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**THE EPIDEMIOLOGY OF *THEILERIA ORIENTALIS* IKEDA TYPE IN
NEW ZEALAND**

A thesis submitted in partial fulfilment of the requirements for the degree of

**Doctor of Philosophy
in
Veterinary Clinical Sciences**

**Massey University, Palmerston North
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**“If I knew I was going to write a PhD at my age,
I would have taken better care of my brain”**

Kevin Lawrence

Abstract

The research presented in this thesis was primarily conducted to document and understand the *Theileria orientalis* Ikeda type epidemic in New Zealand from 2012 onwards. The thesis summarises the epidemiology of the initial outbreak, presents the results of a prevalence study conducted by the Ministry for Primary Industries in 2013, presents and analyses the common history, haematology and biochemistry changes associated with acute *T. orientalis* infection, uses different modelling techniques to analyse the spatial-temporal effects on the epidemic, to predict the likely extent of the *T. orientalis* epidemic and to project the likely effects of global warming on the ecology of *Haemaphysalis longicornis*, the only competent vector for *T. orientalis* Ikeda type in New Zealand. In addition, two observational field studies were conducted, the first was a cross-sectional study to investigate the vertical trans-placental transmission of *T. orientalis* infection from dam to calf and the second was a longitudinal study to investigate the temporal dynamics and effects of *T. orientalis* infection on haematocrit, production and reproduction in three commercial New Zealand dairy herds.

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Publications

Publications related to thesis research

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Abbreviations

ACVM	Agricultural Compounds and Veterinary Medicines
AHL	Animal Health Laboratory
ANI	Average Nucleotide Identity
APR	Acute Phase Response
APVMA	Australian Pesticides and Veterinary Medicines
AST	Aspartate aminotransferase
AUC	Area under the curve
AWC	Available Water Capacity
BAM	Biotic Abiotic Mobility
BCS	Body Condition Score
BPQ	Buparvaquone
BVD	Bovine viral diarrhoea
CA	Correspondence analysis
CFT	Complement fixation test
CPHM	Cox proportional hazards model
DIM	Days in milk
DNA	Deoxyribonucleic acid
ECM	Energy Corrected Milk
ELISA	Enzyme-linked immunosorbent assay
ENM	Environmental niche model
ESRI	Environmental Systems Resource Institute
FANI	Field Anaemia Nearest Indicator
FC	Feature class
FN	False negative
FOL	Farms-On-Line
GEE	Generalised estimating equations
GGT	Gamma glutamyl transferase
GHG	Greenhouse gas
GLDH	Glutamate dehydrogenase
GOF	Goodness-of-fit
HCT	Haematocrit
HR	Hazard ratio
ICC	Intraclass correlation coefficient
IFAT	Indirect fluorescent antibody technique
IFN	Interferon
IgG	Immunoglobulin G
IgM	Immunoglobulin M
IPCC	Intergovernmental Panel on Climate Change
ITS	Internal transcribed spacer
kDa	Kilodalton
LAMP	Loop-mediated isothermal amplification

LIC	Livestock Improvement Corporation
LOQ	Limits of quantification
MHC	Major Histocompatibility Complex
MPI	Ministry for Primary Industries
MPSP	Major Piroplasm Surface Protein
MSD	Merck Sharp & Dohme
MTP	Minimum Training Presence
NAIT	National Animal Identification and Tracing scheme
NASA	National Aeronautics and Space Administration
NIWA	National Institute of Water and Atmospheric Research
NSW	New South Wales
NZ	New Zealand
NZTM	New Zealand Transverse Mercator
NZVP	New Zealand Veterinary Pathology
OR	Odds Ratio
PCR	Polymerase Chain Reaction
PCV	Packed Cell Volume
PI	Persistently infected
POC	Point of contact
PPV	Positive predictive value
QOD	Every other day
qPCR	Quantitative PCR
RBC	Red Blood Cell
RCP	Representative Concentration Pathways
RM	Regularisation multiplier
RNA	Ribonucleic acid
ROC	Receiver operating characteristic
RT-PCR	Real Time Polymerase Chain Reaction
SFTS	Severe Fever with Thrombocytopenia Syndrome
SMCO	s-methyl cysteine sulfoxide
SSU	Small-subunit ribosomal
TABA	<i>Theileria</i> Associated Bovine Anaemia
TNF	Tumour necrosis factor
UK	United Kingdom
USA	United States of America
WBC	White blood cell
WHP	Withhold period

Preface

The first cases of *Theileria* associated bovine anaemia (TABA) in New Zealand were diagnosed in August 2012 and in February 2013 I joined the Ministry for Primary Industries (MPI) for 12 months, whilst on leave without pay from Massey University. For the 12 months I was at MPI, I worked mostly on the TABA epidemic together with Andy McFadden and David Pulford and one of my roles was to help maintain the *Theileria* data base. The *Theileria* data base was continued until November 2014 and represents an almost unique record of a disease epidemic at a national scale. Included in the data base are the date and location of the outbreak, the age and stock class of the animals affected, the results of the molecular testing and the results of any disease investigations done through the private veterinary laboratories. After I returned to Massey University MPI kindly agreed to give me continued access to the *Theileria* data set, which forms the basis for much of the work presented in this thesis.

The introduction and literature review (Chapter One) provides basic details of the life cycle, epidemiology and clinical consequences of *Theileria orientalis* Ikeda type infection in cattle, with a detailed review of the diagnosis of oriental theileriosis in cattle and current recommendations for its control. The literature review was constantly updated, up until this thesis was completed in 2020, which means it post-dates some of the experimental work reported in this thesis – this will be explained in context as it is relevant. Although novel to New Zealand oriental theileriosis is well researched in Japan and Korea, where it had had been attributed to an organism known as *Theileria sergenti*. The emergence of oriental theileriosis in Australia pre-dated New Zealand by about 6 years. This literature review further will attempt to bring together the results of the Japanese and Korean studies, which are often only available in English as abstracts, and the more recent findings from the Australian and New Zealand epidemics.

Chapter 2 describes the epidemiology of the epidemic of bovine anaemia associated with *Theileria orientalis* Ikeda type in New Zealand between August 2012 and March 2014. This chapter describes how the epidemic unfolded from a Ministry for Primary Industries (MPI) perspective and shows that the disease is highly seasonal, that there are breed and age differences in susceptibility and that cases clustered both in time and space. This generated the hypothesis that disease spread was a combination of moving infected parasitaemic cattle between areas at a national level and the vectoring of infected ticks by wildlife at a local level.

A vertical transfer study to test the null hypothesis that *T. orientalis* Ikeda type is not vertically transmitted from dam to calf, across the placenta, in naturally infected New Zealand dairy cattle, was conducted in 2014 and presented in Chapter 3. No *T. orientalis* Ikeda type infected calves were born to either *T. orientalis* Ikeda type infected or uninfected dams and the study concluded that vertical trans-uterine transmission of *T. orientalis* Ikeda type infection is unlikely in chronically infected dairy cows and thus not a factor in the epidemiology of the spread of *T. orientalis* Ikeda type infection.

The results of an analysis of the haematology and biochemistry results from clinical cases of *Theileria* associated bovine anaemia are presented in Chapter 4. The analysis showed that haematology and biochemistry changes, associated with *T. orientalis* Ikeda type infection, were consistent with extravascular haemolytic anaemia being the main pathogenesis of disease and that adult dairy cows were much more likely to be severely anaemic (<0.15 HCT) when tested than calves less than 6 months old. Furthermore, adult dairy cattle were more likely to show anoxic liver damage and an inflammatory response to the anoxic damage than calves. The conclusions from this study were that calves appeared to be less likely to develop severe anaemia than adults and that deliberately exposing young cattle to *T. orientalis* Ikeda type infection could be a viable option for controlling disease in endemic unstable areas of New Zealand.

Chapter 5 describes the results of a cluster analysis of the 605 clinical histories of cattle affected with bovine anaemia associated with *T. orientalis* Ikeda type infection. The study found that the six most common words used in the clinical histories were jaundice (204/605), lethargic (162/605), pale mucous membranes (161/605), cow (151/605), anaemia (147/605), and off milk (115/605). The frequency of some history words was significantly different across age, farm type and anaemia status. Two distinct history word clusters were identified, the first was the average or usual clinical histories associated with acute TABA and the second was characterised by young, moderately anaemic or non-anaemic beef cattle showing ill thrift, diarrhoea and deaths.

The results of an analysis of the temporal and spatial effects of *T. orientalis* Ikeda type infection on the sample submission rates and haematocrits of infected cattle over the first two years of the New Zealand epidemic are presented in Chapter 6. The results showed that the sample submission rates by month and farm type were highly seasonal with dairy farm submissions peaking in September a month before beef farm submissions peaked. Infected beef animals

tended to be less severely affected than dairy animals and that the month of sampling and latitude of the sampled farm had significant and interacting effects on the level of anaemia associated with *T. orientalis* Ikeda type infection.

Chapter 7 describes the results of a maximum entropy ecological niche model to predict the relative environmental suitability for *T. orientalis* transmission within New Zealand, to predict the proportion of cattle farms potentially suitable for active *T. orientalis* infection by region, Island and the whole of New Zealand and to estimate the average relative environmental suitability per farm by region, island and the whole of New Zealand. The study showed that the potential spatial distribution of *T. orientalis* environmental suitability was much greater than presumed in the early part of the *Theileria* associated bovine anaemia (TABA) epidemic. The Maxent model predicted that 99% of North Island cattle farms (n=36,257), 64% South Island cattle farms (n=15,542) and 89% of New Zealand cattle farms overall (n= 51,799) could potentially be suitable for *T. orientalis* transmission.

Building on the work described in Chapter 7, Chapter 8 describes a study to predict the habitat suitability of New Zealand for the tick *H. longicornis* using a simple rule-based climate envelope model. The model was validated against published data and used to project an expansion in habitat suitability for *H. longicornis* under two alternative climate change scenarios for the periods 2046-2065 and 2081-2100, relative to the climate of 1981–2010. The *H. longicornis* climate envelope model predicted that 75% of cattle farms in the North Island, 3% of cattle farms in the South Island and 54% of cattle farms in New Zealand overall have habitats potentially suitable for the establishment of *H. longicornis*. Only for the following South Island regions, West Coast, Marlborough, Tasman, and Nelson, did the climate change scenarios project an increase in the proportion of cattle farms with low or high *H. longicornis* habitat suitability.

Chapter 9 describes a longitudinal study conducted on three dairy farms in three different tick risk areas of New Zealand. The study showed that the average infection intensity for prevalence cases, on all farms, was low throughout the milking season, <7,000 Ikeda organisms/μL, and remained relatively stable, despite concurrent disease or nutritional stresses. No effect of infection on reproduction was shown but on one farm, incidence cases produced 20kg less milk solids than prevalence cases over the lactation.

Chapter 10 summarises the results of a series of on-farm herd prevalence studies conducted by the Ministry for Primary Industries (MPI), as part of several epidemiological studies, in 2013.

The data were collected from March 2013 to September 2013 by myself and Andrew McFadden and comprised 26 farms. The prevalence studies showed that *T. orientalis* Ikeda type infection rates and anaemia rates, were already high in herds, 87% and 26% respectively, when the index case of TABA was first reported and that on average it took 80 days for the within herd prevalence of anaemia to return to zero after the initial diagnosis.

For each chapter my input was greatest. The preliminary ideas for some of the studies were a collaboration between several of the published authors but I devised the details of the research, undertook the fieldwork, usually with William Pomroy or Claire Lawrence, my wife, analysed the data and wrote the published manuscripts. For the vertical transmission study, Chapter 3, the blood sampling of dams and calves at birth was carried out by Gerard Lynch, farm owner, after instruction by me. The PCR work for the vertical transmission study and the studies which used the MPI *Theileria* data set were completed by David Pulford and Edna Gias, Animal Health Laboratory, Wallaceville, and Kristene Gedye, School of Veterinary Science, Massey University. The PCR work for the longitudinal study was completed by Kristene Gedye, School of Veterinary Science, Massey University, and myself. Kristene completed about 90% of the PCR work with me doing the rest. A declaration of authors' contribution to each paper is included at the conclusion of each chapter that reports a published paper. Further assistance such as statistical input or laboratory assistance is reported in the acknowledgements section of each chapter.

The two animal experiments described in this body of work, the vertical transmission study and the longitudinal study, were approved by the Massey University Animal Ethics Committee, Protocol 14/54, this is also documented within each respective chapter

Chapter 1

Literature Review

1.1 Introduction

Another country's diseases are like their famous people - of little interest until the day you find one taking a shower in your bathroom. So, it was with *T. orientalis* Ikeda type, a seemingly unimportant protozoal disease of Japan, Korea and East Asia, until it started killing cattle in New Zealand, in August 2012.

This literature review will focus on the haemoparasite *Theileria orientalis* and the Ikeda type. However, included in this review are many references to *Theileria sergenti*, which, prior to the development of the requisite molecular techniques, and necessary agreement on taxonomy, was described as a separate group and associated with infectious anaemia in Japanese and Korean cattle. Since the Japanese and Korean work describing *T. sergenti* constitutes almost the largest body of peer reviewed research available on *T. orientalis* it will be extensively referenced and will be considered as pertaining to a mixed *T. orientalis* infection, likely including the *T. orientalis* Ikeda and *T. orientalis* Chitose types.

1.2 Taxonomy of *Theileria orientalis*

Bovine *Theileria* species are tick-borne obligate, intracellular haemoprotozoan parasites that cause severe and mild infections in ruminants worldwide (Aktas et al. 2006; Eamens et al. 2013b). *Theileria orientalis* is one of six *Theileria* species known to affect cattle (Allsopp et al. 1993), but unlike other more pathogenic *Theileria* species, i.e. *T. annulata* and *T. parva*, it is non-lymphoproliferative (Kim et al. 2017) and is the only *Theileria* species present in New Zealand (Watts et al. 2016). Other types of *T. orientalis* can also infect yaks and buffaloes, which may be an important factor in the epidemiology of benign theileriosis in some countries (Sivakumar et al. 2014; Uilenberg et al. 1985). *Theileria orientalis* Ikeda type is a type of the *T. orientalis* group, causing what is sometimes referred to as benign or oriental theileriosis. The *T. orientalis* group are widely disseminated globally due to the worldwide presence of suitable tick vectors in the genus *Haemaphysalis*.

Theileria belong to the phylum Apicomplexa and as with other organisms in this phylum share a common characteristic of having an apical complex which contains secretory organelles, rhoptries/microspheres, considered to be involved in cell invasion or attachment and establishment of the parasite in the mammalian or invertebrate host (Bishop et al. 2004).

Agreement about the taxonomy of *T. orientalis* group or clade is still uncertain and until recently it was usually referred to as the *T. sergenti/buffeli/orientalis* group, in that way satisfying all schools of thought. However unacceptable this may seem in hindsight, the confusion was almost inevitable given that the different members of the *T. sergenti/buffeli/orientalis* group had almost unique geographic

origins; *T. sergenti* from Japan and Korea, *T. buffeli* from Australia and *T. orientalis* from Great Britain (Fujisaki, 1992; Chae et al. 1999a; Jeong et al. 2010; Kawazu et al. 1992a) and seemingly unique clinical presentations. Adding extra layers of confusion were the discoveries that *T. sergenti* was in fact a mixed infection of Ikeda and Chitose types (Matsuba et al. 1993a; Onuma et al. 1997) and that *T. sergenti* had previously been used to name a *Theileria* species in sheep. The latter discovery subsequently made *T. sergenti* ineligible for use as the group name (Morel and Uilenberg 1981; Fujisaki et al. 1994).

Since then, morphological, vector specificity, pathogenicity and molecular studies, using the 18S small subunit ribosomal RNA or the major piroplasm surface protein (MPSP) sequences, have shown that these three groups are from the same species (Uilenberg et al. 1977; Uilenberg et al. 1985; Gubbels et al. 2000; Jeong et al. 2010) and so legitimately only one name should apply. Subsequently the most widely adopted species name, at this point in time, is *T. orientalis* (Kawazu et al. 1999; McFadden et al., 2011; Watts et al. 2016) and despite almost universal uptake it must be acknowledged that under the strict rules of taxonomy, in which the oldest allocated name should take precedence, *T. buffeli* which was first described in 1908 predates *T. orientalis* which was first described in 1931 (Fujisaki, 1992; Morel and Uilenberg, 1981) and should, in fact, be the correct species name! For an excellent and comprehensive summary of the confusion around and chronology of *T. orientalis/buffeli/sergenti* classification see Table 2 from the master's thesis of Cufos (2012b).

It is highly likely that this confusion will continue now that the draft sequence of the *T. orientalis* Ikeda, Chitose and Buffeli genomes has shown that these types are more dissimilar than was previously thought. The average nucleotide identity (ANI) between Ikeda and Chitose (82.5%) or between Ikeda and Buffeli (82.5%) are as low as between *T. annulata* and *T. parva* (79.6%), whereas Chitose and Buffeli are slightly more like each other (86.2%) (Bogema et al. 2018). These findings could possibly support different species classifications for the Ikeda, Chitose and Buffeli types.

The major piroplasm surface protein (MPSP) gene is abundantly expressed in the merozoite (piroplasm) stage (Kawazu et al. 1992b, 1992c; Shiels et al. 1995) and sporozoite stage (Sako et al. 1999). It is a 32 kDa glycoprotein (Matsuba et al. 1993a, 1995) and plays an important role in the host immune response to infection (Jeong et al. 2010; Zhuang et al. 1994). It is also highly diverse between types and sequencing of the MPSP gene has identified 11 *T. orientalis* types (Khukhuu et al. 2011), namely, Type 1 (Chitose), Type 2 (Ikeda), Type 3 (Buffeli), Types 4–8 and Types N1–N3 (Khukhuu et al., 2011; Kamau et al., 2011b; Cufos et al., 2012a; Watts et al., 2016; Hammer et al., 2015). Alternatively sequencing of the 18S small subunit ribosomal RNA (18s rRNA) gene has identified at least 8 types, A, B, B1, C, D, E, H, and *T. buffeli* (Warwick) (Gubbels et al. 2000). Correlation between the two molecular methods appears reasonable (Gubbels et al. 2000), with type A corresponding to Chitose and types B and E to Ikeda (Yam et al. 2018). However, the phylogenetic

tree based on the MPSP gene seems to be the more widely accepted and concerns that the 18s rRNA gene is insufficiently diverse has led to the suggestion that the 28s rRNA gene may perform better for phylogenetic analysis (Gou et al. 2013).

As mentioned earlier the erroneously named *T. sergenti* has been proven to be an undifferentiated mixed infection of *T. orientalis* Chitose type and *T. orientalis* Ikeda type (Kubota et al. 1995, 1996a; Matsuba et al. 1992, 1993a; Onuma et al. 1998) so had this name not previously been used for a sheep *Theileria* species it may still not have survived this molecular bigamy. Further subdivisions of this group are inevitable e.g. there now appears to be good evidence, both phylogenetic and pathogenic, that the Chitose type may contain two separate types Chitose A and Chitose B (Jenkins et al. 2015).

1.3 Life cycle and basic biology of *Theileria orientalis*

Theileria orientalis has a heteroxenous life cycle, as illustrated in Figure 1-1, although many details of the life cycle remain vague. The following account of the life cycle is largely taken from reports on the genotype *T. sergenti* (Higuchi, 1985, 1986, 1987; Higuchi et al. 1987; Sato et al. 1993, 1994) and to what extent they apply to all genotypes remains to be confirmed. There are two infectious stages of *T. orientalis*; sporozoites and merozoites. The sporozoites are infectious to cattle and the merozoites (also referred to as piroplasms) are infectious to ticks, with the sporozoites being released in the saliva of infected tick vectors when feeding and the merozoites being found in the ingested erythrocytes imbibed from infected cattle. The lifecycle of the *T. orientalis* is exquisitely synchronised with that of the tick host and has likely evolved to compensate for non-transovarian infection transmission (Higuchi, 1985).

The lifecycle also demonstrates tremendous efficiency and conservation of energy, with zygotes only transforming into kinetes once the tick has moulted and the process of sporogony and the release of sporozoites only beginning once the tick commences feeding. It is not known whether sporozoites are released if a tick feeds on a non-bovine host, but it would seem unlikely that this extra level of sophistication should exist.

1.3.1 *Merozoites and sporozoites*

Within 24 hours of ingestion, merozoites are released from the digested RBC in the tick mid-gut. *T. sergenti* merozoites are small, round, comma-shaped or spindle-shaped and measure 1.0-2.5µm (Higuchi, 1987). Following a further 24-48 hours micro and macrogametes have developed and at 3-5 days post-feeding, after fusion, zygotes measuring 5.0µm are seen. By 9 days post-feeding the zygotes are found in the epithelial cells of the gut. The zygote is the only diploid phase of the entire

Theileria life cycle, it then undergoes meiotic division and differentiates into a motile haploid kinete. Just after the tick moults the kinete escapes the epithelial cells of the gut, enters the tick's haemolymph and eventually invades the acinar cells of the salivary gland where it develops into an infectious sporozoite (Heath, 2013b; Takahashi et al. 1993), a process known as sporogony. Kinetes are first detected in the haemolymph 25 days after engorgement, reaching a maximum number at 32 days and almost completely disappearing by 44 days post engorgement (Higuchi et al. 1987).

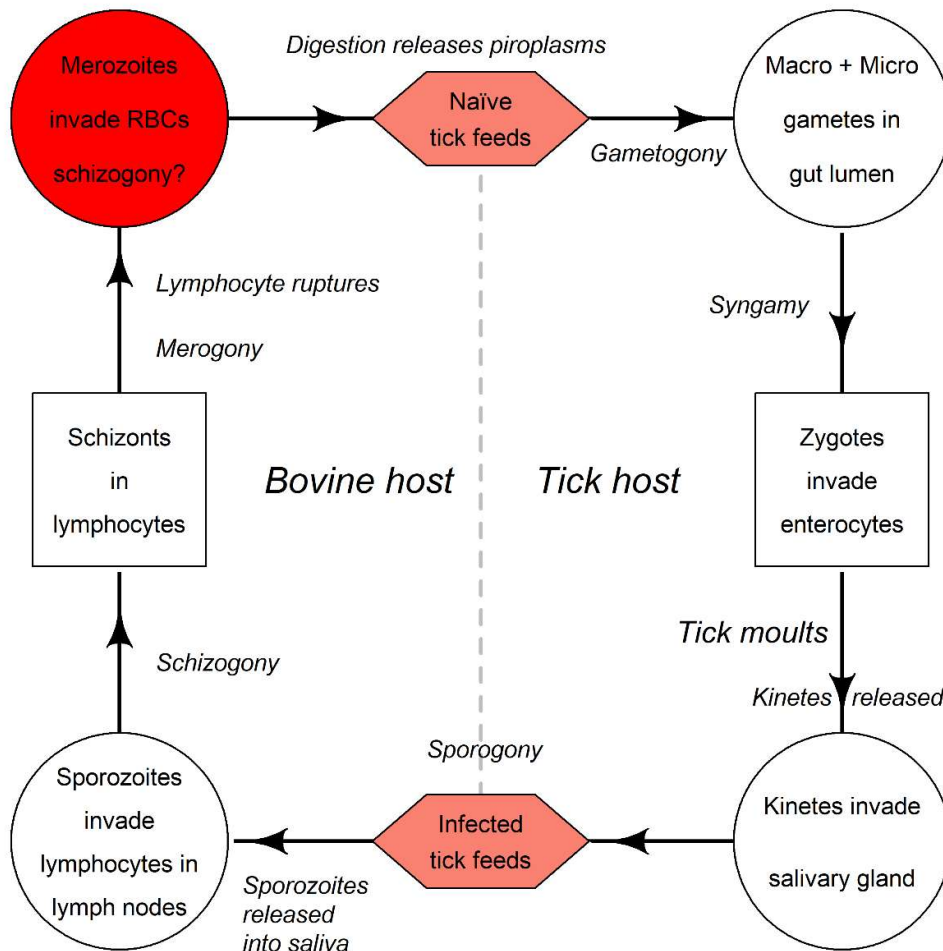


Figure 1-1. The life cycle of *Theileria orientalis* (adapted from Shaw, 2002)

Ixodid ticks have several different acini types, I to IV, and each acinar type contains a variety of secretory cells, nominally labelled 'a-h'. Evidence from *T. parvum* shows that the kinetes from this species selectively invade Type 'e' secretory cells within Type III acinar cells (Shaw and Young,

1995). Although, yet not researched it is likely that *T. orientalis* kinetes have a similar specificity for acinar types and secretory cells.

Sporogony is the only multiplicative stage completed within the tick and results in large numbers of sporozoites being produced per acinar cell, in the range of 30,000 to 140,000 sporozoites per acinar cell for other *Theileria* species (Bishop et al. 2004). Higuchi (1986) observed in *T. sergenti* three stages of sporoblast development i.e. primary, secondary and tertiary sporoblasts, before finally evolving into sporozoites in the acinar glands. Maximum sporozoite production occurs 3 to 4 days post commencement of tick feeding. The trigger for the transformation of the zygote into the kinete appears to be tick moulting and involves a process of invagination (Fujisaki et al. 1993) whereas the trigger for sporogony is the onset of tick feeding.

A period of exposure to 20°C to 25°C temperature for the recently moulted tick, for at least 10 days in nymphs, is required for the sporoblasts to be sufficiently developed for sporogony to proceed (Fujisaki and Kamio, 1988). Longer periods of exposure to 20°C to 25°C leads to higher acinar infection rates, reaching a maximum infection rate around 175 days post engorgement (Sasaki et al. 1990). This probably explains the great variability in infection rates of ticks and tick salivary glands from field collected ticks reported by Kamio et al. (1990).

1.3.2 *Schizogony*

Sporozoites are injected into the host with saliva, when the infected tick feeds. They invade host lymphocytes, probably in the proximal lymph node draining the area of tick attachment, forming multinucleated syncytial schizonts (Minami et al. 1990; Kawazu et al. 1991; Sato et al. 1993, 1994; Lee et al. 1997). Sporozoites rapidly bind and enter lymphocytes through a passive “zippering process” in which the sporozoite folds into the lymphocyte (Shaw, 1997, 2003). Once internalised, discharges from the secretory organelles facilitate the escape of the sporozoite from the host membrane that still surrounds it (Nene et al. 2016; Shaw, 2003). Schizonts can be found in the local lymph nodes between 4 and 8 days after infection, taking 3 days to form and disappearing by days 9 and 10 (Hagiwara et al. 1997a).

The host lymphocytes enlarge to 250µm after invasion and three schizont developmental stages have been observed, young schizont, macroschizont and microschizont, at 4-, 6- and 8-days post-infection respectively (Sato et al, 1994). The microschizonts are about 5µm and correspond to merozoite formation, displaying a rosette-like appearance ((Sato et al, 1994). The host lymphocyte is destroyed when the merozoites are released. The observation that different stages of shizogony can occur in the same host cell supports the idea that more than one sporozoite could infect the same cell ((Sato et al. 1994).

The key difference between the transforming and non-transforming *Theileria* species occurs at this stage, whereas *T. parva* and *T. annulata* invade circulating lymphocytes and causes the production of eternal cells, *T. orientalis* appears to mostly invade lymphocytes in the regional lymph node and not produce eternal cells (Jenkins, 2018). This leads to a major contrast in the disease pathogenesis with the piroplasm (merozoite) phase in *T. orientalis* being responsible for anaemia and the schizont phase in the transforming *Theileria* being responsible for the lethal cancer-like state of the lymphocytes (Jenkins, 2018). The macroschizonts observed in circulating lymphocytes associated with infection by the transforming *Theileria* species are referred to as Koch's blue bodies (Meyer, 1911) and although *T. orientalis* schizonts have also been observed in circulating peripheral lymphocytes (Kang and Choi, 1997) and transiently in the spleen and liver (Sato et al. 1993), as far as can be ascertained, they have never been referred to as Koch's blue bodies.

Since it is possible to transmit infection by blood transfusion it seems logical that some circulating leucocytes do carry schizonts. Kang and Choi (1997) suggested an alternative explanation for experimental transmission of infection by transfusion, whereby some merozoites released from ruptured RBCs retain the ability to invade lymphocytes and revert to schizonts. Alternatively, Kawamoto et al. (1990b) suggested that piroplasms could multiply in the peripheral blood stream in the absence of schizonts through directly invading erythrocytes themselves.

One ongoing area of conjecture regarding the *T. orientalis* lifecycle is whether the schizont stage is only exoerythrocytic and not erythrocytic as well. Since a schizont stage in RBC has been described (Kawamoto et al. 1990a), in which 4 daughter merozoites were observed to develop from the invading merozoite, the schizont stage is likely to be both exoerythrocytic and erythrocytic. Binary fission has also been seen (Baek et al. 1990) and prior to schizogony or binary fission the merozoite first developed into a structure resembling a trophozoite (Kawamoto et al. 1990a). Entry of *T. orientalis* merozoites into RBCs is facilitated through binding of the MPSP to heparin-like structures on the surface of the erythrocyte wall (Takemae et al. 2014) and it has been shown that heparin and Sulfated carboxymethylchitin III competitively inhibits the invasion of host RBCs by *T. orientalis* merozoites (Hagiwara et al. 1997b; Hagiwara et al. 1999).

The lack of significant haemoglobinuria associated with *T. orientalis* infection (Yagi et al. 1989; Shimizu et al. 1990) would suggest that there is not excessive intravascular RBC destruction which means that schizogony either arrests at 2 or 4 daughters and doesn't burst the RBCs or is so slow that the release of haemoglobin from ruptured RBCs does not exceed the capacity of the liver hepatocytes to remove it from the circulation or the renal threshold for excretion. The slow turnover explanation is likely since the rate of RBC invasion by merozoites is estimated to be low, between 0.2 and 0.8% (Kawamoto et al. 1990b) and even at peak parasitaemia, in 10 experimentally infected Friesian bulls, only 1.2% of RBCs were on average infected (Lawrence et al. 2018b).

Different intra-erythrocytic *T. orientalis* structures have been observed on blood smears, bars (aka rods), rings and veils (Sugimoto and Fujisaki, 2002; Takao et al. 1983). The bar structure is thought to represent a resting stage before division of the merozoite (Kawai et al. 1989) and the veils are formed by intra-erythrocytic precipitation of haemoglobin and other proteins excreted by the parasites (Sugimoto et al. 1992). There seem to be few, if any, reports in the literature of piroplasms being seen in the state of either binary division or schizogony.

1.4 Distribution of *Theileria orientalis* in world

The following countries have published reports of *T. orientalis* Ikeda type. They include Australia (Kamau et al. 2011a); Brazil (Sivakumar et al. 2014); China (Kakuda et al. 1998); Egypt (Elsify et al., 2015); India (Kakati et al. 2015); Japan (Ota et al. 2009); Korea (Park et al. 2017); New Caledonia (C. Jenkins pers. com.); New Zealand (Pulford et al. 2016a); Pakistan (Gebrekidan et al. 2017a); Philippines (Ochirkhuu et al. 2015); USA (Oakes et al. 2019); Vietnam (Gebrekidan et al. 2017c). Whereas the following countries have published reports of non-Ikeda or undifferentiated *T. orientalis* types, Algeria (Ziam and Benaouf, 2003); Burundi (Kiltz et al. 1986); Cambodia (Inoue et al. 2001); Ethiopia (Gebrekidan et al. 2014, 2016); France (L'Hostis and Seegers, 2002); Germany; Greece (Papadopoulos et al. 1996); Hungary (Hornok et al. 2015); Indonesia (Java, Sumatra) (Govaerts et al. 2002; Payne et al. 1988); Iran (Ghaemi et al. 2012); Italy (Savini et al. 1998); Kenya (Ngumi et al. 1994); Malaysia (Kho et al., 2017); Mongolia (Altangerel et al., 2011a); Myanmar (Bawm et al., 2014); Portugal (Brigido et al. 2004); Romania (Ionita et al. 2013); Russia (Yakimoff and Dekhteref, 1930); Spain (Gimenez et al. 2009); Sri Lanka (Sivakumar et al. 2013); Tanzania (Fyumagwa et al. 2011); Switzerland (Riond et al. 2008); Taiwan (Wang et al. 1998); Thailand (Altangerel et al. 2011b); Tunisia (M'ghirbi et al. 2008); Turkey (Zhou et al. 2016); Uganda (Oura et al. 2011); UK (Uilenberg et al. 1985).

Figure 1-2 shows the worldwide distribution of *T. orientalis* types at the end of 2019. It is important to note that any dark blue country potentially has the necessary tick infrastructure to support Ikeda type infection should it gain entry. No information was found on the infected status of Bangladesh, Nepal and Bhutan, but given their proximity to Ikeda positive countries they are likely to be also Ikeda positive. Similarly, no information was available for Laos, but this country shares borders with both Ikeda and non-Ikeda positive countries so it is likely to be at least *T. orientalis* positive.

The distribution of *T. orientalis* non-Ikeda types is worldwide and more than likely cattle domiciled in countries with a suitable tick vector from the *Haemaphysalis* genus would test positive if investigated. Such is the lack of pathogenicity associated with the *T. orientalis* non-Ikeda types that many other countries will probably be unaware that their cattle already carry this haemoparasite,

especially if they have other more pathogenic haemoparasites such as *Babesia*, *Anaplasma* or *T. annulata*. A specific relationship between the Ikeda type and *H. longicornis* undoubtedly does exist, as evidenced by the 3 confirmed outbreaks of TABA in Virginia, USA in 2017 (Oakes et al. 2019), which have only occurred since the successful invasion of *H. longicornis* into the USA (Rainey et al. 2018).

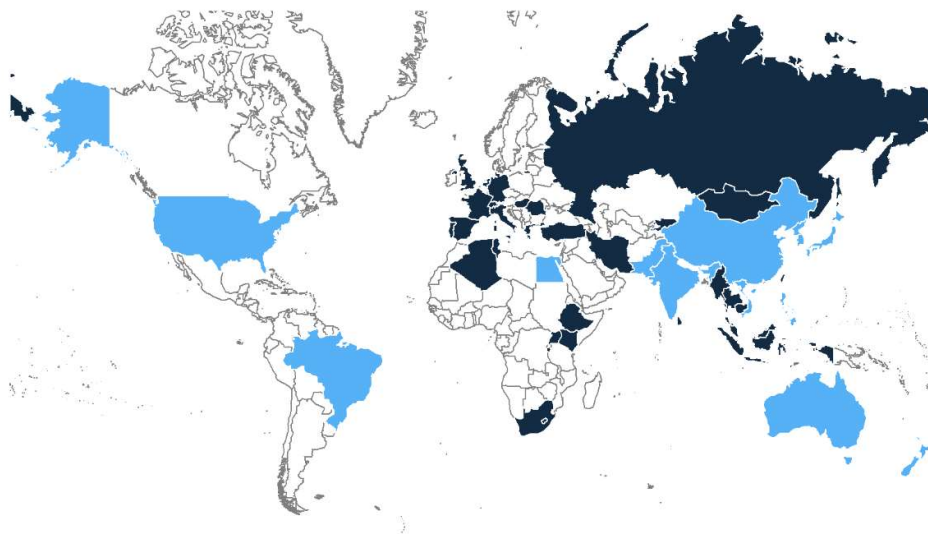


Figure 1-2. Worldwide distribution of *Theileria orientalis* types at end of 2019, in light blue are countries with published reports of *T. orientalis* Ikeda type infection in cattle and in dark blue are countries with published reports of non-Ikeda or undifferentiated *T. orientalis* types

1.5 Species specificity

In general, most apicomplexan parasites are highly species and tissue specific. The same assumption was initially made regarding *T. orientalis* until overseas researchers identified sheep as latent carriers of some *T. orientalis* types, Type 3 (Uilenberg et al. 1985), Type C (Cao et al. 2013) and Type N-1 (Khukhuu et al. 2011). It is possible that New Zealand sheep could also maintain a very low latent infection of *T. orientalis* Ikeda type, if so, this may have played an important role in the rapid spread of the epidemic through North Island, New Zealand. In contrast cross infection between deer and cattle for *T. orientalis* types has not been shown (Shibata et al. 2018).

1.6 New Zealand and Australian epidemics

The New Zealand epidemic began in 2012 with the index cases identified on a dairy farm in Reporoa on the 30th August (Pulford et al. 2016a). The epidemic was initially mostly restricted to beef farms in Northland but by the autumn of 2013 had spread to autumn calving dairy herds in the Waikato, when infected pregnant dairy cows returned from summer grazing in Northland, and by spring of 2013 had spread over most of the upper North Island. It is likely that the live importation of infected cattle from Australia, prior to 2012, was responsible for the introduction of the Ikeda type into New Zealand. Before the emergence of *T. orientalis* Ikeda type in 2012 it was believed that New Zealand cattle were only parasitised by the more benign *T. orientalis* types, Chitose and Buffeli, with just sporadic disease outbreaks reported (James et al. 1984; Rawdon et al. 2006; McFadden et al. 2011). The Australian epidemic was first recognised in New South Wales (NSW) in November 2006 (Izzo et al. 2010) and up until 2008 was largely restricted to this state (Biddle et al. 2013; Eamens et al. 2013a; Proctor et al. 2016). Early disease outbreaks in NSW often involved cattle that had been moved from the dry interior to coastal areas (Izzo et al. 2010), although later the disease then followed the return movement of infected coastal cattle to the interior (Watts et al. 2016). As the epidemic progressed, infection spread up the coast to lower Queensland (Kamau et al. 2011a) and by March 2011 into Victoria, following the movement of infected cattle from NSW in November 2010 (Islam et al. 2011; Perera et al. 2013). The movement of infected cattle from NSW was also linked to the first cases of oriental theileriosis in South Australia in October 2014 (Gebrekidan et al. 2015). Cases were first reported in Western Australia in 2013 (Anonymous, 2014), likely through infected cattle movements but specific details are not recorded.

Although solid evidence is lacking, it is likely that the introduction of the Ikeda type into Australia followed the live importation of potentially infected Wagyu cattle from Japan via America, there being no protocol to import cattle directly from Japan. In 1997, the first live imports of five Wagyu cattle into Australia from the USA occurred and these were followed in 1999 by a further 40 Wagyu females and 9 bulls (Ribs & Burgers, 2019). Some of these were Japan born and registered females, exported to America from Japan in 1993 and 1996, and some were full blood progeny of these same cattle, born in the USA (Austpec Pastoral, 2019). A further consignment of sixteen Wagyu bulls and three Wagyu heifers were exported from the USA to Australia in October 2002 (Wagyu International, 2013).

Overall 173 Wagyu cattle were imported into America from Japan between 1993 and 1997, prior to Japan's ban on exports of Wagyu cattle in 1997 (Beyond Beef, 2019) and it has to be presumed that many of these cattle were chronically infected with *T. orientalis* at the time of import. These cattle and any descendants from natural births could constitute a serious and ongoing risk of TABA to cattle

on the same properties and on contiguous properties should a competent tick vector be present on these properties.

Given that *T. orientalis* infection is lifelong and Australia has a capable tick vector, then there can be no surprise that Ikeda outbreaks followed the importation of Japanese born Wagyu cattle into Australia, it is only surprising that it took until 2006 to see the first cases. Clinical disease outbreaks of oriental theileriosis in Pakistan (Gebrekidan et al. 2017a) and Vietnam (Gebrekidan et al. 2017c) have similarly followed the live export of infected cattle from Australia. These latter outbreaks rapidly followed the importation of stressed infected cattle.

1.7 The clinical outcomes of *Theileria orientalis* Ikeda type infection in cattle

Despite the higher pathogenicity of *T. orientalis* Ikeda type most New Zealand farms affected in the Ikeda epidemic have recorded relatively low mortality and morbidity rates, the medians being 0.23% and 0.97% respectively (Vink et al. 2016). However, in a small number of farms these rates are much higher, up to 5% and 30% respectively, often for no readily discernible reason (McFadden et al. 2013). The morbidity rates reported for *T. sergenti* in Japanese cattle are similar with 0.24% of adult dairy cattle and 1.1% of sucking beef calves affected (Shimizu et al. 1992). The morbidity and mortality rates reported from Australia are mostly from case studies and not survey based but do appear to be much higher than those reported in New Zealand or Japan (Izzo et al. 2010; Eamens et al. 2013b). These higher morbidity and mortality rates in Australia may reflect higher levels of stress, poorer nutrition or concurrent infections with other haemoparasites such as *Anaplasma* and *Babesia*. Cattle affected with *T. orientalis* Ikeda type usually show a combination of the following clinical signs; anaemia, lethargy, production drop, anorexia, ill-thrift, diarrhoea, constipation, jaundice, collapse, pale udders, possible haemoglobinuria, abortion and inappetance (Islam et al. 2011; Cufos et al. 2012a; Lawrence et al. 2013). Post-mortem examination usually shows a massively enlarged “raspberry jam” spleen (the spleen removes parasitized RBCs from circulation) and a bronze coloured liver with generalised jaundice (Izzo et al. 2010; Gebrekidan et al. 2017c).

In a summary of the clinical findings from 101 cases in the 1982–1986 *T. orientalis* epidemic (James et al. 1984), the two most common presenting signs were ill-thrift (29/101) and diarrhoea (23/101); it is noteworthy that anaemia and jaundice were not commonly reported in that epidemic (Thompson, 1991). The 1982–1986 epidemic was likely associated with the Chitose type and the agreement between two different *T. orientalis* types, Ikeda and Chitose, may lend some support to the supposition that the pathological effects of *T. orientalis* infection are not just limited to extravascular haemolytic anaemia, and in the absence of anaemia, the Ikeda and Chitose types can potentially produce similar disease syndromes of ill-thrift and diarrhoea.

In a review of eight herd outbreaks of TABA in Australia, with clinical signs recorded at the herd level, the most common presenting complaints were inappetence (8/8 farms) and lethargy (8/8 farms) and the most common clinical signs were icterus and pale mucous membranes (8/8 farms) (Izzo et al. 2010). Overall the outbreaks of *T. orientalis* on Australian farms often involved introduced cattle, with disease commonly presenting in the periparturient period, and stillbirth, abortion or death being frequently reported (Izzo et al. 2010; Perera et al. 2013).

Observations on both experimentally and naturally infected cattle agree that pyrexia is usually seen when piroplasms first appear in the peripheral circulation around day 10 (Uilenberg et al. 1985; Shimizu et al. 1990). However, a second temperature spike, after 25–30 days, was only reported in splenectomised calves (Shimizu et al. 1990). Pyrexia is not a consistent finding in cases of TABA. Late term abortion and cow deaths were a much more frequent finding in the Australian epidemic (Izzo et al. 2010; Perera et al. 2013) than the New Zealand one (MPI, data on file). Perera et al. (2013) reported that 10/19 (53%) farms surveyed had abortions and 14/19 (74%) farms had cow deaths.

1.8 Haematology and biochemical changes associated with infection

Reports of the changes in haematology and biochemistry specifically associated with infection by *T. orientalis*, in contrast to *T. annulata* and *T. parva*, are limited and often based on either small sample numbers, samples from just one herd or samples from cattle infected by multiple pathogens. The usual haematological changes reported are macrocytic, hypochromic, regenerative anaemia that results in pre-hepatic hyperbilirubinaemia, with associated jaundice, and hypoxic liver damage, with associated leakage of liver function enzymes (Haron et al. 2015; Izzo et al. 2010; Riond et al. 2008). There are no reports as to whether the haematology and biochemistry changes are similar for young and mature cattle.

1.8.1 Pathogenesis of anaemia

The exact pathogenesis of the anaemia resulting from *T. orientalis* infection remains uncertain. Abnormal morphology and increased erythrocyte osmotic fragility (Yagi et al. 1989); oxidative damage and lipid peroxidation of erythrocytes (Shiono et al. 2003b; Yagi et al. 2002); and decreased survival of erythrocytes, irrespective of their true parasitised status (Yagi et al. 1991) are all considered to have important roles. The latter finding also suggests that the removal of RBCs in the liver and spleen by the host's immune system is excessive and non-specific. Although the destruction of erythrocytes appears to be non-specific and independent of antibody and complement levels

(Hagiwara et al. 1995), increases in IgG-bound RBC coinciding with the development of anaemia and the peak in parasitaemia have been observed (Shiono et al. 2004).

The resulting anaemia has been reported to be accompanied by methaemoglobinaemia and by increased erythrocyte malondialdehyde concentration. Both these changes are indicative of oxidative damage to the erythrocytes and are probably caused by the host's own phagocytes (Shiono et al. 2001, 2003a). Intravascular haemolysis of peripheral blood is not considered to be a feature of *Theileria* infection (Yagi et al. 1989; Shiono et al. 2001). Although it is suggested that repeated rounds of erythrocyte invasion by merozoites and their intra-erythrocyte multiplication, with resulting destruction of RBC, does occur (Shaw, 2002), the clinical pathology and clinical history results would dispute this suggestion. In conclusion splenic capture rather than RBC lysis is the probable cause of the anaemia seen in oriental theileriosis (Yam et al. 2018).

1.8.2 *Pathogenesis of anorexia, ill-thrift and live weight changes*

Live weight effects associated with *T. orientalis* infection have only rarely been reported or quantified (Fukasawa et al. 2003; Kawamoto et al. 1991; Lawrence et al. 2018b, 2019). However, they can be inferred from an Australian study in which 8/8 (100%) infected farms reported that the cows were suffering from “inappetence” (Izzo et al. 2010). When live weight effects have been reported it is said that they occur in the convalescence period (Kawamoto et al. 1991), although what was meant by the convalescence period was not clearly defined.

Minami et al. (1980) reported that anorexia was observed in parallel with increases in parasitaemia rates for *T. sergenti* infection. A possible explanation for this observation is the acute phase response (APR). The APR is an innate non-specific immunological response to infection which results in the release of pro-inflammatory cytokines (Gruys et al. 2005). In cattle infected with *Theileria annulata* the cytokines TNF- α , IL-1 β , IL-6 and IL-12 are released by macrophages at the site of infection and are responsible for the clinical signs of pyrexia, anorexia, and inappetence (El-Sebaei et al. 2014). It is likely a similar release of pro-inflammatory cytokines with *T. orientalis* Ikeda type infection also results in anorexia. Growth hormone and insulin-like growth factor levels were also observed to decrease with anaemia due to theileriosis (Baek et al. 1997a), which could further explain some of the live weight effects seen with acute *T. sergenti* infection.

One conclusion that can be drawn from the observation made by Minami et al. (1980), that anorexia parallels parasitaemia, is that HCT cannot be causally associated with live weight, since HCT changes also track the same increases in infection intensity as anorexia.

1.9 Disease outbreak management

To assist in the rapid assessment of individuals in a herd outbreak of *T. orientalis* Ikeda type the FANI (Field Anaemia Nearest Indicator) card was developed by MPI in 2013, in which colour charts are used to assess the level of anaemia in individual animals, based on examining the mucous membrane of the vulva (Vink et al. 2013). The FANI card has four colour categories, which span the range from healthy to severely anaemic animals, and a fifth category differentiating anaemia due to blood loss, Fig. 1-3. This system was designed to provide enough representation of the full range of disease signs but be simple enough to facilitate classification. It enables a cow-side interpretation and decision to be made based on each observation (Vink et al. 2013). Animals with a PCV below 0.12 will likely die without a blood transfusion. During the New Zealand TABA epidemic thousands of blood transfusions were given by veterinarians, for a full description of how to perform a bovine blood transfusion see Vink et al. (2013) and Briggs (2014).

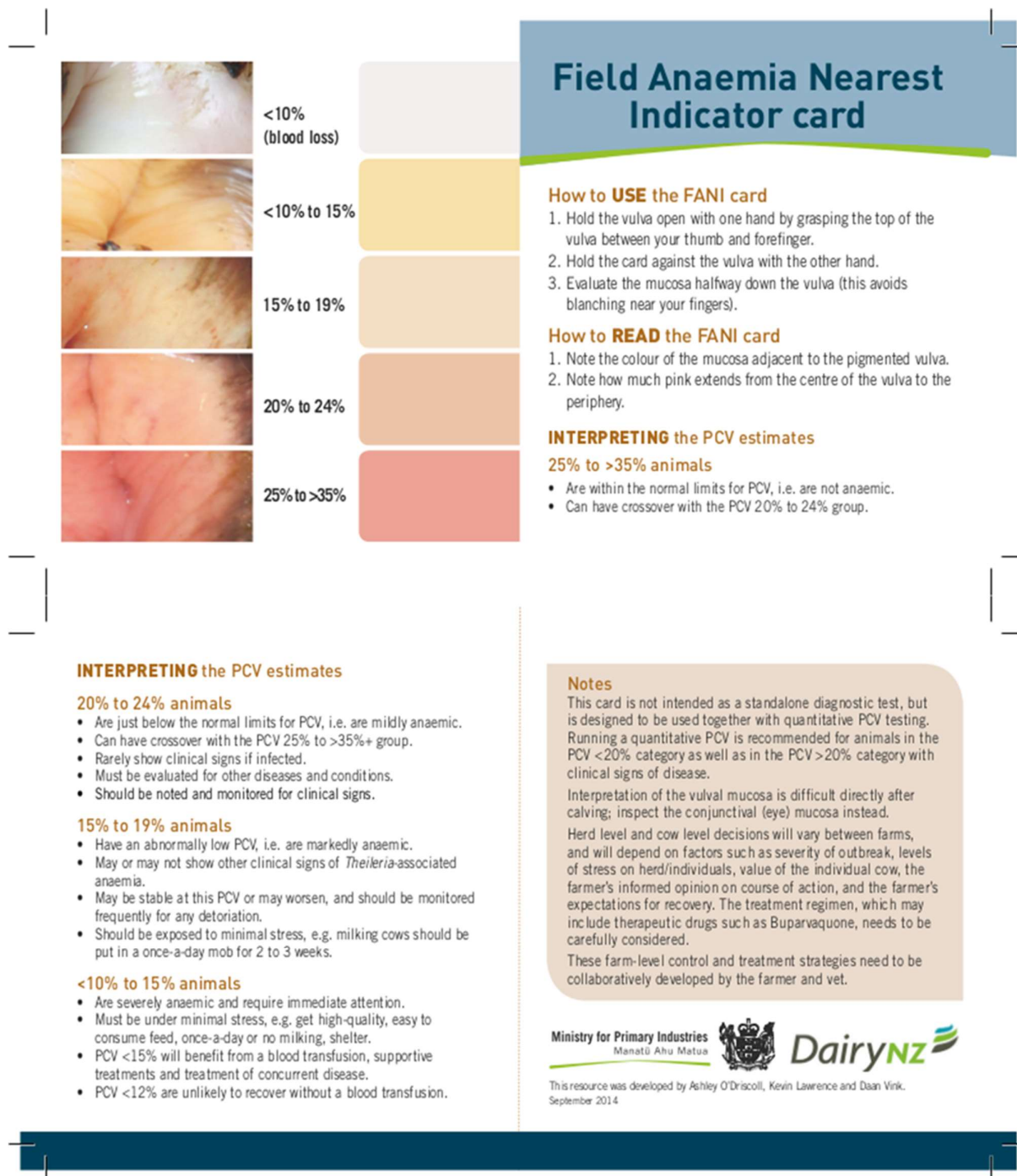


Figure 1-3. The FANI card (version September 2014)

1.10 Pattern of infection

In high tick-risk areas, where TABA is endemic (as in parts of Australia and North Island, New Zealand) and where cattle calve at pasture, then newborn beef calves will be 100% infected soon after birth (Swilks et al. 2017b, Lawrence et al. 2019). Dairy calves that are collected soon after birth and

housed for the first 3 to 8 weeks, are likely to escape immediate infection but will become rapidly infected once turned out to pasture in endemic disease areas (R. Hickson, data on file).

In infected countries where cattle are housed over winter and calve indoors, e.g. Korea and Japan, the pattern of infection will be different again. This is because the cattle will be older when turned out to graze in the summer and the timing of turn-out may not be synchronous with the questing behaviour of infected ticks. Choi et al. (2016) found that 60% of yearling cattle were *T. orientalis* positive after grazing mountainous Korean pasture from spring to fall whereas Fukasawa et al. (2001) found 100% of winter-born calves were infected by 2 months when turned out to graze from late May in Naruko, Japan. Over the whole grazing season Masatani et al. (2016) observed that parasitaemia peaked in late summer and that there was temporal switching between the dominant types of *T. orientalis*. The Chitose type being more prevalent in the winter months than the Ikeda type.

1.11 Transmission of *Theileria orientalis* infection to cattle

1.11.1 *Horizontal transmission*

Horizontal spread of *T. orientalis* infection between cattle in New Zealand is through the arthropod vector *Haemaphysalis longicornis* Neumann (Acari: Ixodidae) (Heath, 2016; Watts et al. 2013). *Haemaphysalis longicornis* is native to Japan, China, Primorsky Krai region of eastern Russia, and Korea; and is well-established as an invasive species in Australia, New Zealand, and on several Pacific Islands (Hoogstraal et al. 1968). It is regionally referred to as the East Asian long-horned tick, the bush tick (Australia), and the cattle tick (New Zealand) and has recently invaded and established in the USA (Rainey et al., 2018).

The species *H. longicornis* is comprised of parthenogenetic and bisexual populations (Oliver and Herrin, 1976). However, only the triploid parthenogenetic species is present in New Zealand and Australia whereas both populations are found in parts of China and Japan (Chen et al. 2014). The bisexual species has 21 or 22 chromosomes and the triploid species has 30 to 35 (Chen et al. 2014). The triploid species demonstrates thelytokous parthenogenesis in which females are produced from unfertilized eggs (Hongfu et al. 1989), there being no males produced. Phenotypic differences are also reported, the triploid female is both significantly heavier (Chen et al. 2012) and larger (Oliver and Herrin, 1976).

H. longicornis is a species of hard tick (Ixodidae), the only one that infests livestock in New Zealand and is the only competent vector for *T. orientalis* in New Zealand (Heath, 2016). *T. orientalis* infected ticks release parasitic sporozoites into the blood stream of cattle when taking a blood meal and uninfected ticks become infected through ingesting merozoites when feeding on parasitaemic cattle.

Although it is not known for certain, it is believed that very few infected ticks are required to infect an individual cow with *T. orientalis*, possibly only one, and infection of cattle is lifelong (Onuma et al. 1998; Sugimoto and Fujisaki, 2002).

Ticks have four stages in their life cycle; egg, six-legged larva, eight-legged nymph, and eight-legged adult and are hematophagous during all the active life stages. *H. longicornis* is a three-host tick, requiring a new host for each of the active stages (Heath 2016). It is widespread in the North Island, occurring as far south as Waikanae in the west and the Wairarapa in the east and is also established in the top of the South Island (Heath 2013a). *H. longicornis* has a one-to-many species relationship with its hosts and will happily feed on a wide range of animals for each of its developmental stages, i.e. the larva, nymph and adult stages. However out of this wide range of potential hosts it is believed, until recently, that *H. longicornis* can only transmit *T. orientalis* infection to cattle. Within the tick life cycle transmission of *T. orientalis* infection is trans-stadial but not trans-ovarial (Higuchi 1985; Kevin Lawrence data on file). Therefore, larvae or nymphs acquire the infection from feeding on an infected cattle host and then transmit it to a new bovine host at each succeeding stage left in the life cycle after moulting. Neither the fed adults nor the unfed newly hatched larvae can transfer the infection to a new bovine host. Summarising the epidemiology for *T. orientalis* in New Zealand, the reservoir hosts are infected cattle (which maintain lifelong infection), the new potential hosts are naïve cattle and the arthropod vector responsible for transmitting infection from the reservoir host to the new host is *H. longicornis*.

The progressive expansion of the range of *H. longicornis* in New Zealand has been mapped at least three times since first discovered in 1911 near Kaitaia, Northland (Myers, 1924). Myers (1924), Neilson (1980) and Heath (2016) compiled these distribution maps. The Myers (1924) map was based on field observation of ticks on livestock and anecdotal evidence, the Neilson (1980) map was based on a postal survey, published data (Heath, 1974, 1977a) and personal communication, and the Heath (2016) map was the result of a comprehensive telephone survey, field observation and tick surveillance on deer (McFadden et al. 2016a). A comprehensive illustrated key to identifying *H. longicornis* has recently been published (Egizi et al. 2019).

Questing is the unique behaviour that ticks display when acquiring a new host. During questing, each instar in the tick life cycle ascends vegetation to wait for suitable hosts and only descends to rehydrate in the litter zone (Estrada-Pena et al. 2013). If a suitable host brushes against the questing tick it will climb aboard and then move to areas on the host where the skin is thinner e.g. the ears or escutcheon of the udder to facilitate easier feeding. For the individual tick, survival becomes a balancing act between maintaining energy reserves, maintaining hydration and acquiring a host. Water exchanges in ticks only occur through the general cuticle surface (Browning, 1954), thus the hydration status of the tick will depend on the ambient temperature, rainfall and the atmospheric water pressure.

Logically these will all be important and limiting environmental variables in the spatial distribution of *H. longicornis*.

Behavioural diapause is another unique characteristic of tick phenology, in which the nymph (and possibly the adult), responding to decreased photoperiod and reduced temperature, will cease questing and enter a period of inactivity (Heath, 2016). Japanese research found that diapause occurs in unfed nymphs and unfed adults which were exposed to short-day photoperiod, but not in engorged larvae and engorged nymphs (Fujimoto, 1995; Fujimoto, 2000). The diapause in New Zealand lasts around 3 months from around mid-March to late July and usually involves over-wintering unfed nymphs and some unfed adults (Heath, 2016). Diapause activity should not affect the distribution of *H. longicornis*, only affecting the time taken to complete its life cycle. Japanese research has found that all developmental stages of *H. longicornis*, except the eggs, overwinter by burrowing into the soil of pastures (Ito et al. 1983; Fujisaki et al. 1985), with ticks being found at a depth of 5-15 cm under shade trees (Shiraishi et al. 1989).

Hoogstraal et al. (1968) reported that on average, under favourable laboratory conditions, parthenogenetic *H. longicornis* eggs hatch after 24 to 31 days, rest as unfed larvae for 3 to 5 days, feed for 4 to 5 days then drop-off and moult by 14 to 17 days. The unfed nymphs then rest for 2 to 3 days, feed for five to seven days, drop-off and moult by 12 to 16 days before resting as unfed adults for 4 to 6 days prior to questing. The adults then feed for 11 to 19 days, drop off and rest for 3 to 7 days before laying eggs for a further 11 to 27 days. This gives a range of 103 to 143 days, under favourable conditions, for the lifecycle to be completed. Thus, it is not surprising that in Northland 2 lifecycles of ticks can occur in one year and as a result adult ticks can be seen questing in the autumn.

The abiotic requirements for ticks have been investigated by Heath (1979, 1981) and Yano et al. (1988) and show that relative humidity; rainfall and temperature are integral to the development and survival of *H. longicornis* ticks and that for each instar there are subtle differences in these requirements. The biotic requirements for ticks are cosmopolitan and suitable hosts include cattle, deer, goats, horses, hares, sheep, dogs, kiwis, and even humans (Myers 1924; Heath 2016). There is some suggestion that ticks are genetically programmed to select deer based on the questing height they adopt on vegetation (Tsunoda and Tatsuzawa, 2004), which may help explain the strong association between deer and ticks observed in New Zealand (Wilson et al. 1987). Even though ticks are only capable of actively travelling no more than 2 to 3 m off host (Myers, 1924) when feeding on a host they are capable of being passively transported considerable distances, ranging from 5 to 15 km on hares (Heath et al. 1987) to over 1000 km on trucked stock or birds. The only limitation to the distance transported is whether the tick completes feeding (usually 5 – 7 days) and drops off the host before the host reaches its destination.

Recently, *H. longicornis* ticks have been identified as one of the main vectors of Severe Fever with Thrombocytopenia Syndrome (SFTS). SFTS is caused by a novel bunyavirus and symptoms in people include high fever, vomiting, diarrhoea, thrombocytopenia, leukopenia, and multiple organ failure. The disease has a 6–30% case-fatality rate and has been recorded in China, South Korea and Japan (Kim et al. 2013; Liu et al. 2012; Takahashi et al. 2013). Furthermore, the experimental infection of *H. longicornis* ticks with canine parvovirus has highlighted the potential role of this tick in transmitting other viruses (Mori et al. 2015) and there is even a suggested role for *H. longicornis* in the spread of Lyme disease in China (Wan et al. 1998). Of considerable contemporary interest is the finding of *H. longicornis* in northeastern USA (Beard et al. 2018; Rainey et al. 2018) showing that it and many other species of ticks (Burridge 2011) are still threatening invasion around the globe.

The New Zealand climate is warm temperate with a fully humid, warm summer; Cfb in the Köppen-Geiger classification (Maunder 1970), which means that similar regions of the planet, excluding desert ecosystems, should be suitable for *H. longicornis* to inhabit. The Köppen-Geiger classification is a widely used climate classification system in which climates are divided into 5 main groups (A – E), in which group C is temperate. The second and third letters further sub-divide the climate group based on precipitation and temperature patterns respectively.

The following ticks have been implicated in the spread of *T. orientalis* in overseas countries, Australia: *Haemaphysalis longicornis* (Hammer et al. 2015), *Haemaphysalis bancrofti* and *Haemaphysalis humerosa* (Stewart et al., 1987); China: *Haemaphysalis longicornis*, *Haemaphysalis qinghaiensis* (Yin et al. 2004); Hungary: *Haemaphysalis punctata* (Hornok et al. 2015); India: *Haemaphysalis bispinosa* (Shastri et al. 1988), *Rhipicephalus* (Boophilus) *microplus* (Kakati et al. 2015), *Rhipicephalus haemaphysaloides* (Devadevi et al. 2018); Japan: *Haemaphysalis longicornis* (Kamio et al. 1990), *Haemaphysalis mageshimaensis* (Fujisaki et al. 1988), *Haemaphysalis megaspinosa*, *Haemaphysalis douglasi*, *Ixodes persulcatus*, and *Ixodes ovatus* (Yokoyama et al. 2012), Korea: *Haemaphysalis longicornis* (Kang et al. 2013); Romania: *Hyalomma marginatum* (Ionita et al. 2013); USA:); *Amblyomma americanum* and *Dermacentor variabilis* (Chae et al. 1999b); *Haemaphysalis longicornis* (Oakes et al. 2019); Vietnam: *Rhipicephalus* (Boophilus) *microplus* (Khukhuu et al., 2011).

For many countries, the competent ticks include members of the genus *Haemaphysalis* as well as some other species. However, the comparative competency of these other species for transmitting *T. orientalis* is unclear and further work will be needed to demonstrate their significance (Yam et al. 2018).

Recent work conducted in Benin suggests that *Amblyomma variegatum* ticks appear unlikely to transmit *T. orientalis* (Moumouni et al. 2018). The identification of *Rhipicephalus* (Boophilus) *microplus* as a potential vector in India and Vietnam is interesting since early Australian transmission

studies concluded that this tick was not capable of transmitting *Theileria mutans* (Callow and Hoyte, 1961). Empirical evidence would suggest that *R. microplus* should be unlikely to transmit *Theileria* since it is a one-host tick. This means that the larvae once hatched from eggs on pasture attach to a host and remain there (going through a feed/moult cycle to produce a nymph and a feed/moult cycle to produce an adult) until the engorged female drops to pasture to lay eggs and die. If, as we believe, *Theileria* is not transmitted trans-ovarially then there is no opportunity for the recently hatched larvae to transmit infection when they feed on a new host.

1.11.2 *Vertical trans-placental transmission in cattle*

There is much uncertainty over whether vertical transmission of *T. orientalis* occurs in field-infected cattle. Both an experimental study (Baek et al. 2003) and an observational study (Onoe et al. 1994) supported the occurrence of some vertical trans-placental transmission of *T. sergenti*. Baek et al. (2003) found 100% (6/6) trans-placental transmission of *T. sergenti* in an experimental study, where 6 heifers were deliberately infected with *T. sergenti*, using infected ticks, just after artificial insemination, and Onoe et al. (1994), in an observational study, found 7% (4/55) *T. sergenti* positive calves born to 55 naturally infected dams. Of the 6 heifers in the Baek et al. (2003) study, 2 heifers aborted one at 6 and one at 7 months, one calf was delivered by caesarean section at 8 months and the 3 others calved normally to term. Two further references to trans-placental transmission of *T. sergenti* in the literature (Baek et al. 1993; Savini et al. 1998) are problematical since the experimental design and results from both these studies are unclear.

More recently Australian and Japanese observational field studies estimated the *T. orientalis* Ikeda type infection rates for calves born to infected dams at between 0% (Hammer et al. 2016, Mekata et al., 2018) and 2.1% (Swilks et al. 2017a). The latter study included abattoir material, where opportunities for cross contamination are very likely and may be difficult to prevent. Swilks et al. (2017a) was also not able to recover *T. orientalis* Ikeda type from any aborted fetuses, which contrasts with Baek et al. (1997b) who detected schizonts in the spleen of aborted fetuses using monoclonal antibodies, and immunohistochemical staining. The study by Mekata et al (2018) did find 9.6% calves born to *Theileria*-infected dams became PCR positive at 3-month-old compared to none of the calves born to *Theileria* negative dams. This is difficult to explain but transmission by lice, possibly acquired when the calves suckled from their infected dams, cannot be ruled out.

The role of trans-placental transmission in the New Zealand epidemic is not known. However, *T. orientalis* is unlikely to be a direct cause of bovine abortion but rather the abortion is secondary to the severe maternal anaemia and consequential foetal hypoxia. Hammer et al. (2015) also found molecular evidence of *T. orientalis* in colostrum but was unable to link this finding to increased

infection rates in the suckled calves drinking the infected colostrum. It is not unusual to have blood contamination of bovine colostrum, which could explain why *T. orientalis* was found by Hammer et al. (2015).

1.11.3 *Mechanical and iatrogenic transmission*

Biting flies (*Stomoxys calcitrans* (stable fly) (Hadi and Al-Amery, 2012) and *Tabanus trigeminus* (Horse fly) (Hammer et al., 2016)), *Linognathus vituli* (sucking lice) (Fujusaki et al. 1993; Hammer et al., 2016), mosquitoes (de Marco et al. 2016) and iatrogenic transmission have all been suggested as additional (bridging) vectors of *T. orientalis*, however there is little field data to support these claims (Hammer et al. 2016; Heath, 2013b; Yamane et al. 2010) and if substantiated will likely only be involved in limited local spread, if at all.

That said, the evidence for transmission by sucking lice would appear to be the strongest, with the transmission of infection being achieved by the experimental infestation of naïve (splenectomised) calves with lice that had previously fed on an infected animal (Fujusaki et al. 1993). The method of infection transmission in lice is through regurgitation of contaminated gut contents, there being no active *T. orientalis* intermediate stage within lice. This would likely be the same method of transmission for haematophagous biting flies and although there has been some debate over whether the volume of blood carried by a stable fly would be sufficient to transmit infection (Heath, 2013b), it has proved adequate for transmitting the trypanosome *Trypanosoma evansi*, which relies almost entirely on mechanical spread of infection (Desquesnes et al. 2013). Hammer et al. (2016) was able to transmit infection by intravenous inoculation using just 100µL of blood, however *Stomoxys* flies can only consume an average of 11–15 µL of blood per meal (Schowalter and Klowden, 1979) so further work will be needed to settle this debate.

If mechanical transmission of haploid piroplasms is successful, it is important to note that this method of transmission would bypass the sexual phase of the *T. orientalis* lifecycle, which can only occur in the tick. Without the sexual phase of the lifecycle and the ensuing random genetic recombination there is likely to be less genetic diversity, a characteristic which may be important in the ability of *T. orientalis* to evade the host's immune system.

1.11.4 *Experimental methods of transmission*

Intravenous and subcutaneous inoculation of infected blood into naïve recipients has been successfully used to achieve experimental infection in Japan, Korea, Netherlands, Australia and New Zealand (Fujisaki and Kamio, 1988; Hammer et al. 2016; Hoyte, 1971; Lawrence et al. 2018b;

Shimizu et al. 1990; Uilenberg et al. 1985). The volumes used have been highly variable, with the smallest successful volumes being 100µL used by Hammer et al (2016) and the largest being 30ml by Lawrence et al. (2018b). The deliberate attachment of infected ticks on naïve cattle has also proved successful (Baek et al. 2003) as well as the use of homogenates of infected ticks injected subcutaneously (Fujisaki and Kamio, 1988).

In many of the earlier transmission trials the bovine recipients were first splenectomised to facilitate disease transmission and diagnosis. Prior to the development of molecular techniques, diagnosis by stained blood smear was the gold standard and splenectomising the recipient led to higher levels of parasitaemia and improved diagnostic sensitivity. It may have also made it easier to infect the calves through handicapping the animal's immune response.

1.12 Cattle breed susceptibility

Some beef and indigenous breeds appear to have a lower susceptibility to *T. orientalis* infection compared to some dairy breeds (Higuchi et al. 2003; Sivakumar et al. 2017; Terada et al. 1995). Similarly, Jang and Suh (1990) showed that parasitaemia levels were higher in imported cattle breeds than native Korean cattle. An explanation was suggested by the finding that Wagyu cattle have significantly lower levels of I-active ganglioside in their erythrocytes compared to Holstein-Friesian cattle (Watarai et al. 1995). I-active ganglioside is important for the attachment and invasion of erythrocytes by *T. orientalis* merozoites (Watarai et al. 1994).

1.13 Endemic stability

An endemically stable area, in relation to a tick-borne disease, is defined as one where the level of clinical disease does not dramatically fluctuate over time (Jonsson et al, 2012) and in which clinical disease is scarce despite high levels of infection within the population (Coleman et al. 2001). To achieve endemic stability requires a high infectious force and this in turn will require a high environmental suitability of tick habitats (Hay, 2001). The following North Island regions: Northland, Auckland, Waikato, Bay of Plenty and Taranaki will almost certainly achieve endemic stability (McFadden and Marchant, 2014). The paradox of endemic stability is that despite a high infectious force, less disease is seen in adult cattle and more in young cattle, but with the disease in young cattle often being milder, with fewer fatalities, and leading to lifelong protective immunity (Hay, 2001).

For lower North Island regions, the environmental suitability for *T. orientalis* transmission is much more heterogeneous. The more southern North Island regions Manawatu and Wellington will probably be endemically unstable. In endemically unstable areas, the exposure to infected ticks is

highly variable leading to naïve cattle often being infected as adults rather than as calves, which is usual in stable areas. L’Hostis and Seegers (2002) describe two scenarios for tick-borne disease in endemically unstable areas. The first scenario, referred to as high incidence endemic instability, occurs when the herd prevalence of infected cows is between 10 and 75% of cows and the tick attack rate is less than that in the endemically stable areas. This results in a high incidence of clinical disease and a moderate case fatality rate. In the second scenario, referred to as low incidence endemic instability, the herd prevalence of infected cows is less than 10% and results in a low incidence of disease but a higher case fatality rate. It is likely that both situations will be seen in New Zealand with the second scenario occurring further south in the North Island or the top of the South Island.

1.13.1 *Infection intensity*

Bogema et al. (2015) found that 95% of clinically ill cattle, showing one or more signs of theileriosis, had a parasitaemia $>300\,000$ organisms/ μ l. They described this infection intensity as high and categorised recovering or in contact non-clinical cattle as either having moderate infection intensity $>15,000$ but $\leq 300,000$ organisms/ μ l or low $\leq 15,000$ organisms/ μ l. Although only one infected tick bite may be enough to infect an individual animal, it is probable that more than one tick bite may be required to cause the higher infection intensities seen on farms from high-risk tick areas in New Zealand or in New South Wales, Australia (Swilks et al. 2017b). Once past the acute phase of the infection the usual chronic infection intensity is < 10 organisms/1000 RBCs ($<1\%$) (Jang and Suh, 1990; Song and Sang, 2003) assuming one organism per erythrocyte and may be as low as 0.02–0.03% (Kamio et al. 1990; Shimizu et al. 1992).

Cross-sectional studies have failed to find a strong linear relationship between infection intensity and HCT (Eamens et al. 2013c), however longitudinal studies have found a moderate negative association between infection intensity and HCT (Swilks et al. 2017b; Lawrence et al. 2019). This is not surprising since the infection intensity usually peaks 1 to 2 weeks before the lowest HCT and is falling by the time the animals are diagnosed as clinically anaemic (Jenkins and Bogema, 2016). Which often means that quite severely anaemic animals may only have a moderate parasitaemia of 1 to 5% (Eamens et al. 2013c).

1.13.2 *Production effects*

It is likely that adverse production effects result from the combined effects of both anaemia and anorexia. In Australian oriental theileriosis is estimated to cost the red meat industry \$19.6M per annum (Lane et al., 2015), and \$202 per affected cow in lost production for dairy cows in a single

infected herd (Perera et al. 2014). In New Zealand McDougall et al. (2014) found \$196 per clinical cow in lost reproductive performance in an infected dairy herd. One of the first Northland dairy farms affected in the New Zealand epidemic had approximately 20 cows die during the calving season, had a six-week in-calf rate of only 44 percent (target 78%) during the mating season and the per-cow milk season production was just 230kg milk solids – well down on the regional average of 315kg (Stewart, 2014). In another outbreak where naïve cattle were moved to an endemic area, costs in excess of \$NZ 1 million were incurred by a single herd (McFadden and Marchant, 2015).

In a study of suckled beef calves, infected calves were found to grow 127g/day less in the autumn compared to uninfected calves (Lawrence et al. 2019) and in a clinical trial of 2-year-old Friesian bulls, some of the infected bulls, 4/10, grew 2kg/week less than the control bulls (Lawrence et al. 2018b). Modelling carried out by veterinarians at MPI in May 2013 showed that the average farm impact of *T. orientalis* infection could be approximately \$14,000, but the range was \$4,000–\$29,000 (Stewart, 2014). The full cost of the current epidemic in New Zealand is unlikely to ever be accurately estimated, since herds were often almost 100% infected, over a very short period (MPI, data on file). This meant that uninfected controls for matching to and contrasting with infected animals were seldom available for herd-based production studies.

1.14 Methods of disease prevention

1.14.1 Acaricides

The use of flumethrin 10g/L as a pour-on acaricide has been found to have little benefit in preventing the spread of the disease to naïve cattle in areas of New Zealand where it is endemic (Riddle, 2014). Similarly, acaricide treatments (excluding 1% flumethrin pour-on, which is not registered for use in on cattle in Australia) were also shown to be ineffective in the Australian epidemic (Biddle et al. 2013). Extended monthly treatments with flumethrin pour-on in the Kumamoto prefecture of Japan for 6 years did however; result in an 80% reduction in the incidence of *T. sergenti* associated disease (Shimizu et al. 2000). It is likely that this method of control was neither cost effective nor sustainable and given the choice of controlling internal parasites or using acaricides to prevent *T. orientalis*, Yamane et al. (2001) found that the growth response for ivermectin treatment of cattle was greater than for flumethrin treatment, again indicating that acaricides have a limited role in disease control.

1.14.2 *Vaccinations*

Currently there are no vaccinations available for preventing *T. orientalis* infection in New Zealand or Australia. The use of vaccination in New Zealand to prevent *T. orientalis* infection has two logical approaches, either vaccinate individual cattle against *T. orientalis* Ikeda type infection itself or vaccinate individual cattle against successful *H. longicornis* attachment and feeding, since only the one competent vector is present.

Research into *T. sergenti* vaccines showed some early promise which has never been commercially developed. Baek et al. (1992a, 1992b, 1994) prepared antigens from merozoites and were able to show a protective effect for vaccinated animals in field trials conducted in Japan and Onuma et al. (1997) developed a trial vaccine for Ikeda and Chitose types using recombinant baculovirus p32 MPSP antigen.

A draft genome of *T. orientalis* Ikeda type has recently been sequenced (Hayashida et al. 2012; Bogema et al. 2018) and using reverse vaccinology methods such as VACCEED (Goodswen et al. 2014) it could be possible to predict which *T. orientalis* Ikeda type proteins would be the most suitable as an antigen, in an anti- *T. orientalis* Ikeda type vaccine. VACCEED is a Linux-based set of programs that can accept large proteome datasets as input, predict antigenicity, localization, topology, and interactions with MHC I and II alleles, and output a ranked set of vaccine antigen candidates. Previously it has been proposed that vaccination with benign types of *T. orientalis* may provide cross protection against the pathogenic genotypes (Yam et al. 2018), this would seem unlikely given that prior to 2012 many herds in New Zealand were already positive for non-pathogenic *T. orientalis* types and yet they still became severely affected in the 2012 *T. orientalis* Ikeda type epidemic (McFadden et al. 2016b).

H. longicornis ticks release serpins (serine protease inhibitors) in their saliva when feeding which are important for regulating endogenous proteases within the host involved in coagulation and inflammatory response. Serpins are also present in the tick haemolymph where they protect against fungal and bacterial infections (Imamura et al. 2005). It has been successfully shown that recombinant *Haemaphysalis longicornis* serpin-2 could be used as an anti-tick vaccine (Imamura et al. 2005). Other recombinant vaccination approaches using tick saliva proteins (p29, p34 and p35) have also been investigated (Mulenga et al. 1999; Tsuda et al. 2001).

To date the only commercially available tick vaccine in the world (Willadsen et al. 1995) is against *Rhipicephalus microplus*, after the US Cattle Tick Consortium developed several anti-tick vaccine antigens (Guerrero et al. 2014, 2016).

1.14.3 *Other methods of prevention*

Other pasture management strategies that have been implemented to reduce the on-farm tick challenge to cattle, include the strategic use of cross-grazing with sheep to “clean” the pasture of ticks, prior to grazing cattle and the use of pasture topping to keep the pasture residuals low and “open up” the sward so that ticks or eggs are more likely to desiccate and die before finding a new host or hatching (Heath, 2016).

For farms in the endemic unstable areas the only other method of disease control, that future proofs a herd against clinical disease outbreaks in adult cattle, is to deliberately expose the newborn calves to infection in their first year of life. This requires farmers either identifying areas on their farms with a high density of infected ticks (Rankin, 2015) or sending the naïve calves off farm to graze in endemic stable areas for at least their first season.

1.15 **Methods of disease treatment**

Animals with a PCV below 0.12 will likely die without a blood transfusion (Vink et al. 2013). During the 2012 New Zealand TABA epidemic, thousands of blood transfusions were given by New Zealand veterinarians in the field, for a full description of how to perform a bovine blood transfusion see Vink et al. (2013).

Buparvaquone is a second-generation hydroxynaphthoquinone related to parvaquone (McHardy et al, 1985) and many New Zealand veterinarians consider the use of buparvaquone (2.5 mg/kg) as essential for the successful treatment of TABA (McFadden and Marchant, 2015; Rankin, 2015). Buparvaquone causes progressive cytoplasmic vacuolation in *Theileria* spp. by inhibiting mitochondrial electron transport (Fry et al., 1984; McHardy et al., 1992). A Queensland Government clinical trial of buparvaquone on splenectomised calves found that treatment resulted in an 89% reduction in parasitaemia by Day 4 (Carter, 2011). Despite these encouraging results, the unfavourable results of an Australian residue trial (Bailey, 2013) means that buparvaquone is not registered for use in cattle in Australia and, as far as can be ascertained, any application by private veterinarians to import buparvaquone has been denied by the Australian Pesticides and Veterinary Medicines Authority (APVMA). In New Zealand, the Agricultural Compounds and Veterinary Medicines (ACVM) Group have responded more favourably and have granted several private veterinarians Special Circumstances Approval to import buparvaquone and treat animals in their care. This action became necessary in late 2013 after MPI seized several consignments of buparvaquone at the border, destined for private New Zealand farmers having been ordered over the internet.

Even so the success of treatment of TABA with buparvaquone has proved to be variable with some practitioners experiencing consistently high results (Rankin, 2015) and others less so (Meredith Love pers. comm.). Anecdotally, efficacy appears higher in acutely ill dairy cows rather than beef calves, which may be less of a reflection on the efficacy of buparvaquone than the ability of the affected animal to mount a successful bone marrow response to the anaemia. This is also suggested as one of the reasons for a poor success in transfusing severely anaemic calves (Meredith Love pers. comm.). In countries where buparvaquone is registered for animal treatment, the recommended withholding period are 48 hours for milk and 42 days for meat (McDougall et al. 2016)., However, industry funded slaughter trials conducted in New Zealand in 2013 (McDougall et al. 2016) found concentrations of buparvaquone, above the limits of detection using liquid chromatography-mass spectrometry, in some treated cows, at 35 days in milk, at 119 days at the injection site and 328 days in the liver post injection. These findings have led to the following legal requirements for milk and meat withhold periods for buparvaquone treated cattle in New Zealand, 43-day milk, 548-day meat and all offal is permanently withheld. Furthermore, all buparvaquone treated animals must be recorded in the MPI data base and have a 'THL' tag cross-referenced to the NAIT tag in their ear. Calves born to buparvaquone treated dams have a 9-month meat withhold and those calves drinking milk from a buparvaquone treated cow have a 91-day meat withhold. Clearly, these long withdrawal periods have greatly handicapped the use of buparvaquone in New Zealand but are deemed unavoidable to protect red meat exports.

Alternative formulations of buparvaquone have also been shown to improve efficacy, Kim (1993) found that the incorporation of buparvaquone into liposome vesicles prior to intravenous injection resulted in complete *T. sergenti* cures by day 3. This discovery also appears to have not resulted in any commercial uptake and unless it reduces overall tissue withdrawal periods is unlikely to be of interest to the New Zealand beef and dairy industry.

Some Australian and New Zealand veterinarians, seeking licensed alternatives to buparvaquone with shorter withhold periods, have tried other chemotherapeutic treatment options; oxytetracycline at a dose rate of 10mg/kg for 5 days, oxytetracycline at a dose rate of 20mg/kg QOD for 10 days, erythromycin at a dose rate of 8mg/kg for 4 days or imidicarb dipropionate at a dose rate of 2.5mls/100kg S/C (not registered in New Zealand), however no rigorous evaluation of the efficacy of these various treatments is available (Glassop and Kerr, 2013). Drugs with proven efficacy against other apicomplexan parasites have also been tried including halofuginone (Halocur 0.5 mg/ml, MSD animal health) at a dose rate 1.0 mg/kg (10 times the recommended dose rate for cryptosporidiosis) and toltrazuril (Baycox 50 mg/ml, Bayer New Zealand Ltd) at a dose rate 15 mg/kg. Anecdotally, there have been some reports of success using toltrazuril at 3 weeks of age in beef calves (McFadden and Marchant, 2015) although again no robust blinded clinical trials have been carried out. Recently

the drug Draxxin® (tulathromycin) has been found, in vitro, to be effective against *Babesia bovis*, *Babesia bigemina* and *Theileria equi* (Silva et al. 2018). Again, there have been no clinical trials assessing its efficacy against *T. orientalis*, but this drug could warrant further investigation. He et al., (2005) researched the prohibitin-like gene of *T. orientalis* in the hope of developing a new treatment for theileriosis, which would trigger apoptosis, again there appears to be no commercial uptake.

1.16 The immune response to *Theileria orientalis* infection in cattle

A better understanding of how the immune response to *T. orientalis* is affected by pregnancy or stress would greatly assist in the development of disease control strategies or even vaccine development (Weston, 2011), however very little is known in this area. In general, humoral responses are targeted against extracellular parasites in the bloodstream or tissue fluids whereas cell-mediated responses target intracellular parasites (Tizard, 2000). This classic “division of labour” paradigm for immune responses has however been recently challenged and it is suggested that obligate intracellular pathogens may be susceptible to humoral immunity during extracellular phases (Casadevall, 2003). *T. orientalis* infections often present as mixed infections, with an apparent temporal shift in population dominance between Ikeda and Chitose types, (Jenkins and Bogema, 2016; Kubota et al. 1996a; Onuma et al. 1998; Matsuba et al. 1993b). It is suggested that mixed infections and the temporal switching of dominant genotypes may help the parasite evade the host’s immune response (Jenkins et al. 2015; Kubota et al. 1996b; Masatani et al. 2016), however it is widely accepted that once cattle are infected, they are probably infected for life (Onuma et al. 1998).

Since some of the studies that report temporal shifting were conducted at pasture then superinfection by other *T. orientalis* strains through infected ticks feeding is also possible. Genetic recombination in the sexual phase of the tick cycle could conceivably produce a genetically diverse population of sporozoites, which could then superinfect the animal and overwhelm the immune system. It is likely that as with all Apicomplexan infections the host/pathogen/environment interactions are extremely complex.

1.16.1 Humoral immunity

Jenkins and Bogema (2016) using an antibody ELISA showed that 89% of anaemic animals seroconverted to major surface protein of *T. orientalis*, whereas only 45% of animals with a normal PCV seroconverted. They further showed that significant seroconversion only occurred against the Ikeda type and not against the Chitose or Buffeli types. This supports the finding by Casadevall (2003)

that a humoral response occurs in response to a significant extracellular phase, which is linked to erythrocyte destruction and seen with the more virulent Ikeda type and not the more benign Chitose or Buffeli types. The lysis of erythrocytes allows merozoites to be released into the circulation and be presented to the host's humoral immune system.

Jenkins and Bogema (2016) found that seroconversion occurred 2 to 3 weeks after *Theileria* were first detected by qPCR and although antibodies were still detectable at the end of the study (11 weeks post exposure to infection), the levels had dropped steeply from a peak at between days 34 and 40. In the same study only 35% of subclinical (< 15,000 organisms/ μ L) were positive, again indicating that immunity wanes when there is no significant extracellular phase to boost it. The persistence of different classes of antibody is also variable, with IgG persisting longer than IgM and IgG₂ persisting the longest (Kawazu et al. 1988). The relevance of seroconversion for protecting the animal from further infection or eliminating the current infection is unknown and its value as a marker of recent infection would appear to be not always reliable.

Passively acquired immunity from the colostrum also appears to be short lived, with antibodies undetectable in calves by 4 weeks of age, despite being born in an endemic area of Australia (Swilks et al. 2017b). The value of short-lived colostrum derived antibodies in preventing infection in calves is debatable, since peak morbidity and mortality rates are seen in suckled beef calves at between 2 and 3 months of age (Lawrence et al. 2018c). Despite some conflicting results, it appears that in naturally acquired *T. orientalis* infections there is no serological cross-reactivity between types (Iwasaki et al. 1998; Jenkins and Bogema, 2016). This again supports the view that benign *T. orientalis* types such as Buffeli cannot be used as a live vaccine against the Ikeda type.

1.16.2 *Cell-mediated immunity*

T cells (Yasutomi et al. 1991a, 1991b), natural killer cells (Yasutomi et al. 1991b) and macrophages (Asaoka et al. 1991; Kawazu et al. 1991; Ishii et al. 1992; Yanagisawa et al. 1997b) could all be important in controlling the progression of parasitaemia in infected cattle. Gamma interferon (IFN- γ), interleukin 2 (IL-2), IgG1 and IgG2 have also been observed to increase in response to infection, indicating a Th-1-type immune response to *T. orientalis* infection (Hagiwara et al. 2005; Yanagisawa and Kamiyama, 1997a). However, it is important to remember that mature un-nucleated red blood cells lack Major Histocompatibility Complex (MHC) 1 molecules, although immature nucleated RBCs may contain small traces of MHC 1 molecules. MHC 1 molecules are cell surface glycoproteins, which present processed antigens to CD8 T cells, an integral part of cell mediated immunity. This inability to target piroplasm infected RBCs with cell mediated immunity probably explains why intravascular haemolysis is rare in *T. orientalis* Ikeda type infection.

