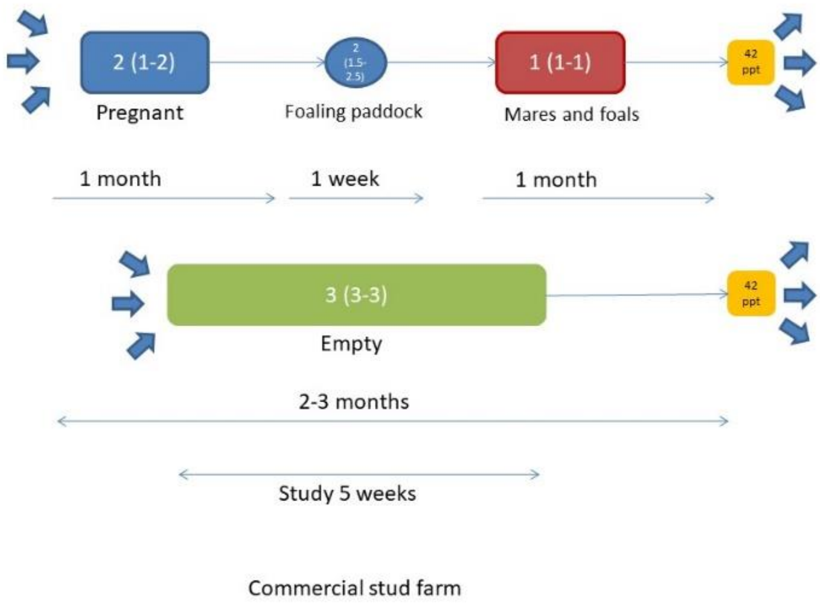

Figure 7. *The average number of movements of the different categories of mares on a commercial stud farm (farm 1). The numbers in the squares and circles is the average number and (inter quartile range) of mare movements from one cohort to another during five weeks of study. The squares and circles represent the cohorts and the arrows the movements of mares and approximate time mares stay in same category.42 ppt = 42 days positive pregnancy test and the mares leave the farm or are sorted into new groups according to this breeding status*

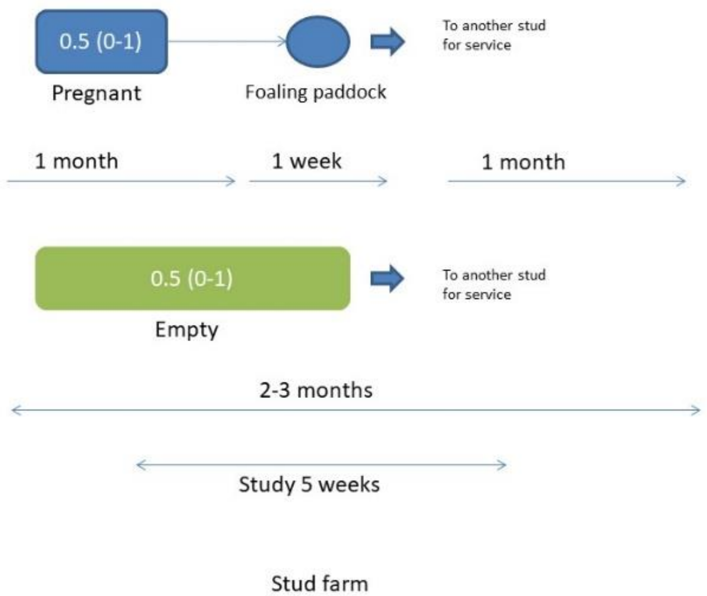

Figure 8. *The average number of movements of the different categories of mares on stud farms (farm 2-4). The numbers in the squares and circles is the average number and (inter quartile range) of mare movements from one cohort to another during five weeks of study. The squares and circles represent the cohorts and the arrows the movements of mares and approximate time mares stay in same category*

In Figures 9-13 the movements of the broodmares in the cohorts on the four farms are illustrated weekly. The cohorts are presented as colored squares with the total numbers of mares in brackets. The numbers in the circles are the number of horses that are moving to another cohort each week and the arrows show where the mares moved (to the same cohort, another cohort or left the farm). The color of arrows, squares and circles represent the original cohort for the mares.

In Figure 9 the empty mares of farm 1 are represented. The first week there were only two cohorts to follow with a larger number of mares in each cohort. There is a constant moving of horses in between cohorts due to breeding status (in heat, covered, pregnant) to make the management easier. The mares are pulled out of the original cohort and mixed with others, forming new cohorts. Also, there are mares from other farms coming in and getting mixed with their own mares to fit in the management and get enough pasture to graze. This management resulted in the fifth week of study with empty mares divided into five cohorts with fewer mares in each group (3, 6, 4, 5 and 4 respectively). Unfortunately, in the fourth week of study the data was not able to be obtained from Group 12.

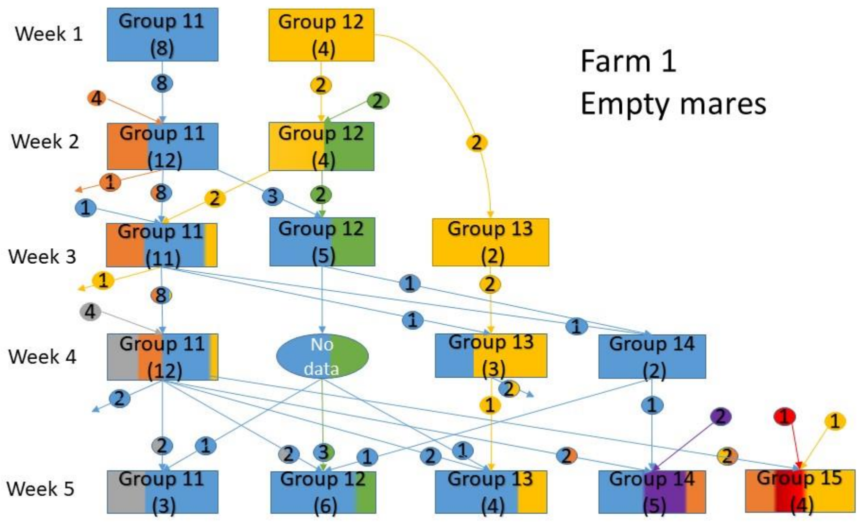

Figure 9. *Movements of the empty mares in between different cohorts on farm 1 during five weeks of study. The total numbers of mares in each cohort is shown in brackets in the square. The numbers in the circles represent the numbers of mares that moved. The arrows show the mares' movement from one week to the next (whether they stay in the original cohort, change cohort or leave the farm.) Each cohort represents an original color to easier follow the mares' movements every week*

Figure 10 shows the movement of pregnant mares and mares with foals on farm 1. Also, this figure shows there is significant movement of mares between cohorts. As for the pregnant mares (Group 20-25) they are starting off as four groups with a large number of horses which narrows down to fewer numbers of cohorts with large number of horses due to a constant flow of mares coming from other farms. The pregnant mares are either resident mares or from other studs visiting for 8-10 weeks. All mares are sorted according to expected foaling date and the ones closest to foaling are kept near the stables in smaller paddocks (foaling paddocks) at a high density. In the pregnant cohorts there were many mares (maximum 22) and the mares were moved every week, some mares moved to other pregnant cohorts and other mares foaled. The mares that foaled (Group 31-35) were hopefully still to be found on the farm and created new cohorts. The mares that foaled were put together in groups of 2-3 and as the foals got older the mares were put in larger mobs and paddocks.

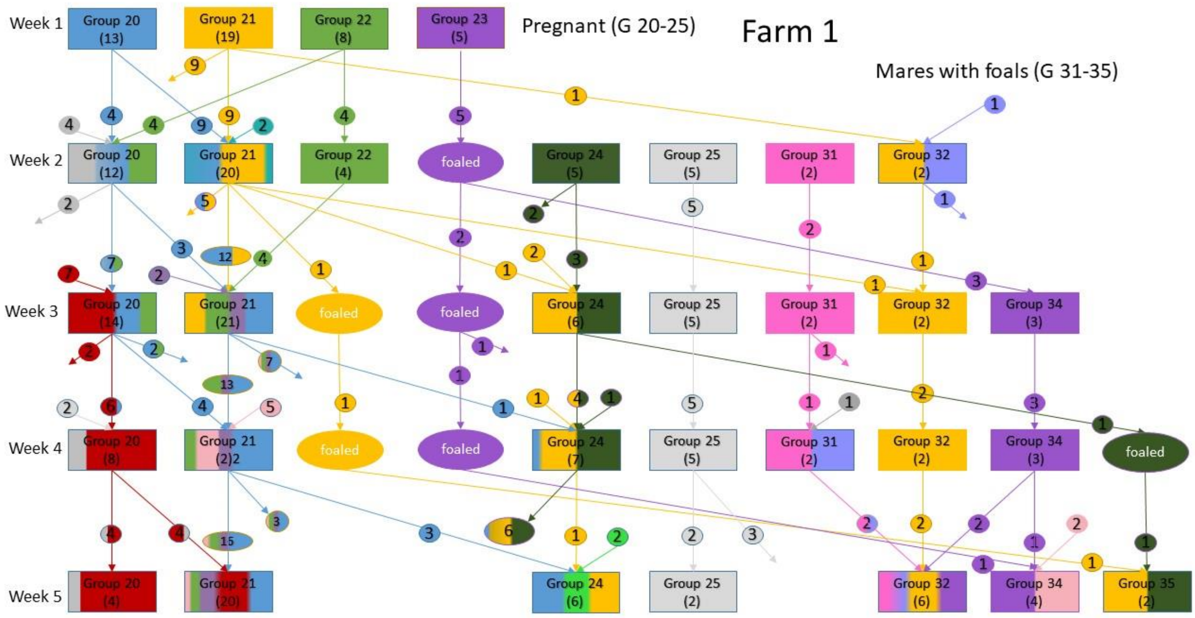

Figure 10. *Movements of the pregnant mares and mares with foals in between different cohorts on farm 1 during five weeks of study. The total numbers of mares in each cohort is shown in brackets in the square. The numbers in the circles represent the numbers of mares that moved. The arrows show the mares' movement from one week to the next (whether they stay in the original cohort, change cohort or leave the farm.) Each cohort represents an original color to easier follow the mares' movements every week*

Figure 11 shows all the cohorts on farm 2 and how they were moving throughout the study. One cohort of mares with foals (and week 4 there was one more cohort), one cohort of empty mares and two cohorts of pregnant mares sorted according to foaling date were followed. In this farm, the pregnant mares kept adding throughout the study due to non-resident mares coming for surveillance during foaling and then sent off to other studs for breeding. Like farm 1, there is a mixture of horses in between cohorts of the same category (the pregnant mares according to expected foaling date) and when the mares foaled. The empty mares (Group 2) were sent off to other studs for covering and then coming back to the same cohort.

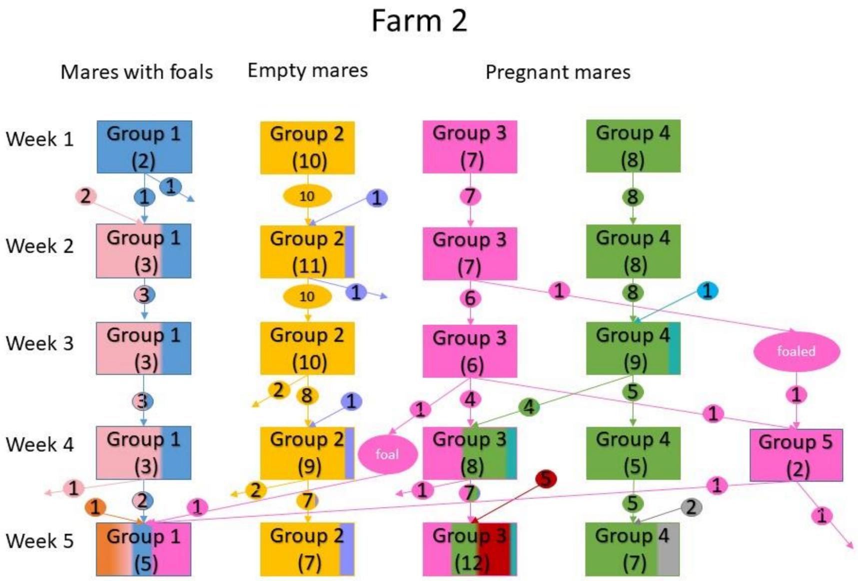

Figure 11. *Movements of the broodmares in between different cohorts on farm 2 during five weeks of study. The total numbers of mares in each cohort is shown in brackets in the square. The numbers in the circles represent the numbers of mares that moved. The arrows show the mares' movement from one week to the next (whether they stay in the original cohort, change cohort or leave the farm.) Each cohort represents an original color to easier follow the mares' movements every week*

Figure 12 shows the mares movement in farm 3. On this farm there were no mares with foals during the study period. Group 1 were empty mares kept in the same cohort and leaving the farm to be bred at other stud farms so one mare left every week. Group 2 was a cohort of mares with a larger group size with a later expected foal date than Group 3 and 4. Horses were moved in between cohorts at this farm due to foaling date and to get covered at other farms.

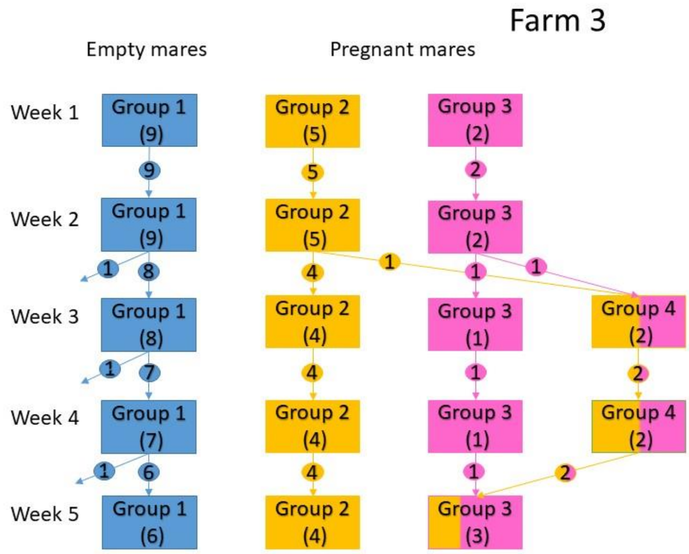

Figure 12 Movements of the broodmares in between different cohorts on farm 3 during five weeks of study. The total numbers of mares in each cohort is shown in brackets in the square. The numbers in the circles represent the numbers of mares that moved. The arrows show the mares' movement from one week to the next (whether they stay in the original cohort, change cohort or leave the farm.) Each cohort represents an original color to easier follow the mares' movements every week

Figure 13 illustrates the movements in between cohorts at farm 4. Group 1 is a cohort with only pregnant mares while Group 2 is a mixed group of empty and pregnant mares. Like farm 2 and 3, the empty mares leave the farm to get covered and the pregnant mares move due to foaling date and foaling.