1.17 Diagnosis of *Theileria orientalis* Ikeda type in cattle

1.17.1 *Blood smear*

Historically microscopic techniques for diagnosis of tick-borne diseases would have been considered the gold standard. However, the difficulty in differentiating between pathogenic and non-pathogenic types of *T. orientalis* based on morphology and the potential false positive diagnoses associated with concurrent infection with other haemaplasmas (McFadden, 2016c) brings the value of blood smears for diagnosis into question. Perera et al. (2013) estimated the sensitivity and specificity of blood smears for detecting *Theileria* as 38.7% (95% CI 32-46%) and 100% (95% CI 95-100%) respectively. This means that although blood smears have a low sensitivity, the high specificity means that the positive predictive value (PPV) of being smear positive is relatively high. Another major concern with using blood smears to diagnose theileriosis is that for chronically infected animals the number of parasites will be so low as to be virtually undetectable by microscopy. In malaria, when people are detected as infected by PCR but not on blood smear examination, this level of infection is described as sub-microscopic. Sub-microscopic malarial infections are more common in endemic unstable regions and play a significant role in maintaining infection in these areas. Preparing and reading smears is also quite labour intensive and requires trained technicians. Overall the best value for blood smears is probably as an adjunct to a clinical examination, in which case if the animal is anaemic, jaundiced and showing lethargy then the parasitaemia will be high and the smear should be relatively easy to interpret, thus confirming the diagnosis.

1.17.2 *Serology*

When merozoites (piroplasms) occur at densities below the sensitivity of microscopy then indirect methods of diagnosis can be used instead. These include serological tests which utilise the antigen-antibody reaction to detect either antibodies or antigens. Historically, the three most common serological tests associated with *T. orientalis* diagnosis are the complement fixation test (CFT), the indirect fluorescent antibody technique (IFAT), and the enzyme-linked immunosorbent assay (ELISA).

Kajikawa et al. (1985) prepared monoclonal antibodies against *T. sergenti* merozoites and used indirect fluorescent antibody staining to estimate the percentage of infected erythrocytes. From this work, the 23kD and 32kD components were identified as the most important immunogenic piroplasm surface proteins (Kobayashi et al. 1987) and further showed that monoclonal antibodies prepared against the 32kD major piroplasm surface protein (MPSP) could prevent clinical disease in

experimentally infected calves (Tanaka et al. (1990). As a result of this early work the MPSP gene is now the most studied genetic marker for *T. orientalis* (Cufos, 2012b). It is a single copy gene, conserved among all *Theileria* spp. and encodes an immunodominant protein in the piroplasm surface expressed during its intraerythrocytic (piroplasm) stage (Cufos, 2012b; Kubota et al., 1996a).

Fujinaga and Minami (1981) used indirect fluorescent antibody (IFAT), method developed by Takahashi et al. (1972), and complement fixation tests (CFT), method adapted from Fujinaga et al. (1980), to detect antibodies to *T. sergenti*. They found that both methods performed well but the IFAT gave a positive result much earlier than CFT.

Shimizu et al. (1988) developed an ELISA test for detecting antibodies to *T. sergenti* wherein piroplasm antigen was prepared using nitrogen cavitation. Although crude antigens can perform well in ELISA the requirement of infected animals as a source of piroplasms and batch-to-batch variability means that recombinant proteins have replaced crude antigens (Gubbels et al. 2000). In Australia, ELISAs have recently been developed for detecting antibodies to *T. orientalis* using recombinant antigens (Jenkins and Bogema, 2016; Hammer et al. 2016). Jenkins and Bogema (2016) study found that acutely infected animals seroconverted quickly (within 2-3 weeks post-infection) and that the humoral response to the parasite was maintained for at least 10 weeks (limit of the experiment). However, the test only achieved a moderate sensitivity, 68.7%, detecting mainly animals that were also anaemic. Thus, its usefulness in detecting chronic lifelong infections a year or two after the animal was initially infected remains in doubt.

It is likely that these indirect serological methods will have little utility in diagnosing Ikeda infections since they lack sensitivity and the antibodies, they measure may not persist for chronic infections, although this is not known for certain.

1.17.3 *Nucleic acid-based diagnostic techniques*

Since the unequivocal identification of *Theileria* to species or type is not possible, using morphology or serology (Cufos et al. 2012b), molecular nucleic acid-based diagnostic techniques have been developed to characterize the piroplasms genetically. These have proved to be sensitive, easy to use, are capable of efficiently analysing large number of samples and can detect the parasites directly in blood or tissue samples (Salih et al. 2015). Today nucleic acid-based diagnostic techniques are the mainstay of infectious disease diagnosis. Furthermore, they are independent of the immunocompetence of animals and can detect infection in the latent phase of the disease when the level of parasitemia is often below the detection limits of microscopic and serological methods (Bursakov and Kovalchuk, 2019).

The molecular markers used to diagnose disease and differentiate between *T. orientalis* types include, in addition to the previously mentioned 32 kDa MPSP gene (p32), a 23 kDa piroplasm membrane protein (p23), a small-subunit ribosomal ribonucleic acid (SSU-rRNA) gene and the first and second internal transcribed spacers (ITS) of nuclear ribosomal DNA (ITS-1 and ITS-2) (Kamau et al. 2011b). Internal transcribed spacers are the spacer DNA situated between the small-subunit ribosomal RNA (rRNA) and large-subunit rRNA genes, ITS1 is located between the 18S and 5.8S rRNA genes and ITS2 is between the 5.8S and 28S rRNA genes (Kamau et al. 2011b).

The MPSP, SSU-rRNA and p23 genes have all been used to differentiate between *T. orientalis* types, although the p23 gene has been found to have lower genetic diversity than the MPSP so may be less useful (Gebrekidan et al. 2017b; Yokoyama et al., 2011).

A MPSP DNA probe for detection of *T. sergenti* was developed by Kajiwaru et al. (1990), evaluated by Hirano et al. (1991) and further modified by Kawazu et al. (1992b). The first recorded use of polymerase chain reaction (PCR) to diagnose *T. sergenti* was in 1993 (Tanaka et al. 1993) when PCR was used to amplify the MPSP gene of *T. sergenti*. This method was found to be sufficiently sensitive to detect four parasites per μL of blood using a $10\mu\text{L}$ sample.

Briefly, PCR is a laboratory method of making multiple copies of a specific segment of DNA (here after referred to as the target DNA). The method uses two primers (oligonucleotides) that bind to either end of the target portion of the DNA and the enzyme DNA polymerase to extend the length of each respective primer, after they have annealed to the target DNA. The double stranded template DNA has previously been heated to denature the DNA i.e. separate it into single strands. The pre-programmed cycle of heating and cooling, controlling the processes of denaturing, annealing and elongation, is repeated 30 to 40 times, inside a PCR machine, with synthesised product DNA acting as the templates for later cycles and the yield of synthesised DNA doubling at each cycle from the second cycle on. The discovery that DNA polymerase from the thermophilic bacterium *Thermus aquaticus* (Taq) was not damaged by the high temperatures required for denaturing the DNA, removed the onerous requirement to add DNA polymerase after every cycle and significantly accelerated the acceptance of this technique in mainstream laboratories.

The amplified DNA product from the PCR cycle is usually referred to as the amplicon and traditionally was detected using either agarose gel electrophoresis, Southern blot or ELISA (Mackay, 2004). For an excellent and comprehensive review of the available molecular techniques for diagnosing *T. orientalis* infection see Gebrekidan et al. (2020).

A table of published primer sequences used for molecular diagnosis are shown in Table 1-1. The table is by no means exhaustive and serves to illustrate how research into molecular methods of *T. orientalis* diagnosis continues to evolve.

Table 1-1. Published primers used for molecular diagnosis of *Theileria orientalis* and *Theileria sergenti*

Parasite	Primer name	Sequence	Reference
<i>T. orientalis</i> Ikeda	NZIk1-F	5'-AGTTAACGCCACCGCAGCCG-3'	Pulford et al. 2016b
	NZIk1-R	5'-ACGCGGTATCCCTCTTCGGCA-3'	
	Probe	[6FAM]-CGC CTC AAA CGC CAA CGA CG-[BHQ1]	
<i>T. orientalis</i> Ikeda	MPSP-I-F	5'-ATTGGTAGACGGAATGGAAGAAGG-3'	Jenkins et al 2015
	MPSP-I-R	5'-GAGACTCAATGCGCCTAGAGATAATAGA-3'	
	Pr-I	VIC-CATGAACAGTGCTTGGC -MGB-NFQ	
<i>T. orientalis</i> Ikeda	Ts-Ikeda SSU rRNA	5'-AAGGATCCGTCTCTGTACCGCCGC-3'	Kubota et al. 1996a
	Ts-R SSU rRNA	5'-TGTGAGACTCAATGCGCCTA-3' (universal)	
<i>T. sergenti</i>	Forward	5'-TATGTTGTCCAAGAGATCGT-3'	Kawazu et al 1992b
	Reverse	5'-TGAGACTCAGTGCGCCTAGA-3'	
<i>T. sergenti</i>	Forward	5'-CACGCTATGT'GTCCAAGAG-3'	Tanaka et al 1993
	Reverse	5'-TGTGAGACTCAATGCGCCTA-3' (universal)	
<i>T. sergenti</i>	Forward	5'-CAGTACCTCGATGAAGTTGTA-3'	Jeong et al. 2003
	Reverse	5'-CGAGTCTTACGACTTTCTTCT-3'	
	Probe	[6FAM]-CTCGACGCATCCAAGTTCGCAG-[TAMRA]	
<i>T. orientalis</i>	MPSP-F	5'-CTTTCCTAGGATACTTCCT-3'	Ota et al. 2009
	MPSP-R	5'-ACGGCAAGTGGTGAGAACT-3'	
<i>T. orientalis</i>	MPSP-AJ-F	5'-TTCCTCCAACAGTCGCCCACA-3'	Cufos et al. 2012a
	MPSP-AJ-R1	5'-ACGTAACTTTGACTGCGGTG-3'	
<i>T. orientalis</i>	MPSP-F	5'-GCAAACAAGGATTTGCACGC-3'	Bogema et al. 2015
	MPSP-R	5'-TGTGAGACTCAATGCGCCTAGA-3'	
<i>T. orientalis</i>	Th.oriMPSP-F	5'-TCCTTGTTGCCTCGCTCTGCT-3'	Pulford et al. 2016b
	Th.oriMPSP-R	5'-AGGCAGGTCTTTTGCCGCTGA-3'	
<i>T. orientalis</i>	MPSP-AJ-F	5'-TTCCTCCAACAGTCGCCCACA-3'	Cufos et al. 2012a
	MPSP-AJ-R1	5'-ACGTAACTTTGACTGCGGTG-3'	
<i>T. orientalis</i>	SSU-rRNA Foward	5'-ATTGGAGGGCAAGTCTGGTG-3'	Kamau et al 2011a
	SSU-rRNA Reverse	5'-CTCTCGGCCAAGGATAAACTCG-3'	
<i>T. orientalis</i>	rRNA ITS1 Forward	5'-CGCTTGTTGAGAGGATGCCT-3'	Kamau et al. 2011b
	rRNA ITS1 Reverse	5'-CCTTCATCGTTGTGTGAGCCAA-3'	
<i>T. orientalis</i>	rRNA ITS2 Forward	5'-TGGCTCACACAACGATGAAG-3'	Kamau et al. 2011b
	rRNA ITS2 Reverse	5'-GGTCACTGAAATGGGAGTAC-3'	
<i>T. orientalis</i>	SSU-F	5'-GGTGAAACTGCGAATGGCTCA-3'	Islam et al. 2011
	SSU-R	5'-GAATGCCCCCAACTGTTC-3'	
<i>T. orientalis</i>	18S SSU - FThBa	5'-GAGGTAGTGACAAGAAATAACAATA-3'	Gubbels et al., 1999
	18S SSU - RThBa	5'-CTAAGAATTCACCTCTGACAGT-3'	
<i>T. orientalis</i>	p23-F	5'- GTACACACCTTGAAATCTGGC-3'	Ota et al. 2009
	p23-R	5'- CAAGAGAGGCAACAACAACGA-3'	

1.17.4 *Real-time PCR*

The development of real-time PCR (RT-PCR) led to the rapid expansion and acceptance of PCR, owing to its improved rapidity, sensitivity, reproducibility and the reduced risk of carryover contamination compared to traditional amplicon detection methods (Mackay, 2004). The technique

of RT-PCR uses either double strand DNA binding fluorescent dyes e.g. SYBR green or fluorescent probes e.g. Taqman that release fluorescent signals during amplification. With the strength of that signal being directly proportion to the amount of amplicon present.

The invention of Taqman fluorescent probes followed on from the discovery of Taq polymerase and utilize the 5' exonuclease activity of the enzyme Taq polymerase to release the fluorescent signal. Briefly a Taqman probe is an oligonucleotide complementary to an internal portion of the target DNA, between where the forward and reverse primers attach. The probe has a fluorescent reporter dye attached to the 5' end and a quencher dye attached to the 3' end, and whilst they are in proximity the quencher dye suppresses the signal from the reporter dye.

However, during the extension phase of the PCR reaction, the Taq polymerase replicates the template to which the TaqMan probe is bound and in so doing cleaves the probe releasing the fluorescent reporter dye and breaking the influence of the quencher. This process repeats in every cycle and the intensity of the fluorescence increase with the amount of product.

The TaqMan PCR for diagnosis of *T. sergenti* was developed by Jeong et al. (2003) and now is the gold standard for *T. orientalis* Ikeda type diagnosis (Pulford et al. 2016b).

1.17.5 **Multiplex PCR**

Multiplex PCR is a modification of conventional PCR designed to detect mixed infections using several different and unique primers specific to target DNA on each infectious agent. Previously multiplex PCR has been employed to detect concurrent haemoprotozoan infections in cattle e.g. *Babesia bigemina*, *B. bovis* and *Anaplasma marginale* (Figuerola et al. 1993) and this is possibly the strength of multiplex PCR, differentiating between morphologically different species that could all be legitimate differential diagnoses. Several multiplex PCR methods have been developed for *T. orientalis* (Bogema et al. 2015; Gebrekidan et al. 2015, 2017b; Perera et al. 2015a; Perera et al. 2015b), although given that only Ikeda is pathogenic a universal *T. orientalis* probe and a specific Ikeda probe would be enough in my opinion. Furthermore, the p23 gene has been found inadequate to differentiate between the Buffeli and Ikeda types in a multiplex PCR designed to detect, differentiate, and quantify four commonly prevalent pathogenic (Chitose and Ikeda) and non-pathogenic (Buffeli and Type 5) *T. orientalis* types (Gebrekidan et al. 2017b)

1.17.6 **LAMP**

Loop-mediated isothermal amplification (LAMP) was developed in 2000 by the Eiken Chemical Company Ltd., Japan (Notomi et al. 2000) and represents an innovative and significant advancement

in molecular diagnosis and pathogen detection. The technique is claimed to be Simple, Specific, Rapid, Robust, Cost Effective, Isothermal and requires no denaturation. The rapid protocol of loop mediated isothermal amplification (LAMP) is performed at a single temperature, unlike PCR, in a single tube, and has been developed for several disease diagnostic tests, including different species of *Theileria*.

Other advantages of LAMP over standard PCR include a greater detection limit, higher amplification specificity (because it uses 4 to 6 primers) and much quicker (it takes less than 30 minutes to complete). The yield of DNA from LAMP is typically much higher than PCR (50x to 100x) which means diagnosis can be made using relatively simple visualization methods. In addition, the LAMP diagnostic tests can be carried out on crude DNA samples, without complex sample preparation, which makes them suitable for point of contact (POC) tests.

Since a LAMP diagnostic test can be performed at the POC with the patient, it has the potential to provide a rapid easy to use diagnostic tool for New Zealand veterinarians. Current visualisation methods, to determine a positive result from LAMP, are based around conventional molecular biology techniques (UV visualization or fluorescence), however, methods are currently being developed to utilize lateral flow immunoprecipitation and also cell phone cameras.

A LAMP method has recently been developed for detecting *Theileria sergenti*. In which four primers were designed from six distinct regions of the target gene, a 33-kDa major piroplasm surface protein (p33) gene in *T. sergenti* (Wang et al. 2010). This LAMP assay proved to be as specific as, and more sensitive than, conventional PCR.

1.17.7 *Milk testing*

Hammer et al. (2016) were able to demonstrate Ikeda antigens and Ikeda antibodies in 4/30 and 6/30 colostrum milk samples respectively. The benefits to farmers and industry in being able to use bulk milk samples to confirm the Ikeda infection status of a herd would be enormous, as evidenced by the role of bulk milk testing in the monitoring of BVD virus exposure in New Zealand herds (Hill et al. 2010).

1.18 Methods of control of benign theileriosis in cattle

Farm biosecurity measures proved inadequate in the prevention of the spread of TABA in both the New Zealand and Australian epidemics. At the time, it was believed that open naïve herds were likely infected by the introduction of infected cattle and closed naïve herds by the introduction of live

infected ticks from contiguous infected properties, possibly carried by wildlife or feral livestock. In each case the successful introduction of infection required an environment that would support a viable tick population, since non-tick associated transmission of infection was presumed to be rare and unlikely to propagate an outbreak. Non-tick associated transmission may help perpetuate infection in a closed herd when ticks are not present.

Currently the methods used to control benign theileriosis depend upon which region of New Zealand the farm is situated in, i.e. whether the farm is in an endemically stable, an endemically unstable, or a disease-free area (McFadden and Marchant, 2015). In the endemically stable areas, the farm policy revolves around preventing the introduction of naïve animals into an infected herd whereas in the disease-free areas the aim is the reverse, not to introduce infected animals into a naïve herd. Although in areas without ticks, the implications of introducing infected cattle into a naïve herd are low and may be an acceptable risk.

It is in the endemically unstable areas where the future TABA battles will be fought. The long-term aim for farms in the endemically unstable areas should be to reduce the prevalence of naïve adult cattle in their herd and this can only be achieved by deliberately exposing their replacement cattle to infection as calves. For farms in endemically unstable areas, control measures are likely to incur significant financial costs, especially if they require the transporting of replacement cattle to infected areas, in order to become infected during their first grazing season. The alternative strategy of doing nothing on farms in endemically unstable areas will only result in ongoing disease outbreaks, with deaths of peri-parturient dairy cows, and production losses in recovering animals.

Fukasawa et al. (2001) found a strong positive correlation between HCT and plasma phospholipid levels ($r=0.69$, $P<0.01$), a weak negative correlation between HCT and vitamin E ($r=-0.25$, $P=0.06$) and between HCT and IgG ($r=-0.29$, $P<0.01$). They suggested that finding methods to maintain the plasma phospholipid levels may prevent severe anaemia developing with *T. orientalis* infection. It was further shown that increasing the average HCT would increase the average daily live weight gain of infected calves (Fukasawa et al. 2003).

1.18.1 *Minimising other stressors*

The infection intensity peaks around 40 to 60 days post-infection, and since beef calves born in the endemic areas are infected soon after birth it is important to avoid stressful procedures at one to two months of age, such as castrating or dehorning, since this may suppress immunity, resulting in higher infection intensities and more severe anaemias.

The spring calving period on dairy farms coincides with the spring questing period for nymphs so it is important to carefully transition cows to avoid nutritional or physiological stress. In addition to

reducing stress, avoid feeding high brassica diets during the late dry period since brassicas are known to cause red blood cell fragility and subsequent haemoglobinuria. A lower PCV could make the cow more vulnerable to a lower infection intensity of *T. orientalis* Ikeda. Low phosphorus levels, associated with feeding fodder beet or green oats, can also increase RBC fragility and cause haemoglobinuria 2 to 4 weeks post calving.

1.19 Conclusions

Theileria orientalis Ikeda type is a new disease for New Zealand veterinarians and cattle farmers to cope with. Very early in the epidemic it became clear that other countries' experience of this disease was not always transferrable to New Zealand. In many ways the New Zealand experience appears closer to Japan's rather than Australia's, where high levels of clinical disease, deaths and abortion appear to be the norm. This may partly be explained by the high prevalence of other pathogenic haemoparasites in Australia and potentially other stressors, such as drought.

Real time qPCR methods of diagnosis are now well established, are available through the private diagnostic laboratories and offer an accurate method of disease diagnosis especially in animals with chronic infections. As a result of educational work carried out by MPI and the NZVA, veterinarians are better able to recognise the disease and treat anaemia, however control of the disease in the unstable endemic regions of New Zealand will continue to be a challenge. The long-term use of buparvaqone is untenable and work should be initiated on either developing a new chemotherapeutic agent for treating *T. orientalis* Ikeda type infection or a subunit vaccine against either *T. orientalis* Ikeda type or the biological vector *H. longicornis*.

Chapter 2

Epidemiology of the epidemic of bovine anaemia associated with *Theileria orientalis* Ikeda type between August 2012 and March 2014

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2.1 Preface

The data presented here was collected whilst I worked as an exotic disease incursion officer at the Ministry for Primary Industries from February 2013 to February 2014.

2.2 Abstract

AIMS: To describe the epidemiology of the epidemic of bovine anaemia associated with *Theileria orientalis* infection (TABA) in New Zealand between 30 August 2012 and 4 March 2014.

METHODS: Blood samples and associated data were obtained from cases of TABA. The case definition for TABA was met when piroplasms were present on blood smears and the haematocrit was ≤ 0.24 L/L. Samples were analysed using quantitative PCR (qPCR) assays for the detection of *T. orientalis* Ikeda type. Only cases that were positive in the qPCR assays were included in the analysis. A case herd was defined as a herd that had ≥ 1 animal positive for *T. orientalis* Ikeda.

Movement records for farms were accessed through the national animal identification and tracing scheme (NAIT). The OR for cattle movements onto a case compared to a non-case farm was estimated using a generalised estimating equation model and the geodesic distance for movements onto case and non-case farms compared using Student's *t*-test. The kernel smoothed risk of disease at the farm level was calculated using an extraction map and the clustering of diseased farms in time and space was measured using the spatial temporal inhomogeneous pair correlation function.

RESULTS: In the first 18 months there were 496 case herds; 392 (79%) were dairy and 104 (21%) beef herds. Of 882 individual cases, 820 (93.0%) were positive for *T. orientalis* Ikeda in the qPCR assays. Case herds were initially clustered in the Northland, then the Waikato region. The OR for a case farm compared to a non-case farm having ≥ 1 inward cattle movements was 2.03 (95% CI=1.52–2.71) and the distance moved was 26 (95% CI=20.8–31.3) km greater for case farms. The risk of disease was highest in a north, north-eastern to south, south-western belt across the Waikato region. The spatial-temporal analysis showed significant clustering of infected herds within 20–30 days and up to 15 km distance from a case farm.

CONCLUSIONS: *Theileria orientalis* Ikeda type is likely to have been introduced into regions populated with naïve cattle by the movement of parasitaemic cattle from affected areas. Local spread through dispersed ticks then probably became more important for disease transmission between herds once the disease established in a new area.

CLINICAL RELEVANCE: Dairy and beef farming in the North Island of New Zealand will be significantly changed in the coming years by the incursion of this new disease.

2.3 Introduction

Bovine *Theileria* species are tick-borne intracellular haemoprotozoan parasites that cause severe and mild infections in ruminants worldwide (Aktas et al. 2006; Eamens et al. 2013b). *Theileria* species are widely distributed around the world, although the distribution of individual species is largely dependent on the distribution of the relevant tick vector. Consequently some species, such as the highly pathogenic lymphoproliferative *T. parva*, the cause of East Coast Fever, occupy defined geographical distributions, whilst other species such as the *T. orientalis* group, known as benign or oriental *Theileria*, are much more widely disseminated due to the cosmopolitan distribution of suitable tick vectors in the genus *Haemaphysalis* (Hoogstraal et al. 1968; Yokoyama et al. 2012). Although generally classed as benign, it is well established that at least some types of *T. orientalis* can cause anaemia, jaundice, abortion and death in naïve cattle, particularly if they have been stressed or debilitated in some way (Thompson 1998; McFadden et al. 2011). Eleven types of *T. orientalis* have been recognised based on their major piroplasm surface protein nucleotide sequences. Those named using this classification include Type 1 (Chitose), Type 2 (Ikeda) and Type 3 (Buffeli); with the remaining Types 4–8 and Types N1–N3 yet to be allocated taxonomic names (Khukhuu et al. 2011; Watts et al. 2016).

Theileria orientalis was first reported in Australia in 1910 (Kamau et al. 2011a) but was only reported in New Zealand for the first time in 1982 on a dairy farm near Wellsford (James 1984; James et al. 1984). The ensuing New Zealand epidemic covered the period 1982–1986, with herd outbreaks involving one or more sick cattle peaking at 60 in 1985 (Thompson 1991). Most of these outbreaks were in the Northland region and a small number were seen in the Bay of Plenty. At the time it was believed that *T. orientalis* had been imported into New Zealand by subclinically infected parasitaemic cattle (Thompson 1991). The only known competent arthropod vector for *T. orientalis* in New Zealand is the three-host tick *Haemaphysalis longicornis*, which is the only tick that infests livestock in New Zealand (Heath 2016). *H. longicornis* is classified as a three-host tick because each stage of the life cycle, the larvae, nymphs and adults, feed on different hosts which, in the case of *H. longicornis*, are usually, but not necessarily always, ruminants. *H. longicornis* is widespread in the North Island, and it is haematophagous during all active life stages (Heath 2016).

In late 2012 there were reports that a new epidemic of infectious anaemia associated with *Theileria* was affecting cattle in the upper North Island, and most of the initial notifications were in the

Northland region (Pulford et al. 2016a). Northland is the most northern of New Zealand's regions. Because of its sub-tropical climate, it has long been considered that ticks were more suited to Northland than elsewhere in New Zealand (Myers 1924). Furthermore, during the recent epidemic there was anecdotal evidence from rural practitioners that calves in Northland, and in particular beef calves, were suffering a greater incidence of clinical disease than were adults.

The aim of this paper is to describe the first 18 months of the epidemic of bovine anaemia associated with *T. orientalis* infection (TABA) in New Zealand, covering the period from the 30 August 2012 to 4 March 2014, and to investigate differences in the risk of disease for beef and dairy calves, to compare the frequency of movements and the distance moved of cattle onto case and non-case herds and to understand the spatial-temporal pattern of the epidemic.

2.4 Materials and methods

2.4.1 *Data collection*

Data on reported outbreaks of TABA were requested from the regional veterinary laboratories (New Zealand Veterinary Pathology and Gribbles Veterinary Pathology) under Section 46 and 48 of the Biosecurity Act 1993. Specific farm details relating to the affected animals were obtained from the laboratory submission forms or directly from the referring veterinary practice.

The data made available were often incomplete but could include owner name and address, date of sampling, the sex and age (adult or calf) of affected animal, type of farm (dairy or beef) and varying amounts of clinical history. Affected cattle sampled by veterinarians in the field usually showed a combination of the following clinical signs; anaemia, lethargy, production drop, anorexia, ill-thrift, diarrhoea, constipation, jaundice, collapse, pale udders, possible haemoglobinuria, and inappetance.

2.4.2 *Haematological examinations*

For each blood sample examined by the regional veterinary laboratories a thin blood smear was prepared, stained with Leishman's stain and examined under oil immersion using light microscopy. Erythrocytes were examined for the presence of signet or coma ring-shaped organisms consistent with merozoites of *Theileria* spp. piroplasms. Initially the laboratories were requested to report the number of infected red blood cells (RBC) per 1,000 RBC observed; however, when it became clear that the number of *Theileria* poorly predicted the degree of anaemia seen in the affected animal the counting requirement was simplified to reporting the presence or absence of piroplasms. In addition, the haematocrit (HCT) was measured for each submitted sample using either the Sysmex XT-2000i

(Sysmex Corporation, Japan) or the Cell-Dyn 3700 (Abbott Laboratories, Philippines) automated haematology analyser, if the samples were sent to New Zealand Veterinary Pathology or Gribbles Veterinary Pathology, respectively.

2.4.3 *Molecular testing*

The case definition for submission of a blood sample from an outbreak of TABA for molecular evaluation at the Animal Health Laboratory (AHL; Wallaceville, Upper Hutt, NZ) was met where suspected *Theileria* spp. piroplasms were present on a blood smear and the HCT was ≤ 0.24 L/L. When this case definition was met the EDTA-treated whole blood, or occasionally serum, was made available to the AHL by the regional veterinary laboratories.

In addition to these referred samples, there was retrospective testing of banked serum, routinely collected each year for arbovirus surveillance from 10–25 herds around New Zealand. The serum was stored at the AHL and was tested using the same molecular methodology as the EDTA samples. The cattle sampled within each of these surveillance herds were randomly selected and did not necessarily have either anaemia or piroplasms present in blood. The surveillance samples selected for molecular testing were from herds in recognised tick areas i.e. the top of the South Island and the upper North Island and covered the period December 2008 to December 2012 but did not include 2010. For these samples, molecular testing was carried out on pooled samples collected from approximately 12 cattle per herd, in order to give an indication of when *T. orientalis* Ikeda type may have first appeared in New Zealand. There were 101 herd pooled serum samples available for testing.

For a full description of the molecular techniques undertaken see Pulford et al. (2016b). Briefly, EDTA-treated blood samples were routinely diluted 1:5 in sterile water prior to DNA extraction, whereas serum samples were used undiluted. Samples were processed on a Corbett Extractorgene robot (Qiagen, Germany) to extract DNA which was eluted in 200 μ L of diethylpyrocarbonate treated sterile water. All purified DNA samples were subject to an 18S quantitative PCR (qPCR) to measure sample consistency and the absence of PCR inhibitors. Samples were then analysed using two different qPCR assays, a *T. orientalis* high resolution melt (HRM) assay and an Ikeda type-specific TaqMan qPCR assay. The qPCR results with a quantification cycle threshold ≤ 38 were recorded as positive, >38 as suspicious and samples with no signal were considered negative. There were potentially 3 combinations of results; a sample could be positive in both the *T. orientalis* and the Ikeda-specific qPCR, a sample could be positive in the *T. orientalis* and negative in the Ikeda-specific qPCR and a sample could be negative in both the *T. orientalis* and the Ikeda-specific qPCR. These results were interpreted as follows; both assays positive meant that the sample included Ikeda and could be a unique or mixed infection with other unknown *T. orientalis* types, if only the *T. orientalis*

assay was positive meant that the sample contained a unique or mixed infection of unclassified *T. orientalis* types (other than Ikeda) and if both assays were negative meant no *T. orientalis* types present. Only samples that tested positive in both assays were considered positive for Ikeda. PCR analysis was carried out solely by the AHL until January 2014 when the work was ceded to the private laboratories. The same molecular techniques developed at the AHL were used, but only the Ikeda type specific TaqMan qPCR was run. Results were then reported as either *T. orientalis* Ikeda-positive or negative.

2.4.4 *Definitions*

Only one clinical case of TABA Ikeda type was observed in the South Island, so the descriptive and analytical epidemiology is restricted to the North Island of New Zealand. The case definition used in this analysis was applied at the herd level. Thus, a case herd was defined as a herd that had at least one animal positive for TABA. Where Ikeda type was confirmed using PCR analysis, the herd was referred to as TABA Ikeda type positive. Only cases where Ikeda type was confirmed using PCR analysis were included in the statistical analysis, except for several Northland case farms that were diagnosed in the very early stages of the epidemic. On these farms the Ministry for Primary Industries (MPI) investigators were satisfied that the clinical evidence indicated the farm was experiencing an outbreak of TABA Ikeda type. Where outbreak farms had multiple submissions, the date of the first submission was used as the notification date for that farm. In addition, where the age of affected cattle changed over time, the age of cattle affected at the first notification was used for analytical purposes. An animal recorded as aged 1–6 months on the laboratory submission form was entered as a calf, otherwise as an adult. The main production type of the case farm was recorded as beef or dairy, and where non-lactating dairy cattle were affected at a grazier's farm the case was entered as dairy. There were only a small number of these latter cases, so any associated misclassification bias was minimal.

The Cartesian X and Y coordinates (New Zealand Transverse Mercator 2000 projection) of the centroid for each affected farm were obtained from Farms on Line (<http://farmsonline.maf.govt.nz/>) and used as the geographical location of farms for the purposes of spatial analysis. Movement records for affected farms were accessed through the National Animal Identification and Tracing (NAIT) scheme (<http://www.nait.co.nz/>), which records cattle movements between people in charge of animals. A unique NAIT number links a person in charge of animals to a property identified through Farms on Line. The scheme allows for a one-to-many relationship between people in charge of animals and properties, such that each person in charge of animals can have more than one property and each property can have more than one person in charge of animals, provided the animals are kept separate. Where a person in charge of animals has two or more properties <20 km apart, only one

NAIT number is required for them all. The NAIT scheme only became mandatory for cattle movements from 1 July 2012 so records for the early part of the epidemic were incomplete.

Over 30 unique combinations of production type are recorded for farms in NAIT and these were reclassified as dairy, beef or other. Any farm that listed dairy as one of its production types was classed as dairy, similarly any farm that had not listed dairy but listed beef as one of its production types was classed as beef and all other farms that were neither dairy or beef were classed as other. Thus, a farm that described itself as both dairy and beef was classed as dairy for the purpose of the analysis.

The epidemic was divided into three time periods, of approximately 6 months duration; Period 1 was between 30 August 2012 and 28 February 2013, Period 2 between 1 March 2013 and 31 July 2013, and Period 3 between 1 August 2013 and 4 March 2014.

2.4.5 *Statistical analysis*

Analysis of variance was used to test the null hypothesis that the mean HCT of *T. orientalis* Ikeda type-positive cattle, non-Ikeda *T. orientalis*-positive cattle and PCR-negative cattle were the same. Tukey's honest significant difference, using a significance of 0.05, was used to control the Type 1 error rate for multiple comparisons (Tukey 1949).

The Mantel-Haenszel method (Mantel and Haenszel 1959) was used to test the null hypothesis that there was no difference in the risk of disease for beef or dairy calves stratified by region (Northland or all other regions of the North Island). This method provides both a crude and adjusted measure of association, based on combining weighted averages of stratum specific measures. It assumes that the measure of association is homogenous across strata and the Breslow-Day statistic tests the null hypothesis that the strata are homogenous. However, this test is considered to have low power and some authors advocate a significance level of 0.1 or even 0.15 to compensate (Fleiss et al. 2013). If the test for homogeneity is significant then interaction is present and the measure of association for each stratum is presented separately. If the test for homogeneity is not significant then the crude and adjusted measures are compared. If there is a >10% difference in their values, then confounding is assumed to be present and the adjusted measure is quoted. If the crude and adjusted measures are similar, then confounding is not serious, and the crude measure is correct.

Using the NAIT cattle movement records a generalised estimating equations (GEE) model was constructed with the outcome variable being whether a farm had an inward movement of cattle during the period from 1 July 2012 to 4 March 2014 or not. Only two categorical explanatory variables were tested in the model, whether the farm was a TABA Ikeda type case farm or not, and farm production

type (beef or dairy). The full data set was reduced to include only movements to farms with the same post codes as the case farms and with the same production type as the case farms. Farms that were classified as other for production type were dropped from the analysis. This gave a final data set for GEE modelling with cases and non-cases matched on postcode and production type, with the postcode used as a grouping variable in the GEE model. Explanatory variables were retained in the model at $p < 0.05$ using the Wald statistic and an exchangeable correlation structure was used along with a binomial link function. GEE models are a very flexible tool for dealing with correlated data (Liang and Zeger 1986; Zeger and Liang, 1986) and can be expected to produce a robust estimate of the standard errors for the parameters in the model. GEE models differ from random effects or multilevel models in that they produce a population-averaged interpretation through using a weighted combination of observations based on the within cluster correlation.

Using the same data set, the geodesic distance from the farm where the cattle movement originated, to the farm where the movement terminated, was calculated using Pythagoras's theorem and compared for case and non-case farms using Student's *t*-test.

All the farm data and laboratory results were entered and maintained in an Access 2007 database (Microsoft Corporation, Redmond, Washington, USA). All analyses were undertaken using R v3.0.2 (R Development Core Team, 2010; R Foundation for Statistical Computing, Vienna, Austria).

2.4.6 Exploratory spatial data analyses

First-order spatial effects describe the way in which the intensity of the diseased farms varies spatially across the North Island (large-scale trends) and second-order spatial effects capture the dependency between diseased farms in space and time (small-scale effects). The first- and second-order spatial effects of the epidemic were investigated.

An extraction map of disease risk at the farm level was prepared using the Farms on Line X and Y Cartesian coordinates for each cattle holding (Rowlingson et al. 2005). An extraction map represents the ratio of two kernel smoothed intensity layers, the farm cases being the numerator layer and the at-risk population the denominator layer. The at-risk population included all the cattle holdings in the North Island, both dairy and beef farms, recorded in the Farms on Line database ($n=36,496$). The resulting ratio surface represents the spatial distribution of the cumulative disease risk of TABA Ikeda type-positive farms over the first 18 months of the outbreak. Both kernel smoothed density layers were generated using a bivariate quartic kernel with a fixed bandwidth of 20 km projected onto 1 km^2 grids. The bandwidth was selected through a combination of methods that included least squares cross validation, plausibility and exploratory plots of test bandwidths. The more computer intense adaptive

smoothing techniques, although potentially offering some advantages in plot detail, took too long to converge and were rejected.

On the assumption that infectious diseases are characterised by cases occurring close to each other in time and space, the second order spatial effects were analysed using the spatial temporal inhomogeneous pair correlation function (Gabriel et al. 2013). This function relates to the relative positions of pairs of events, defined in space and time, and indicates how much more or less likely it is that a pair of events will occur at specified spatial temporal locations than predicted by an inhomogeneous Poisson process with the same intensity. An inhomogeneous point process is one in which the average intensity of points varies spatially. In this case the intensity of cases of TABA Ikeda type could vary with the density of tick habitats or the density of cattle farms. The pair correlation function describes the effect or interaction of one point on the spatial temporal configuration of another point, where a pair correlation function >1 means there is significant aggregation of points, equal to one means there is a random distribution of points and <1 means the points are uniformly distributed.

2.5 Results

The first notifications of cases of regenerative anaemia, subsequently determined to be TABA Ikeda type were reported to MPI on the 30 August 2012 and 7 September in dairy herds in Reporoa, Waikato and Kamo, Northland, respectively. Between 30 August 2012 and 4 March 2014, 496 herds were recorded with ≥ 1 clinical case of TABA. During the period when only the AHL carried out the PCR analysis, 882 samples from 494 unique cattle farms were submitted for qPCR analysis, which met the case definition for submission. Of these, 820/882 (93.0 (95% CI=91.1–94.5)%) were positive in both the *T. orientalis* and the Ikeda-specific qPCR assays, 43/882 (4.9 (95% CI=3.6–6.5)%) were positive in the *T. orientalis* qPCR, but negative in the Ikeda-specific qPCR assay, and 19/882 (2.1 (95% CI=1.4–3.3)%) were negative in both qPCR assays, despite being positive on blood smears.

The median number of submissions per case farm was 1 (inter-quartile range (IQR) 1–3). Of the 43 samples that were *T. orientalis*-positive but Ikeda-negative, 33 came from 30 herds for which this was the only isolate and 10 samples came from 10 herds which had multiple sample submissions, including at least one positive for *T. orientalis* Ikeda type. Of the 19 samples that were negative in both *T. orientalis* qPCR assays, 15 came from 15 herds for which this was the sole submission and four samples came from four herds which had multiple sample submissions, including at least one positive for *T. orientalis* Ikeda type.

For samples that were positive for *T. orientalis* Ikeda type, the mean HCT (0.14 L/L) was less than for samples that were non-Ikeda *T. orientalis*-positive (0.18 L/L) ($p<0.001$), or were negative in both qPCR assays (0.17 L/L) ($p=0.02$). There was no difference in mean HCT of samples that were non-Ikeda *T. orientalis*-positive or qPCR-negative ($p=0.78$).

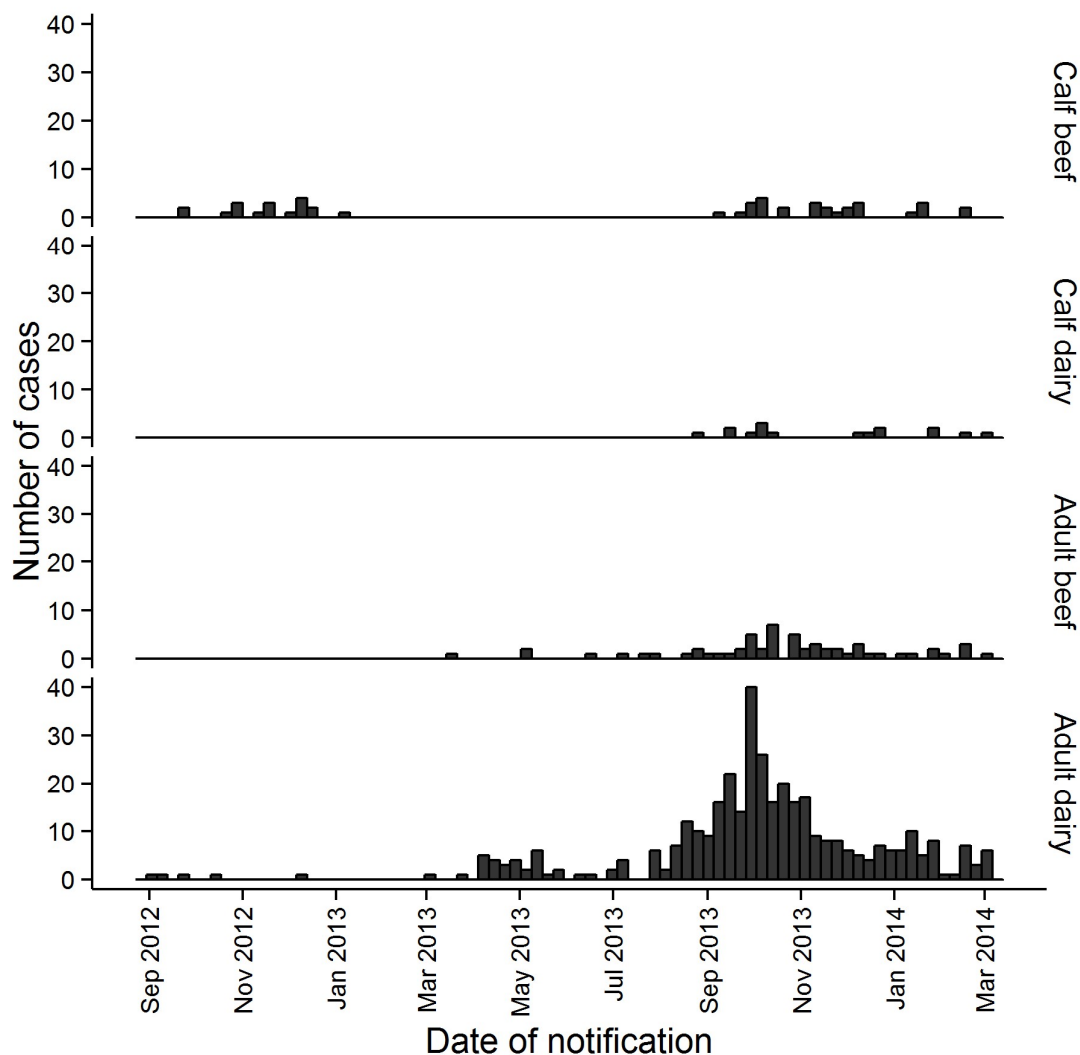


Figure 2-1. Number of herds with ≥ 1 case of anaemia associated with *Theileria orientalis* Ikeda type diagnosed between 30 August 2012 and 4 March 2014 in the North Island of New Zealand, categorised by farm type (beef or dairy) and whether the index case was a calf (1–6 months old) or adult. The bin width is 7 days.

Figures 2-1 and 2-2 show that in Period 1 most case herds of TABA Ikeda type were clustered in the Northland region; primarily affecting calves in beef herds. By Period 2 the focus of infection had moved south to the Waikato region and was affecting predominantly adult cows in dairy herds; at the time these were believed to be mostly autumn or split calving herds. There then followed an exponential increase in the number of cases during Period 3 when dairy calves were also affected for the first time.

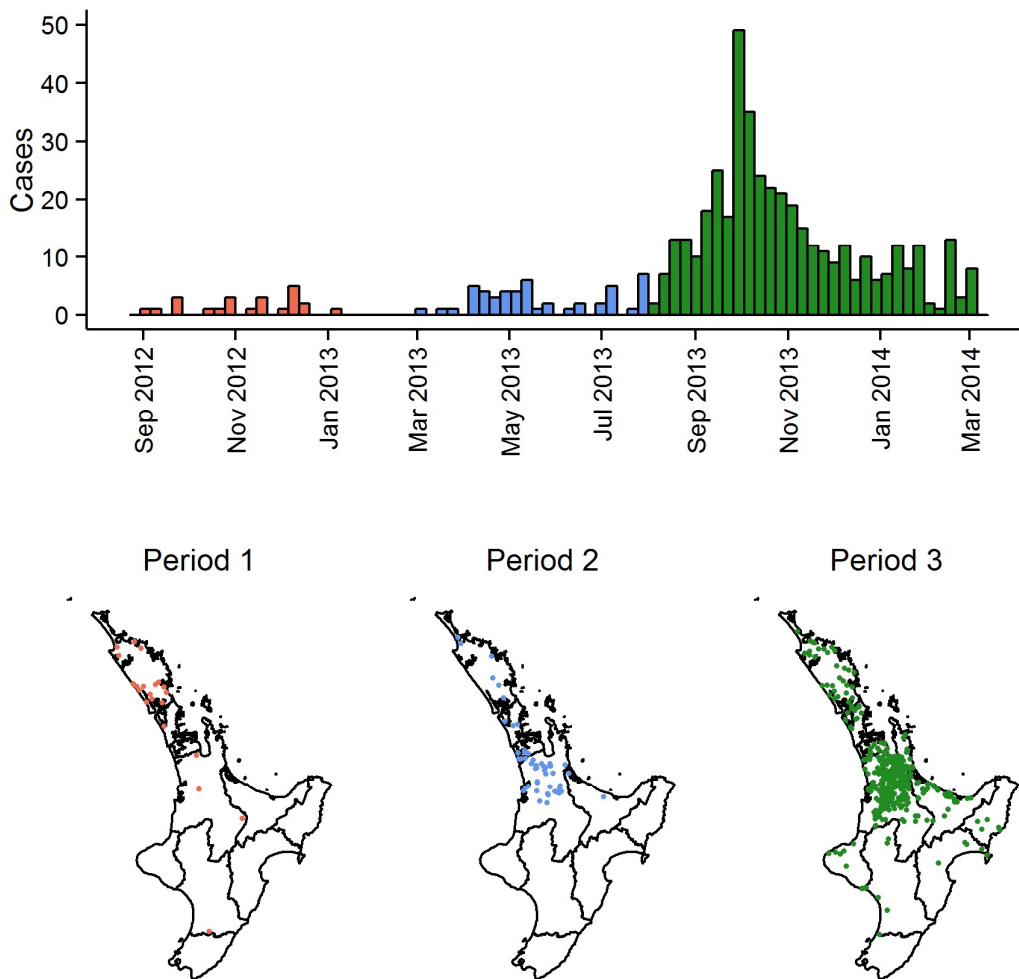


Figure 2-2. Number of case herds with ≥ 1 case of anaemia associated with *Theileria orientalis* Ikeda type diagnosed between 30 August 2012 and 4 March 2014, and the spatial distribution of case farms in the North Island of New Zealand during Period 1 (30 August 2012 to 28 February 2013), Period 2 (1 March 2013 to 31 July 2013), and Period 3 (1 August 2013 to 4 March 2014). The bin width is 7 days.

The number of cases of TABA Ikeda type per week peaked during the week of 1 October 2013 at close to 50 cases (Figure 2-2). Overall, 392/496 (79% (95% CI=75.1–82.5)) cases were reported in dairy herds and 104/496 (21% (95% CI=17.5–24.9)) in beef herds. There was a relatively long period from mid-December 2012 to the end of March 2013 when there were only four cases of TABA (Ikeda). In contrast, for the equivalent period 12 months later the epidemic curve continued to rise (Figure 2-3).

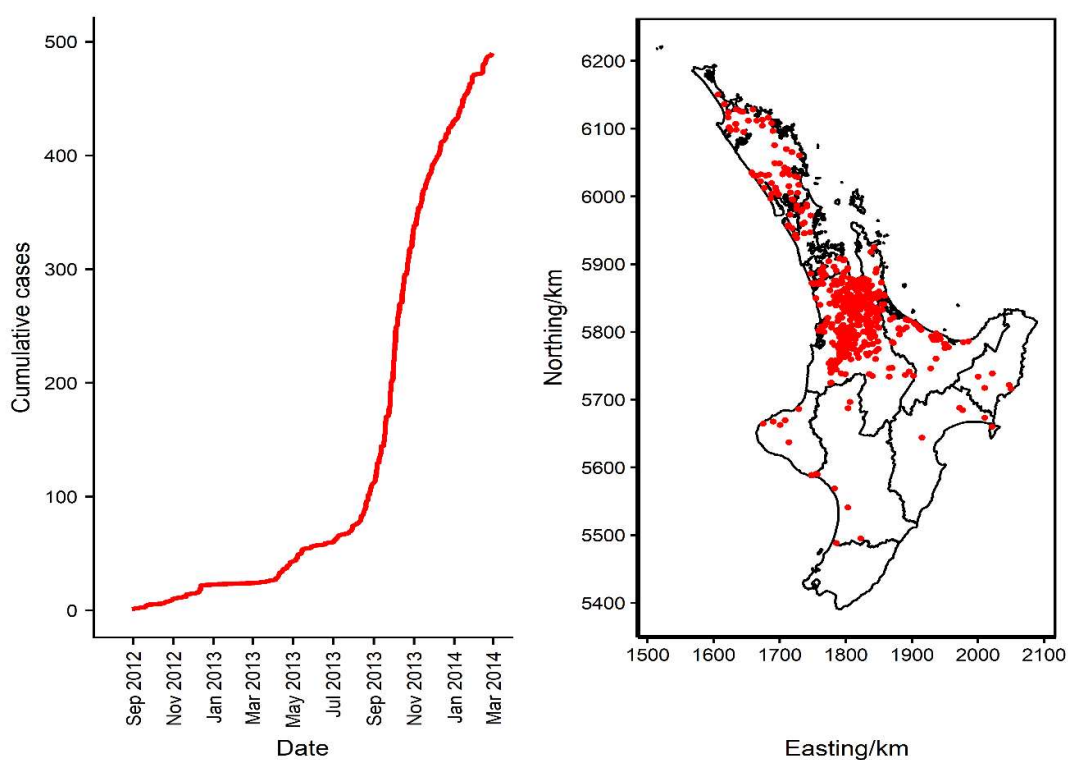


Figure 2-3. The left plot shows the spatial distribution of all case farms in the North Island of New Zealand, and the right plot shows the cumulative number of case herds by date, with ≥ 1 case of anaemia associated with *Theileria orientalis* Ikeda type diagnosed between 30 August 2012 and 4 March 2014.

Across the North Island affected calves were more often seen on beef farms than on dairy farms (Table 2-1).

Table 2-1. Number of cases of anaemia associated with *Theileria orientalis* Ikeda type infection on beef and dairy farms, in calves (1–6 months old) and adults, for three time periods during the first 18 months of the epidemic of infection with *T. orientalis* Ikeda type.

Period	Start date	End date	Calf beef	Adult beef	Calf dairy	Adult dairy	Total
Period 1	30 August 2012	28 February 2013	18	0	0	5	23
Period 2	01 March 2013	31 July 2013	0	7	0	44	51
Period 3	01 August 2013	04 March 2014	28	51	16	327	422

As an age group, calves were more often affected in Northland 42/74 (56.8% (95% CI=45.4–67.4)) than the rest of the North Island 20/422 (4.7% (95% CI=3.1–7.2)). The results of the Mantel-Haenszel analysis of the association between age and farm type, stratifying by region, showed that the Breslow-Day test was not significant ($p=0.16$), indicating that the association between animal age and farm

type was not different across farms from Northland and elsewhere in the North Island. Nevertheless, the overall crude and adjusted OR were markedly different, indicating that there was still some confounding by region. The adjusted OR (adjusting for region) showed that the odds of a beef farm having an affected calf were 8.4 (95% CI=4.4–15.9) times the odds of a dairy farm having an affected calf. Collapsing the data over farm type, the odds of a dairy or beef farm in Northland having an affected calf were 26.0 (95% CI=13.2–52.9) times the odds of a dairy or beef farm elsewhere in the North Island having an affected calf.

From the reduced NAIT data set there were 19,614/24,823 farms with the same post codes and production types as the case farms that received ≥ 1 cattle movement between 1 July 2012 and 4 March 2014. Within the 24,823 farms there were 185 postcodes with a mean of 134 (min 7, max 524) farms per post code. Adjusted for farm production type, the odds of a case farm receiving ≥ 1 cattle between 1 July 2012 and 4 March 2014 were 2.03 (95% CI=1.52–2.71) times the odds for a non-case farm. The odds of a dairy herd receiving ≥ 1 cattle were 1.86 (95% CI=1.74–1.99) times the odds for a beef farm. There was no interaction between whether a farm was a case farm and its production type. The mean geodesic distance for movements onto case farms was 84.4 km compared to 58.4 km for non-case farms ($p < 0.001$). Thus farms from where the cattle movement originated were 26 (95% CI=20.8–31.3) km further away from the destination farm for case compared with non-case farms.

2.5.1 *Exploratory spatial data analyses*

The risk of disease was highest in a north, north-eastern to south, south-western belt across the Waikato region, with the highest cumulative incidence of $>8\%$ of cattle holdings with clinical disease occurring in the Hauraki plain between Hamilton and Ngatea (Figure 2-4).

The pair correlation function, examining case farms by time and distance, showed one very strong cluster of case farms at 20–30 days and 5–20 km from another case farm and a second weaker aggregation of cases that occurred within 5 days and up to 20 km from another case farm (Figure 2-5).

2.5.2 *Retrospective testing*

Of the 101 herd pooled samples collected between December 2008 and December 2012, 32 (32%) were positive for *T. orientalis* with six (6%) positive for the Ikeda type. The Ikeda type was not detected between December 2008 and March 2011, although no samples were collected in 2010. One pooled sample, from Helensville (Auckland region), was positive for Ikeda in December 2011, and five pooled samples were positive in December 2012. They were from Whangarei, Kaitaia, Dargaville

(Northland region), Raglan (Waikato region) and Helensville. No clinical cases were reported on any of these Ikeda-positive farms.

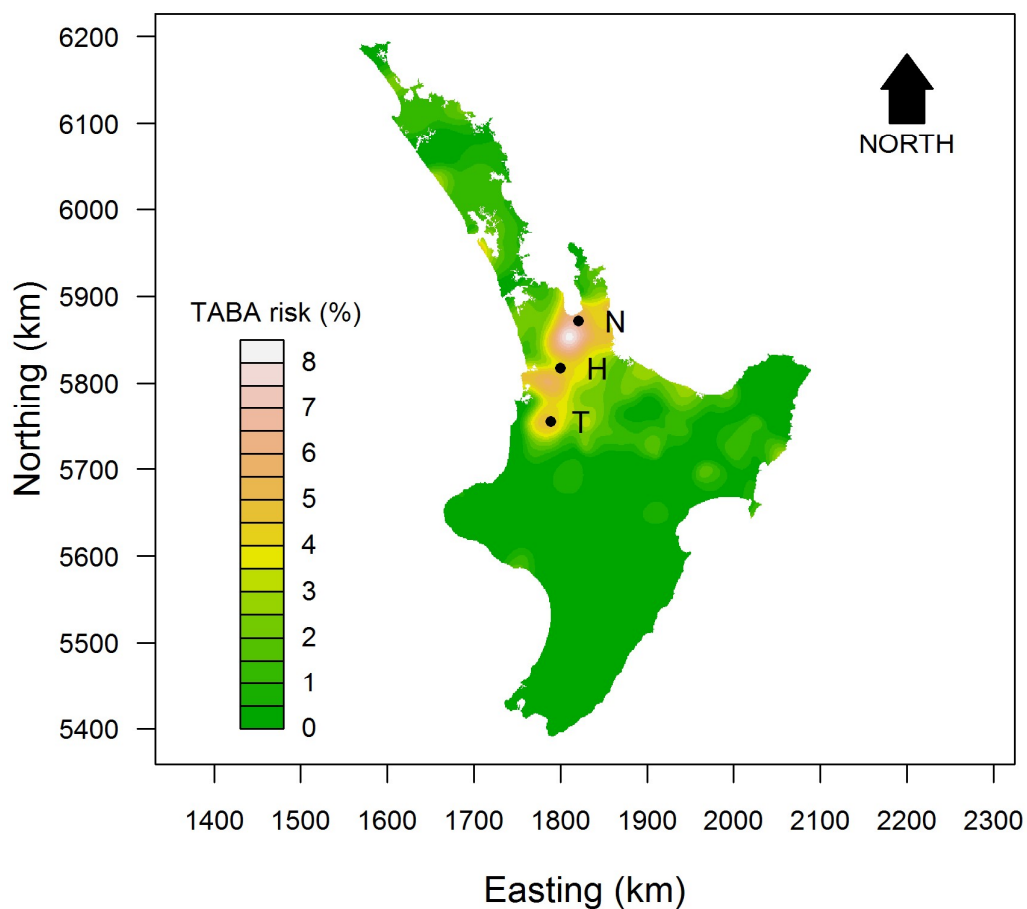


Figure 2-4. Extraction map showing the spatial distribution of the risk (%) of anaemia associated with *Theileria orientalis* Ikeda type (TABA) at the farm level across the North Island of New Zealand between 30 August 2012 and 4 March 2014. N = Ngatea, H = Hamilton and T = Te Kuiti.

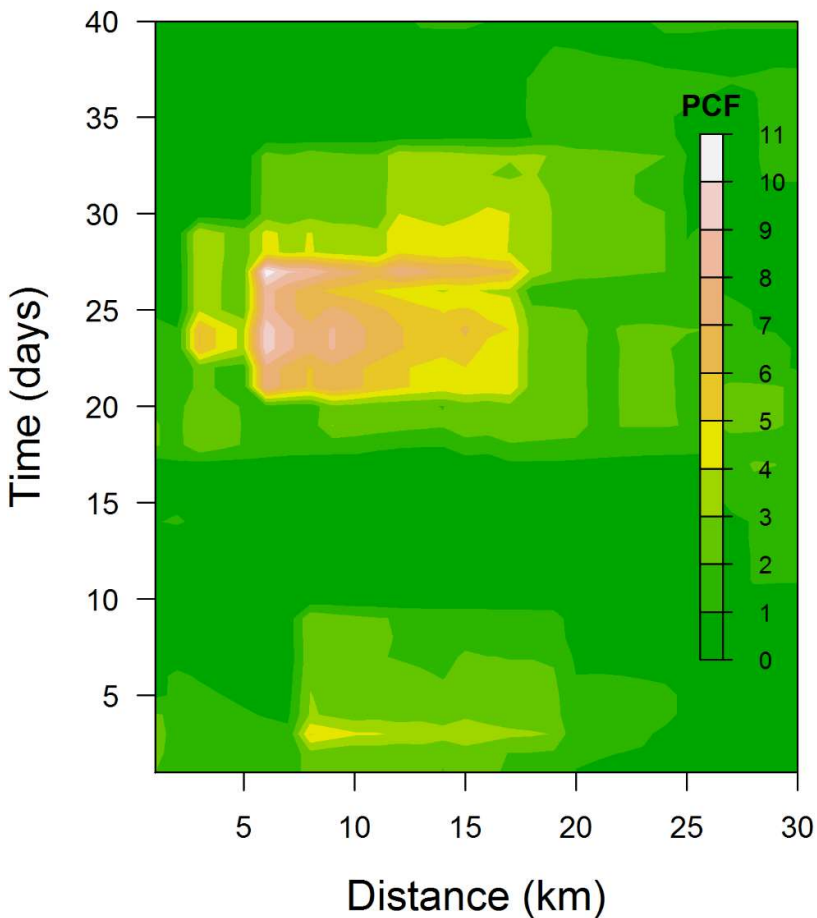


Figure 2-5. Contour plot showing the temporal spatial clustering of case herds with anaemia associated with *Theileria orientalis* Ikeda type diagnosed between 30 August 2012 and 4 March 2014. There are two main temporal spatial clusters, the strongest at approximately 20–30 days and up to 20 km from another case farm and the weaker occurring within 5 days and up to 20 km from another case farm. Clustering is indicated when the pair correlation function (PCF) is >1 .

2.6 Discussion

The epidemic of anaemia associated with *T. orientalis* infection in New Zealand reached 496 farms in just over 18 months. In comparison, the Australian epidemic took approximately 7 years to reach the same number of infected farms (Perera et al. 2014). Whilst there may be differences in disease reporting and tick distribution between the two countries the speed and extent of disease spread in New Zealand was dramatic.

This study found that 93% of submitted samples were positive for *T. orientalis* Ikeda type in the qPCR assays, compared with 97% of samples in Australia that were positive on blood smears from herds suspected of having TABA being Ikeda-positive (Eamens et al. 2013a). The main difference between the two studies is the finding that 4.8% of laboratory submissions in New Zealand were *T. orientalis*-positive but Ikeda-negative. Three non-Ikeda *T. orientalis* types have been confirmed as present in New Zealand and these are Type 1 (Chitose), Type 3 (Buffeli) and Type 5 (Pulford et al. 2016b). *Theileria orientalis* (Chitose) is known to cause anaemia in some affected animals (McFadden et al. 2011), whereas *T. orientalis* (Buffeli) is truly benign (Watts et al. 2016) and little is known about the pathogenicity of Type 5.

For samples to be accepted for qPCR testing by the AHL the animal had to be both anaemic and have a positive blood smear result. It is likely that this case definition, although robust, may have led to under enrolment of cases. Eamens et al. (2013a) found that 57% of samples from animals that were smear-negative from herds suspected of having TABA were positive for *T. orientalis* Ikeda type in a PCR assay. Perera et al. (2013) estimated the sensitivity and specificity of blood smears for detecting *T. orientalis* as 39% (95% CI=32–46) and 100% (95% CI=95–100), respectively. Furthermore, the removal of parasitised erythrocytes by the spleen can be highly variable such that some animals can have a high level of parasitaemia and yet not have a haematocrit low enough to be classed as anaemic (Biddle et al. 2013). It is well established that there is a close relationship between HCT and counts of RBC, however a cut point of $<5.0 \times 10^{12}$ RBC as a measure of anaemia was shown to be a better predictor of animals positive for Ikeda in a PCR assay compared to HCT <0.24 L/L; 24% of animals positive using PCR had a RBC $<5.0 \times 10^{12}$ compared to only 7.8% with an HCT <0.24 L/L (Perera et al. 2013). Automated haematology analysers calculate the HCT by multiplying the RBC count by the mean corpuscular volume (MCV). Since anisocytosis is commonly observed on blood smears from cattle affected with TABA, it is possible that the change in RBC MCV biases the HCT estimation and this accounts for the difference in predictive ability between RBC count and HCT.

The finding that 2.1% of our laboratory submissions were negative in qPCR assays, despite being positive on blood smears, is consistent with that reported by Eamens et al. (2013a) who found 3% of smear-positive samples were PCR-negative. Possible reasons for this include misclassified artefacts on the blood smear, i.e. a false positive, another yet unidentified novel haemoparasite, or insufficient *T. orientalis* DNA present in the blood sample for detection by PCR, i.e. a false negative. The limit of detection for the Ikeda-specific qPCR is one gene copy when using plasmid DNA as a pure source of genetic material (Pulford et al. 2016b) so false negatives are very unlikely.

The likely origin of the 2012 New Zealand epidemic is the importation of parasitaemic cattle. There are no data available to conclusively prove this hypothesis. However, the results from testing the stored arbovirus surveillance sera suggests that, irrespective of the route of entry for *T. orientalis* Ikeda type, this was probably no earlier than 2008 or 2009, which would be after the first notification of TABA Ikeda type in Australia in 2006 (Izzo et al. 2010).

The distribution of *H. longicornis* is widespread in the North Island although the density of ticks in different areas is probably highly variable (Heath 2016); it is likely that in sub-tropical Northland the climate is more suitable for *H. longicornis* and so ticks could be more numerous (Myers 1924). With very few exceptions the TABA Ikeda type cases in the North Island have occurred in recognised tick areas. The only established tick populations in the South Island are around Nelson and Golden Bay (Heath 2016) and since October 2014 there have been a small number of clinical cases reported in the top of the South Island (McFadden et al. 2015)

The Mantel-Haenszel analysis showed that beef calves were at a greater risk of infection with *T. orientalis* than dairy calves and that as an age group calves have a higher infection risk in Northland than further south. These findings could result from higher tick density and an earlier resumption of questing in Northland than further south, ensuring that young calves in Northland, whether from beef or dairy herds, are infected far earlier in life than calves born further south. The diapause in ticks is principally controlled by photoperiod and temperature and in Northland is likely to be restricted to just the month of June, with tick questing resuming by July (Heath 2016). By comparison, to beef calves only a few herd cases were reported in dairy calves (Table 2-1). Data for *T. parva* in Africa has shown that as regions become more endemically stable then the incidence of overt clinical disease falls and is often just restricted to the young calves (Norval *et. al.* 1992). Endemic stability may help explain the apparent low risk of disease in Northland (Figure 2-4) and the propensity to affect calves.

It is possible that the date calves are born and the differing husbandry systems between beef and dairy systems also have marked effects on their exposure to ticks and *T. orientalis*. The start of calving in beef herds tends to be later than dairy herds (McFadden et al. 2005), and dairy calves are housed at birth for 3–5 weeks depending on the weather and so escape early exposure. In contrast, the birth date of beef calves probably coincides with the peak questing activity of over wintered unfed nymphs (Heath 2016).

The initial shape of the epidemic curve in Period 1, as well as the phase from mid-May 2013 to August in Period 2, is highly suggestive of a propagating epidemic (Figure 2-2). It is reasonable to hypothesise that each wave of infected herds, first in the Northland and later in the Waikato regions, acted as a source of infectious ticks that were dispersed locally to infect neighbouring naive cattle

herds. The concept of local spread from infected herds is critical to our understanding of the spread of *T. orientalis* Ikeda type within regions.

Analysis of the NAIT data showed that case farms were 2.03 times more likely than non-case farms to have had inward cattle movements between 1 July 2012 and 4 March 2014 and dairy herds were 1.86 times more likely than beef herds to have had inward cattle movements. This would suggest that for some farms infection has been acquired by inward movements of parasitaemic cattle and could help explain why more dairy farms than beef farms were affected. However, it is important to remember that OR tend to inflate the measure of effect especially when the outcome (i.e. movement) is quite common (Davies et al. 1998), which means that the association, although still significant, may be less strong than it first appears. Therefore, whether these increases in cattle movements are sufficient, on their own, to account for the rapid spread of TABA Ikeda type within New Zealand is difficult to say. The greater geodesic distance of 26 km for cattle movements onto case farms compared to non-case farms could mean that the transported cattle are more likely to originate from infected areas.

When interpreting the spatial-temporal analysis in Figure 2-5 it is useful to imagine a case farm at the origin (0 km, 0 days) and to evaluate the potential disease clustering in time and space from this point. There is a strong cluster of case farms at 20–30 days and up to 20 km distance from a case farm and a weaker aggregation of case farms within 5 days and up to 20 km from a case farm. Possible causes for the weaker cluster of cases, seen within 5 days, could be that these farms have been coincidentally infected by the same method that brought infection to the case farm (at the origin) or that this is a form of detection bias where a veterinarian having observed the condition on the first farm is more actively searching for the disease on farms in the immediate vicinity.

A convincing explanation for the strong cluster of cases seen at 20–30 days and up to 20 km distance is equally challenging and could depend on whether the observed temporal lag of 20–30 days equates to a phase of the tick lifecycle or to the incubation period from infection to disease in naïve cattle. There is only transtadial and no transovarial transfer of *Theileria* spp. in ticks (Higuchi 1985; Izzo et al. 2010), so if the explanation for the strong clustering is the dispersal of infected ticks, then neither fed adults nor unfed newly hatched larvae can transfer the infection to a new host. Therefore, only infected nymphs can be responsible. Hoogstraal et al. (1968) reported that *H. longicornis* nymphs feed for 5–7 days, then drop off to moult for 12–16 days and then rest as adults for 4–6 days prior to questing and feeding as adults. This gives a range of 21–29 days, under ideal conditions, for the nymph stage to be completed which fits within the observed temporal lag. If local spread of infected ticks is the cause then possible animal vectors for the movement of infected ticks include horses, feral

deer, dogs, feral goats, sheep and hares, as ticks are only capable of moving 1–2 m of their own volition (Myers 1924; Heath et al.1987) In certain months of the year European hares (*Lepus europaeus*) are capable of carrying up to 100 ticks on the posterior edges of the ears (Heath et al.1987).

Uilenberg et al. (1985) reported that for the more pathogenic types of *T. orientalis* the prepatent period until parasitaemia in cattle is around 10 days following infection and that the peak parasitaemia is around 30–40 days post infection. The lowest HCT (and most severe clinical signs) usually coincides with peak parasitaemia (Uilenberg et al. 1985; Kawamoto et al. 1991).-The median calving date for dairy cows in the North Island, depending on region, is between 1 and 14 August (Anonymous 2013) and the peak of TABA (Ikeda) cases was seen in early October 2013 (Figure 2-2). Assuming that Uilenberg's observation is correct this indicates that many dairy cows were infected soon after calving, probably by unfed infected nymphs that had overwintered from autumn 2013. If it is the case that many farms were actually latently infected the previous autumn then the tick dispersal mechanism could fit the data, with some of the overwintered unfed nymphs feeding on e.g. hares rather cattle and being transported off the farm to a new property.

Cattle infected with the pathogenic types of *Theileria* spp. are often pyrexia towards the end of the prepatent period, possibly just before piroplasms can be detected by blood smear (Uilenberg et al. 1985). These findings have important implications in the epidemiology of the disease; firstly, by the time cattle are clinically anaemic they may have been infectious to ticks for up to 40 days and, secondly, sick, pyrexia cows examined just before they become parasitaemic (i.e. negative on blood smears) would not have met our case definition and would have been excluded from the analysis. The consequence is that any tick control strategies undertaken after a herd develops clinical cases will more than likely be too late to prevent disease spread within a herd and between properties.

In New Zealand flumethrin treatment has been advocated as a way of moderating the effects of *T. orientalis* Ikeda type in both beef and dairy herds (McFadden and Marchant, 2014). It is not clear how successful these strategies have been, if at all, but clearly better methods of predicting tick activity, such as using cumulative growing degree-days (Moore et al. 2014) to predict when overwintering nymphs will emerge from their seasonal diapause, need to be developed before any real progress can be made in this area.

The high risk of disease in the North, North-Eastern Waikato, Hauraki plains area probably reflects the high density of dairy farms in this area and the environmental conditions, e.g. the 10,000-hectare Kopuatai Peat Dome wetland in the middle of this area, which may allow the tick population to successfully interact with the dairy cattle population. In particular, the re-emergence of over-

wintering nymphs, from the diapause, possibly coincides with the spring calving period in dairy cows. The economic value of the dairy industry compared to the beef industry also meant that there was almost certainly a dairy bias to the data set, which may also explain the apparent lower risk of disease in the Northland region where beef farming is more common.

The period from mid-December 2012 to the end of March 2013 had relatively few cases reported. This probably reflects the spread of the disease from the Northland to the Waikato region. On the one hand in Northland the beef calves were probably old enough to withstand infection without showing clinical signs, and on the other hand in the Waikato region there were relatively few infected unfed adult ticks to spread disease. Disease spread in the Waikato region was almost certainly delayed until the autumn when enough infected nymphs were available to spread the disease to naïve cattle, further complicated by a scarcity of parasitaemic cattle to infect the questing larvae in the first place.

In New Zealand, on 1 June it is common for farms to change ownership or management. Consequently, thousands of cows are moved around this time. The NAIT records for the fortnight covering 1 June 2013 showed that there were just over 26,000 stock movements involving approximately 500,000 cattle. This number is twice the usual number of cattle moved in any other fortnight in the year. The impact of this mixing of naïve ticks and infected herds, and naïve herds and infected tick populations on the spread of *T. orientalis* Ikeda type cannot be underestimated.

The New Zealand outbreak demonstrated significant variation in the impact experienced by dairy and beef farms, with some farms appearing to have only minor impacts whilst in a small number of farms there was significant impact (Vink et al. 2016). However, there have been no rigorous studies completed on the financial costs of *T. orientalis* Ikeda-type on dairy or beef farms in New Zealand. In Australia, Perera et al. (2014) showed a significant effect on production for dairy cows that were clinically ill and PCR assay-positive for *T. orientalis* Ikeda type but no effect on reproduction. The balance of disease effects on a dairy herd may well depend on the stage of lactation when the cows are first infected, the amount of stress the herd is under at that time and what the farmer does to mitigate the effects of infection.

During this epidemic of anaemia associated with *T. orientalis* Ikeda type, cattle farms were either infected by the inward movement of parasitaemic cattle or the local dispersion of infected ticks. However, the relative importance of these two methods of disease spread cannot be reconciled and further work is required to better understand the observed spatial-temporal pattern of disease. The full effects of the TABA (Ikeda) epidemic on the New Zealand cattle industry are still unfolding and until a state of endemic stability is reached, they can only be guessed. What is certain is that the huge movements of cattle that typify the New Zealand cattle industry at certain times of the year are no

longer without risk, especially if they involve the movement of naive cattle into infected regions. Currently there is an urgent need to determine the true costs of *T. orientalis* Ikeda type for all cattle production systems, to develop better control options and to research molecular methods to assess herd infection status, preferably through bulk milk testing if possible.

2.7 Acknowledgements

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Chapter 3

An observational study of the vertical transmission of *Theileria orientalis* Ikeda type in a New Zealand pastoral dairy herd

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3.1 Preface

Prior to this experiment, there was no reliable data on the vertical transmission of naturally acquired *Theileria orientalis* Ikeda type infection. This study was undertaken to fill a large gap in the epidemiology of this disease. Since its completion, the same study has been replicated three times, twice in Australia and once in Japan, all with very similar results.

3.2 Abstract

Although only recently recognised, *Theileria orientalis* Ikeda type is now the most important infectious cause of anaemia in New Zealand cattle. The aim of this study was to test if vertical transmission of *T. orientalis* Ikeda type from dam to calf across the placenta occurs in naturally infected New Zealand dairy cattle and to also test whether the infection status of the dam at calving affects the future susceptibility of its offspring to *T. orientalis* Ikeda type infection. Dairy cows (n=97) and their calves were sampled at calving; and the calves again at 4 months of age. All samples were measured for haematocrit and screened for *T. orientalis* genotypes using a multiplex Buffeli, Chitose and Ikeda specific TaqMan assay. Ikeda positive samples were further tested by singleplex PCR in triplicate to calculate the Ikeda infection intensity as genomes/ μ L of blood from each infected animal.

No *T. orientalis* Ikeda type infected calves were born to either *T. orientalis* Ikeda type infected or uninfected dams. There were 56/97 dams positive for *T. orientalis* Ikeda type infection at calving and 79/90 calves positive for *T. orientalis* Ikeda type infection at 4 months of age but no effect on calf susceptibility of dam infection status at calving. There was a significant negative effect of infection intensity on haematocrit after controlling for whether the infected animal was a dam or a 4-month-old calf.

Vertical trans-uterine transmission of *T. orientalis* Ikeda type infection is unlikely in chronically infected dairy cows and thus not a factor in the epidemiology of *T. orientalis* Ikeda type infection.

3.3 Introduction

Theileria orientalis Ikeda type is a type of the *Theileria orientalis* group, which is also sometimes referred to as benign or oriental theileriosis. The *T. orientalis* group comprises tick-borne obligate intracellular apicomplexan haemoprotozoan parasites that are widely disseminated globally due to the worldwide presence of suitable tick vectors in the genus *Haemaphysalis*. The taxonomy of *T.*

orientalis remains uncertain and continues to be investigated. At present there are considered to be 11 types, namely, Type 1 (Chitose), Type 2 (Ikeda), Type 3 (Buffeli), Types 4–8 and Types N1–N3 (Khukhuu et al., 2011; Kamau et al., 2011b; Cufos et al., 2012a; Hammer et al., 2015; Watts et al., 2016). Adding to the confusion a further type known as *Theileria sergenti* has historically been described as belonging to the *T. orientalis* group (Kamau et al., 2011b). It now appears that *T. sergenti* was an undifferentiated mixed infection of *T. orientalis* (Chitose) and *T. orientalis* Ikeda type (Kubota et al., 1996a; Onuma et al., 1998).

Theileria orientalis Ikeda type is probably the most pathogenic member of the *T. orientalis* group and since 2006 has been associated with extensive epidemics of *Theileria* associated bovine anaemia (TABA), first in Australia (Kamau et al., 2011a; Eamens et al., 2013b) and then later in New Zealand (McFadden et al., 2013; Lawrence et al., 2016b). Prior to the emergence of *T. orientalis* Ikeda type in 2012 it was believed that New Zealand cattle were parasitised by only the more benign *T. orientalis* types, Chitose and Buffeli, with only sporadic disease outbreaks reported (McFadden et al., 2011). Despite the higher pathogenicity of *T. orientalis* Ikeda type, most New Zealand farms affected in the recent epidemic have recorded relatively low mortality and morbidity rates, the medians being 0.23% and 0.97% respectively (Wink et al., 2016). However, in a small number of farms these rates are much higher, up to 5% and 30% respectively, often for no readily discernible reason (McFadden et al., 2013).

Affected cattle usually show a combination of the following clinical signs; anaemia, lethargy, production drop, anorexia, ill-thrift, diarrhoea, constipation, jaundice, collapse, pale udders, possible haemoglobinuria, and inappetance (Lawrence et al., 2016b). The severity of these usually approximates the degree of anaemia in affected animals (Lawrence et al., 2013). Late term abortion is a more frequent finding in the Australian epidemic (Izzo et al., 2010; Perera et al., 2015a) than the New Zealand one (Ministry for Primary Industries, data on file). Oriental theileriosis is estimated to cost the Australian red meat industry \$19.6M per annum (Lane et al., 2015) and \$202 per affected cow in lost production for dairy cows in a single infected herd (Perera et al., 2014). McDougall et al. (2014) found \$196 per affected cow in lost reproductive performance in a New Zealand dairy herd. The only known competent arthropod vector for *T. orientalis* in New Zealand is the 3-host tick *H. longicornis* which is widely distributed over the North Island but restricted to the top of the South Island (Heath, 2016). *Haemaphysalis longicornis* would appear to be the main vector for *T. orientalis* Ikeda type transmission in southern Australia as well (Hammer et al., 2015). Within the lifecycle of the arthropod vector, inheritance of *T. orientalis* infection is transstadial but not transovarial (Higuchi, 1985) so larvae always hatch naive. Few infected ticks, possibly just one, are required to infect an individual cow, and infection of cattle with *T. orientalis* is considered life-long (Sugimoto and Fujisaki, 2002).

Theileria orientalis infection in cattle in Australia was first reported in 1910 (Kamau et al., 2011a) and in New Zealand in 1982 (James et al., 1984). Despite the long recognition of *T. orientalis* as a potential bovine haemoparasite much of the epidemiology and transmission dynamics of *T. orientalis* as a group are still poorly understood. There is uncertainty over whether vertical transmission of *T. orientalis* occurs in naturally infected cattle. Both an experimental study (Baek et al., 2003) and an observational study (Onoe et al., 1994) supported the occurrence of some vertical transplacental transmission of *T. sergenti* but these findings have never been replicated in the field in Australia or New Zealand. Two further references to transplacental transmission of *T. sergenti* in the literature (Baek et al., 1993; Savini et al., 1998) are problematical, with the experimental design and results from both unclear. Similarly, there are only a small number of published reports of transplacental transmission of *Theileria annulata* (Godara et al., 2010; Sudan et al., 2015).

The aim of the present study was to test whether *T. orientalis* Ikeda type is vertically transmitted from dam to calf across the placenta in naturally infected New Zealand dairy cattle. A secondary aim was to test whether the infection status of the dam at calving affects the future susceptibility of its offspring to *T. orientalis* Ikeda type infection.

3.4 Materials and methods

This was a cross-sectional study using a convenience sample of cows and calves from a 550-cow spring-calving, mainly Friesian, dairy herd in the Wanganui region of New Zealand. Wanganui is in a low-risk tick area (Heath, 2016). The latter selection criterion was important since it was hypothesised that where the prevalence of ticks is low the within herd spread of *Theileria* could possibly be much slower giving us the opportunity to blindly sample both infected and uninfected dams at calving.

The subject herd was first acknowledged as infected with *T. orientalis* Ikeda type in spring 2013, the first blood samples from cattle with TABA being submitted on 23/08/2013 to the Animal Health Laboratory (AHL, Wallaceville). This herd was one of a small number of farms throughout New Zealand in 2013 to experience much higher mortality and morbidity rates than usual with a total of 20 (3.6%) cow deaths and 80 (14.5%) clinically affected cows.

The number of animals selected for sampling was based on power analysis of the chi square test. New Zealand *T. orientalis* (Chitose) data have shown a prevalence of 55% on a single infected farm using blood smear diagnosis (James, 1984) and Australian molecular data has shown a prevalence of 45% for *T. orientalis* Ikeda type on a single dairy farm in Victoria (Perera et al., 2014). Given an expected dam infection prevalence of 50% then a sample size of 100 cows using a medium effect size of 0.3

would give a power of > 0.8 to detect a significant association between dam and calf infection. Since mis-mothering in the calving paddock is a common occurrence on New Zealand dairy farms (Burton and Vosges, 2002), DNA testing to verify parentage was carried out on all cow-calf pairs.

Sampling of cows and calves started on the 22/07/2014 and was completed by 5/08/2014. The blood sampling was carried out as soon as possible after birth. Routinely on this farm freshly calved cows and their calves are collected each morning. A cow-calf pair was selected for sampling where a mutual bond had clearly been observed. Blood was collected into EDTA tubes and stored on farm at -20°C before molecular testing once sample collection was complete. On the 11/08/2014 further blood was taken into EDTA tubes from the dams to provide fresh samples for haematocrit measurement. On the farm calves were initially reared in sheds then on pasture at the home property, where ticks have never been seen by the owner. After weaning, at 100kg body weight, they were moved to pasture on a coastal property where ticks are known to occur. Calves were resampled for molecular testing and haematocrit measurement at 4 months of age on 3/12/2014, 6 weeks after potential exposure to infected ticks. The haematocrit was measured by reading micro-capillary tubes centrifuged for 5 minutes at 10,000 g with the average of two samples recorded for each animal. If the haematocrit for paired samples differed by greater than 2% then a repeat centrifugation and reading were done.

3.4.1 *DNA extraction, molecular typing and quantification of Ikeda*

Theileria orientalis genotypes in DNA samples were quantified from extracted blood using methods described previously (Pulford et al., 2016b). Briefly, 200 μL of diluted (1:5) blood sample in sterile water was extracted using an automated QIAxtractor and the Dx Universal Liquid Sample Kit (QIAGEN SCIENCES, Maryland, USA) according to the manufacturer's instructions. DNA was eluted in 200 μL elution buffer and DNA quality was assessed as compatible for amplification by measuring 18S RNA signals in samples using TaqMan[®] Ribosomal 18S RNA PCR (Applied Biosystem, Austin, Texas, USA) for evidence of amplification inhibition.

All samples were first screened for *T. orientalis* genotypes using the multiplex Buffeli, Chitose and Ikeda specific TaqMan assay chemistry (Pulford et al., 2016b). Quantitative PCR were performed in 96-well plates on a Bio-Rad CFX96 qPCR thermocycler (Bio-Rad Laboratories, Hercules, California, USA). Samples screened by multiplex PCR included known blood extraction controls that were positive or negative for *T. orientalis* Ikeda type, as well as known positive and negative DNA controls, and a no template control sample. The cycle threshold (Cq) values for all amplification plots were auto calculated by the Bio-Rad CFX96 analysis software. Positives were identified if the sample produced a $\text{Cq} \leq 38$ or as suspicious at $\text{Cq} 38\text{-}45$ (Pulford et al., 2016b).

Ikeda positive samples identified by multiplex PCR were then each tested in triplicate in separate test runs using singleplex Ikeda-specific qPCR. The gene copy number was calculated using a plasmid containing the Ikeda MPSP gene sequence. Nanograms of pure plasmid DNA (Integrated DNA Technologies) in TE were accurately measured by fluorometry (Qubit® dsDNA HS assay, Life Technologies, New Zealand) and then a log step dilution series of plasmid DNA in sterile water was created. The plasmid DNA copy number was determined at each dilution using $P / M \times A$ where P =grams of plasmid DNA, M =plasmid molecular weight ($MW=1609610$) and A =Avogadro's number (6.022×10^{23}). The plasmid DNA dilution series containing between $2.25 - 2.25 \times 10^7$ Ikeda genome copies was used in duplicate alongside samples on each 96 well PCR plate. A standard curve plotting Ikeda Cq values against plasmid copy number was used to calculate Ikeda MPSP gene copies per sample using the CFX manager software (Bio-Rad Laboratories, Hercules, California, USA). The mean copy number estimate, standard deviation and 95% confidence intervals for each sample were calculated using Microsoft Excel 2008 software (Millar, 2001). The mean copy number estimates were adjusted to account for dilution of blood prior to extraction and input volume ($3\mu\text{L}$) of DNA per PCR to give the mean genomes/ μL of blood.

3.4.2 *Verification of parentage*

DNA testing to verify parentage was carried out by GeneMark, Livestock Improvement Corporation (LIC, 140 Riverlea Road, Private Bag 3016, Hamilton, New Zealand). The GeneMark DNA Parent Verification included nominated sire and dam profiles to complete the parentage analysis.

3.4.3 *Statistical analysis*

The distribution of the Ikeda infection intensity (mean genomes/ μL) variable was highly right skewed requiring a cube root transformation prior to statistical analysis. Dam age was categorised into “young”, (3 or 4 years), and “older”, (over 4 years).

The chi-square test or, if sample sizes were small, the Fisher's exact test, was used to test the null hypothesis of no association, between dam infection status and calf infection status at 4 months of age, between dam infection status and whether a calf was missing at 4 months of age and between dam age, categorised as “young” or “older”, and calf infection status at 4 months of age. The Student's t-test was used to test for a significant difference between the haematocrit for the infected and uninfected dams; the haematocrit for the infected and uninfected calves at 4 months of age; the infection intensity (genomes/ $\mu\text{L}^{1/3}$) of dams and the infection intensity (genomes/ $\mu\text{L}^{1/3}$) of calves at 4 months of age; the infection intensity (genomes/ $\mu\text{L}^{1/3}$) of dams by dam age, categorised as “young”

or “older”; the infection intensity (genomes/ $\mu\text{L}^{1/3}$) of positive calves at 4 months of age depending on whether the dam was positive or negative for Ikeda, and the infection intensity (genomes/ $\mu\text{L}^{1/3}$) of positive calves at 4 months of age depending on dam age, categorised as “young” or “older”.

The Wilcoxon rank-sum test with continuity correction was used to test whether there was a significant difference between the ages of the dams depending on their infection status at calving. Pearson's product-moment correlation coefficient was used to assess the relationship between the infection intensity (genomes/ $\mu\text{L}^{1/3}$) of the infected dam and the infection intensity (genomes/ $\mu\text{L}^{1/3}$) of its offspring at 4 months of age, where both the dam and calf were infected.