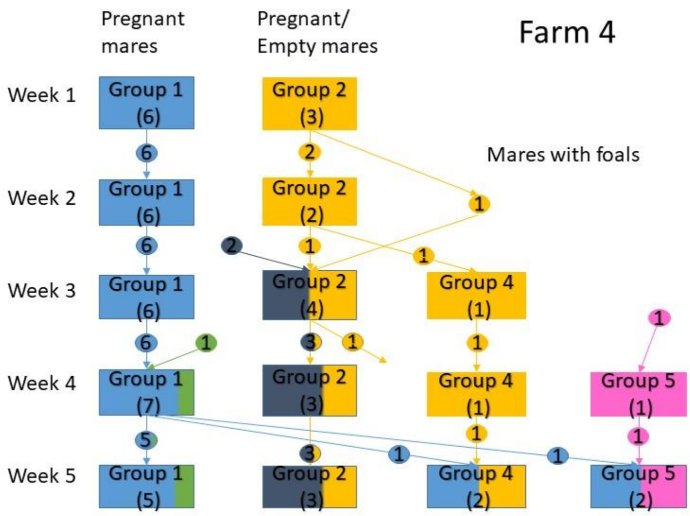

Figure 13. *Movements of the broodmares in between different cohorts on farm 4 during five weeks of study. The total numbers of mares in each cohort is shown in brackets in the square. The numbers in the circles represent the numbers of mares that moved. The arrows show the mares' movement from one week to the next (whether they stay in the original cohort, change cohort or leave the farm.) Each cohort represents an original color to easier follow the mares' movements every week*

4.4 Pasture management

The pastures were very similar on the four farms, the majority were square shaped and bordered with trees, bushes and tall grass (toi toi), see Appendix 3. All paddocks had one-two water sources as open troughs shared between two paddocks or kept separately in the paddock. In the paddocks where horses were fed extra haylage (or grains and minerals) there tended to develop muddy areas, especially on farm 1 where the density was high and the haylage was not spread out in the paddocks. Due to the rainy and cold spring, all managers experienced very muddy paddocks and a delayed pasture growth which forced them to supplement the horses with haylage, except on farm 3.

4.4.1 Pasture herbage mass and changes over time

Table 8 shows the average PDM, inter quartile range (IQR) and ratio of lawns and roughs for each category of mares in the cohorts. Foaling paddocks are paddocks <0.8 ha in farm 1 where the pregnant mares foal down and stay for 1-2 weeks. The distribution of PDM throughout the farms are similar, 46% of the lawns on the farms are below 1400 kg DM/ha and 54% are above 1400 kg DM/ha throughout the study period. The PDM of the lawns ranges from 521 below and 401 above 1400 kg DM/ha (except farm 4 with a cohort of 1881 kg DM/ha over 1400).

Table 8. *Average pasture dry matter (PDM) and ratio of lawns (L) and roughs (R) on four farms and four different categories of horses*

	Empty				**Pregnant**			
	Average PDM (kg DM/ha)				**Average PDM (kg DM/ha)**			
	Total (IQR)	**Lawns (IQR)**	**Roughs (IQR)**	**Ratio L:R**	**Total (IQR)**	**Lawns (IQR)**	**Roughs (IQR)**	**Ratio L:R**
Farm 1	1670 (1385-2933)	1401 (1185-2391)	2523 (2101-4835)	0.56	1444 (1369-2203)	1343 (800-2923)	3228 (1775-4845)	0.42
Farm 2	1344 (1002-1737)	1164 (940-1411.3)	2915 (2278-3479)	0.40	2258 (1796-2373)	1801 (1411-1970)	3823 (278-4171)	0.47
Farm 3	1176 (1140-1468)	1180 (1153-1317)	1838 (1780-2459)	0.64	1993 (1646-2602)	1759 (1559-2028)	3502 (2860-4182)	0.50
Farm 4	911 (793-1132)	879 (653-974)	1074 (1006-1785)	0.82	1144 (1124-2428)	1048 (911-1843)	2317 (2201-3644)	0.45
	Foaling paddock				**Mares with foals**			
	Average PDM (kg DM/ha)				**Average PDM (kg DM/ha)**			
	Total (IQR)	**Lawns (IQR)**	**Roughs (IQR)**	**Ratio L:R**	**Total (IQR)**	**Lawns (IQR)**	**Roughs (IQR)**	**Ratio L:R**
Farm 1	2045 (2001-2854)	1827 (1527-2017)	2960 (2639-3818)	0.62	1610 (1409-2159)	1338 (1121.7-1827.4)	2617 (2496.3-2975.5)	0.51
Farm 2	-	-	-	-	1962 (1827-2290)	1690 (1195-1706)	3465 (3213-3697)	0.49
Farm 3	-	-	-	-	-	-	-	-
Farm 4	-	-	-	-	3222 (2894-4517)	3281 (3197-3997)	4898 (4666-5161)	0.67

Total

The empty mares had an average total pasture dry matter of 1505 kg DM/ha (1055-2357), the pregnant mares 2006 kg DM/ha (1727-2275) and the mares with foals 2546 kg DM/ha (1962-2970) throughout the four farms during the study period. It is mainly from week 3 and 4 of study that the total PDM is increasing for the cohorts on the farms, see Figure 14. This coincides with the warmer temperatures and less density in the paddocks which allows the grass to grow, increasing the pasture herbage mass.

Empty mares

These cohorts had paddocks with the lowest pasture herbage mass and were kept in wet pastures at a high density, see Table 8. The total PDM was increasing during the study period; on farm 1 they were strip-grazed (the paddocks got larger with more grass) and on the other farms the mares were changing paddocks and left the farm (density decreased), see Figure 14.

Pregnant mares

The pregnant mares were kept at a low pasture herbage mass, prioritized more than the empty mares but less than the mares with foals. The PDM for the pregnant mares was slowly increasing but very much set at a steady state (see Figure 14). On farm 1 the PDM was varying and decreasing since a majority of mares were coming from other farms to foaling and covering (high density in wet pastures) and on farm 2-4 it was increasing as horses move to other paddocks and farms.

Mares with foals

The mares with foals and foaling paddocks had the highest PDM of all categories. Mares with foals on farm 1 have a high pasture herbage mass in the beginning (>1400 kg DM/ha) then decreasing as the density increases with an increased number of mares foaling. Farm 2 & 4 have an increasing PDM as seen in Figure 14 when mares are put on pastures saved for these categories.

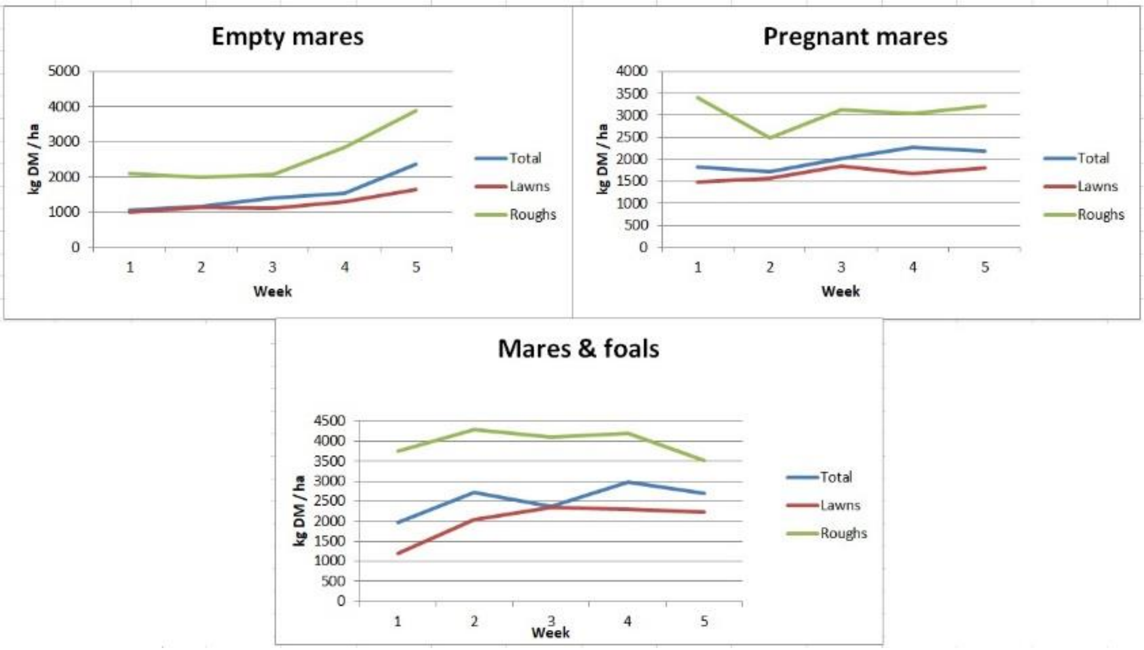

Figure 14. *Average dry matter (kg DM/ha) for the three categories of cohorts on all farms for five weeks*

5. Discussion

5.1 Farm and horse management

5.1.1 Livestock and pest management as a risk for exposure

The four farms have horses and other species of livestock and implement both cross- and co-grazing with other species (see Table 4). Sheep were not vaccinated against leptospirosis though Farm 2 had vaccinated dairy heifers and Farm 1 vaccinated beef heifers. Another similarity was the fact that all beef cattle (and most of the sheep) present at a farm originated from sale yards or agents and were possibly already mixed from several farms (with unknown disease- and vaccination status). All the farms also have pests present, especially around the stables and paddocks, and they are managed by poisoned bait stations to keep the numbers down. Farm 4 has only sheep due to management (they are light and do not damage the paddocks as much as cattle and horses) and usually follow the horses with sheep or vice versa. Farms 2 and 3 have both sheep and cattle which cross- and/or co-graze with the horses. Normally Farm 1 is co- and cross-grazing with beef cattle but during the observation period the beef cattle were in paddocks fence-to-fence to horses or further away from the horses studied. The grazing of different livestock species and horses in the same paddocks may pose risks for spreading leptospirosis (Dreyfus, 2013). In the dairy industry recommendations to protect the livestock is vaccination and controlling the rodents and wildlife on the farm through baiting, trapping and having buildings pest-proof (Heuer *et al.,* 2017) which all farms were implementing.

5.1.2 Serostatus on farms

The Thoroughbred broodmares in New Zealand are exposed to at least the five serovars Ballum, Hardjo, Pomona, Tarassovi and Copenhageni (Bolwell *et al.,* 2017) and this is correspondent to other studies that found horses picking up leptospirosis and being positive (Båverud *et al.,* 2009; Ellis, 2015). A seropositivity to leptospirosis is most prominent in the New Zealand broodmares compared to race horses according to Bolwell et al. (2017). The commercial stud farm 1 had a relatively high positive serostatus (15.6%), see Table 6 when compared to the results from Bolwell et al. (2017), most likely due to the large numbers of resident mares on the farm, number of outside mares coming to the farm, a high density, muddy and wet pastures with a difficult soil-type, small foaling paddocks with many mares going through and a low PDM.

Farm 1 had the lowest seropositivity (15.6%) in this study and this is the farm with most mares present. On farm 2 which take mares in for foaling, the seropositivity is higher (18.8%). The highest seropositivity (66.7%) was found in stud farm 3 which sends all the broodmares off to other studs for breeding. Presumably, this has to do with the management of horses but in this study it could be due to the small number of horses studied on farm 3 with known serostatus (n=3). Farm 4 was seronegative since none of the previously tested positive mares were found.

All farms had livestock and rodents present and the potential shedding and survival of leptospires in paddocks are most likely, especially when the paddocks are wet with sitting water and horses of a high density grazing in the soil interface and giving birth at pasture. The serovars associated with infection in cattle and sheep are Pomona, Hardjo, Ballum and Tarassovi, serovars associated with rats are Ballum and Copenhageni and the serovar associated with pigs is Tarassovi (see Table 1).

The environmental factors could be the root of infection but studies also found that transmission of serovars adapted to horses might be transmitted through direct horse-to-horse contact, either mare-to-mare or stallion-to-mare (Hamond *et al.,* 2013). Hamond et al. (2014) found that there is presence of *Leptospira* spp. in both vaginal fluid and urine and that the incidental serovar Copenhageni was more common in urine. Infected horses may shed *Leptospira* spp. in the urine for at least 4-5 months (Frellstedt, 2009) which makes the paddocks a possible route of infection.

The serovars found in Bolwell et al. (2017) study are not just the typical serovars found in cattle and sheep which may indicate that it is not only cross- and co-grazing with livestock and/or rodents at paddocks that expose horses to leptospirosis but also horse-to-horse contact.

5.1.3 Horse serostatus and ages

There is a cluster of mares in age 12-14 (see Figure 6) which could affect the results and be misleading because the number of mares in this age group is higher than age group 15-20. The seropositive mares are from age 12 to 19 and these older mares have been moved around within and in between farms, getting mixed multiple times throughout the years serving as broodmares. This is a horse management associated with risks for picking up and shedding diseases as leptospirosis (Båverud *et al.,* 2009; Bolwell *et al.* 2017; Rogers & Firth, 2007; Tsegay *et al.,* 2016; Lees & Gale, 1994). What Figure 6 also shows is a representative sample of New Zealand's base population of broodmares on commercial farms where most mares are young (less than 12 years old) and represent the active breeding population (Rogers, Chris; personal communication). As the mares get older they are kept because of their genetics and breeding value but are culled if they do not get pregnant and produce foals (Rogers *et al*., 2016 & 2017). The older mares in my study with high titres for *Leptospira* spp. are still broodmares because they are producing foals every year, the clinical signs of leptospirosis reported from overseas are commonly abortions which these mares probably did not have. The association between age, breeding records and serostatus is something to evaluate in future studies and also why there is a cluster of seropositive mares around ages 12-14.

5.1.4 Horse numbers and density

All breeding farms send mares off to other properties (see Table 5) during breeding season (even farm 1 with three stallions present) which potentially reduces the horse density on the boutique stud farms but increases the grazing pressure on the stud farms with stallions (like farm 1). The farms are of different sizes and extent of horses kept at the farm and the main occupation differs (commercial stud farm versus boutique stud farm versus racing farm). The mares are sent off from the boutique studs to the commercial farms to be bred. In addition to the higher horse density on these farms the mares are often mixed with others, foaling down in small paddocks where other mares already been grazing, foaling and shedding urine, placentas, blood and other body fluids.

The main differences in the horse management were the density of horses in the different paddocks (Figure 5) and the pregnant and empty mares tended to have the highest density throughout the four farms. On farm 1, the pregnant mares are having a density of 5.9 n/ha (see Table 5) which is 3.5 times higher than the mares with foals at their side, slowly decreasing as the weeks go by (due to smaller groups of pregnant mares as the foal). When mares are foaling; the increased numbers of mares in this category makes the farm run out of foaling paddocks and the stocking density increase while the pregnant mares' density decreases as demonstrated in Figure 5 for farm 2. At farm 1 and 4 the stocking density for mares with foals stays the same and decreases as the farms have large paddocks saved for bigger groups of mares with foals.