Multiple regression was used to predict the effect of infection intensity (genomes/ $\mu\text{L}^{1/3}$) on haematocrit % with a dummy variable fitted to control for the effect of the age group, i. e. dams or 4-month-old calves. Analysis of variance tested whether there was an effect of sire on infection intensity in calves at 4 months of age.

Statistical analyses were carried out using R v2.15.2 (R Development Core Team, 2010; R Foundation for Statistical Computing, Vienna, Austria).

3.5 Results

A total of 105 observed cow-calf pairs were sampled at birth, with DNA testing confirming parentage for 97 of these. Of these correctly identified calves, 90 were re-sampled at age 4 months. There were 58% (56/97) Ikeda positive dams at calving; of these, a single dam had a mixed infection of Buffeli and Ikeda whilst the rest were infected with Ikeda alone. Out of the 41 Ikeda negative dams, one was infected with Chitose. No neonatal calves tested positive for the *T. orientalis* types Ikeda, Chitose or Buffeli at birth, although by 4 months of age 88% (79/90) calves were positive for *T. orientalis* Ikeda type but not for any of the other *T. orientalis* types tested, Table 3-1. At this time, 7 calves were missed, one possibly sold, and one had died, with the fate of the others unknown. For 78/79 of the infected 4-month-old calves, parentage testing also identified their sire. There were nine unique sires identified, with the number of progeny per sire ranging from two to 20 calves.

A summary the PCR results is shown in Table 3-1 and a summary of the age, haematocrit and genomes/ μL results is shown in Table 3-2.

Table 3-1. Summary of PCR results for dams at calving, neonates and 4-month-old calves for parentage tested cow-calf pairs

<i>T. orientalis</i> result	Count	Calf neonate		Calf 4 months		Missing
		Ikeda positive	Ikeda negative	Ikeda positive	Ikeda negative	
Ikeda positive	56 ^a	0	56	46	5	5
Ikeda negative	41 ^b	0	41	33	6	2
Total	97	0	97	79	11	7

^aIncludes a single Ikeda positive cow also positive for Buffeli. ^bIncludes a single cow only positive for Chitose

With zero Ikeda-positive neonates found, no valid statistical test of association between dam infection status and neonate infection status was available or necessary.

There was no association between infection status of the dam at calving and that of the calf at 4 months of age ($p = 0.52$, Fisher's exact test), or between a calf being missing at 4 months of age and dam infection status ($p=0.69$, Fisher's exact test), and between the dam's age category, and the infection status of the calf at 4 months of age ($p=0.69$, Chi-squared test).

Table 3-2. Summary of age, haematocrit (HCT) and genome/ μL results for dams at calving and for calves at 4 months old of age

<i>T. orientalis</i> result	Dam at calving			Calf 4 months		
	Age/years ^a	Ht ^b	genomes/ μL ^a	Age/days ^b	Ht ^b	genomes/ μL ^a
Ikeda positive	6 (3, 11)	28.7 (0.47)	79790 (66, 3081000)	127 (0.42)	31.0 (0.37)	777200 (1268, 5841000)
Ikeda negative	3 (3, 5)	32.6 (0.37)	---	125 (1.21)	38.2 (0.55)	---

^aMedian (minimum, maximum), ^bMean (SE)

The Student's t-test showed a significant difference for dam haematocrit depending on infection status ($p < 0.0001$), for calf haematocrit depending on infection status ($p < 0.0001$), and between the infection intensity (genomes/ $\mu\text{L}^{1/3}$) of dams at calving and calves at 4 months of age ($p < 0.0001$) (Table 3-2). The reduction in the haematocrit % for the infected dams was 3.9 (95%CI=2.7–5.1) and for the infected 4-month-old calves 7.2 (95%CI=5.8–8.6), (Figure 3-1). The back transformed average infection intensity was 73966 (95%CI= 33051 – 139493) genomes/ μL higher in 4-month-old calves than dams.

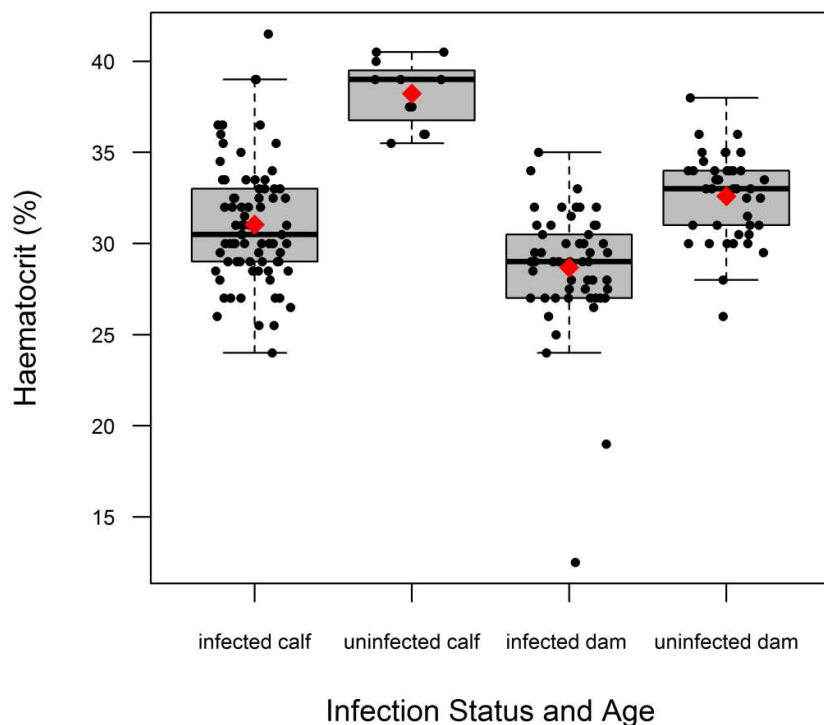


Figure 3-1. Box and whisker plots, with raw data points, showing the median, the interquartile range and the maximum and minimum of haematocrit (%) values for infected and uninfected 4-month-old calves and for infected and uninfected dams at calving. The mean haematocrit for each group is marked with a red diamond.

There was no significant difference between the dam infection intensity (genomes/ μL) by age category of the dam ($p = 0.25$), between the infection intensity of infected calves at 4 months of age depending on the infection status of the dam ($p = 0.28$) or between the infection intensity of infected calves at 4 months of age depending on the age category of the dam ($p = 0.31$). The Wilcoxon rank-sum test showed that the age of the tested dams was significantly different for the Ikeda-positive and Ikeda-negative groups, with a median difference of 2 years (95% CI=1–3 years). There were 46 parentage tested cow-calf pairings where a calf born to an infected dam was itself also infected by 4 months of age. A significant, although weak, negative correlation between infection intensity (genomes/ $\mu\text{L}^{1/3}$) of the dams and the infection intensity (genomes/ $\mu\text{L}^{1/3}$) of their offspring at 4 months of age was found ($p < 0.05$), $r = -0.29$ (95% CI=-0.001–0.54).

The dam haematocrit and transformed genome counts included an influential outlier ($H_t=12.5$, genomes/ $\mu\text{L}^{1/3} = 145.5$). The results of the multiple regression, with the influential point dropped from the data, were significant ($F(2, 128) = 22.7$, $p < 0.0001$), with an R^2 of 0.25. The predicted

haematocrit (%) was equal to $35.1 - 0.045 \times \text{infection intensity} - 4.01 \times \text{age group}$, where infection intensity was measured in genomes/ $\mu\text{L}^{1/3}$ and age group was coded 1 for an infected dam and 0 for an infected 4-month-old calf. The predicted haematocrit fell 0.045% (95% CI=-0.028--0.062) for each unit increase of genomes/ $\mu\text{L}^{1/3}$ and dams had a predicted haematocrit 4.0% (95% CI=2.8–5.2%) lower than 4-month-old calves, Figure 3-2. Both infection intensity and age group were significant predictors of haematocrit (%). A test for an interaction between age and infection intensity was not significant, $p=0.78$. There was no effect of sire on infection intensity in 4-month-old calves, $p=0.18$.

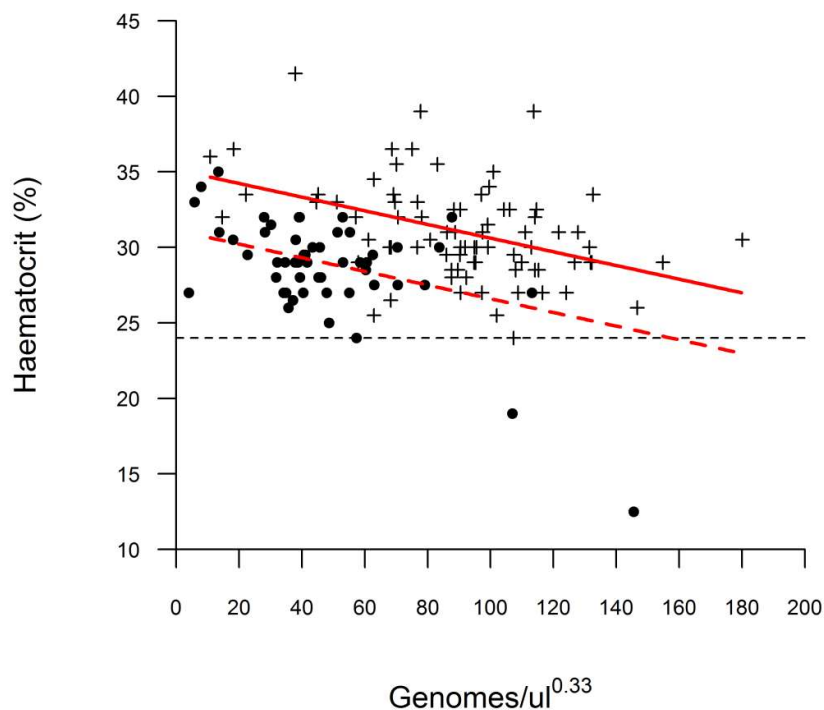


Figure 3-2. Plot of the haematocrit (%) against the infection intensity in genomes/ $\mu\text{L}^{0.33}$ for *T. orientalis* Ikeda type infected recently calved dams (●) and 4-month-old calves (+). The solid red line shows a regression line fitted to the 4-month-old calf data and the broken red line shows a regression line fitted to the dam data. The horizontal broken line shows the cut point for anaemia $\leq 24\%$; three dams and one calf were anaemic.

The back transformed average infection intensity of the 4 anaemic animals (3 cows and 1 calf) was 11.3×10^5 genomes/ μL , which was nearly three times the back transformed average infection intensity of the non-anaemic animals at 3.9×10^5 genomes/ μL .

3.6 Discussion

The subject herd was almost exclusively infected with *T. orientalis* Ikeda type which allowed for the testing of a very specific hypothesis relating to one type of pathogen. The study clearly demonstrated that vertical transmission of *T. orientalis* Ikeda type infection is highly unlikely. Furthermore, there was no association between infection status of the dam at calving and that of its calf at 4 months of age.

Unequivocal as these results are, they are at odds with those of Baek et al. (2003) who found 100% (6/6) transplacental transmission of *T. sergenti* in an experimental study, where 6 dams were deliberately infected with *T. sergenti* just after artificial insemination, and Onoe et al. (1994) who in an observational study found 7% (4/55) *T. sergenti* positive calves born to 55 naturally infected dams. So how is it possible to reconcile the results from these three studies? A legitimate explanation, since these historic studies were based on *T. sergenti*, could be that *T. orientalis* Ikeda type does not cross the placenta whereas *T. orientalis* (Chitose) does and that the contrasting results observed in the Baek et al. (2003) and Onoe et al. (1994) trials reflect a difference in the relative abundance of these two *T. orientalis* types in the *T. sergenti* strain used in each of these studies.

This would seem unlikely and a more likely explanation is that the probability of transplacental infection heavily depends on whether the dam is acutely or chronically infected whilst pregnant, irrespective of which type of *T. orientalis* is involved, i.e. whether the dam is infected for the first time when pregnant or is already infected before becoming pregnant. It is likely that the level of parasitaemia experienced by the dam when first infected is also important and would also allow for those circumstances in which a chronically infected pregnant animal becomes stressed, experiences a recrudescence, and becomes sufficiently parasitaemic to infect its foetus. The finding that the infection intensity for acutely infected calves at 4 months of age was significantly higher than for chronically infected dams at calving, would support the supposition that acute infection leads to higher levels of parasitaemia than that seen in chronic infection.

The tick challenge used in the Baek et al. (2003) study was 200 infected ticks per heifer. This was not excessive by observed counts of naturally occurring infestations made in the field in New Zealand (ACG. Heath pers. comm. 2015). Although it is important to note, that in the field the effective tick count from a *T. orientalis* perspective, is likely to be less since not all ticks infesting an animal will be infected or will have the same level of infection. Kamio et al. (1990) found that the proportion of *T. sergenti* infected ticks in Honshu, Japan varied by month of collection, ranging from about 10 to 50% of nymphs collected, and that the burden of infection also varied with usually only 3 salivary acini infected per tick although up to 96 infected acini were seen.

In the Wanganui herd most of the clinical cases seen in the previous milking season were prior to the start of mating in mid-October 2013. This probably meant that these cows were infected by overwintered infected nymphs and were already infected when they were inseminated between mid-October and late December 2013. In the Onoe et al. (1994) trial there is no information on the age of the dams but if only a subset of the dams were naïve at the beginning of the grazing season then this could account for the relatively small number of infected calves born to infected dams seen in this study, 4/55, compared to 6/6 in the Baek et al. (2003) study.

Perera et al. (2013) estimated the sensitivity and specificity of blood smears for detecting *Theileria* as 39% (95% CI 32-46%) and 100% (95% CI 95-100%) respectively. This means that although blood smears have a low sensitivity, the high specificity means that the positive predictive value (PPV) of being smear positive should be very high. Therefore, the Onoe et al. (1994) results could be an underestimate of the true vertical transmission rate but the high PPV gives confidence in their findings.

As stated earlier, late-term abortion has been more commonly seen in the Australian outbreaks and supports the findings of Baek et al. (2003), where 2/6 dams aborted, that acute infection in pregnant cows can be responsible. The more frequent exposure of naïve pregnant cows to infection in Australia could be due to the higher adoption of the year-round calving system for dairy herds there than in New Zealand, where most cows are calving in spring. Alternatively, climate factors may mean that tick activity is better synchronised with pregnancy in Australia than in New Zealand, even for those areas where seasonal calving herds predominate. In New Zealand tick dormancy (diapause) occurs through winter finishing sometime in mid to late July, which corresponds with late pregnancy in spring calving herds. The peak questing period for over-wintering nymphs is August or September leading to acute infection in naïve cattle at or about calving, which would limit the opportunity for late term abortion. Furthermore, this peak nymph activity is generally prior to the breeding period for spring calving dairy herds, which is mid-October to late December.

For some apicomplexan species the transplacental transfer of infection is critical for the survival of the species. For example, the efficacy of *Neospora caninum* as a parasite of bovine populations can probably be attributed to its endogenous transplacental infection rate which may approach 90-100% for infected dams (Reichel et al., 2014). Even for *Toxoplasma gondii*, where an initial infection during pregnancy will generally result in transplacental infection, and then congenital infection or abortion (Hide et al., 2009), host foetal loss can still be viewed as a successful outcome for the parasite since this leads to heavy environmental contamination and opportunities for horizontal spread if cats as intermediate hosts get access to the aborted material.

In the case of *T. orientalis* Ikeda type vertical transmission is clearly not an important method of ensuring survival of the parasite, instead the successful maintenance and transmission of this parasite in bovine populations is dependent on the success of its arthropod vector (Heath, 2016) and the

lifelong infection status of the host. However, if correct, the low levels of vertical transmission found by Onoe et al. (1994) in naturally infected animals could provide a method by which infection may be maintained on a naïve property, until suitable arthropod vectors become established.

It is possible that if this study was repeated in a New Zealand autumn calving herd or in a herd with a mixed *T. orientalis* infection then the result could be different. The potential for vertical transfer will also depend on whether the farm is in an endemically stable or unstable area (McFadden and Marchant, 2014). Cattle reared in an endemically stable area should have enough exposure to infected ticks to be inoculated and chronically infected prior to mating, whereas cattle reared in an endemically unstable area or in a tick-free zone may only become infected much later in life, quite possibly whilst they are pregnant.

The current study considered only transplacental transfer of theileriosis infection whereas another possible method, transfer by colostrum, was not investigated. Biting flies, sucking lice, mosquitoes and iatrogenic transmission have also been suggested as additional, mechanical, vectors of *T. orientalis* (Fujusaki et al., 1993; Hadi and Al-Amery, 2012; Hammer et al., 2015). It is unknown what role these alternative vectors have in the epidemiology of *T. orientalis* in New Zealand, but we can imagine no circumstances in which they could confound the conclusions from this study.

The lack of a significant association between dam infection status and calf infection status at 4 months or between dam infection status and calf infection intensity at 4 months would support the conclusion that the infection status of the dam at calving does not affect the future susceptibility of the offspring to infection. However, the weak negative correlation between dam infection intensity and calf infection intensity could indicate that calves born to dams, which had high infection intensity at calving, were more likely to have low infection intensity at 4 months of age. A possible explanation for this is that high parasitaemia in the dam close to calving stimulates the production of better-quality colostrum which then protects the calf through passive immunity. This protection could lead to lower levels of parasitaemia when the calf itself is eventually infected. If this finding is valid it would strongly contradict the use of acaricides on pregnant cows in endemic areas in the lead up to calving. Studies of passive colostrum derived immunity against *T. equi* in ponies and donkeys found that it is transitory and wanes by 63 to 77 days of age (Kumar et al., 2008). The form and duration of colostral immunity against *T. orientalis* in cattle is not known but is likely to be similar or less since outbreaks of TABA observed in beef calves are commonly reported between ages 2 to 4 months (Lawrence et al., 2016b).

Uilenberg et al. (1985) reported that for the more pathogenic types of *T. orientalis* the prepatent period until parasitaemia in cattle is around 7 to 12 days following infection, with macroshizonts seen from Day 7 and piroplasms seen from Day 10. The peak parasitaemia is around 30 to 40 days post infection, which coincides with the lowest PCV. If the vertical transfer of *T. orientalis* infection was at the point

of calving, then testing calves at birth could be expected to yield mostly false negative results. However, if this were the case then the studies by Baek et al. (2003) and Onoe et al. (1994) would also have failed to find infected offspring. It is likely that if there is vertical transmission of *T. orientalis* in cattle it occurs at dam maximum parasitaemia and not at any specific physiological point in the gestation period.

Allsop et al. (2007), investigating the transmission dynamics of *T. equi* in mares, found by serially aborting a group of infected pregnant mares, and testing the aborted foetus using PCR, that transuterine infection in horses occurs very early in pregnancy, possibly before 4 months pregnant. Clearly the equine placenta is very different to the bovine, which makes this analogy tenuous at best; it does however show the potential for transuterine transmission within a similar parasite group.

The significant difference in ages between the infected and uninfected dams probably reflects the difference in exposure history of the dairy cows to infected ticks from the previous season and not an age susceptibility. During the spring of 2013, only the older cows were sent to graze on the coastal property where ticks were known to occur, whilst younger cows either stayed on the home farm or grazed elsewhere and in both of these latter areas ticks have not been observed by the farmers. At the run-off however, these older cows were exposed to infected ticks for the first time. Intuitively, the difference in age between the two groups can have no bearing on the result, since no infected calves were born no matter what the age of dam. There was also no effect found of dam age on infection intensity in either the cows or their offspring.

The interaction term tested in the multiple regression was not significant. This indicates that the rate of erythrocyte destruction is linearly dependent on the infection intensity (genomes/ μL) and not affected by whether the infected animal is young or old, acutely or chronically infected. This helps explain why the reduction in haematocrit percentage was greater in the calves than the dams since they had significantly higher infection intensity (genomes/ μL) than the chronically infected dams. Although the dam haematocrit data were potentially biased, being collected on average 13 days (range 6 to 20) after the first samples on which the molecular work was completed. The finding that there was no effect of sire on infection intensity in 4-month-old calves was not surprising given the small numbers involved. Differences in breed susceptibility to *Theileria* infection have been demonstrated (Terada et al., 1995) so logically there could also be some within breed differences for disease susceptibility.

Bogema et al. (2015) found that 95% of clinically affected cattle had infection intensities above 3×10^5 genomes/ μL ; this is like the average infection intensity found in the non-anaemic animals from the current study at 3.9×10^5 genomes/ μL . The average infection intensity for the 4 anaemic animals identified in the current study was 11.3×10^5 genomes/ μL . interestingly this level of infection would not have predicted clinical anaemia from the regression equation. The modest R-squared for the

multiple regression shows that infection intensity (genomes/ μ L) and age group do not explain about 75% of the variability in haematocrit percentage. For this reason, it is important to consider infection intensity as a necessary but not sufficient cause of TABA, meaning that a recently infected naïve animal will often require an additional stressor or concurrent illness before developing full clinical disease.

The range of values for the haematocrits of the uninfected calves and uninfected dams agrees with published data (Knowles et al. 2000; Rowlands et al., 1974) indicating that the calves or cows in this study were probably not affected by a concurrent cause of anaemia. The much higher haematocrits in uninfected 4-month-old calves compared to uninfected dams was fortunate since it meant that the 4-month-old calves could withstand a drop of 7.3% in haematocrit values, after infection, without significant levels of anaemia occurring (only one infected 4 month old calf was anaemic, Figure 3-2). Had a similar drop occurred in the dams then most of them would have become anaemic rather than just three.

Herein probably lies the explanation for why some herds from the New Zealand TABA epidemic have had such catastrophic outcomes. The cows in those herds are possibly already experiencing low haematocrits, for some other reason such as dietary, and after acute *T. orientalis* Ikeda type infection the equivalent drop in haematocrit values, to that seen in the 4-month-old calves, leads to high levels of anaemia and clinical disease.

3.7 Conclusion

There were no infected calves born to infected dams and the infection status of the dam at calving did not influence the future susceptibility of its calf to infection. It appears that cows chronically infected with *T. orientalis* Ikeda type are unlikely to produce infected calves however it remains unproven in the field as to whether acute infection during pregnancy, leading to high levels of parasitaemia, could potentially lead to the birth of *T. orientalis* Ikeda type infected calves.

3.8 Ethical approval

This experiment was performed under the approval of Massey University Animal Ethics Committee, Protocol 14/54

3.9 Acknowledgements

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Chapter 4

Clinical haematology and biochemistry profiles of cattle naturally infected with *Theileria orientalis* Ikeda type in New Zealand

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4.1 Preface

This study was instigated to fill a large gap in the epidemiology of this disease and was based on laboratory data collected when I worked for the Ministry for Primary Industries between February 2013 and February 2014.

4.2 Abstract

AIMS: To present the haematology and biochemistry profiles for sick New Zealand cattle naturally infected with *Theileria orientalis* Ikeda type over the period 2012 to 2014.

METHODS: The results of 213 haematology and 97 biochemistry sick animal profiles from *T. orientalis* Ikeda PCR positive cattle were summarised and tabulated for adult dairy cows, beef calves and dairy calves (<6 months old). Data sets for adult dairy cattle and calves (less than 6 months old) matched on individual haematocrit were prepared to examine the effects of age on the haematology and biochemistry responses to *T. orientalis* Ikeda type infection. Testing for significant differences between production groups was performed as follows; a linear model was initially used to correct for the effect of laboratory on the measured parameter and the residuals from this model were then regressed against the cattle production groups.

RESULTS: The haematology and biochemistry changes, associated with *T. orientalis* Ikeda type infection, were consistent with extravascular haemolytic anaemia being the main pathogenesis of disease. Sick adult dairy cattle were significantly more likely to be severely anaemic than calves, when sampled on farm for either haematology or biochemistry testing. After adjusting for the effect of laboratory and anaemia status there were significant differences in the average haematology and biochemistry values between adult dairy cattle and calves. However, many of these differences likely have a physiological rather than pathological basis. Overall, the haematology changes in < 6-month-old calves appear less severe than adult dairy cattle.

CONCLUSIONS AND CLINICAL RELEVANCE: Calves appear to be less likely to develop severe anaemia than adults. By exposing calves to *T. orientalis* Ikeda type infection, dairy farmers in endemic unstable areas could manage the risk of infectious bovine anaemia in their adult cattle.

4.3 Introduction

Commencing in 2012, an epidemic of infectious bovine anaemia associated with *Theileria orientalis* (TABA) has been present in New Zealand (McFadden et al. 2013). *T. orientalis* Ikeda type was previously unrecorded in New Zealand (Pulford et al. 2016a) and has become the most important

cause of clinical anaemia in New Zealand cattle. Approximately 80% of recorded clinical cases are from dairy farms and 20% are from beef farms. On dairy farms, mature cows are mostly affected around calving or in early lactation, i.e. at periods of peak stress, whilst on beef farms calves between the age of 2 and 4 months are more usually affected (Lawrence et al. 2016b).

Diagnosis of TABA in individual cattle is usually based on clinical presentation, haematological changes consistent with a regenerative anaemia, the identification of piroplasms on stained blood smears and PCR testing. Reports of the changes in haematology and biochemistry specifically associated with infection by *T. orientalis*, in contrast to *T. annulata* and *T. parva*, are limited and often based on either small sample numbers, samples from just one herd or samples from cattle infected by multiple pathogens (Riond et al. 2008; Izzo et al. 2010; Haron et al. 2015). The usual haematological changes reported are macrocytic, hypochromic, regenerative anaemia that results in pre-hepatic hyperbilirubinaemia, with associated jaundice, and hypoxic liver damage, with associated leakage of liver function enzymes.

The exact pathogenesis of the anaemia resulting from *T. orientalis* infection remains uncertain. Abnormal morphology and increased erythrocyte osmotic fragility (Yagi et al. 1989), oxidative damage and lipid peroxidation of erythrocytes (Yagi et al. 2002; Shiono et al. 2003b) and decreased survival of erythrocytes, irrespective of their true parasitised status (Yagi et al. 1991) are all considered to have an important role. The resulting anaemia has been reported to be accompanied by methaemoglobinaemia and by increased erythrocyte malondialdehyde concentration. Both these changes are indicative of oxidative damage to the erythrocytes and are probably caused by the host's own phagocytes (Shiono et al. 2001, 2003a).

In our companion paper, we described the commonly reported clinical signs in cattle infected with *T. orientalis* Ikeda type in the New Zealand epidemic, and how these differed between age groups and between beef and dairy farms (Lawrence et al. 2017a). There have been no accounts, identified by the authors, on whether the changes in haematology and biochemistry changes are consistent across different age groups and different farm types. The objectives of this study were to present haematology and biochemistry profiles for cattle naturally infected with *T. orientalis* Ikeda type and investigate if the results differed between adult dairy cattle and calves aged <6 months.

4.4 Materials and methods

4.4.1 Data collection

This was a retrospective observational study using an opportunistic sample of haematology and biochemistry results from cattle which tested positive for *T. orientalis* Ikeda type by PCR. These

results were obtained from blood samples accompanying submissions from suspected cases of TABA. The submitted blood samples were collected by veterinary practitioners and it is presumed that the sampled cattle were clinically ill at the time of examination. No additional data were provided regarding the duration of the illness or when the diseased animal may have first become infected. The data used in this analysis were provided by private regional laboratories (New Zealand Veterinary Pathology (NZVP) and Gribbles Veterinary Pathology), under Section 46 and 48 of the Biosecurity Act 1993. The data were collected from 17 October 2012 to 24 November 2014.

Molecular testing for confirmation of infection with *T. orientalis* Ikeda type, using a type-specific quantitative PCR assay, as described by Pulford et al. (2016b), was carried out by the Animal Health Laboratory (Wallaceville, Upper Hutt, NZ) until January 2014 when the work was ceded to the private regional laboratories.

Haematology results were obtained using a Sysmex XT-2000i (Sysmex Corporation, Japan) automated haematology analyser at NZVP, and a Cell-Dyn 3700 (Abbott Laboratories, Philippines) automated haematology analyser at Gribbles Veterinary Pathology. For each laboratory, the white blood cell (WBC) differential counts obtained from each analyser were confirmed by manual evaluation of a blood smear using a Leishman–May Grunwald staining technique (Merck Millipore Corporation, Merck KGaA, Darmstadt, Germany). For biochemistry testing both laboratories used the same chemistry analyser, a Roche Modular P800 (Roche Diagnostics Corporation, Indianapolis, USA). The reference intervals used for all results were those provided by NZVP.

In addition to the haematology and biochemistry results, data were obtained for each sample for age of animal and farm of origin, as entered by the consulting veterinarian on the laboratory submission forms. Farm production type was categorised as dairy, beef or dry based on the description in the AgriBase database maintained byASUREQuality Limited (www.asurequality.com), which includes the spatial coordinates and demographic details for approximately 140,000 New Zealand farms. Age of animal was categorised as calf if <6 months, young if 6–23 months, adult if ≥ 2 years old or unknown if age was not entered on the submission form.

4.4.2 *Statistical analysis*

Many haematology or biochemistry parameters were not normally distributed, but the central limits theorem was evoked to summarise and make statistical inferences about the data. Summary results were generated for the most common production types (adult dairy, beef calves and dairy calves) both as the full data set and categorised by haematocrit (HCT), which was categorised as normal if HCT was >0.24 L/L, moderate anaemia if HCT was 0.15 – 0.24 L/L, and severe anaemia if HCT was <0.15 L/L (Riond et al. 2008).

To control for the effect of differing HCT when comparing results between production types, matched haematology and biochemistry data sets were prepared. Matching was based on individual HCT results using propensity scoring (Randolph et al. 2014). Because of low sample numbers, just two production types, adult dairy cattle and calves <6 months of age (combined beef and dairy calves), were matched on individual HCT and the results presented.

The χ^2 test or Fisher exact test was used to test for associations between categorical variables. For continuous variables, the *t*-test and linear regression were used to compare the haematology and biochemistry results for each categorical variable. To correct for bias due to data originating from two different laboratories the data for each haematology or biochemistry parameter were first regressed against laboratory, and the residuals from this model were then regressed against production type or HCT category. The family-wise error-rate, for multiple post-hoc comparisons, was controlled using Tukey's honest significant difference test.

To understand and contrast the RBC response, the WBC response and the potential adverse effects of anoxia on liver function between age groups, the RBC, MCV, MCH and MCHC results, the WBC, lymphocyte, segmented neutrophil and eosinophil results and the GLDH, AST, Bilirubin and GGT results, for each respective matched data set, were plotted against HCT. Loess (locally weighted scatterplot smoothing) regression curves, for adult dairy cattle and calves <6 months old, were fitted to the scatterplots of the data, with the span width, i.e. proportion of the data used at each local neighbourhood, set at 0.75 for haematology results and at 0.9 for biochemistry results. A span width, based on visual inspection of plots and the bias-corrected AIC criterion (Hurvich et al. 1998), was chosen which gave the least amount of smoothing appropriate for the data. Ninety five percent confidence intervals were fitted to the loess regression curves. The equality of the fitted curves was tested using the method of Dette and Neumeyer (2001) which generalises an ANOVA-type method to a non-parametric regression (Wang and Ye, 2010). The two non-parametric curves were said to be significantly different at $p < 0.05$.

The haematology results also included a qualitative assessment of red blood cell (RBC) morphology, based on microscopic examination of stained blood smears. The following RBC morphology changes, anisocytosis, polychromasia, poikilocytosis, basophilic stippled cells and macrocytosis were scored as absent, mild, moderate or marked in a 1000x magnification (100x oil objective) "counting window" by the haematologist reading the blood smear. Fisher's exact test of independence was used to compare the distribution of RBC morphology scores for each RBC morphological characteristic between adult dairy cattle and calves <6 months old. As previously described, matching on individual HCT was used to correct for the effect of anaemia on RBC morphology scores.

All analyses were undertaken using R v3.3.1 (R Development Core Team, 2016; R Foundation for Statistical Computing, Vienna, Austria).

4.5 Results

The number of samples submitted for haematology and biochemistry testing from cattle that tested positive for *T. orientalis* Ikeda type on PCR analysis is shown in Table 4-1. Except for samples from dairy cattle of unknown age, the three most common categories were adult dairy, beef calves and dairy calves. When categorised by HCT, the proportion of samples with HCT<0.15 (severe anaemia) was greater for adult dairy cattle than for beef or dairy calves, for both haematology ($p<0.002$) and biochemistry ($p<0.001$) submissions.

Summary haematology results for blood samples from 60 adult dairy cattle and 60 calves <6 months of age, matched for HCT, are shown in Table 4-2. For these samples, there were differences between adult dairy cattle and calves in mean RBC counts ($p=0.016$), mean corpuscular volume ($p<0.001$), mean corpuscular haemoglobin ($p<0.001$), and banded neutrophil ($p=0.03$), eosinophil ($p<0.001$) and lymphocyte ($p<0.001$) counts. In addition, for both adult dairy and calves, mean values for concentrations of haemoglobin, HCT, mean corpuscular volume, and counts of RBC, nucleated red blood cells, reticulocytes and banded neutrophils were outside their respective reference intervals.

Table 4-1. Number (proportion) of blood samples submitted for haematology or biochemistry testing to two regional laboratories (NZVP and Gribbles) from cattle that tested positive for *Theileria orientalis* Ikeda type on PCR analysis, categorised by farm type, age^a and haematocrit (HCT; L/L).

Farm type	Age ^a	Haematology				Biochemistry			
		HCT <0.15	HCT 0.15– 0.24	HCT >0.24	Total	HCT < 0.15	HCT 0.15– 0.24	HCT >0.24	Total
Dairy	Adult	88 (0.25)	36 (0.1)	27 (0.08)	151 (0.43)	39 (0.26)	17 (0.11)	13 (0.09)	69 (0.47)
	Young	7 (0.02)	6 (0.02)	3 (0.01)	16 (0.05)	3 (0.02)	2 (0.01)	0 (0)	5 (0.03)
	Calves	6 (0.02)	3 (0.01)	11 (0.03)	20 (0.06)	1 (0.01)	3 (0.02)	10 (0.07)	14 (0.09)
	Unknown	40 (0.11)	28 (0.08)	18 (0.05)	86 (0.24)	19 (0.13)	9 (0.06)	7 (0.05)	35 (0.24)
Beef	Adult	2 (0.01)	6 (0.02)	6 (0.02)	14 (0.04)	0 (0)	3 (0.02)	2 (0.01)	5 (0.03)
	Young	2 (0.01)	8 (0.02)	4 (0.01)	14 (0.04)	0 (0)	2 (0.01)	1 (0.01)	3 (0.02)
	Calves	16 (0.05)	13 (0.04)	13 (0.04)	42 (0.12)	3 (0.02)	5 (0.03)	6 (0.04)	14 (0.09)
	Unknown	3 (0.01)	4 (0.01)	2 (0.01)	9 (0.03)	1 (0.01)	1 (0.01)	1 (0.01)	3 (0.02)
Dry	Adult	1 (0.01)	0	0	1 (0.00)	0	0	0	0
Laboratory	NZVP	128 (0.36)	93 (0.26)	72 (0.2)	293 (0.83)	44 (0.3)	37 (0.25)	38 (0.26)	119 (0.8)
	Gribbles	37 (0.1)	11 (0.03)	12 (0.03)	60 (0.17)	22 (0.15)	6 (0.04)	2 (0.01)	30 (0.2)
	Total	165 (0.47)	104 (0.29)	84 (0.24)	353 (1)	66 (0.45)	42 (0.28)	40 (0.27)	148 (1)

^a Where calf was <6 months, young 6–23 months and adult ≥2 years of age

Table 4-2. Summary haematology results for blood samples submitted from adult dairy cattle (n=62) and calves <6 months of age (both dairy and beef; n=62) that tested positive for *Theileria orientalis* Ikeda type on PCR analysis, matched on haematocrit, with reference intervals for different age groups.

Parameter	Adult dairy		Calves		Reference interval	
	Mean±SE	Min, max	Mean±SE	Min, max	Adult	Calf
Red blood cells (x 10 ¹² /L)	3.66±0.3 ^x	0.8, 7.6	4.98±0.43 ^y	0.7, 12	5.0–7.7	6.5–11.9
Haemoglobin (g/L)	67.3±4.66	22, 153	69.7±4.7	16, 149	85–130	85–140
Haematocrit (L/L)	0.21±0.01	0.06, 0.42	0.21±0.01	0.06, 0.44	0.24–0.40	0.24–0.42
MCV (x10 ⁻¹⁵ L)	66.1±2.43 ^x	42, 107	51.9±2.3 ^y	26, 92	38–56	27–44
MCH (pg)	20.7±0.55 ^x	13, 29	16.75±0.67 ^y	10, 33	14–20	9–16
MCHC (g/L)	320.4±3.95	245, 378	328.5± 3.77	263, 403	320–400	310–390
NRBC (/100 leucocytes)	15.6±4.2	0, 160	25.6±7.32	0, 304	0–0	0–1
Reticulocytes (x 10 ⁹ /L)	35.5±6.18	0, 154	21.6±5.4	0, 182	0–1	0–1
Platelets (x 10 ⁹ /L)	428.7±17.5	295, 896	511.3±29.5	216, 1302	220–640	220 – 950
White blood cells (x 10 ⁹ /L)	11.8±0.89	3.4, 30.7	11.2±0.83	2.9, 31.3	3.8–11.0	5.6–13.7
Banded neutrophils (x 10 ⁹ /L)	0.81±0.25 ^x	0, 12.6	0.22±0.08 ^y	0, 3.7	0.0–0.1	0–0.1
Segmented neutrophils (x 10 ⁹ /L)	6.18±0.68	0.8, 24.3	4.83±0.69	0.1, 22.4	0.7–4.9	0.6–6.1
Lymphocytes (x 10 ⁹ /L)	3.67±0.21 ^x	0.4, 8.6	5.42±0.27 ^y	0.8, 10	1.0–5.8	2.2–8.7
Monocytes (x 10 ⁹ /L)	0.7±0.08	0, 3.4	0.73±0.07	0, 2	0.0–0.9	0.2–1.2
Eosinophils (x 10 ⁹ /L)	0.33±0.05 ^x	0, 1.8	0.06±0.03 ^y	0, 2	0.0–1.9	0–0.3
Fibrinogen (g/L)	5.95±0.38 ^x	1.6, 20	5.18±0.28 ^x	2.5, 12.2	2.0–7.0	2.0–8.0

^{x,y} Means with different superscripts within the same row differ between age groups (p<0.05)

MCH=mean corpuscular haemoglobin; MCV= mean corpuscular volume, MCHC= mean corpuscular haemoglobin concentration, NRBC=nucleated red blood cells

The relationships between increasing HCT and RBC counts, mean corpuscular volume, mean corpuscular haemoglobin, and mean corpuscular haemoglobin concentration, for adult dairy cattle and calves <6 months of age, are shown in Figures 4-1a–d. For each of the scatter plots the fitted non-parametric curves were significantly different; RBC ($p<0.005$), MCV ($p<0.005$), MCH ($p<0.005$) and MCHC ($p=0.045$).

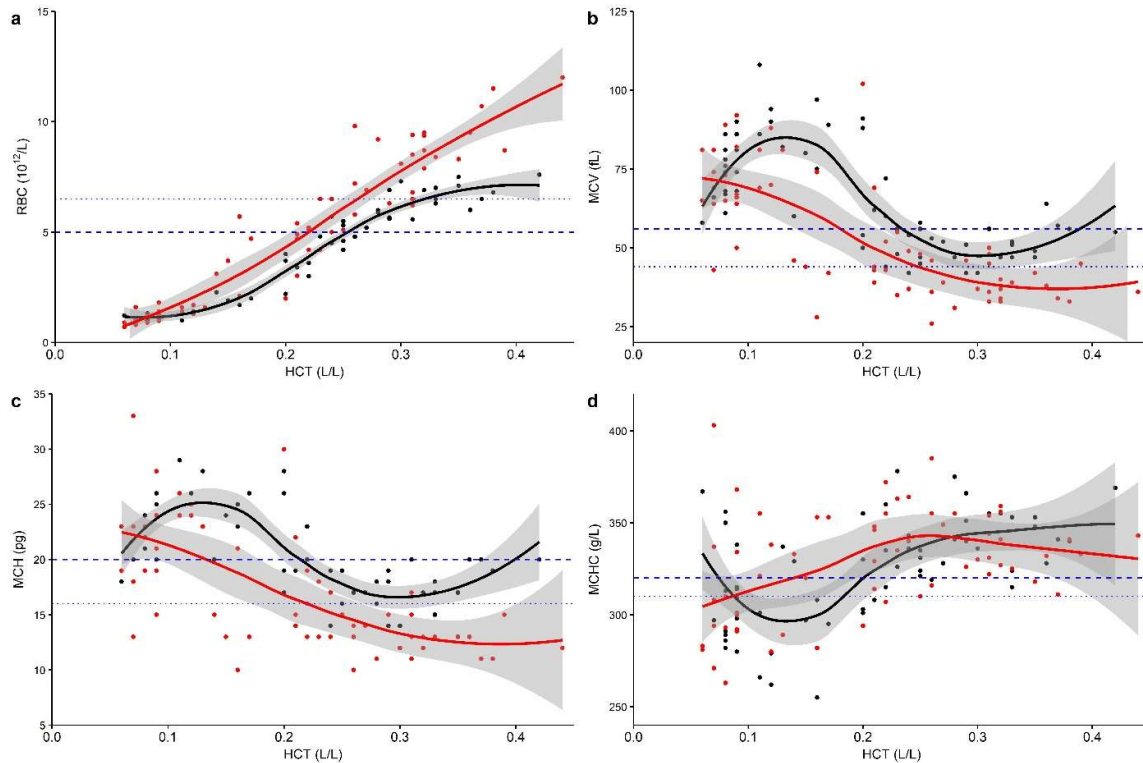


Figure 4-1. Relationships between haematocrit (L/L; HCT) and (a) red blood cell counts ($\times 10^{12}/L$; RBC), (b) mean corpuscular volume ($\times 10^{-15} L$; MCV), (c) mean corpuscular haemoglobin (pg; MCH) and (d) mean corpuscular haemoglobin concentration (g/L; MCHC), in blood samples collected from adult dairy cattle (black, $n=62$) and calves <6 months of age (red; $n=62$) that tested positive for *Theileria orientalis* Ikeda type on PCR analysis, matched on HCT. For (d) the broken blue and the dotted blue lines are the lower normal reference levels for adult dairy cattle and calves <6 months of age respectively. Loess curves, with 95%CI, are fitted using a span width of 0.75.

For calves, there was a linear relationship between RBC count and HCT but for adult dairy cattle this was more sigmoidal. There were complex cubic relationships with mean corpuscular volume, mean corpuscular haemoglobin, and mean corpuscular haemoglobin concentrations for adult dairy cattle but not for calves. In samples from adult dairy cattle, as HCT decreased from 0.24 to 0.15 (moderate anaemia), there was an increase in mean corpuscular volume and mean corpuscular haemoglobin and a decrease in mean corpuscular haemoglobin concentration, whereas for samples with $HCT<0.15$ (severe anaemia) values returned towards those measured in adult cattle with a normal HCT (>0.24). The relationships between increasing HCT and WBC counts, lymphocyte counts, segmented neutrophil counts and eosinophil counts, for adult dairy cattle and calves <6 months of age, are shown

in Figures 4-2a–d. The fitted non-parametric curves are significantly different for lymphocyte count ($p<0.005$) and eosinophil count ($p<0.005$) but not for WBC ($p=0.1$) and segmented neutrophil count ($p=0.06$). The lymphocyte count for calves fell with decreasing HCT whereas for adults this remained relatively unchanged. There was little effect of HCT on eosinophil count, with adults consistently having a higher count across all levels of HCT. Both WBC and lymphocyte counts showed a similar pattern of change with calves having higher counts at normal HCT and adults having rapidly increasing counts at $HCT<0.15$ (severe anaemia).

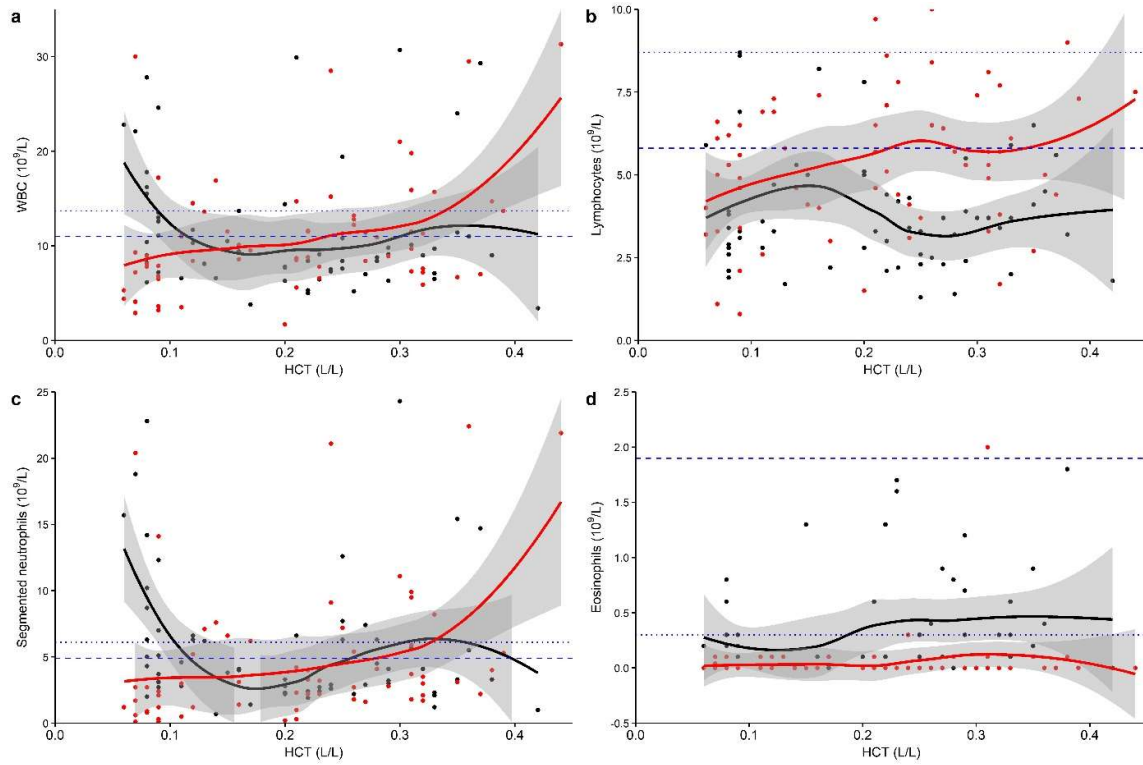


Figure 4-2. Relationships between haematocrit (L/L; HCT) and (a) white blood cell counts ($\times 10^{12}/L$; WBC), (b) mean lymphocyte counts ($\times 10^9/L$), (c) mean segmented neutrophil counts ($\times 10^9/L$) and (d) mean eosinophil counts ($\times 10^9/L$), in blood samples collected from adult dairy cattle (black, $n=62$) and calves <6 months of age (red; $n=62$) that tested positive for *Theileria orientalis* Ikeda type on PCR analysis, matched on HCT. Loess curves, with 95%CI, are fitted using a span width of 0.75.

The distributions of results for RBC morphology for blood smears from 62 adult dairy cattle and 62 beef and dairy calves, matched by HCT, are presented in Table 4-3. In both age groups anisocytosis was frequently recorded. Scores for anisocytosis and polychromasia were similar for both age groups ($p>0.1$), but the proportion of blood smears showing low and moderate macrocytosis was greater in adults than calves ($p=0.01$), and low and moderate poikilocytosis was greater in calves than adults ($p=0.005$). There was a tendency for smears showing low or moderate basophilic stippled cells to be greater in adults than calves ($p=0.07$).

Table 4-3. Number (proportion) of blood smears from adult dairy cattle (n=62) and calves <6 months of age (n=62) that tested positive for *Theileria orientalis* Ikeda type on PCR analysis, matched on haematocrit, that showed morphological changes in red blood cells.

Morphology	Adult dairy	Calves	P-value ^a
Anisocytosis			0.18
Absent	19 (0.32)	20 (0.33)	
Mild	16 (0.27)	20 (0.33)	
Moderate	22 (0.37)	13 (0.21)	
Marked	3 (0.05)	8 (0.13)	
Polychromasia			0.18
Absent	34 (0.55)	41 (0.66)	
Mild	14 (0.23)	15 (0.24)	
Moderate	13 (0.21)	5 (0.08)	
Marked	1 (0.02)	1 (0.02)	
Poikilocytes			0.005
Absent	54 (0.87)	40 (0.65)	
Mild	7 (0.11)	11 (0.18)	
Moderate	1 (0.02)	9 (0.15)	
Marked	0 (0)	2 (0.03)	
Stippled cells			0.07
Absent	41 (0.66)	49 (0.79)	
Mild	14 (0.23)	12 (0.19)	
Moderate	7 (0.11)	1 (0.02)	
Marked	0 (0)	0 (0)	
Macrocytosis			0.01
Absent	31 (0.5)	47 (0.76)	
Mild	12 (0.19)	5 (0.08)	
Moderate	17 (0.27)	10 (0.16)	
Marked	2 (0.03)	0 (0)	

^aSignificance of Fisher's exact test of independence

Summary biochemistry results for blood samples from 28 adult dairy cattle and 28 calves <6 months of age, matched for HCT, are shown in Table 4-4. For these samples, there were differences between adult dairy cattle and calves in mean concentrations of potassium ($p<0.001$), creatinine ($p=0.04$), phosphate ($p<0.001$), calcium ($p<0.001$), magnesium ($p=0.02$), total protein ($p<0.001$), albumin ($p=0.001$), globulin ($p<0.001$), albumin/globulin ratio ($p<0.001$) and β -hydroxybutyrate ($p=0.03$). However, the mean concentrations for all these parameters were within their respective reference intervals. There were no differences between age groups in any of the parameters expected to rise in

response to extravascular haemolysis and anoxic liver damage: mean concentrations of bilirubin, mean activities of glutamate dehydrogenase (GLDH), aspartate aminotransferase (AST) or γ -glutamyl transferase (GGT). Mean concentrations of bilirubin were greater than the reference intervals in both calves and adults, and activities of GGT and GLDH were elevated in adult dairy cattle.

Table 4-4. Summary biochemistry results for blood samples submitted from adult dairy cattle (n=28) and calves <6 months of age (n=28) that tested positive for *Theileria orientalis* Ikeda type on PCR analysis, matched on haematocrit, with reference intervals.

Parameter	Adult dairy		Calves		Reference interval
	Mean (SE)	Min, max	Mean (SE)	Min, max	
Sodium (mmol/L)	138.4±0.74	131, 147	136.3±1.2	117, 145	132–152
Potassium (mmol/L)	4.9±0.14 ^y	3.2, 6.9	5.5±0.17 ^x	4.1, 8.4	3.9–5.8
Chloride (mmol/L)	95.9±0.73	88, 105	96±0.93	86, 106	96–104
Creatinine (mmol/L)	52.1±3.1 ^y	31, 100	82±14.4 ^x	34, 384	55–130
Urea (mmol/L)	6.14±0.55	1.1, 14.4	8.01±1.74	2.8, 51.9	2.7–12.3
Phosphate (mmol/L)	1.81±0.11 ^y	0.69, 3.05	2.55±0.1 ^x	1.6, 4.1	1.1–2.8
Total protein (g/L)	72.1±8.9 ^y	52, 99	62.8±1.6 ^x	43, 79	60–86
Albumin (g/L)	28.6±0.97 ^y	18, 36	33.3±0.88 ^x	21, 42	25–40
Globulin (g/L)	43.4±2.07 ^y	25, 81	29.5±1.75 ^x	15, 50	28–53
Albumin/globulin	0.71±0.04 ^y	0.22, 1.16	1.27±0.1 ^x	0.58, 2.8	0.5–1.2
Calcium (mmol/L)	2.15±0.03 ^y	1.9, 2.55	2.43±0.05 ^x	1.97, 3.26	2.0–2.6
Magnesium (mmol/L)	0.75±0.03 ^y	0.49, 1.02	0.83±0.03 ^x	0.43, 1.16	0.49–1.15
Bilirubin (μmol/L)	15.9±6.01	1, 167	29.4±13.93	1, 373	0–13
GLDH (IU/L 37°C)	73.4±24.48	4, 478	24.3±4.86	3, 136	8–41
β -hydroxybutyrate (mmol/L)	0.42±0.04 ^y	0.1, 1.1	0.33±0.04 ^x	0, 0.9	0.2–1.0
AST (IU/L 37°C)	162.4±35.0	51, 1,003	104.4±13.4	39, 317	0–179
Creatine kinase (IU/L 37°C)	615.4±214.7	73, 6183	805±295.5	60, 8366	0–578
GGT (IU/L 37°C)	46.8±12.9	2, 277	21.3±8.3	2, 241	0–36

^{x,y} Means with different superscripts within the same row differ between age groups (p<0.05)

AST=aspartate aminotransferase; GGT= γ -glutamyl transferase; GLDH=glutamate dehydrogenase

The relationships between increasing HCT and concentrations of bilirubin, and GLDH, AST and GGT activity, for adult dairy cattle and calves <6 months of age, are shown in Figures 4-3a–d. The fitted non-parametric curves were significantly different for; GLDH (p=0.015) and AST (p=0.045) but not for Bilirubin (p=0.33) and GGT (p=0.45). In adult dairy cattle, there were curvilinear relationships between HCT and activities of GLDH and AST, with increasing activities at HCT <0.15

(severe anaemia). The results for GGT and bilirubin showed very similar changes for both calves and adults with gradual increases in activity as the HCT fell.

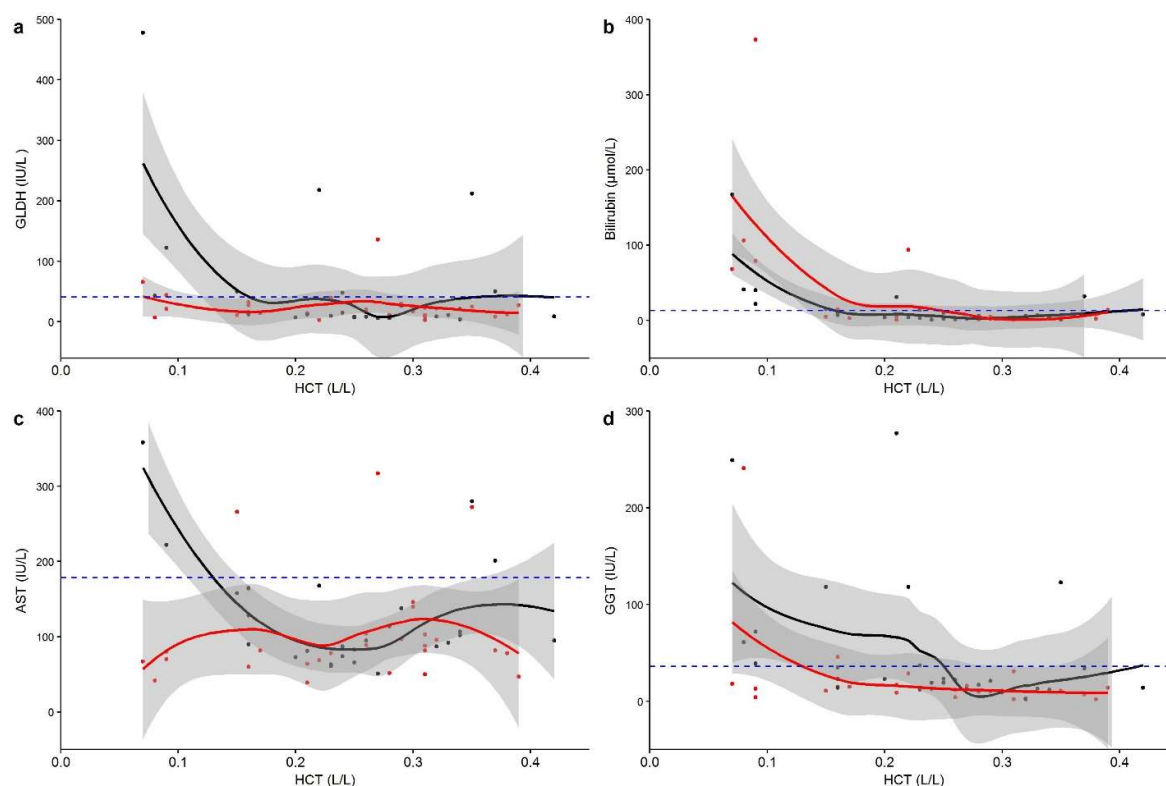


Figure 4-3. Relationships between haematocrit (L/L; HCT) and (a) glutamate dehydrogenase activity (IU/L; GLDH), (b) bilirubin concentration (μmol/L), (c) aspartate aminotransferase activity (IU/L; AST) and (d), γ-glutamyl transferase activity (IU/L; GGT), in blood samples collected from adult dairy cattle (black, n=28) and calves <6 months of age (red; n=28) that tested positive for *Theileria orientalis* Ikeda type on PCR analysis, matched on HCT. In each plot, a broken blue line shows the upper normal reference level for that parameter. Loess curves, with 95%CI fitted using a span width of 0.9.

Summary results of all the haematology and biochemistry data for adult dairy, beef calves and dairy calves are presented in Supplementary Tables 4-5 and 4-6, respectively. Summary results for haematology data categorised by HCT, for adult dairy cattle and calves <6 months of age are shown in Supplementary Tables 4-7 and 4-8, respectively. Summary results for biochemistry data, categorised by HCT, for adult dairy cattle and calves <6 months of age are shown in Supplementary Tables 4-9 and 4-10, respectively. The distributions of all results for RBC morphology for blood smears from adult dairy cows, beef calves and dairy calves are presented in Supplementary Table 4-11.

Clumping of platelets was an extremely common finding in the samples. Platelet clumping was reported for 102/151 (67.5%) samples from adult dairy cows, 23/42 (55%) samples from beef calves and 7/20 (35%) samples from dairy calves.

4.6 Discussion

The sample submission rates, haematology and biochemistry profiles for cattle naturally infected with *T. orientalis* Ikeda type have been presented and show that there are some differences between adult dairy cattle and calves < 6-month-old.

The haematology results showed that cattle infected with *T. orientalis* Ikeda type usually suffer from a regenerative extravascular haemolytic anaemia. The mean RBC counts and haemoglobin concentrations for both calves and adult cattle were below their respective reference intervals (Table 4-2). While the type of anaemia could correctly be described as macrocytic (increased mean corpuscular volume), with the average mean corpuscular volume for calves and adults being greater than the reference ranges, it was not consistently hypochromic (decreased mean corpuscular haemoglobin concentration). The average mean corpuscular haemoglobin concentration was within the normal range for both adults and calves (Table 4-2). However, Figure 4-1d showed that moderately and severely anaemic adult dairy cattle did suffer from hypochromic anaemia whereas for calves the mean corpuscular haemoglobin concentrations were maintained just above the lower reference level for nearly all values of HCT. Mean reticulocyte and nucleated red blood cell counts were also elevated and the most common erythrocyte morphological change observed was anisocytosis in both adults and calves.

Age-related changes in the RBC parameters are reported in normal cattle, with 3-month-old calves usually having higher RBC counts, lower mean corpuscular volume and mean corpuscular haemoglobin, higher lymphocyte counts, and lower eosinophil counts than adults (Brun-Hansen and Lund 2006; Mohri et al. 2007). The lower mean corpuscular volume reported in calves is associated with the replacement of the RBC containing fetal haemoglobin with smaller RBC containing haemoglobin A (Knowles et al. 2000). This change is compensated for by higher RBC counts allowing normal haemoglobin concentrations to be maintained (Brun-Hansen and Lund 2006). These age-related changes probably explain most of the differences between adult dairy cattle and calves identified in Table 4-2 and indicate that both adult dairy cattle and calves <6 months old mount a similar haematological response to *T. orientalis* infection. However, there were also some important differences between calves and adult dairy cattle. As HCT decreased there was a more linear change in mean corpuscular volume and mean corpuscular haemoglobin in calves compared to adult dairy cattle. In adult cattle there was a marked increase in these parameters as HCT decreased from 0.25 to 0.15 L/L, from moderate to severe anaemia (Figures 4-1b, c). Furthermore, although anisocytosis was observed on blood smears from both groups, the proportion with low and moderate poikilocytosis was greater in calves, and with macrocytosis was greater in adult dairy cattle. Macrocytosis is the production of RBC that are larger than normal and was reflected in the changes in mean corpuscular

volume in adult dairy cattle with moderate anaemia. Blood samples from cows with severe anaemia showed decreases in mean corpuscular volume and mean corpuscular haemoglobin, likely a consequence of bone marrow depletion of RBC and haemoglobin. In addition, for much of the range of HCT calves maintained higher RBC counts than the adult cattle (Figure 4-1a).

The biochemistry results (Table 4-4) also showed some differences between adults and calves, however, the results were often still within the reference intervals for both groups. Age related changes in biochemistry parameters are also reported, with 3-month-old calves usually having higher phosphate, lower total protein, globulin and AST (Mohri et al. 2007). The Loess regression curves, Fig. 4-3a-d, illustrated that although bilirubin and GGT activity had a similar response across HCT, adult cattle were more likely to show elevated activities of AST and GLDH at low HCT (<0.15). These increases were probably associated with hypoxic liver damage caused by the anaemia (Riond et al. 2008). It is possible that the high metabolic demands placed on the liver by lactating dairy cows make their hepatocytes more vulnerable to the effects of hypoxia. Furthermore, the increase in GLDH and AST activity in adult dairy cattle, at low HCT, was mirrored by similar increases in WBC and segmented neutrophil counts (Fig. 4-2a, c) supporting an association between hypoxic tissue damage and inflammation (Eltzschig and Carmeliet, 2011). Concentrations of bilirubin were increased in severely anaemic adult dairy cattle and calves (Figure 4-3b) which was likely a consequence of pre-hepatic icterus, with RBC destruction producing bilirubin at a faster rate than the liver could conjugate and excrete (Ehrmann, 2003). Jaundice was the most commonly reported clinical sign on submission forms for cattle infected with *T. orientalis* Ikeda type (Lawrence et al. 2017a).

The method of data collection is a significant limitation for this study, being both an opportunist sample and having no information regarding the on-farm sampling decisions made by farmers and their veterinarians. It is likely that financial concerns greatly impacted the sampling distributions found in this study and possibly resulted in reduced laboratory submissions from beef farms compared to dairy farms, and from calves compared to adults. Even so, the data strongly suggest that adult dairy cattle were more likely to be severely anaemic than either beef or dairy calves, when they were sampled for laboratory testing. The endemic stability theory argues that as a vector-borne disease such as *Theileriosis* becomes endemic then the incidence of clinical disease falls across all age groups, and when disease does occur it is mostly restricted to calves, often with a milder presentation (Coleman et al. 2001; Jonsson et al. 2012). The proportions of submissions, categorised by HCT (Table 4-1) appear to support the proposition that anaemia was less severe in calves than adults, as the proportion of samples with $HCT < 0.15$ was greater for adult dairy cattle than for beef or dairy calves.

A further major limitation to the study was that the data originated from two independent laboratories, each with multiple centres, and so there is potential for systematic bias in the data. The authors

attempted to control for this in the analysis and although the methodology appeared reasonably successful, some bias from the different laboratories must remain.

Intravascular haemolysis of peripheral blood is not a feature of *Theileria* infection (Yagi et al. 1989; Shiono et al. 2001). The finding that haemoglobinuria was not a commonly reported clinical sign (Lawrence et al. 2017a), a sign usually associated with intravascular haemolysis of RBC, is supported by the results in Table 4-2. Which showed that the average potassium and phosphate levels, for both adult cattle and calves, were within the reference intervals. Potassium and phosphate may increase outside their reference intervals at lower levels of intravascular haemolysis; potassium often with mild and phosphate with moderate haemolysis (Mather and Mackie 1960). The lifecycle of *T. orientalis* within the bovine host has not been fully described and although it is suggested that repeated rounds of erythrocyte invasion by merozoites and their intra-erythrocyte multiplication, with resulting destruction of RBC, does occur (Shaw 2002); the clinical history and haematology data do not support this suggestion.

Platelet counts, for those samples unaffected by clumping, were generally within reference intervals for both adults and calves indicating that thrombocytopaenia was also not a feature of *T. orientalis* infection. Thrombocytopaenia is a common finding in bovine babesiosis (Smith et al. 1980) and contributes to morbidity and mortality (Pantanowitz 2003). The high overall rate of clumping reported in the current study indicates that practitioners should take more care collecting blood samples, although evidentially this may not be that easy when sampling anaemic animals.

In calves experimentally infected with *T. orientalis*, when piroplasms first appear in the peripheral circulation, around day 10 post-infection, there is a temporary leucopaenia and when the peak parasitaemia is reached, around day 25–30 post-infection, the WBC count also peaks whilst the HCT and RBC count reach their nadir (Shimizu et al. 1990). This association between WBC count and HCT or RBC count appears to be supported by only the data for adult dairy cattle where the highest WBC counts were seen in animals with HCT <0.15 (Figure 4-2a). As stated earlier, this association between high WBC count and low HCT possibly reflects an acute inflammatory response secondary to hypoxic tissue damage.

Mean concentrations of fibrinogen and globulin were within reference intervals across both age groups. This would suggest that the immune response to *T. orientalis* Ikeda type infection is probably cell mediated rather than humoral, although the possibility that *T. orientalis* Ikeda type may cause immune suppression should not be discounted. Ticks are known to secrete pharmacologically active molecules in their saliva, which modulate the host's innate and adaptive immune response (Šimo et al. 2017). For example, *Haemaphysalis longicornis*, the only competent host for *T. orientalis* in New Zealand (Heath 2016), secretes a homolog to macrophage migration factor which slows the migration of immune cells to the tick attachment site (Umemiya et al. 2007). Furthermore, for many tick-borne

organisms it has been shown that tick saliva enhances their transmission (Šimo et al. 2017), so it is likely a similar relationship between *T. orientalis*, *H. longicornis* and the host's immune system exists.

In conclusion, the response to *T. orientalis* Ikeda type infection appears to be similar for adult dairy cattle and calves <6 months old however the data suggest that overall calves appear to be less likely to develop severe anaemia than adults.

4.7 Supplementary tables

Table 4-5. Haematology profiles for unwell *Theileria orientalis* Ikeda type PCR positive dairy calves, beef calves and adult dairy cattle.

Parameter	Dairy calves (n = 20)		Beef calves (n = 42)		Adult dairy (n = 151)		Reference interval	
	Mean (se)	Range	Mean (se)	Range	Mean (se)	Range	Calf	Adult
RBC ($10^{12}/L$)	5.9^a (0.82)	0.8–11.5	4.38^a (0.48)	0.7–12	2.54^b (0.16)	0.8–7.6	6.5 – 11.9	5.0 – 7.7
Haemoglobin (g/L)	78.3^a (8.3)	22–130	64.3^a (5.5)	16–149	51.1^b (2.4)	22–153	85 –140	85 – 130
HCT (L/L)	0.24^a (0.02)	0.07–0.39	0.19^{ab} (0.02)	0.06–0.44	0.16^b (0.01)	0.06–0.42	0.24 –0.42	0.24 – 0.40
MCV (fL)	50.1^a (4.2)	26–81	54.5^a (2.9)	28–102	75.8^b (1.6)	42–121	27 –44	38–56
MCH (pg)	16.5^a (1.4)	10–33	17.4^a (0.8)	10–30	22.7^b (0.3)	13–31	9 –16	14 – 20
MCHC (g/L)	332.9^a (7.2)	282–403	325.1^a (4.3)	263–372	307.5^b (2.5)	237–378	310 –390	320 – 400
NRBC (/100 leucocytes)	9.8 ^a (6.6)	0–127	33.0 ^a (9.8)	0–304	24.6 ^a (2.8)	0–160	0 –1	0 – 0
Reticulocytes ($10^9/L$)	14.5^a (7.9)	0–126	23.9^a (6.8)	0–182	62.8^b (4.7)	0–203	0 –1	0 –1
Platelets ($10^9/L$)	493.5 ^a (48.7)	216–961	519.9 ^a (18.9)	250–1302	433.0 ^a (13.0)	50–896	220 – 950	220–640
WBC ($10^9/L$)	10.89 ^a (0.9)	3.5–21	11.09 ^a (1.14)	1.7–31.3	11.23 ^a (0.46)	3.4–30.7	5.6–13.7	3.8–11.0
Band Neutrophils ($10^9/L$)	0.07 ^a (0.03)	0–0.6	0.28 ^a (0.12)	0–3.7	0.61 ^a (0.11)	0–12.6	0–0.1	0.0 –0.1
Seg. Neutrophils ($10^9/L$)	3.79 ^a (0.7)	0.1–11.1	5.16 ^a (0.94)	0–22.4	5.41 ^a (0.34)	0.7–24.3	0.6 – 6.1	0.7– 4.9
Lymphocytes ($10^9/L$)	6.11^a (0.37)	2.6–9	4.99^a (0.34)	0.8–10	4.12^b (0.15)	0.4–9.1	2.2 – 8.7	1.0 –5.8
Monocytes ($10^9/L$)	0.87 ^a (0.12)	0.2–1.9	0.65 ^a (0.08)	0–2	0.73 ^a (0.05)	0–3.4	0.2 –1.2	0.0 – 0.9
Eosinophils ($10^9/L$)	0.02^a (0.01)	0–0.1	0.08^a (0.05)	0–2	0.26^b (0.03)	0–1.8	0 –0.3	0.0–1.9
Fibrinogen (g/L)	4.56 ^a (0.41)	2.8–10.9	5.49 ^a (0.34)	2.5–12.2	5.29 ^a (0.19)	1.6–20	2.0 –8.0	2.0–7.0

^{a,b}variables with different superscripts for their respective groups in the same row are significantly different at $P < 0.05$

Table 4-6. Biochemistry profiles for unwell *Theileria orientalis* Ikeda type PCR positive dairy calves, beef calves and adult dairy cattle.

Parameter	Dairy calves n=14		Beef calves n=14		Adult dairy n=69		Reference interval
	Mean (se)	Range	Mean (se)	Range	Mean (se)	Range	
Sodium (mmol/L)	135.6 ^a (1.6)	125 – 144	137 ^a (1.83)	117 – 145	138.4 ^a (0.53)	114 – 147	132 – 152
Potassium (mmol/L)	5.74^a (0.31)	4.1 – 8.4	5.26^a (0.15)	4.1 – 6.1	4.64^b (0.09)	3.2 – 6.9	3.9 – 5.8
Chloride (mmol/L)	95.5 ^a (1.47)	86–105	96.5 ^a (1.18)	88 – 106	94.2 ^a (0.83)	57–105	96 – 104
Creatinine (mmol/L)	56.1 ^a (5.3)	34–111	107.9 ^b (27.1)	35 – 384	60.5 ^a (3.6)	31–259	55 – 130
Urea (mmol/L)	6.22 ^a (0.67)	2.8 – 10.6	9.81 ^a (3.41)	3.2 – 51.9	7.68 ^a (0.59)	1. –35.9	2.7 –12.3
Phosphate (mmol/L)	2.63^a (0.14)	1.6 – 3.13	2.47^a (0.15)	1.77 – 4.1	1.9^b (0.07)	0.69 – 3.9	1.1 – 2.8
Total Protein (g/L)	64.5^a (1.2)	57 – 72	61.1^a (2.9)	43 – 79	76.9^b (1.2)	52 – 105	60 – 86
Albumin (A) (g/L)	34.4^a (1.1)	28 – 42	32.1^{ab} (1.4)	21 – 40	31.3^b (0.6)	18 – 40	25 – 40
Globulin (G) (g/L)	30.1 ^a (1.7)	15 – 43	28.9 ^a (3.1)	17 – 50	45.6 ^b (1.26)	25 – 84	28 – 53
A/G Ratio	1.24 ^a (0.13)	0.67 – 2.8	1.3 ^a (0.16)	0.58 – 2.35	0.73 ^b (0.02)	0.22 –1.21	0.5 – 1.2
Calcium (mmol/L)	2.41 ^a (0.04)	2.22 – 2.74	2.45 ^a (0.09)	1.97–3.26	2.22 ^b (0.03)	1.9 –3.41	2.0 – 2.6
Magnesium (mmol/L)	0.89^a (0.04)	0.58–1.16	0.77^{ab} (0.04)	0.43 – 0.92	0.74^b (0.03)	0.25 –1.43	0.49 – 1.15
Bilirubin (μmol/L)	12.4 ^a (7.3)	1 – 106	46.4 ^a (26.6)	1 – 373	28.6 ^a (4.0)	1–167	0 – 13
GLDH (IU/L 37°C)	27.6 ^a (8.7)	7 – 136	21 ^a (4.5)	3 – 66	170.9 ^a (32.3)	4 – 1503	8 – 41
B.OHB (mmol/L)	0.29 ^a (0.04)	0.1 – 0.5	0.38 ^a (0.07)	0 – 0.9	0.51 ^a (0.05)	0.1 – 3	0.2 – 1.0
AST (IU/L 37°C)	105.7 ^a (19.1)	42 – 317	103.1 ^a (19.4)	39 – 272	434.9 ^a (85.9)	51 – 4097	0 – 179
CPK (IU/L 37°C)	462.6 ^a (83.1)	60 – 1133	1147.4 ^a (581.3)	102 – 8366	668.7 ^a (105.5)	73 – 6183	0 – 578
GGT (IU/L 37°C)	28.6 ^a (16.6)	2 – 241	13.9 ^a (2.1)	3 – 31	86.9 ^a (18.9)	2 – 993	0 – 36
HCT (L/L)	0.27^a (0.02)	0.08 – 0.39	0.22^a (0.02)	0.07 – 0.35	0.16^b (0.01)	0.06 – 0.42	0.24 – 0.40

^{a,b} variables with different superscripts for their respective groups in the same row are significantly different at P < 0.05

Table 4-7. Haematology results for adult dairy cattle 2 years and older categorised into severe anaemia (HCT < 0.15), moderate anaemia (HCT= 0.15 to 0.24) and normal (HCT > 0.24).

Parameter	HCT < 0.15 n=88		HCT 0.15 to 0.24 n=36		HCT > 0.24 n=27		Reference interval
	Mean (se)	Range	Mean (se)	Range	Mean (se)	Range	
RBC	1.33^a (0.03)	0.8-2.3	2.78^b (0.22)	1.3-5.7	6.17^c (0.18)	4.2-7.6	5.0 – 7.7 x10 ¹² /L
Haemoglobin	31.5^a (0.59)	22-46	58.5^b (2.55)	37-87	105.4^c (3.39)	79-153	85 – 130 g/L
HCT	0.11^a (0)	0.06-0.14	0.19^b (0.01)	0.15-0.24	0.31^c (0.01)	0.25-0.42	0.24 – 0.40 L/L
MCV	82.3^a (1.46)	54-112	78.7^a (3.69)	42-121	50.8^b (0.97)	42-64	38–56 fL
MCH	24.19^a (0.32)	18-30	23.19^a (0.78)	13-31	17.3^b (0.35)	14-20	14 – 20 pg
MCHC	299.7^a (2.97)	237-367	302.9^a (5.5)	237-378	339.2^b (3.11)	315-375	320 – 400 g/L
NRBC	29.7^a (3.52)	0-160	30.3^a (7.02)	0-159	0.07^b (0.05)	0-1	0 – 0 /100 leucocytes
Abs.Retic	80.9^a (4.97)	0-195	65.7^a (11.62)	0-203	0.11^b (0.06)	0-1	0 – 1 x10 ⁹ /L
Platelets	455.4 ^a (20.25)	50-896	418.1 ^a (20.1)	264-668	378.6 ^a (17.83)	240-494	220 – 640 x10 ⁹ /L
WBC	12.01^{ac} (0.54)	3.7-27.8	9.28^{bc} (0.9)	3.8-29.9	11.3^c (1.33)	3.4-30.7	3.8 – 11.0 x10 ⁹ /L
Band.Neut	0.56 ^a (0.07)	0-3.3	0.69 ^a (0.37)	0-12.6	0.68 ^a (0.31)	0-7.6	0.0 – 0.1 x10 ⁹ /L
Seg.neut	5.93^a (0.44)	0.7-22.8	3.65^b (0.49)	0.8-16.1	6.07^a (1.02)	0.9-24.3	0.7 – 4.9 x10 ⁹ /L
Lymphocytes	4.44^a (0.2)	0.7-9.1	3.84^{ab} (0.29)	0.4-8.2	3.43^b (0.26)	1.3-6.5	1.0 – 5.8 x10 ⁹ /L
Monocytes	0.82^a (0.07)	0-3.4	0.52^b (0.07)	0.1-2.3	0.71^{ab} (0.1)	0.1-1.9	0.0 – 0.9 x10 ⁹ /L
Eosinophils	0.21 ^a (0.02)	0-0.9	0.29 ^a (0.08)	0-1.7	0.38 ^a (0.09)	0-1.8	0.0 – 1.9 x10 ⁹ /L
Fibrinogen	4.54^a (0.15)	1.6-8.8	5.31^a (0.25)	3.3-10	7.71^b (0.7)	3.8-20	2.0 – 7.0 g/L

^{a,b,c} variables with different superscripts for their respective groups in the same row are significantly different at P < 0.05

Table 4-8. Haematology results for calves less than 6 months old categorised into severe anaemia (HCT < 0.15), moderate anaemia (HCT= 0.15 to 0.24) and normal (HCT > 0.24).

Parameter	HCT < 0.15 n=22		HCT 0.15 to 0.24 n=16		HCT > 0.24 n=24		Reference interval
	Mean (se)	Range	Mean (se)	Range	Mean (se)	Range	
RBC	1.32^a (0.11)	0.7-3.1	4.56^b (0.33)	1.99-6.5	8.35^c (0.36)	5.1-12	6.5 – 11.9 x10 ¹² /L
Haemoglobin	27.8^a (1.76)	16-48	68.9^b (3.24)	44-87	106.4^c (3.1)	77-149	85 – 140 g/L
HCT	0.09^a (0)	0.06-0.14	0.21^b (0.01)	0.15-0.24	0.32^c (0.01)	0.25-0.44	0.23 – 0.42 L/L
MCV	70.9^a (2.81)	43-92	49.9^b (4.54)	28-102	38.8^c (1.27)	26-50	27 – 44 fL
MCH	22.1^a (0.96)	13-33	16.3^b (1.22)	10-30	13^c (0.35)	10-17	9 – 16 pg
MCHC	311.1^a (7.33)	263-403	335.9^b (6.56)	282-372	337.3^b (3.64)	310-385	310 – 390 g/L
NRBC	71.6^a (15.99)	2-304	0.3^b (0.25)	0-4	0^b (0)	0-0	0 – 0 /100 leucocytes
Abs.Retic	52.0^a (11.35)	0-182	9.1^b (6.68)	0-100	0.1^b (0.06)	0-1	0 – 1 x10 ⁹ /L
Platelets	439.1 ^a (33.9)	216-689	576.4 ^a (91.1)	307-1302	537.7 ^a (43.5)	257-961	220 – 950 x10 ⁹ /L
WBC	9.15 ^a (1.34)	2.9-30	10.56 ^a (1.45)	1.7-28.5	13.06 ^a (1.36)	5.9-31.3	5.6 – 13.7 x10 ⁹ /L
Band.Neut	0.28 ^a (0.14)	0-2.5	0.28 ^a (0.23)	0-3.7	0.11 ^a (0.06)	0-1.2	0.0–0.1 x10 ⁹ /L
Seg.neut	3.5 ^a (1.07)	0.1-20.4	4.4 ^a (1.26)	0.2-21.1	6.04 ^a (1.16)	1.6-22.4	0.6 – 6.1 x10 ⁹ /L
Lymphocytes	4.7 ^a (0.41)	0.8-7.3	5.42 ^a (0.56)	1.5-9.7	5.9 ^a (0.42)	1.7-10	2.2 – 8.7 x10 ⁹ /L
Monocytes	0.61 ^a (0.13)	0-2	0.7 ^a (0.1)	0-1.7	0.82 ^a (0.11)	0.1-1.9	0.2 – 1.2 x10 ⁹ /L
Eosinophils	0.03 ^a (0.01)	0-0.1	0.04 ^a (0.02)	0-0.3	0.1 ^a (0.08)	0-2	0.0 – 0.3 x10 ⁹ /L
Fibrinogen	4.9 ^a (0.4)	2.8-10.9	5.21 ^a (0.52)	2.5-8.9	5.41 ^a (0.49)	3.3-12.2	2.0 – 8.0 g/L

^{a,b,c} variables in bold with different superscripts for their respective groups in the same row are significantly different at P < 0.05

Table 4-9. Biochemistry results for adult dairy cattle categorised into severe anaemia (HCT < 0.15), moderate anaemia (HCT= 0.15 to 0.24) and normal (HCT > 0.24).

Parameter	HCT < 0.15 n=39		HCT 0.15 to 0.24 n=17		HCT > 0.24 n=13		Reference interval
	Mean (se)	Range	Mean (se)	Range	Mean (se)	Range	
Sodium	139.4 ^a (0.49)	134-147	137.9 ^a (0.94)	131-146	136.1 ^a (1.99)	114-144	132 – 152 mmol/L
Potassium	4.4^a (0.11)	3.2-6.4	4.9^b (0.18)	3.8-6.9	5^b (0.15)	4.4-6	3.9 – 5.8 mmol/L
Chloride	94 ^a (0.99)	63-104	96.2 ^a (0.63)	91-100	92 ^a (3.11)	57-105	96 – 104 mmol/L
Creatinine	66.9 ^a (5.63)	39-259	54.4 ^a (4.03)	39-100	49.5 ^a (5.18)	31-90	55 – 130 mmol/L
Urea	8.9 ^a (0.84)	4.4-35.9	5.2 ^a (0.53)	1.1-10.2	7.1 ^a (1.56)	3.1-23.7	2.7 – 12.3 mmol/L
Phosphate	1.92 ^a (0.1)	0.69-3.9	1.68 ^a (0.1)	0.82-2.41	2.12 ^a (0.2)	1.27-3.49	1.1 – 2.8 mmol/L
Total Protein	79.4^a (1.49)	62-105	75.8^{ab} (1.55)	64-88	71^b (3.75)	52-99	60 – 86 g/L
Albumin (A)	32.8^a (0.53)	21-40	29.9^{ab} (1.35)	20-36	28.9^b (1.49)	18-37	25 – 40 g/L
Globulin (G)	46.6 ^a (1.68)	29-84	45.9 ^a (1.28)	37-57	42.1 ^a (4.07)	25-81	28 – 53 g/L
A/G Ratio	0.74 ^a (0.03)	0.25-1.21	0.66 ^a (0.04)	0.37-0.89	0.76 ^a (0.07)	0.22-1.16	0.5 – 1.2 ratio
Calcium	2.2 ^a (0.04)	1.9-3.41	2.2 ^a (0.03)	1.99-2.39	2.2 ^a (0.06)	1.94-2.66	2.0 – 2.6 mmol/L
Magnesium	0.76 ^a (0.04)	0.25-1.43	0.68 ^a (0.04)	0.29-0.99	0.78 ^a (0.04)	0.49-0.98	0.49 – 1.15 mmol/L
Bilirubin	43.3^a (6.0)	4-167	11.7^b (2.5)	1-31	6.5^b (2.3)	1-32	0 – 13 µmol/L
GLDH	269.4^a (50.8)	5-1503	53.5^b (25.2)	7-406	29^b (15.6)	4-212	8 – 41 IU/L 37°C
B.OHB	0.54 ^a (0.08)	0.2-3	0.42 ^a (0.04)	0.1-0.8	0.55 ^a (0.11)	0.2-1.6	0.2 – 1.0 mmol/L
AST	680^a (140.2)	73-4097	116.3^b (11.3)	61-227	116.2^b (17.0)	51-280	0 – 179 IU/L 37°C
CPK	889.8 ^a (176.2)	91-6183	370.7 ^a (56.8)	105-904	394.9 ^a (77.0)	73-1126	0 – 578 IU/L 37°C
GGT	124 ^a (31.5)	15-993	49.4 ^a (16.5)	4-277	24.8 ^a (8.5)	2-123	0 – 36 IU/L 37°C
HCT	0.1^a (0)	0.06-0.14	0.19^b (0.01)	0.15-0.24	0.31^c (0.01)	0.25-0.42	0.24 – 0.42

^{a,b,c} variables in bold with different superscripts for their respective groups in the same row are significantly different at P < 0.05

Table 4-10. Biochemistry results for calves <6 months old categorised into severe anaemia (HCT < 0.15), moderate anaemia (HCT= 0.15 to 0.24) and normal (HCT > 0.24).

Parameter	HCT < 0.15 n=4		HCT 0.15 to 0.24 n=8		HCT > 0.24 n=16		Reference interval
	Mean (se)	Range	Mean (se)	Range	Mean (se)	Range	
Sodium	133.8 ^a (3.04)	125-139	135.3 ^a (3.21)	117-145	137.4 ^a (1.2)	125-144	132 – 152 mmol/L
Potassium	4.8 ^a (0.29)	4.1-5.5	5.6 ^a (0.11)	5-6.1	5.6 ^a (0.28)	4.1-8.4	3.9 – 5.8 mmol/L
Chloride	95.3 ^a (2.25)	89-99	96.9 ^a (2.08)	88-106	95.8 ^a (1.2)	86-105	96 – 104 mmol/L
Creatinine	82.8 ^a (18.6)	34-124	101 ^a (40.8)	44-384	72.3 ^a (15.3)	35-289	55 – 130 mmol/L
Urea	9.4 ^a (1.84)	5.8-13.4	11.4 ^a (5.85)	2.8-51.9	6 ^a (0.83)	3.2-14.9	2.7 – 12.3 mmol/L
Phosphate	2.2 ^a (0.23)	1.6-2.61	2.6 ^a (0.25)	1.82-4.1	2.6 ^a (0.12)	1.77-3.11	1.1 – 2.8 mmol/L
Total Protein	61.3 ^a (3.7)	56-72	59.3 ^a (3.5)	43-75	64.9 ^a (1.95)	50-79	60 – 86 g/L
Albumin (A)	36 ^a (2.42)	29-40	32.8 ^a (2.3)	21-42	32.9 ^a (0.89)	26-39	25 – 40 g/L
Globulin (G)	25.3 ^a (6.01)	17-43	26.5 ^a (3.64)	15-45	32.1 ^a (1.92)	18-50	28 – 53 g/L
A/G Ratio	1.7 ^a (0.36)	0.67-2.35	1.4 ^a (0.25)	0.67-2.8	1.1 ^a (0.07)	0.58-1.78	0.5 – 1.2 ratio
Calcium	2.7 ^a (0.21)	2.31-3.26	2.3 ^a (0.08)	1.97-2.61	2.4 ^a (0.04)	2.13-2.74	2.0 – 2.6 mmol/L
Magnesium	0.7 ^a (0.04)	0.64-0.82	0.8 ^a (0.08)	0.43-1.16	0.9 ^a (0.02)	0.66-0.98	0.49 – 1.15 mmol/L
Bilirubin	156.5 ^a (72.6)	68-373	17.6 ^a (11.1)	1-94	3.6 ^a (0.81)	1-14	0 – 13 µmol/L
GLDH	34.5 ^a (13.0)	7-66	19.1 ^a (4.4)	3-40	24.4 ^a (7.7)	3-136	8 – 41 IU/L 37°C
B.OHB	0.3 ^a (0.12)	0-0.5	0.4 ^a (0.1)	0.1-0.9	0.3 ^a (0.03)	0.1-0.5	0.2 – 1.0 mmol/L
AST	64.8 ^a (8.1)	42-80	102.8 ^a (26.7)	39-266	115.2 ^a (18.9)	47-317	0 – 179 IU/L 37°C
CPK	367 ^a (165.7)	60-680	557.8 ^a (308.6)	96-2704	1038.1 ^a (492.6)	195-8366	0 – 578 IU/L 37°C
GGT	69^a (57.4)	4-241	19.3^{ab} (4.4)	9-46	10.3^b (1.7)	2-31	0 – 36 IU/L 37°C
HCT	0.1^a (0)	0.07-0.09	0.2^a (0.01)	0.15-0.23	0.3^b (0.01)	0.26-0.39	0.24 – 0.42

^{a,b} variables in bold with different superscripts for their respective groups in the same row are significantly different at P < 0.05

Table 4-11. Qualitative RBC morphology results for blood smears from PCR positive *Theileria orientalis* Ikeda type cattle by age and type classification, the P-value is the result of the Fisher exact test.