5.1.5 Horse movements

On farm 1 (Figure 9 and 10), there is a lot of movement of individuals between the cohorts each week. When looking at the empty mares (Figure 9) this has a lot to do with the attempt to get mares in heat and make sure they are bred in time. These mares went to see the teaser stallions (used as heat detectors) every day and were sorted into different cohorts according to breeding status. The empty mares originated from the studied farm (resident mares) but also from many other stud farms, mixed with each other in the different cohorts. The pregnant mares (Figure 10) were also moved around in between other groups of pregnant mares due to expected foaling date. A lot of mixing was seen when the pregnant mares foaled and were moved from the original cohort to foaling paddocks and put together with other mares that had foals of a similar age. Also, these mares were covered as soon as they came in heat and mixed with other bred mares. At farm 1 there were mares from other stud farms coming to foal down and get bred by one of the stallions at the stud, meanwhile the mare and her foal were put together with other mares and foals from the same farm she originated from, mares from the farm of the stallion (farm 1) or other mares from other farms also visiting the stallions temporarily.

The similar movements are seen in farm 2 (Figure 11) where another 20 mares are coming to the farm for surveillance during foaling and the first critical days of the new foals' life. These non-resident mares were also put in different groups of pregnant mares but once close to foaling they tended to be housed separately in a higher extent than farm 1. This might be because the non-resident mares and foals did not stay as long as if they were also going to be bred at the stud (as farm 1).

On farm 3 and 4 (Figure 12 and 13) the mares are kept in the same cohorts at a much higher extent since these farms send their resident mares off property to foal and be bred at other studs, they come and go during breeding season.

Throughout the four farms (Figure 9-13) the empty mares are moving in between groups and leave the farms to go to other studs for covering. This management is seen in previous studies of Rogers et al. (2007) where the attempt to get empty mares bred and having an expected foaling date as close to the official birth date of all Thoroughbreds in New Zealand (September 1st). The mares that just foaled are covered as soon as they are in heat again so it is important to have them in a good condition and pasture while lactating and recovering from previous pregnancy to quickly get pregnant again (Rogers *et al.*, 2017). The mares that foaled are moved to other smaller groups with foals of a similar age to keep track of the mares foal heat. Either the mares are sent off to other studs before foaling or go with the foal at their side and then comes back to their home stud a couple of weeks later. The mares that are covered by local stallions might be walked in during the day and are brought back to home stud the very same day (a principle used a lot of farm 3 and 4). The farms had a similar way of moving their horses around within the farms but the time the different groups of animals spend at the same paddock differs in between the farms. Also, the paddock- and herd size are different on the farms which makes the stocking density of each farm vary a lot. Throughout the year the horses tend to be set stocked in the same paddock for longer periods of time (up to 6 months) but during the breeding season (and especially this extra wet and difficult spring) the horses inevitably have to move around in between paddocks to be arranged according to pasture herbage mass and breeding status.

5.2 Pasture management

5.2.1 Pasture herbage mass

During the study period (September to October) it was early spring and the pastures had not started to grow as much as needed to keep the pasture dry matter high enough to feed the horses sufficiently (lawns PDM >1400 kg DM/ha). This was due to a wet and cold spring but from week 3 and 4 of study the weather changed (higher temperatures and more days of sunshine) and pasture herbage mass started to increase on all farms. In farm 2-4, which are not commercial, the density of mares is decreasing during the study period as the empty and pregnant mares are sent off to commercial farms for covering.

In the dairy industry the focus on the pastures and how to optimize pasture growth is large, a target post-grazing residual of 1500-1600 kg DM/ha during spring and early summer to maintain a good pasture quality (Dairy NZ). In the same guide one key to success is to maintain the pre-grazing cover around 2800-3200 kg DM/ha during spring. This can in many ways be applicable to horses. Especially for horses at pasture there are limited data of the feeding management (Rogers *et al.*, 2017). Pregnant broodmares are usually managed with 6-12 mares in paddocks 2-4 ha and they are set stocked for 4-6 weeks with a pre-grazing mass of approximately 3500 kg DM/ha (Rogers *et al.*, 2017).

When the farms are under pressure, such as this spring, the managers have to prioritize which horses get the best pastures. The mares with foals have high demands once they foaled; they need energy for lactation, recovering from pregnancy and quickly get in heat again to get covered by the stallion on the farm – this is why these mares are highly prioritized. The pregnant mares also need a sufficient pasture to maintain their body condition during pregnancy and the farms try to look after these mares.

The empty mares are least prioritized – no foal this season and they basically need to be maintained until covered and pregnant again. These mares are offered the worst paddocks with low pasture herbage mass with lawns under 1400 kg DM/ha and basically grazing in the ground. The ground is wet with sitting water and surface floods – a perfect environment for leptospires to grow in. Empty mares are mixed and moved around in different groups on the commercial farms (and some at the other farms as well) which makes the routes of exposure large (mixed ages and farm origin).

Another category of mares with a risk for exposure to leptospirosis is the mares close to foaling. They are kept in smaller paddocks with rapidly decreasing pasture herbage mass which got muddier as the mares were run through week after week. All pregnant mares eventually have to go through the foaling paddocks and then get mixed with other mares with foals of similar age – this is also an area where leptospires may be since the mares are stressed and shed many body fluids (placentas, urine, blood) in a small, wet area with hard pressure on the paddock.

5.3 Answers to questions

The original questions of this thesis were:

- Could the stocking density during the breeding season, in association with the reduced pasture dry matter, provide potential exposure of Thoroughbred broodmares (TBB) to *Leptospira* spp.?
- What aspects of pasture management of TBB during the breeding season pose a risk for exposure and spreading of *Leptospira* spp.?

When it comes to pasture and horse management (stocking density and movements) of TBB in New Zealand there are two main areas identified during the breeding season that may pose high risks for broodmares getting leptospirosis – the empty mares and the foaling paddocks.

The empty mares are run hard in their paddocks with a low pasture herbage mass (<1400 kg DM/ha) and grazing in the soil-interface at a high density with mares from other farms and of different ages. These paddocks are wet and muddy with surface floods which may have leptospires in the soil shed from infected mares, livestock and/or rodents exposing the mares in the paddocks. The empty mares are constantly moving around in between and within the farms due to breeding status therefore getting exposed to many mares from different areas.

The foaling paddocks are usually small with a pasture herbage mass which is constantly decreasing. All pregnant mares are at some point during breeding season run through these, getting stressed and shedding body fluids at a high extent which may lead to exposure to leptospirosis from other horses and wildlife occupied close to and within the stables and foaling paddocks. These mares are also mixed with other mares once foaled and are moving around before and after foaling.

5.4 Sources of uncertainty

5.4.1 Observations

Horse movements was very difficult to keep track of on farm 1 during every week of study. The mares were constantly moving (daily) and taken to the teaser stallions, stallion for cover and moved to a suitable group/cohort of horses or left farm. The identities of the cohorts (especially on farm 1) had to change to follow the same mares as much as possible and more cohorts were added. The farm data collection sheet (Appendix 1) was very useful for collecting environment, horse and pasture data and keeping track of previous records.

5.4.2 Horses serostatus

The horses followed were tested for serostatus one year earlier and their status were not possible to follow up whereby this study was not a cohort in its true meaning but more an illustration of the horse management in New Zealand stud farms. It was difficult to get enough cohorts and number of horses in these cohorts, especially the cohorts with mares with foals and also all categories on farm 2-4 since their business were not as extensive. Many mares were either lost to follow up or showed up later on. By then it was hard to look for information about the contact between mares (just knew which farm and stallion they went to).

All the farms and horses where conveniently sampled: same gender, breed, occupation, close to the University which also influences my study design. This study also had very few mares (n=57) and a lot of mares had to be ruled out due to unknown serostatus, many horses positive with a titre of 1:25 that had to be regarded as seronegative in this study. According to what Favero et al. (2017) found a titration of 1:50 indicates exposure whereas 1:100 or higher indicates disease. If a sample was to be analyzed as positive there should be agglutination in at least the 1:50 solution why mares with a cut-off titre of 1:50 were chosen in this study.

5.4.3 Farm questionnaire

The farm questionnaire was a useful assessment to get information from the managers/owners in a wide range of questions. It was very hard to achieve a good seasonal variation and numbers since the managers/owners did not always remember and knew the general management of the pastures and horses.

5.4.4 Estimating pasture dry matter

Most stud farms in New Zealand have a pasture composition and pasture dry matter cover (kg DM/ha) which is very similar to that observed on dairy farms (Rogers *et al.,* 2017) and that is why this formula was used in this study. There are different formulas to calculate pasture cover depending on season, pasture composition and so on.

The pasture plate meter is a fast and easy equipment to use when estimating the pasture dry matter. It is robust and neither calibration nor sensitivity is affected in the event of normal transport and field use (Earle & McGowan, 1979). When used in green perennial rye grass/white clover the EPM has been found to be very accurate when estimating pasture yield (Earle & McGowan, 1979). During my study period 15% of the paddocks (on farm 1) were so flooded, treaded and uneven that no pasture dry matter could be measured at some point during the weeks of study.

6. CONCLUSIONS

Thoroughbred broodmares in New Zealand stud farms are exposed to many different serovars of *Leptospira* spp. The management of these mares are similar compared to different farms and involves several areas which could pose risks for getting leptospirosis. The mares are kept in wet paddocks at a high density with a low pasture herbage mass, run through foaling paddocks, constantly moved and mixed with other mares from different farms and of different ages during a stressful series of events, co- and cross-grazing with unvaccinated livestock and potentially exposed to rats and other pests in the farms. All these areas would be of interest to examine further in New Zealand to find the main risk factors of horse management for leptospiral exposure in the broodmares.

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Appendix 1

Farm data collection sheet

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

FARM DATA COLLECTION SHEET

Date:

Farm ID:

Farm details	
Name	
Main occupation	
Status Leptospirosis	
Terrain, Soiltype	
Water source	
Floods in follow up	
Livestock contact, vacc lepto	
Pest management	
Location of burn pile	

Farm ID:	**Pasture ID:**	**Group ID:**

Pasture details					
Size of pasture					
Demography of pasture (puddles, feeding area, water source, still water, pugged, trees, shade, grass and weed)					
Distance to burn pile					
Distance to water source/still water					
Sec RPM - First RPM = clicks			kgDM/ha = (clicks/readings) x 158 + 200		
Pasture plating	First # RPM	Sec # RPM	Clicks	Readings	KgDM/ha
Total				40	
Roughs				30	
Lawns				30	
Horse details					
Number of mares in pasture					
Identity of mares					

Appendix 2

Approval participating in the study and farm questionnaire

EQUINE LEPTOSPIROSIS NZ

INFORMATION SHEET FOR PARTICIPANTS

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Contact person

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Principle investigators

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Dr Jackie Benschop, Co-Director, Molecular Epidemiology and Public Health Laboratory, Massey University
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Dr Julie Collins-Emerson, Senior Research Officer, Molecular Epidemiology and Public Health Laboratory, Massey University
Dr David Wilkson, Postdoctoral Research Fellow, Molecular Epidemiology and Public Health Laboratory, Massey University

More information on Equine Research Centre at Massey University can be found at www.erc.massey.ac.nz

What is this study about?

Leptospirosis (lepto) is an important infectious disease in New Zealand, found in domestic animals, wildlife and humans. Although we know how often it occurs in livestock, we have very little information about the occurrence of lepto in horses in New Zealand. Last year we sampled race horses and broodmares and found that many horses had been exposed to *Leptospira* (the bacteria that can cause leptospirosis). Racing horses and broodmares are managed differently, which means that factors such as housing, nutrition, contact with standing water and exposure to wildlife may also influence the chance of horses being exposed to lepto.

We would like to collect information about the management of broodmares to identify if there are specific factors that might increase the chance of horses being exposed to leptospirosis. This work will allow us to increase our knowledge about the occurrence of lepto in broodmares in New Zealand.

What participation means for you

We would like to invite you to take part in this study. If you agree to participate we would like to ask you a short questionnaire about farm and pasture management – such as whether or not paddocks are grazed with livestock or constitute suitable wildlife habitat. The questionnaire should take no longer than 10 mins to complete. We also ask for permission to take pictures of pastures, horses and property details in a way that cannot be identified and traced back to your farm.

Results and Confidentiality

All of the information you give us is confidential. All information given will be anonymized so no material that could personally identify you or your horses will be used in any report on this study. Information given in the questionnaire will be stored in an electronic database, along with the results of the pasture plating and pictures.

Participant rights

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the study;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the project findings when it is concluded.

Statement of ethical approval

Questionnaire:
"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Dr Brian Finch, Director, Research Ethics, telephone 06 356 9099 x 86015, email humanethics@massey.ac.nz".

Participant's consent

I have read the Information Sheet and the details of the study have been explained to me. I have been informed about the study protocol including the questionnaire, photos and the use of past ure plating.

Signature………………………………………………….. Date ……………………………………………………….

Farm ID:	**Date:**

Farm management									
On the farm map could you please indicate **streams/open** drains (-------)									
On the farm map could you please identify **paddocks** with drainage (D)									
On the farm map could you please identify the **burn pile (B)**									
On the farm map could you please identify paddocks/areas prone to **surface water** and **pugging (S)**									
On the farm map could you please indicate the **typical** pasture/paddocks grazed by the following classes of horses:									
	1. Mares and foals	**2.** In foal brood mares	**3.** Empty brood mares	**4.** Spelling race horses	**5.** Race horses	**6.** Weanlings	**7.** Yearlings	**8.** Stallions	**9.** Other
Number of horses **on** property in **autumn**?									
Number of horses **on** property in **winter**?									
Number of horses **on** property in **spring**?									
Number of horses **on** property in **summer**?									

Farm ID:	**Date:**

Farm management									
	1. Mares and foals	2. In foal brood mares	3. Empty brood mares	4. Spelling race horses	5. Race horses	6. Weanlings	7. Yearlings	8. Stallions	9. Other
Number of horses **off** property in **autumn**?									
Number of horses **off** property in **winter**?									
Number of horses **off** property in **spring**?									
Number of horses **off** property in **summer**?									
Number of **resident** mares in total			Number of resident mares **sent off** to stud			Number of **non-resident** mares on farm to be bred			

Farm ID:	**Date:**

Pasture management

	Alternatives	**All year**	**Autumn (feb-may)**	**Winter (jun-aug)**	**Spring (sep-nov)**	**Summer (dec-jan)**
How much of farm is resown (ha) and how often?	Planned					
	Actual					
Do you know the levels of following in pasture:	Soil pH					
	Olsen P					
How is a pasture managed in general during the last five years?	Rest					
	Fertilizing					
	Crops					
	Livestock					
In what order do mobs of animals graze?	**Dry mares**					
	In foal mares					
	Mares with foal					
	Yearlings					
	Racehorses					
	Stallions					
	Other					
In general, for how long is a pasture grazed before changing mobs?	1-3 days					
	4-7 days					
	1-2 weeks					
	2-3 weeks					
	1 month					
	1-6 months					
Generally, for how long do **dry/empty mares** graze in same pasture and for what reasons?	1-3 days					
	4-7 days					
	1-2 weeks					
	2-3 weeks					
	1 month					
	1-6 months					