RBC morphology	Result	Adult dairy n (proportion)	Beef calf n (proportion)	Dairy calf n (proportion)
Anisocytosis P=0.004	none	21 (0.14)	12 (0.29)	8 (0.4)
	low	40 (0.27)	15 (0.37)	5 (0.25)
	moderate	72 (0.49)	9 (0.22)	4 (0.2)
	high	15 (0.1)	5 (0.12)	3 (0.15)
Polychromasia P<0.0001	none	43 (0.28)	26 (0.62)	15 (0.75)
	low	49 (0.32)	10 (0.24)	5 (0.25)
	moderate	55 (0.36)	5 (0.12)	0 (0)
	high	4 (0.03)	1 (0.02)	0 (0)
Poikilocytes P<0.0001	none	133 (0.88)	27 (0.64)	13 (0.65)
	low	17 (0.11)	6 (0.14)	5 (0.25)
	moderate	1 (0.01)	7 (0.17)	2 (0.1)
	high	0 (0)	2 (0.05)	0 (0)
Stippled cells P<0.0001	none	63 (0.42)	33 (0.79)	16 (0.8)
	low	59 (0.39)	8 (0.19)	4 (0.2)
	moderate	29 (0.19)	1 (0.02)	0 (0)
	high	0 (0)	0 (0)	0 (0)
Macrocytosis P<0.0001	none	48 (0.32)	35 (0.83)	12 (0.6)
	low	35 (0.23)	3 (0.07)	2 (0.1)
	moderate	58 (0.38)	4 (0.1)	6 (0.3)
	high	10 (0.07)	0 (0)	0 (0)

Chapter 5

Cluster analysis of the clinical histories of cattle affected with bovine anaemia associated with *Theileria orientalis* Ikeda type infection

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5.1 Preface

Prior to this study, an analysis of the common history words associated with *Theileria orientalis* Ikeda type infection had not been completed in either Australia or Japan. This study was instigated to fill an important gap in the epidemiology of the disease and was based on data collected when I worked for the Ministry for Primary Industries between February 2013 and February 2014.

5.2 Abstract

AIM: To determine the most commonly used words in the clinical histories of animals naturally infected with *Theileria orientalis* Ikeda type; whether these words differed between cases categorised by age, farm type or haematocrit (HCT), and if there was any clustering of the common words in relation to these categories.

METHODS: Clinical histories were transcribed for 605 cases of bovine anaemia associated with *T. orientalis* (TABA), that were submitted to laboratories with blood samples which tested positive for *T. orientalis* Ikeda type infection by PCR analysis, between October 2012 and November 2014. χ^2 tests were used to determine whether the proportion of submissions for each word was similar across the categories of HCT (normal, moderate anaemia or severe anaemia), farm type (dairy or beef) and age (young or old). Correspondence analysis (CA) was carried out on a contingency table of the frequency of the 28 most commonly used history words, cross-tabulated by age categories (young, old or unknown). Agglomerative hierarchical clustering, using Ward's method, was then performed on the coordinates from the correspondence analysis.

RESULTS: The six most commonly used history words were jaundice (204/605), lethargic (162/605), pale mucous membranes (161/605), cow (151/605), anaemia (147/605), and off milk (115/605). The proportion of cases with some history words differed between categories of age, farm type and HCT. The cluster analysis indicated that the recorded history words were grouped in two main clusters. The first included the words weight loss, tachycardia, pale mucous membranes, anaemia, lethargic and thin, and was associated with adult ($p<0.001$), severe anaemia ($p<0.001$) and dairy ($p<0.001$). The second cluster included the words deaths, ill-thrift, calves, calf and diarrhoea, and was associated with young ($p<0.001$), normal HCT ($p<0.001$), beef ($p<0.001$) and moderate anaemia ($p<0.001$).

CONCLUSIONS AND CLINICAL RELEVANCE: Cluster analysis of words recorded in clinical histories submitted with blood samples from cases of TABA indicates that two potentially different disease syndromes were associated with *T. orientalis* Ikeda type infection. One was consistent with the affected cattle suffering from a severe regenerative extravascular haemolytic anaemia, the second displaying as ill thrift and diarrhoea, particularly in young beef cattle.

5.3 Introduction

Theileria orientalis is a tick-borne apicomplexan haemoparasite that causes both mild and severe anaemia in grazing cattle around the world (Aktas et al. 2006; Eamens et al. 2013b). Currently there are 11 identified allelic types of *T. orientalis* (Sivakumar et al. 2014; Watts et al. 2016), with the Ikeda type being strongly associated with disease in Japan, Korea, Australia and New Zealand (Onuma et al. 1998; Kamau et al. 2011a; Pulford et al. 2016a). Since 2012, New Zealand has suffered a substantial epidemic of infectious bovine anaemia associated with *T. orientalis* (TABA). Infection with *T. orientalis* Ikeda type was previously unrecorded in New Zealand (Pulford et al. 2016a) and spread rapidly through the naïve beef and dairy farms of the North Island (Lawrence et al. 2016b).

There was a previous report of cattle disease in New Zealand associated with *T. orientalis* (James et al. 1984). This earlier outbreak covered the period 1982–1986 and was probably associated with the less pathogenic Chitose type (McFadden et al. 2011). Commencing in 2012, the Ministry for Primary Industries kept records of farm outbreaks of TABA until the end of 2014, by which time well over 1,000 cattle farms in New Zealand had at least one clinical case of TABA, and when recording stopped there was no indication that the number of reported new cases was declining (McFadden et al. 2016a).

Most cases of TABA in a recently infected herd are usually subclinical with only a small proportion of animals developing clinical disease or dying (Shimizu et al. 1992; Vink et al. 2016). If clinical disease does develop, signs that are commonly observed include anaemia, lethargy, production drop, anorexia, ill-thrift, constipation, jaundice, collapse, pale udders, haemoglobinuria (less commonly), inappetence and abortion (Izzo et al. 2010; McFadden et al. 2013; Vink et al. 2016).

A disease syndrome is a collection of signs or symptoms that characterise a disease or condition (Aktas et al. 2010). Cluster analysis is a statistical method that can be used to identify which signs or symptoms are associated with a disease syndrome, or alternatively identify new or

emerging disease syndromes (Aktas et al. 2010). The use of clustering algorithms is becoming a standard component of modern public health syndromic disease surveillance (Heffernan et al. 2004).

Correspondence analysis (CA) is one statistical method available to analyse the clustering of disease signs and symptoms. This is realised by calculating the correspondence (association) between rows and columns in a contingency table of categorical variables. It is similar to principal components analysis, but applies to categorical rather than continuous data, with the aim of summarising the data so that relationships between categories of variables can be presented graphically in two or three dimensions (Nenadic and Greenacre 2007). This is accomplished by displaying the results of the CA as coordinates on a two-dimensional biplot. When interpreting the CA biplot, row variables are displayed as points and the closer two points are together then the stronger the presumed association between those two variables. It is also possible to project the column variables as points onto the same biplot, and where a row variable is close to a column variable this indicates that the row variable has an important weight in the column variable profile. As a rule of thumb, the further away from the origin of the biplot two associated points are, the more confident you can be that a genuine association exists between them.

The histories and clinical signs associated with *T. orientalis* infection have only been systematically recorded on a few occasions (Thompson 1991; Izzo et al. 2010). There has however, been no further work to investigate whether certain signs cluster within age groups or farm types, or if the same disease syndrome is observed across all infected animals following *T. orientalis* infection produces. The aims of this study were to determine the words used most commonly in the clinical histories of animals naturally infected with *T. orientalis* Ikeda type; whether these words differed between cases categorised by age, farm type or haematocrit (HCT), and if there was any clustering of the common words in relation to these categories

5.4 Materials and methods

5.4.1 Data collection

This was a retrospective cross-sectional study based on a convenience sample of case histories submitted with blood samples which qualified for molecular testing, as part of the response of the Ministry for Primary Industries to the epidemic of TABA commencing in 2012. The data used in this analysis were collected from 17 October 2012 to 24 November 2014.

Cases enrolled in the analysis only included those for which blood samples had been accepted for molecular testing at the Animal Health Laboratory (AHL) or private regional laboratories (New Zealand Veterinary Pathology (NZVP) and Gribbles Veterinary Pathology). Initially samples were only accepted if piroplasms were present on a blood smear and the HCT was ≤ 0.24 L/L. Subsequently samples were accepted if either piroplasms were present on blood smear, or the HCT was ≤ 0.24 L/L. Molecular testing using an Ikeda type-specific quantitative PCR assay, as described by Pulford et al. (2016b), was carried out solely by the AHL until January 2014 when the work was ceded to the private regional laboratories

5.4.2 *Clinical histories*

The clinical histories were transcribed by hand by three of the authors (KEL, SFF, BV) from scanned digital images of the original specimen submission forms sent to NZVP or Gribbles, and were stored in a Microsoft Access (Microsoft Corporation, CA, USA) data base. Prior to text analysis these histories were pre-processed into more precise and accurate clinical terminology. For example, elevated heart rate was renamed tachycardia, elevated respiratory rate was renamed tachypnoea, a cow ill up to 4 weeks post-calving was described as postparturient and a cow sick just at calving was referred to as periparturient. When necessary, consecutive words within a history were run together so that their context and meaning wasn't lost, e.g. animals losing weight were renamed weightloss and animals with pale mucous membranes were renamed palemm. For many of the histories, the referring veterinarians were suspicious of theileriosis, however the words *Theileria* or theileriosis were excluded from the text analysis as the authors were only interested in the description of the clinical presentation. Where the submitted history referred to multiple diseased or dead animals then the history descriptor was pluralised to reflect this e.g. cow became cows, calf became calves and death became deaths.

Unless the submitting veterinarian had clearly differentiated between animals and given separate histories on the submission forms, then only one history was accepted for each laboratory submission, even if multiple samples were included in that same laboratory submission. For those submissions that included one history but multiple blood samples then the mean HCT was used for categorisation, if the group of samples had the same result based on PCR analysis.

In preparation for text mining each unique laboratory submission history became an individual document in a structured collection of text documents (a corpus). From the corpus of

submission histories, a mathematical matrix of the frequency of common words (a term-document matrix) in the laboratory submission histories was prepared, after removing unwanted text such as stop words and grammar (Meyer et al. 2008). For this analysis the term-document matrix had the laboratory submission ID as the row identifier and the history words as the column headings. A 1 or 0 was entered in the matrix depending on whether the history word (column) was present in the laboratory submission (row), and the column totals gave the frequency of that history word in all the laboratory submissions in the term-document matrix.

5.4.3 *Statistical analysis*

All analyses were undertaken using R v3.3.1 (R Development Core Team, 2016; R Foundation for Statistical Computing, Vienna, Austria). A visual summary of all the history words, that had a frequency ≥ 2 , was initially displayed using a word cloud, in which the size of font was proportional to the frequency of text such that the most common words used in the histories had the largest font.

The analysis was restricted to just the clinical histories from submissions that were positive for *T. orientalis* Ikeda type on PCR analysis of blood samples. In addition to the history words, the following variables were recorded for each laboratory submission: HCT was categorised as normal if HCT was >0.24 L/L, moderate anaemia if HCT was $0.15\text{--}0.24$ L/L, and severe anaemia if HCT was <0.15 L/L (Riond et al. 2008). Age of animal was categorised as young if 0–23 months, adult if ≥ 2 years old or unknown if age was not entered on submission form. Farm production type was categorised as dairy, beef or dry based on the description in the AgriBase database maintained byASURE Quality Limited (www.asurequality.com), which includes the spatial coordinates and demographic details for approximately 140,000 New Zealand farms.

For the categorical variables HCT, age and farm type, χ^2 tests were used to assess linear trends, or equality of proportions, for each of the 28 most common history words, across categories. For HCT, the null hypothesis was that there was no linear trend in the proportions of submissions for each word across the HCT categories. The Benjamini-Hochberg adjustment was used to control the false discovery rate (Benjamini and Hochberg 1995). Dry stock farms and unknown age group were not included in the analyses, as there were too few of these categories represented in the data set. For the age variable the words cows and calves were combined into a term multiple sick because these words were otherwise mutually exclusive and could not be compared.

Correspondence analysis was used to examine the potential clustering of the 28 most common history words (rows of the contingency table) in relation to age, categorised as young, old or unknown (columns of the contingency table). In addition, two supplementary column categories were added to the contingency table, these being farm type, categorised as beef or dairy (again excluding dry stock) and HCT, categorised as normal, moderate anaemia and severe anaemia. In CA, supplementary explanatory categories are passive and so are not included in the calculation of the CA coordinates but can still be displayed on the same CA biplot.

The CA produced a χ^2 statistic and correlation coefficient which were used to test whether there was an association between the rows and columns of the contingency table, with a correlation coefficient >0.2 indicating a significant linear dependency between rows and columns. The maximum number of dimensions generated by a CA is one less than the minimum number of rows or number of columns in the contingency table. Therefore, as there were only three categories of age, two dimensions were generated, with an eigenvalue calculated for each dimension. The closer the eigenvalue is to 1.0 the more exclusive the association between rows and columns for that dimension. The sum of the eigenvalues is the total inertia, and the proportion of the total inertia explained by the eigenvalue for one dimension is the percentage of variance explained by that dimension.

In order to more clearly identify any potential clustering of history words from the CA, agglomerative hierarchical clustering, using Ward's method (Ward and Hook, 1963),

, was performed on the coordinates from the CA. Agglomerative clustering is a data mining technique which builds a hierarchy of clusters from the bottom up; Ward's method is used to select the first clusters for joining based on those which together cause the least gain in within-cluster variability (Husson et al. 2010). The final number of clusters was derived by both visually examining the agglomerative hierarchical clustering tree and statistically by identifying the cut-point which maximised the gain in the between-cluster variability. The history words closest to the centre of each cluster were chosen as most representative of that cluster and the positive contributions of all explanatory variables, age, farm-type and HCT, to each cluster were quantified and statistically tested using the v-test (Husson et al. 2010).

5.5 Results

Over the data collection period, 677 unique submission histories were recovered, relating to 805 blood sample submissions, and 605 submissions were from Ikeda-positive cattle. Of these, 83/605 (13.7%) submissions were from Gribbles and 522/605 (86.3%) were from NZVP laboratories, with 409/605 (67.6%) from adult cattle, 104/605 (17.2%) from young cattle and 92/605 (15.2%) from animals for which age was unknown. Overall, 407/605 (67.4%) submissions were for cattle with severe anaemia, 143/605 (23.7%) for cattle with moderate anaemic, 54/605 (8.9%) were for cattle with normal HCT. The HCT result was missing for one submission. Dairy farms were responsible for 478/605 (79.5%) submissions, beef farms for 101/605 (16.8%) submissions, dry stock farms for 22/605 (3.7%) submissions, and farm type was not recorded for four submissions.

The frequency of the history words that were used twice or more is presented in supplementary Table 5-2 and is summarised visually in Figure 5-1. The most common words were jaundice (204/605), lethargic (162/605), pale mucous membranes (161/605), cow (151/605), anaemia (147/605), and off milk (115/605). The word haemoglobinuria was only recorded in seven submissions. Johne's disease was mentioned in 11 submissions, and aggressive, dangerous behaviour was recorded in seven submissions. Ticks were recorded in 11/605 submissions, of which 5/104 (4.8%) were from young cattle and 6/409 (1.5%) from adult cattle. Abortion was mentioned in four submissions and cattle were described as bought-in in 14 submissions. The word postparturient was recorded in 82 and periparturient in 10 submissions, with autumn calving recorded on four submissions.

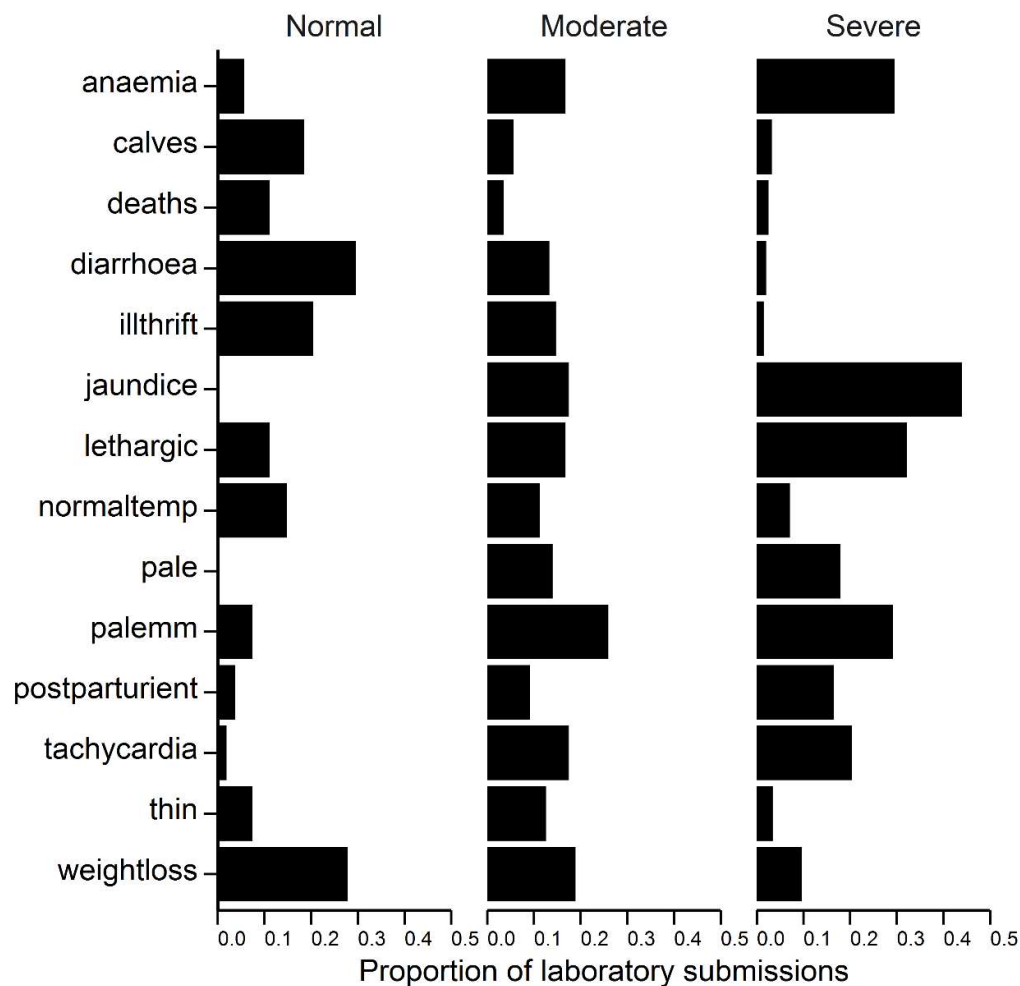


Figure 5-2. Proportion of words recorded in clinical histories, submitted with blood samples from cattle that tested positive for *Theileria orientalis* Ikeda type on PCR analysis, that differed ($p<0.05$) between cases with a haematocrit (HCT) >0.24 L/L (Normal; $n=54$), $0.15\text{--}0.24$ L/L (Moderate anaemia; $n=143$) or <0.15 L/L (Severe anaemia; $n=407$).

There was a higher proportion of cases from dairy than beef farms with the words cow ($p<0.001$), jaundice ($p=0.006$), off-milk ($p<0.001$), pale ($p=0.01$) and postparturient ($p=0.006$), and a higher proportion of cases from beef than dairy farms with the words calf ($p<0.001$), calves ($p=0.01$), deaths ($p=0.014$), diarrhoea ($p<0.001$), ill-thrift ($p<0.001$) and pyrexia ($p<0.001$). The proportion of submissions including words that differed between dairy and beef farms is presented in Figure 5-3.

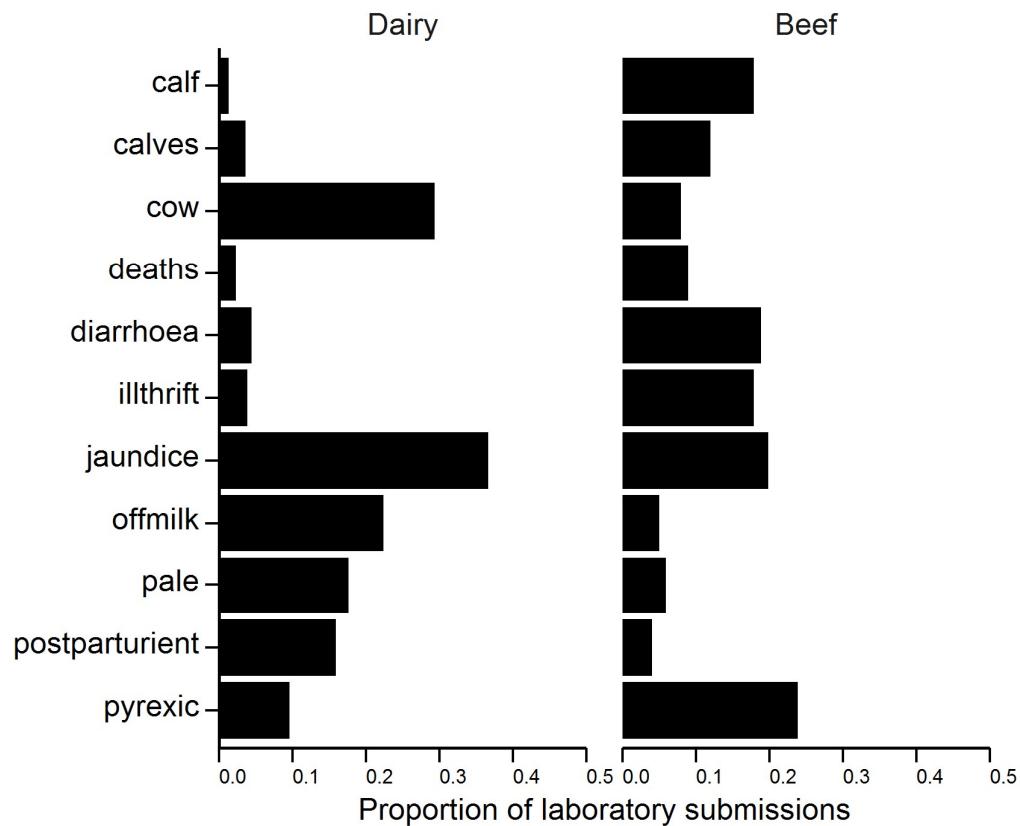


Figure 5-3. Proportion of words recorded in clinical histories, submitted with blood samples from cattle that tested positive for *Theileria orientalis* Ikeda type on PCR analysis, that differed ($p < 0.05$) between cases from dairy ($n = 478$) or beef ($n = 101$) farms.

There was a higher proportion of adult than young cases with the words jaundice ($p < 0.001$) and postparturient ($p < 0.001$), and a higher proportion of young than adult cases with words deaths ($p < 0.001$), diarrhoea ($p < 0.001$), ill thrift ($p < 0.001$) and multiple sick ($p = 0.013$). The proportion of submissions including words that differed between young and adult cattle is presented in Figure 5-4.

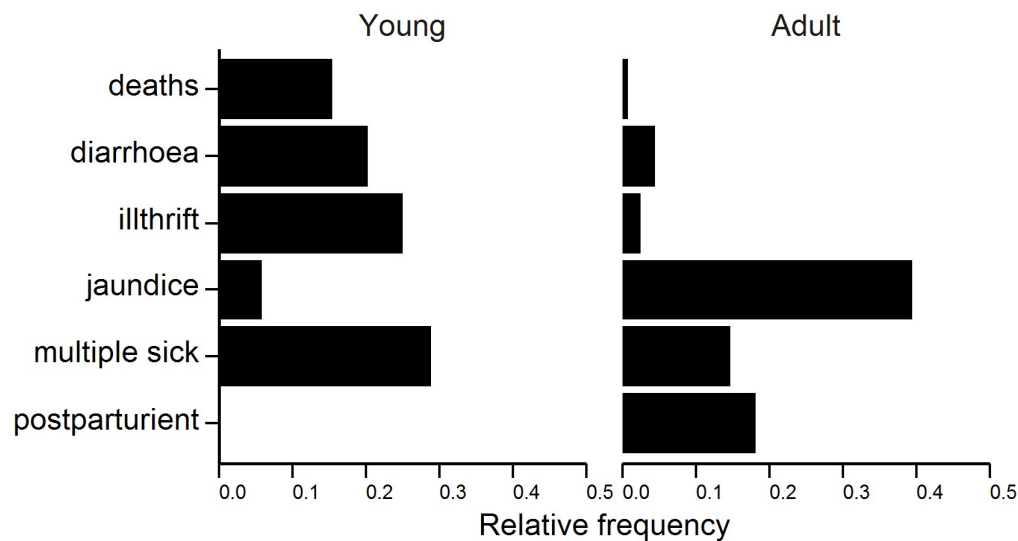


Figure 5-4. Proportion of words recorded in clinical histories, submitted with blood samples from cattle that tested positive for *Theileria orientalis* Ikeda type on PCR analysis, that differed ($p < 0.05$) between cattle aged 0–23 months (Young; $n=104$) or ≥ 2 years (Adult; $n=409$).

The contingency table used for the CA is presented in Table 5-1. The test of independence ($\chi^2=598$, $p < 0.0001$) and the correlation coefficient (0.55) indicated significant linear dependency between row and column variables. The total inertia for the CA was 0.3, the eigenvalue for the first dimension was 0.287 and for the second dimension was 0.013. The CA biplot is presented in Figure 5-5; the first dimension (Dim 1) explains 0.287/0.3 (95.7%) of the inertia and clearly differentiates between adult or unknown-age cattle and young cattle. The second dimension (Dim 2) explains only 0.013/0.3 (4.3%) of the inertia and differentiates between adult and unknown-age cattle

Table 5-1. Contingency table showing the frequency of words recorded in clinical histories submitted with blood samples from cattle that tested positive for *Theileria orientalis* Ikeda type on PCR analysis, categorised by age, farm type and haematocrit (HCT) result of each submission.

History word	Age			Farm type			HCT (L/L)		
	Adult	Young	Unknown	Total	Beef	Dairy	>0.24	0.15–0.24	<0.15
Anaemia	101	24	22	147	22	119	3	24	120
Anorexic	34	8	9	51	8	41	8	10	33
Calf	0	26	0	26	18	6	5	7	14
Calves	1	30	0	31	12	17	10	8	13
Constipated	17	0	2	19	1	18	0	3	16
Cow	129	2	20	151	8	140	13	35	102
Cows	60	1	9	70	12	56	2	17	51
Death	12	7	0	19	6	12	1	8	10
Deaths	3	16	2	21	9	11	6	5	10
Dehydration	12	1	4	17	4	13	2	6	9
Diarrhoea	18	21	4	43	19	21	16	19	8
Heifer	14	5	3	22	6	12	2	7	13
Ill thrift	10	26	2	38	18	18	11	21	6
Jaundice	161	6	37	204	20	175	0	25	179
Lethargic	110	26	26	162	32	121	6	24	131
Low temp	17	4	2	23	1	22	1	5	17
Normal temp	33	14	6	53	13	36	8	16	29
Off milk	106	0	9	115	5	107	10	24	81
Pale	68	10	16	94	6	85	0	20	74
Pale mucous membranes	113	23	25	161	26	125	4	37	119
Postparturient	74	0	8	82	4	76	2	13	67
Pyrexia	39	19	14	72	24	46	8	15	49
Sick	46	14	6	66	13	49	4	16	46
Tachycardia	83	13	13	109	13	91	1	25	83
Tachypnoea	37	12	5	54	9	43	4	16	34
Thin	28	5	3	36	8	28	4	18	14
Weak	14	7	1	22	2	17	1	4	17
Weight loss	60	10	11	81	14	64	15	27	39
Total	1400	330	259	1989	333	1569	147	455	1384

The results of the cluster analysis indicated that the recorded history words were grouped in two main clusters (Figure 5-6). One large cluster of words (enclosed by the red box) appeared to be grouped around the explanatory categories dairy, adult and severe anaemia in Figure 5-5. The second smaller cluster (enclosed by the green box), Figure 5-6, appeared associated with the categories young, beef and normal HCT in Figure 5-5.

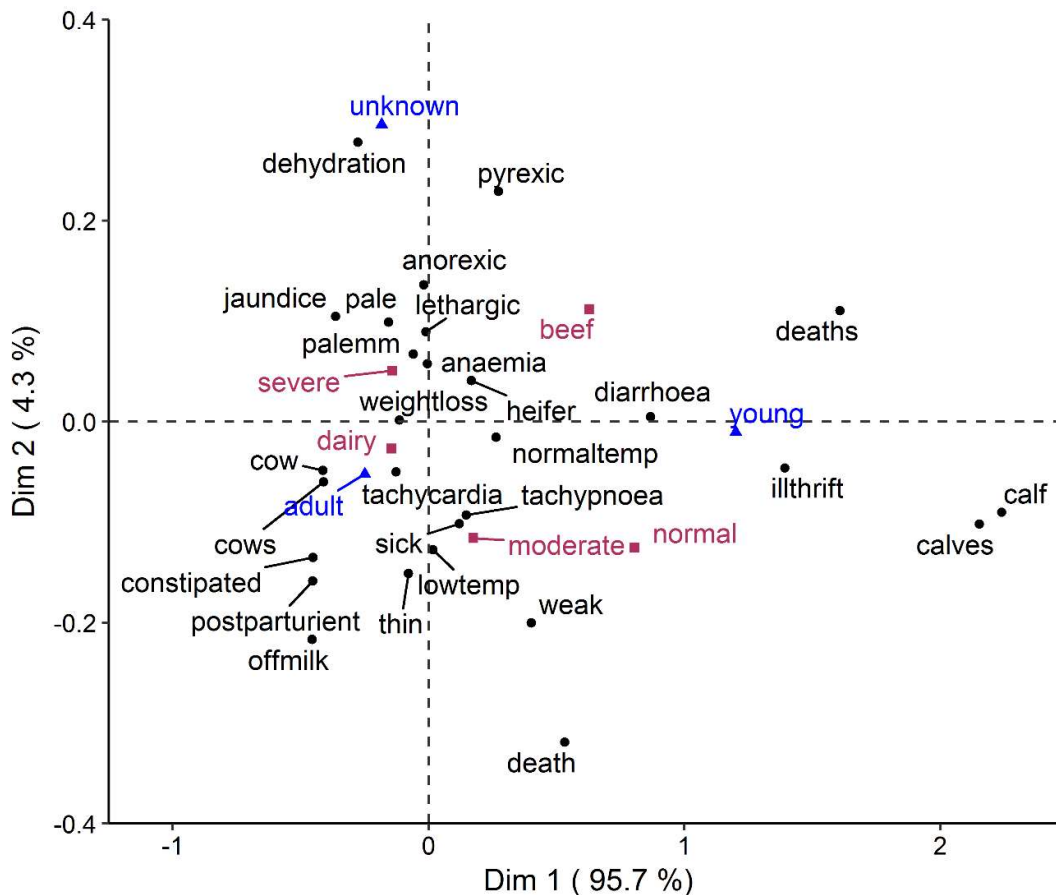


Figure 5-5. Correspondence analysis (CA) biplot of the co-ordinates for the 28 most common words (black) recorded in clinical histories, submitted with blood samples from cattle that tested positive for *Theileria orientalis* Ikeda type on PCR analysis, with the explanatory variable categories (blue and red words) for age (young, adult and unknown), farm type (dairy and beef) and haematocrit (normal, moderate and severe) projected onto the same biplot. Dim 1=the first dimension and Dim 2=the second dimension generated by the CA.

The most representative history words for the large cluster were weight loss, tachycardia, pale mucous membranes, anaemia, lethargic and thin, and for the second cluster were deaths, ill-thrift, calves, calf and diarrhoea. The explanatory variables which were positively associated with the first cluster were adult ($p<0.001$), severe anaemia ($p<0.001$), dairy ($p<0.001$) and age unknown ($p<0.001$) and with the second cluster were young ($p<0.001$), normal HCT ($p<0.001$), beef ($p<0.001$) and moderate anaemia ($p<0.001$). The first cluster included 1,368/1,400 (98%) of all the history words recorded for adult cases, 1,333/1,384 (96%) of all the history words recorded for severe anaemia cases, 1,496/1,569 (95%) of all the history words recorded for dairy cases and 251/259 (97%) of all the history words recorded for unknown age cases. The second cluster included 119/330 (36%) of all the history words recorded for young cattle cases,

48/147 (33%) of all the history words recorded for normal HCT cases and 76/333 (23%) of all the history words recorded for beef farm cases.

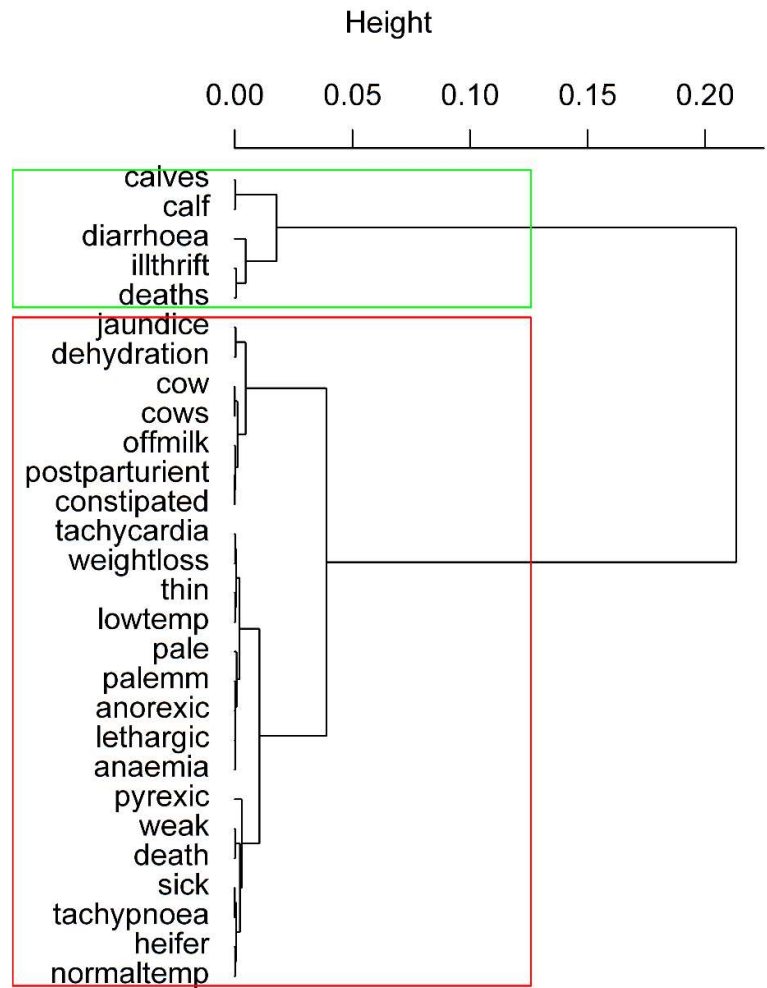


Figure 5-6. Dendrogram showing the results of the agglomerative hierarchical cluster analysis performed on the results of a correspondence analysis on the 28 most common words recorded in clinical histories, submitted with blood samples from cattle that tested positive for *Theileria orientalis* Ikeda type on PCR analysis. Two main clusters were identified that are outlined by red and green boxes.

5.6 Discussion

This analysis of words used in clinical histories of cases of cattle infected with *T. orientalis* Ikeda type has demonstrated that the words most commonly used were consistent with the affected cattle suffering from a severe regenerative extravascular haemolytic anaemia, in that the affected cattle show anaemia and jaundice without haemoglobinuria. The most commonly

used history words were found to differ between cases categorised by age, farm type and HCT. The cluster analysis revealed two main groupings for these words with the larger cluster of history words centred on the CA biplot origin (Figure 5-5), suggesting that these are the typical words associated with TABA, and a second smaller cluster that was well separated from the first cluster on the first dimension of the CA. These two clusters of history words potentially indicate that two different disease syndromes associated with TABA exist, with the main or usual disease syndrome seen in adult, severely anaemic dairy cattle and the second disease syndrome seen in young beef animals with a normal HCT.

On the CA biplot the disease seen in young beef animals appeared quite separate to the main disease syndrome seen mostly in adult dairy cows. This is supported by the eigenvalue for the first dimension which was reasonably high and clearly separated young from adults or unknown-age animals. However, the eigenvalue for the first dimension indicated that the clustering was not exclusive, as supported by the cluster contributions. For adult dairy cows, >95% of their history words were associated with the main cluster, but for young cattle only 36% of their history words were associated with the second cluster. This could indicate that young beef animals can be affected with either disease syndrome, whereas adult dairy cattle are mostly affected with the first more usual disease syndrome.

There may be a pathophysiological basis for the two disease syndromes. Differences in some haematology results between young beef cattle and mature dairy cows have been found in some of our analyses (Lawrence et al. 2018a). In addition, beef breeds appear to have a lower susceptibility to *T. orientalis* infection compared to dairy breeds (Terada et al. 1995; Higuchi et al. 2003). However, evaluating whether age or breed is more important in determining clinical outcomes is difficult in New Zealand because data on the frequency of disease in dairy calves is confounded by dairy calves being housed for the first 3–5 weeks of life, leading to entirely different tick exposure patterns compared with beef calves.

Haemoglobinuria was only reported for 7/605 laboratory submissions and supports the assertion that intravascular haemolysis is not a feature of *T. orientalis* infection (Yagi et al. 1989; Shimizu et al. 1990).

Despite their importance in disease transmission, ticks were only reported in 11 submission histories, with a tendency for them to be observed more often on young stock than adults. This possibly indicates that ticks are more easily observed in young stock or that veterinarians were not routinely examining cattle for ticks. It is also likely that by the time the animal was clinically ill the ticks responsible for infecting the animal had already fed and dropped off the animal. The lowest HCT is reached 4–6 weeks after infection (Uilenberg et al. 1985; Shimizu

et al. 1990) and this is the point at which most sick animals reach their nadir and possibly show clinical signs. However, this point may also coincide with a period of low tick activity or absence.

Pyrexia was more often reported in cases from beef than dairy farms and there was a decreasing linear trend for normal temperature across HCT categories from normal to severe anaemia. Observations on both experimentally and naturally infected cattle agree that pyrexia is usually seen when piroplasms first appear in the peripheral circulation (Uilenberg et al. 1985; Shimizu et al. 1990). However, a second temperature spike, after 25–30 days, was only reported in splenectomised calves (Shimizu et al. 1990). Pyrexia is not a consistent finding in cases of TABA.

In a summary of the clinical findings from 101 cases in the 1982–1986 *T. orientalis* epidemic (James et al. 1984), the two most common presenting signs were ill-thrift (29/101) and diarrhoea (23/101); it is noteworthy that anaemia and jaundice were not commonly reported in that epidemic (Thompson 1991). These signs are like those associated with young beef cattle in the current study. Although they are non-specific, the agreement between two different *T. orientalis* types may lend some support to the supposition that the pathological effects of *T. orientalis* infection are not just limited to extravascular haemolytic anaemia, and in the absence of anaemia, the Ikeda and Chitose types can potentially produce similar disease syndromes. It is important to note that many of the Ikeda-positive infections diagnosed in New Zealand since 2012 would have probably been mixed infections of Ikeda and Chitose, Ikeda and Buffeli or all three types (Pulford et al. 2016a).

In a review of eight herd outbreaks of TABA in Australia, with clinical signs recorded at the herd level, the most common presenting complaints were inappetence (8/8 farms) and lethargy (8/8 farms) and the most common clinical signs were icterus and pale mucous membranes (8/8 farms) (Izzo et al. 2010). Overall the outbreaks of *T. orientalis* on Australian farms often involved introduced cattle, with disease commonly presenting in the periparturient period, and stillbirth, abortion or death being frequently reported (Izzo et al. 2010; Perera et al. 2013). Abortion was apparently not a common feature of the New Zealand histories with only four reports of abortion recorded for Ikeda-positive submissions. This is possibly because the peak in tick nymph activity corresponds to the seasonal calving period in New Zealand whereas in Australia the more popular all-year-calving system allows cattle to be potentially infected in the late dry period rather than at the point of calving or in early lactation as in New Zealand. Unlike the Australian outbreaks, cattle were only described as bought-in in 14 cases. This observation is likely biased as previous analysis, using National Animal Identification and

Tracing (OSPRI, Wellington, New Zealand) movement data, found that farms with clinical cases of TABA were twice as likely as farms without clinical cases of TABA to have had inward cattle movements over the first 18 months of the *T. orientalis* Ikeda epidemic (Lawrence et al. 2016). The low frequency of the word bought-in in the submission histories could reflect deficiencies in either practitioners' history taking or form completion. In addition, only four case histories mentioned autumn calving herds. There has been some discussion that the autumn peak in TABA cases was due to the infection of autumn-calving dairy cows (McFadden et al. 2016a), however the low frequency of this history word would probably refute this association.

The limitations of this study include it being based on a convenience sample of submission histories, which in turn relied on practitioners fully completing the history section of the laboratory submission form. It could be argued that busy practitioners don't always have time to fully complete submission forms. However, it is likely that even in these circumstances the most important findings would still be recorded. Furthermore, working with untidy data is a reality for this type of study and at times this required the subjective interpretation of illegible entries, however it is believed that by accessing over 600 submission histories the conclusions reached are reasonably robust. The data used in this study were sourced from the two private veterinary laboratories in New Zealand, no attempt was made to access history data held by private veterinary practices or the Ministry for Primary Industries. We believe this is not a serious bias to the study.

An additional limitation is the cross-sectional study design. With no temporal information on the duration of the disease when the animals were sampled and the histories taken, this raises the possibility that the two clusters represent different stages of the same disease. The poor representation of mature dairy cattle in the second smaller cluster, might suggest that this is not a valid conclusion.

Currently there is no easy method to recover the history from laboratory submission forms in New Zealand. In this study, the histories were laboriously copied into the data base by hand from scanned images of the original forms. As a result, the value of histories to understanding the epidemiology of a new disease and in conducting syndromic disease surveillance could easily be lost. Furthermore, this study has shown how remarkably accurate and important practitioners' observations can be in an exotic disease incursion. The significant increase in the proportion of submissions including the words jaundice, lethargy and pale mucous membranes for the three categories of HCT shows that practitioners can be an accurate source of observational data.

Further work needs to be carried out in New Zealand to explore methods to efficiently capture laboratory submission histories, and to enable practitioners to submit legible and complete histories, so that important epidemiological data do not continue to be lost.

5.7 Supplementary table

Table 5-2. History words, with a frequency greater than 2, for 605 submitted histories from unwell cattle positive by PCR for *Theileria orientalis* Ikeda type

Word	Frequency	Word	Frequency	Word	Frequency
jaundice	204	heartmurmur	13	heifers	4
lethargic	162	sudden	13	melaena	4
palemm	161	johnes	11	yearlings	4
cow	151	ticks	11	bull	3
anaemia	147	noisylungs	10	bullbeef	3
offmilk	115	periparturient	10	driedoff	3
tachycardia	109	slow	10	gut	3
pale	93	ataxic	9	mastitis	3
postparturient	82	dyspnoea	9	murmur	3
weightloss	81	bottlejaw	8	paleudder	3
pyrexia	72	aggressive	7	poorcoat	3
cows	70	down	7	precalving	3
sick	66	emptyrumen	7	rfm	3
tachypnoea	54	galloprhythm	7	sounds	3
normaltemp	53	haemoglobinuria	7	abdominaldistention	2
anorexic	51	nad	7	bulls	2
diarrhoea	43	photosensitisation	7	condition	2
illthrift	38	yearling	7	dry	2
thin	36	depressed	6	emaciated	2
calves	31	salivating	6	empty	2
calf	26	coughing	5	hypermotilerumen	2
lowtemp	23	jugularpulse	5	hypomotileguts	2
heifer	22	metritis	5	hypomotilerumen	2
weak	22	pneumonia	5	ketosis	2
deaths	21	abortion	4	lice	2
constipated	19	acute	4	nofaeces	2
death	19	arrythmia	4	oedema	2
dehydration	17	autumncalving	4	poor	2
boughtin	14	dystocia	4	slowrumen	2

Chapter 6

The effect of month, farm type and latitude on the level of anaemia associated with *Theileria orientalis* Ikeda type infection in New Zealand cattle naturally infected at pasture

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6.1 Preface

Although seasonality for many tick-borne diseases is well described including *Theileria* associated bovine anaemia, what has never been shown previously is whether seasonality also affects the severity of disease presentation. This study was instigated to fill an important gap in the epidemiology of the disease and was based on data collected by the Ministry for Primary Industries between August 2012 and November 2014.

6.2 Abstract

Commencing in 2012, an epidemic of infectious bovine anaemia associated with *Theileria orientalis* Ikeda type has been present in New Zealand. The aims of this study were to analyse the temporal and spatial effects of *T. orientalis* Ikeda type infection on the sample submission rates and haematocrits of infected cattle over the first two years of the New Zealand epidemic. The data were collected from 30/08/2012 to 28/11/2014 and included all samples that met the case definition for *Theileria* associated bovine anaemia (TABA) and tested positive for *T. orientalis* Ikeda type by PCR. The sample submission rates by month and farm type were highly seasonal with dairy farm submissions peaking in September a month before beef farm submissions peaked. A second lesser peak of dairy farm submissions in April was absent for beef farms. A mixed effects model was fitted to the data and showed a significant interaction between farm production type (dairy or beef) and month of sampling ($p = 0.006$) and a between latitude and month of sampling ($p = 0.024$). The estimated haematocrit, adjusted for month and latitude, for dairy cattle = 0.125 (95%CI 0.121-0.129) and for beef cattle = 0.151 (95% CI 0.138-0.165), $p < 0.0001$. This research shows that infected beef animals tend to be less severely affected than dairy animals and that the month of sampling and latitude of the sampled farm have significant and interacting effects on the level of anaemia associated with *T. orientalis* Ikeda type infection.

6.3 Introduction

Commencing in 2012, an epidemic of infectious bovine anaemia associated with *Theileria orientalis* Ikeda type has been present in New Zealand (McFadden et al. 2013). *T. orientalis* Ikeda type is one of eleven recognised allelic types of *T. orientalis* and is almost certainly the most pathogenic (Hammer et al. 2016). *T. orientalis* comprise tick-borne obligate intracellular

apicomplexan haemoprotozoan parasites of cattle around the world (Aktas et al. 2006) and, except for the Ikeda type, are only rarely associated with severe disease outbreaks (Watts et al. 2016). To the best of our knowledge 4 of the 11 types of *T. orientalis* are presently found in New Zealand cattle, Type 1 (Chitose), Type 2 (Ikeda), Type 3 (Buffeli) and Type 5 (Pulford et al. 2016b). The Chitose and Buffeli types have probably been present in New Zealand since 1982 and have been sporadically associated with mild outbreaks of bovine anaemia in the upper North Island (James et al., 1984; Rawdon et al., 2006; McFadden et al., 2011).

The Ikeda type is associated with a pandemic of infectious bovine anaemia originating in East Asia before spreading first to Australia in 2006 (Kamau et al. 2011a; Eamens et al. 2013b) and then New Zealand in 2012 (McFadden et al. 2013; Pulford et al. 2016a). The source of the Australian outbreak is not known, but historically the disease has long been described in Japan and Korea (Onuma et al. 1998), and the importation of infected Wagyu cattle from Japan via Guam is suggested as the likely incursion pathway (McFadden and Marchant, 2015). Similarly, the spread of disease to New Zealand probably followed the live importation of cattle from Australia prior to 2012. Little is known about the pathogenicity of Type 5 but it is presumed to be benign (Pulford et al. 2016a), it too was not found in New Zealand until 2012.

There is only one competent arthropod vector for *T. orientalis* in New Zealand, the hard tick *Haemaphysalis longicornis*, and its lifecycle and distribution have been thoroughly reviewed (Heath, 2016) and modelled (Lawrence et al. 2017b). In New Zealand the *H. longicornis* life cycle is usually completed within 12 months, with over-wintering nymphs mainly engorging from July to September, adults from November to December and larvae from February to April (Fig. 2, Heath, 2016). Once infected, cattle probably remain infected and infectious for life (Onuma et al., 1998) and although non-tick associated, mechanical spread of infection is also described through biting flies, sucking lice or hypodermic needles (Hadi and Al-Amery, 2012; Fujusaki et al., 1993; Hammer et al., 2015; Hammer et al., 2016) it is not thought to be important in the epidemiology of *Theileria* associated bovine anaemia (TABA). However, its involvement in some New Zealand TABA outbreaks cannot be ruled out altogether. Likewise, vertical transmission of infection from dam to calf across the placenta is unlikely to be significant in the epidemiology of the disease (Lawrence et al., 2016c; Hammer et al., 2016; Swilks et al. 2017a).

Infection rarely leads to overt signs of disease (Fairley, 1992; Vink et al., 2016) but when clinical disease is observed then symptoms consistent with hypoxia and extravascular

haemolysis are reported (McFadden et al., 2013, Lawrence et al., 2017a), with a case fatality rate of about 25% (Vink et al., 2016). The disease is highly seasonal with a major peak observed in October and a lesser one in April (McFadden et al., 2016a). Whereas the spring peak is easily explained by the feeding activity of over-wintered infected nymphs, the autumn peak does not correlate well with the active tick stage since it encompasses the period of larval questing and larvae are considered to hatch uninfected (Higuchi, 1985). Although the seasonality of the epidemic curve in New Zealand has been documented there has been no investigation of the effect of month, farm type, longitude or latitude on the level of anaemia observed in the individual diseased animals and the sample submission rates. The aim of this study was to test the hypothesis that the effect of *T. orientalis* Ikeda type infection on the haematocrit and the case submission rate is significantly different between beef and dairy farms, across different months of the year and across different latitudes and longitudes.

6.4 Materials and methods

6.4.1 Data collection

This was a retrospective observational study using data collected by the New Zealand Ministry for Primary Industries (MPI) in response to the epidemic of TABA. The data analysed in this study were collected from 30/08/2012 to 28/11/2014 and included the sampling date, the farm production type (whether dairy, beef or dry stock), the PCR test result, the haematocrit, the farm Cartesian X and Y coordinates (New Zealand Transverse Mercator 2000 projection) of the sampled farm and the number of piroplasm infected red blood cells (RBC) per 1,000 RBC (when carried out). Data on animal age was rarely entered on the sample submission forms so consequently was not routinely recorded in the database. Farm production type was categorised as dairy, beef or dry based on the description in the AgriBase database maintained byASUREQuality Limited (www.asurequality.com). The spatial coordinates of the centroid of each farm were obtained from Farms on Line (<http://farmsonline.maf.govt.nz/>). All the farm data and laboratory results were entered and maintained in an Access 2007 data base (Microsoft Corporation, Redmond, Washington, U.S.). Initially MPI were responsible for keeping the *Theileria* data base but this was contracted out to ASUREQuality (www.asurequality.com) at the end of 2013 and data recording officially finished at the end of November 2014.

6.4.2 *Haematology testing*

All the haematology work was completed at the private regional veterinary laboratories (New Zealand Veterinary Pathology (NZVP) and Gribbles Veterinary Pathology) who received blood samples from suspect cases of TABA, submitted by private veterinarians in the field. For each blood sample a thin blood smear was prepared, stained with Leishman's stain and examined under oil immersion using light microscopy. Erythrocytes were examined for the presence of ring-shaped or coma-shaped organisms consistent with *Theileria* piroplasms and the number of *Theileria* infected red blood cells per 1000 red blood cells observed was used as a measure of infection intensity. This counting requirement proved to be too time consuming and was later simplified, by MPI, to just reporting if piroplasms were present on the smear. The haematocrit (HCT) was measured for each submitted sample using either the Sysmex XT-2000i (Sysmex Corporation, Japan) or the Cell-Dyn 3700 (Abbott Laboratories, Philippines) automated haematology analyser if the samples were sent to NZVP or Gribbles Veterinary Pathology respectively. The sampled animals were classed as anaemic if the haematocrit (HCT) ≤ 0.24 L/L (Riond et al. 2008).

6.4.3 *Molecular testing*

The molecular testing was completed either through the Animal Health Laboratory (AHL, Wallaceville, Wellington, New Zealand) or through the private regional veterinary laboratories. For a full description of the molecular techniques undertaken see Pulford et al. (2016b). Briefly, EDTA-treated blood samples were routinely diluted 1:5 in sterile water prior to DNA extraction, whereas serum samples were used undiluted. Samples were processed on a Corbett Extractorgene robot (Qiagen, Germany) to extract DNA which was eluted in 200 μ L of diethylpyrocarbonate treated sterile water. All purified DNA samples were subject to an 18S quantitative PCR (qPCR) to measure sample consistency and the absence of PCR inhibitors. Samples were then analysed using an Ikeda type-specific TaqMan qPCR assay. The qPCR results with a quantification cycle threshold ≤ 38 were recorded as positive, > 38 as suspicious and samples with no signal were considered negative. PCR analysis was carried out solely by the AHL until January 2014 when the work was ceded to the private regional laboratories, where the same molecular technique developed at the AHL were used.

6.4.4 *Data manipulation and statistical analysis*

The analysis was restricted to only those samples that met the following requirements; the sampled bovine was anaemic ($HCT \leq 0.24$ L/L), *Theileria* were identified on the blood smear by light microscopy, and the sample was positive by PCR for *T. orientalis* Ikeda type.

In the early part of 2013, MPI commissioned multiple samples from 26 recently infected cattle herds to gain a better understanding of the within herd prevalence and epidemiology of TABA (Lawrence et al., 2018c). These data were removed from the data set since they were purposively sampled and would likely bias the results. Coincidentally there were several farms, not included in the prevalence study, where the consulting veterinarians independently submitted many samples. Although it was conceivable that these farms were experiencing an extensive TABA outbreak, it was also highly likely that the veterinarians' sampling protocols were influenced by the knowledge that MPI were fully subsidising the PCR costs. These multiple samples clearly represented an additional challenge to the analysis. On the one hand, it was considered important to reflect genuine increased seasonal or farm type susceptibility but on the other without the bias of excessive non-case-based sampling. As a compromise, a random sub-sample of up to 3 Ikeda-positive anaemic submissions was made from all submissions that met the full case definition, for the same farm, on the same sample date. Each farm-sample date was then given a unique ID. If the same farm later submitted additional samples, which again met the case definition, a random sample of up to 3 submissions was again selected and tied to the later submission date with a new unique ID. Only beef or dairy farms and only North Island cases were included in the analysis; the dry stock cases and the two South Island cases were dropped.

A two-sample t-test was used to test whether there was any systematic bias in the estimated HCT between the two labs, given that the different laboratories used different haematology analysers. A plot of the proportion of total submissions, with standard error bars, contrasting beef and dairy farms by month of sampling was constructed and a chi-square test of independence carried out.

A linear mixed effects model was built using the cleaned data set. A mixed effects linear model is one that has both fixed and random effects. Fixed effects are constant across individuals and estimate the mean effect whereas random effects vary across data levels and estimate the variance.

The equation for the multilevel mixed effects models used in this analysis was

$$Y_{ij} = b0_j + b1X_{ij} + \varepsilon_{ij}$$

$$b0_j = b0 + u0_j$$

Where Y_{ij} is the HCT for the i^{th} cow in the j^{th} herd, $b0_j$ is the random intercept for the j^{th} herd which is broken down into the average model intercept $b0$ and an error term for each herd, $u0_j$. The fixed effects are $b1X_{ij}$ and ε_{ij} is the error term for the i^{th} cow in the j^{th} herd. The two error terms $u0_j$ and ε_{ij} are independent and normally distributed with a mean of zero. The family wise error rate for multiple post-hoc comparisons was controlled using Tukey's HSD. The fixed effect variables tested were month of sampling, farm production type (beef or dairy) and the latitude and longitude coordinates of the affected farm. The latitude coordinates were centred on the city of Hamilton to improve interpretation of the model results. Interaction terms were also tested in the model and all variables and interactions were retained at $p < 0.05$ using the log likelihood ratio test. To establish how the variance in HCT was distributed across the two levels of the data, the individual animal and the herd, an unconditional model was fitted with no predictor variables but with herd entered as a random effect (Bell et al. 2013). The intraclass correlation coefficient (ICC) estimates what proportion of the total variance of HCT is accounted for by the farm. The higher the ICC the more similar are the HCTs of cows in the same herd and the more clustered the data.

Linear estimates of significant model interactions were made using least-squares means (Lenth, 2016), with the latitude effects equivalent to the cities of Whangarei, Hamilton and Palmerston North estimated. These cities are the regional capitals of Northland, the Waikato and the Manawatu respectively which are the regions most severely affected by the TABA epidemic. Residual plots were used to assess the fit of the linear mixed effects model and the spatial autocorrelation of the residuals was also examined using bubble plots (Bivand et al., 2013) and a semivariogram (Pebesma, 2004).

All analyses were undertaken using R v3.2.3 (R Development Core Team, 2016).

6.5 Results

After the removal of the purposively sampled (MPI prevalence study) submissions there were 1645 individual samples from anaemic, Ikeda PCR positive cattle submitted during the

collection period. Of these 1350/1645 (82.1%) were from dairy farms, 240/1645 (14.6%) were from beef farms and 55/1645 (3.3%) were from dry stock farms. There were 275/1645 (16.7%) of samples with a piroplasm count, as opposed to just being recorded as piroplasms present, and the geometric mean piroplasm count was 13.6 *Theileria* infected red blood cells per 1000 red blood cells (1.4%). Only 2/1645 samples, both from dairy farms, were submitted from the South Island.

The 1645 samples were from 1306 unique farm-sample date submissions, the median number of submissions per farm per sample date was 1 (range 1 to 8). The South Island samples (2) and dry stock samples (55) were dropped from the analysis, leaving 1588 samples, and taking a random sample of up to 3 farm-day submissions retained 1529/1588 (96.3%) of the original data. In the final data set the 1529 samples were taken on 1258 unique farm- sample dates from 1120 farms. There was no systematic bias in the HCT estimated between the two private regional laboratories ($p = 0.78$).

Figure 6-1 shows the location of farms sampled over the epidemic, the positions of the cities of Whangarei, Hamilton and Palmerston North are also shown. The total sample submissions over the sampling period by farm production type and month, excluding those farms purposively sampled, are shown in Fig. 6-2. The plot illustrates two annual submission peaks, a major peak from August through to November and a lesser one from March through to May. The annual submission profiles by month for the two farm types are shown in Fig. 6-3. The chi-square test was significant, $\chi^2 = 78.1$, $df = 11$, $p < 0.0001$, and the greatest differences between observed and expected counts for the two farm production types was in April, August, September and November. Over the 12 months the two farm types show a similar pattern of sample submissions with two main differences: the dairy submissions peak in September whereas the beef submissions peak a month later in October and the dairy submissions have an additional lesser peak in April whereas the beef farms don't.

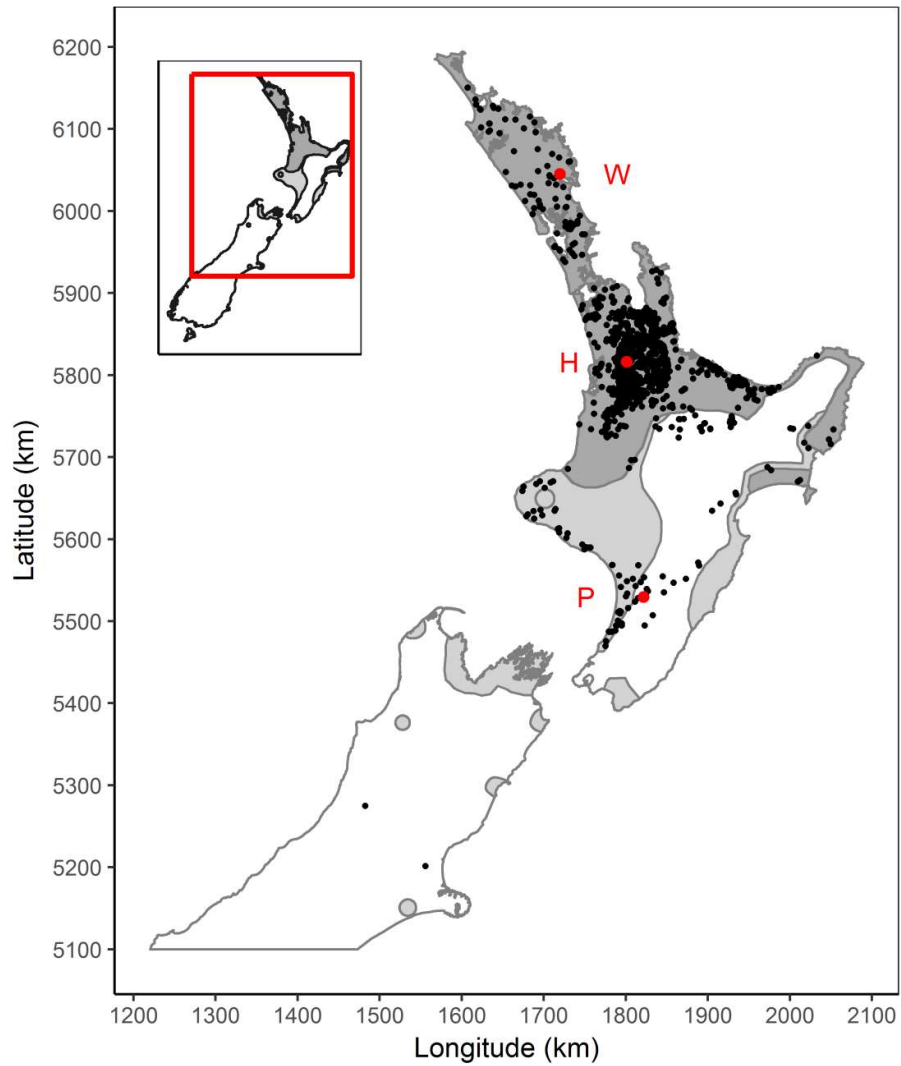


Figure 6-1. Location of farms with *Theileria orientalis* Ikeda type PCR positive cases of *Theileria* associated bovine anaemia between August 2012 and November 2014. The dark grey areas are high risk, the light grey areas are low risk and the white areas are zero risk of *Haemaphysalis longicornis* infestation (Heath, 2016). The following cities; Whangarei, (W), Hamilton (H) and Palmerston North (P) are identified.

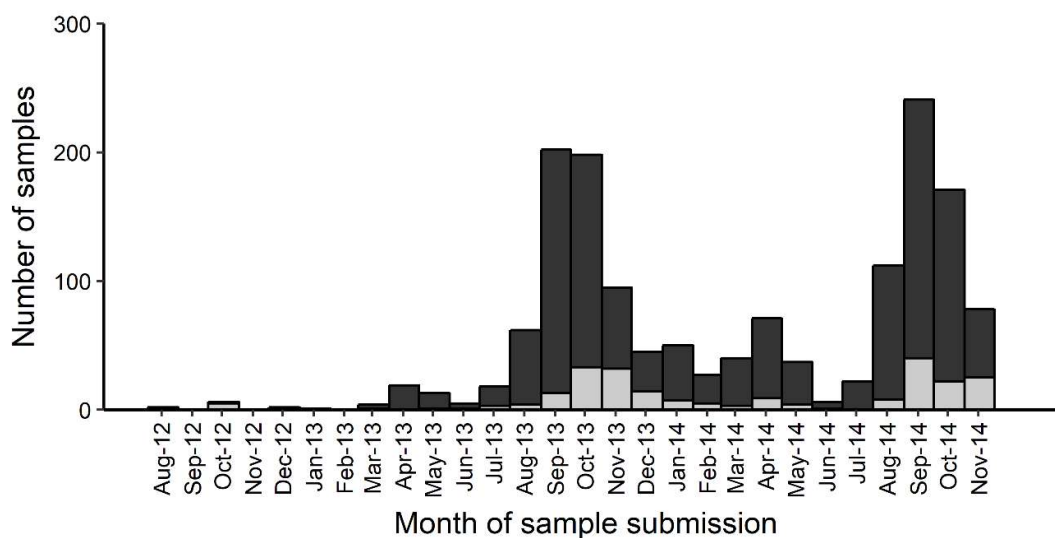


Figure 6-2. The number of samples from PCR positive cases of bovine anaemia associated with *Theileria orientalis* Ikeda type infection, by farm production type and month over the sampling period. The dark grey bars are dairy farms and the light grey bars are beef farms.

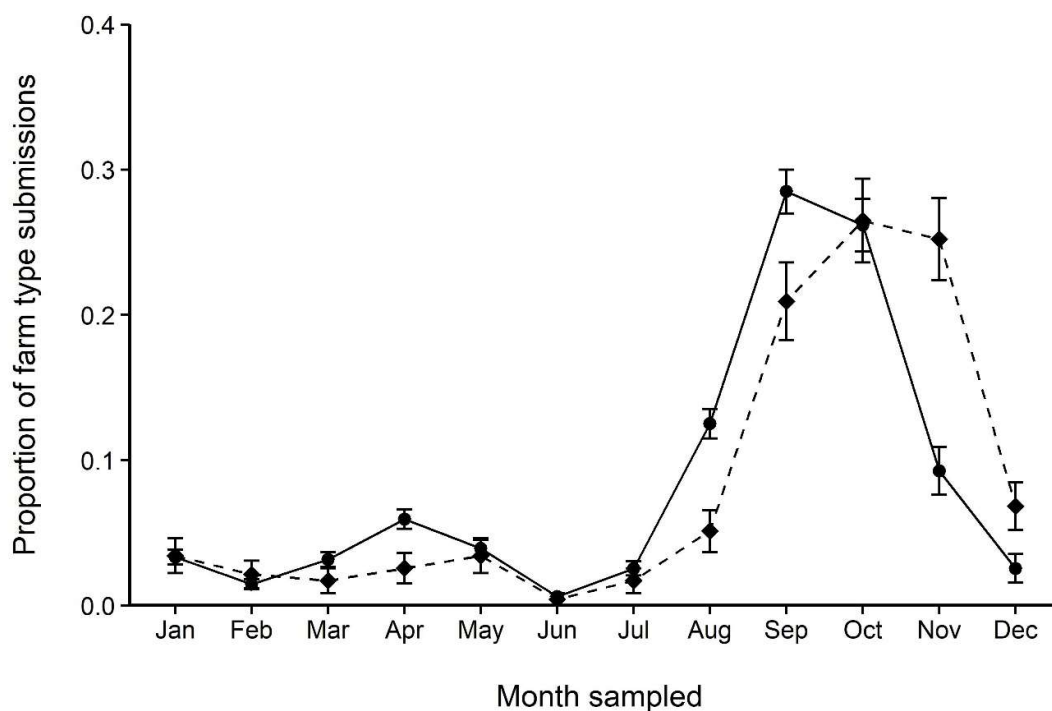


Figure 6-3. Proportion of total submissions, with standard error bars, for anaemic *Theileria orientalis* Ikeda type PCR positive animals, by farm production type and month of disease. Dairy farms are shown by circles joined by a solid line and Beef farms are shown by diamonds joined by a broken line. There were 1295 samples from dairy farms and 234 samples from beef farms

The linear mixed effects model was fitted with a log base 2 transformation of HCT. The final model showed two significant interactions, the first between farm production type and month

of sampling ($p = 0.006$) and the second between latitude and month of sampling ($p = 0.024$). Longitude was not significant in the final model ($p = 0.59$). The adjusted estimated HCT for dairy cattle was 0.125 (95%CI 0.121-0.129) and for beef cattle was 0.151 (95% CI 0.138-0.165), $p < 0.0001$. The HCT was significantly higher for beef cattle in March, May, July, September and November, and for no month was the HCT of beef cattle significantly lower than dairy cattle.

The intraclass correlation coefficient (ICC) was 0.35 (95% CI 0.26–0.43) indicating that 35% of the variability of HCT was explained by herd and 65% by the individual cattle. The bubble plots and semi-variogram plots showed no indication of spatial autocorrelation and the residuals were normally distributed.

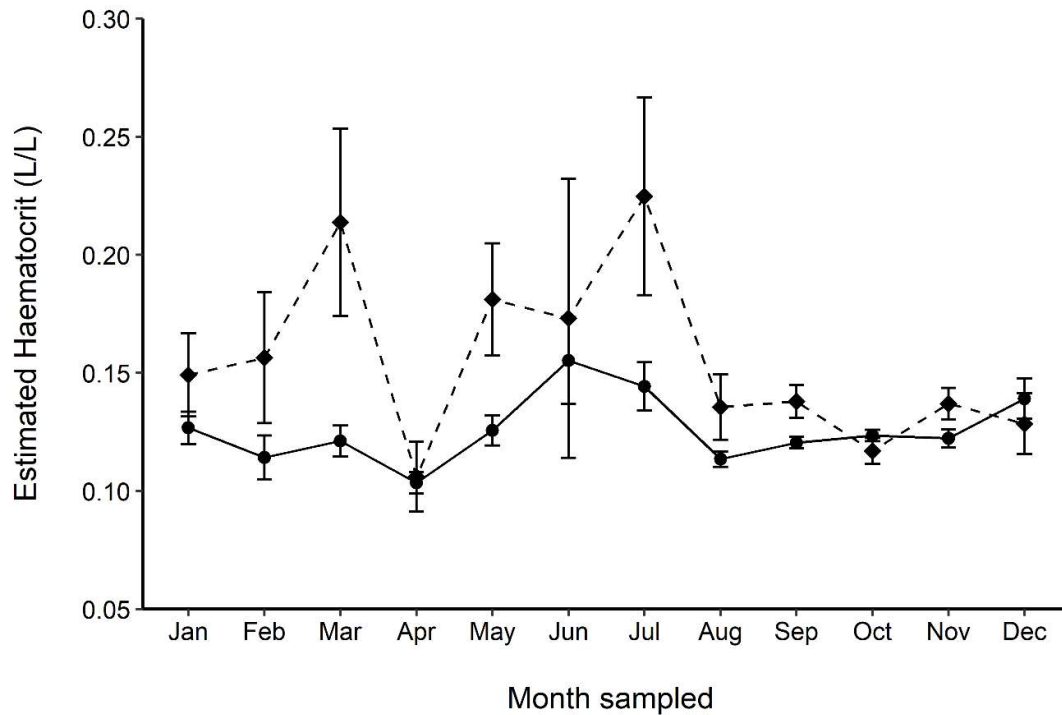


Figure 6-4. The least square means, with standard error bars, for the effect of *Theileria orientalis* Ikeda type infection on the haematocrit by farm production type and month of sample submission (controlling for the effect of latitude). Dairy farms are shown by circles joined by a solid line and Beef farms are shown by diamonds joined by a broken line.

The LSmeans plot for the farm type x month interaction, controlling for the effect of latitude, Fig. 6-4, shows that for August through to December the beef and dairy cattle have a similar pattern with the average HCT of infected beef cattle being higher in August, September and November, and slightly lower in October and December. For the remainder of the year the beef HCTs were much higher with the exception of April. Paradoxically although there is no spike

in beef submissions in April (Fig. 6-3), the cases that do present are on average amongst the most anaemic seen on all farms, irrespective of type, throughout the year (Fig. 6-4).

The LSmeans plot for the latitude x month interaction, controlling for the effect of farm type, Fig. 6-5, shows that for the months, August through to December, the effect of *T. orientalis* Ikeda type infection on HCT is similar irrespective of the farm latitude. However for the months January through to April and for June the effect of *T. orientalis* Ikeda type infection on HCT is highly dependent on latitude, with the further north a sample originates, the higher the HCT (less severe the anaemia) was.

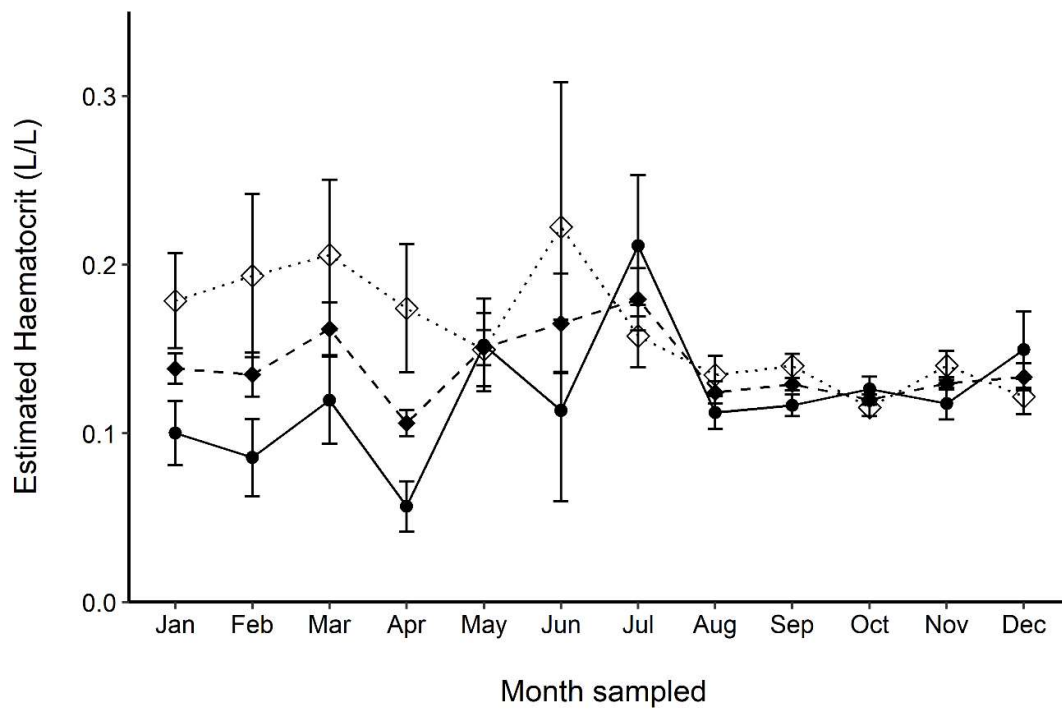


Figure 6-5. The least square means, with standard error bars, for the effect of *Theileria orientalis* Ikeda type infection on the haematocrit by latitude and month of sample submission (controlling for the effect of farm production type), the dotted line represents a latitude equivalent to Whangarei, the broken line is equivalent to Hamilton and the solid line is equivalent to Palmerston North.

6.6 Discussion

The haematocrit results by month, latitude and farm type have been presented and support the hypothesis that the haematocrit for anaemic animals infected with *T. orientalis* Ikeda type is significantly different across farm production type, month and latitude.

The New Zealand dairy cattle industry is highly seasonal and overwhelmingly based on cows calving during late winter and early spring i.e. between mid-July and early-October. In general, irrespective of the farming system or country, the periparturient and early postparturient periods are highly stressful for dairy cows. In the North Island this period coincides with the peak questing activity of over-wintered nymphs and is the likely explanation for the peak in dairy TABA submissions seen from August through to November, Fig. 6-2. The beef industry is also seasonal and on average beef herds calve about a month later than dairy herds (McFadden et al. 2005), which again probably explains the peak in beef sample submissions occurring a month later than for dairy cases, Fig. 6-3. Furthermore, unlike on dairy farms, it is usually the calves and not the adults that get sick on beef farms (Eamens et al. 2013b; Lawrence et al. 2016b). Only a small percentage of New Zealand dairy cows calve in the autumn, between February and April, which may partly explain the lesser peak in dairy submissions seen in April.

The HCT of beef cattle was significantly higher than dairy cattle across almost the whole year (Fig. 6-4). This suggests that beef cattle possibly have an innate resistance to *T. orientalis* infection, have an innate resistance to *H. longicornis* infestation or have a higher normal HCT. A higher normal HCT potentially means that for a similar *T. orientalis* Ikeda type infection intensity beef cattle are less likely to develop severe anaemia compared to dairy animal. Overall the RBC count is normally higher in beef breeds compared to dairy breeds, higher in males compared to females and higher in non-lactating compared to lactating animals (Roland et al. 2014). A higher RBC should mean a higher HCT in beef breeds compared to dairy breeds. Differences in breed susceptibility to *Theileria* have been observed between Japanese Black cattle and Holstein cattle (Terada et al., 1995) and between Santa Gertrudis and Japanese Shorthorn (Higuchi et al., 2003), with the beef breeds in both studies being less susceptible to infection than the dairy breeds. Alternatively, an innate resistance to ticks could affect tick feeding or attachment and, in this way, possibly reduce the infection intensity delivered by the tick to beef cattle.

Interestingly the effect of breed on HCT is lost in April and beef or dairy cases from this month have similar low HCTs. In both the New Zealand dairy and beef production calendars April is a highly stressful month being associated with drying-off of some spring calving dairy herds, weaning of calves off beef cows and early lactation for the autumn calving dairy herds. Unfortunately, the data was not sufficiently detailed to state whether it was adults or weaned beef calves that were affected in this period.

The significant effect of latitude on HCT, whilst controlling for farm type, is almost certainly an effect of tick density. Previous surveys and modelling have shown that the habitat suitability for *H. longicornis* is high in the north of the North Island and progressively falls as you travel south (Heath 2016; Lawrence et al. 2017c). In the north of the North Island the better habitat suitability results in high tick densities, this means that the naïve animals, i.e. the spring-born calves, are almost 100% infected in the spring. This leaves very few naïve animals susceptible to infection later in the year. In contrast as you move south, more naïve animals will escape infection in the spring, owing to less suitable tick habitats and lower tick densities, and likely becoming infected either later in the same year or even not until the following year. Adult dairy cattle are significantly more likely to become severely anaemic ($HCT < 0.15$) than <6 month old calves (Lawrence et al. 2018a). Since animals that escape infection in the spring will be older when ultimately infected then this could explain the more severe anaemia seen in cattle from latitudes equivalent to Palmerston North sampled outside of the spring period. Palmerston North is on the edge of a low risk of tick infestation area (Heath, 2016) which would make this region (Manawatu) endemically unstable.

Calves from Northland (the most northerly region of New Zealand) were 26 times more likely to present as clinical cases than calves from other regions of the North Island (Lawrence et al. 2016b) and by June 2013 94% of sampled Northland herds were already Ikeda positive (McFadden et al. 2016b). These observations again support highly successful spring infection rates and reinforce the conclusion that TABA had rapidly become endemically stable in Northland. The endemic stability theory argues that as a vector-borne disease such as theileriosis becomes endemic then the incidence of clinical disease falls across all age groups, and when disease does occur it is mostly restricted to calves, often with a milder presentation (Coleman et al. 2001; Jonsson et al. 2012). Fig. 6-5 suggests that this conclusion may not be entirely correct, the spring HCT results are similar across the 3 regions of the North Island, but markedly different outside of the spring. Possibly the more correct interpretation of endemic stability is that outside of peak periods of infection the effect of infection is mild. The more

severe anaemia seen at lower latitudes outside of the spring period suggests that in less stable or unstable regions more adult cattle are succumbing to infection and as stated earlier adult cattle are more likely to develop severe anaemia.

The New Zealand cattle industry is typified by frequent stock movements especially around June 1st, colloquially known as “gypsy day”, when the ownership or share milking arrangements of dairy farms change hands. This involves the translocation of up to half a million dairy cows, with the inevitable movement of some naïve herds into infected areas. Unfortunately, there have been significant outbreaks of clinical disease involving adult animals in the spring following such stock movements. Stress is also a key determinant of the outcome of *T. orientalis* Ikeda type infection, especially for dairy cattle in the spring and possibly beef cattle in the autumn. This leads to the inevitable conclusion that the association between breed, month and haematocrit is further confounded by the degree of stress, nutritional, lactational or physiological, the animal is under at the time of infection. Reducing stress and controlling concurrent diseases, e.g. BVD, are thus the key management interventions required to reduce the impact of *T. orientalis* Ikeda type infection in naïve cattle.

6.7 Conclusions

The risk of severe clinical disease in adult cattle can only be reduced by ensuring that cattle are infected with *T. orientalis* Ikeda type as calves in their first grazing season. For farms in endemic unstable areas, such as the Manawatu, this will require deliberately exposing their weaned calves to infection by grazing them off-farm in an infected area.

Chapter 7

Predicting the potential environmental suitability for *Theileria orientalis* transmission in New Zealand cattle using maximum entropy niche modelling

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7.1 Preface

Maximum entropy niche modelling is widely used in zoology to predict likely species distributions based on occurrence and environmental data. Only a small number of studies have applied this same technique to modelling the distribution of tick-borne disease, based on the locations of disease outbreaks and climate data. This study was instigated to explore the value of maximum entropy niche modelling in predicting the likely extent of the 2012 TABA epidemic and was based on outbreak data collected by the incursion investigation veterinarians at the Ministry for Primary Industries between August 2012 and November 2014.

7.2 Abstract

The tick-borne haemoparasite *Theileria orientalis* is the most important infectious cause of anaemia in New Zealand cattle. Since 2012 a previously unrecorded type, *T. orientalis* type 2 (Ikeda), has been associated with disease outbreaks of anaemia, lethargy, jaundice and deaths on over 1000 New Zealand cattle farms, with most of the affected farms found in the upper North Island. The aim of this study was to model the relative environmental suitability for *T. orientalis* transmission throughout New Zealand, to predict the proportion of cattle farms potentially suitable for active *T. orientalis* infection by region, island and the whole of New Zealand and to estimate the average relative environmental suitability per farm by region, island and the whole of New Zealand.

The relative environmental suitability for *T. orientalis* transmission was estimated using the Maxent (maximum entropy) modelling program. The Maxent model predicted that 99% of North Island cattle farms (n=36,257), 64% South Island cattle farms (n=15,542) and 89% of New Zealand cattle farms overall (n= 51,799) could potentially be suitable for *T. orientalis* transmission. The average relative environmental suitability of *T. orientalis* transmission at the farm level was 0.34 in the North Island, 0.02 in the South Island and 0.24 overall.

The study showed that the potential spatial distribution of *T. orientalis* environmental suitability was much greater than presumed in the early part of the *Theileria* associated bovine anaemia (TABA) epidemic. Maximum entropy offers a computer efficient method of modelling the probability of habitat suitability for an arthropod vectored disease. This model could help estimate the boundaries of the endemically stable and endemically unstable areas for *T. orientalis* transmission within New Zealand and be of considerable value in informing practitioner and farmer biosecurity decisions in these respective areas.

7.3 Introduction

Theileria orientalis is a tick-borne obligate intracellular protozoan parasite of cattle and buffaloes and belongs to the phylum Apicomplexa (Watts et al., 2016). This phylum includes some of the most pathogenic parasitic protozoa of humans and domestic animals (Morrisette and Sibley, 2002). Eleven different *T. orientalis* genotypes have been described including Type 1 (Chitose), Type 2 (Ikeda) and Type 3 (Buffeli). Types 4–8 and Types N1–N3 which remain unnamed (Khukhuu et al., 2011; Kamau et al., 2011b; Cufos et al., 2012; Watts et al., 2016; Hammer et al., 2015). Infected cattle sometimes develop *Theileria*-associated bovine anaemia (TABA) which can be a severe and life threatening (McFadden et al., 2011). Some genotypes are more pathogenic than others.

There have been two recorded epidemics of TABA in New Zealand, the first starting in 1982, peaking at 60 cases in 1985 before almost completely disappearing after 1986 (James et al., 1984; Thompson, 1991). The second outbreak started in August 2012 and is still ongoing (McFadden et al., 2013; Lawrence et al., 2016b), with over 1000 cattle farms since August 2012, mostly in the upper North Island, having at least one recorded clinical case of TABA. Molecular investigation of sporadic outbreaks of TABA since 1982 but prior to the current 2012 outbreak showed that the first TABA outbreak in New Zealand was probably associated with the *T. orientalis* types, Type 1 (Chitose) and Type 3 (Buffeli) (McFadden et al., 2011). The present epidemic is strongly associated with Type 2 (Ikeda) which had been previously unrecorded in New Zealand (Gias et al., 2016).

The Ikeda type is much more pathogenic than either the Chitose or Buffeli types (Hammer et al., 2015). Even so, for most New Zealand cattle farms Ikeda infection is not associated with high incidence of clinical disease as the median mortality and morbidity rates in newly infected cattle herds are reported as 0.23% and 0.97% respectively (Vink et al., 2016). However, there have also been a small number of herds where the mortality rate has exceeded 5%, often without any clear indication why this has occurred (McFadden et al., 2013). Many infected animals are sub-clinical (Fairley, 1992) but if clinical disease does develop the following clinical signs have been observed: anaemia, abortion, lethargy, production drop, anorexia, ill-thrift, constipation, jaundice, collapse, pale udders, haemoglobinuria (less commonly) and inappetance (McFadden et al., 2013). On dairy farms, mature cows are most often affected around calving or in early lactation, i.e. at peak stress periods, whilst on beef herds calves between the age of 2 and 4 months are more usually affected (Lawrence et al., 2016b).

The *T. orientalis* group is widely disseminated around the world due to the favourable distribution of suitable tick vectors in the genus *Haemaphysalis*. In New Zealand *H. longicornis* is the only known competent vector for *T. orientalis*. This tick species is widespread in the North Island, occurring as far south as Waikanae in the west and the Wairarapa in the east, it is also established in the top of the South Island (Heath, 2013, 2016). In New Zealand the *H. longicornis* life cycle is usually completed within 12 months, with over-wintering nymphs mainly engorging from July to September, adults from November to December and larvae from February to April (Fig. 2, Heath, 2016). Once infected, cattle probably remain infected and infectious for life (Onuma et al., 1998) and although biting flies, sucking lice, mosquitoes and iatrogenic transmission have been suggested as additional mechanical vectors of *T. orientalis*, there is little field data to support these claims (Fujusaki et al., 1993; Hadi and Al-Amery, 2012; Hammer et al., 2015).

Environmental niche modelling, also known as species distribution modelling, is defined as the quantitative modelling of species-environment relationships in order to interpolate species habitat suitability over much larger spatial extents (Franklin, 2010). The classic approach to niche modelling condenses the biotic (B), the abiotic (A) and the mobility (M) requirements for a species into a heuristic framework known as a Biotic Abiotic Mobility (BAM) diagram (Peterson, 2014). This is usually portrayed as a 3 circle Venn diagram, where each circle is either the B, A or M requirement and the realised niche for a species is described by the intersection $B \cap A \cap M$.

Since *T. orientalis* is an obligate intracellular parasite its geographic distribution is potentially equivalent to that of its reservoir host, cattle. However, active transmission of *T. orientalis* infection between infected and naïve cattle will only occur where the distribution of cattle intersects with the realised niche for *H. longicornis* ticks. Incorporating these assumptions into a single heuristic framework for modelling purposes means that the intersection $B_{\text{tick}} \cap A_{\text{tick}} \cap M_{\text{cattle}}$ should describe the realised niche for *T. orientalis* transmission in New Zealand. It is important to acknowledge that this framework does make the assumption that the environmental requirements for the development of *T. orientalis* within the tick are similar to those required by the tick for survival off host.