Farm ID:	**Date:**

Pasture management						
	Alternatives	**All year**	**Autumn (feb-may)**	**Winter (jun-aug)**	**Spring (sep-nov)**	**Summer (dec-jan)**
Generally, for how long do **in foal/pregnant mares** graze in same pasture and for what reasons?	1-3 days					
	4-7 days					
	1-2 weeks					
	2-3 weeks					
	1 month					
	1-6 months					
Generally, for how long do **mares with foals** graze in same pasture and for what reasons?	1-3 days					
	4-7 days					
	1-2 weeks					
	2-3 weeks					
	1 month					
	1-6 months					
Generally, for how long do **livestock** graze in same pasture and for what reasons	1-3 days					
	4-7 days					
	1-2 weeks					
	2-3 weeks					
	1 month					
	1-6 months					
For how long do pastures rest in between changing mobs of horses and livestock in general?	1-3 days					
	4-7 days					
	1-2 weeks					
	2-3 weeks					
	1 month					
	1-6 months					
What do you look for when deciding to change pasture for a mob of horses?	Estimate PDM					
	Estimate sward height					
	Look at animals BCS					
	Look at pasture					
	Time schedule					
	Other					

Farm ID:	**Date:**

Grazing management						
	Alternatives	**All year**	**Autumn (feb-may)**	**Winter (jun-aug)**	**Spring (sep-nov)**	**Summer (dec-jan)**
What kind of livestock graze horses pastures on farm? Approximately how many in every mob?	Beef cows					
	Beef heifers/steers R1					
	Beef heifers/steers R2					
	Mixed age beef					
	Dairy cows					
	Dairy heifers R1					
	Dairy heifers R2					
	Dairy steers/weaner bulls R1					
	Dairy steers/weaner bulls R2					
	Sheep ewes					
	Sheep lambs					
	Sheep mixed					
	Deer					
From where do livestock originate?	Own					
	Neighbor's					
	Agent					
	Saleyards					
	Don't know					
Do livestock leave farm and come back to graze horses pastures? If yes, when?	Yes					
	No					
	Don't know					
Are livestock vaccinated against Leptospirosis?	Yes					
	No					
	Don't know					

Farm ID:	**Date:**

Grazing management						
	Alternatives	**All year**	**Autumn (feb-may)**	**Winter (jun-aug)**	**Spring (sep-nov)**	**Summer (dec-jan)**
Which species and vaccination strategy – when are they vaccinated?	Beef cows					
	Beef heifers/steers R1					
	Beef heifers/steers R2					
	Mixed age beef					
	Dairy cows					
	Dairy heifers R1					
	Dairy heifers R2					
	Dairy steers/weaner bulls R1					
	Dairy steers/weaner bulls R2					
	Sheep ewes					
	Sheep lambs					
	Sheep mixed					
	Deer					

Farm ID:	**Date:**

Pest management						
	Alternatives	**All year**	**Autumn (feb-may)**	**Winter (jun-aug)**	**Spring (sep-nov)**	**Summer (dec-jan)**
What kind of pests do you have on farm?	Rats/Mice					
	Possums					
	Ferrets/Stoats					
	Rabbits/Hares					
How often do you see **Rats/Mice** at the farm? Numbers of them?	Every day					
	Several times a week					
	Once a week					
	Once a month					
	Twice a year					
	Once a year					
How often do you see **Possums** at the farm? Numbers of them?	Every day					
	Several times a week					
	Once a week					
	Once a month					
	Twice a year					
	Once a year					
How often do you see **Ferrets/Stoats** at the farm? Numbers of them?	Every day					
	Several times a week					
	Once a week					
	Once a month					
	Twice a year					
	Once a year					
How often do you see **Rabbits/Hares** at the farm? Numbers of them?	Every day					
	Several times a week					
	Once a week					
	Once a month					
	Twice a year					
	Once a year					

Farm ID:	Date:

Pest management						
	Alternatives	**All year**	**Autumn (feb-may)**	**Winter (jun-aug)**	**Spring (sep-nov)**	**Summer (dec-jan)**
Where and when do you see evidence of pests?	Barn					
	Feed storage					
	Stables					
	Pastures					
	Road					
	Morning					
	Day					
	Evening					
	Night					
How many pests are shot/poisoned every month?	1-3					
	4-7					
	8-14					
	15 or more					
How often do you have to refill traps with poison?	Once a week					
	Once a month					
	Twice a year					
	Once a year					
	More seldom					
How often is burn pile disposed?	Once a week					
	Once a month					
	Twice a year					
	Once a year					
	More seldom					

Appendix 3

Farm background

Farm 1

The farm was visited Thursdays from 8 September – 5 October. In this period the rainfall was high and throughout the farm visits it was sunny to cloudy and mostly rainy, evidence of the wet weather showed in the pastures and runways where it was very wet and muddy with puddles and surface floods. The farm had been flooded on and off the last 12 months.

Farm and pasture information

Farm 1 is a commercial stud farm with 121 ha and also an additional "run-off" farm with another 40 ha which was not visited. The natural water source is a river and through the property runs a creek which some pastures have access to (see Figure 1). The pastures are flat and free-draining with clay ground and bushes, trees and tall grass bordering the fences and the pastures studied are numbered from 1-20.

Figure 1 Overview of Farm 1. Red lines show pasture borders and yellow x is burn pile.

Every year an average of 10 ha is resown with

4ryegrass and clover and kept for haylage. The pastures are grazed in an average of 2-4 weeks before changing mob of horses/livestock, the empty mares are usually set stocked for 1-6 months if pastures and management allows.

Horses

There are no race horses in training on the property but throughout the year 30-60 spelling horses (horses having a break from racing) are situated on the farm along with approximately 60 weanlings and 40 yearlings. The main focus is breeding and the property stands three stallions for service. During the study it was very busy with mares from other farms coming for covering during the day or staying for weeks (delivering foals and getting covered). The number of mares varies throughout the year with a peak in spring during breeding season (250-300 mares). The number of resident mares is 100-130, 20 mares non-pregnant and 80-110 pregnant. This farm also sends 20 of their resident mares to other stallions in the regions of Waikato, Taranaki and Wairarapa. The number of horses per paddock varies between 2-6 and 7-22. All the pregnant mares (and weanlings and yearlings) are fed extra grains and minerals, all horses are fed extra haylage when needed.

Livestock

The managers use own beef cattle and sheep for co- and cross grazing horses paddocks throughout the year. The beef cattle are vaccinated against leptospirosis but not the sheep and originally the livestock comes from sale yards. The cattle present were 26 beef heifers up to one year old and 19 beef heifers one-two years old. During the study there was no evidence of co-grazing but the horses and livestock usually do and they are cross- grazing the paddocks, share the same water source and have fence-to-fence contact.

Pest management

On the farm there is evidence of possums, rats, mice, rabbits and ducks. The ducks and rabbits were visible during the observations. Baits with poison for possums, rats and mice are managed by the local council and refilled once a month. Present on the farm is also cats and dogs. The manure/burn pile is situated by the main stable and disposed once every year.

Farm 2

The farm was visited Wednesdays from 14 September to 11 October 2017. The rainfall in this region was high and during the farm visits it was occasionally sunny but mostly cloudy and rainy (once it was heavy showers). The runways were muddy and the pastures wet with puddles and surface floods. The farm had been flooded on and off the last 12 months. The farm gave the impression of being neat and tidy.

Farm and pasture information

Figure 2: Overview of Farm 2. Red lines show pasture borders and yellow x is burn pile.

This is a stud farm of 86 ha situated close to a river. The farm is relatively dry, flat and free-draining with pastures having tall grass, bushes and trees bordering the fences (see Figure 2). The soil is sampled once a year for nutritional values and paddocks are fertilized with extra lime yearly. In spring 8-12 ha are resown with maize silage and harvested in autumn. The manager attempt to resow the paddocks so the grass in the paddocks is not older than 5-6 years. Paddocks are sown with grass in March-April and then grazed by lambs for 6-10 weeks. Afterwards, the lambs are sold and another mob of young lambs are put on the pasture. The paddock is then rested during the winter and silage is harvested for the horses. In the spring broodmares are put on since the young horses are kept in smaller paddocks. After horses have been grazing, dairy heifers from the neighbor are grazing from November to June. The rest of the year, beef heifers from the sale yard Co-/cross-graze paddocks during the winter and are sold in spring. Horses are followed with whatever livestock the farm have at the moment and the horses do not really rotate. Usually the paddocks are grazed somewhat in between 2-3 weeks up to 6 months of the same groups, mares with foals at their side change pastures more often (every 2-4 weeks) while empty mares are set stocked for up to 6 months. The latter is also applied to livestock.

Horses

There is no stallion present and of the 28 resident mares 24 are sent off to other studs for covering (Manawatu, Auckland, Waikato, Hawkes bay and Wairarapa). During spring the farm also house approximately 20 other mares for surveillance of their foaling. So depending on when you visit the farm there could be something between 4 and 48 mares on the property. After the breeding season there are about 2 horses that are still non-pregnant and 26 pregnant. On the property there are no horses in training but 2-3 horses at spell. Each year there are 20-22 weanlings and 6-8 yearlings. The number of horses in each paddock varies from 2-6 and 10-14.

Livestock

The livestock present at the farm are own lambs and up to two year old beef heifers bought from sale yards and same aged dairy heifers borrowed from the neighbor. At least the dairy cattle are vaccinated against *Leptospira* spp. but probably not the other species. The cattle are kept in groups of 10-30 and the lambs of 200-300 animals. There are dogs present on the farm and they are vaccinated against leptospirosis.

Pest management

On the farm there are evidence of rabbits, mice, rats, and possums. Usually rats and mice are visualized once a week while the rabbits are spotted every day. The baits in traps for possums, rats and mice are refilled once a year and rabbits are also shot. Approximately 4-7 pests per month are taken care of. The manure/burn pile is disposed (burned) once every month and situated right next to the pastures.

Farm 3

The farm was studied on Fridays from 15 September to 13 October 2017. The rainfall was high and during the farm visits it was occasionally sunny but mostly cloudy and rainy. The runways were muddy and the pastures wet with puddles and surface floods. The farm had been flooded on and off the last 12 months. The farm was neat and tidy.

Farm and pasture information

This stud farm consists of 160 ha (see Figure 3) of which a lot is swampy areas (not shown in picture) which horses do not have access to. There is a creek running through the property, it is flat and free draining. On a regularly basis the paddocks are analyzed and every autumn the farm is fertilized with 200 kg Dicalcic/ha (lime). Approximately 20 ha are resown in spring with wheat/maize and harvested in autumn. In the autumn they are resown with grass and either sheep are grazing (light animals) or the grass is saved for silage. After that the horses are put on (when the paddock is strong enough to hold them) and stay in the different paddocks depending on horse category (pregnant mares are kept close to the stables and empty mares are further away). The yearlings are staying in the same paddock just moving occasionally. The average group size is 5-6 horses depending on size of paddock. The owner keeps enough horses in the paddock for the grass to grow, if the herbage mass cannot keep up the horses are fed extra silage. If the sward height in the paddocks is tall the beef are grazing after/same time as horses and if it is a lot of clover sheep are grazing paddocks.

Figure 3: Overview of Farm 3. Red lines show pasture borders and yellow x is burn pile.

Horses

There are no stallions (apart from teaser) or race horses present and of the 20 resident mares all are off to other studs for covering at some point during spring. Most of the mares are transported to Waikato and some to Wairarapa and south Auckland, the ones going locally are just served during the day and then come back home again. 5 mares every year may stay empty and the annual foal crop is 15, all of them kept until weanlings. At the weanling sales 7-8 horses are sold and the rest of them (7-8) are kept as yearlings and sold in the spring. The yearlings and pregnant mares are given additional feed (grain and haylage if needed) and all horses are given minerals. The number of horses in each paddock is usually 6-8.

Livestock

The livestock present at the farm are own beef cattle and sheep (not vaccinated against leptospirosis) bought from sale yard or agent, also chickens, dogs and cats. The cattle and sheep are co-/cross-grazed with the horses and share water sources. Approximately 100-200 one year old beef heifers are bought in the autumn and kept until spring where additional livestock can be bought during winter resulting in 100-400 heifers in the spring. The heifers are kept in mobs of 20-30. Lambs are 1000-1500 on the farm and kept in mobs of 200-300/mob.

Pest management

The farm has rats, mice, possums, ferrets, hedgehogs and rabbits, possums and rabbits are seen every day, rats and mice every month and ferrets twice a year. Once a year the council comes and set baits and poison the pests. The manure/burn pile is located close to the main building and mares with foals and it is burned once a year.

Farm 4

The farm was studied on Mondays from 18 September to 17 October 2017. The rainfall was high and during the farm visits it was occasionally sunny but mostly cloudy and rainy. The runways were drained and pretty dry compared to the other farms. Some paddocks were wet with puddles and surface floods while other paddocks were fairly dry. The farm had been flooded on and off the last 12 months. The farm gave a neat and tidy impression.

Farm and pasture information

This stud and training farm consists of 20 ha of flat and free-draining land, there is a creek running through the farm and the river is close to the property (see Figure 4).

Figure 4: Overview of Farm 4. Red lines show pasture borders and

Soil was sampled 23 years ago but the soil is very fertile due to flood plain ground. Fertilizer with lime is distributed every second year. Pastures are sprayed and 6-7 ha are resown with ryegrass and clover. Some of the grass is kept for haylage and then sheep are grazing to chew it off for 2-3 months. When the grass is thicker horses are put on, the grazing is not in a particular order. The horses are kept on the same paddock usually 2-4 weeks (the empty mares are kept for longer periods). Usually the horses co-graze with sheep or the sheep are put on the paddock straight after horses and vice versa.

Horses

On this farm there is no stallion and all the 12 resident mares are sent off to other studs, 10-11 mares get pregnant every year and 1-2 horses are empty. The total number of horses on the farm is on average 50 (12 resident mares, 20 race horses, 6 spelling horses, 7 weanlings and 5 yearlings). The broodmares are either sent off to the Waikato region for cover or are walked in to other studs in Manawatu during the day. All horses are fed minerals, grains and haylage. In average the mobs of horses are 1-2 or 6-8.

Livestock

Co/cross-grazing with 1000 owned sheep of mixed ages which are not vaccinated against leptospirosis.

Pest management

The farm has rats and mice which are poisoned and the traps are refilled with bait several times a year. Possums are shot and poisoned (traps are refilled once a year), then there is evidence of hedgehogs, rabbits and ferrets. In average there are 4-7 possums and rodents poisoned/shot every month. The possums are seen several times a week and the mice/rats are seen once a month around stables and pastures. On the farm there is one pile with trees located in a pasture and another behind the barn with manure and shavings (which is kept for compost).