Entropy means uncertainty and a probability distribution is said to have maximum entropy when it is closest to uniform (most spread out) but still explains any constraints in the data (Philips et al., 2006). The three aims of this paper are to use maximum entropy (Maxent) to

predict the relative environmental suitability for *T. orientalis* transmission across New Zealand, to estimate the proportion of cattle farms with potentially suitable environments for active *T. orientalis* transmission and to estimate the average farm relative environmental suitability by region, island and the whole of New Zealand.

7.4 Materials and methods

7.4.1 *Maxent* program

In this paper a machine-learning approach was used to map the probability of environmental suitability for *T. orientalis* transmission using the Maxent modelling program (Phillips et al., 2006; Phillips and Dudik, 2008), adapting the methodology described by Slater and Michael (2012). Version 3.3.3k of the Maxent maximum entropy species distribution model was used in this analysis.

Since the true prevalence of TABA disease is unknown and the case data were collected in a non-random fashion, a Bayesian solution, although attractive from a modelling perspective, is not definable (Elith et al 2011). Maxent provides an elegant solution to this impasse by fitting a probability distribution to the data using the principle of maximum entropy. This involves fitting a probability distribution to the multivariate environmental data at the case farms, with the only constraint being that it should have the same mean as the case data and contrasting it with a uniform probability distribution fitted to the background sampling points. Maxent then selects the probability distribution for the case environmental data that minimises the entropy between these two distributions, which has the effect of maximising the entropy of the final probability distribution (Elith et al 2011). This probability distribution is then used to define the relative environmental suitability for every 500m x 500m pixel across a raster map of New Zealand. A raster map is an efficient method of storing spatial data as an array of equal sized cells (pixels) where each pixel contains a value. Using the default logistic output from Maxent a raster map of the relative environmental suitability for every pixel in the New Zealand map is produced. The higher the pixel value, which ranges between 0 and 1, then the higher the relative environmental suitability of that pixel for *T. orientalis* transmission.

7.4.2 *Case data*

The case data were cattle farms that had at least one case of clinical TABA during the period 30 August 2012 to 1 November 2014. The TABA case definition was as follows, haematocrit (HCT) ≤ 0.24 L/L, positive on blood smear for *Theileria* piroplasms and positive on PCR for *T. orientalis* Ikeda type. For a full description of the case definition and laboratory methodology see Lawrence et al. (2016b) and Pulford et al. (2016b). The Cartesian X and Y coordinates (NZTM2000 projection) of the centroid for each affected farm were obtained from AsureQuality's (Auckland, New Zealand) Agribase (Sanson, 2005) and used as the geographic location of the case data.

7.4.3 *Background sampling*

Maxent randomly samples 10,000 data points from the background extent in order to contrast the environmental conditions found there with those found at the cases (Merow et al., 2013). It was decided to use the complete case data points for the analysis and control for any potential biases therein by sampling the background data points from a kernel density of North Island dairy farms, which was entered as a bias layer into Maxent. A bias layer is a proven method of controlling for bias in the case data by directing Maxent to sample the background data points from a geographical extent that shares the same biases (Elith et al., 2011). The bias layer was produced in ArcMap (Environmental Systems Resource Institute ArcMap 10.2.1. ESRI, Redlands, California, USA) using the Kernel Density Estimator tool and the spatial coordinates of North Island dairy farms recorded in the Farms-On-Line (FOL) data base (Ministry for Primary Industries, Wellington, New Zealand). This tool calculates a fixed kernel density estimate using the quartic approximation of a true Gaussian kernel function; the bandwidth was automatically selected using the Gaussian approximation.

The autocorrelation of the case and background data was assessed by calculating the spatial sorting bias, using the method described by Hijmans (2012). Spatial sorting bias values close to zero indicate high spatial sorting bias and values close to 1 indicate low spatial sorting bias.

7.4.4 *Environmental and Demographic data*

The B_{tick} , A_{tick} and M_{cattle} variables initially considered for this analysis are shown in Table 7-1. The B_{tick} and A_{tick} variables were selected based on the environmental variables hypothesised by Neilson (1980) and Heath (1974, 1979, 1981, 2016) as being required for tick development

and survival off the animal under New Zealand conditions. In his thesis Neilson (1980), also proposed snow cover as an important determinant of tick survival, however these data were not available.

Table 7-1. Description and source of the environmental and demographic variables considered for inclusion in Maxent to model the relative environmental suitability for *Theileria orientalis* transmission. NIWA (National Institute of Water and Atmospheric Research), FOL (Farms-on-Line), MPI (Ministry for Primary Industries)

Variable name	Units	Description	Source
meanrain	mm/year	The mean annual rainfall, 1981-2010	NIWA
meantemp	°C	The mean annual temperature, 1981-2010	NIWA
meanfrosts	days/year	The mean annual number of days of air frosts, 1981-2010	NIWA
meanjulymax	°C	The mean July daily maximum temperature, 1981-2010	NIWA
meanjulymmin	°C	The mean July daily minimum temperature, 1981-2010	NIWA
medianFMAVP	hPa	The median 9am vapour pressure (VP) for the months February-March-April, 1981-2010	NIWA
medianFMAVPdef	hPa	The median 9am vapour pressure deficit (VPD) for the months February-March-April, 1981-2010	NIWA
medianjansoildef	days/January	The median number of soil moisture deficit days for the month of January, 1981-2010	NIWA
elevation	m	New Zealand 80m Digital Elevation Model from the NASA Shuttle Radar Topography mission	koordinates.com
cattle	farms /km ²	Kernel density of cattle farms in New Zealand	FOL (MPI)
deer	farms /km ²	Kernel density of deer farms in New Zealand	FOL (MPI)

The variables median vapour pressure for the months February, March and April (medianFMAVP) and median vapour pressure deficit for the months February, March and April (medianFMAVPdef) (Table 7-1) were proposed by Heath (2016) because these are the months when larvae are most active. Vapour pressure is the portion of the total atmospheric pressure due to the presence of water vapour and vapour pressure deficit is the difference between the potential vapour pressure if the air was saturated and actual vapour pressure recorded at the ambient temperature. Both variables are measured in hectoPascals (hPa). Although larvae are not necessarily the most vulnerable stage in the tick life cycle, in regard to desiccation (Neilson, 1980; Heath, 1981), the months when they are active coincides with the driest periods in the New Zealand calendar, thus effectively making them the most vulnerable stage.

The available water capacity (AWC) of the soil in New Zealand is prescribed as 150mm, based on measured values for a typical silt loam soil type and dairy pasture land-use, with daily inputs of rain and losses through evapotranspiration maintaining the balance. If the soil moisture content falls below 75mm (50% of AWC) then a soil moisture deficit day is recorded. The

variable “medianjansoildef” describes the median soil moisture deficit days for January over the period 1981-2010.

All the weather variables were supplied by New Zealand’s National Institute of Water and Atmospheric Research (NIWA, Wellington, New Zealand), and are based on the average or median for each respective variable over the period 1981 to 2010 at a 500m x 500m resolution. The period 1981-2010 for the meteorological data was used because it is the current standard 30-year normal period, as sanctioned by the World Meteorological Organisation. The NIWA weather variables were produced by spatial interpolation of actual data from weather stations throughout New Zealand using thin plate smoothing splines, which include a linear dependence on elevation (Wratt et al., 2006). The New Zealand 80m Digital Elevation Model from the NASA Shuttle Radar Topography Mission (<https://koordinates.com>) was used for estimating elevation.

Both the cattle and deer farm demographic density layers were prepared from their respective spatial coordinates as entered in the FOL data base. For each of these demographic layers a kernel smoothed density estimate was also produced in ArcMap using the Kernel Density Estimator tool. The density output was selected to show the number of cattle farms or deer farms/km².

All data layers were matched for the same projection, NZGD2000 (NZTM), the same extent, and all grids were set at 500x500m. Owing to some occasional errors from the spatial interpolation methodology the cell values for each environmental raster layer were checked for consistency and corrected where necessary.

7.4.5 *Correlations*

The Pearson correlations were estimated for the 11 environmental and demographic variables (Table 7-1) using 10,000 points randomly sampled from the background bias layer and the case data points. A dendrogram of clustered dissimilarities was constructed from these correlation values using the unweighted pair group mean averaging method for hierarchical clustering (Figure 7-1). Significant clustering was identified between elevation, meantemp, meanjulymax, meanjulymin, meanfrosts and medianFMAVP.

7.4.6 Variable Selection and Model Calibration

From the correlated variables (Figure 7-1), the variable from the inner cluster (meanjulymin and medianFMAVP) considered to be the most biologically relevant to *H. longicornis* was selected to represent the correlated variables (Kumar et al., 2014). Using this method, the variable medianFMAVP was selected and together with the other remaining non-correlated variables, cattle, deer, meanrain, medianFMAVPdef, medianjansoildef and elevation (for the model with elevation), constituted the initial exploratory model selection.

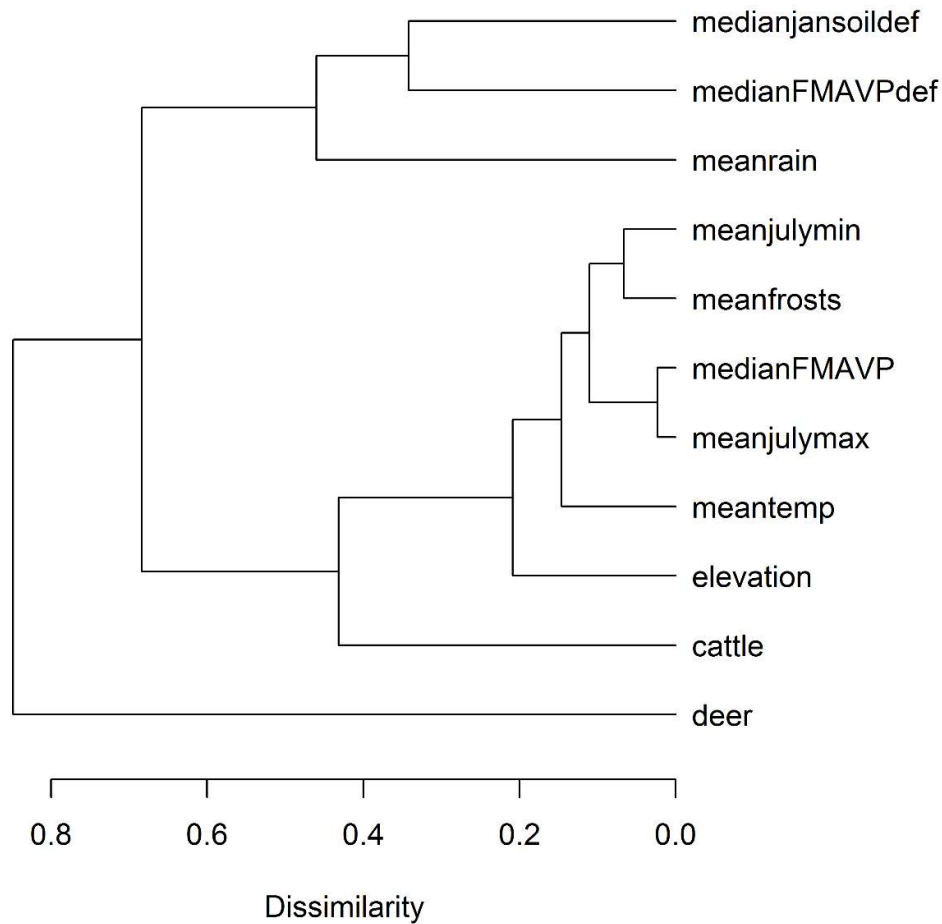


Figure 7-1. Dendrogram showing clustering of environmental variables, the horizontal axis shows the dissimilarity distance between the variables

Maxent uses several default settings: maximum iterations; convergence threshold; feature class (FC) (describing transformation of the variables); and regularisation multiplier (RM) (which

manipulates model complexity by controlling the number of variable transformations included in the model). These default settings can be calibrated by the user with the aim of achieving a better model fit. Using the selected variables an initial 15-fold cross-validation exploratory model (Hijmans, 2012) was run in Maxent using the following default settings. The maximum iterations were set to 2000, the convergence threshold set to 10^{-6} , the FC functions left on auto and the RM set to 1. Cross-validation is a straightforward, quick and useful method for resampling data for training and testing models (Elith et al., 2011). In a 15-fold cross-validation model, the data is randomly divided into 15 bins of size $n/15$. At each run of the model 14 bins are used as the training data and the remaining bin is used as the test data. The model then iterates until all 15 bins have been used once for the test data and the average of the 15 model runs is the predictive output.

After examining the output from this first exploratory 15-fold cross validation model, those variables contributing <3% to the permutation importance (Groff et al., 2014) were dropped. Maxent provides two measures of variable importance for guiding model building: the percent contribution and the permutation importance (Songer et al., 2012). Of these two measures, permutation importance is less affected by collinearity and consequently gives the clearest indication of the value of each variable to the model (Phillips et al., 2012; James et al., 2015).

The remaining variables were retained, and the model calibrated by selecting a subset from the six Maxent FC functions and by decreasing or increasing the Maxent RM option (Radosavljevic and Anderson, 2013; Kumar et al., 2014). The FC has six available options; linear (L), quadratic (Q), product (P), threshold (T), hinge (H) and categorical (no categorical variables were included in this analysis). Increasing the RM generally fits a less complex model.

Model calibration was based on the small-sample-size corrected Akaike Information Criterion (AICc) (Warren and Seifert, 2011). The following six FC combinations were tested L, H, LQ, LQP, LQHP, LQHPT and the regularisation multiplier was tested at 0.5, 1, 2 and 4 for each of the six FC combinations giving a total of 24 models tested altogether. The model calibration with the lowest AICc was selected using a masked k -fold geographically structured cross-validation approach (Muscarella et al., 2014, Radosavljevic and Anderson, 2014).

Once the final model calibration was identified the variables dropped from the initial exploratory model were retested in the final model one-by-one and reinstated at $P < 0.05$ using the Chi-square test on the change in the log-likelihood (nested models). A final 15-fold cross

validation model using the identified calibration settings, the retained variables and any reinstated variables was then run to produce the average relative environmental suitability raster layer.

In order to test the utility of elevation as a predictive variable, two nearly identical models were constructed using the methodology described above, the first with elevation included *a priori* and the second without. The niche overlap between the two models' predictive layers was quantified using the I similarity statistic and Schoener's D (Warren et al., 2008; Schoener, 1968). The model with the lowest AICc was selected (Burnham and Anderson, 2004) and used to predict the relative environmental suitability for *T. orientalis* transmission across New Zealand.

7.4.7 Threshold selection

Two cut points were chosen to divide the relative environmental suitability for *T. orientalis* transmission into unsuitable, low and high suitability areas. The minimum training presence (MTP) threshold identifies all areas where the relative suitability of *T. orientalis* transmission is greater or equal to the lowest predicted relative suitability for a case farm from the training data (Giovanelli et al., 2010). This cut point was chosen to define the threshold between unsuitable and suitable environments. The 10% training omission rate (10% OR) is the lowest predicted relative suitability that excludes the lowest 10% and includes the remaining 90% of the training case data (Pearson et al., 2007). This cut point was chosen to divide the suitable environments into low and high suitability.

7.4.8 Assessing model goodness of fit

Model goodness-of-fit (GOF) was assessed using the Boyce index (Boyce et al., 2002; Hirzel et al., 2006) and by checking for over-fitting (Rodda et al., 2011). In a correctly fitted model, as opposed to an over-fitted model, the averaged results for the test data and training data from the 15-fold cross-validation model, in respect to the area under the curve (AUC) and the omission rates at the selected cut points, should be almost identical.

7.4.9 Model predictions

The predicted relative environmental suitability for each cattle farm recorded in FOL was extracted from the final Maxent *T. orientalis* model output. The relative environmental suitability was then summarised to give the proportion of farms by region, by island and for

the whole of New Zealand potentially suitable for transmission of *T. orientalis* infection, categorised by the MTP and 10% OR cut points. The average relative suitability for farms in each region of New Zealand was also calculated.

7.5 Results

7.5.1 Cases and spatial sorting bias

There were 921 cases included in the final model, with only two cases from the South Island. The spatial sorting bias of the case and background data was 0.91 (figures close to 1 are desirable).

7.5.2 Predictive model

The model including elevation had the lowest AICc and was the preferred model. The niche overlap of the model with and without elevation gave an I similarity statistic = 0.99 and Schoener's D = 0.92. Together with elevation the final model included the variables: medianFMAVP, cattle farm density, deer farm density, and medianjansoildef. The percent contribution and permutation importance of each of these variables is shown in Table 7-2. Based on permutation importance, Table 7-2 shows that medianFMAVP ranked first among the determinants of environmental suitability for *T. orientalis* transmission.

Table 7-2. Maxent model output showing the percent contribution and the permutation importance for the five environmental variables retained in the final model

Variable	Percent contribution	Permutation importance
medianFMAVP	75.2	57.2
elevation	2.4	18.5
cattle	18.0	17.8
deer	2.8	4.1
medianjansoildef	1.6	2.4

The calibration of the final model was FC = LQPHT and RM = 4. The GOF tests gave a value of 0.91 for the Boyce index (figures close to 1 are desirable) and for the assessment of over-fitting the results were as follows; the average training data AUC = 0.914, the average test data AUC = 0.913, at the MTP threshold the average omission rate for test data = 0.11% and at the 10% OR threshold the average omission rate for the test data = 10.46%. Both the GOF tests

indicate that the model was a good fit and that over-fitting was not considered an issue at these model calibrations.

Figure 7-2a shows the actual relative suitability values for *T. orientalis* transmission outputted from the final Maxent model and Figure 7-2b shows the raw values categorised by the MTP and 10% OR cut points into areas of unsuitable, low and high relative environmental suitability for *T. orientalis* transmission.

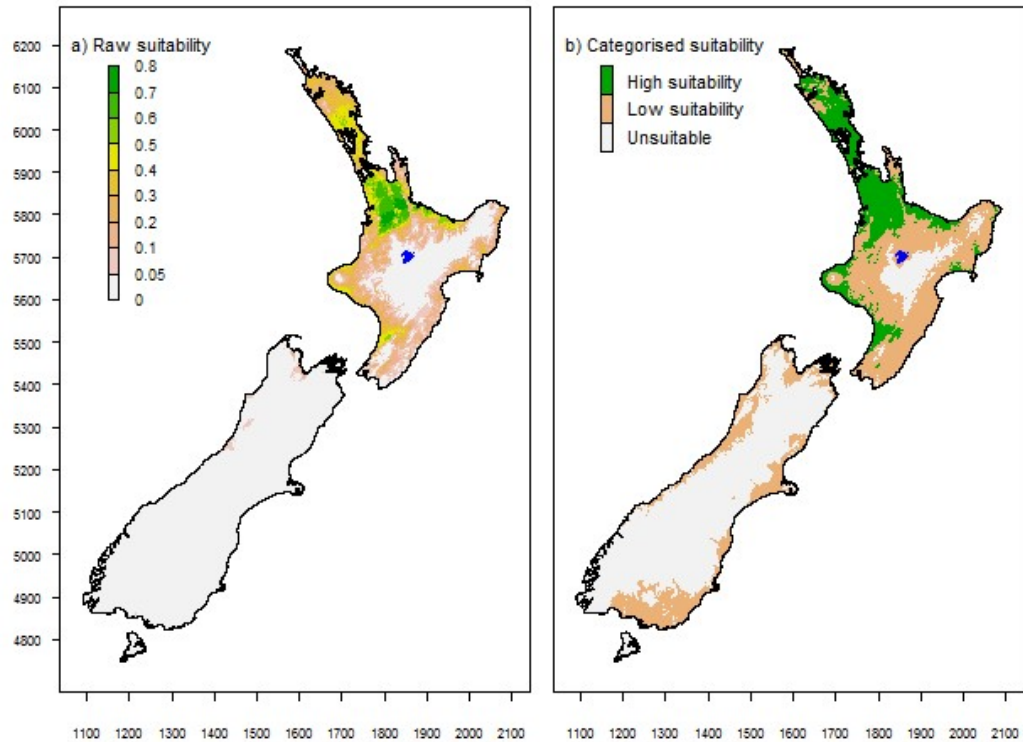


Figure 7-2. a) Shows the raw, actual relative environmental suitability values for *Theileria orientalis* transmission outputted from the final Maxent model. b) Shows the raw values categorised by the minimum training presence and the 10% omission rate cut points into areas of unsuitable, low and high relative environmental suitability for *Theileria orientalis* transmission

These cut points were 0.004 and 0.254 respectively. The proportion of farms potentially suitable for *T. orientalis* transmission, categorised by the MTP and 10% OR cut points, and the average relative environmental suitability of farms in each region, island and the whole of New Zealand are shown in Table 7-3. The average relative suitability for *T. orientalis* transmission at the farm level was 0.34 in the North Island, 0.02 in the South Island, and 0.24 overall.

Table 7-3. The proportion of cattle farms with potentially suitable environments for active *Theileria orientalis* transmission, categorised by the two threshold cut points, 10% omission rate (10% OR) and minimum training presence (MTP), and the average farm relative environmental suitability by region, island and the whole of New Zealand. Farm numbers are from Farms-On-Line and cattle numbers are from the 2012 Agricultural Census, Statistics New Zealand (Anon., 2012). * denotes a South Island region.

Region	Number of cattle farms	Number of cattle	Proportion of farms potentially suitable		Average farm relative suitability
			10% OR	MTP	
Northland Region	5,537	778,483	0.89	1.00	0.36
Auckland Region	2,119	234,739	1.00	1.00	0.43
Waikato Region	9,599	2,338,249	0.85	1.00	0.53
Bay of Plenty Region	2,133	405,683	0.74	1.00	0.40
Gisborne Region	1,225	284,694	0.35	0.99	0.19
Hawke's Bay Region	3,117	564,057	0.18	0.98	0.15
Taranaki Region	4,152	707,929	0.73	1.00	0.32
Manawatu-Wanganui Region	6,720	1,055,031	0.35	0.98	0.20
Wellington Region	1,655	248,594	0.09	1.00	0.15
West Coast Region*	958	202,653	0.00	0.93	0.04
Canterbury Region*	5,559	1,671,039	0.00	0.39	0.01
Otago Region*	4,003	626,676	0.00	0.69	0.01
Southland Region*	3,755	842,731	0.00	0.85	0.02
Tasman Region*	774	112,105	0.00	0.82	0.06
Nelson Region*	17	NA	0.00	0.94	0.03
Marlborough Region*	476	93,345	0.00	0.66	0.02
North Island	36,257	6,617,459	0.64	0.99	0.34
South Island	15,542	3,562,634	0.00	0.64	0.02
Total	51,799	10,180,093	0.45	0.89	0.24

The marginal probability plots for the five variables retained in the final model are shown in Figure 7-3. The shaded areas show the range of values for each variable where the model predicts the probability of environmental suitability for *T. orientalis* transmission greater than the 10% OR threshold, whilst keeping the value of the other variables in the model at their mean.

These marginal probability plots (Figure 7-3) illustrate a complex non-linear relationship between some of the variables and the relative environmental suitability for *T. orientalis* transmission. They show that a median FMAVP of 14.2 to 17.7 hPa, a medianjansoildef of 2 to 18 days, an elevation of less than 220 m, a deer farm density of 0.002 to 0.02 farms/km² and a cattle farm density > 0.27 farms/km² are associated with high environmental suitability for *T. orientalis* transmission

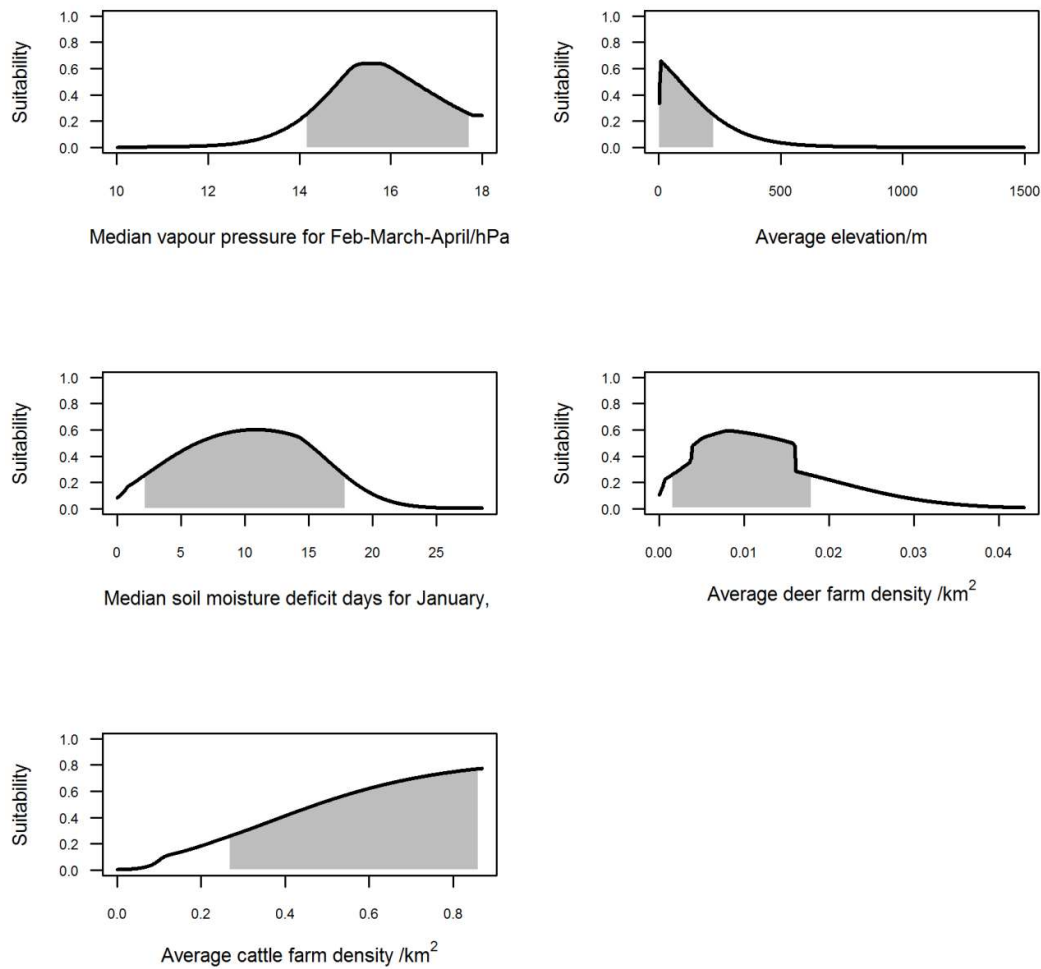


Figure 7-3. Marginal probability plots for each of the variables retained in the final Maxent maximum entropy model with the other variables in the model held at their average value. The shaded area shows the range of values for which the predicted relative suitability for *Theileria orientalis* transmission was greater than the 10% omission rate (10% OR) cut point (>0.254)

7.6 Discussion

The results show that the relative environmental suitability for *T. orientalis* transmission is very much higher in the North Island than the South Island and that within the North Island the northern regions are relatively more suitable than the southern ones. Overall the model showed that 89% of New Zealand cattle farms are potentially suitable for *T. orientalis* transmission and that 45% of New Zealand cattle farms, all from the North Island, have a high suitability for *T. orientalis* transmission (Table 7-3). The region with the highest average farm relative

suitability was the Waikato and the regions with the lowest were Otago and Canterbury (Table 7-3). It is presumed that the relative environmental suitability is highest where the variables are meeting the biotic and abiotic requirements for *T. orientalis* transmission.

Without the disease prevalence being known, the probability that the environment is suitable for transmission of *T. orientalis* cannot be used as a proxy for the probability of disease itself. However, the ordering of the relative environmental suitability should be equivalent to the ordering of the disease probability. Such that where the relative environmental suitability is high there should be more disease and where the relative environmental suitability is low there should be less.

Care should be taken interpreting the results of this study; the case data used in the Maxent model is almost exclusively from the upper North Island, whereas the model has been asked to predict suitability for farms at the bottom of the South Island. The potential environmental suitability for *T. orientalis* transmission on farms even as far south as Southland, albeit very low, was surprising. It is, however, a matter of public record that *H. longicornis* ticks did establish for a short period in Lumsden, Southland in 1999 (Heath, 2016). Lumsden is within the boundaries of the model predictions for Southland.

Although the use of case data in environmental niche modelling is not common there are precedents. Mueller et al., (2013) used clinical case data to estimate the potential ecological distribution of *Cytauxzoon felis* in domestic cats. Furthermore, they contrasted their results with a more conventional model based on reservoir host and vector occurrence data and concluded that the two methods gave reasonably similar results.

Median 9am vapour pressure for the months February-March-April (medianFMAVP) was the most significant of the 5 variables included in the final model, with a permutation importance of 57.2% (Table 7-2). Springer et al., (2015), using an ensemble modelling approach, found that average vapour pressure in July was by far the most important determinant of habitat suitability for the Lone Star tick (*Amblyomma americanum*).

Both the biotic variables, cattle farm density and deer farm density, were included in the final model with a permutation importance of 17.8 and 4.1% respectively (Table 7-2). Since cattle are the reservoir host for *T. orientalis* the importance of cattle farm density was expected. In Japan deer are an amplifier species for ticks (Tsukada et al., 2014). This result shows that deer may also be important for the maintenance of ticks in New Zealand and supports the use by

MPI of deer herds as sentinels for tracking tick infestation in less environmentally suitable areas (McFadden et al., 2015). Although the density of deer farms required does not appear to be particularly high, Fig. 7-3. Sheep farm density was not tested in the model and although they are a suitable host for *H.longicornis* (Myers, 1924; Heath et al., 1977b) they were not considered to be as important as deer in determining the realised niche for *H.longicornis* (Heath, 2016).

The other two abiotic variables included in the final model were elevation and median number of soil moisture deficit days for the month of January (medianjansoildef) with a permutation importance of 18.5 and 2.4% respectively (Table 7-2). Hof et al. (2012), reviewing the inclusion of elevation in species distribution models concluded that elevation was less valuable than many researchers have previously suggested. In our analysis the model which included elevation had the lowest AICc but the predicted niche for the two models either with or without elevation were almost identical. This would indicate that the elevation variable whilst improving the model fit was not indispensable to the modelling outcome. Also, it is almost never certain, when included, whether elevation is an important variable or is acting as a proxy for another unmeasured climatic variable (Gilbert, 2010).

Studies on *H.longicornis* conducted in Australia and Japan have observed ticks at 526 m altitude (Sutherst and Bourne, 1991) and over 1000m (Shiraishi et al. 1982) respectively. Using our model these altitudes would have had a very low probability of being suitable for *T. orientalis* transmission, Fig. 7-3. Low elevation has significantly predicted high habitat suitability for some tick species including *Ixodes ricinus* (Qviller et al., 2014) and for *Dermacentor variabilis* (James et al., 2015). However, these findings could also be ambiguous since it cannot be certain whether elevation is predicting habitat suitability for the tick or for the more favoured tick hosts.

The two abiotic variables medianjansoildef and medianFMAVP potentially impact *H. longicornis* phenology at two successive stages, medianjansoildef affects adult tick and egg survival and medianFMAVP affects larval survival. These two variables, when acting in series, could severely deplete the tick population in some areas and may explain why summer-dry North Island regions such as the Hawke's Bay and Wellington have low relative suitability for *T. orientalis* transmission (Table 7-3). The abiotic variable mean annual rainfall was surprisingly dropped from the final model despite its documented effect on tick distribution and abundance (Tsukada et al., 2014; Del Fabbro et al., 2015). It is possible that the information contained in this variable is already captured by cattle farm density, since cattle farms need good rainfall, natural or artificial, to grow enough grass for profitable production under the

New Zealand pastoral system. Furthermore, the cattle farm density variable possibly captures additional information for areas where pasture irrigation is common. Had the mean annual rainfall variable been included in the final model, those areas which use significant pasture irrigation could possibly have been misclassified as low or zero risk (Heath, 2016). Alternatively, it may be as important to consider when in the year the rain falls as well as the total amount that falls. This means that the variable “the median number of soil moisture deficit days for the month of January” could be controlling for the strategic effect of rainfall, even if rainfall *per se* is not included in the model. The median number of soil moisture deficit days for the month of January is also probably a better measure of water availability, at a critical point in the tick lifecycle, than annual rainfall could be (Estrada-Peña et al., 2015).

Lawrence et al., (2016b) demonstrated significant spatial-temporal clustering of TABA infected herds within 20 to 30 days and up to 15km distance from a case farm. It was considered that this spatial autocorrelation was supplying important information about the realised niche for *T. orientalis*. However, the case data also contained several potentially significant biases. This was an evolving epidemic, so cases at the spatio-temporal periphery of the epidemic could either be less well represented because the disease had not yet become established in these areas or these areas were themselves less environmentally suitable for *T. orientalis* transmission (McFadden et al., 2016b). Furthermore, cases were almost exclusively recorded in the North Island; cases involving dairy cattle appeared to be reported more often than beef cattle and the epidemic which began in the north of the North Island, was spreading south, with significant clustering of disease in the Waikato Region of the North Island which has a high intensity of dairy farms (Lawrence et al., 2016b).

The recognised methods for controlling for sampling bias include spatial thinning (Anderson and Raza, 2010; Boria et al., 2014) or using a sampling bias layer (Anderson and Raza, 2010; Syfert et al., 2013). In this study spatial thinning was rejected in favour of using a sampling bias layer, with good apparent success (spatial sorting bias close to 1).

An endemically stable area, regarding tick-borne disease, is defined as one where the level of clinical disease does not dramatically fluctuate over time (Jonsson et al., 2012) and in which clinical disease is scarce despite high levels of infection in the population (Coleman et al., 2001). To achieve endemic stability requires a high infectious force and this will in turn require a high environmental suitability (Hay, 2001). The following North Island regions: Northland, Auckland, Waikato, Bay of Plenty and Taranaki have greater than 70% of cattle farms with high environmental suitability (Table 7-3). These regions will almost certainly be endemically stable areas (McFadden and Marchant, 2014). The paradox of endemic stability is that despite

a high infectious force, less disease is seen in adult cattle and more in young cattle, but with the disease often being milder, with fewer fatalities, and leading to lifelong protective immunity (Hay, 2001).

For North Island regions where the environmental suitability is much more heterogeneous: Gisborne, Hawke's Bay, Manawatu and Wellington then these regions will probably be endemically unstable (Table 7-3). In endemically unstable areas the exposure to infected ticks is highly variable leading to naïve cattle often being infected as adults rather than as calves in endemically stable areas. L'Hostis and Seegers (2002) describe two scenarios for tick-borne disease in endemically unstable areas. The first scenario, referred to as high incidence endemic instability, occurs when the herd prevalence of infected cows is between 10 and 75% of cows and the tick attack rate is less than that in the endemically stable areas. This results in a high incidence of clinical disease and a moderate case fatality rate. In the second scenario, referred to as low incidence endemic instability, the herd prevalence of infected cows is less than 10% and results in a low incidence of disease but a higher case fatality rate. It is likely that both situations will be seen in New Zealand but in different areas with the second scenario occurring further south in the North Island.

For most herds in the South Island, where the relative suitability for *T. orientalis* transmission is comparatively low (the average relative suitability = 0.02), the disease will probably remain sporadic and is unlikely to reach endemic status, except possibly for small areas of the Tasman region, Table 7-3. This is almost certainly because in most areas of the South Island the abiotic requirements of the tick are not being fully met. Clearly within any region of New Zealand the environmental suitability will not be homogeneous, and farmers and veterinarians will need to work together to quantify the risk at the local level.

The Maxent program was ranked as one of the better performing model algorithms when compared to 15 other modelling techniques (Elith et al., 2006). Elith et al. (2011) also noted that it is more stable in the face of correlated variables than other algorithms. The final Maxent model from this analysis included two highly negatively correlated variables medianFMAVP and elevation, $r = -0.82$. A pairwise correlation > 0.7 is considered problematic in traditional modelling methods (Aguirre-Gutiérrez et al., 2013; Dormann et al., 2013). The niche overlap results showed that had model GOF been a problem, then elevation could have been dropped from the model if necessary. Using remotely sensed data instead of interpolated data could be

an option for reducing spatial autocorrelation and collinearity for future studies (Estrada-Peña et al., 2013).

Apart from the use of AUC in assessing over-fitting there has been a conscious decision in this paper not to use AUC, the kappa or the correlation coefficient for model diagnostics. All these measures have been widely used in environmental niche modelling for assessing model fit, including Maxent models, and yet when used to evaluate models based only on case data, with no control data, these metrics are difficult to interpret and can be highly biased (Lobo et al., 2008). In this paper the AICc (Warren and Seifert, 2011) and Boyce index (Boyce et al., 2002) were used to select and test the model, as both tests are appropriate for presence only data (Franklin, 2010). There is an increasing interest in the use of Maxent for mapping disease risk (Stevens and Pfeiffer, 2011) and it is hoped that the relatively straight-forward approach described here may encourage the wider uptake of Maxent for disease modelling. Certainly, some of the major advantages of using Maxent are that it brings a fresh ecological perspective to vectored disease modelling and is computationally inexpensive, capable of handling relatively large data sets.

7.7 Conclusion

The relative environmental suitability for active *T. orientalis* transmission is much greater than was presumed in the early part of the 2012 TABA epidemic. It is likely that the epidemic will expand to involve a small number of cattle farms on the South Island although disease incidence there will remain relatively low, both within and between farms. Maximum entropy and the Maxent program offer a computer efficient method of modelling environmental suitability for arthropod vectored diseases.

7.8 Acknowledgements

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Chapter 8

Using a rule-based envelope model to predict the expansion of habitat suitability within New Zealand for the tick *Haemaphysalis longicornis*, with future projections based on two climate change scenarios

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8.1 Preface

The maximum entropy model described in Chapter 7 was the catalyst for creating a far simpler rule-based environmental model to predict the habitat suitability for *Haemaphysalis longicornis* in New Zealand. This study was based on the work completed by Nielson in 1980 for a Massey University Master's degree.

8.2 Abstract

Haemaphysalis longicornis is the only species of tick present in New Zealand which infests livestock and is also the only competent vector for *Theileria orientalis*. Since 2012, New Zealand has suffered from an epidemic of infectious bovine anaemia associated with *T. orientalis*, an obligate intracellular protozoan parasite of cattle and buffaloes. The aim of this study was to predict the spatial distribution of habitat suitability of New Zealand for the tick *H. longicornis* using a simple rule-based climate envelope model, to validate the model against published data and use the validated model to project an expansion in habitat suitability for *H. longicornis* under two alternative climate change scenarios for the periods 2046-2065 and 2081-2100, relative to the climate of 1981–2010.

A rule-based climate envelope model was developed based on the environmental requirements for off-host tick survival. The resulting model was validated against a maximum entropy environmental niche model of environmental suitability for *T. orientalis* transmission and against a *H. longicornis* occurrence map. Validation was completed using the I-similarity statistic and by linear regression.

The *H. longicornis* climate envelope model predicted that 75% of cattle farms in the North Island, 3% of cattle farms in the South Island and 54% of cattle farms in New Zealand overall have habitats potentially suitable for the establishment of *H. longicornis*. The validation methods showed an acceptable level of agreement between the envelope model and published data. Both climate change scenarios, for each of the time periods, projected only slight to moderate increases in the average farm habitat suitability scores for all the South Island regions. However, only for the West Coast, Marlborough, Tasman, and Nelson regions did these increases in environmental suitability translate into an increased proportion of cattle farms with low or high *H. longicornis* habitat suitability.

These results will have important implications for the geographical progression of *Theileria*-associated bovine anaemia (TABA) in New Zealand and will also be of interest to *Haemaphysalis longicornis* researchers in Australia, Japan, Korea and New Zealand.

8.3 Introduction

Haemaphysalis longicornis is a species of hard tick (Ixodidae) and the only one that infests livestock in New Zealand (Heath, 2016). The progressive expansion of the range of *H. longicornis* in New Zealand has been mapped three times since first discovered in 1911 near Kaitaia, Northland (Myers, 1924). These distribution maps were compiled by Myers (1924), Neilson (1980) and Heath (2016) and are reproduced in Fig. 8-1. The Myers (1924) map was based on field observation of ticks on livestock and anecdotal evidence, the Neilson (1980) map was based on a postal survey, published data (Heath, 1974, 1977a) and personal communication, and the Heath (2016) map was the result of a comprehensive telephone survey, field observation and tick surveillance on deer (McFadden et al., 2016a). However, no attempt has been made to model the spatial distribution of *H. longicornis* in the interim.

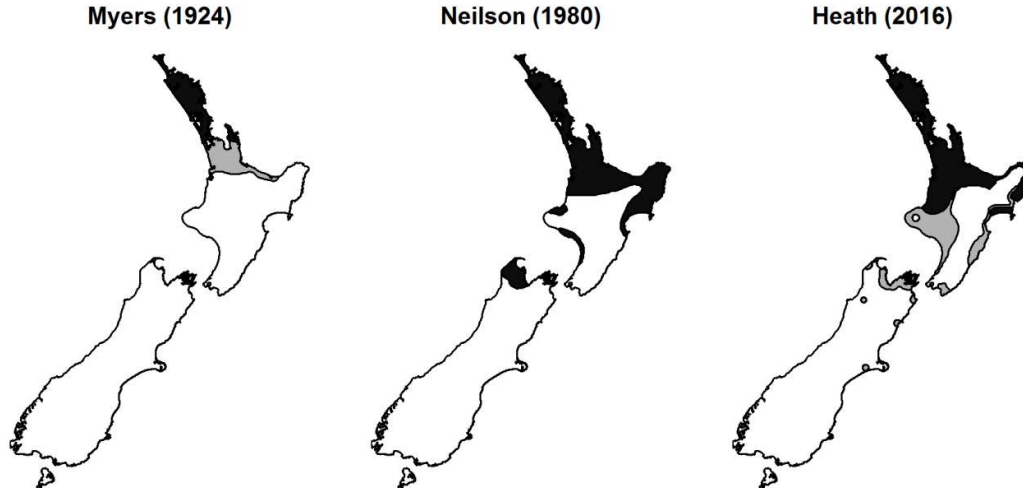


Figure 8-1. Evolution of *Haemaphysalis longicornis* distribution maps in New Zealand (reproduced by digitalisation of printed originals). The black areas are high risk, the grey areas are low risk and the white areas are zero risk of *Haemaphysalis longicornis* infestation. Neilson (1980) didn't differentiate between levels of tick risk within his map and the low risk tick area in Myers (1924) is interpolated from his original published figure which showed a line of towns situated outside of his high-risk areas where ticks had been reported.

The phenology of *H. longicornis* has been extensively reviewed by Heath (2016), but briefly *H. longicornis* is a three-host tick, requiring a new host for each of the three independent feeding stages, and has four stages in its life cycle; egg, six-legged larva, eight-legged nymph, and eight-legged adult. The largest proportions of the tick's life cycle by time are occupied by the free-living stages which are spent mostly hidden under herbage at ground level. Studies on the abiotic (= free-living) requirements of *H. longicornis* stages and instars show that relative humidity, rainfall and temperature are integral to their development and survival and that for each stage there are subtle differences in these requirements (Heath, 1979, 1981, 2016; Yano et al., 1985). The biotic (= on-host) requirements for *H. longicornis* are extensively met in New Zealand and suitable hosts include cattle, deer, goats, horses, hares, sheep, dogs, kiwis, and even humans (Myers, 1924; Heath, 2016).

H. longicornis is haematophagous during all the active life stages and is the only competent vector for *Theileria orientalis* in New Zealand (Heath, 2016). Other bovine disease organisms for which *H. longicornis* is a known competent vector include *Babesia ovata* (cattle), *B. major* (cattle and wild ruminants) and *Anaplasma bovis* (cattle and small ruminants). However, none of these pathogens occur in New Zealand (Heath, 2002). The haemoplasmas *Mycoplasma wenyonii* and *Candidatus Mycoplasma haemobos* do occur in New Zealand (McFadden et al., 2016a) and it is probable that *H. longicornis* is also involved in their transmission.

T. orientalis is a tick-borne, obligate intracellular protozoan parasite of cattle and buffaloes, and belongs to the phylum Apicomplexa (Watts et al., 2016). *Theileria*-associated bovine anaemia (TABA) is an infectious disease of cattle associated with types of the *T. orientalis* group, in which affected cattle can sometimes develop a severe and life-threatening anaemia (McFadden et al., 2013). Since 1982 there have been 2 epidemics of TABA in New Zealand (James et al., 1984; Lawrence et al., 2016a) with the latest starting in 2012 being associated with the more pathogenic *T. orientalis* Ikeda type (Gias et al., 2016; Pulford et al., 2016a)). Even so the estimated mortality rates associated with Ikeda infection are low, 0.24% in New Zealand (Vink et al., 2016) and between 0.13 and 0.29% in Japan (Shimizu et al., 1992).

Even without any additional known tick-borne diseases of livestock, ticks themselves have significant direct effects on animal health in New Zealand. Anaemia and deaths have been recorded in lambs and fawns (Neilson, 1976; Neilson and Mossman, 1982; Roper, 1987), hide damage, velvet antler damage and sub-clinical losses in growth and production in older deer (Wilson et al., 1987; Mackintosh and Wilson 2005), and hide damage in cattle (Whitten, 1970).

Climate envelope models were one of the earliest methods developed for mapping species distribution (Busby, 1986) and despite increasing complexity and paradigm shifts they remain fundamentally unchanged. The concept of envelope models is relatively straightforward; the potential species' distribution is defined as a multi-dimensional environmental space in which the boundaries for each dimension are the minimum and maximum values observed at species' occurrences for each of the environmental or climate variables measured (Franklin, 2010). One of the key differences between the early envelope models such as BIOCLIM (Busby, 1986) and the more recent developments such as Maxent (Phillips et al., 2006) are that the early models could not incorporate species' traits or additional habitat information (Watling et al., 2013). A rule-based climate envelope model is an example of an early "BIOCLIM" type model in which rules, instead of the minimum and maximum observed environmental values, are used to define the boundaries of the species' habitat envelope.

Over the last century New Zealand annual mean temperatures have increased by about 0.9 °C (Mullan et al., 2010). This trend is likely, depending on the success of global greenhouse gas (GHG) emission controls, to either continue at the present rate, or accelerate over the coming century. Recognising the need to ensure consistency across all branches of climate change science, the Intergovernmental Panel on Climate Change (IPCC) introduced a standard set of climate change scenarios in 2013 (Flato et al., 2013). These are known as the Representative Concentration Pathways (RCPs): RCP8.5 (Riahi et al., 2011), RCP6.0 (Masui et al., 2011), RCP4.5 (Thomson et al., 2011) and RCP2.6 (Vuuren et al., 2011). The numbers attached to each RCP refer to the expected total radiative forcings in Watts per metre² (Wm⁻²) for each RCP at the end of the 21st century (2100) compared to pre-industrial 1750 (Wayne, 2013) and represent +2.6, +4.5, +6.0, and +8.5 Wm⁻², respectively. Radiative forcings quantify the change in the balance between incoming solar radiation and outgoing thermal infrared radiation to the atmosphere resulting from GHG emissions (Flato et al., 2013). RCP2.6 is referred to as the mitigation or peak and decay scenario in which some GHG is removed from the atmosphere after peaking in 2020; RCP4.5 and RCP6.0 are two alternate stabilisation scenarios, with GHG emissions peaking in 2040 for RCP4.5 and 2080 for RCP6.0. RCP8.5 is what is sometimes referred to as the "business as usual" scenario in which GHG emissions continue uncontrolled and even accelerate.

The aim of this study was to develop a simple climate model to determine the spatial extent of habitat suitability for *H. longicornis* in New Zealand. The model was developed using a rule-based climate envelope model based on the environmental requirements proposed by Heath

(1974) and Neilson (1980) for off-host tick survival. Sensitivity analysis was used to test the weighting of each environmental variable entered into the climate model and the accuracy of the final model was then validated against two recently published models. These models were a maximum entropy environmental niche model of environmental suitability for *T. orientalis* transmission (Lawrence et al., 2016a) and a tick occurrence map based on published and unpublished data, combined with an extensive telephone survey (Heath, 2016). The validated model was then used to project the effect of climate change on tick habitat suitability using two alternative climate change scenarios for the periods 2046-2065 and 2081-2100 respectively.

8.4 Materials and methods

8.4.1 *Environmental data*

Neilson (1980), following on from Heath (1974), proposed the following environmental requirements as necessary for *H. longicornis* survival off the animal under New Zealand climate conditions.

1. Annual mean temp >12 °C
2. Minimum July temp >2 °C
3. Maximum July temp >12 °C
4. Frosts < 50 per annum
5. Snow ≤ 1 day per annum
6. Annual rainfall >1000mm
7. Altitude < 300m

Neilson (1980) developed these environmental requirements through combining the results of a postal survey of sheep farmers in the Hawke's Bay and Gisborne regions, in which the survey results were correlated against local climate station data, and the laboratory work completed by Heath (1974, 1977a). Data on New Zealand snow cover were not available so were not included in the rule-based envelope model. However, despite this, it was believed that the remaining six dimensions could still successfully define the boundaries of a robust environmental envelope. The description and source of the environmental variables used in this analysis are shown in Table 8-1.

All the weather variables were supplied by the National Institute of Water and Atmospheric Research of New Zealand (NIWA, Wellington, New Zealand) and were based on the average

for each respective variable over the period 1981 to 2010 and were provided at 500x500m resolution.

Table 8-1. Description and source of the environmental variables used to determine the spatial extent of habitat suitability for *Haemaphysalis longicornis* in New Zealand using a rule-based climate envelope model

Variable name	Units	Description	Source
meanrain	mm/year	The mean annual rainfall, 1981-2010	NIWA
meantemp	°C	The mean annual temperature, 1981-2010	NIWA
meanfrosts	days/year	The mean annual number of days of air frosts, 1981-2010	NIWA
meanjulymax	°C	The mean July daily maximum temperature, 1981-2010	NIWA
meanjulymin	°C	The mean July daily minimum temperature, 1981-2010	NIWA
elevation	m	New Zealand 80 m Digital Elevation Model from the NASA Shuttle Radar Topography mission	koordinates.com

The period 1981-2010 for the meteorological data was used because it is the current standard 30-year normal period, as sanctioned by the World Meteorological Organisation (WMO). The NIWA weather variables were produced by spatial interpolation of actual data from weather stations throughout New Zealand using thin plate smoothing splines, which include a linear dependence on elevation (Tait et al., 2006; Wratt et al., 2006). The New Zealand 80 m Digital Elevation Model from the NASA Shuttle Radar Topography Mission (<https://koordinates.com>) was used for estimating elevation.

8.5 Climate change data

The analysis was based on two RCP scenarios, RCP4.5 and RCP8.5, and two time periods, 2046-2065 and 2081-2100 were chosen to represent mid-term and long-term projections respectively. In the present world political climate (extent of anthropogenic change and ability to ameliorate such change) these two RCPs may be thought to represent the likely low and high global warming outcomes for New Zealand. The projected changes for each of Neilson's environmental requirements, for each of these two RCPs and time periods, were estimated by NIWA, using an ensemble of the six best performing Global Circulation Models (GCMs) for the New Zealand region, selected from approximately 40 GCMs submitted to the fifth phase of the Coupled Model Intercomparison Project (Tait et al., 2016). The six GCMs were selected on their ability to accurately simulate the past climate of New Zealand. Each of the these 6 GCMs were run independently through to the end of the 21st century, the first model run was driven by a forcing of 4.5 Wm⁻² and the second by a forcing of 8.5 Wm⁻². These GCM simulations were then downscaled and bias corrected for New Zealand conditions, to a 5km

grid, with the aid of a regional climate model and using statistical methods (Tait et al., 2016). Projected changes in Neilson's climate variables between mid-term and present-day, and between long-term and present-day, were then calculated at this resolution for each GCM and for each of the RCP forcings. The average of the ensemble models' projected changes, for each of Neilson's climate variables, were then applied to high resolution (500m X 500m) present-day climate grids, which had been derived from average ground-based observations for 1981-2010, to give the four mean climate change scenarios for the periods 2046-2065 and 2081-2100, under RCP4.5 and RCP8.5.

8.5.1 *Data manipulation*

All data layers were matched for the same projection, NZGD2000 (NZTM), the same extent, and all pixels (grid cells) were set at 500x500m.

8.5.2 *Environmental envelope model and habitat suitability thresholds*

Initially the six environmental layers, noted in 8.4.1 (excluding snow cover data), when entered the envelope model were given an equal weighting. Using Boolean logic, the value in each 500x500m pixel in each environmental raster layer was converted to 1 if the environmental rule proposed by Neilson (1980) was met and 0 if it wasn't. Equal weighting assumes that each rule proposed by Neilson is as important as the others for defining the boundary of the habitat suitability envelope. After applying the respective suitability rule to each climate layer, the six raster layers were then summed over each pixel to give a summary habitat suitability raster layer.

If an individual pixel score from the summary habitat suitability raster layer equalled 6, this meant that all of Neilson's (1980) six proposed environmental requirements had been met. As a result, this pixel was considered to contain a highly suitable habitat for *H. longicornis* and therefore had a high risk of tick establishment. Where a pixel ≥ 5 , but < 6 , the suitability of the habitat for *H. longicornis* establishment was described as low and for pixels < 5 the habitat was unsuitable for *H. longicornis* to establish. A raster is an efficient method of storing spatial data as a grid of equal sized cells (pixels) where each pixel contains a value.

The presumption of equal weighting was tested using a one-at-a-time local sensitivity analysis (Pianosi et al., 2016), in which the effect of increasing or decreasing the threshold for each of the environmental variables by 10% was evaluated, whilst keeping the other variables unchanged. The effects measured were the percent change in the proportion of cattle farms in North Island, in South Island and in the whole of New Zealand with a habitat suitability score ≥ 5 (combined low and high suitability) and with a habitat suitability score = 6 (high suitability), relative to the baseline 1981-2010 model built with equal weighting. The environmental variables were then ranked from most influential to least influential based on the proportional change in farms with a score ≥ 5 or = 6 and a new adjusted weighting assigned based on the relative impact of each variable on habitat suitability. The adjusted weightings for each layer then became the new value each 500x500m climate layer pixel in the new contemporary 1981-2010 model was converted to if that environmental requirement was met. As previously for the model with equal weightings, the adjusted weightings contemporary model still summed to 6 if all environmental requirements were met for a summary layer pixel.

To evaluate the effect of climate change, a new value was first calculated for each pixel in each climate layer under the respective climate change scenario for that climate variable, before again applying the environmental rules proposed by Neilson (1980). As before, if the environmental requirement was met the pixel value was converted to the new adjusted weighting or 0 if not, before summing the pixels across the entire climate variables to give a summary climate change raster layer. This process was repeated for each of the 2 climate change scenarios over each of the 2 time periods, to give a total of 4 climate change habitat suitability raster summary outputs.

8.5.3 *Model prediction and validation*

The raster values for each cattle farm, dairy and beef, recorded in the Farms-On-Line (FOL) data base (Ministry for Primary Industries, Wellington, New Zealand) were extracted from the summary habitat-suitability raster layer. These values were then aggregated to give the proportion of farms at risk of *H. longicornis* infestation by region (as defined in Fig. 8-2), by island and for the whole of New Zealand, categorised for the two cut points of 6 (high habitat suitability) and 5 or more (combined low and high habitat suitability) respectively. The average *H. longicornis* habitat suitability scores for cattle farms in each region were also calculated.

This process was repeated for the contemporary 1981-2010 data and for the projected 4 climate change habitat suitability raster outputs.

Using the results from a maximum entropy environmental niche model (ENM) of environmental suitability for *T. orientalis* transmission (Lawrence et al., 2016a), a linear regression model was built to predict the average farm environmental suitability for *T. orientalis* transmission by region from the average farm *H. longicornis* habitat suitability score by region. The relative environmental suitability measures the relative suitability of each pixel's environment for *T. orientalis* transmission and ranges from 0, unsuitable, to 1, highly suitable (Lawrence et al., 2016a). Polynomials were tested in the linear regression model and retained at $P < 0.05$. The fit of the final linear model was assessed using the adjusted R-square, the F statistic and by examination of residual plots.

The I-similarity statistic (Warren et al., 2008) was used to calculate the niche overlap between the Heath (2016) *H. longicornis* occurrence map and the predicted habitat suitability map from the envelope model, categorised as high, low and zero risk pixels. Both distribution raster matrices were reclassified so that high risk or high habitat suitability pixels = 2, low risk or low habitat suitability pixels = 1 and zero risk or zero habitat suitability pixels = 0. The I-similarity statistic sums the pair-wise differences between two predictions to create a single value representing the similarity of the two distributions. The I-similarity statistic ranges from a value of 0, where two distributions have no overlap, to 1 where two distributions are identical (Warren et al., 2008). The I-similarity statistic was also calculated for the niche overlap between the envelope model and the ENM of relative environmental suitability for *T. orientalis* transmission. For this comparison the output from the rule-based envelope model was divided by 6 to scale the habitat suitability to between 0 and 1, like the output from the ENM.

8.6 Results

The results from the one-at-a-time sensitivity analysis and the new adjusted weightings derived from the sensitivity analysis are shown in Table 8-2. Using mean maximum temperature and the North Island as an example the interpretation of the results is as follows; if the threshold for mean maximum temperature is increased from 12.0°C to 13.2°C then there will be a 10.7% decrease in North Island farms with habitat suitability ≥ 5 and a 26.5% decrease in North Island farms with a habitat suitability = 6. If the threshold for mean maximum temperature is decreased

from 12.0°C to 10.8°C then there will be a 6.9% increase in North Island farms with habitat suitability ≥ 5 and a 11.6% increase in North Island farms with a habitat suitability =6. Overall the sensitivity analysis showed that mean annual temperature and mean maximum July temperature have the largest influence on the envelope model, that mean annual rainfall and elevation are less influential, and least influential of all are mean minimum July temperature and number of frost days.

Table 8-2. One-at-a-time sensitivity analysis of the equal weighting envelope model, showing the effect (%) of decreasing or increasing the threshold for each environmental rule by 10%, whilst keeping the other variables in the model unchanged. The effect measured is the percent increase or decrease in the proportion of cattle farms with habitat suitability score ≥ 5 or $= 6$, from the North Island, South Island and the whole of New Zealand, relative to the output of the equal weighting envelope model. Based on the relative impact of each variable on habitat suitability, the environmental variables were ranked from most influential to least influential and an adjusted weighting assigned and implemented in the final envelope model.

Variable (threshold, threshold-10%, threshold+10%)	North Island habitat suitability ≥ 5	North Island habitat suitability $= 6$	South Island habitat suitability ≥ 5	South Island habitat suitability $= 6$	New Zealand habitat suitability ≥ 5	New Zealand habitat suitability $= 6$	Ranking	Adjusted weighting
meanjulymax (12, 10.8, 13.2)	(6.9, -10.7) %	(11.6, -26.5) %	(70.7, -35.1) %	(41.1, -78.9) %	(8.5, -11.4) %	(12.0, -27.2) %	1	2
meantemp (12, 10.8, 13.2)	(2.1, -17.4) %	(0.9, -18.6) %	(49.1, -44.9) %	(18.1, -91.5) %	(3.3, -18.1) %	(1.1, -19.6) %	2	1.5
meanrain (1000, 900, 1100)	(1.6, -1.3) %	(4.9, -7.1) %	(5.7, -7.0) %	(2.1, -4.3) %	(1.7, -1.5) %	(4.9, -7.1) %	3	1
elevation (300, 270, 330)	(-1.4, 1.0) %	(-1.0, 0.4) %	(-1.1, 0.5) %	(0, 0) %	(-1.4, 1.0) %	(-1.0, 0.4) %	4	0.75
meanjulymmin (2, 1.8, 2.2)	(0.1, -0.1) %	(0.1, -0.1) %	(6.3, -2.3) %	(5.4, -1.5) %	(0.2, -0.1) %	(0.2, -0.1) %	5	0.5
meanfrosts (50, 45, 55)	(0, 0) %	(0, 0) %	(0, 0) %	(0, 0) %	(0, 0) %	(0, 0) %	6	0.25

Using these new adjusted weightings, the envelope model predicted that 75% of cattle farms in the North Island, 3% of cattle farms in the South Island and 54% of cattle farms in New Zealand overall potentially have a habitat suitable for *H. longicornis* establishment, (Table 8-3).

Table 8-3. Proportion of total cattle by region in New Zealand. The average cattle farm habitat suitability score by region for *Haemaphysalis longicornis* establishment (the proportion of cattle farms by region with habitat suitability score ≥ 5 , the proportion of cattle farms by region with habitat suitability score = 6), for contemporary climate and future climate change scenarios. The results are shown for 1981-2010 data and for 2 future climate change scenarios and 2 time period projections. The cattle percentages are from the 2012 Agricultural Census, Statistics New Zealand (Anon., 2012).

Region	2012	1981-2010	2046-2065 (mid-term)		2081-2100 (long-term)	
	Total cattle (%)	Contemporary	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Northland	8	6 (1, 0.98)	6 (1, 0.98)	6 (1, 0.98)	6 (1, 0.98)	6 (1, 0.98)
Auckland	2	6 (1, 1)	6 (1, 1)	6 (1, 1)	6 (1, 1)	6 (1, 1)
Waikato	23	5.5 (0.87, 0.86)	5.6 (0.87, 0.86)	5.6 (0.87, 0.87)	5.6 (0.87, 0.86)	5.6 (0.87, 0.86)
Bay of Plenty	4	5.3 (0.82, 0.76)	5.5 (0.83, 0.8)	5.5 (0.83, 0.8)	5.5 (0.83, 0.79)	5.5 (0.83, 0.8)
Gisborne	3	5.2 (0.78, 0.73)	5.2 (0.8, 0.73)	5.2 (0.8, 0.7)	5.2 (0.8, 0.69)	5.3 (0.81, 0.61)
Hawke's Bay	6	4.7 (0.74, 0.34)	4.8 (0.74, 0.34)	4.9 (0.74, 0.34)	4.8 (0.74, 0.32)	4.8 (0.74, 0.31)
Taranaki	7	5.1 (0.66, 0.66)	5.2 (0.65, 0.65)	5.2 (0.65, 0.65)	5.2 (0.65, 0.65)	5.2 (0.65, 0.65)
Manawatu-Wanganui	10	3.8 (0.4, 0.17)	4.1 (0.4, 0.2)	4.2 (0.4, 0.21)	4.1 (0.4, 0.19)	4.2 (0.4, 0.2)
Wellington	2	4.4 (0.5, 0.26)	4.7 (0.54, 0.3)	4.7 (0.55, 0.3)	4.7 (0.54, 0.29)	4.7 (0.55, 0.27)
West Coast*	2	3.0 (0.14, 0.14)	3.8 (0.22, 0.2)	4.0 (0.24, 0.22)	3.9 (0.23, 0.22)	4.3 (0.26, 0.26)
Canterbury*	16	1.0 (0, 0)	1.6 (0, 0)	1.8 (0, 0)	1.7 (0, 0)	2.4 (0, 0)
Otago*	6	0.8 (0, 0)	0.8 (0, 0)	0.9 (0, 0)	0.9 (0, 0)	1.7 (0, 0)
Southland*	8	1.7 (0, 0)	1.8 (0, 0)	1.9 (0, 0)	1.9 (0, 0)	2.9 (0, 0)
Tasman*	1	3.5 (0.37, 0.23)	3.9 (0.39, 0.31)	4.0 (0.4, 0.34)	4.0 (0.4, 0.33)	4.4 (0.41, 0.4)
Nelson**	NA	4.3 (0.47, 0.06)	4.6 (0.36, 0.36)	4.6 (0.36, 0.36)	4.6 (0.36, 0.36)	4.7 (0.36, 0.36)
Marlborough*	1	3.1 (0.23, 0.04)	3.5 (0.31, 0.11)	3.6 (0.32, 0.12)	3.6 (0.31, 0.11)	3.8 (0.32, 0.12)
North Island	65	5.1 (0.75, 0.65)	5.2 (0.75, 0.66)	5.3 (0.75, 0.66)	5.2 (0.75, 0.65)	5.3 (0.75, 0.65)
South Island	35	1.4 (0.03, 0.02)	1.8 (0.04, 0.03)	1.9 (0.04, 0.03)	1.9 (0.04, 0.03)	2.6 (0.05, 0.04)
Total	10.2 million	4.0 (0.54, 0.47)	4.2 (0.54, 0.47)	4.2 (0.54, 0.47)	4.2 (0.54, 0.47)	4.5 (0.54, 0.47)

^a Cattle numbers not known for Nelson but likely small since only 17 herds are recorded in census data

* denotes a South Island region.

The regions with the highest habitat suitability for *H. longicornis* were Northland and Auckland with 100% of cattle farms having suitable habitats, and the lowest were Canterbury, Southland and Otago with no cattle farms predicted as having a suitable tick habitat, (Table 8-3). The average *H. longicornis* habitat suitability score at the farm level was 5.1 in the North Island, 1.4 in the South Island and 4.0 overall, (Table 8-3). Almost all the farms at high risk of *H. longicornis* establishment were situated in the North Island or at the very top of the South

Island. With 65% of New Zealand's total cattle domiciled in the North Island, (Table 8-3), this probably represents over 4 million cattle at serious risk of infection with *T. orientalis*.

The density of cattle farms per km² by region is shown in Figure 8-2. The highest density of cattle farms is found in the Waikato, Taranaki and Manawatu-Wanganui regions of the North Island and comprises predominantly dairy farms. Southland has the highest density of cattle farms in the South Island and again has many dairy farms.

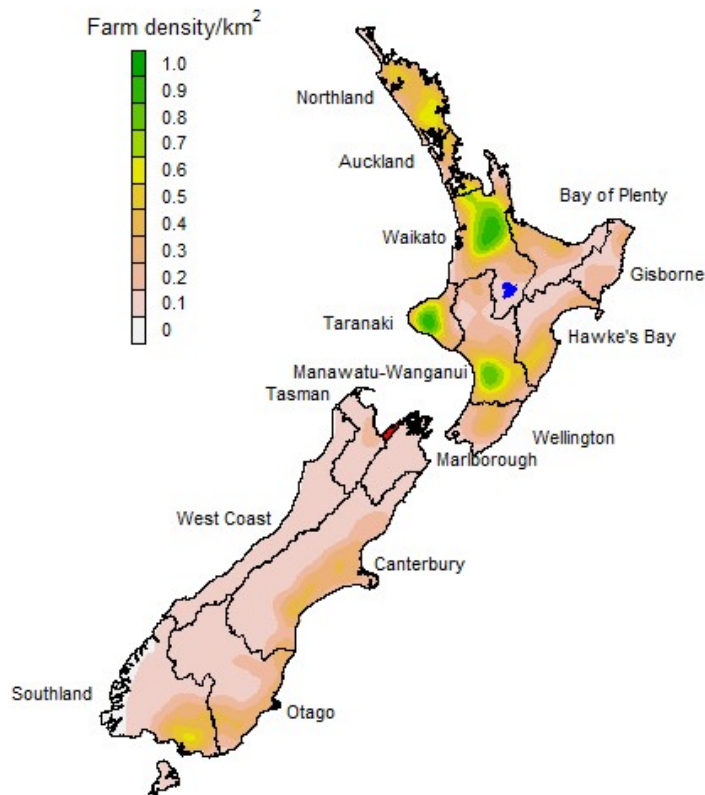


Figure 8-2. Kernel density map showing the density of cattle farms per km² in New Zealand with the regions overlaid. The small region of Nelson is coloured red.

The results for the climate change scenarios are also shown in Table 8-3. For the North Island, with many of the regions currently having highly suitable habitats, there were no significant changes in habitat suitability. Although there was a slight tendency for the proportion of Hawke's Bay and Gisborne cattle farms with highly suitable habitats to fall over the long-term projections. In contrast the mid and long-term climate change scenarios all projected moderate increases in the average farm habitat suitability scores for all the South Island regions, (Table

8-3). However, only for the West Coast, Marlborough, Tasman, and Nelson regions did these increases in environmental suitability translate into an increased proportion of cattle farms with low or high habitat suitability. Despite these regional increases, the relatively low numbers of cattle farms in West Coast, Marlborough, Tasman, and Nelson meant that overall for New Zealand there was no effect of climate change on the total proportion of total New Zealand cattle farms with low or high habitat suitability, (Table 8-3). Contrasting the two RCP scenarios it is only for the long-term projection (2081-2100) that substantial differences are seen. For this time period RCP8.5 projects dramatic increases in suitability for the least suitable South Island regions of Canterbury, Otago and Southland.

Figure 8-3a shows the predicted habitat suitability values for *H. longicornis* establishment outputted from the contemporary climate envelope model and Figure 8-3b shows the raw values of habitat suitability categorised into areas of unsuitable (<5), low ($\geq 5, < 6$) and high habitat suitability (=6). The envelope model failed to identify areas of suitable tick habitation, i.e. a habitat score of 5 or over, much further south than Westport on the West Coast, South Island, (Figure 8-3b).

The mid-term and long-term change in projected habitat suitability under the RCP4.5 and RCP8.5 scenarios are shown in Supplementary Figures 8-5a-b, Supplementary Figures 8-6a-b, Supplementary Figures 8-7a-b and Supplementary Figures 8-8a-b respectively. In general, they show little to moderate change with some limited expansion of habitat suitability into the central area of the North Island, down the western coast of the South Island and across the top of the South Island.

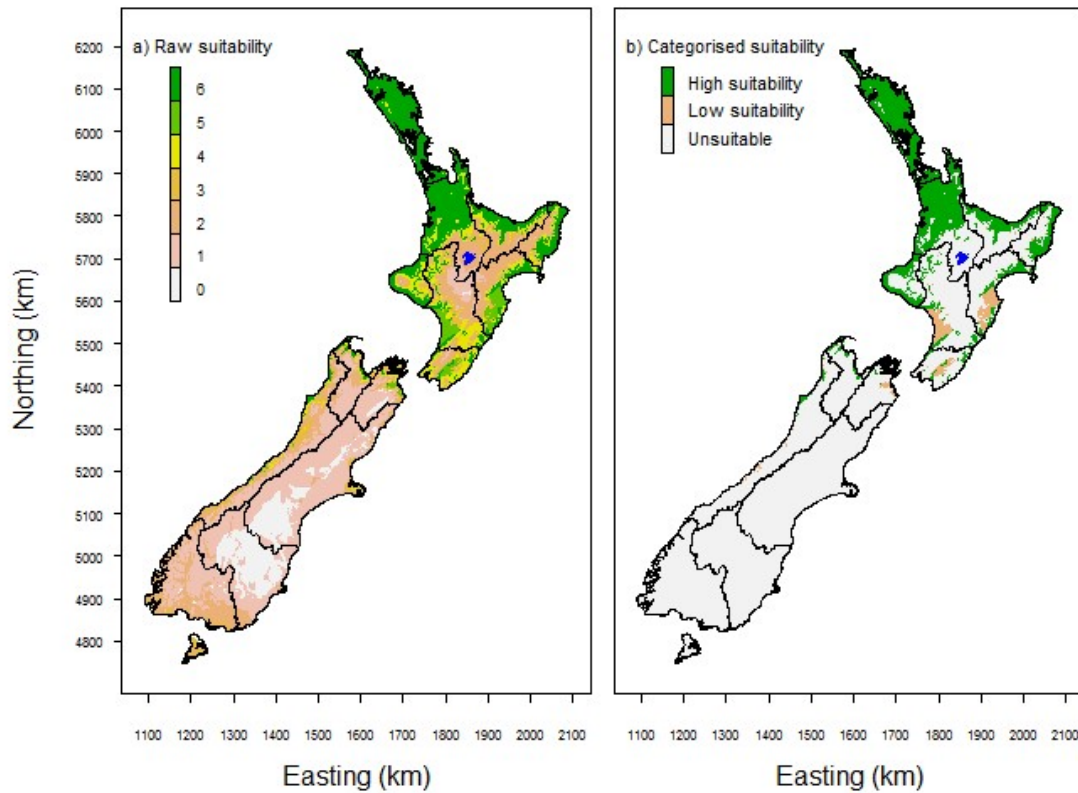


Figure 8-3. a) Raw habitat suitability values for *Haemaphysalis longicornis* establishment, outputted from the rule-based envelope model based on the six environmental requirements proposed by Neilson (1980). b) Shows the raw values categorised by two cut points, ≥ 5 and $=6$, into three areas of unsuitable, low and high habitat suitability for *Haemaphysalis longicornis* establishment.

The linear regression of average farm relative environmental suitability for *T. orientalis* transmission on average farm habitat suitability for *H. longicornis* establishment included a significant linear and quadratic function. A plot of the average relative environmental suitability of *T. orientalis* transmission against the average habitat suitability score by region is shown in Figure 8-4.

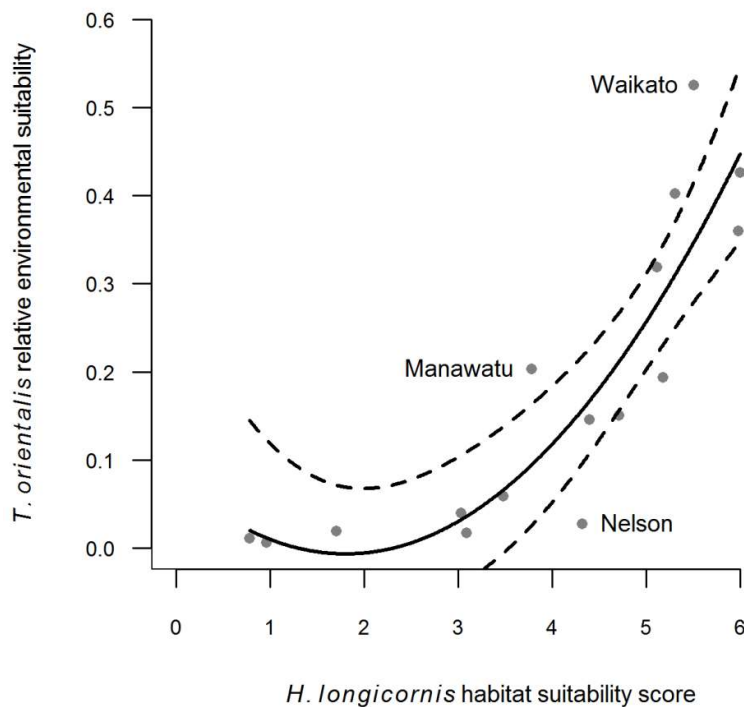


Figure 8-4. Regression plot of the average relative environmental suitability for *Theileria orientalis* transmission against the average *Haemaphysalis longicornis* habitat suitability score for cattle farms by region of New Zealand. The solid line shows the average predicted change in the relative environmental suitability for *Theileria orientalis* transmission for changing *Haemaphysalis longicornis* habitat suitability; the broken lines show the upper and lower 95% confidence intervals for the average.

The data points shown on Figure 8-4 are the average farm relative environmental suitability for *T. orientalis* transmission and the average farm habitat suitability for *H. longicornis* for each region of New Zealand. The plot clearly shows that the average farm relative environmental suitability for *T. orientalis* transmission is low up to a habitat suitability of about 4.0, after which there is a dramatic increase in the average farm relative environmental suitability for *T. orientalis* transmission. Although the curve in the lower part of the plot makes little biological sense the inclusion of a quadratic function gave a better fit over a more intuitive broken line regression. The linear regression was significant, $F(2,13) = 25.5$, $p < 0.001$, with an adjusted $R^2 = 0.77$. There were no significant outliers identified from the residual plots. The Waikato, Nelson and Manawatu-Wanganui data points are identified on Fig. 8-4 for comparative purposes.

There were good niche overlaps between the habitat suitability envelope model and the Heath (2016) occurrence map, I-similarity statistic = 0.78, and between the habitat suitability envelope model and the ENM of relative environmental suitability for *T. orientalis* transmission, I-similarity statistic = 0.85.

8.7 Discussion

A simple rule-based envelope model of habitat suitability for *H. longicornis* establishment in New Zealand has been presented, having been successfully validated against published data and used to make future climate change projections of habitat suitability. Overall the model projected that the effect of climate change on *H. longicornis* habitat suitability in New Zealand is only slight to moderate with the greatest increases in farm habitat suitability seen in the South Island. These results are like Williams et al. (2015) who modelled the effects of climate change on climate suitability for European ticks. They found only moderate increases in habitat suitability for some species of tick, with a northern expansion of suitable climates (a northern expansion in the Northern hemisphere being equivalent to a southern expansion in the Southern hemisphere).

The similar habitat suitability projections under RCP4.5 and RCP8.5 for the mid-term (2046-2065) period are not unexpected since GHG emissions under RCP4.5 peak in 2040 just before this period. It is only for the long-term projections (2081-2100) that a dramatic increase in habitat suitability under RCP8.5, compared to RCP4.5, is seen. This is because under RCP8.5 the GHG emissions continue to increase through most of the 21st century.

However, as the model does not include maximum boundaries for two of the more important tick survival abiotic variables, i.e. temperature and rainfall, it could be argued it is possibly biased. This is because the proposed rules for these two variables are only based on minimum values. Therefore, any negative impact of excessive heat or excessive rainfall on habitat suitability is not accounted for in the model. Despite these reservations, the effects of these potential biases on the model projections may not be great since neither of the RCP climate change scenarios described lead to excessively hot or excessively wet areas within New Zealand, in the time periods covered by those projections.

The good spatial agreement between the environmental suitability model and the tick distribution map (Heath, 2016) was important given that this map was based on observational

field data recovered by telephone survey, superimposed upon surveillance data, published data and unpublished data. Effectively the Heath (2016) map provides observational data for the envelope model and gives good external validity that the climate model is accurately predicting suitable tick habitats. The excellent agreement with the ENM of environmental suitability for *T. orientalis* transmission, although also important, would be expected since both models are largely based on the work of Heath (1974, 2016) and Neilson (1980), although the modelling methodology is entirely different.

Although the validated envelope model was used, in this study, to estimate the proportion of cattle farms throughout New Zealand with suitable tick habitats, and by extension the proportion of farms potentially at risk of *T. orientalis* infection, it could easily have been used to estimate habitat suitability for sheep farms, deer farms or even equine facilities instead. This flexibility gives the model greater utility and means it could be used to inform farm biosecurity decisions or preventative health measures, even at the individual farm level if the climate and elevation data for that property is available.

The adoption of the adjusted weightings did not affect the distribution of high suitability habitats, since these areas required all 6 environmental requirements to be met, irrespective of their weighting. However, there was an impact on the distribution of those areas predicted as having low habitat suitability. Under equal weighting, areas would be classified as having low habitat suitability when 5/6 of the environmental requirements were met, notwithstanding which environmental requirements were satisfied. Whereas under the adjusted weightings no area can be predicted as being of low suitability without the two most influential environmental requirements, mean annual temperature and mean maximum July temperature, being met. This was not the case with equal weighting. Interestingly under the adjusted weightings it is now possible to achieve low suitability with just 4 environmental requirements met, although these must include the three most influential variables: mean maximum July temperature, mean annual temperature and mean annual rain.

The sensitivity analysis further showed that mean annual frost days had little impact on habitat suitability. This variable also failed to achieve significance in the ENM of environmental suitability for *T. orientalis* transmission (Lawrence et al., 2016a). It is likely that had data on snow cover been available, then this variable would also have proved equally redundant. Japanese evidence would suggest that *H. longicornis* is well able to survive snow cover for up

to 6 months in Hokkaido (Heath. 2013a) so the inclusion of this variable could even have severely biased the model.

Heath (2016) raised concerns that pasture irrigation could affect tick habitat suitability. This seems entirely plausible, especially for the warm but dry eastern coastal regions of the North Island (Hawkes Bay and Gisborne) where the provision of irrigation could easily promote a property from unsuitable into low or high habitat suitability. However, for irrigation to have a widespread impact on an area, the average farm suitability score in that area needs to be at least 4 with mean annual rainfall below the threshold of 1000mm. Ironically, given the projected slight to moderate effects of climate change, the impact of irrigation on habitat suitability could be as great or greater than climate change for some regions.

Canterbury is often proposed as the region where pasture irrigation could significantly affect habitat suitability. Canterbury has 18% of New Zealand's total dairy cows (Anon., 2012) and irrigation is widely used to improve pasture dry matter production for dairying. However, the potential effects of pasture irrigation on habitat suitability in Canterbury are not obvious. The average predicted farm habitat suitability score in Canterbury is only 1.0, (Table 8-3) but this is averaged over a wide area and many farms. It is likely that there are some areas within Canterbury that have a more favourable local climate and where the provision of irrigation will potentially lift the habitat suitability into at least the low suitability classification (the results from the envelope model showed about 60 Canterbury farms (1%) have a predicted habitat suitability score of 4 or better). Two recent records of established tick populations on the outskirts of metropolitan Christchurch (see map in Heath (2016)) suggest that, even in the absence of irrigation, there are suitable, albeit scattered, habitat locations in parts of Canterbury. In order to fully investigate the effect of irrigation in regions like Canterbury, the envelope model would have to be applied at a local scale, using data from local weather stations and having the extent of irrigation added to the total rainfall.

The tick distribution maps, (Figure 8-1), appear to display a continued southward expansion of tick habitation over time, which could either mean that ticks have not yet reached the limit of their realised niche or that climate change or changing farming practices are continually modifying the boundaries of that niche. Furthermore the finding that the *H. longicornis* habitat suitability envelope model explains 77% of the variability in the environmental suitability for *T. orientalis* transmission model again confirms our belief that *H. longicornis* is the only competent vector for *T. orientalis* in New Zealand. A number of additional mechanical vectors

for *T. orientalis* transmission have been suggested such as biting flies, sucking lice, mosquitoes and iatrogenic transmission, however presently there are little available data to support these claims (Fujisaki et al., 1993; Hadi and Al-Amery, 2012; Hammer et al., 2015; Hammer et al., 2016).

The linear regression plot, (Figure 8-4), shows that below an average regional tick habitat suitability score of about 4.0 the relative environmental suitability for *T. orientalis* transmission is less than 0.1 and remains low over the range of habitat suitability values up to 4.0. However, once the habitat suitability score exceeds 4.0 the environmental suitability for *T. orientalis* transmission increases dramatically for comparatively small increases in the habitat suitability score. This indicates that at low relative suitability, below 0.1, the environmental suitability for *T. orientalis* transmission is driven by the *H. longicornis* abiotic requirements, but once these are near satisfied, i.e. when the habitat suitability score exceeds 4.0, then the environmental suitability for *T. orientalis* transmission model switches to being driven by the biotic requirements of *H. longicornis*. As a result, the linear model under predicts the environmental suitability of the Manawatu-Wanganui and Waikato regions for *T. orientalis* transmission and over predicts for the Nelson region. This is not surprising since the Manawatu-Wanganui and Waikato regions have high densities of cattle farms (Figure 8-2), with 10 and 23% of New Zealand's total cattle population respectively, whereas Nelson has only 17 cattle farms.

Although the West Coast, Marlborough, Tasman, and Nelson regions have proportionally far fewer cattle than other regions, the case numbers of TABA should still steadily increase in the future given the projected changes in habitat suitability for these regions. In contrast the projected increases in habitat suitability for Canterbury and Southland are not expected to change the proportion of farms with low and high habitat suitability. However, with these two regions having between them 24% of the total New Zealand cattle numbers then any changes in habitat suitability, no matter how small, will inevitably lead to some increase in TABA cases.

It is likely that areas with high habitat suitability for *H. longicornis* will rapidly attain endemically stability in regard to TABA disease (McFadden and Marchant, 2015) whereas areas with low habitat suitability will fail to achieve endemic stability and remain endemically unstable (Hay, 2001; Jonsson et al., 2012). As a result, the prevalence of clinical TABA will probably fall in the high habitat suitability areas (Coleman et al., 2001) and remain unpredictable in the low habitat suitability areas (L'Hostis and Seegers, 2002). What is certain is that for now, and for the foreseeable future, New Zealand cattle farmers will continue to run

considerable risks of clinical TABA disease if they relocate naïve cattle from unsuitable to low or high habitat suitability areas within New Zealand.

8.8 Conclusion

Climate envelope models use relatively uncomplicated data sets and are, as a result, simple to implement and understand (Watling et al., 2013). The rule-based envelope model described in this study, although biased, has, because of its relatively accurate depiction of current tick distribution, improved our understanding of the present and future distributions of *H. longicornis* in New Zealand under climate change. The model could prove useful for estimating the boundaries of the endemically stable and unstable TABA areas within New Zealand or for projecting future *H. longicornis* habitat suitability if alternate climate change scenarios are developed.

8.9 Acknowledgements

Professor Mark Stevenson of Melbourne University is thanked for his help and instruction on manipulating raster data sets.

8.10 Supplementary material

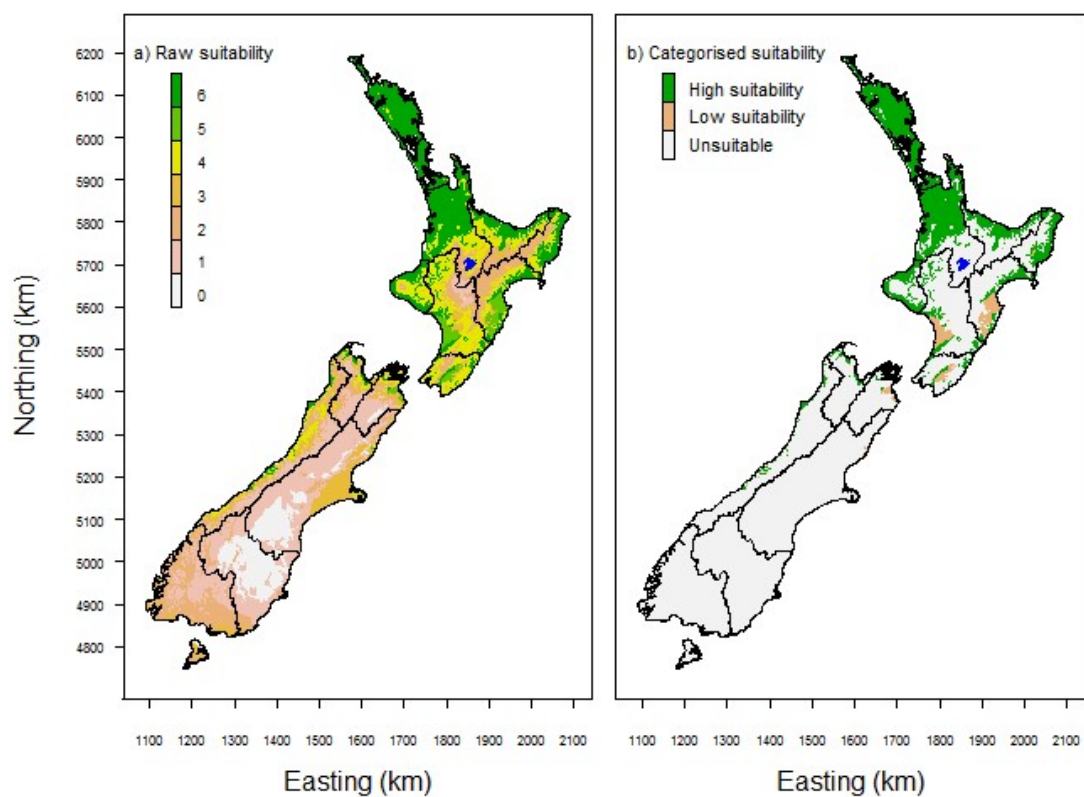


Figure 8-5. a) Raw projected habitat suitability values for *Haemaphysalis longicornis* establishment for 2046-2065 (mid-term) RCP4.5 climate change scenario. Supplementary b). Shows the raw values categorised by two cut points, ≥ 5 and $=6$, into three areas of unsuitable, low and high habitat suitability for *Haemaphysalis longicornis* establishment.

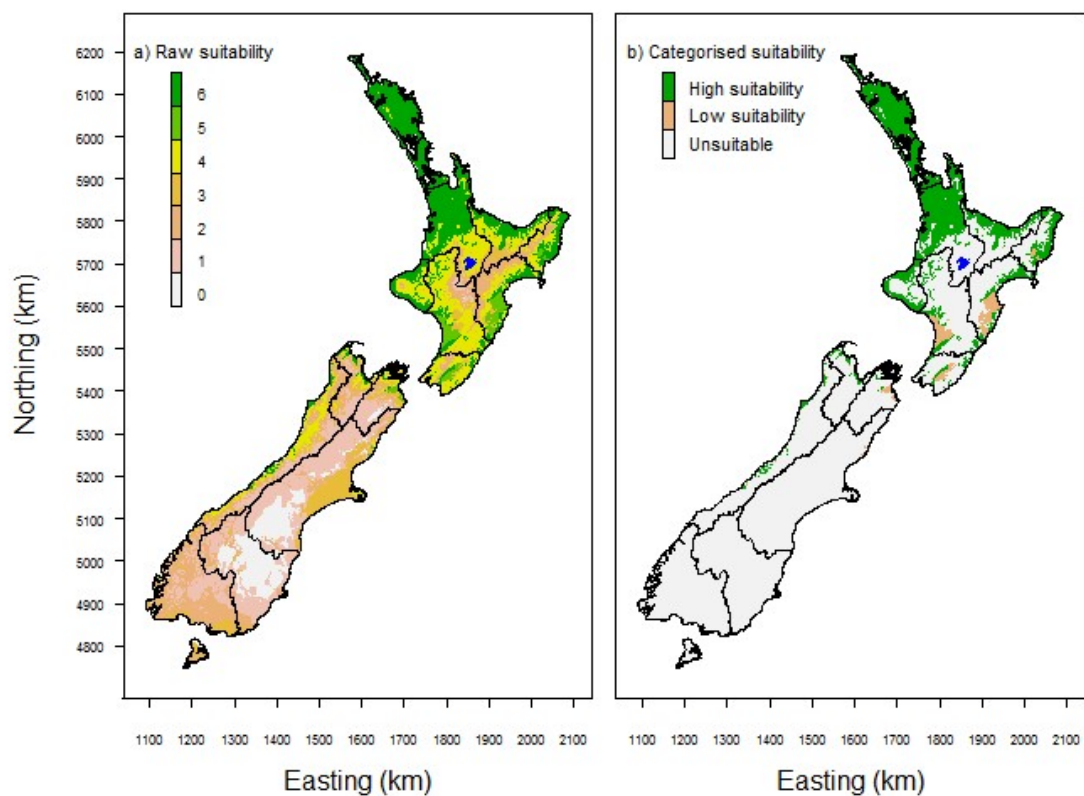


Figure 8-6. a) Raw projected habitat suitability values for *Haemaphysalis longicornis* establishment for 2046-2065 (mid-term) RCP8.5 climate change scenario. b). Shows the raw values categorised by two cut points, ≥ 5 and ≤ 6 , into three areas of unsuitable, low and high habitat suitability for *Haemaphysalis longicornis* establishment.

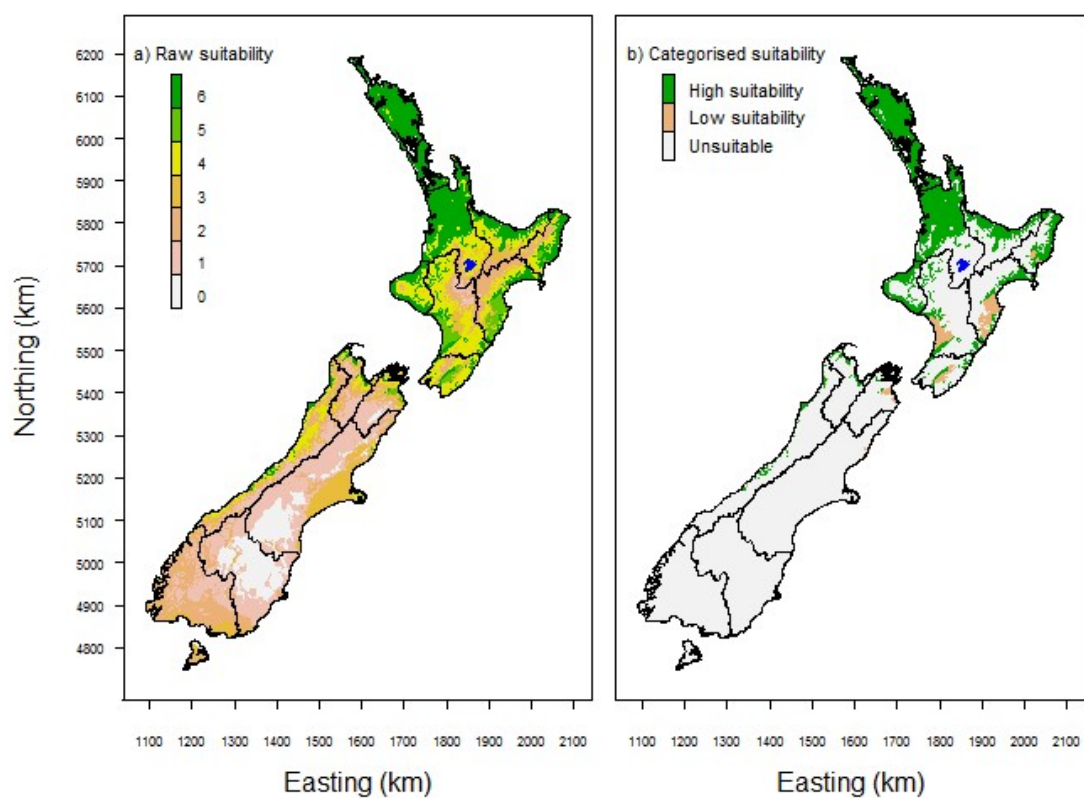


Figure 8-7. a) Raw projected habitat suitability values for *Haemaphysalis longicornis* establishment for 2081-2100 (long-term) RCP4.5 climate change scenario. b). Shows the raw values categorised by two cut points, ≥ 5 and ≤ 6 , into three areas of unsuitable, low and high habitat suitability for *Haemaphysalis longicornis* establishment.

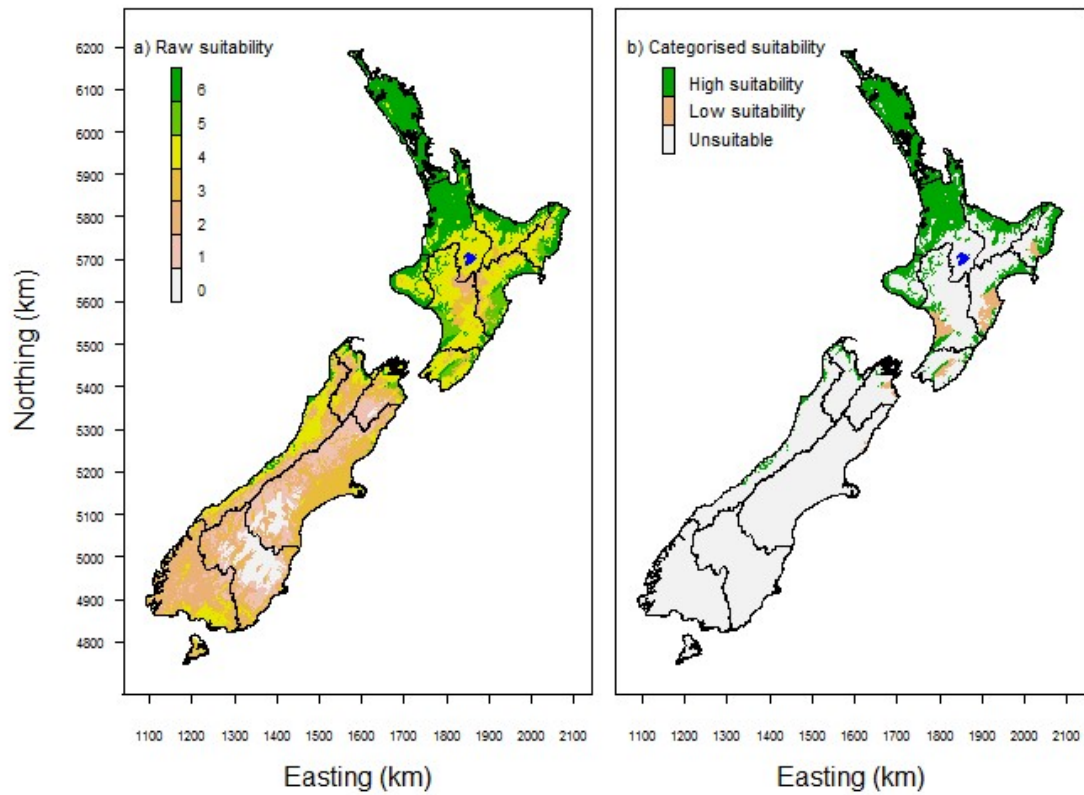


Figure 8-8. a) Raw projected habitat suitability values for *Haemaphysalis longicornis* establishment for 2081-2100 (long-term) RCP8.5 climate change scenario. b). Shows the raw values categorised by two cut points, ≥ 5 and ≤ 6 , into three areas of unsuitable, low and high habitat suitability for *Haemaphysalis longicornis* establishment.

Chapter 9

A longitudinal study of the effect of *Theileria orientalis* Ikeda type infection on three New Zealand dairy farms naturally infected at pasture

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9.1 Preface

The results presented in this Chapter are from a prospective observational study completed on three New Zealand dairy farms from 2014 to 2015. Prior to commencing this study no New Zealand cows infected with *T. orientalis* Ikeda type had been repeatedly sampled over an extended period. This meant there was no data on how the infection intensity changed over time and whether it was affected by stressful events. This study was undertaken to fill a gap in the knowledge.

9.2 Abstract

AIMS: The aims of this study were to monitor the change in *Theileria orientalis* Ikeda type infection intensity, haematocrit, milk production and reproduction on three New Zealand spring calving dairy herds, over the 2014 to 2015 milking season.

METHODS: Dairy cows from three spring calving herds from three different *Haemaphysalis longicornis* risk areas in North Island, New Zealand were followed through the 2014 to 2015 milking season. The three farms, A, B and C, were from high risk (endemically stable), low risk (endemically unstable), and zero risk (disease-free) tick areas respectively. Farms A and B were first infected with *T. orientalis* Ikeda type the previous season in spring 2013 and Farm C was first infected in spring 2014. On Farms, A and B, 100 cows were randomly selected at the first visit, and the same cows blood sampled every month thereafter, whilst on Farm C, the whole herd was blood sampled bimonthly (140 cows). Blood samples were tested for haematocrit by centrifugation and Ikeda infection intensity, using qPCR. Animals that were Ikeda type PCR positive at the first sampling were described as prevalence cases and cows that were negative at the first sampling and became PCR positive during the sampling period were described as incidence cases. Production and reproduction data were accessed through LIC MINDA[®] and milk production data was standardised to energy corrected milk (ECM). In addition, the effect of buparvaquone (BPQ) treatment on milk production was estimated on Farm B, where all suspected clinical cases of oriental theileriosis were treated with BPQ.

RESULTS: The prevalence of infection at the first sampling was 100% on Farm A, 57% on Farm B and 26% on Farm C. The incidence risk of infection over the sampling period on Farms B and C was 25% and 2% and the incident rate was 0.026 and 0.002 cases per cow-month respectively. The average infection intensity for prevalence cases on all farms was low throughout the milking season, <7,000 Ikeda organisms/ μ L however, cases of anaemia still

occurred. There was no direct effect of infection intensity on milk production or being a prevalence case compared to an uninfected cow on milk production, across all farms. However, on Farm B there was a loss of 266kg (95% CI 82–450) ECM (~20kg milk solids) for incidence cases and a loss of 458kg (95% CI 211–710) of ECM for buparvaquone treated cows, compared to uninfected cows. No significant effect of Ikeda infection on reproduction could be shown for Farms B and C, reproductive data for Farm A was not available.

CONCLUSIONS AND CLINICAL RELEVANCE: The effect of *T. orientalis* Ikeda type infection on production and reproduction appears to be minimal once animals have passed through the acute phase of infection and reached the chronic, asymptomatic carrier phase of infection.

9.3 Introduction

First diagnosed in 2012 (McFadden et al 2013) bovine anaemia associated with *Theileria orientalis* Ikeda type infection (TABA) is now the principal cause of bovine anaemia in New Zealand. The spread of infection between cattle is via the tick *Haemaphysalis longicornis* (Heath, 2016) and the disease has rapidly reached endemic stability in the upper North Island of New Zealand, owing to both the favourable climate and habitats for tick infestation and the high density of cattle farms found there (Lawrence et al., 2017b). Anecdotally, endemic stability has resulted in a drop in clinical disease in these areas. However, for much of the lower North Island and parts of the upper South Island, where climate and habitat are less favourable for ticks, the disease remains endemically unstable and *T. orientalis* Ikeda type infection continues to cause significant outbreaks of infectious anaemia and deaths on some dairy and beef farms in these areas. Parts of the North Island and much of the lower South Island remain disease free to this day.

Theileria orientalis comprise tick-borne obligate intracellular apicomplexan haemoprotezoan parasites of cattle around the world (Aktas et al., 2006) and are only rarely associated with severe disease outbreaks (Watts et al., 2016). To the best of our knowledge 4 of the 11 types of *T. orientalis* (Khukhuu et al., 2011) currently recognised, are found in New Zealand cattle. These are Type 1 (Chitose), Type 2 (Ikeda), Type 3 (Buffeli) and Type 5 (Pulford et al., 2016a). Of these the Ikeda type is the most pathogenic (Lawrence et al., 2016b) although the Chitose type has been sporadically associated with mild outbreaks of bovine anaemia in New Zealand since 1982 (James et al., 1984; Rawdon et al., 2006; McFadden et al., 2011).

There is only one competent arthropod vector for *T. orientalis* in New Zealand, the ixodid tick *Haemaphysalis longicornis*, and its lifecycle and distribution have been thoroughly reviewed (Heath, 2016). Non-tick associated, mechanical spread of infection is also described through biting flies, sucking lice or hypodermic needles (Hadi and Al-Amery, 2012; Fujusaki et al., 1993; Hammer et al., 2015; Hammer et al., 2016) however this method of spread is not thought to be important in the wider epidemiology of *Theileria* associated bovine anaemia (TABA).

Cattle affected with *T. orientalis* Ikeda type usually show a combination of the following clinical signs; anaemia, lethargy, production drop, anorexia, ill-thrift, diarrhoea, constipation, jaundice, collapse, pale udders, possible haemoglobinuria, abortion and inappetance (Islam et al., 2011; Cufos et al., 2012a; Lawrence et al., 2013). The morbidity rates reported in New Zealand and Japan for TABA are low, usually < 1% (Shimizu et al. 1992; Vink et al. 2016) with mortality rates of 0.25% (only recorded for New Zealand cattle; Vink et al. 2016). Post-mortem examination of dead animals often shows a massively enlarged “raspberry jam” spleen (the spleen removes parasitised RBCs from circulation) and a bronze coloured liver with generalised jaundice (Izzo et al., 2010; Gebrekidan et al., 2017c).

Robust industry estimates of the cost of TABA for New Zealand don’t exist, however within Australia, oriental theileriosis is estimated to cost the red meat industry \$19.6M per annum (Lane et al., 2015). Recent Australian and New Zealand studies have shown negative impacts of *T. orientalis* Ikeda type infection on milk production (Australia), on reproduction (New Zealand), on live weight gain in Friesian bulls (New Zealand) and on live weight gain in beef calves (New Zealand) (McDougall et al., 2014; Perera et al., 2014; Lawrence et al., 2018b; Lawrence et al., 2019).

Overall, chemotherapy of TABA is considered unrewarding but one of the few drugs shown to have some efficacy against *T. orientalis* Ikeda type infection is buparvaquone (BPQ) given at a dose rate of 2.5mg/kg (Carter, 2011). BPQ is a second-generation hydroxynaphthoquinone related to parvaquone (McHardy et al, 1985) and many New Zealand veterinarians consider its use as essential for the successful treatment of TABA (McFadden and Marchant, 2015; Rankin, 2015). Buparvaquone (BPQ) works by causing progressive cytoplasmic vacuolation in *Theileria* spp. through inhibiting mitochondrial electron transport (Fry et al., 1984; McHardy et al., 1992). Industry-funded slaughter trials conducted in New Zealand in 2013 (McDougall et al. 2016) found concentrations of BPQ, above the limits of detection using liquid chromatography-mass spectrometry, up to 35 days in milk, up to 119 days at the injection site and up to 328 days in the liver post injection. These findings have led to the following legal requirements for milk and meat withhold periods (WHP) for BPQ treated cattle in New

Zealand, 43-day milk, 548-day meat. In addition, calves born to BPQ treated dams have a 9-month meat withhold, calves drinking milk from a BPQ treated cow have a 91-day meat withhold and offal from treated animals has a permanent withhold.

The New Zealand dairy cattle industry is highly seasonal and overwhelmingly based on cows calving from late winter to early spring i.e. between mid-July and early-October, with only a small proportion of herds or split calving herds calving in the autumn. The beef industry is also predominantly spring calving, although on average they calve about a month later than dairy herds (McFadden et al., 2005). The almost universal adoption of spring calving in New Zealand means that there is considerable synchronicity between questing *H. longicornis* nymphs, stressed peri-parturient cows and the birth of naïve calves.

The aims of this study were to document the change in infection status, infection intensity and HCT over a lactation on three spring calving dairy herds, the first from an endemically stable area, the second from an endemically unstable area and the third from a disease-free area (McFadden and Marchant, 2015). Furthermore, the effects of infection and infection intensity on milk production and reproduction were estimated for each farm.

9.4 Materials and methods

The study was a prospective longitudinal observational study, in which a random sample of dairy cows on three spring calving New Zealand dairy farms were followed through the 2014-2015 milking season. The three dairy farms were purposively selected based on their location, TABA history and their willingness to participate in the study. Farm A was an 800-cow dairy farm in the Waikato region and was a recent diversification for a large beef and sheep station. This farm had the misfortune to suffer a severe outbreak of TABA, with >5% mortality, in their first milking season in 2013. Farm B was an established 570-cow family dairy herd in the Manawatu-Wanganui region. This herd had also suffered a severe outbreak of TABA in 2013 with a total of 20 (3.5%) cow deaths and 80 (14.0%) clinically affected cows. Farm C was a 140-cow family dairy herd in the Wairarapa region, which had converted to the once-a-day milking system in 2013. Three clinical cases of TABA occurred in this herd at calving in late August 2014, with no associated deaths. Unlike Farms A and B, Farm C was first infected in 2014.

The outbreak of TABA on Farm A was linked to mixing of cattle from different herds in 2013, in order to establish the new herd, which unfortunately included the purchase of two persistently infected (PI) BVD cows. At the time of the outbreak in 2013 it was hypothesised

that the presence of the two BVD PIs had suppressed herd immunity leading to a more severe outbreak of TABA than usual. The outbreak on Farm B was linked to wintering cows on a tick-infested coastal run-off, close to the main milking platform, from which the older cows were moved back to the milking platform just prior to calving in 2013, and on Farm C all three clinical cases were amongst 39 cows recently returned from winter grazing in the Hawke's Bay region.

The three selected farms were situated in three different *Haemaphysalis longicornis* risk areas (Heath, 2016), Farm A was in a high risk (endemically stable) area, Farm B was in a low risk (endemically unstable) area and Farm C was in a zero risk (disease-free) area. Farms A and B were visited every month from August to drying off, which was April 2015 for Farm A (9 visits) and May 2015 for Farm B (10 visits). On each of these two farms 100 cows were selected at the first farm visit in August 2014 using systematic random sampling, with every Nth cow on the rotary platform selected, where $N = \text{total cows in-milk}/100$, rounded to the nearest integer. These same 100 cows, on Farms A and B, were then repeatedly blood sampled at each visit through the milking season. In contrast, Farm C was visited only 4 times (bimonthly) through the season starting in September 2014 and the whole herd, 140 cows, blood sampled at each visit. Blood sampling on each farm commenced at the same time at each sampling visit. This was at the AM milking on Herds A and B and in the early afternoon on Herd C (the cows had been already milked in the morning). For Farm A the planned start of calving was mid-July 2014, for Farm B was the third week July 2014 and for Farm C was the first week of August 2014.

Farm A dried off one month earlier than expected, in April 2015, owing to the effects of severe sporidesmin toxicity (facial eczema), Farm B fed turnips from mid-February through to the end of March 2015 and Farm C suffered a feed pinch in the late summer 2015. Farm A ran two milking herds, normal and light, with herd membership based on body condition score, $BCS \geq 4$ or $BCS < 4$ respectively, Farm B ran two milking herds partitioned on age and Farm C just ran one herd.

9.4.1 *Haematocrit*

Blood samples were collected from the tail vein into 10ml EDTA tubes and after measuring the haematocrit were stored at -20°C until molecular testing was carried out. The haematocrit was measured by reading micro-capillary tubes centrifuged for 5 minutes at 10,000 g, using a Heraeus Pico 17 (Thermo Fisher Scientific, Langenselbold, Germany), with the average of two

samples recorded for each animal. If the haematocrit for paired samples differed by greater than 2% then a repeat centrifugation and reading were done. The sampled animals were classed as anaemic if the haematocrit (HCT) ≤ 0.24 L/L (Riond et al. 2008).

9.4.2 Milk production data

Farm A had 3 Livestock Improvement Corporation (LIC) herd tests (the 4th LIC herd test was cancelled due to early dry-off), Farm B had 5 LIC herd tests, and Farm C had 4 LIC herd tests. Most New Zealand dairy farms that use the LIC herd testing scheme, have 4 herd tests a year in which 24-hour test-day milk data is recorded for each lactating cow in the herd. The main aim of herd testing in New Zealand is the genetic evaluation of sires and cows for lactation yield (Johnson, 1996; Harris et al., 2006). The LIC herd test results were accessed through MINDA[®] (LIC, Hamilton, New Zealand). MINDA[®] is a web-based software program that allows farmers to access and manage their herd production data, including herd test results, with the aim of making better on-farm management decisions.

The outcome measure used for the milk production analyses was 24-hour test-day energy-corrected milk (ECM; kg) production per cow at each herd test. This was calculated using the following formula (Santschi et al., 2011):

$$\text{ECM (kg/d)} = 12.55 \times \text{fat (kg/d)} + 7.39 \times \text{protein (kg/d)} + 0.2595 \times \text{milk yield (kg/d)}$$

New Zealand herd test data is recorded as volume and not as weight. The density of milk is estimated at 1.03kg/L and although using volume instead of weight introduces a small bias, the calculation of ECM was not altered and remains consistent with the approach used by Mason et al. (2012).

9.4.3 Reproduction data

Reproduction data, where available, was also accessed through MINDA[®].

9.4.4 DNA Extraction.

DNA was extracted from 250 μ L of cow blood collected from the trial herds. DNA was extracted with 250 μ L of an SDS lysis buffer (20mM EDTA-Na₂H₂O, 60mM Tris HCl, 1% sodium dodecyl sulphate, 1% Triton X-100, pH 8.0), and Proteinase K at 0.5mgml⁻¹ (Roche

Diagnostics, Switzerland). The slurry was incubated at 56°C for 30 minutes and equal volumes of phenol:chloroform:iso-amyl alcohol (25:24:1, Sigma, MO, USA) were added. Aqueous and organic phases were separated by centrifugation at 13,400xg for 15 minutes at 4°C. DNA was precipitated using a 10:1 solution of ice cold 100% ethanol and 3M sodium acetate (Sigma, MO, USA). The DNA was washed twice with 70% ethanol, allowed to air dry and resuspended in R40 (40µgmL⁻¹ RNaseA [Sigma, MO, USA] in TE [10mM Tris, 1mM EDTA, pH 8.0]) overnight at 4°C. Extracted DNA was quantified with a Nanodrop (Thermo Scientific, MA, USA) and stored at -20°C.

9.5 Quantitative PCR

Quantitative PCR (qPCR) on the extracted DNA was performed using the primers and probe previously described for *T. orientalis* Ikeda type by Pulford et al. (2016b), all primers and probes were sourced from Integrated DNA Technologies (Iowa, USA). qPCR was performed with the following conditions; 1 x Platinum™ Quantitative PCR SuperMix-UDG (Invitrogen, CA, USA), 0.5 µM of each primer, 0.4 µM of the probe and 5 µL of template DNA in a final volume of 20 µL. Thermalcycling was performed in a Rotor-Gene Q thermalcycler (Qiagen, Hilden, Germany). Thermalcycling conditions were as follows; 95 °C for 2 min, followed by 45 cycles of 95 °C for 15 s and 60 °C for 30 s, with fluorescence capture on the 60 °C step. Standard curves were produced utilizing a serial dilution of a plasmid from a previously produced clone of a section of the *T. orientalis* Ikeda MPSP gene (provided by K. Gedye) and ranged from 100 pg to 10 fg/µL of the plasmid. Runs were analysed using the Rotor-Gene Q software and exported for further statistical analysis. The standards were also the positive controls, with negative controls being PCR grade water and the DNA extracted from naïve cattle.

Because of the large number of samples and financial constraints only one PCR molecular test was completed per animal. The individual cow PCR test was only repeated if the test gave an unexpected result compared to previous and succeeding test results.

9.5.1 *Gene copies and validation of assay performance*

The DNA extracted from 250µL of whole blood was eluted in 50µl and then 5µL was pipetted for the PCR analysis. A serial 10-fold dilution of 5 Ikeda plasmid DNA standards (10¹ to 10⁵

fg/ μ L) was used to quantify the gene-copies of Ikeda MPSP found in bovine blood sample. This was accomplished by multiplying the molarity of the *Theileria* DNA in the blood sample, as calculated from the standard curve using the Cq value for the PCR amplification, by Avogadro's number (6.022×10^{23}).

Two measures were used to assess the performance of the molecular assay, the limits of quantification (LOQ), which is defined as the lowest amount of analyte that can be accurately quantified to an acceptable level of precision, but may still indicate the animal is infected, and the cut point, which is defined as the quantity of analyte above which a sample can be categorised as positive (= animal is infected). For the LOQ, the lower limit of the Ikeda target gene DNA standards serial dilutions was extended to include 10^{-3} , 10^{-2} , 10^{-1} and 10^0 fg/ μ L, and the assay was repeated with 3 replicates for each dilution. The linearity and R^2 of these extended standard curves were assessed and the PCR efficiency calculated. PCR efficiency (E) was calculated using the following formula; $E = 10 - (1/\beta) - 1$ where β is the slope of the linear regression of Cq on $\log_{10}$ of the standard concentration. Acceptable target values for R^2 are > 0.98 and for PCR efficiency are 0.90 -1.05 (Johnson et al., 2013). For estimating the cut point ROC curves were constructed using the qPCR results from the first sampling at Farm C where *a priori* we believed that the only infected cows were the ones returning from winter grazing in the Hawke's Bay Region. A ROC curve is a plot of sensitivity against 1 - specificity for a set of known positive and negative samples. Where sensitivity (Se) is the proportion of infected cattle diagnosed infected at a cut point and specificity (Sp) is the proportion of uninfected cattle diagnosed uninfected at the same cut point. The cut point is identified as that value which maximises the Youden index (J) where $J = Se + Sp - 1$.

9.5.2 Interpretation of molecular results

Animals with an infection intensity $>300,000$ Ikeda organisms/ μ L were considered to be acutely infected, animals with a moderate infection intensity, $>15,000$ but $\leq 300,000$ organisms/ μ L, were considered to be convalescing and animals with a low infection intensity, $\leq 15,000$ organisms/ μ L, were presumed to be chronically infected (Bogema et al., 2015).

Using the cut point, previously established, and the pattern of results over the season for each individual cow on their respective farm, each sampled animal was categorised as either a prevalence case, an incidence case or uninfected. A cow was categorised as a prevalence case if they had an estimated infection intensity above the cut point at their first sampling and for

many of their subsequent samplings. A cow was classed as an incidence case if they had previously tested below the cut point for a number of samplings and then tested above the cut point at the next sampling, and a cow was classed as uninfected animal if they tested below the cut point for all their samplings. Some incidence cases had missing samples before testing positive or only had one previous negative test before testing positive, for these animals an acute infection intensity $>300\,000$ organisms/ μL or a precipitate fall in the haematocrit in either the same month or at the next month after testing positive were used to support the diagnosis of incidence case.

Some prevalence cases had almost all positive results except for one or two tests where the estimated infection intensity was below the cut point, these results were called false negatives and were presumed to reflect the normal variability in infection intensity for chronically infected animals. Alternatively, some uninfected animals had all negative samples, i.e. estimated infection intensity below the cut point, except for a small number (1 or 2 maximum) of isolated positive samples, with no corresponding change in HCT at the current or subsequent sampling. These were called false positives and their occurrence recorded and analysed as such. Once an animal was categorised as a prevalence or incidence case the LOQ was the lower limit to which the infection intensity could be accurately estimated, and these values were then included in all statistical analyses. Three measures of disease frequency were calculated for each farm (where appropriate), the prevalence, defined as the proportion of *T. orientalis* Ikeda type infected cows at a particular time, the incidence risk, defined as the proportion of the uninfected cows contracting *T. orientalis* Ikeda infection over the study period and the incidence rate defined as the incidence risk standardised by the number of cow-months the uninfected cows were at risk of contracting *T. orientalis* Ikeda infection over the study period.

9.5.3 *Statistical analysis*

Two additional continuous variables were calculated from the data, days in milk (DIM) was the time in days from calving to each of the LIC herd tests and days to sampling (DTS) was the time in days from calving to each sampling visit. The infection intensity data was normalised using a $\log_{10}$ transformation and age of cow was categorised by quartiles into 4 age groups: Age_Group 1= cows aged 2 or 3 years; Age_Group 2= cows aged 4 or 5 years; Age_Group 3= cows aged 6 or 7 years; and Age_Group 4= cows aged 8 years and over.

The data structure itself was hierarchical and had 2 levels of information and potential variability, the 1st level was the repeated herd tests and sampling tests on individual cows, the 2nd level was the individual cows within each herd. It is reasonable to presume that measurements made on the same cow will be more similar than those made on different cows in the same herd. To account for this dependency in the data, a linear mixed effects model was built using the LMER package in R (Bates et al., 2014). A linear mixed effects model is one that has both fixed and random effects. Fixed effects are constant across individuals and estimate the mean effect whereas random effects vary across data levels and estimate the variance.

The equation for the multilevel mixed effects models used in this analysis was

$$Y_{ij} = b_{0j} + b_{1j}X_{ij} + \varepsilon_{ij}$$

$$b_{0j} = b_0 + u_{0j}$$

$$b_{1j} = b_1 + u_{1j}$$

Where Y_{ij} is the HCT or ECM or infection intensity for the i^{th} sampling in the j^{th} cow, b_{0j} is the random intercept for the j^{th} cow which is broken down into the average model intercept b_0 and an error term for each cow, u_{0j} , b_{1j} is the random slope for j^{th} cow which is broken down into the average model slope b_1 and an error term for each cow's slope u_{1j} . ε_{ij} is the error term for the i^{th} sampling in the j^{th} cow. The two error terms u_{0j} and u_{1j} are not independent and have a covariance structure whereas ε_{ij} is normally distributed with a mean of zero and is independent. The family wise error rate for multiple post-hoc comparisons was controlled using Tukey's HSD.

The fixed effects tested in the mixed effects models were age, DIM, DTS and Farm, a random intercept was fitted for cow and a random slope fitted for DIM or DTS. Polynomials and biologically plausible interactions were also tested in the model and all significant coefficients were retained in the final model at $p < 0.05$ using the log likelihood test. Model fit was assessed by graphing the residuals. Only data from prevalence or incidence cases where the infection intensity was above the LOQ were included in the mixed effect models and where possible, and appropriate, the data from more than one farm was combined in the same model with Farm fitted as a fixed effect. For Farm B, where several cows with suspected clinical TABA were treated with Buparvaquone, a mixed effects model was built to estimate the effect of BPQ treatment on ECM production compared to uninfected cows.

When only small numbers of cows were available for analysis, matched data sets were prepared using propensity scoring (Randolph et al., 2014). Matching case and control animals on

baseline data can improve study efficiency by improving precision in the analysis (Pearce, 2016).

Survival analysis was used to analyse the reproductive data, using a Cox proportional hazards regression model (Mills, 2010), with days from planned start of mating to conception used as the outcome variable. Empty cows for each farm were right censored on the last day of mating for that farm. Model fit for the Cox proportional hazards model (CPHM) was assessed through plotting the Cox-Snell residuals and testing the proportional hazards assumption by estimating the Schoenfeld residuals (Mills, 2010).

9.6 Results

The location of the three study farms is shown in Fig. 9-1, and the sampling dates and LIC herd test dates are shown for the three study farms in Table 9-1. For Farm A, except for the November herd test, there is reasonable temporal proximity between LIC herd test dates and sample dates. For Farm B the temporal proximity is again good except for the September herd test and for Farm C the proximity is poor with only the December sample and LIC herd test dates occurring within the same calendar month.

Table 9-1. Dates of sampling and herd tests for three subject farms

Month	Farm A		Farm B		Farm C	
	Sample	LIC Herd test	Sample	LIC Herd test	Sample	LIC Herd test
Aug	3/08/2014	---	11/08/2014	---	---	---
Sep	2/09/2014	---	9/09/2014	29/09/2014	22/09/2014	---
Oct	6/10/2014	1/10/2014	9/10/2014	---	---	19/10/2014
Nov	6/11/2014	27/11/2014	10/11/2014	12/11/2014	---	---
Dec	9/12/2014	---	10/12/2014	7/12/2014	15/12/2014	15/12/2014
Jan	13/01/2015	---	8/01/2015	---	---	---
Feb	11/02/2015	8/02/2015	8/02/2015	2/02/2015	---	8/02/2015
Mar	3/03/2015	---	9/03/2015	---	4/03/2015	---
Apr	16/04/2015	---	9/04/2015	1/04/2015	---	7/04/2015
May	---	---	19/05/2015	---	7/05/2015	---

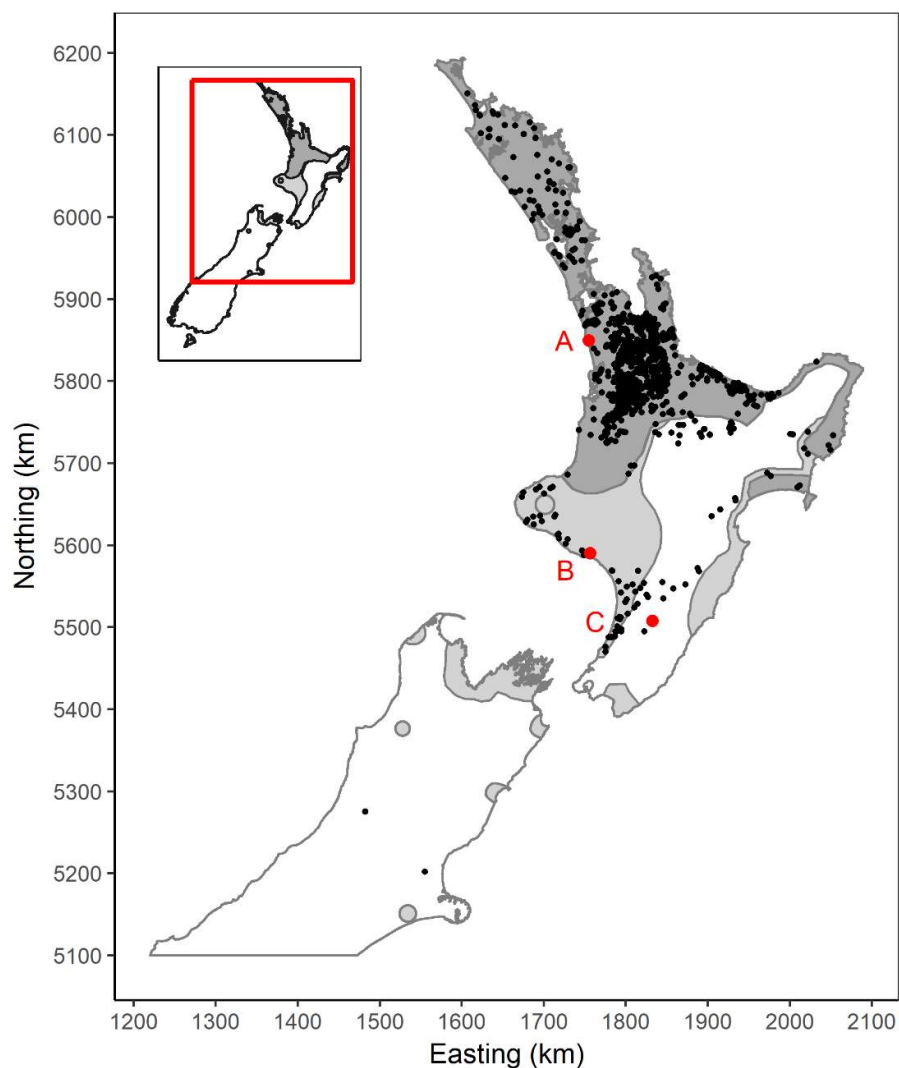


Figure 9-1. Location of the three study farms, A, B, and C, with the coordinates of all farms with Ikeda type PCR positive cases of *Theileria* associated bovine anaemia identified between August 2012 and November 2014 shown as black dots. The dark grey areas are high risk, the light grey areas are low risk and the white areas are zero risk of *Haemaphysalis longicornis* infestation (Heath, 2016).

9.6.1 Limits of quantification and cut point results

The LOQ plot was approximately linear to 100ag (0.1fg)/ μ L, Fig. 9-2, with an R^2 of 0.89 and a PCR amplification efficiency of 91%, for target DNA dilutions down to this point. At 100ag (0.1fg)/ μ L the LOQ was equivalent to 22 Ikeda organisms per μ L.

ROC curve analysis of the September sampling data from Farm C showed that the Youden index was maximised at a cut point of 5.2 fg/ μ L (1140 organisms/ μ L) with a sensitivity of 1.0 (95% CI 0.91 – 1.00) and a specificity of 0.98 (95% CI 0.94 – 1.00). At this cut point there were 2 false positive results and 0 false negative results.

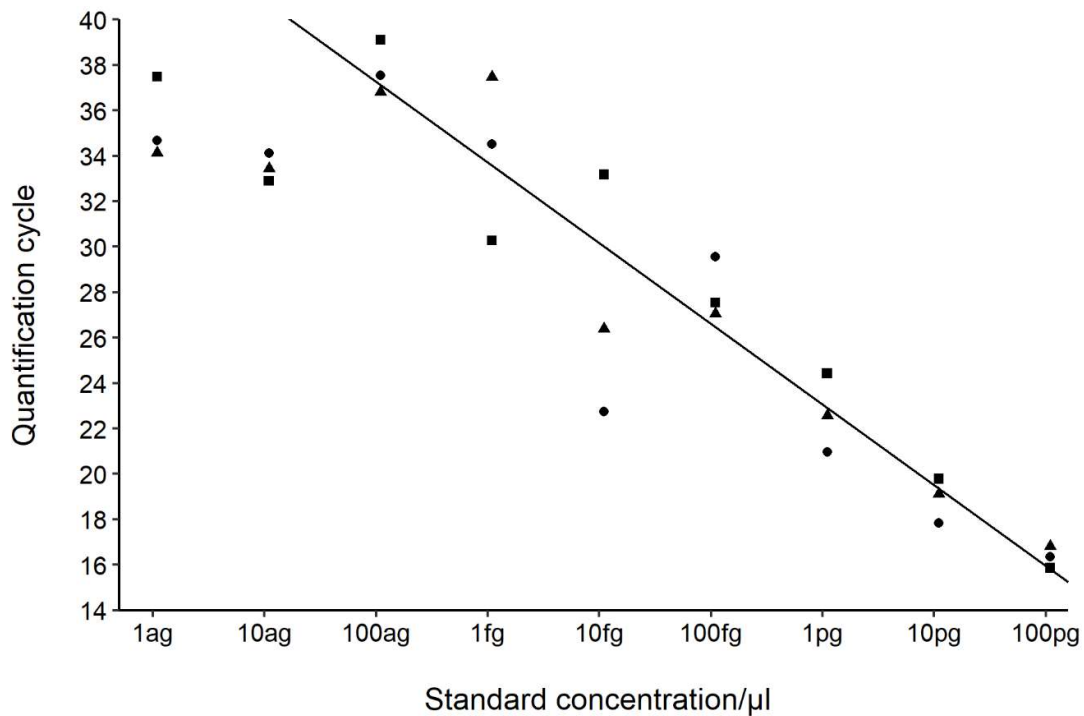


Figure 9-2. Linear regression of quantification cycle on concentration of target DNA, with the 3 repetitions at each dilution shown respectively as a filled square, filled triangle and filled circle points.

9.6.2 Milk production

The average ECM milk production by farm and LIC herd test is shown in Table 9-2.

Table 9-2. the average Energy corrected milk (ECM) production per cow at each herd test and across all herd tests for the three subject Farms

Month	Farm A		Farm B		Farm C	
	ECM (kg)	95% CI	ECM (kg)	95% CI	ECM (kg)	95% CI
Aug	---	---	---	---	---	---
Sep	---	---	28.4	27.5 – 29.2	---	---
Oct	19.6	18.8 – 20.4	---	---	24.2	23.5 – 24.8
Nov	16.4	15.7 – 17.1	25.1	24.4 – 25.8	---	---
Dec	---	---	25	24.4 – 25.6	19.1	18.5 – 19.8
Jan	---	---	---	---	---	---
Feb	9.9	9.4 – 10.4	16.8	16.4 – 17.2	12.2	11.6 – 12.9
Mar	---	---	---	---	---	---
Apr	---	---	15.4	14.9 – 15.9	11.3	10.6 – 12.0
May	---	---	---	---	---	---
Average	15.4	14.8–16.0	22.1	21.6–22.6	17.0	16.5–17.6

Farm B achieved the highest average ECM production across the 5 herd tests, whilst production on Farm A was the poorest and dropped dramatically in mid-summer due to sporodesmin toxicity, which triggered an early dry off. Farm C achieved good production for a once-a-day milking herd in only its second season after conversion from twice-a-day, Table 9-2.

9.6.3 *Farm A*

Overall 865 blood samples from 106 different cows were taken during the 9 farm visits. The prevalence of infection on Farm A at the August sampling was 100%, with all cows testing above the cut point at least once during the season. The infection intensity results for all samples were as follows, 550/865 (63.4%) of samples returned an infection intensity above the cut point (1140 organisms/ μ L), 245/865 (28.3%) of samples returned an infection intensity below the cut point but above the LOQ (22 organisms/ μ L) and 70/865 (8.1%) of samples were below the LOQ. The median number of samples taken per cow was 8 (range 1 – 9), the median number of results with infection intensities below the cut point was 2 (range 0 – 8) and the median number of results below the LOQ per cow was 0 (range 0 to 3). Overall, the proportion of false negative results for Farm A was 315/865 (36.4%).

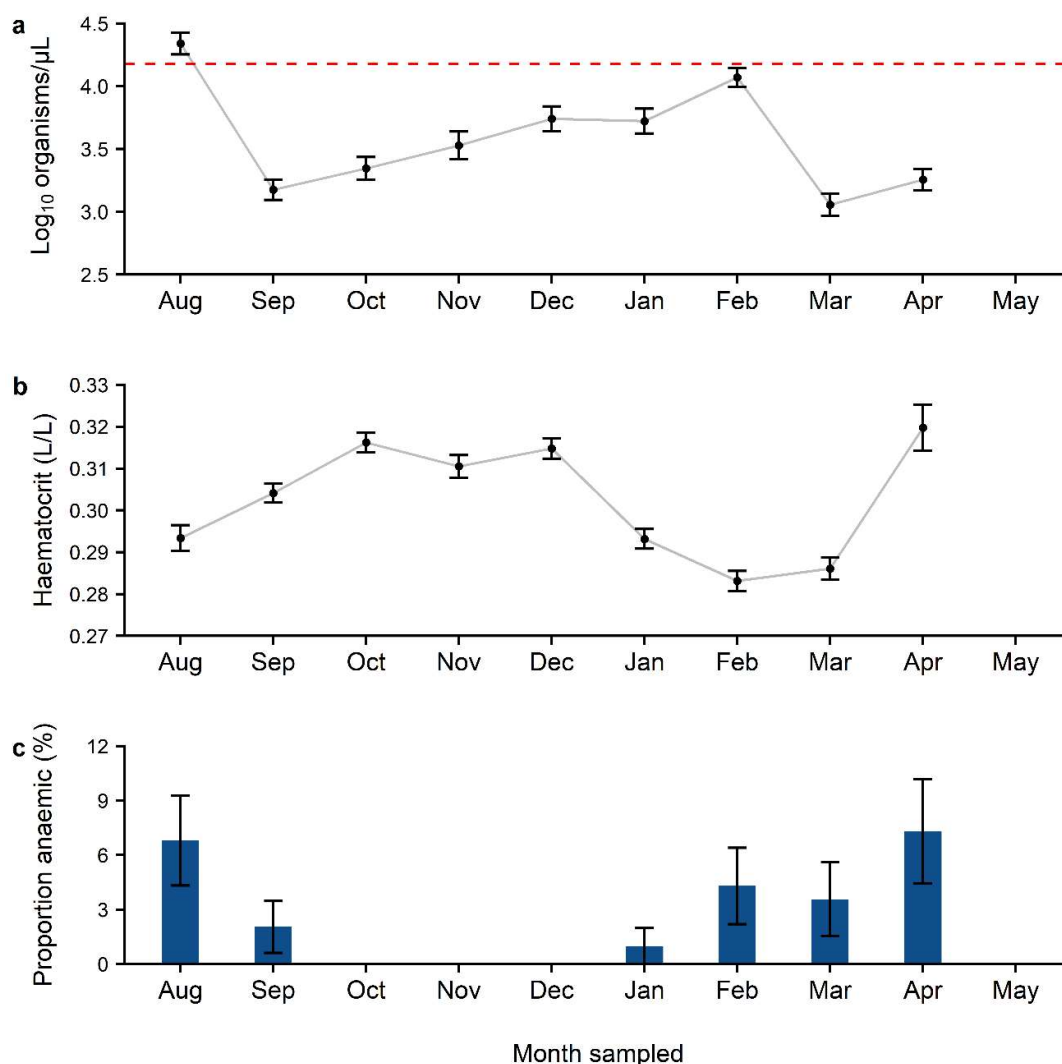


Figure 9-3. Graph for Farm A showing the change in infection intensity (9-3a), haematocrit (9-3b) and proportion anaemic (9-3c) by month from August 2014 to May 2015. The prevalence of infection on Farm A was 100% so no results for uninfected cows are included. The cows were dried off in April due to severe sporodesmin toxicity, so no data were collected for May 2015. The broken red line in plot 9-3a is equivalent to a low infection intensity of 15,000 Ikeda organisms/μL (Bogema et al., 2015).

The average log₁₀ (infection intensity) was 3.66 (4,500 organisms/μL), range (1.65 (45 organisms/μL) to 6.36 (2,280,000 organisms/μL)) and apart from the August sampling when the mean infection intensity was 22,000 organisms/μL, the average herd infection intensity by month was low <15,000 organisms/μL, Fig. 9-3a. Sixteen samples from 14 different cows (2 cows each had 2 samples >300,000 organisms/μL) returned infection intensities equivalent to an acute infection. Of these, seven cows were recorded in August 2014, three in January 2015 and two in December 2014.

The average HCT peaked in April 2015 and was lowest in February 2015, Fig. 9-3b. Twenty-three samples from 17 different cows were anaemic (1 cow had 3 anaemic samples and 4 cows each had 2 anaemic samples). Proportionally cows with acute infections were more likely anaemic, 2/16 (12.5%), both 2-year-old-cows from the thin herd sampled in August 2014, compared to 17/779 (2.2%) of cows which didn't have acute infections ($p=0.065$, Chi-squared test). The distribution of the anaemic cases over the sampling period is seen in Fig. 9-3c, although the cases observed in the mid-summer to early autumn 2015 were potentially confounded by sporodesmin toxicity.

The herd test ECM results are shown in Table 9-2. There was no difference between the light and normal herds in infection intensity ($p=0.26$) and milk production ($p=0.89$). However, the average HCT was slightly lower in the light herd, HCT=0.300, compared to the normal herd, HCT=0.306 ($p=0.014$), and the average age was also younger 4.1 years compared to 4.9 years ($p<0.0001$). The sample date and herd test dates were 5 days apart for October (2014-10-06), 21 days apart for November (2014-11-06) and 3 days for February (2015-02-11), Table 9-1.

Table 9-3. Body Condition Score (BCS) by month for Normal and Thin herds on Farm A. In New Zealand a BCS scale of 1 (thin) to 10 (fat) is used to assess dairy cows.

Herd	2.9.2014	6.10.2014	6.11.2014	9.12.2014	13.1.2015	11.2.2015	3.3.2015
Normal	4.3	4.1	4	4	3.9	3.8	3.8
Thin	3.9	3.7	3.9	3.8	3.7	3.6	3.5

Both the normal and light herds struggled to maintain body condition through the milking season and progressively lost BCS up to March 2015, Table 9-3, when the thinnest cows from both herds were dried off and the remaining cows combined into one herd. The BCS in April 2015 of the combined herd was 3.9.

9.6.4 *Farm B*

Overall there were 982 blood samples collected from 102 cows over 10 farm visits, the median number of samples per cow was 10 (range 2 – 10). The prevalence of *T. orientalis* Ikeda PCR positive cows at the August sampling was 58/102 (57%). For the prevalence cases identified in August 449/545 (82.4%) samples returned an infection intensity above the cut point (1140 organisms/ μ L), 76/545 (13.9%) samples returned an infection intensity below the cut point but above the LOQ (22 organisms/ μ L) and 20/545 (3.7%) were below the LOQ. One prevalence

case was culled after 2 months. There were 44/102 (43%) uninfected cows identified at the August, of which 11 became infected during the study giving an incidence risk of 11/44 (25%) and an incidence rate of 0.026 cases per cow-month at risk. The other thirty-three cows diagnosed uninfected in August remained uninfected throughout the whole study.

The average $\log_{10}$ (infection intensity) of the prevalence and incidence cases was 3.84 (7,000 organisms/ μ L) range (1.95 (88 organisms/ μ L)–7.3 (20,500,000 organisms/ μ L)). Thirty-three samples returned infection intensities equivalent to an acute infection, i.e. >300,000 organisms/ μ L, with 22 samples were from 18 prevalence cows (1 cow had 3 samples and 2 cows each had 2 samples >300,000 organisms/ μ L) and 11 samples were from 8 incidence cows (3 cows each had 2 samples >300,000 organisms/ μ L). Forty two samples from 26 different cows were anaemic, 9 samples were from 7 uninfected cows (1 cow had 3 anaemic samples), 20 samples were from 10 prevalence cows (1 cow had 6 samples, 1 cow had 3 samples and 3 cows each had 2 samples ≤ 0.24 L/L) and 13 samples were from 9 incidence cows (1 cow had 3 samples and 2 cows each had 2 samples ≤ 0.24 L/L).

For the prevalence cases, infection intensities equivalent to an acute infection occurred throughout the lactation, although the highest number were seen in August (n=8), whereas in the incidence cases they occurred close to when the cow first tested positive. The proportion of false positive results for the uninfected cows was 7/344 (2%) and false negative results in the prevalence cases was 92/553 (16.6%).

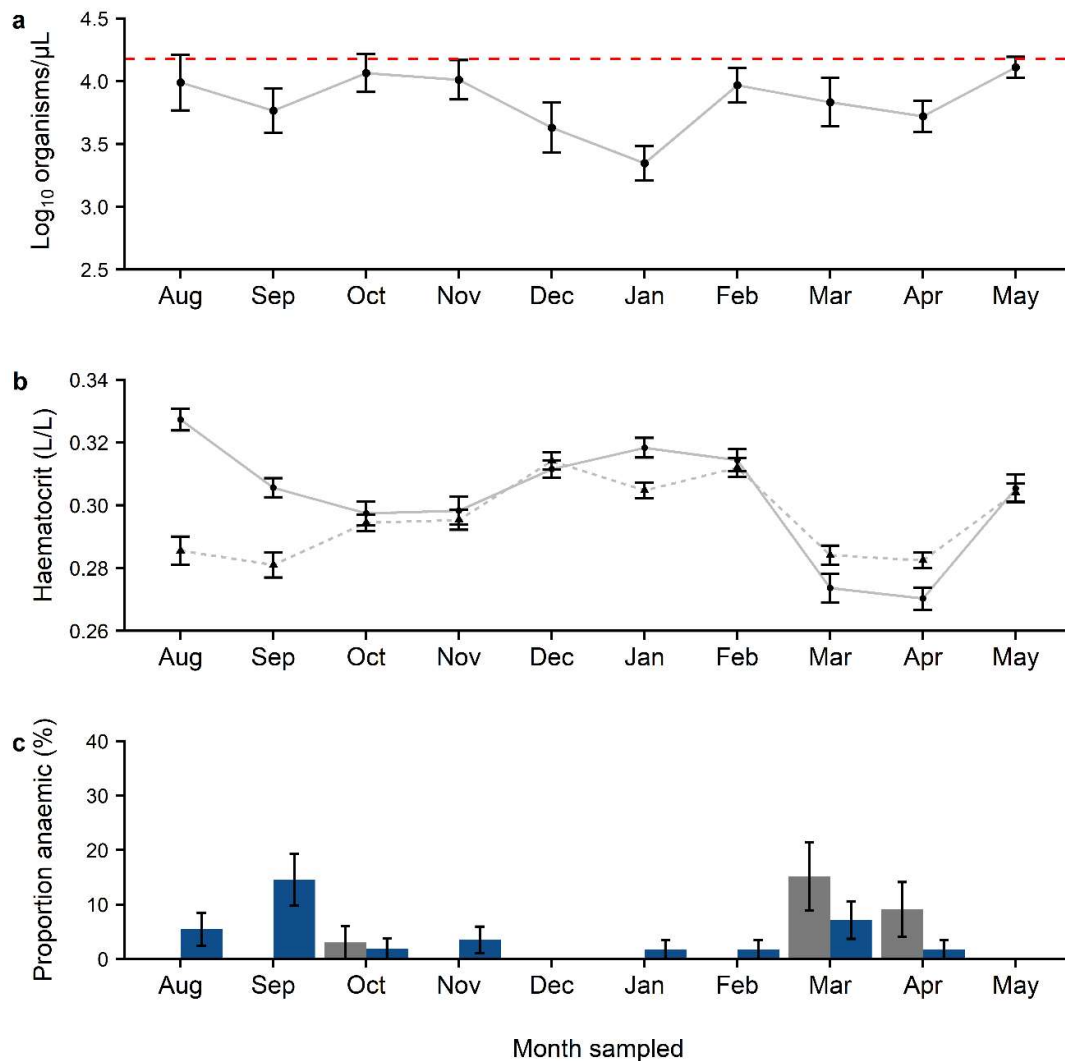


Figure 9-4. Plots for Farm B showing change in infection intensity (9-4a), haematocrit (9-4b) and proportion anaemic (9-4c) by month and infection status from August 2014 to May 2015, for prevalence cases and uninfected cows. The uninfected cows are shown with a solid line in figure 9-4b and as a grey bar in figure 9-4c and the infected prevalence cows are shown as a broken line in figure 9-4b and as a dark blue bar in figure 9-4c. The broken red line in plot 9-4a is equivalent to a low infection intensity of 15,000 Ikeda organisms/μL (Bogema et al., 2015).

Ten incidence cases became infected in spring 2014, with six cows first testing positive PCR in September, three in October, and one in November. A further incidence case occurred in January 2015, this latter cow was diagnosed severely anaemic in February 2015, HCT =0.145, and dried-off soon after. The infection intensity, HCT and proportion anaemic is shown in Figure 9-5 for the prevalence and uninfected cows. The LIC herd test results are recorded in Table 9-2. The young herd had significantly lower ECM 20.2kg (95% CI 19.3–21.2) compared

to the older herd 22.9kg (95% CI 22.3–23.6) ($p<0.0001$) however, there was no significant difference in HCT between the two herds ($p=0.32$). Except for September there was good temporal proximity between the blood sample dates and the LIC herd tests; 9th September 2014 (-20 days), 10th November 2014 (-2 days), 10th December 2014 (-1 day), 8th February 2015 (+6 days) and 9th April 2015 (+8 days), Table 9-1.

9.6.4.1 Prevalence cases, Farm B

The average age of the prevalence cases at the start of the lactation was 5.9 years old which was significantly higher than the average age of the uninfected cows which was 3.6 years ($p<0.0001$). Further scrutiny of the data showed that 54/58 (93%) prevalence cases came from the older herd and only 4/58 (7%) from the younger herd ($p<0.0001$ Chi-squared test). The infection intensity of the prevalence cases remained consistently below 15,000 organisms/ μ L over the whole sampling period, with the lowest average infection intensity reached in January 2015, 2,200 organisms/ μ L, Fig. 9-4a. The prevalence cases also had a significantly lower HCT than the uninfected cows at the August sampling, 0.283 versus 0.330 ($p=0.002$).

9.6.4.2 Incidence cases, Farm B

The eleven incidence cases found on Farm B were evenly spread across the two milking herds, with 6/11 (55%) from the older herd and 5/11 (45%) from the younger herd. The infection intensity, haematocrit and proportion anaemic relative to the month they tested positive is shown in Fig. 9-5. For 7/11 cows the lowest HCT corresponded with the peak infection intensity, for 5/7 the peak infection intensity and the lowest HCT were at the month the cows first tested positive (month 1) and for 2/7 the peak infection intensity and the lowest HCT were measured the month after they first tested positive (month 2). Six of these seven cows, where the lowest HCT corresponded with the peak infection intensity, were mildly anaemic and one was severely anaemic (HCT <0.15), average HCT =0.216. For the remaining 4/11 cows the infection intensity peaked later, in 2 cows the lowest HCT occurred one month after the infection intensity peaked and in the other two cows the lowest HCT occurred before the infection intensity peaked.

With only 5/11 incidence cows having peak infection intensities in the month they first tested positive this meant that overall the average $\log_{10}$ (infection intensity) for that month was only

moderate, 4.96 (92,000 organisms/ μ L), and remained at a similar intensity, 4.87, for the month after (Figure 9-5a). However, the average $\log_{10}$ (infection intensity) for the month when the infection intensity peaked for each incidence case was 5.99 (980,000 organisms/ μ L). In the same month the incidence cases first tested PCR positive, 45% (95% CI 17–77) were anaemic ($HCT \leq 0.24$), 1 month later 40% were still anaemic but by 2 months none were anaemic (Fig. 9-5c).

9.6.4.3 Turnips, Farm B

Turnips were fed on Farm B from mid-February through to the end of March 2015 and there was an unexpected effect on the HCT results observed for March and April, Figure 9-4c. Whilst consuming the turnips and for the month after the HCT dropped across all cows but not uniformly. The prevalence cases tended to have a slightly higher HCT than the uninfected cows during this period. In March 2015, 3/56 (5.1%) of the prevalence cows, 3/10 (30%) of the incidence cases and 5/33 (15.1%) of the uninfected cows were diagnosed anaemic ($p=0.048$, Chi-squared test).

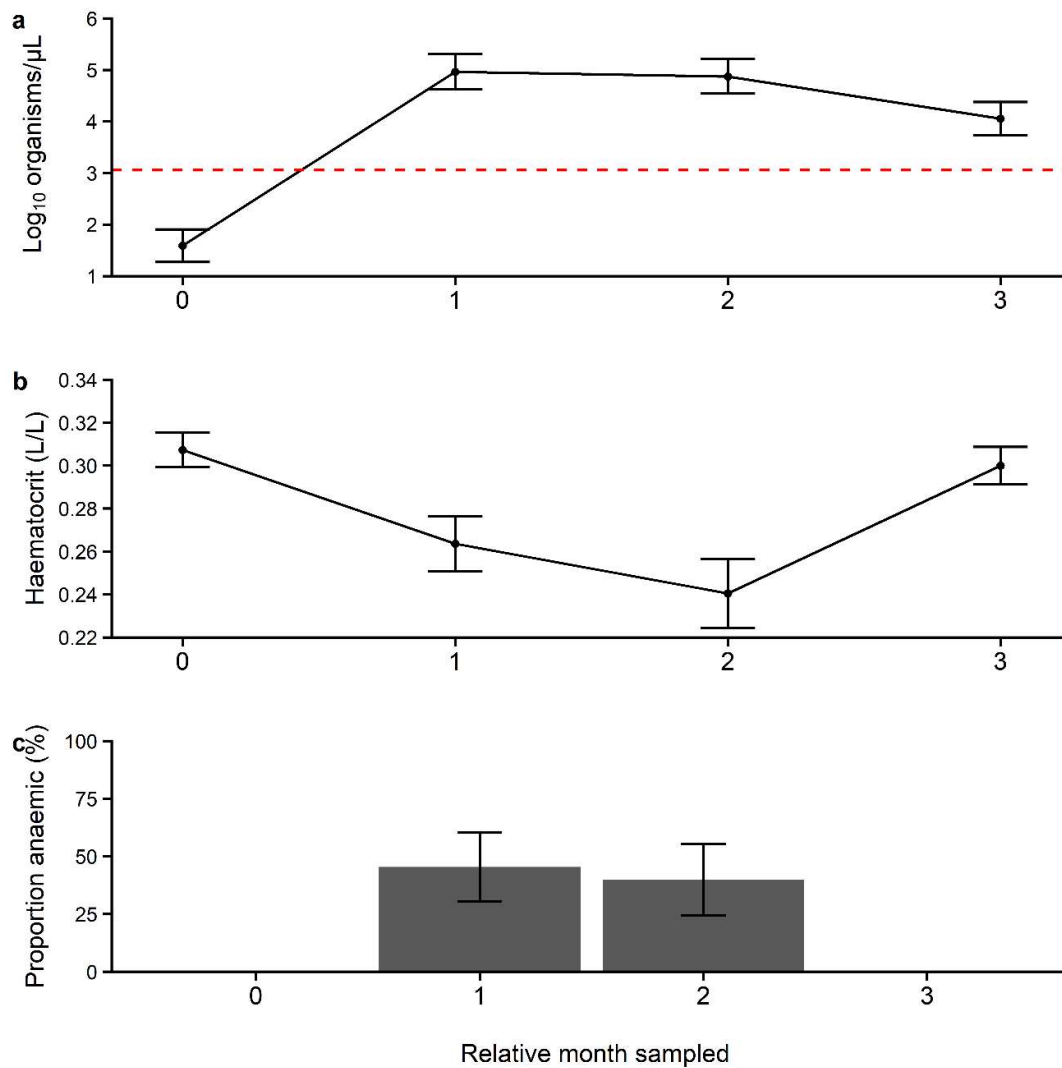


Figure 9-5. Incidence cases for Farm B showing, Fig. 9-5a the *Theileria orientalis* Ikeda type infection intensity (log₁₀ organisms/μL), Fig. 9-5b haematocrit (HCT) and Fig. 9-5c the proportion anaemic (%) for the 11 incidence cases relative to the month they were sampled. Month 0 is the sample month before returning a positive test, Month 1 is the month the cow tested positive and Months 2 and 3 are the subsequent two months. The broken red line in plot 9-5a is equivalent to a low infection intensity of 15,000 Ikeda organisms/μL (Bogema et al., 2015).

9.6.5 Farm C

There were 579 blood samples collected from 154 different cows over 4 farm visits, the median number of samples per cow was 4 (range 1 – 4). The prevalence of infection at the September visit was 40/154 (26%), with 114/154 (74%) uninfected. The average infection log₁₀ intensity of the prevalence cases over the whole lactation was 3.76 (5,800 organisms/μL) range (1.37 (22 organisms/μL) – 6.82 (6,550,000 organisms/μL)), although the average log₁₀ infection

intensity for September was much higher 5.06 (115,000 organisms/ μ L). The incidence risk of disease was low, only 2/114 (1.8%) cases occurring, one in December 2014 and one in May 2015, giving an incidence rate of 0.0021 cases per cow-month. The December incidence case developed a high infection intensity of 490,000 Ikeda organisms/ μ L whereas the infection intensity for the May case was very low, 7,100 Ikeda organisms/ μ L, neither of these incidence cases were diagnosed as anaemic.

Of the 39 cows from Farm C that went to the Hawkes Bay for winter grazing 38 were subsequently retained in the milking herd. Of these 37/38, as well as an additional 2 cows that did not travel to the Hawkes Bay, tested above the cut point at the September sampling visit. The average calving date for the cows that went to winter grazing was 18th September 2014 and for the cows that remained on farm was 19th August 2014. The log₁₀ infection intensity of the 2 prevalence cases that did not travel to winter grazing was higher than those cows that went to winter grazing, 6.2 compared to 5, however the difference was not significant ($p=0.3$). Twenty samples returned infection intensities equivalent to an acute infection, i.e. >300,000 organisms/ μ L, with 19 recorded in September 2014 (prevalence cases) and one in December 2014 (incidence case). There were 13 samples classed as anaemic; 11 samples from prevalence cases in September and 2 samples from uninfected cows in December. Farm C had the highest proportion of false negative (FN) results of all farms tested, with 55/150 (36.7%) of prevalence samples testing below the cut point. These FN results were not evenly distributed over the sampling year, 1/40 (2.5%) in September 2014, 9/40 (22.5%) in December 2014, 31/40 (77.5%) in March 2015 and 14/30 (46.7%) in May 2015. In contrast to Farm B there were fewer false positive results, with only 2/421 (0.5%), recorded in the uninfected cows over the whole 4 samplings on Farm C.

At the September sampling 11/40 prevalence cases (27.5%) were anaemic, this fell to 0% by the December sampling (3 months later), although 2/110 (1.8%) uninfected cows were found anaemic at the December sampling (Fig. 9-6c). The average HCT of the uninfected cattle in September 2014 was 0.320, which was significantly higher than that of the prevalence cases (HCT = 0.265; $p<0.0001$; Fig. 9-6b). Similarly, the average HCT of the uninfected cattle in March 2015 was 0.324 which was significantly higher than the prevalence cases (HCT = 0.30; $p<0.0001$). Interestingly, the associated average infection intensity of the prevalence cases at the March sampling was the lowest for the four samplings (Fig. 9-6a).

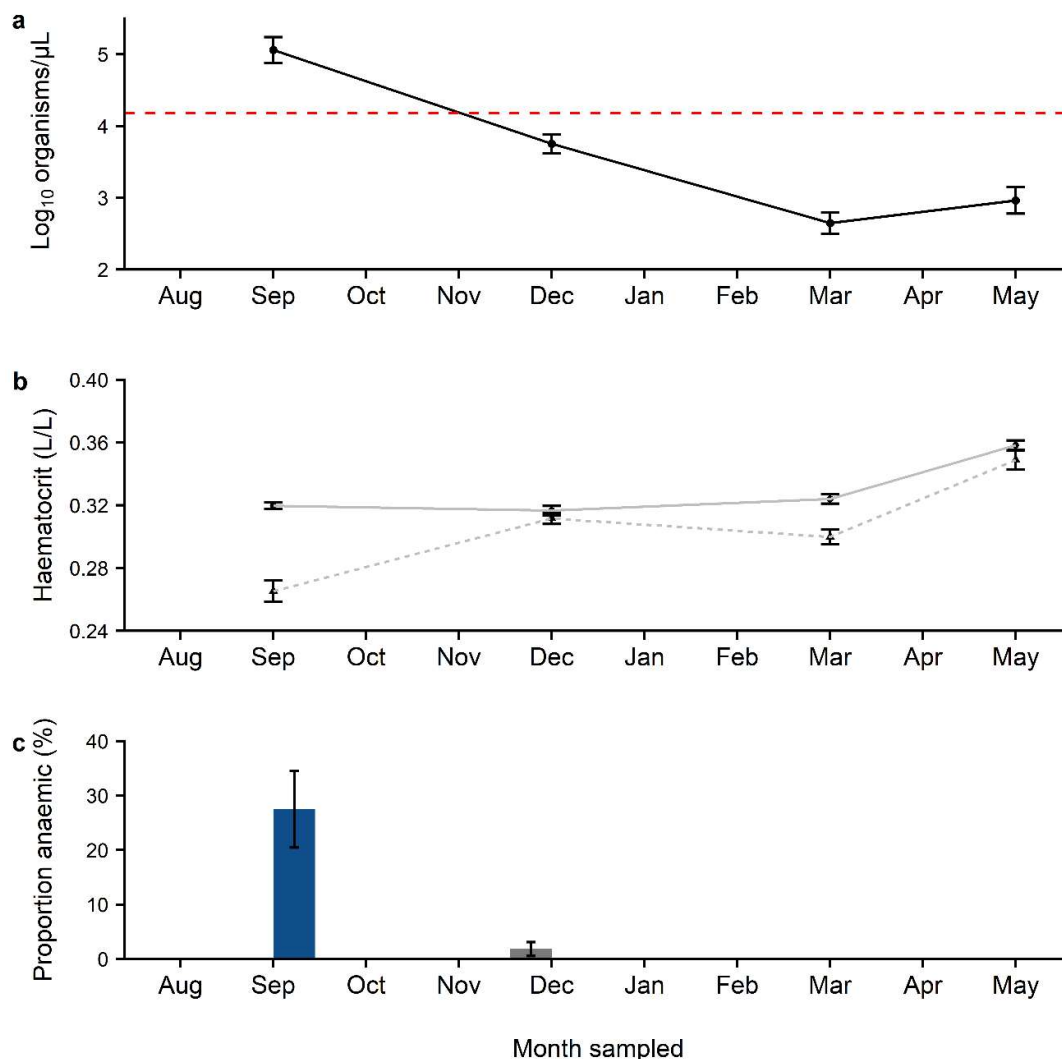


Figure 9-6. Plots for Farm C showing the change in infection intensity (9-6a), haematocrit (9-6b) and proportion anaemic (9-6c) by month and infection status from August 2014 to May 2015. The uninfected cows are shown with a solid line in Fig. 9-6b and as a grey bar in Fig. 9-6c. The infected cows are shown as a broken line in Fig. 9-6 and as a dark blue bar in Fig. 9-6c. Sample collection started in September 2014, so no data were collected for August 2014. The broken red line in Fig. 9-6a is equivalent to a low infection intensity of 15,000 Ikeda organisms/μL (Bogema et al., 2015).

9.6.6 Prevalence cases, HCT and production effects across all farms

The average log₁₀ (infection intensity) by month for each subject farm is shown in Fig. 9-7. The individual farm plots are not particularly similar although the infection intensity of all 3 farms is almost identical in December 2014 and on all 3 farms the infection intensity increases slightly in late autumn 2015, just before dry-off. The highest infection intensity was seen in September 2014 on Farm C, which was infected for the first time in 2014. The

average infection intensities of the prevalence cases from the farms infected in 2013, A and B, were consistently below 15,000 Ikeda organisms/ μL , except from August for Farm A.

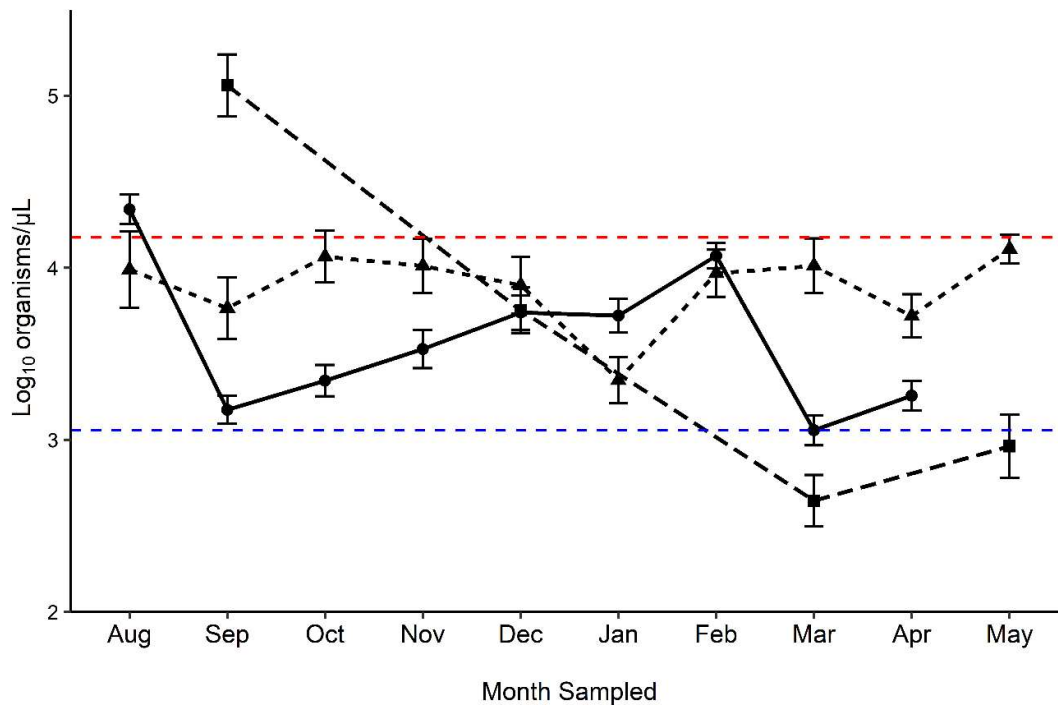


Figure 9-7. Plot of average $\log_{10}$ infection intensity, with SE error bars, by month sampled for the prevalence cases from the three subject farms. The solid line with round points is Farm A, the dotted line with triangular points is Farm B, and the broken line with square points is Farm C. The broken red line is equivalent to a low infection intensity of 15,000 Ikeda organisms/ μL (Bogema et al., 2015) and the broken blue line is equivalent to the cut point of 1140 Ikeda organisms.

A linear mixed effects model fitted to the prevalence case data for all 3 farms showed a significant interaction between Farm and infection intensity on HCT ($p < 0.0001$, $R^2 = 0.43$) in which the effect of infection intensity on HCT depended on the farm (Fig. 9-8). There was an apparent weaker association between infection intensity and HCT for farms A and B, than Farm C where the association appeared much stronger (Fig. 9-8c). No effect of age on infection intensity ($p = 0.23$) was found for the prevalence cases.

A matched data set was prepared, for the prevalence cases and uninfected cows from Farms B and C, with prevalence cases and uninfected cows matched 1:1 within Farm, on age and DIM. A linear mixed effects model fitted to the matched data set found no effect of being a prevalence case on ECM compared to being uninfected, adjusting for age and DIM ($p = 0.92$).

For prevalence cases from Farms A and B there was no effect of infection intensity on ECM either at the same month as LIC herd testing ($p = 0.30$) or lagged one month (infection intensity

of previous month used as predictor of ECM at LIC herd test), ($p=0.91$). However, there was a significant interaction between HCT and DIM on ECM for prevalence cases on Farms A and B adjusting for the effect of Farm ($p=0.015$, R-squared = 0.92). Fig. 9-9 shows that at a low HCT, i.e. below 0.25, the ECM decreases with decreasing HCT.

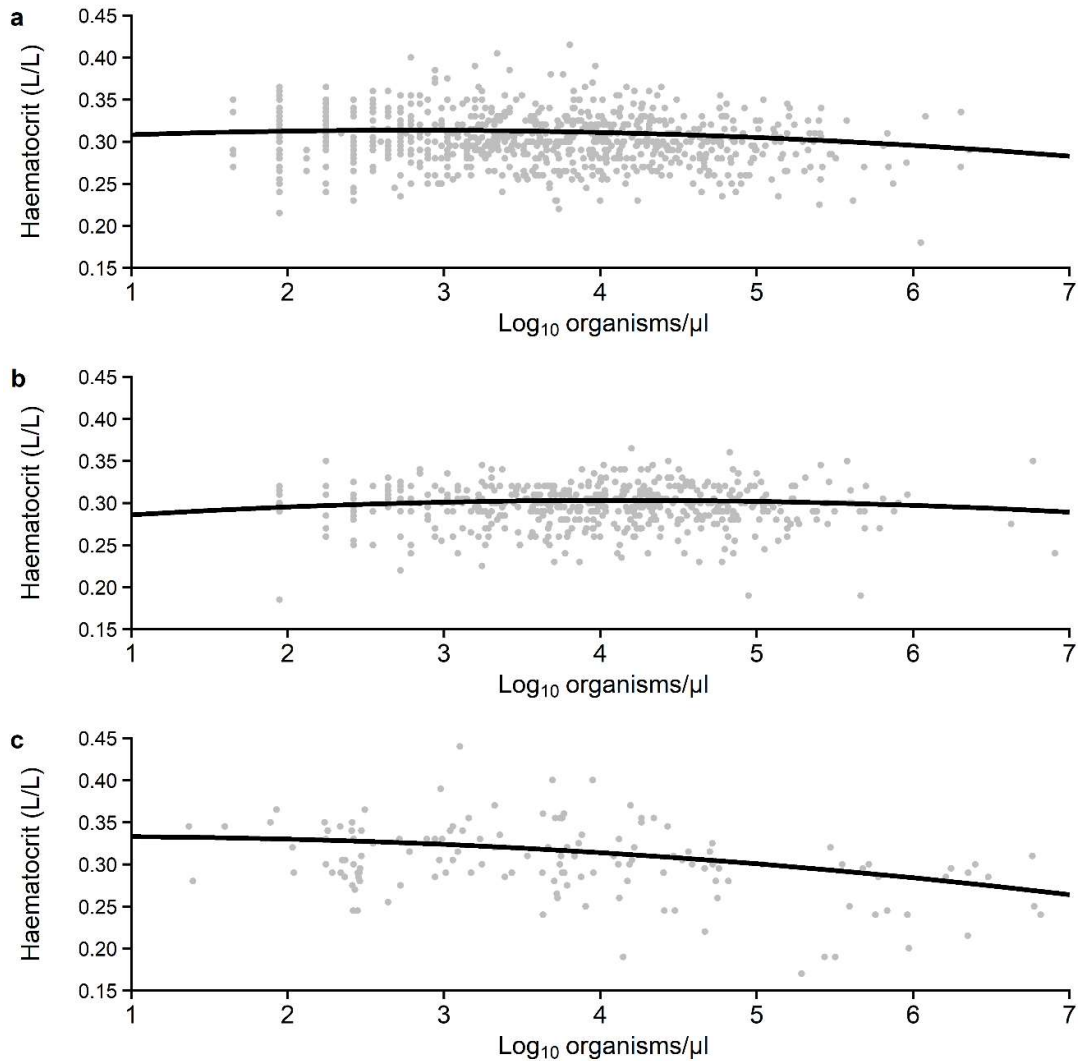


Figure 9-8. Plot of the estimated effect of infection intensity of prevalence cases on haematocrit for 3 subject farms, Fig.9-8a, = Farm A, Fig. 9-8b = Farm B and Fig. 9-8c = Farm C.

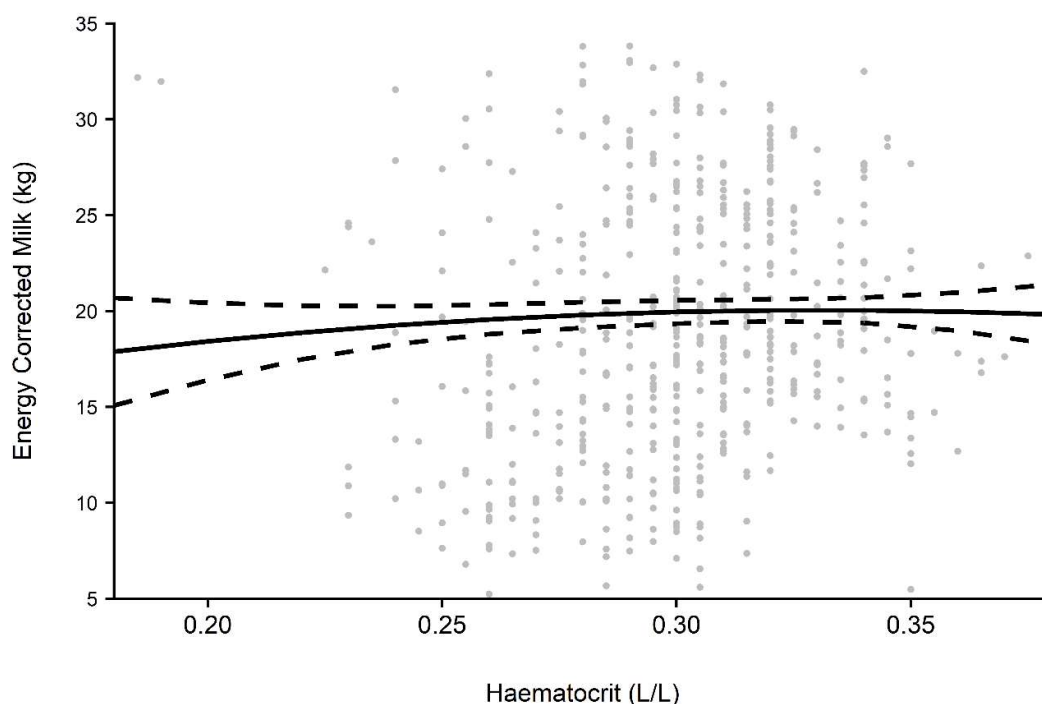


Figure 9-9. Plot of the effect of haematocrit on ECM for prevalence cases across Farms A and B, adjusting for the effect of Farm and DIM

9.6.7 *Incidence cases production effects across farms*

There were 11 incidence cases identified on Farm B and 2 on Farm C, however only incidence case data from Farm B were used in the analysis because the incidence cases on Farm C occurred too late, relative to the LIC herd tests. Each of the nine incidence cases from September and October on Farm B were matched 1:1 on age, DIM and HCT at the August sampling (i.e. prior to infection) to one of the 33 uninfected cows. A mixed effects model with ECM as the outcome variable, controlling for the effect of age and DIM, found that the incidence cases produced on average 2.6 kg/day (95% CI 0.8–4.3) ECM less at the September and November tests ($p=0.02$) compared to the uninfected cows (Fig. 9-10). However, the effect was no longer significant by December ($p=0.08$), or over the 5 herd tests ($p=0.25$). The average days in milk at the November herd test for the incidence cases was 104 days which represents an average total loss of 266kg (95% CI 82–450) of ECM, equivalent to 19.8kg (95% CI 5.7–33.9) of milk solids, up to this point in lactation compared to uninfected cows.

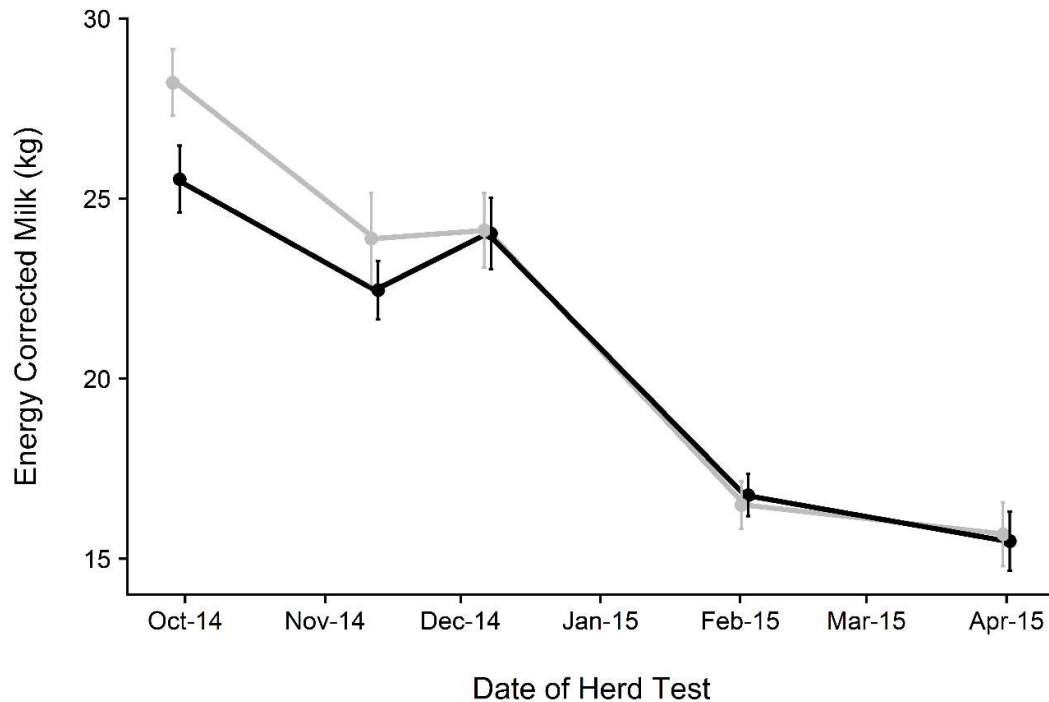


Figure 9-10. Plot showing the mean production with standard error bars by herd test for incidence cases, black line and points, and uninfected matched controls, grey line and points, from Farm B.

9.6.8 Buparvaquone treatment and production effects

During August, September and early October 2014, 48/573 (8.4%) cows from Farm B were treated with buparvaquone (BPQ) by the farm's private veterinarian (Fig. 9-11). Selection for BPQ treatment was based on severity of clinical signs and vulval mucous membrane colour, using the FANI card (Vink et al. 2013). Two cows, 2/48 (4%), treated with BPQ subsequently died. The remaining 46 BPQ treated cows included 3 cows selected for the trial, one prevalence case (treated 18/08/2014), one September incidence case (treated 30/09/2014) and one uninfected cow (treated 30/09/2014). Interestingly, the uninfected cow was moderately anaemic when sampled in October 2014, HCT=0.225, which may explain how it was erroneously selected for treatment based on mucous membrane colour. For the single prevalence case treated with BPQ, the infection intensity dropped from 7,660,000 organisms/ μ L on 11/8/2014 (7 days before treatment) to 71,000 organisms/ μ L on the 9/9/2014 (equivalent to a 99% reduction in infection intensity by 22 days after treatment), with a corresponding increase in the HCT from 0.125 to 0.24 L/L.

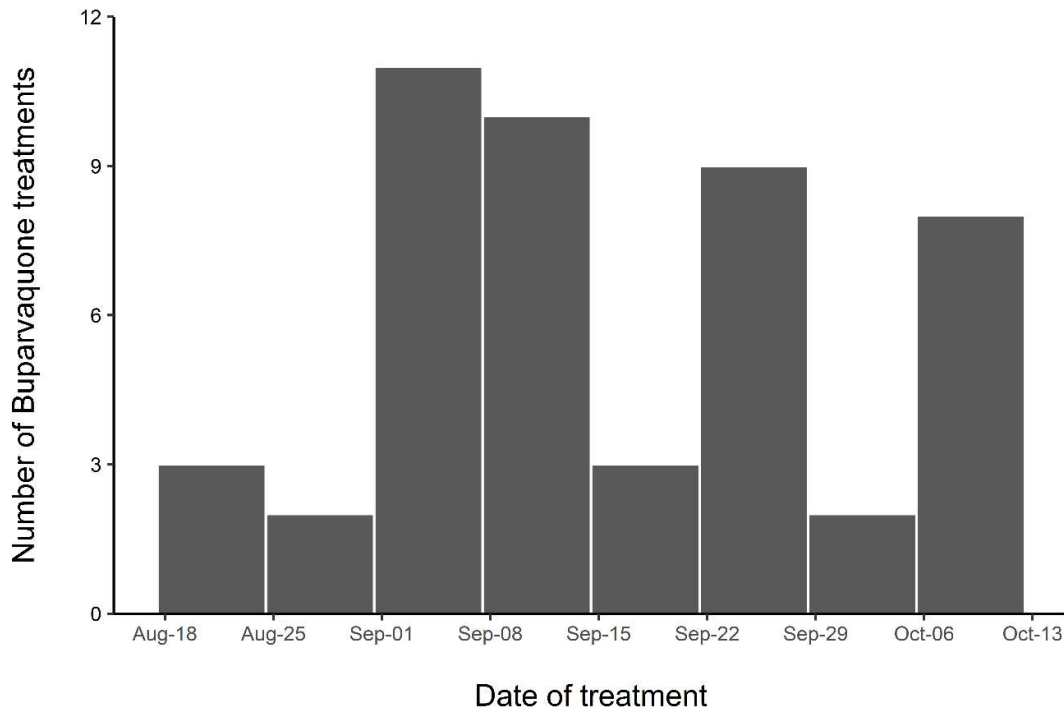


Figure 9-11. Count of buparvaquone (BPQ) treatments given to suspected *Theileria* Associated Bovine Anaemia cases on Farm B by week, for spring 2014

A subset of the full Farm B data set was then prepared, henceforth referred to as the BPQ data set, and consisting of 45 BPQ treated cows (minus 2 cows which died) and 32 uninfected cows (minus one uninfected cow that was BPQ treated). A mixed effects model fitted to the BPQ data set, adjusting for DIM and age, showed that over the 5 herd tests, the BPQ treated cows produced on average 1.75 kg/day (95% CI 0.8–2.7) less ECM milk than the uninfected cows. The average DTS at the May sampling test, completed just before the herd was dried off, was 262 days for the BPQ treated cows which represents a total loss of approximately 458kg (95% CI 211–710) of ECM per BPQ treated cow, compared to uninfected cows, over the whole lactation. As Fig. 9-12 shows all the lost milk production was in the period up to the second LIC herd test. This amount is the gross reduction in ECM and makes no allowance for additional milk losses due to the statutory WHP of 43 days.

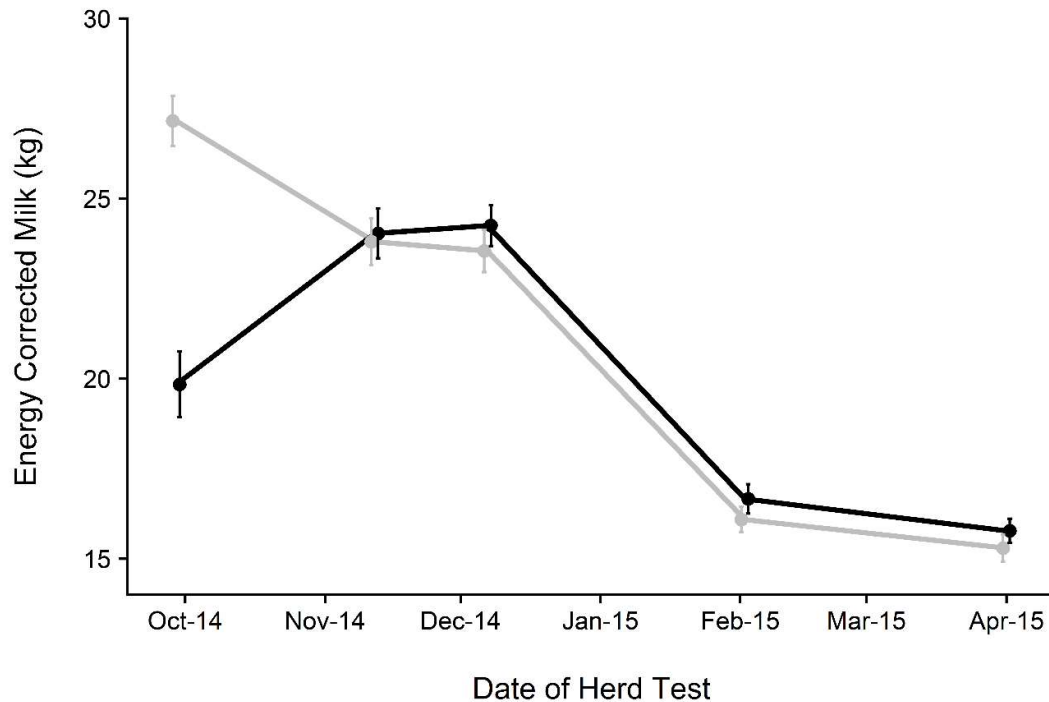


Figure 9-12. Plot from Farm B showing the mean production with standard error bars by herd test for BPQ treated cases, black line and points, and untreated controls, grey line and points.

9.6.9 Reproduction effects across farms

The reproductive data for Farm A was not available, for the entire herd on Farm B the overall empty rate was 61/557, 10.9%, but amongst the subject cows the empty rate was much lower 4/102, 3.9% (1/33 uninfected, 0/11 incidence and 3/58 prevalence cows), and for Farm C the whole herd empty rate was 9/152 (5.9%). Survival analysis using Cox Proportional hazard on the days to conception, with data right censored at 31/12/2014 on Farm B and at 20/1/2015 on Farm C, showed that on Farm B there was a non-significant reduction in the hazard of conceiving for incidence cases, HR = 0.61 (95% CI 0.30–1.2) and for prevalence cases HR = 0.83 (95% CI 0.53–1.3) compared to uninfected cows and on Farm C there was a similar non-significant reduction in the hazard of pregnancy for prevalence cases, HR = 0.88 (95% CI 0.61–1.3) compared to uninfected cows found. For both models the proportional hazards assumption was met.

9.7 Discussion

The change in infection status, infection intensity and HCT over the 2014 to 2015 milking season on three spring calving New Zealand dairy herds has been presented. The effects of infection and infection intensity on milk production and reproduction were estimated for each farm

Previously there have been a number of studies which have repeatedly sampled individual *T. orientalis* Ikeda type infected cattle over an extended period, Lawrence et al. (2018b) repeatedly sampled 17 artificially infected bulls for 20 weeks, Lawrence et al. (2019) repeatedly sampled 240 calves for 8 months, Jenkins and Bogema (2016) repeatedly sampled 10 animals for 76 days and McFadden et al. (2017) repeatedly sampled 19 cows for 6 months. However, the study presented here is the first to follow so many adult cattle through both the acute and chronic asymptomatic stages of infection.

The results for Farm A, from an endemically stable area, and for Farm B from an endemically unstable area show that the prevalence cases, on average, maintained a low infection intensity, <15,000 Ikeda organisms/ μ L, throughout almost all their lactation and yet some cases of anaemia still occurred. In contrast the prevalence cases from Farm C, once they were past the acute phase of infection, returned the lowest average infection intensities found across all the farms. The results also showed that a significant proportion of samples from the prevalence cases on each farm, 36% from Farm A, 18% from Farm B and 37% from Farm C returned a false negative (FN) result. The difference in FN rates between the three farms is difficult to explain but clearly the continued exposure of cows to infected ticks and how recently the prevalence cases were infected had a huge impact on the FN rate. The variable prevalence of FN results in infected herds, depending on whether they are from endemically stable, endemically unstable or disease-free areas, and whether they are in the acute or chronic asymptomatic phase of infection, could have important consequences when testing cattle to establish freedom from disease.

For Farms B and C there were no significant difference in ECM production over the lactation between prevalence cases and uninfected cows. This finding is in complete agreement with Perera et al. (2014) who also found no difference between non-clinical Ikeda infected cows and uninfected cows at 100 days and 305 days in milk. This is a welcome result for producers and should mean that established dairy farms within endemic stable areas will have little ongoing production losses, once their infected cows have entered the chronic asymptomatic state.

Milk production on Farm A was poor and was likely the result of under-nutrition and the serious outbreak of sporodexin toxicity from mid-summer 2015. Yet despite this highly stressful environment the infection intensity of the Farm A cows remained low throughout the whole milking season. This clearly suggests that the physiological responses to stress do not impact the infection intensity of *T. orientalis* Ikeda type in individual animals. Although this appears counter-intuitive it makes some sense from an evolutionary standpoint, if the *Theileria* infection capitalised on the host's ill health or poor nutrition by increasing schizogony then this could potentially contribute to the death of the host and prevent further opportunities for disease transmission. It may even be possible that during stressful periods, when the physiological effects of stress may be expected to confound the effect of infection intensity on the haematocrit or production (such that the same infection intensity has a greater negative effect on HCT or ECM during a stressful period), that the infection intensity may actually drop to prevent this occurring. This latter supposition is supported observations made on Farm C during a late summer feed pinch, where the HCT of the prevalence cases dropped relative to the uninfected cows in March 2015, even though the infection intensity was at its lowest for the sampling period.

Although no direct effect of infection intensity on milk production for prevalence cases was shown, there was a weak effect of infection intensity on HCT and a weak association between HCT and ECM for HCT < 0.25 L/L. Logically this should mean that some indirect effects of chronic infection on production through HCT could occur. However, this study would suggest that these indirect effects in chronically infected animals are both complex and small and are of minor importance compared to the direct effects of under-nutrition or disease. On Farm B the average age of the prevalence cases was much higher than the incidence cases, owing to most prevalence cases being present in the older herd. This was expected since in the previous year the TABA disease outbreak mostly occurred in the older herd. The older herd having been moved back to the coastal run-off in the lead up to the 2013 calving season, due to a feed shortage on the main milking platform, whereas the younger cows did not graze on this other grazing area.

The estimated production loss for incident cases from Farm B in September and October was 266kg ECM at 104 DIM, again this result is in close agreement with Perera et al. (2014) who found that infected cows with mild clinical signs, produced on average 274kg ECM (153L, 13.6kg fat, 8.6kg protein) less milk compared to uninfected cows at 100 DIM. The Fonterra pay out for 2014 – 2015 season, including dividend, was \$4.65 per kg MS which would represent a loss of around \$92 (95% CI \$26.5– \$157.6) per incidence case on Farm B.

The prevalence of infection on Farm B was 57% at the beginning of the testing season which would categorise it as a high incidence, endemically unstable herd (L'Hostis and Seegers, 2002). This occurs when the herd prevalence of infected cows is between 10 and 75% of cows and results in a high incidence of clinical disease and a moderate case fatality rate. This classification seems appropriate for Farm B with 8.4% cows being treated with buparvaquone for suspected clinical TABA in the 2014 to 2015 season.

Perera et al. (2014) found that untreated clinical TABA cows produced on average 892kg ECM (624L, 42.9kg fat, 26.0kg protein) less milk over a 305-day lactation compared to uninfected cows. In contrast, BPQ treated cows on Farm B produced on average 458kg (95% CI 211–710) less ECM compared to the uninfected cows over their lactation, although this figure does not include discarded milk through the statutory WHP. The additional milk production lost, discarded during the 43 days of the WHP, over the 1.75kg/day already accounted for, would be about 875kg ECM. The lactation length for Farm B was shorter than Perera et al. (2014) and when corrected up, the results from Farm B equate to a loss in production of around 503kg (95% CI 246–827) over 305 days. Potentially this could mean that treatment with BPQ has reduced the milk production loss associated with TABA from 892kg to 503kg i.e. by 44%. In addition, a reduction in the case fatality rate was also possibly observed in BPQ treated cows. The case fatality rate for clinical TABA in New Zealand has previously been established as 25% (Vink et al., 2016), the case fatality rate for the BPQ treated cows from Farm B was 4%, which is significantly lower than the 25% case fatality rate recorded by Vink et al. (2016) ($p=0.04$, Fisher exact test).

Taken together these two results suggest that BPQ treatment of acute clinical TABA could reduce deaths by around 80% and production loss by around 40%, however it cannot be certain that all cows treated with BPQ on Farm B had TABA. In another herd outbreak of TABA, on a similar sized dairy farm in the same area, the same veterinarian correctly identified 38/46 (83%) cows as infected with *T. orientalis* Ikeda type, with an average HCT=0.18 (K. Lawrence, data on file). Clearly if the BPQ treated cows on Farm B were ill from non-Ikeda associated diseases, then BPQ treatment would not be expected to have any effect on production, in which case the true reduction in lost production attributable to BPQ could be greater. Although the corresponding reduction in case fatality rate would of course be lower.

The prevalence cases from both Farms A and B had a similar average HCT at their first samplings in August 2014 and on Farms B and C the prevalence cases at their first samplings in August and September 2014 respectively had significantly lower average HCTs than the

uninfected cows sampled in the same month. Taken together these results suggest that the HCT of prevalence cases falls during the dry period. Unfortunately, without PCR and HCT results for June and July, it cannot be ascertained if an increased infection intensity during the dry period preceded this lower HCT in early spring.

It is highly likely that on Farm A, and to a much lesser extent on Farm B, cows were seasonally exposed to hundreds of infected tick bites throughout the 2014/2015 grazing season and yet the infection intensities for the prevalence cases on both these Farms did not alter greatly. On Farm A the infection intensity was highest in August and in February and this likely corresponds to the seasonal peak activity of over-wintering infected nymphs and infected adults in July and December respectively (allowing for a lag of 4 to 6 weeks from infected tick bite to peak parasitaemia). It is possible that this continued exposure to infection helped maintain the infection intensity in prevalence cases at around 4,500 to 7,000 organisms/ μ L on Farms A and B. On Farm C, where ticks were absent, it was presumed that the prevalence cows were not challenged by further infected ticks and the infection intensity dropped dramatically throughout the season to extremely low levels just before dry-off, < 1,000 organisms/ μ L.

Theoretically genetic recombination in the sexual phase of the *T. orientalis* life cycle, conducted during the tick phase of the life cycle, could produce a genetically diverse population of Ikeda sporozoites which could then superinfect already infected animals and overwhelm their immune system. The evidence from Farms A, where tick challenge was observably high (ticks were frequently observed feeding on the udder escutcheon at blood sampling), does not support this supposition since the change in infection intensity on average was slight and only a small number of animals achieved infection intensities equivalent to acute infection i.e. >300,000 organisms/ μ L. It is likely that, as with all Apicomplexan infections, the host/pathogen/environment/vector interactions for *T. orientalis* Ikeda type are complex, for example in malaria (*Plasmodium*), current infections have been shown to inhibit the establishment of future infections so that concurrent infections with different genotypes of *Plasmodium* are maintained as low asymptomatic parasitaemias (Portugal et al. 2011). This is thought to have evolved to prevent life-threatening parasitaemias, since a dead host does not ensure the survival of an infectious agent. The results from this study clearly indicate that anaemia in dairy cows can be a consequence of both acute and chronic Ikeda infection, although more often seen in acute infections and recently infected cases as evidenced by the prevalence of anaemia for incidence and prevalence cases from Farms B and C respectively. However, chronically infected prevalence

cases on Farms A and B also became anaemic, and as was clearly shown on these farms it is important for New Zealand veterinarians to discriminate between infectious, dietary and toxic causes of anaemia. Both brassica feeding (Farm B) and sporodesmin toxicity (Farm A) are significant causes of bovine anaemia in New Zealand cattle and practitioners need to differentiate and apportion causality when encountering an outbreak of anaemia. Facial eczema (Lawrence et al., 2016b) and hypophosphataemia (G. Orbell pers. comm.) have previously been misdiagnosed as oriental theileriosis outbreaks within New Zealand.

An important limitation of the study was that cows were not followed through the dry period, and as the findings from Farms A and B would suggest there are significant changes in the HCT of infected cattle from dry-off to calving. Future work would need to establish the change in HCT of infected and uninfected dairy cows through the dry period and early lactation, with a view to finding methods to potentially support the HCT of infected cattle. Since a low peri-parturient HCT in infected cows may be associated with lower production and may predispose them to post-parturient health problems. A further limitation was the lack of repetitions for the molecular assay, more usually in these types of studies three PCR replicates for each sample are carried out and the average used to estimate infection intensity (Lawrence et al, 2016c; Lawrence et al, 2018b). However, the additional expense involved in doing 3 repetitions for such a large sample size meant that at the time this study was completed it was not economically possible. It is likely with 3 replicates the number of reported false negative and false positive results would have dropped.

There was no significant effect of acute infection, i.e. incidence cases, on reproduction found on Farm B, this result was not surprising given the small number of affected animals (n=11). McDougall et al. (2014) found a similar, but significant, reduction in the hazard of conception for 30/446 cows diagnosed as anaemic and recently infected, HR = 0.63 (95% CI 0.42–0.95). No effect of prevalence cases on days to conception for Farms B and C was found, this was also expected since it would be highly unusual in a New Zealand context to find a negative effect on reproduction without a corresponding negative effect on milk production.

The finding on Farm B that uninfected cattle fed on turnips had a lower HCT and were more likely anaemic than prevalence cases was surprising. Turnips can contain s-methyl cysteine sulfoxide (SMCO) which causes intravascular haemolytic anaemia and haemoglobinuria and yet being infected with *T. orientalis* Ikeda type appears in this case to be protective. A likely mechanism for this is that in the prevalence cases erythropoiesis was already increased allowing them to better cope with the effects of SMCO toxicity. In contrast the higher

anaemia rate in the incidence cases suggests that for these animals' erythropoiesis had not recovered sufficiently to cope with the SMCO toxicity.

The prevalence of anaemia in the prevalence cases identified in August on Farm C and the recovery of anaemic animals from Farms B and C was similar to the findings by Lawrence et al. (2018c) that the prevalence of anaemia in recently infected herds is 26% and that the herd prevalence of anaemia returns to around zero after about 80 days. The prevalence of anaemia in the incidence cases on Farm B was higher at 45% however the 95% confidence intervals for this estimate overlapped 26%.

The LOQ for the molecular assay used in this study was 0.1 fg/ μ L (22 organisms/ μ L) and the cut point was 5.2 fg/ μ L (1140 organisms/ μ L) for whole blood. Using an alternative qPCR assay Lawrence et al. (2018b) measured the LOQ as 1 fg/ μ L (219 organisms/ μ L) and the cut point as 1.9 fg/ μ L (415 organisms/ μ L) for whole blood. These results are not as different as they first appear, since 0.1 fg/ μ L is only one serial dilution lower than 1 fg/ μ L, however it does suggest that the molecular assay used in this study was less sensitive but more specific. It is also important to note that as well as using different molecular assays these studies were also conducted on different populations of cattle, under different experimental conditions.

The current study was an observational study of naturally infected dairy cows whereas Lawrence et al. (2018b) was an experimental study of artificially infected Friesian bulls. At the September testing on Farm C all the cows that over-wintered in the Hawkes Bay for their dry period were infected. A further 4 cows that remained on the farm also became infected, 2 prevalence cases identified at the September testing, one incidence case in December and one incidence case in May. It is likely that either infected ticks were carried back to the home farm, to infect other cows domiciled on Farm C, or else non-tick associated spread of disease occurred, since ticks had never been observed on Farm C. The May incidence case is suggestive of non-tick associated spread of infection, given the low infection intensity measured and how late in the year it occurred. May is a period when ticks are unlikely to be active in New Zealand. Possible routes of infection for non-tick associated spread of disease at this time of year could include iatrogenic through routine vaccinations, or mechanical through stable flies or lice (Fujusaki et al. 1993; Hadi and Al-Amery, 2012; Hammer et. al., 2016).

9.8 Conclusion

For chronically infected dairy herds, from endemically stable areas, the effect of *T. orientalis* Ikeda type infection on production are likely to be less important than the effects of poor-nutrition or other endemic diseases. However, managers of farms in these regions should be aware that sporadic cases of *Theileria* associated anaemia will still occur and may not necessarily be associated with stressful conditions. The affected animals will need to be promptly identified and appropriately treated. In herds from endemically unstable areas *T. orientalis* Ikeda type infection will continue to cause sporadic clinical disease, and production losses of around 300kg ECM can be expected for non-clinical incidence cases infected in the spring. This study provides some evidence that if farmers are willing to accept the long withdrawal periods for meat and milk, then buparvaquone treatment may be useful in the control of clinical disease on dairy farms experiencing severe outbreaks of TABA.

9.9 Ethical approval

This experiment was performed under the approval of Massey University Animal Ethics Committee, Protocol 14/54

9.10 Acknowledgements

The authors are thankful to the C Alma Baker Trust for funding this research. The authors would also like to gratefully acknowledge the assistance of the staff, managers and owners of all three subject farms, Gerard and Kate Lynch, Aaron Frazer, and Sean Galvin without whose enthusiastic support this study would not have been possible. Further thanks are given to Barbara Adlington and Anne Tunnicliffe for performing the haematocrits and storing the samples.

9.11 Conflict of Interest

The authors declare there is no conflict of interest with any other parties for this study.

Chapter 10

Prevalence studies for *Theileria orientalis* conducted during the early stages of the 2012 New Zealand epidemic of *Theileria* associated bovine anaemia

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10.1 Preface

Whilst working at MPI in 2013 I assisted Andrew McFadden in conducting a series of prevalence studies on recently infected farms. Presented here is an analysis of the results which at the time provided valuable intelligence about the epidemiology of TABA.

10.2 Abstract

Since 1982 there have been two epidemics of bovine anaemia associated with *Theileria orientalis* infection (TABA) in New Zealand. The latest and more serious epidemic started in 2012 and is associated with the *T. orientalis* Ikeda type. In 2013 the Ministry for Primary Industries (MPI) carried out several epidemiological investigations on the TABA epidemic, which included a series of on-farm herd prevalence studies. The aims of this paper are to present and summarise the results of these herd prevalence studies. The data were collected from March 2013 to September 2013 and comprised 26 farms. For 21/26 of these farms, a *T. orientalis* Ikeda type positive index case of TABA precipitated the follow-up herd prevalence study. Each herd prevalence study involved a random sample of 10 cows for haematocrit, for piroplasm counts (number of *Theileria* infected RBCs per 1000 RBCs) and for PCR molecular diagnosis. Animals were diagnosed anaemic if the haematocrit ≤ 0.24 .

The results showed that for the index cases, the average haematocrit = 0.10 L/L and the average piroplasm count = 10.9 *Theileria* infected RBCs per 1000 RBCs, and for the herd prevalence studies the average haematocrit = 0.26 and the average piroplasm count = 6.9. The average herd prevalence of *T. orientalis* Ikeda type PCR positive cattle and of anaemic cattle was 87% and 26% respectively. For dairy herds (n= 7 herds) it took, on average, 80 days for the within herd prevalence of anaemia to return to zero after the initial diagnosis. In conclusion the prevalence studies showed that infection rates and anaemia rates were already high in herds when the index case of TABA was observed. At the time, these prevalence studies significantly added to our understanding of the epidemiology of the evolving *T. orientalis* Ikeda type epidemic and furthermore met the New Zealand MPI objective of being rapid and applied, fit for purpose and completed at a relatively low cost.

10.3 Introduction

Theileria orientalis is a tick-borne, obligate intracellular haemoprotozoan parasite of cattle and buffaloes, and belongs to the phylum Apicomplexa (Watts et al. 2016). *Theileria*-associated bovine anaemia (TABA) is an infectious disease of cattle associated with types of the *T. orientalis* group, in which affected cattle can sometimes develop a severe and life-threatening anaemia (Aktas et al. 2006; McFadden et al. 2013). Since 1982 there have been two epidemics of TABA in New Zealand (James et al. 1984; Lawrence et al. 2016b) with the latest epidemic starting in 2012 and being associated with the more pathogenic *T. orientalis* Ikeda type type (Gias et al. 2016; Pulford et al. 2016a). To the best of our knowledge only 4 of the 11 types of *T. orientalis* are presently found in New Zealand cattle, Type 1 (Chitose), Type 2 (Ikeda), Type 3 (Buffeli) and Type 5 (Pulford et al. 2016b).

The history and clinical signs associated with TABA include anaemia, lethargy, production drop, anorexia, ill-thrift, constipation, jaundice, collapse, pale udders, haemoglobinuria (less commonly), inappetence and abortion (Izzo et al. 2010; McFadden et al. 2013; Vink et al. 2016, Lawrence et al. 2017a). Even so, the estimated TABA mortality rates are comparatively low, 0.24% in New Zealand (Vink et al. 2016) and between 0.13 and 0.29% in Japan (Shimizu et al. 1992). Once infected, animals probably remain infected and infectious for life (Onuma et al. 1998).

The only competent arthropod vector for *T. orientalis* in New Zealand is the hard tick *Haemaphysalis longicornis* and its lifecycle and distribution has been thoroughly reviewed by Heath (2016). The distribution of TABA in New Zealand closely follows that of *H. longicornis* (Heath, 2016) and as a result the epidemic has spread rapidly through the North Island, with cases increasingly diagnosed in the lower North Island and the upper South Island from 2014 onwards (McFadden et al. 2016a). Given the low mortality rates, there had been some discussion about the difficulty of detecting when animals on a farm are first infected and when a farmer first becomes aware, they have TABA in their herd.

Prevalence studies are frequently used in epidemiology to assess the burden of disease in a population, to contrast the level of disease in distinct populations or to quantify the change in disease prevalence over time (Pearce, 2012). In this report, prevalence studies were mainly used to quantify the extent of *T. orientalis* Ikeda type infection and anaemia in affected herds relative to when the first clinical case of TABA was diagnosed. The prevalence studies

described here were part of a wider group of epidemiological and laboratory investigations undertaken by MPI in 2013 (Bingham, 2016). The other investigations included an assessment of the herd-level impact of the *T. orientalis* Ikeda type epidemic (Vink et al. 2016), an estimation of the prevalence and spatial distribution of cattle herds infected with *T. orientalis* (McFadden et al. 2016a) and the development of high throughput quantitative PCR assays for diagnosing Ikeda and other *T. orientalis* types (Pulford et al., 2016b). The on-farm herd prevalence studies described here were undertaken in a systematic fashion so that the results for all sampled farms could be combined for analysis and interpretation.

The aims of this paper are as follows; to present and summarise the results from 26 on-farm herd prevalence studies conducted by MPI in 2013, to estimate the average herd prevalence of *T. orientalis* Ikeda type infection and anaemia, when the index case was diagnosed, and to estimate how long anaemia persisted in infected herds.

10.4 Materials and methods

10.4.1 Data collection

These were a series of on-farm cross-sectional studies conducted by the Ministry for Primary Industries (MPI) in 2013. Recruitment of study farms was as follows; upon identification of a clinical case of TABA the veterinarian, who submitted the samples, was asked by MPI investigators to randomly sample an additional 10 cattle from the same herd. If the affected herd had subgroups, which could potentially be important in the epidemiology of the disease on that farm e.g. split calving (spring and autumn) herds, recently introduced animals from another region or different age groups affected, then the referring veterinarian was asked to randomly sample 10 animals from each of these subgroups. These requested samples were then submitted first to the veterinarian's preferred private regional veterinary laboratory (New Zealand Veterinary Pathology or Gribbles Veterinary Pathology) for haematocrit and piroplasm counts (the number of *Theileria* infected red blood cells per 1000 red blood cells) before being forwarded to the Animal Health Laboratory (AHL, Wallaceville, Upper Hutt, New Zealand) for molecular diagnosis. In New Zealand, spring calving herds mostly calve from July to September and autumn calving herds mostly calve in February and March.

Seven farms (C1, L1, H3, H5, K1, S1, S2) had repeat blood samples taken to monitor the change in proportion of anaemic cattle over time. The same cows were not consciously sampled

at each repeat sampling and a molecular diagnosis was only completed at the initial sampling and not at any subsequent samplings.

10.4.2 *Case definition*

The case definition for submission of a blood sample for molecular workup at the Animal Health Laboratory from an index case of TABA was met when suspected *Theileria* piroplasms were present on the blood smear and the sampled animal was anaemic. Cattle were classified anaemic where the HCT was ≤ 0.24 L/L (Riond et al. 2008).

10.4.3 *Molecular testing*

For a full description of the molecular techniques undertaken see Pulford et al. (2016b). Briefly EDTA-treated blood samples were routinely diluted 1:5 in sterile water prior to DNA extraction. Samples were processed on a Corbett Extractorgene robot (Qiagen, Germany) to extract DNA which was eluted in 200ul of diethylpyrocarbonate (DEPC) treated sterile water. All purified DNA samples were subject to an 18S PCR to confirm that each extract was compatible with PCR amplification, and with a *T. orientalis* real-time PCR and an Ikeda type specific TaqMan qPCR for the precise identification of Ikeda. The qPCR results with a cycle threshold <38 were recorded as positive, >38 but <45 as suspicious and >45 as negative or undetected for both *Theileria* real-time PCR tests. Any blood samples that gave a suspicious result for both assays were re-tested and if one assay was suspicious and the other assay positive then the suspicious result was assumed to be positive.

There were potentially 3 combinations of results; a sample could be positive in both the *T. orientalis* and the Ikeda-specific qPCR, a sample could be positive in the *T. orientalis* and negative in the Ikeda-specific qPCR and a sample could be negative in both the *T. orientalis* and the Ikeda-specific qPCR. These results were interpreted as follows; both PCR assays positive meant that the sample contained the Ikeda type and could be a unique or mixed infection with other untested non-Ikeda *T. orientalis* types, if only the *T. orientalis* assay was positive meant that the sample contained a unique or mixed infection of untested non-Ikeda *T. orientalis* types and if both assays were negative then no *T. orientalis* types were present. Only samples that positive to both PCR assays were considered positive for the Ikeda type.

10.4.4 *Statistical analysis*

The two-sample t-test was used to test for any bias in the estimation of HCT between the two private laboratories. It was hypothesised that if a systematic bias in the measurement of the HCT existed between laboratories then the average HCT over all the samples would be significantly different.

The data from the index cases were summarised by farm and tabulated to show the farm type, the district, the sampling date, the number of index cases, the average HCT and the average piroplasm count. The data from the prevalence studies were also summarised by farm and tabulated to show the sampling date, the sub-group (if sampled), the number sampled, the proportion of sampled cattle that were positive for Ikeda, positive for untested non-Ikeda *T. orientalis* types or negative for *T. orientalis*, the average HCT for each of these infection categories and the average piroplasm count for each of these infection categories.

Multilevel mixed effects models were used to analyse the data. A multilevel mixed effects model is one that has both fixed and random effects. Fixed effects are constant across individuals and estimate the mean effect whereas random effects vary across data levels and estimate the variance. Separate models were fitted to both the index data and the prevalence data, with a binomial and Poisson link function used for modelling the prevalence and piroplasm count data respectively. The proportion of anaemic animals, $HCT \leq 0.24$, was also modelled for the prevalence data using a binomial link function.

The equation for the multilevel mixed effects models used in this analysis was

$$Y_{ij} = b_{0j} + b_1 X_{ij} + \varepsilon_{ij}$$

$$b_{0j} = b_0 + u_{0j}$$

Where Y_{ij} is the outcome measure for the i^{th} cow in the j^{th} herd (for the binomial models Y_{ij} was logit transformed and for the Poisson models Y_{ij} was log transformed), b_{0j} is the random intercept for the j^{th} herd, which is broken down into the average model intercept b_0 , and an error term for each herd, u_{0j} . The fixed effects are $b_1 X_{ij}$ and ε_{ij} is the error term for the i^{th} cow in the j^{th} herd. The two error terms u_{0j} and ε_{ij} are independent and normally distributed with a mean of zero. The family wise error rate for multiple post-hoc comparisons was controlled using Tukey's HSD. The fit of each model was assessed using residual plots.

The index models only included those farms with a positive TABA index case, and the prevalence models were fitted to only those farms that had a positive TABA index case. Farm W1 was also excluded from the multilevel mixed effects prevalence models because the transmission of infection on this farm was considered mechanical and not associated with ticks.

To establish how the variance of HCT and of piroplasm counts were distributed across the two levels of the data an unconditional model was fitted to the prevalence data with no predictor variables but with herd entered as a random effect (Bell et al. 2013). The intraclass correlation coefficient (ICC) estimates what proportion of the total variance of HCT or piroplasm count is accounted for by the farm. The higher the ICC the more similar is the HCT or piroplasm counts of cows in the same herd and the more clustered the data. Only Ikeda type PCR positive cases were included for the ICC calculations.

The repeated samples data taken to monitor the change in anaemia prevalence were analysed using a repeated measure generalised linear mixed model with a random effect for the repeat samplings within farm.

All statistical analyses were undertaken using R v3.3.1 (R Development Core Team, 2016).

10.5 Results

The two-sample t-test showed no evidence of bias in HCT measurement between the two private laboratories ($p=0.5$). There were 26 farms on which prevalence studies were completed by MPI in 2013, the first farm was sampled on 19/03/2013 and the last on 6/09/2013. Of these, 25/26 farms were from the North Island and only one farm (W1) was from the South Island, Figure 10-1.

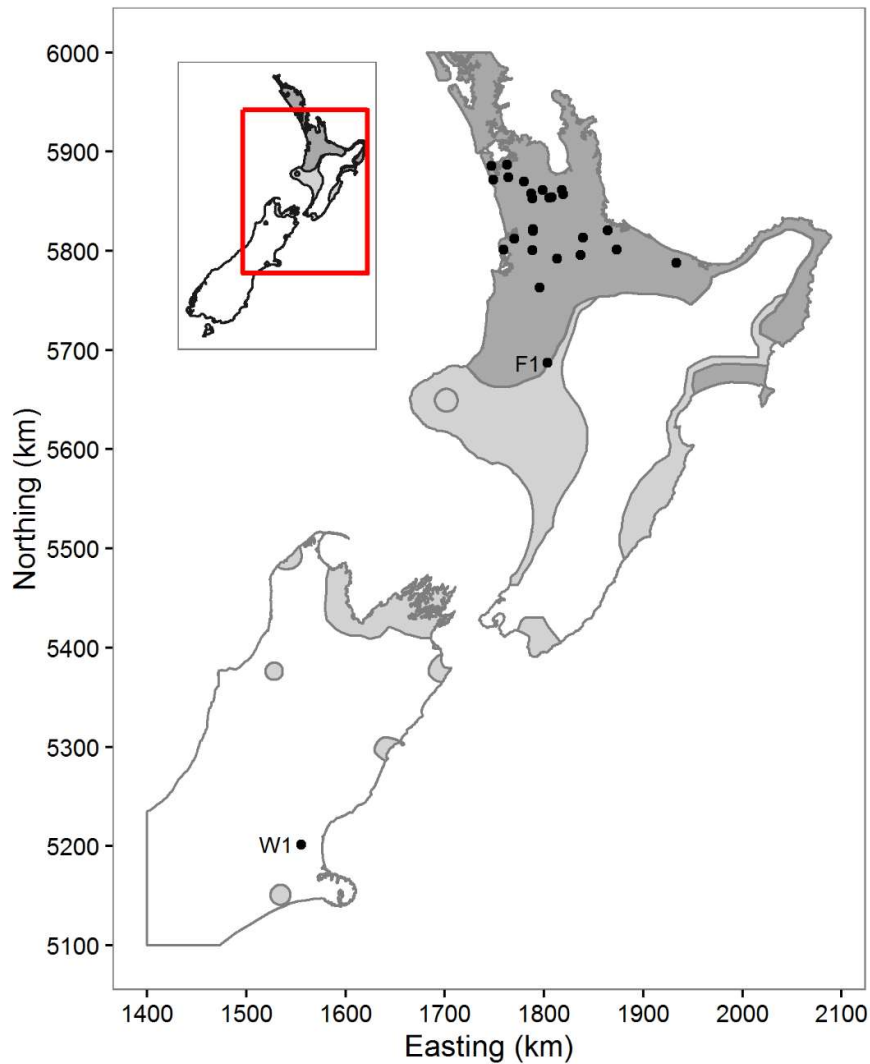


Figure 10-1. Location of farms sampled for prevalence studies. The dark grey areas are high-risk, the light grey areas are low-risk and the white areas are zero-risk of *Haemaphysalis longicornis* infestation (Heath, 2016). All sampled farms are in high-risk areas except F1 which is on the border of high and low-risk areas and W1 which is in a zero-risk area of the South Island.

The locations of the sampled farms in Figure 10-1 overlays a distribution map for the risk of *H. longicornis* infestation (Heath, 2016) and shows that 24/26 farms were from high-risk tick areas in the upper third of the North Island, one farm, F1, was on the boundary of high and low-risk tick areas in the middle third of the North Island and the final farm, W1, was from a zero-risk tick area in the South Island. The farms were mostly sampled in March, April and May 2013 (24/26) with only two farms (P1 and F1) sampled later, in August and September

2013 respectively, Figure 10-2. As can be seen in Figure 10-2 the sampling presaged the exponential growth in TABA cases from August 2013 onwards.

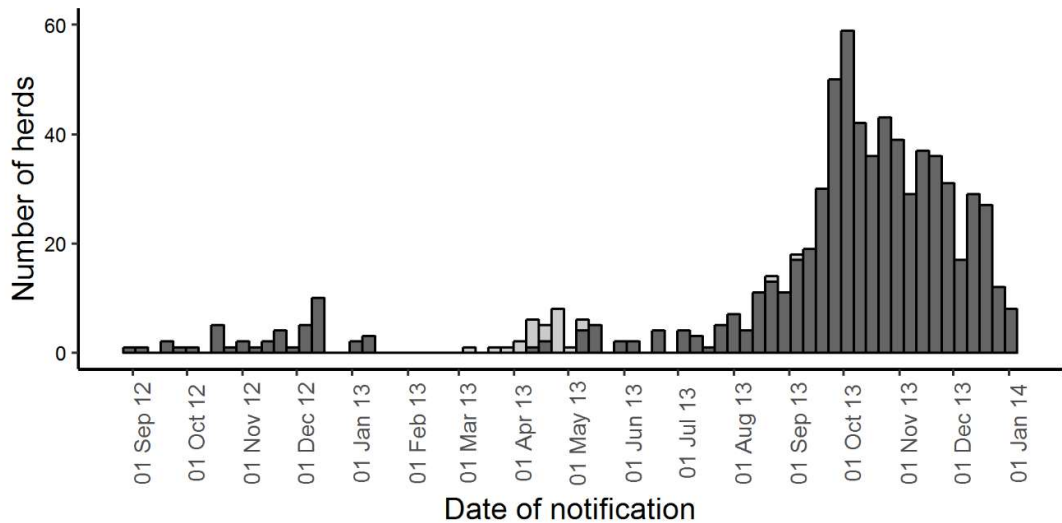


Figure 10-2. Epidemic curve showing the number, by week, of cattle herds with PCR positive cases of *Theileria orientalis* Ikeda type associated bovine anaemia, up to the end of 2013. Herds sampled for the prevalence studies are shown in light grey.

Not all farms were sampled for the same reasons. There were 21 farms sampled after a clinical (index) case of TABA, Table 10-1, and a further 5 farms sampled for alternative reasons. One farm (S2) was sampled as the contiguous neighbour of a farm with a clinical case (S1), 2 farms (D1, M5) were sampled after purchasing dairy cows from the same dairy herd dispersal sale as a farm with a clinical case (C1) and another 2 farms (H2, W4) were sampled because their respective referring veterinarians thought that *T. orientalis* Ikeda type was responsible for an unusual herd health problem, Table 10-2. For these latter farms (S2, D1, M5, H2, W4) no index case was sampled prior to the prevalence study being completed and so they were not included in either the multilevel mixed effects index case models or multilevel mixed effects prevalence models.

The results for the 21 farm index cases are shown in Table 10-1 and for the 26 farm prevalence studies in Table 10-2.

Table 10-1. Summary of the *Theileria orientalis* Ikeda type positive index cases that triggered a follow-up prevalence study on 21 New Zealand cattle farms between March and September 2013. The table shows the date sampled, the number of index cases sampled (N), the average haematocrit (HCT) and the average count of *Theileria* infected RBCs per 1000 RBCs (Ave. piroplasm count) by farm

Farm	Type of farm	District	Date	N	Ave. HCT	Ave. piroplasm count
C1	DTS	Franklin	04/04/2013	1	0.07	9
D2	DSplitC	Franklin	27/03/2013	1	0.18	23
F1	DSC	Ruapehu	02/09/2013	3	0.1	28
G1 ¹	DSC	Waipa	08/04/2013	1	0.09	---
H1	DSC	Waikato	07/05/2013	1	0.09	26
H3 ¹	DSC	Whakatane	05/04/2013	1	0.08	---
H4	DTS	Waikato	05/04/2013	1	0.13	4
H5	DSC	Hauraki	16/04/2013	1	0.13	7
K1	DSC	Waikato	26/04/2013	2	0.11	4
L1	DSC	Waipa	04/03/2013	1	0.08	2
L2	DSC	Franklin	15/04/2013	2	0.1	50
M1 ¹	DSC	South Waikato	22/04/2013	1	0.09	---
M2	DSC	Franklin	24/04/2013	1	0.13	1
M3	DTS	Hauraki	26/04/2013	2	0.1	137.5
M4	DTS	Waikato	05/04/2013	1	0.09	41
M6	Dry stock	Waikato	03/05/2013	1	0.1	40
P1	DSC	Otorohanga	21/08/2013	1	0.1	1
S1	DSC	Waikato	22/04/2013	1	0.13	7
W1 ^{1,2}	DSC	Waimakariri	15/04/2013	1	0.09	---
W2	DSC	Matamata-Piako	30/04/2013	2	0.08	5
W3 ¹	Beef	Waikato	19/03/2013	1	0.21	---

¹No *Theileria* counts were completed on these samples. ² South Island farm. DTS - Dairy town supply; DSplitC - Dairy split calving; DSC - Dairy spring calving

A split calving dairy farm has both spring and autumn calving herds, which are usually managed separately.

A town supply dairy farm mainly calves in the autumn and supplies milk for local consumption over the winter.

Overall Table 10-2 clearly shows that for some farms, D2, K1, M5 and W1, the prevalence of Ikeda and non-Ikeda type infections were markedly different between sub-groups and for other farms, C1, D1, M5 and S1, the average HCT and average piroplasm count were very different between sub-groups.

The index data included 26 samples from 21 farms and is summarised in Table 10-1. The average HCT = 0.10 L/L (95% CI = 0.09–0.12) and the average piroplasm count = 10.9 *Theileria* infected RBCs per 1000 RBCs (95% CI = 5.5–21.4). The median time between the

index case submission and the completion of the prevalence sampling was 5.5 days, range (min = 1, max = 64). The prevalence data included 243 samples from 20 farms and is summarised in Table 10-2. The results from the multilevel mixed effects models showed that the average herd prevalence of *T. orientalis* Ikeda type positive cattle, soon after the index case presented, was 87% (95% CI = 72–95%). The average HCT for Ikeda PCR positive cattle was 0.26 (95% CI = 0.23–0.28), for untested non-Ikeda *T. orientalis* PCR positive cattle was 0.30 (95% CI = 0.27–0.32), and for *T. orientalis* PCR negative cattle was 0.31 (95% CI = 0.28–0.34). The HCT for the Ikeda PCR positive cattle was significantly lower than the untested non-Ikeda *T. orientalis* PCR positive cattle ($P = 0.009$) and the *T. orientalis* PCR negative cattle ($P = 0.0001$), there was no significant difference between the *T. orientalis* PCR negative and *T. orientalis* PCR untested types ($P = 0.64$).

The average prevalence study piroplasm count for Ikeda PCR positive cows was 6.9 (95% CI = 4.3–11), for untested *T. orientalis* PCR positive cattle was 1.3 (95% CI = 0.8–2.3), and for *T. orientalis* PCR negative cattle was 0.12 (95% CI = 0.04–0.32).

All comparisons of piroplasm counts were significantly different between groups, $P < 0.0001$. The average HCT of the index cases was significantly less than the average HCT of the cattle sampled in the prevalence studies ($P < 0.001$) however the average piroplasm counts were not quite statistically different ($P = 0.07$). The prevalence of anaemic cattle ($HCT \leq 0.24$), soon after the index case presented, was 26% (95% CI = 13–43%). The ICC for the HCT, for Ikeda PCR positive animals, was 0.54 (95% CI = 0.37–0.73) and for the piroplasm counts was 0.19 (95% CI = 0.07–0.4).

Table 10-2. Summary of prevalence studies conducted on 26 New Zealand cattle farms between March and September 2013. The table shows the date sampled, the group sampled, the number of animals sampled in each group or sub-group (N), the prevalence (%) of Ikeda (Ik), untested non-Ikeda (Un) and negative (Neg) infected animals, the average HCT (Ave. HCT) by infection category and the average count of *Theileria* infected RBCs per 1000 RBCs (Ave. piroplasm count) by infection category.

Farm	Date	Group	N	Infection prevalence (%)			Ave. HCT			Ave. piroplasm count		
				Ik	Un	Neg	Ik	Un	Neg	Ik	Un	Neg
C1 ¹	11/04/2013	Home	11	91	9	0	0.3	0.28	---	2.1	1	---
		Bought-in	11	100	0	0	0.17	---	---	14	---	---
D1 ¹	11/04/2013	Home	11	100	0	0	0.25	---	---	2.3	---	---
		Bought-in	9	89	0	11	0.17	---	0	6.5	---	0
D2	09/04/2013	Spring calves run-off	10	100	0	0	0.28	---	---	2.9	---	---
		Spring calves home	10	60	40	0	0.35	0.35	---	1.3	0.2	---
		Autumn calves home	10	0	0	100	---	---	0.3	---	---	0
	22/04/2013	Spring calving cows	9	11	67	22	0.28	0.28	0.31	0	0	0
	22/04/2013	Autumn calving cows	10	90	10	0	0.21	0.32	---	27.3	2	---
F1	06/09/2013	Home	15	93	0	7	0.13	---	0.22	16.1	---	0
G1 ⁴⁵	11/04/2013	Home	10	40	0	60	---	---	---	---	---	---
H1	10/05/2013	Home	10	90	0	10	0.29	---	0.3	3.4	---	0
H2 ²	26/04/2013	Home	10	0	80	20	---	0.31	0.32	---	1.5	0
H3	12/04/2013	Home	9	44	44	11	0.21	0.27	0.32	14.5	10	1
H4	16/04/2013	Home	10	100	0	0	0.3	---	---	6.5	---	---
H5	18/04/2013	Home	7	100	0	0	0.18	---	---	2.4	---	---
K1	29/04/2013	Spring calving cows	10	40	10	50	0.27	0.31	0.31	1	1	0.2
		Autumn calving cows	11	73	18	9	0.26	0.29	0.27	2.2	1	0
L1	07/05/2013	Home	12	92	0	8	0.21	---	0.35	36	---	0
L2	19/04/2013	Home	10	60	30	10	0.23	0.28	0.25	5.3	3.3	0
M1	23/04/2013	Home	11	18	0	82	0.26	---	0.32	11.5	---	0.2
M2	30/04/2013	Home	10	100	0	0	0.31	---	---	1	---	---
M3	29/04/2013	Home	10	60	30	10	0.26	0.28	0.27	2.5	1	1
M4	16/04/2013	Home	10	100	0	0	0.26	---	---	3.4	---	---
M5 ¹	12/04/2013	Home	10	30	70	0	0.29	0.26	---	1.3	0.8	---
		Bought-in	8	100	0	0	0.2	---	---	20.8	---	---
M6	08/05/2013	Home	10	80	10	10	0.35	0.34	0.36	2.1	2	0
P1	28/08/2013	Home	28	100	0	0	0.23	---	---	14.5	---	---
S1 ³	30/04/2013	Home	10	70	10	20	0.29	0.34	0.34	22	0	0
S2 ³		Neighbour	10	100	0	0	0.32	---	---	7.6	---	---
W1 ⁵	15/05/2013	Home	10	0	10	90	---	0.29	0.29	---	---	---
		Bought-in	10	80	20	0	0.31	0.32	---	---	---	---
W2	02/05/2013	Home	10	90	10	0	0.24	0.27	---	25.2	1	0
W3 ⁵	28/03/2013	Home	10	100	0	0	0.29	---	---	---	---	---
W4 ²	24/04/2013	Home	10	0	30	70	---	0.31	0.31	---	0	0

¹These farms all bought cows from the same farm dispersal sale. ²These farms were sampled to establish the potential involvement of *T. orientalis* Ikeda type in unusual herd health problems. ³These farms were neighbours.

⁴No PCV counts were completed on these samples. ⁵No *Theileria* counts were completed on these samples.

There were 7 dairy farms with a total of 17 samplings (range per farm, min = 2, max = 4) used in the repeated measures generalised mixed model. The sampling dates and results are shown in Table 10-3 and the fitted model plotted in Figure 10-3. The plot shows that the prevalence of anaemia in the 7 sampled dairy herds dropped quickly and approached zero at 80 days after the first sampling, which was triggered by the index case.

Table 10-3. The farm, the sample date, the numbers sampled, the number diagnosed anaemic (%) for 7 dairy farms repeatedly blood sampled in 2013, to monitor the change in prevalence of anaemia over time

Farm	Sample date	Number sampled	Number anaemic (%)
C1	10/04/2013	22	11 (50)
	30/05/2013	15	3 (20)
L1	07/05/2013	12	8 (67)
	01/07/2013	10	0 (0)
H3	09/04/2013	9	3 (33)
	28/05/2013	10	2 (20)
	01/07/2013	10	0 (0)
H5	18/04/2013	7	6 (86)
	30/05/2013	10	1 (10)
	01/07/2013	10	0 (0)
	31/07/2013	8	0 (0)
K1	29/04/2013	21	4 (19)
	11/06/2013	9	1 (11)
S1	30/04/2013	10	2 (20)
	14/06/2013	10	0 (0)
S2	30/04/2013	10	0 (0)
	29/05/2013	10	0 (0)

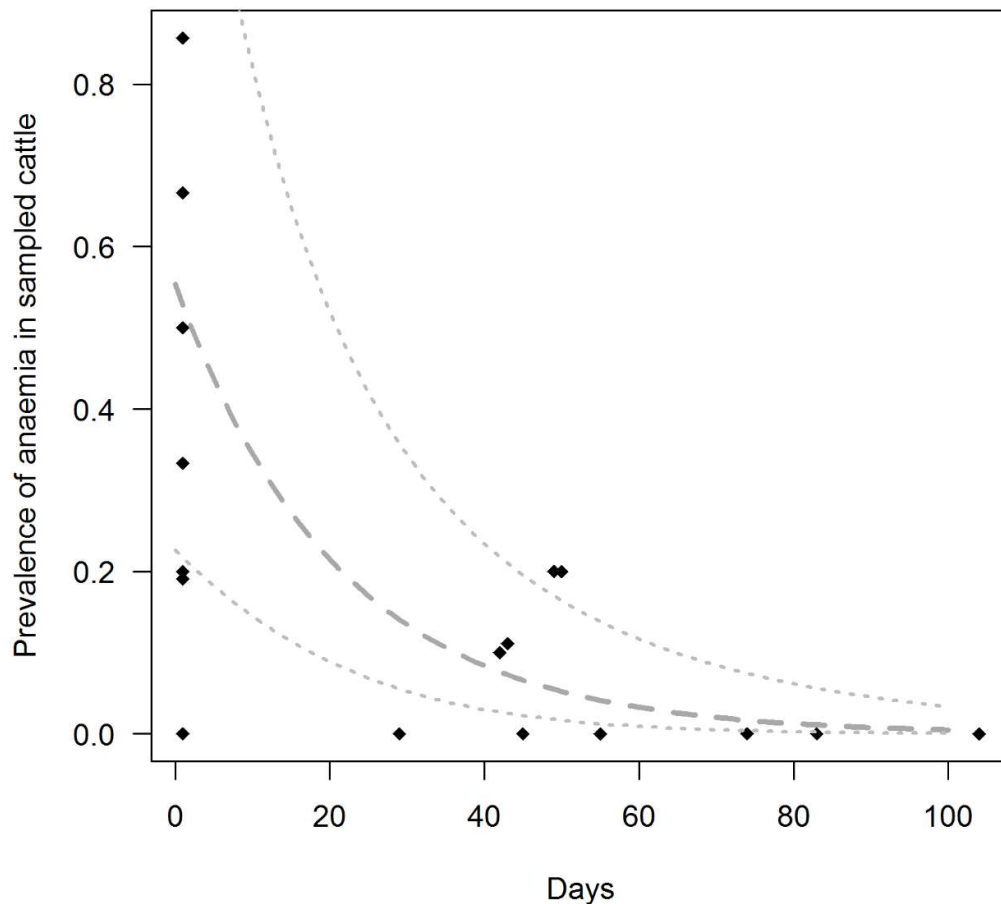


Figure 10-3. Results from the repeated measures generalised linear mixed model showing the estimated change in the average prevalence of anaemic cattle in a *Theileria orientalis* Ikeda type infected dairy herd over time ----, with 95% confidence intervals.

10.6 Discussion

The results of 26 farm level prevalence studies conducted by MPI in 2013 have been presented and analysed. The results show that on average 87% of cattle in a herd were already infected with *T. orientalis* Ikeda type and 26% of cows were anaemic when the first clinical case of TABA was recognised. This supports the findings of Vink et al. (2016) that *T. orientalis* Ikeda type infection is only rarely associated with overt clinical disease. Moreover, it informed industry of how quickly the disease could spread through a herd and yet remain undetected.

The finding also brought into question the widespread promotion of acaricides to control the spread of infection in herds.

Clearly ten cows are not a representative sample for a standalone estimate of disease prevalence in a dairy herd and furthermore it is unlikely that many veterinarians took genuinely randomised samples and in reality, were possibly biased to the unhealthy-looking cattle. However, the use of multilevel mixed effects models does allow individual farm prevalence studies to borrow strength across all prevalence studies and so give a more robust estimate of the average farm prevalence.

The results for farms H2 and W4, Table 10-2, clearly exonerated the involvement of *T. orientalis* Ikeda type in the herd health problems; it was later proven that both these herds were suffering from acute sporodesmin toxicity. The results from the South Island farm W1 showed that only the bought-in cattle were infected. The lack of *T. orientalis* infection in the home herd, with only one animal positive for untested non-Ikeda *T. orientalis* type, and the location of the farm in the Waimakariri District, South Island, suggested, at the time, that ticks were not present on this farm. This led MPI investigators to believe that this was an example of a non-tick associated disease transmission. The sick cow was a donor cow and the bought-in cattle were recipients in an embryo transfer program, so there was potentially some contact between these animals, although it was never established how the infection transferred between them. Biting flies (*Stomoxys calcitrans* (Stable fly)) (Hadi and Al-Amery, 2012), *Linognathus vituli* (sucking lice) (Fujusaki et al. 1993b), mosquitoes (de Marco et al., 2016) and iatrogenic transmission have all been suggested as potential mechanical vectors of *T. orientalis*, however there is little field data to support these claims (Yamane et al., 2010; Heath, 2013; Hammer et al., 2016).

Shortly after completion of the prevalence studies reported here, the requirement by MPI for the private regional laboratories to carry out piroplasm counts on suspect TABA samples was dropped in favour of just recording whether *Theileria* were present or absent on a stained blood smear. Although a sensible practical decision, especially given the extra work involved and the poor correlation found between piroplasm counts and the HCT (Gias et al. 2016), this study does show that average piroplasm counts, when considered together with the average HCT results of the same group, could give an indication of how acute (recent) and how severe the *T. orientalis* Ikeda type infection may be. This is clearly seen for farms C1, D1 and M5 where the bought-in cows all have higher piroplasm counts and lower HCTs than the home cows and

again for the neighbouring herds S1 and S2 where the home farm (S1) has higher piroplasm counts and lower HCTs than the neighbour (S2). Practitioners should still consider requesting piroplasm counts in future TABA outbreak investigations if they are trying to establish the source of an infection, especially when the direction of disease spread between sub-groups or farms is not immediately apparent.

The ICC for HCT and for piroplasm count showed a contrasting degree of clustering for these two outcome measures, with HCT being much more highly clustered within herd than piroplasm count was. These results can be broadly interpreted as follows; the infection intensity experienced by cows, when estimated through piroplasm counts, is reasonably similar across all herds sampled whereas the effect of that infection on an individual cow, as measured by the haematocrit, is highly dependent on which herd the cow is resident in. Why some herds had greater numbers of seriously anaemic or deceased cows than others were not established by the MPI herd-level impact survey (Vink et al. 2016) but it likely reflected the nutritional status, the body condition and the presence of concurrent diseases such as bovine viral diarrhoea virus. The non-significant difference in average piroplasm counts between the index cases and the prevalence samples again supports the conclusion that infection intensity is reasonably similar across most cows infected at a similar time and whether a cow becomes anaemic or not is probably determined by herd orientated factors rather than the cow itself.

The repeated measures model showed that the prevalence of anaemic animals fell quickly after the index case was diagnosed and was virtually zero by 2 to 3 months. However, these data were very limited and probably biased, with only a small number of farms repeatedly sampled, and without molecular diagnostics it was only assumed that the anaemic cattle identified at follow up samplings were Ikeda type positive. Furthermore, the repeat samples themselves were mostly taken in the winter when the nymph stage of the tick lifecycle enters diapause and the spring calving dairy cows are dried off i.e. the infection pressure and cow stress were probably at their lowest for the production year. Even so they do give an indication of how quickly an anaemic herd can recover, which is probably a testament to the resilience of the New Zealand dairy cow.

In conclusion, at the time they were conducted these prevalence studies significantly added to our understanding of the epidemiology of the evolving *T. orientalis* Ikeda type epidemic and furthermore they met the MPI goal of being rapid and applied, fit for purpose and completed at relatively low cost.

10.7 Acknowledgements

Professor Mark Stevenson of Melbourne University is thanked for his help and instruction on constructing the farm location map.

Chapter 11

General discussion

The work presented in this thesis set out to document and investigate epidemiological aspects of the epizootic of bovine anaemia associated with *Theileria orientalis* Ikeda type infection, which began in New Zealand in August 2012. Since New Zealand has no other pathogenic tick-borne cattle haemoparasites, this meant that the effects of the *T. orientalis* Ikeda type infection observed in affected herds and individual animals were not confounded by concurrent haemoparasite infections, as was possibly the case with some herds in the Australian epidemic. This gave an almost unique, unbiased perspective of a new disease and together with New Zealand's seasonal based cattle systems led to a different epidemiological presentation than reported by almost all other affected countries. The opportunity to document the emergence of a new cattle disease in New Zealand has been a privilege and I am very grateful to MPI for allowing me continued access to the *Theileria* data base.

Having verified the establishment of a new disease and identified the associated pathogen, the remaining key requirements of an epidemiological investigation, for a disease affecting production animals, are to describe how the disease spreads, describe the likely impacts of that disease at the individual and herd level and explore methods of disease control or mitigation.

11.1 Spread of disease

The results of **Chapters 2, 6, 7, 8 and 10** have led to the development of Figure 11-1, which suggests that the main method of disease dissemination in the 2012 New Zealand TABA epidemic was the movement of parasitaemic cattle into naïve herds. Infected farms were 2 times more likely to have had cattle movements onto their farms than uninfected farms (**Chapter 2**) and the consequences of that movement depended on the tick density of the area in which the naïve farm was situated. In high tick densities areas, endemic stability rapidly established and on average 87% of a naïve herd were already infected when the first clinical case of TABA was diagnosed (**Chapter 10**). Once endemic stability is established, clinical disease is more likely seen in young cattle. In Northland, which was probably the first region in New Zealand to achieve endemic stability, beef or dairy calves were 26 times more likely to be diseased than calves from all other regions in the North Island (**Chapter 2**).

Local spread of infection to neighbouring farms from recently infected herds is also highly likely in high tick density areas. The epidemic curve described a propagating epidemic in the early stages in Northland (**Chapter 2**) and strong temporal-spatial clustering of case farms at

20–30 days and 5–20 km from another case farm was also proven (**Chapter 2**). Both findings support the importance of local spread in the early stages of this *Theileria* epidemic.

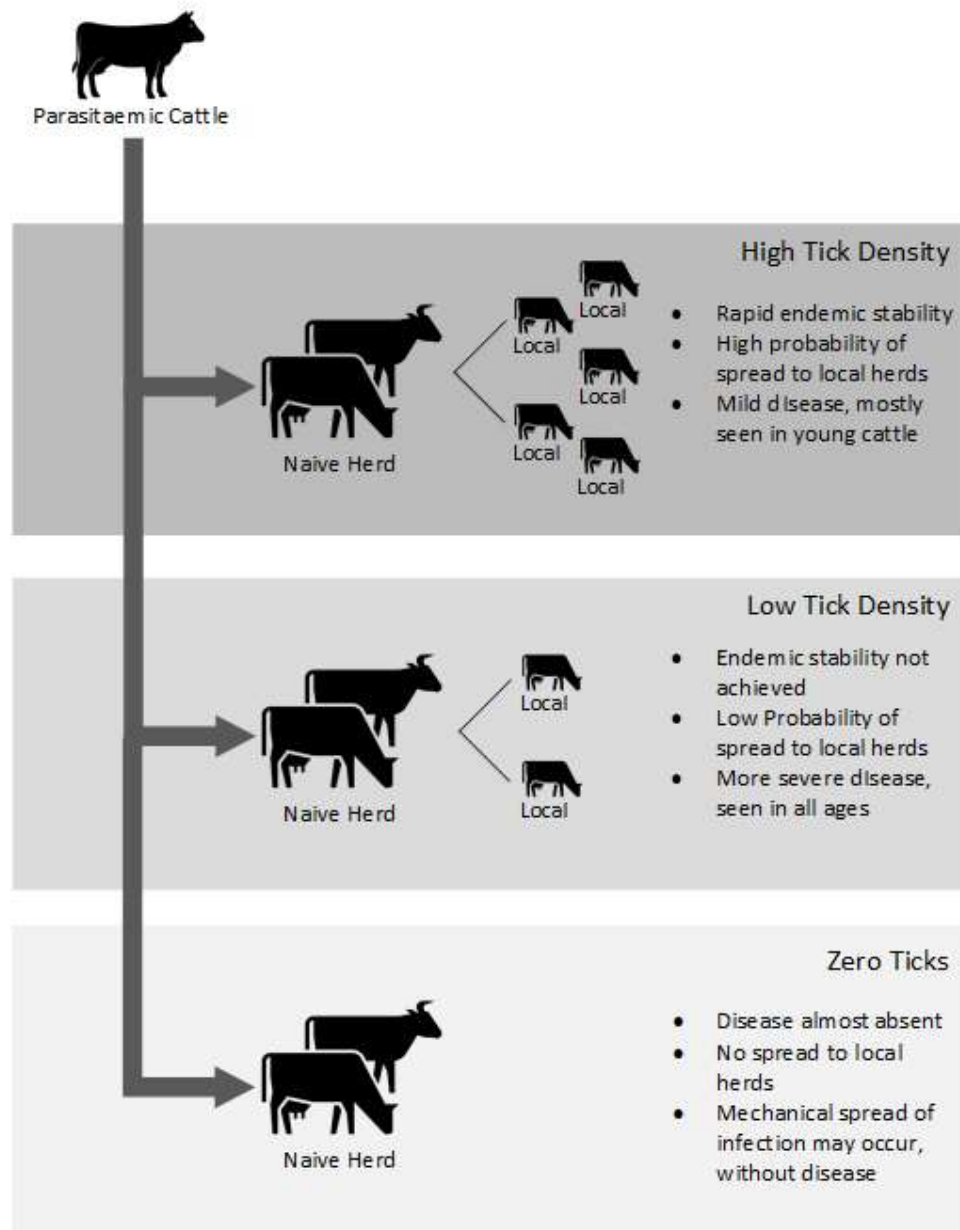


Figure 11-1. Mechanism and consequences of *Theileria orientalis* (Ikeda) spread

The severity of disease and the age group affected, also depends on the tick density. The environmental suitability of tick habitats falls the further south you travel in the North Island (**Chapter 8**). Consequently, cattle are less likely to be infected as calves, since there are fewer ticks to infect them, resulting in clinical disease being seen mostly in adult cattle which is likely

to be more severe than in calves (**Chapter 6**). In areas outside of known tick areas, where ticks are absent, there is still a low probability of non-tick associated disease transmission (**Chapter 7**), however, with no reports of TABA in seven years from these tick -free areas it is unlikely that acute clinical disease occurs after mechanical spread. It is also unlikely that the distribution of tick habitats in New Zealand will be greatly affected by global warming, although some increase in TABA disease frequency may be expected on the West Coast of the South Island (**Chapter 8**).

11.2 Impact of disease

The potential outcomes of *Theileria orientalis* Ikeda infection in naïve animals are shown in Figure 11-2. The concepts that Figure 11-2 are trying to convey are that *T. orientalis* Ikeda type infection is a necessary but not sufficient cause of disease (TABA, production and live weight losses) and that other contributory causes, such as stress (physiological and nutritional), and concurrent disease, have a strong influence on the outcome of infection, at both the individual and the herd level. Furthermore, factors such as sex (**Chapter 4**), breed (**Chapter 4**), age (**Chapter 4**) also impact the infection intensity and thus the clinical outcome. Trans-placental infection is not shown on the diagram as trans-placental infection occurs at a very low level, if at all, in chronically infected cattle, (**Chapter 3**) and has a very minor role in the epidemiology of TABA.

The most common clinical signs recorded for cattle with acute oriental theileriosis are jaundice, lethargy, pale mucous membranes, anaemia, and off milk (**Chapter 5**). In contrast chronic infection is asymptomatic except for the hypothesised syndrome of ill thrift, diarrhoea and death reported in weaned beef calves (**Chapter 5**). The most common haematology and biochemical changes seen in the acute phase of infection were similar in adult and young calves (**Chapter 4**). These were a regenerative extravascular haemolytic macrocytic anaemia, resulting in reduced HCT and RBC counts, and associated biochemistry changes of elevated GGT and bilirubin levels (**Chapter 4**). However, calves were less likely to develop severe anaemia and adult cattle were more likely to show anoxic liver damage at low HCT, with increased levels of AST and GLDH and an inflammatory response (**Chapter 4**).

Very few chronically infected cows appear to recrudesce into acute illness despite nutritional stress or severe concurrent disease (**Chapter 9**). To emphasise this, broken grey lines and arrows were used in Figure 11-2 to show a weak association. Instead it is likely that the role of

T. orientalis Ikeda type in disease presentation changes from the acute to the chronic stage of infection. In the acute phase the effects of the contributory causes influence the pathophysiological response to *T. orientalis* Ikeda infection leading to higher infection intensities and more severe disease outcomes, i.e. the contributory causes help set the conditions under which we see acute TABA. Whereas in the chronic phase *T. orientalis* Ikeda type infection now interacts with these contributory causes, leading to potentially more severe effects of stress (physiological or nutritional) or concurrent disease on production and live weight than would be seen in uninfected cattle. The chronic *T. orientalis* Ikeda type infection decreases the fitness of the animal to tolerate other endemic diseases and deficiencies.

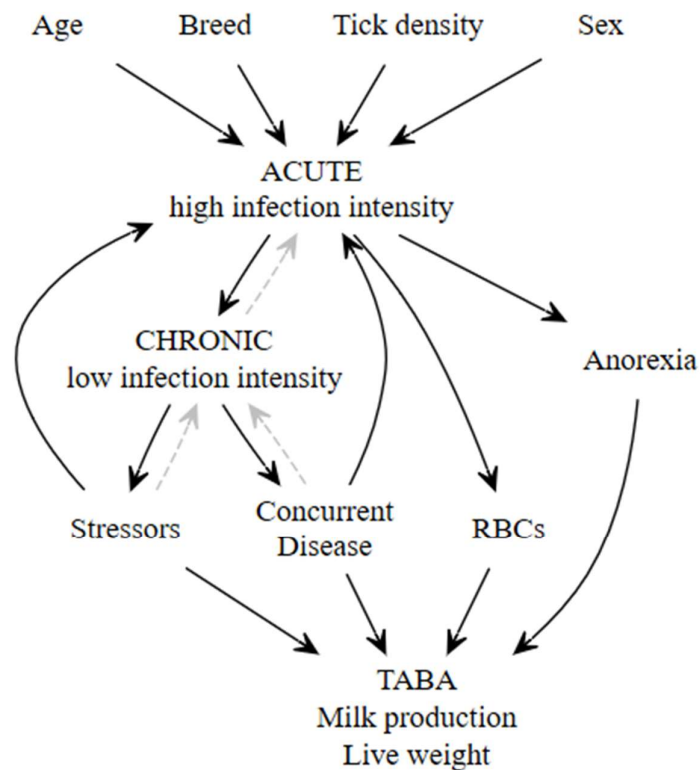


Figure 11-2. Causal diagram for the pathogenesis of disease, anaemia, live weight and production effects in naïve cattle recently infected with *Theileria orientalis* Ikeda type. The broken grey lines and arrows are used to show a weak association.

This reduction in fitness brought on by chronic infection is the likely explanation for the hypothesised syndrome of ill thrift, chronic diarrhoea and death reported in weaned beef calves (**Chapter 5**). These calves present with quite vague illnesses which are likely related to

parasitism, concurrent infections such as BVD and poor nutrition but exacerbated by the chronic *Theileria* infection.

Figure 11-2 further tries to differentiate between the three main outcomes of infection, anaemia (TABA), weight loss and production loss, since weight loss and milk loss can be seen in recently infected animals without these animals being severely anaemic.

The loss in production, for non-clinical incidence cases, was estimated at around 20kg milk solids per cow affected (**Chapter 9**).

11.3 Control of disease

Despite widespread promotion and uptake, the use of acaricides proved largely ineffective at preventing oriental theileriosis in the 2012 epidemic. This was not surprising given that on average 87% of cows were already infected when the first cases of TABA are reported in that herd (**Chapter 10**).

Currently those New Zealand cattle farms in the low-tick density areas which fail to reach or maintain endemic stability are the farms that continue to experience acute clinical theileriosis in older cattle (**Chapter 9**). The most important control method that can be implemented on these farms is the deliberate exposure of young cattle to infection, to drive the herd into endemic stability. Implementing this program should not result in increased cases of TABA since young cattle appear to be less severely affected than older cattle in the acute phase (**Chapter 4**) and once cattle have reached the chronic infection phase, acute disease is rarely seen (**Chapter 9**).

Having said that, there is still an ongoing requirement in New Zealand for an effective chemotherapeutic agent to treat oriental theileriosis. Buparvaquone has shown some efficacy with a possible 80% reduction in case fatality rates and a 40% reduction in milk loss in treated cattle (**Chapter 9**). However, the long legal withhold periods for meat and milk currently enforced for this drug, limit its usage on most New Zealand farms.

11.4 Where to from here.

From a New Zealand perspective there are two pieces of work that would complement the work already completed in this thesis. The first would be to investigate whether latent carriers, such as sheep or deer, played a significant role in the rapid spread of TABA through

the North Island. Although this knowledge would have little bearing on the current epidemic it would help explain how the epidemic spread so quickly and potentially aid disease control in future outbreaks. The second would be to evaluate alternate chemotherapeutic agents to buparvaquone, ones with a shorter, more reasonable, withhold periods. There is still a significant burden of clinical disease in the unstable endemic areas and in naïve herds moving from disease free areas to infected areas. An effective chemotherapeutic agent would dramatically reduce animal suffering and lost production, if it were available. Two drugs that certainly warrant early evaluation are toltrazuril and tulathromycin.

From a world perspective the uncertainty surrounding the taxonomy of the *T. orientalis* group needs to be fully resolved. Although, given the historical confusion over names and their unique geographical origins, there has already been considerable progress in this area. Achieving agreement on taxonomy will allow more effective collaboration across countries, which could be important since the disease continues to spread internationally, having recently established in the USA.

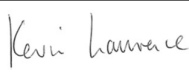
Appendix 1

Statements of Contribution for each published chapter presented in this thesis

Statement of contribution Chapter 2

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

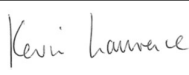
We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate:	Mr. Kevin Edward Lawrence
Name/title of Principal Supervisor:	Professor William Ernest Pomroy
Name of Research Output and full reference:	
Lawrence, K., McFadden, A., Gias, E., Pulford, D., Pomroy, W., 2016. Epidemiology of the epidemic of bovine anaemia associated with <i>Theileria orientalis</i> (Ikeda) between August 2012 and March 2014. New Zealand veterinary journal 64, 38-47.	
In which Chapter is the Manuscript/Published work:	Chapter 2
Please indicate:	
The percentage of the Manuscript/Published Work that was contributed by the candidate:	70%
and	
Describe the contribution that the candidate has made to the Manuscript/Published Work:	
The candidate helped maintain the <i>Theileria</i> data base, analysed the data, and wrote the manuscript	
For manuscripts intended for publication please indicate target journal:	
Candidate's Signature:	
Date:	27/1/2020
Primary Supervisor's Signature:	
Date:	27/1/2020

Statement of contribution Chapter 3

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

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Name of Candidate:	Mr. Kevin Edward Lawrence
Name/title of Principal Supervisor:	Professor William Ernest Pomroy
Name of Research Output and full reference:	
Lawrence, K., Gedye, K., McFadden, A., Pulford, D., Pomroy, W., 2016. An observational study of the vertical transmission of <i>Theileria orientalis</i> (Ikeda) in a New Zealand pastoral dairy herd. <i>Veterinary Parasitology</i> 218, 59-65.	
In which Chapter is the Manuscript/Published work:	Chapter 3
Please indicate:	
The percentage of the Manuscript/Published Work that was contributed by the candidate:	70%
and	
Describe the contribution that the candidate has made to the Manuscript/Published Work:	
The candidate designed the experiment, collected some of blood samples, analysed the data, performed the haematocrits, and wrote the manuscript	
For manuscripts intended for publication please indicate target journal:	
Candidate's Signature:	
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Statement of contribution Chapter 4

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Name of Candidate:	Mr. Kevin Edward Lawrence
Name/title of Principal Supervisor:	Professor William Ernest Pomroy
Name of Research Output and full reference:	
Lawrence, K., Forsyth, S., Vaatstra, B., McFadden, A., Pulford, D., Govindaraju, K., Pomroy, W., 2018. Clinical haematology and biochemistry profiles of cattle naturally infected with <i>Theileria orientalis</i> Ikeda type in New Zealand. New Zealand veterinary journal 66, 21-29.	
In which Chapter is the Manuscript/Published work:	Chapter 4
Please indicate:	
The percentage of the Manuscript/Published Work that was contributed by the candidate:	75%
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The candidate collated and entered all the laboratory results into an Access data base, analysed the data, and wrote the manuscript	
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Statement of contribution Chapter 5

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Name/title of Principal Supervisor:	Professor William Ernest Pomroy
Name of Research Output and full reference:	
Lawrence, K., Forsyth, S., Vaatstra, B., McFadden, A., Pulford, D., Govindaraju, R., Pomroy, W., 2017. Cluster analysis of the clinical histories of cattle affected with bovine anaemia associated with <i>Theileria orientalis</i> Ikeda type infection. New Zealand Veterinary Journal, 1-24.	
In which Chapter is the Manuscript/Published work:	Chapter 5
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Statement of contribution Chapter 6

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Name of Candidate:	Mr. Kevin Edward Lawrence
Name/title of Principal Supervisor:	Professor William Ernest Pomroy
Name of Research Output and full reference:	
Lawrence, K., Sanson, R., McFadden, A., Pulford, D., Pomroy, W., 2018. The effect of month, farm type and latitude on the level of anaemia associated with <i>Theileria orientalis</i> Ikeda type infection in New Zealand cattle naturally infected at pasture. Research in Veterinary Science 117, 233-238.	
In which Chapter is the Manuscript/Published work:	Chapter 6
Please indicate:	
The percentage of the Manuscript/Published Work that was contributed by the candidate:	80%
and	
Describe the contribution that the candidate has made to the Manuscript/Published Work:	
The candidate analysed the data, and wrote the manuscript	
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Date:	27/1/2020
Primary Supervisor's Signature:	
Date:	27/1/2020

Statement of contribution Chapter 7

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

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Name of Candidate:	Mr. Kevin Edward Lawrence
Name/title of Principal Supervisor:	Professor William Ernest Pomroy
Name of Research Output and full reference:	
Lawrence, K., Summers, S., Heath, A., McFadden, A., Pulford, D., Pomroy, W., 2016. Predicting the potential environmental suitability for <i>Theileria orientalis</i> transmission in New Zealand cattle using maximum entropy niche modelling. Veterinary parasitology 224, 82-91.	
In which Chapter is the Manuscript/Published work:	Chapter 7
Please indicate:	
The percentage of the Manuscript/Published Work that was contributed by the candidate:	80%
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Describe the contribution that the candidate has made to the Manuscript/Published Work:	
The candidate analysed the data, and wrote the manuscript	
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Date:	27/1/2020
Primary Supervisor's Signature:	
Date:	27/1/2020

Statement of contribution Chapter 8

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

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Name of Candidate:	Mr. Kevin Edward Lawrence
Name/title of Principal Supervisor:	Professor William Ernest Pomroy
Name of Research Output and full reference:	
Lawrence, K., Summers, S., Heath, A., McFadden, A., Pulford, D., Tait, A., Pomroy, W., 2017. Using a rule-based envelope model to predict the expansion of habitat suitability within New Zealand for the tick <i>Haemaphysalis longicornis</i> , with future projections based on two climate change scenarios. Veterinary parasitology 243, 226-234.	
In which Chapter is the Manuscript/Published work:	Chapter 8
Please indicate:	
The percentage of the Manuscript/Published Work that was contributed by the candidate:	80%
and	
Describe the contribution that the candidate has made to the Manuscript/Published Work:	
The candidate analysed the data, and wrote the manuscript	
For manuscripts intended for publication please indicate target journal:	
Candidate's Signature:	
Date:	27/1/2020
Primary Supervisor's Signature:	
Date:	27/1/2020

Statement of contribution Chapter 9

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

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Name of Candidate:	Mr. Kevin Edward Lawrence
Name/title of Principal Supervisor:	Professor William Ernest Pomroy
Name of Research Output and full reference:	
Lawrence, K. E., K. Gedy, and W. E. Pomroy. "A longitudinal study of the effect of <i>Theileria orientalis</i> Ikeda type infection on three New Zealand dairy farms naturally infected at pasture." <i>Veterinary parasitology</i> 276 (2019): 108977.	
In which Chapter is the Manuscript/Published work:	Chapter 9
Please indicate:	
The percentage of the Manuscript/Published Work that was contributed by the candidate:	75%
and	
Describe the contribution that the candidate has made to the Manuscript/Published Work:	
The candidate designed the experiment, collected all the samples, carried out some of the HCT and PCR work, analysed the data, and wrote the manuscript	
For manuscripts intended for publication please indicate target journal:	
Candidate's Signature:	
Date:	27/1/2020
Primary Supervisor's Signature:	
Date:	27/1/2020

Statement of contribution Chapter 10

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

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Name of Candidate:	Mr. Kevin Edward Lawrence
Name/title of Principal Supervisor:	Professor William Ernest Pomroy
Name of Research Output and full reference:	
Published as: Lawrence, K., McFadden, A., Bingham, P., Pulford, D., Vink, W., Pomroy, W., 2018. Prevalence studies for <i>Theileria orientalis</i> conducted during the early stages of the 2012 New Zealand epidemic of <i>Theileria</i> associated bovine anaemia. Veterinary Parasitology: Regional Studies and Reports 13, 38-44.	
In which Chapter is the Manuscript/Published work:	Chapter 10
Please indicate:	
The percentage of the Manuscript/Published Work that was contributed by the candidate:	65%
and	
Describe the contribution that the candidate has made to the Manuscript/Published Work:	
The candidate helped coordinate the collection of samples by practitioners, analysed the data, and wrote the manuscript	
For manuscripts intended for publication please indicate target journal:	
Candidate's Signature:	
Date:	27/1/2020
Primary Supervisor's Signature:	
Date:	27/1/2020

Appendix 2

The following tables contain the data sets used for most of the chapters presented in this thesis

Table 1. Cartesian coordinates of farm centroid, farm type and age group of cattle affected in *Theileria* associated bovine anaemia (TABA) epidemic up to March 2014, **Chapter 2.**

Easting	Northing	Date	Farm	Age	Easting	Northing	Date	Farm	Age
1896070.98	5741325.43	30/08/2012	Dairy	Adult	1803950.88	5842079.05	5/10/2013	Dairy	Adult
1712295.11	6039803.83	7/09/2012	Dairy	Adult	1815839.38	5848373.34	6/10/2013	Dairy	Adult
1626155.37	6097386.41	20/09/2012	Beef	Calf	1786703.37	5875035.55	7/10/2013	Dairy	Adult
1723961.34	5943544.3	20/09/2012	Dairy	Adult	1782778.61	5895907.59	7/10/2013	Dairy	Adult
1693765.9	6012719.16	25/09/2012	Beef	Calf	1633366.98	6106673.45	7/10/2013	Dairy	Adult
1822924.49	5494879	17/10/2012	Dairy	Adult	1661187.9	6030909.11	7/10/2013	Beef	Calf
1698720.37	6002366.04	19/10/2012	Beef	Calf	1828804.52	5785021	7/10/2013	Dairy	Adult
1686467.19	5996217.19	25/10/2012	Beef	Calf	1857844.63	5854884.64	7/10/2013	Dairy	Adult
1705731.69	6034079.08	30/10/2012	Beef	Calf	1734007.51	5980492.07	7/10/2013	Beef	Calf
1673904.36	6113134.49	31/10/2012	Beef	Calf	1768305.13	5808893.34	8/10/2013	Dairy	Adult
1720314.22	5994567.97	8/11/2012	Beef	Calf	1794689.17	5836782.26	8/10/2013	Dairy	Adult
1713055.48	6038887.64	20/11/2012	Beef	Calf	1761410.84	5839551.45	8/10/2013	Beef	Calf
1794827.32	5880306.02	20/11/2012	Beef	Calf	1688068.05	6003567.75	9/10/2013	Dairy	Calf
1660067.88	6127957.8	21/11/2012	Beef	Calf	1850289.35	5805612.82	9/10/2013	Dairy	Adult
1800257.96	5804659.57	4/12/2012	Beef	Calf	1795093.74	5800952.01	9/10/2013	Dairy	Adult
1671118.32	6021756.71	10/12/2012	Beef	Calf	1795067.54	5763067.2	10/10/2013	Dairy	Adult
1665418.95	6029822.36	10/12/2012	Beef	Calf	1815235.57	5862825.15	10/10/2013	Dairy	Adult
1723939.27	6029238.87	12/12/2012	Beef	Calf	1915410.56	5643400.72	10/10/2013	Dairy	Adult
1729464.15	6016816.65	12/12/2012	Dairy	Adult	1799536.57	5800476.27	10/10/2013	Dairy	Adult
1657846.37	6034995.33	12/12/2012	Beef	Calf	1777678.15	5739600.74	10/10/2013	Beef	Adult
1622428.15	6116069.49	13/12/2012	Beef	Calf	1775168.2	5753307.04	10/10/2013	Beef	Adult
1658694.31	6033616.34	13/12/2012	Beef	Calf	1786182.15	5744173.73	11/10/2013	Dairy	Adult
1679153.19	6030548.86	9/01/2013	Beef	Calf	1846511.58	5852132.11	14/10/2013	Dairy	Adult
1788514.33	5800695.01	4/03/2013	Dairy	Adult	1692401.51	6075290.73	14/10/2013	Dairy	Calf
1807695.54	5854089.07	20/03/2013	Beef	Adult	1790306.89	5757492.93	14/10/2013	Dairy	Adult
1788480.78	5852743.8	27/03/2013	Dairy	Adult	1768789.61	5809889.03	14/10/2013	Dairy	Adult
1805100.32	5853159.89	5/04/2013	Dairy	Adult	1779848.4	5743712.2	14/10/2013	Beef	Adult
1798494.42	5861409.58	5/04/2013	Dairy	Adult	1829355.94	5847957.78	14/10/2013	Dairy	Adult
1813560.81	5792036.19	8/04/2013	Dairy	Adult	1838312.35	5917601.04	14/10/2013	Dairy	Adult
1933739.77	5787643.07	9/04/2013	Dairy	Adult	1806868.68	5817109.39	14/10/2013	Dairy	Adult
1747239.42	5885474.33	10/04/2013	Dairy	Adult	1839945.76	5838059.05	15/10/2013	Dairy	Adult
1780240.88	5869009.42	11/04/2013	Dairy	Adult	1845637.69	5770699.42	15/10/2013	Dairy	Adult
1748648.65	5871756.59	11/04/2013	Dairy	Adult	1903617.43	5812444.14	15/10/2013	Beef	Adult
1555532.03	5201629.39	15/04/2013	Dairy	Adult	1808766.4	5841877.38	16/10/2013	Dairy	Adult
1819122.77	5856980.59	16/04/2013	Dairy	Adult	1788169.67	5815808.4	16/10/2013	Dairy	Adult
1763908.22	5874080.28	16/04/2013	Dairy	Adult	1665469.21	6111461.11	16/10/2013	Beef	Adult
1837068.89	5795590.14	22/04/2013	Dairy	Adult	1683055.39	6115933.11	16/10/2013	Beef	Adult
1788969.83	5821848.47	23/04/2013	Dairy	Adult	1848743.13	5785656.75	16/10/2013	Beef	Adult
1789247.7	5820159.48	23/04/2013	Dairy	Adult	1943236.73	5789286.87	16/10/2013	Dairy	Adult
1817868.25	5861542.24	26/04/2013	Dairy	Adult	1796225.25	5809832.79	17/10/2013	Dairy	Adult
1787228.4	5857626.37	27/04/2013	Dairy	Adult	1850470.73	5818752.72	17/10/2013	Dairy	Adult
1762630.32	5886658.12	27/04/2013	Dairy	Adult	1818676.71	5794921.62	17/10/2013	Dairy	Adult
1839115.23	5813130.44	1/05/2013	Dairy	Adult	1805022.15	5838077.2	17/10/2013	Dairy	Adult

1759278.08	5801319.14	6/05/2013	Beef	Adult	1806692.51	5842959.04	17/10/2013	Dairy	Adult
1769935.06	5812283.32	6/05/2013	Dairy	Adult	1810567.93	5874013.18	17/10/2013	Dairy	Adult
1761950.4	5890056.53	8/05/2013	Dairy	Adult	1793939.25	5789190.24	18/10/2013	Dairy	Adult
1622739.05	6123592.9	8/05/2013	Beef	Adult	1798002.49	5802297.94	18/10/2013	Dairy	Adult
1816771.24	5810158.04	9/05/2013	Dairy	Adult	1723354.19	5941237.17	21/10/2013	Beef	Calf
1837687.62	5807338.5	9/05/2013	Dairy	Adult	1825782.06	5818297.7	21/10/2013	Dairy	Adult
1823555.39	5840708.83	14/05/2013	Dairy	Adult	1688446.29	6107913.65	21/10/2013	Beef	Calf
1850563.12	5859415.41	14/05/2013	Dairy	Adult	1795689.55	5834987.23	22/10/2013	Dairy	Adult
1763110.36	5807538.37	15/05/2013	Dairy	Adult	1803419.31	5805329.9	22/10/2013	Dairy	Adult
1808574.31	5839040.33	15/05/2013	Dairy	Adult	1820794.41	5839091.71	22/10/2013	Dairy	Adult
1795099.56	5778604.33	17/05/2013	Dairy	Adult	1825299.26	5837799.98	22/10/2013	Dairy	Adult
1754185.78	5872151.09	29/05/2013	Dairy	Adult	1802788.18	5843777.45	22/10/2013	Dairy	Adult
1831787.66	5798816.19	29/05/2013	Dairy	Adult	1799969.65	5774636.61	22/10/2013	Dairy	Adult
1805870.1	5847607.75	6/06/2013	Dairy	Adult	1906095.36	5810565.47	22/10/2013	Dairy	Adult
1827331.79	5800155.31	19/06/2013	Dairy	Adult	1714245.63	5636859.58	23/10/2013	Dairy	Adult
1857756.15	5840785.25	19/06/2013	Beef	Adult	1798201.34	5762139.44	23/10/2013	Dairy	Adult
1810571.4	5774512.39	2/07/2013	Dairy	Adult	1822846.26	5843999.81	23/10/2013	Dairy	Adult
1802395.79	5856941.5	2/07/2013	Dairy	Adult	1777313.19	5746411.89	23/10/2013	Dairy	Adult
1841990.32	5799473.76	5/07/2013	Dairy	Adult	1872024.79	5783452.43	24/10/2013	Beef	Adult
1737496.99	5945019.8	5/07/2013	Dairy	Adult	1807217.81	5828751.97	24/10/2013	Dairy	Adult
1776532.9	5861048.88	8/07/2013	Beef	Adult	1849618.88	5774560.7	24/10/2013	Dairy	Adult
1718569.39	5953236.1	9/07/2013	Dairy	Adult	1849071.86	5850644.95	24/10/2013	Dairy	Adult
1812042.76	5794343.57	10/07/2013	Dairy	Adult	1928892.14	5745726.6	25/10/2013	Dairy	Adult
1704812.26	6032289.16	18/07/2013	Beef	Adult	1833163.56	5764676.37	25/10/2013	Dairy	Adult
1716171.14	6005358.97	25/07/2013	Beef	Adult	1751877.08	5869978.71	25/10/2013	Dairy	Adult
1690042.75	6096358.08	26/07/2013	Dairy	Adult	1634555.38	6128020.41	25/10/2013	Beef	Adult
1785008.18	5850906.62	29/07/2013	Dairy	Adult	1846155.82	5849580.14	26/10/2013	Beef	Adult
1692861.8	6048808.27	29/07/2013	Dairy	Adult	1827641.33	5840050.01	28/10/2013	Dairy	Adult
1616439.51	6136072.15	31/07/2013	Dairy	Adult	1846133.94	5835441.84	29/10/2013	Dairy	Adult
1769310.53	5884079.74	31/07/2013	Dairy	Adult	1777159.54	5724118.7	29/10/2013	Dairy	Adult
1746448.29	5946722.38	31/07/2013	Dairy	Adult	1794536.66	5804140.39	29/10/2013	Dairy	Adult
1828772.55	5873784.94	3/08/2013	Dairy	Adult	1799551.2	5737596.01	29/10/2013	Beef	Adult
1783108.14	5875626.67	6/08/2013	Dairy	Adult	1758981.95	5870368.24	29/10/2013	Dairy	Adult
1835574.01	5857690.63	9/08/2013	Dairy	Adult	1822372.17	5819587.63	29/10/2013	Dairy	Adult
1821942.45	5877304.09	10/08/2013	Dairy	Adult	1779574.17	5756728.26	30/10/2013	Beef	Adult
1791079.04	5792000.18	12/08/2013	Dairy	Adult	1700892.73	5662527.91	30/10/2013	Dairy	Adult
1783771.44	5780017.98	12/08/2013	Dairy	Adult	1813762.27	5864426.1	30/10/2013	Dairy	Adult
1821002.06	5816033.62	13/08/2013	Dairy	Adult	1803454.51	5893909.12	30/10/2013	Dairy	Adult
1951310.03	5781567.73	13/08/2013	Dairy	Adult	1843413.24	5828965.93	30/10/2013	Dairy	Adult
1788955.73	5847505.57	13/08/2013	Dairy	Adult	1803303.18	5799284.84	31/10/2013	Dairy	Adult
1770533.8	5813749.08	16/08/2013	Dairy	Adult	1807760.21	5759221.45	31/10/2013	Dairy	Adult
1797039.41	5769052.09	16/08/2013	Dairy	Adult	1832029.05	5867235.62	31/10/2013	Dairy	Adult
1792051.41	5798806.6	17/08/2013	Dairy	Adult	1791875.01	5796089.37	31/10/2013	Dairy	Adult
1950217.42	5780713.73	17/08/2013	Dairy	Adult	1787143.4	5868795.42	31/10/2013	Dairy	Adult
1881826.52	5795706.4	18/08/2013	Dairy	Adult	1806362.87	5696480.24	1/11/2013	Beef	Adult
1765440.56	5870739.17	19/08/2013	Dairy	Adult	1839270.23	5868318.93	1/11/2013	Dairy	Adult

1779033.7	5811396.56	19/08/2013	Beef	Adult	1832444.91	5833147.4	1/11/2013	Dairy	Adult
1726298.08	5986720	20/08/2013	Dairy	Adult	1766607.37	5881999.39	4/11/2013	Dairy	Adult
1688135.96	6019595.32	20/08/2013	Dairy	Adult	1867422.97	5817727.56	4/11/2013	Dairy	Adult
1791982.44	5759952.36	20/08/2013	Dairy	Adult	1762616.87	5802593.11	4/11/2013	Beef	Adult
1764640.33	5807590.47	20/08/2013	Dairy	Adult	1809999.92	5877344.69	4/11/2013	Dairy	Adult
1795894.59	5762984.92	21/08/2013	Dairy	Adult	1821982.94	5816186.31	5/11/2013	Dairy	Adult
1808897.69	5798812.84	21/08/2013	Dairy	Adult	1804087.86	5834808.38	5/11/2013	Dairy	Adult
1741159.53	5984849.5	23/08/2013	Dairy	Calf	1762538.3	5804024.33	5/11/2013	Dairy	Adult
1756896.3	5589811.73	23/08/2013	Dairy	Adult	1794084.41	5783624.26	6/11/2013	Dairy	Adult
1671557.56	6032075.94	23/08/2013	Dairy	Adult	1831108.85	5841162.1	6/11/2013	Dairy	Adult
1780223.5	5783791.11	23/08/2013	Dairy	Adult	1837316.33	5868446.86	6/11/2013	Dairy	Adult
1794738.59	5873926.96	23/08/2013	Dairy	Adult	1778192.55	5724895.16	6/11/2013	Dairy	Adult
1812738.3	5873648.78	26/08/2013	Dairy	Adult	1644618.42	6124568.36	7/11/2013	Dairy	Adult
1755202.6	5849248.34	26/08/2013	Beef	Adult	1814204.48	5873957.17	7/11/2013	Beef	Adult
1820876.07	5834912.27	26/08/2013	Dairy	Adult	1799726.62	5844407.49	8/11/2013	Dairy	Adult
1978002.16	5784344.32	27/08/2013	Dairy	Adult	2010540.96	5673168.57	8/11/2013	Beef	Calf
1812318.39	5801047.86	27/08/2013	Dairy	Adult	1729195.35	5685822.49	8/11/2013	Dairy	Adult
1765557.41	5881662.78	27/08/2013	Beef	Adult	1814629.03	5793645.16	11/11/2013	Dairy	Adult
1813495.22	5875848.43	28/08/2013	Dairy	Adult	1713321.11	5957199.83	11/11/2013	Beef	Calf
1774483.93	5904089.86	28/08/2013	Dairy	Adult	1817788.5	5871774.44	11/11/2013	Dairy	Adult
1806339.06	5803784.61	29/08/2013	Beef	Adult	1695057.18	6007730.75	12/11/2013	Beef	Calf
1787952.99	5844723.44	30/08/2013	Dairy	Adult	2000622.05	5733826.65	12/11/2013	Beef	Adult
1870409.63	5746471.4	1/09/2013	Dairy	Adult	1782673.21	5852829.72	13/11/2013	Beef	Adult
1792837.44	5859012.37	2/09/2013	Dairy	Adult	1811548.91	5836046.67	13/11/2013	Dairy	Adult
1766375.6	5887988.58	3/09/2013	Dairy	Adult	1936651.46	5760083.95	13/11/2013	Dairy	Adult
1789827.94	5874053.5	3/09/2013	Dairy	Adult	1823820.36	5868169.8	13/11/2013	Dairy	Adult
1950498.95	5775731.6	3/09/2013	Dairy	Adult	1827584.95	5872035.84	13/11/2013	Dairy	Adult
1821268.26	5773214.89	4/09/2013	Dairy	Adult	1811475.92	5841605.04	14/11/2013	Dairy	Adult
1790374.33	5776886.71	4/09/2013	Dairy	Adult	1801544.95	5785992.91	14/11/2013	Dairy	Adult
1808450.83	5870991.09	4/09/2013	Dairy	Adult	1834051.78	5805021.2	14/11/2013	Dairy	Adult
1778712.08	5743978.23	5/09/2013	Dairy	Adult	1811033.4	5839432.33	15/11/2013	Dairy	Adult
1865853.63	5746226.68	5/09/2013	Dairy	Adult	1848279.72	5855294.93	15/11/2013	Dairy	Adult
1748109.38	5588636.53	5/09/2013	Dairy	Adult	1816902.49	5860301.64	16/11/2013	Dairy	Adult
1813492.84	5870248.09	5/09/2013	Dairy	Adult	1725899.74	5937957.55	18/11/2013	Beef	Calf
1803782.83	5686967.9	6/09/2013	Dairy	Adult	1865868.43	5733753.49	18/11/2013	Beef	Adult
1836748.91	5841374.7	6/09/2013	Dairy	Adult	1831151.23	5853333.98	18/11/2013	Dairy	Adult
1807931.48	5778453.33	6/09/2013	Dairy	Adult	1955769.7	5776840.04	18/11/2013	Beef	Calf
1801460.15	5780278.43	6/09/2013	Dairy	Adult	1845267.82	5759560.01	20/11/2013	Dairy	Adult
1797955	5906539.25	6/09/2013	Beef	Adult	1819583.79	5761691.69	20/11/2013	Beef	Adult
1823563.92	5878214.19	6/09/2013	Dairy	Adult	1838809.65	5836721.47	21/11/2013	Dairy	Adult
1783376.91	5568760.28	9/09/2013	Dairy	Adult	1652883.91	6111584.63	21/11/2013	Beef	Adult
1798860.07	5861533.06	9/09/2013	Dairy	Adult	1814758.96	5789038.73	22/11/2013	Dairy	Adult
1834406.78	5817286.81	9/09/2013	Dairy	Adult	1633918.29	6106789.79	23/11/2013	Beef	Calf
1826485.82	5819726.04	9/09/2013	Dairy	Adult	1838748.62	5851736.36	23/11/2013	Beef	Adult
1714905.11	6032044.72	10/09/2013	Beef	Calf	1840868.55	5781620.55	23/11/2013	Dairy	Adult
1804335.61	5801420.38	10/09/2013	Dairy	Adult	1801824.64	5806169.62	25/11/2013	Dairy	Adult

1787646.53	5802292.29	11/09/2013	Dairy	Adult	1690777.33	5667420.71	25/11/2013	Dairy	Adult
1818008.83	5830392.22	11/09/2013	Dairy	Adult	1810991.98	5840945.82	27/11/2013	Dairy	Adult
1818799.91	5858722.03	12/09/2013	Dairy	Adult	1798950.21	5848596.65	27/11/2013	Dairy	Adult
1787781	5799705.87	12/09/2013	Dairy	Adult	1801217.12	5843330.6	27/11/2013	Dairy	Adult
1824845.86	5838312.54	12/09/2013	Dairy	Adult	1804048	5831400.59	28/11/2013	Dairy	Adult
1783758.32	5752844.52	12/09/2013	Dairy	Adult	1788880.35	5798458.33	28/11/2013	Dairy	Adult
1808548.55	5777174.95	12/09/2013	Dairy	Adult	1707435.81	6042145.37	28/11/2013	Beef	Calf
1814831.4	5869818.46	12/09/2013	Dairy	Adult	1818569.78	5809421.08	29/11/2013	Dairy	Adult
1793392.71	5871084.31	12/09/2013	Dairy	Adult	1785800.56	5890155.63	29/11/2013	Beef	Calf
1788891.14	5757164.6	16/09/2013	Dairy	Adult	1835833.47	5831061.53	1/12/2013	Dairy	Adult
1790739.13	5765051.14	16/09/2013	Dairy	Adult	1832100.45	5814765.56	2/12/2013	Dairy	Adult
1817449.53	5852024.97	16/09/2013	Beef	Adult	1808630.97	5835085.3	3/12/2013	Dairy	Adult
1844868.59	5854225.8	16/09/2013	Dairy	Adult	2022112.82	5738196.95	4/12/2013	Beef	Adult
1813629.29	5782410.07	17/09/2013	Dairy	Adult	1727318.9	6004913.28	5/12/2013	Dairy	Calf
1801099.84	5794386.57	17/09/2013	Dairy	Adult	1805460.8	5865040.21	6/12/2013	Beef	Calf
1683488.68	6031366.76	17/09/2013	Dairy	Calf	1606915.03	6150117.65	6/12/2013	Beef	Adult
1893008.98	5817381.12	17/09/2013	Dairy	Adult	1791220.33	5769236.93	8/12/2013	Dairy	Adult
1634192.73	6098119.72	17/09/2013	Dairy	Calf	1737826.8	5960902.9	9/12/2013	Beef	Calf
1798802.83	5787340.75	17/09/2013	Dairy	Adult	1976919.88	5684264.81	9/12/2013	Beef	Calf
1797349.06	5840225.46	18/09/2013	Dairy	Adult	1834013.34	5854141.52	10/12/2013	Dairy	Adult
1828473.68	5862407.87	18/09/2013	Dairy	Adult	1732464.22	5977674.42	10/12/2013	Beef	Adult
1817036.12	5768025.68	18/09/2013	Dairy	Adult	1753254.07	5871293.64	11/12/2013	Dairy	Adult
1820574.84	5875087.69	18/09/2013	Dairy	Adult	1837306.7	5806105.33	11/12/2013	Beef	Adult
1756464.89	5871137.1	18/09/2013	Dairy	Adult	1735252.15	5959151.36	11/12/2013	Dairy	Adult
1844628.2	5856115.75	18/09/2013	Dairy	Adult	1847385.12	5828064.76	11/12/2013	Dairy	Adult
1858880.18	5852738.97	18/09/2013	Dairy	Adult	1821563.42	5853946.04	12/12/2013	Dairy	Adult
1836690.86	5792263.44	18/09/2013	Dairy	Adult	1811909.44	5845195.48	12/12/2013	Dairy	Adult
1673866.78	6104213.47	19/09/2013	Dairy	Adult	1699802.17	6048190.37	12/12/2013	Dairy	Calf
1914047.12	5802731.2	19/09/2013	Dairy	Adult	1833166.58	5812990.19	13/12/2013	Dairy	Adult
1801995.31	5773729.12	19/09/2013	Dairy	Adult	1831441.49	5874250.76	17/12/2013	Dairy	Adult
1797079.54	5905148.56	19/09/2013	Beef	Adult	1972707.33	5687870.39	18/12/2013	Beef	Adult
1783296.78	5845214.58	20/09/2013	Dairy	Adult	1938597.33	5794627.35	19/12/2013	Dairy	Adult
1795361.78	5771474.41	20/09/2013	Dairy	Adult	1777782.91	5756150.06	19/12/2013	Dairy	Calf
1880658.02	5804176.59	20/09/2013	Dairy	Adult	1710195.52	6069712.61	19/12/2013	Dairy	Adult
1848302.69	5807178.21	20/09/2013	Dairy	Adult	1641330.35	6125340	20/12/2013	Beef	Adult
1831631.19	5810595.15	23/09/2013	Dairy	Adult	1791020.07	5798621.98	20/12/2013	Dairy	Adult
1797144.3	5881071.97	23/09/2013	Dairy	Adult	1800027.95	5785540.39	23/12/2013	Dairy	Calf
1891699.4	5817555.89	24/09/2013	Dairy	Adult	1834754.02	5875858.45	23/12/2013	Dairy	Adult
1785507.97	5838679.45	24/09/2013	Dairy	Adult	1911507.49	5806494.56	23/12/2013	Dairy	Adult
2047380.75	5721480.98	24/09/2013	Beef	Adult	1824501.64	5847426.58	23/12/2013	Dairy	Adult
1787707.62	5800509.42	24/09/2013	Dairy	Adult	1825328.9	5847145.3	24/12/2013	Dairy	Adult
1718747.1	6065046.94	24/09/2013	Beef	Calf	1831462.66	5767749.12	27/12/2013	Dairy	Adult
1766015.67	5895422.62	25/09/2013	Dairy	Adult	1895678.42	5816473.03	27/12/2013	Dairy	Adult
1755296.59	5589875.2	25/09/2013	Dairy	Adult	1803530.33	5804500	30/12/2013	Dairy	Adult
1846663.5	5892146.87	26/09/2013	Dairy	Adult	1786099.15	5758165.95	30/12/2013	Dairy	Adult
1792918.35	5850973.05	26/09/2013	Dairy	Adult	1820603.07	5809388.3	30/12/2013	Dairy	Adult

1818431.56	5817861.91	26/09/2013	Dairy	Adult	1823170.08	5867968.39	31/12/2013	Dairy	Adult
1902805.37	5734801.69	26/09/2013	Dairy	Adult	1799423.64	5839251.85	3/01/2014	Dairy	Adult
1778986.65	5805959.37	26/09/2013	Dairy	Adult	1801605.46	5793985.9	3/01/2014	Dairy	Adult
1804412.15	5783450.08	26/09/2013	Dairy	Adult	1835937.38	5737547.05	6/01/2014	Dairy	Adult
1815790.99	5863590.11	26/09/2013	Dairy	Adult	1822178.88	5866883.27	7/01/2014	Beef	Adult
1793809.72	5807260.71	26/09/2013	Dairy	Adult	1949465.44	5782186.02	7/01/2014	Dairy	Adult
1804857.53	5766401.98	26/09/2013	Dairy	Adult	1797885.28	5770233.8	7/01/2014	Dairy	Adult
1784226.94	5751287.03	26/09/2013	Dairy	Adult	1796689.14	5800221.63	8/01/2014	Dairy	Adult
1623701.26	6101780.54	26/09/2013	Beef	Calf	1796447.07	5835886.45	9/01/2014	Dairy	Adult
1813740.8	5865256.17	26/09/2013	Dairy	Adult	1813865.87	5822844.05	9/01/2014	Dairy	Adult
1741097.33	5987801.99	26/09/2013	Beef	Calf	1792165.68	5781972.29	10/01/2014	Dairy	Adult
1842624.41	5924708.13	27/09/2013	Beef	Adult	1836674.41	5825437.9	10/01/2014	Dairy	Adult
1827491.09	5869834.01	27/09/2013	Dairy	Adult	1890554.88	5736433.37	11/01/2014	Dairy	Adult
1846799.42	5815065.76	27/09/2013	Beef	Adult	1845185.87	5820566.17	13/01/2014	Dairy	Adult
1797779.95	5842871.41	27/09/2013	Dairy	Adult	1836072.94	5865264.32	13/01/2014	Dairy	Adult
1809888.88	5809291.17	27/09/2013	Dairy	Adult	1778583.54	5757688.28	13/01/2014	Beef	Adult
1840681.9	5734678.04	27/09/2013	Dairy	Adult	1675434.51	5664058.63	14/01/2014	Dairy	Adult
1823842.86	5848157.97	27/09/2013	Dairy	Adult	1708408.2	5669303.95	14/01/2014	Dairy	Adult
1838318.73	5790527.87	27/09/2013	Dairy	Adult	1845898.85	5887277.28	14/01/2014	Beef	Calf
1714198.14	6015043.79	28/09/2013	Beef	Adult	1931966.64	5789479.67	14/01/2014	Dairy	Adult
1838963.4	5847026.68	28/09/2013	Dairy	Adult	1804662.97	5841540.93	16/01/2014	Dairy	Adult
1825676.87	5777632.91	30/09/2013	Dairy	Calf	1747004.24	5971492.7	16/01/2014	Beef	Calf
1821949.94	5838454.79	30/09/2013	Dairy	Adult	1797246.48	5886927.34	17/01/2014	Beef	Calf
1819705.36	5824061.31	30/09/2013	Dairy	Adult	1938763.38	5787841.91	17/01/2014	Dairy	Adult
1819854.63	5848892.87	30/09/2013	Dairy	Adult	1726004.57	5981334.61	20/01/2014	Beef	Calf
1813029.33	5846530.55	30/09/2013	Dairy	Adult	1831662.26	5815757.8	20/01/2014	Dairy	Adult
1802005.95	5798717.29	30/09/2013	Dairy	Adult	1844531.84	5793121.49	22/01/2014	Dairy	Adult
1797125.95	5774861.48	30/09/2013	Dairy	Adult	1930130.11	5793343.08	22/01/2014	Dairy	Adult
1786423.66	5801575.28	30/09/2013	Dairy	Adult	1840268.64	5798055.3	23/01/2014	Dairy	Adult
1762229.1	5874307.02	1/10/2013	Dairy	Adult	1819930.38	5869640.02	24/01/2014	Dairy	Adult
1847167.79	5892723.42	1/10/2013	Dairy	Adult	1803918.41	5869636.07	24/01/2014	Dairy	Adult
1802204.01	5860569.63	1/10/2013	Dairy	Adult	1808274.03	5789979.18	24/01/2014	Dairy	Calf
1809487.48	5821528.21	1/10/2013	Dairy	Adult	1836360.31	5768302.15	25/01/2014	Dairy	Adult
1892077.85	5806591.27	1/10/2013	Dairy	Adult	1833849.24	5780655.88	25/01/2014	Dairy	Adult
1749365.66	5587856.58	1/10/2013	Dairy	Adult	2021521.8	5659823.08	28/01/2014	Beef	Adult
1828796.07	5878258.66	1/10/2013	Dairy	Adult	1712433.2	5955860.69	28/01/2014	Dairy	Adult
1789951.17	5775108.64	1/10/2013	Beef	Adult	1854882.79	5840124.56	28/01/2014	Dairy	Calf
1814065.93	5850032.65	1/10/2013	Dairy	Adult	1942093.49	5793257.03	28/01/2014	Dairy	Adult
1796387.83	5849953.45	2/10/2013	Dairy	Adult	1870723.52	5785029.56	28/01/2014	Beef	Adult
1788935.83	5802143.09	2/10/2013	Dairy	Adult	1803347.16	5540425.27	28/01/2014	Dairy	Adult
1645808.03	6094936.35	2/10/2013	Beef	Calf	1817941.2	5869169.28	30/01/2014	Dairy	Adult
1823912.19	5868504.82	2/10/2013	Dairy	Adult	2010292.04	5717184.76	31/01/2014	Beef	Adult
1880717.58	5805470.33	2/10/2013	Dairy	Adult	1805603.35	5878995.42	11/02/2014	Dairy	Adult
1807579.31	5829619.32	2/10/2013	Dairy	Adult	1809737.19	5834950.15	13/02/2014	Dairy	Adult
1776221.77	5841465.95	2/10/2013	Beef	Adult	1886965.14	5803039.42	13/02/2014	Beef	Adult
1814189.52	5827489.97	2/10/2013	Dairy	Adult	1790484.85	5907586.52	13/02/2014	Beef	Calf

1800545.17	5841203.66	2/10/2013	Dairy	Adult	1821903.24	5832460.16	13/02/2014	Dairy	Adult
1817953.58	5817256.83	3/10/2013	Dairy	Adult	1936990.77	5797389.09	13/02/2014	Dairy	Adult
1773123.87	5820272.25	3/10/2013	Dairy	Adult	1718908.79	5995679.7	13/02/2014	Beef	Adult
1820164.13	5843300.76	3/10/2013	Dairy	Adult	1855167.53	5832197.95	14/02/2014	Beef	Adult
1832385.26	5825539.32	3/10/2013	Dairy	Adult	1806628.97	5825935.81	14/02/2014	Dairy	Adult
1677113.26	6012204.21	3/10/2013	Dairy	Calf	1796222.63	5777985.47	17/02/2014	Dairy	Adult
1826581.28	5838703.79	3/10/2013	Dairy	Adult	1791428.12	5824763.89	17/02/2014	Dairy	Adult
1794135.55	5820432.98	3/10/2013	Dairy	Adult	1938776.57	5793829.67	18/02/2014	Dairy	Adult
2049739.65	5715974.01	4/10/2013	Beef	Calf	1872203.04	5820886.18	18/02/2014	Beef	Calf
1730471.88	6060116.1	4/10/2013	Dairy	Calf	1813425.36	5843880.57	19/02/2014	Dairy	Calf
1792185.11	5784232.08	4/10/2013	Dairy	Adult	1727594.98	6028163.37	20/02/2014	Dairy	Adult
1847381.37	5824925.09	4/10/2013	Dairy	Adult	1840166.48	5812719	21/02/2014	Dairy	Adult
1806866.34	5844969.05	4/10/2013	Beef	Adult	1820979.58	5845950.27	26/02/2014	Dairy	Adult
1767703.53	5799626.85	4/10/2013	Dairy	Adult	1798191.85	5829420.2	27/02/2014	Dairy	Adult
1798804.88	5863089.36	4/10/2013	Dairy	Adult	1786427.17	5487886.61	28/02/2014	Beef	Adult
1787728.02	5754675.92	4/10/2013	Dairy	Adult	1845875.57	5829328.71	3/03/2014	Dairy	Calf
1793091.54	5738426.37	4/10/2013	Dairy	Adult	1790750.66	5803522.98	3/03/2014	Dairy	Adult
1812366.48	5775576.99	4/10/2013	Dairy	Adult	1823526.27	5819548.52	3/03/2014	Dairy	Adult
1716099.26	5972716.51	4/10/2013	Beef	Adult	1985762.79	5785760.67	3/03/2014	Dairy	Adult
1801944.3	5890615.76	5/10/2013	Dairy	Adult	1853969.47	5872444.78	4/03/2014	Dairy	Adult
1806776.97	5878073.85	5/10/2013	Dairy	Adult	1910686.43	5806045.67	4/03/2014	Dairy	Adult

Table 2. Data for 97 cows and their calves sampled at birth, **Chapter 3.**

Cowno	Date	age	Cow calf sampled at birth			Calfno	Calfsex	Calf Ikeda
			copies/ μ L	Cow Ikeda	Cow HCT ¹			
1	27/07/2014	3	---	Negative	30.5	34	F	Negative
4	2/08/2014	3	---	Negative	33.5	68	F	Negative
7	26/07/2014	3	42561	Positive	27	33	F	Negative
11	30/07/2014	7	586500	Positive	30	232	B	Negative
13	3/08/2014	9	66972	Positive	29.5	249	B	Negative
15	23/07/2014	3	---	Negative	36	17	F	Negative
16	28/07/2014	3	---	Negative	34	214	B	Negative
25	2/08/2014	3	135056	Positive	31	239	B	Negative
26	31/07/2014	4	---	Negative	34	61	F	Negative
27	30/07/2014	3	---	Negative	32.5	52	F	Negative
31	22/07/2014	3	72372	Positive	29	13	F	Negative
33	5/08/2014	4	---	Negative	30	83	F	Negative
43	22/07/2014	4	674611	Positive	32	11	F	Negative
45	2/08/2014	6	93083	Positive	28	66	F	Negative
53	31/07/2014	6	350333	Positive	27.5	237	B	Negative
63	27/07/2014	8	59378	Positive	32	210	B	Negative
64	29/07/2014	11	114850	Positive	25	44	F	Negative
74	30/07/2014	4	---	Negative	30	53	F	Negative
79	24/07/2014	6	148439	Positive	32	22	F	Negative
82	24/07/2014	6	103867	Positive	---	24	F	Negative
90	1/08/2014	3	---	Negative	35	244	B	Negative
91	3/08/2014	8	188678	Positive	24	70	F	Negative
100	26/07/2014	4	222944	Positive	29	29	F	Negative
116	2/08/2014	6	244389	Positive	29.5	67	F	Negative
118	27/07/2014	4	69400	Positive	29.5	208	B	Negative
123	27/07/2014	4	66122	Positive	27	206	B	Negative
130	31/07/2014	4	---	Negative	31	236	B	Negative
141	26/07/2014	3	---	Negative	33	32	F	Negative
144	24/07/2014	3	---	Negative	31	21	F	Negative
145	1/08/2014	4	---	Negative	36	245	B	Negative
146	3/08/2014	7	41767	Positive	29	73	F	Negative
147	28/07/2014	3	---	Negative	38	215	B	Negative
148	2/08/2014	6	1222056	Positive	19	246	B	Negative
154	1/08/2014	8	95056	Positive	30	63	F	Negative
165	3/08/2014	4	149000	Positive	29	248	B	Negative
189	5/08/2014	3	---	Negative	34.5	87	F	Negative
192	25/07/2014	6	494000	Positive	27.5	25	F	Negative
196	26/07/2014	5	21867	Positive	32	203	B	Negative
199	31/07/2014	4	---	Negative	29.5	57	F	Negative
201	28/07/2014	3	---	Negative	31.5	39	F	Negative
207	30/07/2014	3	---	Negative	31	55	F	Negative
221	30/07/2014	3	---	Negative	33	51	F	Negative

224	31/07/2014	4	33317	Positive	29	233	B	Negative
226	1/08/2014	5	97744	Positive	28	65	F	Negative
234	22/07/2014	6	166972	Positive	27	14	F	Negative
242	29/07/2014	9	39867	Positive	27	43	F	Negative
272	30/07/2014	4	---	Negative	34	49	F	Negative
273	29/07/2014	5	---	Negative	34	219	B	Negative
284	2/08/2014	4	3081111	Positive	12.5	69	F	Negative
290	5/08/2014	4	---	Negative	34	84	F	Negative
304	31/07/2014	9	54250	Positive	29	240	B	Negative
310	5/08/2014	10	27450	Positive	31.5	85	F	Negative
312	30/07/2014	3	---	Negative	35	50	F	Negative
318	24/07/2014	11	95156	Positive	---	20	F	Negative
320	1/08/2014	4	196	Positive	33	62	F	Negative
323	3/08/2014	6	54761	Positive	30.5	250	B	Negative
327	22/07/2014	4	32244	Positive	28	12	F	Negative
339	31/07/2014	4	22628	Positive	31	58	F	Negative
348	5/08/2014	6	---	Negative	34	86	F	Negative
350	26/07/2014	7	60944	Positive	28	202	B	Negative
357	3/08/2014	4	2574	Positive	31	74	F	Negative
360	28/07/2014	5	---	Negative	26	38	F	Negative
375	3/08/2014	3	---	Negative	33.5	247	B	Negative
377	5/08/2014	6	168278	Positive	31	258	B	Negative
398	25/07/2014	6	11638	Positive	29.5	28	F	Negative
404	29/07/2014	3	5904	Positive	30.5	45	F	Negative
405	28/07/2014	3	---	Negative	30	41	F	Negative
413	27/07/2014	5	2393	Positive	35	207	B	Negative
417	26/07/2014	5	---	Negative	33.5	31	F	Negative
418	30/07/2014	3	---	Negative	31	230	B	Negative
421	26/07/2014	8	109656	Positive	27	201	B	Negative
422	27/07/2014	3	---	Negative	32.5	204	B	Negative
434	31/07/2014	11	77839	Positive	---	234	B	Negative
466	27/07/2014	5	45389	Positive	26	35	F	Negative
471	23/07/2014	4	66	Positive	27	18	F	Negative
472	29/07/2014	3	501	Positive	34	42	F	Negative
474	23/07/2014	4	---	Negative	30	19	F	Negative
494	23/07/2014	6	58117	Positive	29	16	F	Negative
496	27/07/2014	6	51322	Positive	26.5	36	F	Negative
499	4/08/2014	4	---	Negative	33	76	F	Negative
503	1/08/2014	5	250444	Positive	27.5	64	F	Negative
505	1/08/2014	5	---	Negative	35	238	B	Negative
514	30/07/2014	5	348333	Positive	30	235	B	Negative
515	31/07/2014	7	60628	Positive	32	60	F	Negative
530	29/07/2014	4	---	Negative	33	217	B	Negative
531	22/07/2014	5	200494	Positive	29	15	F	Negative
536	27/07/2014	3	---	Negative	30.5	37	F	Negative
538	27/07/2014	3	---	Negative	30	205	B	Negative

543	25/07/2014	9	81739	Positive	30	26	F	Negative
561	29/07/2014	7	1450167	Positive	27	47	F	Negative
561	29/07/2014	7	1450167	Positive	27	218	B	Negative
576	30/07/2014	3	---	Negative	28	231	B	Negative
580	31/07/2014	8	219833	Positive	28.5	59	F	Negative
592	25/07/2014	3	---	Negative	35	27	F	Negative
594	29/07/2014	3	---	Negative	34	228	B	Negative
599	30/07/2014	3	---	Negative	33	56	F	Negative
605	28/07/2014	3	---	Negative	33.5	211	B	Negative

¹Cow HCT measured on blood collected on 11/08/2014, sample taken at calving was immediately frozen

Table 3. Results from sampling 91 calves at 4 months of age, **Chapter 3.**

Cowno	Calfno	Calf sampled at 4 months old				Calf Ikeda
		Date	Calf HCT	copies/ μ L	age/days	
1	34	3/12/2014	31	698778	129	Positive
4	68	3/12/2014	33.5	330833	123	Positive
7	33	3/12/2014	35.5	---	130	Negative
11	232	3/12/2014	33	452167	126	Positive
13	249	3/12/2014	29.5	635667	122	Positive
15	17	3/12/2014	39	469500	133	Positive
16	214	3/12/2014	32.5	737778	128	Positive
25	239	3/12/2014	32	475944	123	Positive
26	61	3/12/2014	31	926611	125	Positive
27	52	3/12/2014	36	---	126	Negative
31	13	3/12/2014	29	1328278	134	Positive
33	83	3/12/2014	28	786389	120	Positive
43	11	NA	NA	NA	NA	NA
45	66	3/12/2014	27	1582222	123	Positive
53	237	3/12/2014	33.5	92011	125	Positive
63	210	3/12/2014	33.5	10907	129	Positive
64	44	3/12/2014	26.5	317491	127	Positive
74	53	3/12/2014	39	---	126	Negative
79	22	3/12/2014	29	850333	132	Positive
82	24	3/12/2014	31	640778	132	Positive
90	244	3/12/2014	40.5	---	124	Negative
91	70	3/12/2014	34	988222	122	Positive
100	29	3/12/2014	30	451389	130	Positive
116	67	3/12/2014	32.5	1506278	123	Positive
118	208	3/12/2014	27	1286222	129	Positive
123	206	3/12/2014	28.5	1532000	129	Positive
130	236	3/12/2014	26	3153889	125	Positive
141	32	3/12/2014	33	133672	130	Positive
144	21	3/12/2014	30	1440222	132	Positive
145	245	3/12/2014	36.5	323667	124	Positive
146	73	3/12/2014	36	---	122	Negative
147	215	3/12/2014	28.5	1487111	128	Positive
148	246	3/12/2014	30	312444	123	Positive
154	63	3/12/2014	30	739611	124	Positive
165	248	3/12/2014	34.5	248889	122	Positive
189	87	3/12/2014	27	741556	120	Positive
192	25	3/12/2014	29	864000	131	Positive
196	203	3/12/2014	32.5	1193500	130	Positive
199	57	3/12/2014	24	1235833	125	Positive
201	39	3/12/2014	30	854500	128	Positive
207	55	3/12/2014	35.5	344389	126	Positive
221	51	NA	NA	NA	NA	NA

224	233	3/12/2014	25.5	1060778	125	Positive
226	65	3/12/2014	36	1268	124	Positive
234	14	3/12/2014	32	1485833	134	Positive
242	43	3/12/2014	31	2090000	127	Positive
272	49	3/12/2014	29	2313889	126	Positive
273	219	3/12/2014	31	1800722	127	Positive
284	69	3/12/2014	36.5	422944	123	Positive
290	84	3/12/2014	39	---	120	Negative
304	240	3/12/2014	30	977167	125	Positive
310	85	3/12/2014	40.5	---	120	Negative
312	50	3/12/2014	35.5	573333	126	Positive
318	20	NA	NA	NA	NA	NA
320	62	3/12/2014	28.5	671389	124	Positive
323	250	3/12/2014	39	1472833	122	Positive
327	12	3/12/2014	29.5	1238722	134	Positive
339	58	3/12/2014	29	3710556	125	Positive
348	86	3/12/2014	40	---	120	Negative
350	202	3/12/2014	28	672944	130	Positive
357	74	3/12/2014	27	1911333	122	Positive
360	38	3/12/2014	37.5	---	128	Negative
375	247	3/12/2014	33.5	2332833	122	Positive
377	258	3/12/2014	33	336667	120	Positive
398	28	3/12/2014	30	871944	131	Positive
404	45	3/12/2014	27	919444	127	Positive
405	41	3/12/2014	32.5	1134250	128	Positive
413	207	NA	NA	NA	NA	NA
417	31	3/12/2014	32	186367	130	Positive
418	230	3/12/2014	32	3158	126	Positive
421	201	3/12/2014	29	194033	130	Positive
422	204	3/12/2014	33	88789	129	Positive
434	234	3/12/2014	31.5	974056	125	Positive
466	35	NA	NA	NA	NA	NA
471	18	3/12/2014	29.5	736611	133	Positive
472	42	3/12/2014	30.5	5840556	127	Positive
474	19	3/12/2014	30	319611	133	Positive
494	16	3/12/2014	30.5	527500	133	Positive
496	36	3/12/2014	25.5	248667	129	Positive
499	76	3/12/2014	32	351221	121	Positive
503	64	3/12/2014	29	2037222	124	Positive
505	238	3/12/2014	36.5	6107	124	Positive
514	235	3/12/2014	33.5	915389	126	Positive
515	60	3/12/2014	30	777250	125	Positive
530	217	NA	NA	NA	NA	NA
531	15	3/12/2014	28.5	1259222	134	Positive
536	37	3/12/2014	29	2290556	129	Positive
538	205	3/12/2014	31	1368389	129	Positive

543	26	3/12/2014	37.5	---	131	Negative
561	47	3/12/2014	39	---	127	Negative
561	218	NA	NA	NA	NA	NA
576	231	3/12/2014	32.5	689500	126	Positive
580	59	3/12/2014	30	2273889	125	Positive
592	27	3/12/2014	41.5	54294	131	Positive
594	228	3/12/2014	35	1027944	127	Positive
599	56	3/12/2014	28.5	719167	126	Positive
605	211	3/12/2014	30.5	229389	128	Positive

Table 4. Biochemistry results for suspect TABA cases up to November 2014, **Chapter 4.**

Disease	Age	Sodium	Potassium	Chloride	Creatinine	Urea	Phosphate
Ik	1-6months	117	5.8	88	384	51.9	4.1
neg	1-6months	NA	NA	NA	NA	NA	NA
Ik	1-6months	138	5.9	98	85	3.2	1.91
Ik	1-6months	132	4.9	93	35	5.6	1.77
Un	1-6months	140	5.3	91	37	8.4	2.32
Ik	1-6months	132	5.5	90	111	10.6	3.08
Ik	1-6months	136	6	95	47	5.1	2.86
Ik	1-6months	139	8	95	50	5.2	3.11
Ik	1-6months	137	8.4	97	41	5	3.09
Ik	1-6months	141	4.1	98	54	6.3	2.59
Ik	1-6months	138	5.5	93	50	3.3	2.69
Ik	1-6months	137	5.3	96	48	3.2	2.05
Ik	1-6months	139	5	97	52	3.9	2.11
Ik	1-6months	142	5.1	105	88	7	3.04
Ik	1-6months	125	5.9	92	52	10.4	2.25
Ik	1-6months	141	4.6	101	52	3.7	2.68
Ik	1-6months	143	5.4	93	289	14.9	3.07
Ik	1-6months	144	5.3	103	56	3.2	3.03
Ik	1-6months	135	5.2	86	47	5.1	2.49
Un	7-23months	133	5	94	28	6.6	2.2
Un	7-23months	140	5	100	39	4.4	1.84
neg	7-23months	140	5	100	39	4.4	1.84
Ik	7-23months	140	5.8	98	47	7.7	2.5
Un	7-23months	139	6	97	89	8.6	2.54
Ik	7-23months	135	5.2	92	41	6.9	1.94
Ik	7-23months	138	4.3	99	61	10.8	1.83
Ik	7-23months	147	5	96	109	22	2.39
Ik	7-23months	141	4.8	94	63	4.1	2.59
Ik	Adult	144	3.4	96	56	10.5	1.36
Ik	Adult	138	4.6	99	57	7.1	0.82
Ik	Adult	140	4.2	95	60	4.4	1.37
Ik	Adult	139	4.5	91	48	5.3	1.94
Ik	Adult	138	3.8	95	48	5.8	1.62
Ik	Adult	142	5	101	96	8.5	1.92
Ik	Adult	147	3.5	103	45	9.4	0.69
Ik	Adult	NA	NA	NA	NA	NA	NA
Ik	Adult	NA	NA	NA	NA	NA	NA
Ik	Adult	145	4.4	104	91	10.2	1.46
Ik	Adult	144	4.1	95	73	12.4	2.33
Ik	Adult	138	6.9	95	78	5.9	2.41
Ik	Adult	132	4.5	91	54	4.9	2.21
Ik	Adult	133	5.7	92	49	7.6	2.36
Ik	Adult	135	5.2	96	33	4.3	1.39

Un	Adult	NA	NA	NA	NA	NA	NA
Ik	Adult	142	5.3	98	57	4.9	1.37
Un	Adult	142	4.3	92	61	6.6	1.82
Ik	Adult	132	6.2	92	43	4.8	1.65
Un	Adult	140	4.6	92	41	2.8	2.09
Un	Adult	140	4.6	96	57	5.5	1.61
Ik	Adult	136	4	96	89	5.5	1.55
Ik	Adult	NA	NA	NA	NA	NA	NA
Ik	Adult	138	4.2	96	92	8.1	2.11
Ik	Adult	138	4.7	105	36	3.5	1.27
Un	Adult	147	4.2	96	139	6.3	1.67
Ik	Adult	140	4.5	94	31	3.6	1.73
Un	Adult	138	4.5	95	33	4.4	1.41
Ik	Adult	NA	NA	NA	NA	NA	NA
Ik	Adult	140	5	96	40	3.6	1.82
Un	Adult	142	4.3	94	93	12	0.98
Ik	Adult	NA	NA	NA	NA	NA	NA
Un	Adult	136	4.3	99	45	4.9	1.9
Ik	Adult	137	4.7	100	39	3.1	1.07
neg	Adult	138	5.1	92	289	11.3	1.69
Ik	Adult	138	3.2	91	60	14.4	1.72
Ik	Adult	135	4.5	95	61	8.2	2.67
Un	Adult	136	4.8	89	27	3	1.71
Ik	Adult	142	3.6	94	66	7.6	2.69
Ik	Adult	138	5.7	91	50	10.5	3.05
Ik	Adult	139	4.9	100	97	4.6	1.31
Ik	Adult	139	4.8	91	45	6.8	2.1
Un	Adult	138	3.9	100	45	3.7	1.01
Ik	Adult	137	5	93	40	7.2	2.8
Ik	Adult	137	4.8	96	72	3.6	2.13
Ik	Adult	137	6.4	96	48	4.9	1.79
Ik	Adult	139	3.7	95	41	6.4	1.48
neg	Adult	142	4.8	92	44	5.3	1.88
Ik	Adult	NA	NA	NA	NA	NA	NA
Ik	Adult	144	4.4	95	84	10.6	2.14
Ik	Adult	140	3.8	97	49	3.3	1.58
Ik	Adult	140	4.3	89	72	6.1	2.64
Un	Adult	147	3.5	98	71	8.7	2.48
Ik	Adult	NA	NA	NA	NA	NA	NA
neg	Adult	133	4.6	92	48	9.4	1.75
Ik	Adult	141	4.3	92	53	12.9	0.84
Ik	Adult	NA	NA	NA	NA	NA	NA
Ik	Adult	NA	NA	NA	NA	NA	NA
Ik	Adult	140	4.9	98	62	8.8	2.01
Ik	Adult	136	3.5	89	53	5.4	2.32
neg	Adult	125	6.7	91	48	8.7	1.47

Ik	Adult	144	3.8	63	259	35.9	3.9
Ik	Adult	140	4.5	95	72	9.4	2.35
Ik	Adult	142	4.5	99	100	10.2	2.08
Ik	Adult	136	4	94	51	8	2.26
Ik	Adult	138	4.8	95	42	3.8	1.28
Un	Adult	142	5	103	49	5.7	2.01
Ik	Adult	136	3.4	92	66	16.2	1.64
Ik	Adult	NA	NA	NA	44	5	1.02
Ik	Adult	137	4.1	93	41	3.1	1.42
Ik	Adult	138	5.1	95	75	9.1	2.83
Ik	Adult	136	4.1	94	50	4.8	1.59
Un	Adult	139	4.9	90	64	5.8	2.08
Un	Adult	126	4.9	87	107	3.8	1.85
Ik	Adult	137	4.8	99	39	6.5	2.01
Ik	Adult	141	4.8	98	50	7.6	1.5
Ik	Adult	138	5.2	96	43	6	1.49
Ik	Adult	141	5.4	94	39	9.4	1.43
Ik	Adult	139	4.5	94	53	7.4	2.12
Ik	Adult	137	5.1	96	43	6.3	1.61
Ik	Adult	NA	NA	NA	NA	NA	NA
Ik	Adult	145	5.4	101	58	6.1	2.25
Un	Adult	145	5.4	101	58	6.1	2.25
Ik	Adult	134	3.9	77	75	10.6	1.2
Ik	Adult	139	4.7	103	89	5.6	1.4
Un	Adult	139	4.1	93	43	3.3	0.66
Ik	Adult	134	4.9	90	65	6.7	1.76
Ik	Adult	NA	NA	NA	NA	NA	NA
Un	Adult	128	4.3	56	172	24.3	5.07
Ik	Adult	146	4.6	97	46	6.4	1.69
Ik	Adult	137	5.5	95	42	3.1	1.29
Ik	Adult	140	5.1	96	85	4.1	1.64
Ik	Adult	139	4.9	88	51	4.2	2.13
Ik	Adult	114	6	57	90	23.7	3.49
Ik	Adult	NA	NA	NA	NA	NA	NA
Ik	Adult	NA	NA	NA	NA	NA	NA
Ik	Adult	140	3.8	95	69	8.1	1.44
Ik	Adult	137	4.5	95	49	6.8	1.93
Ik	Unknown	NA	NA	NA	NA	NA	NA
Ik	Unknown	144	4.2	106	79	8.4	1.96
Ik	Unknown	NA	NA	NA	NA	NA	NA
Ik	Unknown	141	4.9	90	50	8.9	2.43
Ik	Unknown	141	5	97	49	7.4	1.5
Ik	Unknown	142	5.4	95	55	6.9	2.4
Ik	Unknown	140	5.3	96	51	9.1	2
Ik	Unknown	137	4.4	91	58	7.8	1
Ik	Unknown	136	6.3	100	48	2.7	1.66

Ik	Unknown	NA	NA	NA	NA	NA	NA
Ik	Unknown	NA	NA	NA	NA	NA	NA
neg	Unknown	142	3.9	99	59	5.1	1.99
Ik	Unknown	NA	NA	NA	NA	NA	NA
Ik	Unknown	140	3.6	99	62	6.3	0.97
Ik	Unknown	135	3.8	95	59	10.3	1.25
Ik	Unknown	NA	NA	NA	NA	NA	NA
Ik	Unknown	137	3.7	96	42	5.8	1.27
Ik	Unknown	138	6.3	95	58	5.6	2.18
Ik	Unknown	142	4.5	100	98	7.8	1.81
Ik	Unknown	146	4.1	95	59	18.2	2.49
Ik	Unknown	141	4.8	100	73	5.2	2.4
Ik	Unknown	141	4.3	98	59	7.1	1.96
Ik	Unknown	142	3.5	98	57	3.8	1.68
Ik	Unknown	141	5	98	92	11.4	1.44
Ik	Unknown	138	5	95	67	7.2	1.83
Ik	Unknown	NA	NA	NA	NA	NA	NA
Ik	Unknown	139	6	94	73	5.9	2.28
Un	Unknown	137	5	96	54	4.6	1.64
Un	Unknown	138	5.3	94	74	5.7	2.95
Ik	Unknown	133	4	96	87	13	1.82
Ik	Unknown	136	4.4	97	85	8	0.89
Ik	Unknown	NA	NA	NA	87	12.3	2.86
Ik	Unknown	140	6.6	94	42	7	2.46
Ik	Unknown	143	6	97	49	4.2	1.72
Ik	Unknown	140	5.5	99	34	3.9	2.37
Ik	Unknown	NA	NA	NA	NA	NA	NA
Un	Unknown	139	5.7	93	46	7.2	2.62
Ik	Unknown	NA	NA	NA	NA	NA	NA
Ik	Unknown	137	4.8	100	77	12.7	0.83
Ik	Unknown	132	6.5	90	48	6	1.42
Ik	Unknown	136	5.3	92	61	7.9	1.85
Un	Unknown	136	4.7	94	59	7	1.83
Ik	Unknown	NA	NA	NA	NA	NA	NA
Ik	Unknown	NA	NA	NA	NA	NA	NA
Ik	Unknown	140	4.9	95	52	4.5	2.1
Ik	Unknown	138	4.9	94	59	8.4	1.76
Ik	Unknown	145	4.9	102	70	4.8	2.22
Ik	Unknown	140	4.6	98	42	4.7	1.71
Ik	Unknown	134	4	90	78	8.4	2.14
Ik	Unknown	135	4	99	41	4.7	0.69
neg	Unknown	148	3.1	99	60	7.4	1.03

Table 5. Further biochemistry results for suspect TABA cases, **Chapter 4.**

Disease	Age	T. Protein	Albumin	Globulin	A/G Ratio	Magnesium	Bilirubin	GLDH
Ik	1-6months	51	32	19	1.68	0.82	94	3
neg	1-6months	28	17	11	1.55	NA	NA	NA
Ik	1-6months	66	29	37	0.78	0.66	4	9
Ik	1-6months	53	26	27	0.96	0.78	3	3
Un	1-6months	73	29	44	0.66	0.68	3	402
Ik	1-6months	59	31	28	1.11	0.98	1	16
Ik	1-6months	61	31	30	1.03	0.9	2	12
Ik	1-6months	67	32	35	0.91	0.98	2	20
Ik	1-6months	61	33	28	1.18	0.93	2	17
Ik	1-6months	65	36	29	1.24	0.78	1	11
Ik	1-6months	78	33	45	0.73	0.85	4	22
Ik	1-6months	79	29	50	0.58	0.82	5	30
Ik	1-6months	69	32	37	0.86	0.9	2	20
Ik	1-6months	68	39	29	1.34	0.95	3	23
Ik	1-6months	71	39	32	1.22	0.85	2	136
Ik	1-6months	59	34	25	1.36	0.9	1	11
Ik	1-6months	50	32	18	1.78	0.7	4	25
Ik	1-6months	67	37	30	1.23	0.94	14	27
Ik	1-6months	66	33	33	1	0.94	7	8
Un	7-23months	52	19	33	0.58	0.79	2	42
Un	7-23months	57	25	32	0.78	0.75	4	5
neg	7-23months	57	25	32	0.78	0.75	4	5
Ik	7-23months	46	20	26	0.77	0.81	1	5
Un	7-23months	33	16	17	0.94	0.93	1	48
Ik	7-23months	66	25	41	0.61	0.77	6	11
Ik	7-23months	65	36	29	1.24	0.82	73	481
Ik	7-23months	72	31	41	0.76	1.19	17	399
Ik	7-23months	74	37	37	1	0.76	2	44
Ik	Adult	84	40	44	0.91	0.83	107	374
Ik	Adult	84	35	49	0.71	0.71	10	14
Ik	Adult	73	31	42	0.74	0.5	31	74
Ik	Adult	81	35	46	0.76	0.36	5	53
Ik	Adult	86	33	53	0.62	0.65	4	33
Ik	Adult	77	31	46	0.67	0.68	12	33
Ik	Adult	74	26	48	0.54	0.61	167	478
Ik	Adult	NA	NA	NA	NA	0.75	NA	31
Ik	Adult	NA	NA	NA	NA	NA	NA	4
Ik	Adult	63	33	30	1.1	0.72	112	5
Ik	Adult	68	34	34	1	0.62	52	53
Ik	Adult	79	32	47	0.68	0.82	31	406
Ik	Adult	74	27	47	0.57	0.54	14	10
Ik	Adult	67	29	38	0.76	0.94	1	212
Ik	Adult	71	31	40	0.78	0.84	6	9

Un	Adult	106	NA	NA	NA	NA	NA	NA
Ik	Adult	70	33	37	0.89	0.62	11	8
Un	Adult	77	31	46	0.67	0.74	2	15
Ik	Adult	78	21	57	0.37	0.7	4	218
Un	Adult	74	26	48	0.54	0.66	2	28
Un	Adult	74	34	40	0.85	0.92	6	62
Ik	Adult	74	37	37	1	0.71	15	134
Ik	Adult	NA	NA	NA	NA	NA	NA	41
Ik	Adult	76	35	41	0.85	0.81	36	336
Ik	Adult	54	29	25	1.16	0.68	2	6
Un	Adult	64	41	23	1.78	0.76	11	12
Ik	Adult	75	31	44	0.7	0.89	10	8
Un	Adult	89	20	69	0.29	0.57	3	22
Ik	Adult	NA	NA	NA	NA	NA	NA	NA
Ik	Adult	72	28	44	0.64	0.99	1	48
Un	Adult	69	36	33	1.09	0.83	124	891
Ik	Adult	75	34	41	0.83	0.94	NA	81
Un	Adult	91	16	75	0.21	0.42	8	440
Ik	Adult	72	23	49	0.47	0.57	6	15
neg	Adult	94	39	55	0.71	1.13	112	988
Ik	Adult	79	33	46	0.72	1.02	13	316
Ik	Adult	52	21	31	0.68	0.64	4	4
Un	Adult	84	15	69	0.22	0.36	1	23
Ik	Adult	88	32	56	0.57	0.96	132	677
Ik	Adult	67	36	31	1.16	0.67	7	11
Ik	Adult	70	33	37	0.89	0.8	3	5
Ik	Adult	84	29	55	0.53	0.67	105	446
Un	Adult	79	31	48	0.65	0.73	14	5
Ik	Adult	92	33	59	0.56	0.84	17	1503
Ik	Adult	88	33	55	0.6	0.94	15	50
Ik	Adult	76	33	43	0.77	0.82	4	125
Ik	Adult	81	37	44	0.84	0.81	21	69
neg	Adult	71	30	41	0.73	0.61	2	38
Ik	Adult	NA	NA	NA	NA	0.56	NA	NA
Ik	Adult	73	29	44	0.66	0.49	32	50
Ik	Adult	77	36	41	0.88	0.42	9	16
Ik	Adult	81	36	45	0.8	0.25	13	252
Un	Adult	68	38	30	1.27	0.81	5	44
Ik	Adult	80	35	45	0.78	NA	9	38
neg	Adult	36	16	20	0.8	0.59	3	238
Ik	Adult	88	32	56	0.57	1.01	69	120
Ik	Adult	NA	NA	NA	NA	NA	NA	NA
Ik	Adult	74	31	43	0.72	NA	77	1077
Ik	Adult	76	36	40	0.9	0.48	55	191
Ik	Adult	93	35	58	0.6	0.42	40	516
neg	Adult	91	42	49	0.86	0.85	3	13

Ik	Adult	91	36	55	0.65	1.23	62	1021
Ik	Adult	73	35	38	0.92	0.44	42	236
Ik	Adult	80	36	44	0.82	0.7	20	10
Ik	Adult	75	29	46	0.63	1.12	22	122
Ik	Adult	99	18	81	0.22	0.62	6	6
Un	Adult	54	22	32	0.69	0.86	1	9
Ik	Adult	92	31	61	0.51	0.79	56	930
Ik	Adult	83	42	41	1.02	2.37	4	31
Ik	Adult	84	35	49	0.71	0.8	7	12
Ik	Adult	83	34	49	0.69	0.71	39	151
Ik	Adult	81	31	50	0.62	0.49	41	43
Un	Adult	72	27	45	0.6	0.38	21	392
Un	Adult	70	29	41	0.71	0.51	149	223
Ik	Adult	64	22	42	0.52	0.66	1	15
Ik	Adult	77	34	43	0.79	0.29	28	52
Ik	Adult	72	32	40	0.8	0.56	4	7
Ik	Adult	105	21	84	0.25	0.61	52	444
Ik	Adult	77	33	44	0.75	0.7	46	146
Ik	Adult	87	32	55	0.58	0.85	13	17
Ik	Adult	69	NA	NA	NA	NA	NA	12
Ik	Adult	71	32	39	0.82	0.69	14	690
Un	Adult	71	32	39	0.82	0.69	14	690
Ik	Adult	60	26	34	0.76	1.1	23	173
Ik	Adult	51	18	33	0.55	0.87	3	11
Un	Adult	73	33	40	0.83	0.2	5	7
Ik	Adult	87	34	53	0.64	0.71	18	91
Ik	Adult	NA	NA	NA	NA	NA	NA	NA
Un	Adult	70	32	38	0.84	1.25	6	4
Ik	Adult	70	20	50	0.4	0.56	31	12
Ik	Adult	78	34	44	0.77	0.8	3	21
Ik	Adult	80	35	45	0.78	0.49	3	14
Ik	Adult	86	27	59	0.46	0.7	2	26
Ik	Adult	83	37	46	0.8	0.98	8	9
Ik	Adult	NA	NA	NA	NA	NA	NA	NA
Ik	Adult	NA	NA	NA	NA	NA	NA	NA
Ik	Adult	62	33	29	1.14	0.7	46	103
Ik	Adult	80	34	46	0.74	0.89	4	7
Ik	Unknown	73	32	41	0.78	NA	39	184
Ik	Unknown	71	34	37	0.92	0.72	37	13
Ik	Unknown	NA	NA	NA	NA	NA	NA	NA
Ik	Unknown	76	25	51	0.49	0.58	58	48
Ik	Unknown	76	33	43	0.77	0.26	59	191
Ik	Unknown	84	34	50	0.68	0.8	48	295
Ik	Unknown	78	34	44	0.77	0.73	26	194
Ik	Unknown	82	34	48	0.71	0.84	53	1130
Ik	Unknown	57	25	32	0.78	0.74	3	25

Ik	Unknown	NA	NA	NA	NA	NA	NA	NA
Ik	Unknown	NA	NA	NA	NA	NA	NA	NA
neg	Unknown	48	25	23	1.09	0.47	4	115
Ik	Unknown	NA	NA	NA	NA	NA	NA	231
Ik	Unknown	70	32	38	0.84	0.55	11	40
Ik	Unknown	64	30	34	0.88	0.73	133	404
Ik	Unknown	NA	NA	NA	NA	NA	NA	NA
Ik	Unknown	78	39	39	1	0.78	82	127
Ik	Unknown	76	38	38	1	0.99	2	6
Ik	Unknown	53	32	21	1.52	0.86	14	7
Ik	Unknown	83	37	46	0.8	1.46	76	1097
Ik	Unknown	77	31	46	0.67	0.78	36	477
Ik	Unknown	88	38	50	0.76	0.66	10	9
Ik	Unknown	72	34	38	0.89	0.66	10	8
Ik	Unknown	86	35	51	0.69	0.81	100	29
Ik	Unknown	87	39	48	0.81	1	2	5
Ik	Unknown	NA	NA	NA	NA	NA	NA	NA
Ik	Unknown	92	32	60	0.53	0.77	2	201
Un	Unknown	71	35	36	0.97	0.92	2	8
Un	Unknown	73	36	37	0.97	0.64	3	25
Ik	Unknown	87	23	64	0.36	0.55	13	8
Ik	Unknown	73	37	36	1.03	0.66	15	66
Ik	Unknown	85	37	48	0.77	1.84	53	1532
Ik	Unknown	62	30	32	0.94	0.77	2	14
Ik	Unknown	81	32	49	0.65	0.51	2	28
Ik	Unknown	82	22	60	0.37	0.64	1	10
Ik	Unknown	61	21	40	0.53	NA	5	59
Un	Unknown	38	14	24	0.58	0.86	3	12
Ik	Unknown	NA	NA	NA	NA	NA	NA	11
Ik	Unknown	84	25	59	0.42	0.55	28	145
Ik	Unknown	107	39	68	0.57	1.03	3	18
Ik	Unknown	32	15	17	0.88	0.71	3	4
Un	Unknown	82	25	57	0.44	0.71	11	442
Ik	Unknown	NA	NA	NA	NA	NA	NA	18
Ik	Unknown	NA	NA	NA	NA	0.61	NA	NA
Ik	Unknown	74	34	40	0.85	0.81	6	311
Ik	Unknown	78	33	45	0.73	0.31	7	71
Ik	Unknown	67	33	34	0.97	0.79	25	43
Ik	Unknown	76	32	44	0.73	0.97	2	5
Ik	Unknown	70	38	32	1.19	1.37	3	19
Ik	Unknown	82	33	49	0.67	0.65	14	8
neg	Unknown	84	40	44	0.91	1.46	2	58

Table 6. Further biochemistry results for suspect TABA cases, **Chapter 4.**

Disease	Age	B-OHB	AST	CPK	PCV	Haemoglobin	RBC	GGT
Ik	1-6months	0.4	69	410	0.22	83	5.2	29
neg	1-6months	NA	NA	NA	0.16	49	3.7	NA
Ik	1-6months	0.1	50	296	0.31	102	9.4	31
Ik	1-6months	0.4	103	276	0.31	104	6.2	12
Un	1-6months	0.1	389	773	0.41	134	10	17
Ik	1-6months	0.4	104	383	0.26	99	9.8	4
Ik	1-6months	0.5	78	480	0.38	128	11.5	2
Ik	1-6months	0.4	140	524	0.3	95	7.8	11
Ik	1-6months	0.5	146	566	0.3	95	7.6	9
Ik	1-6months	0.2	82	525	0.31	105	6.8	2
Ik	1-6months	0.4	96	766	0.32	108	8.7	3
Ik	1-6months	0.4	97	442	0.29	94	6.3	10
Ik	1-6months	0.4	89	680	0.26	92	7.2	12
Ik	1-6months	0.3	88	1133	0.31	108	8.5	11
Ik	1-6months	0.2	317	1034	0.27	95	6.9	16
Ik	1-6months	0.2	52	433	0.28	100	9.2	10
Ik	1-6months	0.1	272	8366	0.35	111	8.3	11
Ik	1-6months	0.4	47	511	0.39	130	8.7	14
Ik	1-6months	0.3	82	195	0.37	114	10.7	7
Un	7-23months	0.2	147	746	0.25	93	6.78	8
Un	7-23months	0.2	63	173	0.3	97	5.29	7
neg	7-23months	0.2	63	173	0.3	97	5.29	7
Ik	7-23months	0.4	85	331	0.18	63	4.41	7
Un	7-23months	0.2	103	498	0.09	23	1.5	8
Ik	7-23months	0.3	73	221	0.17	53	3.1	15
Ik	7-23months	0.4	518	778	0.11	26	1.1	42
Ik	7-23months	0.4	378	2189	0.09	30	1.2	46
Ik	7-23months	0.3	126	293	0.35	120	7.9	17
Ik	Adult	0.5	2852	1957	0.09	28	1.4	530
Ik	Adult	0.3	90	209	0.16	45	1.6	14
Ik	Adult	0.5	248	297	0.13	36	1.3	81
Ik	Adult	0.6	116	427	0.14	35	1.4	32
Ik	Adult	0.3	158	282	0.14	38	1.4	63
Ik	Adult	0.3	171	253	0.11	32	1.1	81
Ik	Adult	0.5	358	1639	0.07	22	1.1	249
Ik	Adult	NA	NA	NA	0.09	26	1	15
Ik	Adult	NA	NA	NA	0.1	26	0.9	17
Ik	Adult	0.5	260	275	0.12	35	1.7	20
Ik	Adult	0.3	207	629	0.08	25	0.9	30
Ik	Adult	0.3	227	696	0.15	39	1.7	66
Ik	Adult	0.1	63	110	0.23	73	5.4	37
Ik	Adult	0.4	280	303	0.35	120	7.1	123
Ik	Adult	0.3	87	646	0.32	114	6.9	2

Un	Adult	NA	NA	NA	0.31	106	6.4	184
Ik	Adult	0.2	141	904	0.16	43	1.6	15
Un	Adult	0.3	74	96	0.24	80	4.5	30
Ik	Adult	0.2	168	302	0.22	72	4.6	118
Un	Adult	0.4	103	206	0.15	50	2.9	23
Un	Adult	0.2	162	216	0.11	33	1.1	38
Ik	Adult	0.3	301	304	0.13	43	2.3	31
Ik	Adult	NA	NA	NA	0.13	33	1.2	28
Ik	Adult	1	282	647	0.08	24	1.1	39
Ik	Adult	0.7	51	247	0.27	89	5.2	13
Un	Adult	9.8	112	580	0.24	86	4.4	12
Ik	Adult	0.3	66	73	0.25	84	4.6	19
Un	Adult	0.2	74	142	0.23	77	4.5	34
Ik	Adult	NA	NA	NA	0.34	108	6.7	10
Ik	Adult	0.6	74	249	0.24	81	5.7	19
Un	Adult	1.2	1541	2696	0.12	34	1.6	50
Ik	Adult	NA	NA	NA	0.08	28	1.17	46
Un	Adult	0.4	464	93	0.22	80	4.84	520
Ik	Adult	0.4	148	764	0.2	66	4	24
neg	Adult	0.9	828	673	0.22	67	3.3	2
Ik	Adult	0.4	1003	463	0.08	22	0.9	82
Ik	Adult	0.7	107	299	0.34	111	7.3	10
Un	Adult	0.4	73	127	0.23	82	5.3	33
Ik	Adult	0.2	790	468	0.12	31	1.4	993
Ik	Adult	1.1	92	627	0.33	107	6.3	13
Ik	Adult	0.3	61	165	0.4	125	6.5	5
Ik	Adult	0.2	1842	1191	0.1	30	1.3	229
Un	Adult	0.5	95	111	0.27	97	5.1	21
Ik	Adult	0.4	1784	756	0.14	44	2.3	104
Ik	Adult	0.3	158	151	0.15	37	1.5	118
Ik	Adult	0.4	146	218	0.13	37	1.9	39
Ik	Adult	0.5	124	140	0.1	31	1.4	28
neg	Adult	0.4	111	121	0.22	86	4.4	39
Ik	Adult	0.3	NA	NA	0.24	78	3	NA
Ik	Adult	0.4	201	516	0.37	127	6.5	34
Ik	Adult	0.5	128	379	0.16	49	2.1	35
Ik	Adult	0.4	538	403	0.14	43	1.5	75
Un	Adult	2.3	1841	25000	0.44	147	7.9	22
Ik	Adult	NA	NA	NA	0.12	34	1.3	45
neg	Adult	0.2	410	1977	0.08	28	1.44	43
Ik	Adult	0.3	968	1063	0.08	24	1.1	161
Ik	Adult	NA	NA	NA	0.25	84	5.3	184
Ik	Adult	NA	NA	NA	0.09	27	1.2	121
Ik	Adult	0.5	682	519	0.1	30	1.2	45
Ik	Adult	0.4	1287	400	0.11	29	1	101
neg	Adult	0.5	96	989	0.34	121	6.6	12

Ik	Adult	0.6	753	1540	0.11	37	1.5	247
Ik	Adult	0.4	440	743	0.08	26	1.1	33
Ik	Adult	0.4	79	359	0.16	37	1.3	16
Ik	Adult	0.3	222	2114	0.09	24	1.1	39
Ik	Adult	0.2	114	392	0.28	94	5.9	17
Un	Adult	0.3	74	159	0.3	110	7.2	15
Ik	Adult	0.4	2702	3273	0.11	34	1.3	185
Ik	Adult	0.6	149	452	0.36	118	6	14
Ik	Adult	0.5	165	163	0.16	41	1.7	23
Ik	Adult	3	154	430	0.1	26	0.9	36
Ik	Adult	0.3	507	1102	0.08	26	1.1	61
Un	Adult	4.1	456	427	0.23	71	3.9	139
Un	Adult	0.5	421	655	0.27	83	3.3	244
Ik	Adult	0.5	87	346	0.24	83	4.5	13
Ik	Adult	0.7	102	355	0.15	44	1.9	24
Ik	Adult	0.5	132	581	0.2	59	2.2	4
Ik	Adult	0.3	476	133	0.1	34	1.8	683
Ik	Adult	0.3	227	486	0.1	28	1.1	16
Ik	Adult	0.6	73	307	0.12	33	1.3	26
Ik	Adult	0.7	NA	NA	0.22	72	3.6	19
Ik	Adult	0.3	836	1432	0.28	91	5.43	170
Un	Adult	0.3	836	1432	0.28	91	5.43	170
Ik	Adult	0.4	116	464	0.21	80	4.09	24
Ik	Adult	0.5	76	199	0.21	77	4.06	11
Un	Adult	0.8	266	288	0.18	63	3.25	29
Ik	Adult	0.3	211	462	0.12	37	1.25	37
Ik	Adult	NA	NA	NA	0.09	26	1	52
Un	Adult	0.1	100	663	0.53	177	10.6	9
Ik	Adult	0.3	81	364	0.21	66	3.4	277
Ik	Adult	0.3	102	197	0.34	115	6.7	12
Ik	Adult	0.2	266	271	0.48	164	9.4	24
Ik	Adult	0.4	138	238	0.29	98	6.9	21
Ik	Adult	1.6	95	1126	0.42	153	7.6	14
Ik	Adult	NA	NA	NA	0.1	32	1.4	29
Ik	Adult	NA	NA	NA	0.19	49	1.8	55
Ik	Adult	0.3	370	6183	0.09	28	1.4	21
Ik	Adult	0.5	73	265	0.2	60	2.2	23
Ik	Unknown	NA	NA	NA	0.1	30	1.3	32
Ik	Unknown	0.4	245	7304	0.1	34	1.18	18
Ik	Unknown	NA	NA	NA	0.12	40	1.61	7
Ik	Unknown	0.5	200	1255	0.08	30	1.11	55
Ik	Unknown	0.4	294	372	0.09	33	NA	19
Ik	Unknown	0.2	597	225	0.09	31	1.25	68
Ik	Unknown	0.5	154	203	0.1	34	1.53	31
Ik	Unknown	0.8	817	490	0.08	27	1.21	85
Ik	Unknown	0.4	91	168	0.22	77	4.3	8

Ik	Unknown	NA	NA	NA	0.15	40	1.4	35
Ik	Unknown	NA	NA	NA	0.14	38	1.4	136
neg	Unknown	0.4	182	318	0.12	37	1.8	25
Ik	Unknown	NA	NA	NA	0.09	30	1	37
Ik	Unknown	0.5	96	385	0.13	35	1.6	30
Ik	Unknown	0.7	391	1695	0.1	27	1	191
Ik	Unknown	NA	NA	NA	0.15	39	1.4	23
Ik	Unknown	0.8	389	512	0.1	29	1.5	41
Ik	Unknown	0.5	65	178	0.26	77	3.5	16
Ik	Unknown	0.2	72	220	0.1	30	1	10
Ik	Unknown	0.5	2186	1870	0.09	28	1.2	88
Ik	Unknown	0.4	222	501	0.15	40	1.7	74
Ik	Unknown	0.9	72	167	0.19	50	1.8	19
Ik	Unknown	1	89	191	0.2	62	2.5	11
Ik	Unknown	0.3	388	379	0.13	36	1.2	3
Ik	Unknown	0.6	82	850	0.17	45	2	16
Ik	Unknown	NA	NA	NA	0.28	92	5.2	45
Ik	Unknown	0.2	273	188	0.3	96	5.4	16
Un	Unknown	0.3	58	155	0.33	119	6.8	21
Un	Unknown	0.3	148	1509	0.37	126	7.7	12
Ik	Unknown	0.1	71	377	0.18	54	2.5	32
Ik	Unknown	0.3	210	397	0.1	26	1	47
Ik	Unknown	0.5	2549	21236	0.1	28	1	112
Ik	Unknown	0.7	79	150	0.29	90	4.6	8
Ik	Unknown	0.4	92	295	0.28	95	5.8	20
Ik	Unknown	0.4	127	280	0.25	88	5.7	26
Ik	Unknown	NA	NA	NA	0.23	75	4.6	259
Un	Unknown	0.2	121	453	0.15	49	3.2	8
Ik	Unknown	NA	NA	NA	0.2	58	2.4	688
Ik	Unknown	0.2	710	2238	0.17	58	3.3	36
Ik	Unknown	0.4	108	501	0.39	134	7.3	18
Ik	Unknown	0.3	158	159	0.41	131	7.8	2
Un	Unknown	0.2	338	528	0.2	70	4.1	233
Ik	Unknown	NA	NA	NA	0.21	58	1.9	16
Ik	Unknown	0.5	NA	NA	0.2	61	3.6	NA
Ik	Unknown	0.5	638	342	0.15	41	2	63
Ik	Unknown	0.4	108	312	0.14	34	1.5	39
Ik	Unknown	1.7	320	318	0.12	35	1.5	57
Ik	Unknown	0.3	86	207	0.17	48	1.7	36
Ik	Unknown	0.2	91	816	0.28	100	6.5	17
Ik	Unknown	0.5	60	140	0.14	40	1.6	25
neg	Unknown	0.8	113	667	0.38	132	7	32

Table 7. Haematology results for suspect TABA cases up to November 2014, **Chapter 4.**

Disease	Age	RBC	Haemoglobin	PCV	MCV	MCH	MCHC	NRBC	Platelets
Un	7-23months	5.29	97	0.3	56	18	326		637
Neg	7-23months	5.29	97	0.3	56	18	326		637
neg	7-23months	6.91	85	0.23	33	12	370	0	clumped
Un	7-23months	6.78	93	0.25	37	14	372		857
Ik	7-23months	4.41	63	0.18	43	14	350	0	clumped
Ik	10	1.3	29	0.1	76	22	290	37	clumped
Un	10	2.7	48	0.16	57	18	310		clumped
Ik	10	1.6	45	0.16	102	28	276	92	clumped
Ik	10	2.9	67	0.22	76	23	300		334
Ik	10	1.3	36	0.13	102	28	279	27	369
Ik	10	1.4	28	0.09	67	21	308	10	clumped
Ik	11	1.4	35	0.14	101	26	257	26	275
Ik	11	1.4	38	0.14	100	27	271	34	364
Ik	12	1.1	32	0.11	97	28	288	139	
Ik	12	1.8	36	0.1	58	20	342	19.8	824
Ik	14	1.1	22	0.07	66	20	297	9	clumped
Ik	1-4weeks	5.2	83	0.22	43	16	372		clumped
neg	1-4weeks	3.7	49	0.16	42	13	316		537
Ik	1-4weeks	1.8	27	0.09	50	15	300	26	clumped
Ik	15	6.64	112	0.32	47	17	356		
Ik	1-6months	7.8	95	0.3	41	12	317		Clumped
Ik	1-6months	7.6	95	0.3	40	13	315		680
Ik	1-6months	1.4	35	0.11	81	26	321	2	689
Ik	1-6months	0.8	27	0.07	81	33	403	127	216
Ik	1-6months	5.8	83	0.26	46	14	316		551
Ik	1-6months	1.6	39	0.11	69	24	355	14	clumped
Ik	1-6months	6.8	105	0.31	45	15	344		257
Ik	1-6months	7.4	83	0.26	37	11	319		
Ik	1-6months	8.3	111	0.35	42	13	318		Clumped
Ik	1-6months	1.3	25	0.09	67	19	291	44	475
Ik	1-6months	8.4	107	0.33	39	13	325		558
Ik	1-6months	1.41	30	0.09	64	21	334	3	clumped
Ik	1-6months	8.7	130	0.39	45	15	333		clumped
Ik	1-6months	9.5	118	0.36	38	13	332		583
Ik	1-6months	5.1	77	0.25	48	15	310		338
Ik	1-6months	8.7	108	0.32	37	12	341		Clumped
Ik	1-6months	6.3	94	0.29	46	15	326		Clumped
Ik	1-6months	7.2	92	0.26	36	13	355		Clumped
Ik	1-6months	12	149	0.44	36	12	343		
Ik	1-6months	11.5	128	0.38	33	11	341		540
Ik	1-6months	9.8	99	0.26	26	10	385		737
Ik	1-6months	9.4	102	0.31	33	11	331	0	817
Ik	1-6months	8.5	108	0.31	36	13	354		Clumped

lk	1-6months	6.9	95	0.27	39	14	349		961
Un	1-6months	10	134	0.41	41	13	327		clumped
lk	1-6months	6.5	87	0.24	37	13	364		1302
lk	1-6months	10.7	114	0.37	34	11	311		clumped
lk	1-6months	1.1	19	0.07	64	18	271	135	clumped
lk	1-6months	3.1	45	0.13	41	14	349		526
lk	1-6months	2	31	0.1	50	16	316		1083
lk	1-6months	1.04	24	0.07	69	23	337	65	550
lk	1-6months	1.32	32	0.09	66	24	368	186	clumped
neg	1-6months	3.1	34	0.1	33	11	330		971
un	1-6months	11.6	125	0.39	34	11	319	0	clumped
lk	1-6months	6.2	104	0.31	50	17	331		clumped
lk	1-6months	6.5	99	0.31	48	15	322		414
neg	1-6months	5.7	68	0.18	33	12	370	3	Clumped
lk	1-6months	9.2	100	0.28	31	11	355		299
lk	1-6months	9.5	113	0.32	33	12	356		320
lk	1-6months	1.6	37	0.13	81	23	289	6	406
lk	1-6months	3.02	65	0.21	69	22	314	1	824
lk	1-6months	1.69	40	0.12	70	24	338	54	309
lk	1-6months	0.98	27	0.09	92	28	301	304	428
lk	1-6months	1.99	59	0.2	102	30	294	4	
lk	1-6months	7.89	103	0.32	40	13	327		clumped
lk	1-6months	0.9	17	0.06	65	19	283	35	clumped
lk	1-6months	9.36	115	0.32	34	12	359	0	clumped
lk	2	3.29	60	0.18	55	18	331		clumped
lk	2	1.2	28	0.1	85	23	272	10	593
lk	2	1.1	27	0.09	81	26	314		clumped
lk	2	1.2	30	0.1	96	26	300	14	252
lk	2	1	26	0.09	91	27	295	59	316
Un	2	6.4	106	0.31	49	17	341		454
lk	2	7.1	120	0.35	49	17	348		clumped
Un	2	7.1	115	0.33	46	16	354		825
lk	2	4.2	79	0.25	58	19	321		clumped
lk	2	4.79	81	0.26	53	17	319		clumped
Un	2	6.55	109	0.3	46	17	363	0	clumped
lk	2	1.36	33	0.1	73	24	332	2	clumped
lk	2	0.9	26	0.1	105	28	260	9	clumped
Un	2	9.2	145	0.4	43	16	366		386
lk	2	5.15	100	0.31	59	19	327	0	clumped
lk	2	7.5	124	0.35	47	17	353		clumped
lk	2	7.3	101	0.3	42	14	336		clumped
neg	2	5.7	82	0.24	42	14	339		clumped
lk	2	6.6	96	0.28	42	15	348		clumped
lk	2	1.3	29	0.11	81	22	276	7	clumped
lk	2	1.43	31	0.09	76	22	344	16	
lk	2	3.89	58	0.18	46	15	322	0	clumped

Un	2	7	108	0.3	43	16	359		
Ik	2	1.7	39	0.15	89	24	265	44	clumped
Ik	2	5.4	73	0.23	42	13	320		306
Ik	2	6.9	114	0.32	47	17	355		clumped
Ik	2	3.7	71	0.2	54	19	355	0	clumped
Ik	2	1.3	31	0.12	94	24	258	10	clumped
Ik	2	1.5	33	0.11	74	22	306	2	clumped
Ik	2	1.7	35	0.12	68	20	299	2	clumped
Ik	2	0.9	25	0.08	87	28	321		clumped
Ik	2	1.7	33	0.12	72	20	280	0	227
Ik	2	2.1	44	0.14	69	21	310	0	
Ik	3	0.9	28	0.1	112	30	269	77	clumped
Un	3	1.1	33	0.11	103	30	295	22	336
Ik	3	4.6	72	0.22	48	16	327	0	596
Un	3	4.5	80	0.24	52	18	340		565
Ik	3	1.6	43	0.16	96	26	272	76	clumped
Ik	3	5.5	80	0.25	45	15	324		clumped
Ik	3	1.4	29	0.1	73	22	296	22	clumped
Ik	3	1.22	22	0.06	58	18	367	4	clumped
Un	3	2.9	50	0.15	55	17	333	2	831
Un	3	2.6	51	0.17	64	20	309	1	692
Ik	4	4.6	84	0.25	56	19	331		421
Ik	4	1.1	24	0.08	74	21	286	30	594
Ik	4	5.2	89	0.27	52	17	328		clumped
Ik	4	1.2	28	0.1	89	24	272	21	clumped
Un	4	4.4	86	0.24	55	19	352		344
Ik	4	7	103	0.33	47	15	315		486
Ik	4	1	29	0.11	114	30	264	111	242
Ik	4	4.3	69	0.21	49	16	329		clumped
Ik	4	5.7	81	0.24	42	14	336		335
Un	4	4.5	77	0.23	51	17	336		Clumped
Ik	4	2.3	43	0.13	62	19	331	47	50
Ik	4	6.7	108	0.34	50	16	320		240
Ik	4	1.2	33	0.13	110	28	258	65	clumped
Ik	5	6.5	125	0.4	61	19	315		clumped
Ik	5	2.3	44	0.14	64	20	308	16	clumped
Ik	5	0.9	22	0.08	86	24	282	6	clumped
Ik	5	4	66	0.2	50	17	330	0	clumped
neg	5	6.33	104	0.28	44	16	371		
Ik	5	1.9	37	0.13	67	20	291	14	clumped
Ik	5	1.5	45	0.15	104	31	294	56	398
Un	5	1.6	34	0.12	74	22	291	20	603
Ik	5	7.3	111	0.34	47	15	326		347
Ik	5	1	25	0.09	85	24	287	4	360
Ik	5	1.17	28	0.08	68	24	350	50	clumped
Un	5	5.3	82	0.23	45	16	350		374

neg	5	3.3	67	0.22	68	20	302	17	clumped
lk	5	1.4	31	0.12	86	22	256	30	clumped
lk	5	1.5	37	0.15	103	25	245	46	clumped
lk	5	1.8	36	0.12	68	20	293	15	clumped
Un	5	4.84	80	0.22	45	17	364	0	clumped
Un	5	5.1	97	0.27	54	19	357		185
lk	5	1.3	30	0.1	77	23	294	18	clumped
lk	5	1.4	36	0.12	90	27	295	13	640
Un	5	1.56	31	0.09	58	19	338	10	
lk	5	6.3	107	0.33	52	17	324		clumped
lk	6	1.3	34	0.12	94	26	279	31	433
lk	6	1.5	34	0.1	67	23	340	44	clumped
lk	6	1.33	38	0.11	94	29	345	50	clumped
Un	6	7.9	147	0.44	55	19	338		clumped
neg	6	4.4	86	0.22	49	20	400	1	Clumped
lk	6	2.1	49	0.16	75	23	308	159	313
lk	6	1.5	31	0.1	66	20	310	8	clumped
lk	6	1.5	43	0.14	93	28	301	138	clumped
lk	6	1.4	31	0.1	69	22	310	14	clumped
lk	6	1.4	34	0.13	97	25	260		
lk	6	5.04	85	0.27	53	17	322		543
lk	6	1.9	51	0.18	98	27	277	81	547
lk	6	6.5	127	0.37	57	20	341	1	clumped
lk	6	3	78	0.24	79	26	325	28	clumped
lk	6	1	23	0.08	81	24	291	30	297
lk	7	1.4	32	0.12	90	24	262	25	clumped
neg	7	3.4	74	0.21	63	22	352	0	clumped
lk	7	5.3	84	0.25	47	16	335		clumped
neg	7	6.6	121	0.34	51	18	361		clumped
Un	7	1.7	40	0.13	85	24	308	83	273
lk	7	1.5	37	0.13	90	26	285	18	
lk	7	1.1	24	0.08	78	23	289	136	352
neg	7	1.44	28	0.08	57	19	342	21	349
lk	7	1	29	0.11	108	29	266	20	clumped
lk	7	1.2	30	0.1	89	26	288	28	clumped
lk	7	1.2	27	0.09	77	23	293		
Un	7-23months	1.5	23	0.09	66	16	256	9	406
lk	7-23months	3.1	53	0.17	54	17	319		704
lk	7-23months	1.1	26	0.11	96	23	241	33	clumped
lk	7-23months	4.96	71	0.22	44	14	327		239
lk	7-23months	6.37	85	0.25	39	13	339		273
Un	7-23months	5.18	86	0.26	49	17	336	0	
lk	7-23months	1.2	30	0.09	96	25	333	10	217
lk	7-23months	1.2	24	0.09	75	20	267		199
lk	7-23months	7.9	120	0.35	45	15	339		506
lk	7-23months	3.6	53	0.18	48	15	303	0	523

Ik	7-23months	6.3	84	0.28	44	13	304		571
Ik	7-23months	6.4	116	0.36	56	18	327		300
Ik	7-23months	5.7	89	0.27	47	16	332		
Ik	7-23months	5.3	70	0.22	42	13	314	0	clumped
Ik	7-23months	2.4	54	0.19	79	23	287	26	clumped
Ik	7-23months	1.8	26	0.09	51	15	292		
Ik	7-23months	6.4	92	0.28	46	14	329		337
Un	7-23months	11	151	0.44	40	14	346		clumped
Ik	7-23months	12.7	136	0.37	29	11	365		311
Ik	8	6	118	0.36	64	20	328		clumped
Ik	8	6.5	117	0.33	51	18	353		339
Ik	8	1.3	37	0.16	121	29	237	83	374
Ik	8	1.1	26	0.08	76	24	313	10	clumped
Ik	8	2	51	0.17	89	26	295	30	clumped
Ik	8	5.9	94	0.28	47	16	341		323
Un	8	7.2	110	0.3	42	15	368		337
Ik	8	1.3	34	0.11	86	26	301	43	clumped
Ik	8	1.5	37	0.11	86	25	336	56	
Ik	8	1.1	24	0.09	80	23	282	14	498
Ik	9	1.4	34	0.11	80	24	298	10	clumped
Ik	9	1.13	27	0.08	67	24	356	19	clumped
Ik	9	1.1	26	0.08	78	24	310	7	clumped
Ik	9	1.7	41	0.16	97	25	255	50	clumped
Ik	9	0.9	26	0.1	105	28	263	43	344
Ik	9	1.4	29	0.09	68	21	309	4	clumped
Ik	Adult	4.5	83	0.24	54	19	343	0	504
Ik	Adult	3.6	72	0.22	60	20	335	0	668
Ik	Adult	1.4	33	0.1	71	24	330		
Ik	Adult	1.4	27	0.08	57	19	338		
Ik	Adult	1.3	32	0.1	77	25	320		
Ik	Adult	2.2	52	0.17	77	24	313	0	clumped
Ik	Adult	1.3	33	0.12	92	25	277	1	578
Ik	Adult	1.1	28	0.1	96	26	272	5	clumped
Ik	Adult	1.8	34	0.1	54	19	354		clumped
Ik	Adult	2.2	59	0.2	88	26	301		295
Ik	Adult	1.9	44	0.15	80	24	297	8	clumped
Ik	Adult	1.58	44	0.13	82	28	337	15	clumped
Ik	Adult	1.6	39	0.13	82	24	293	41	clumped
Un	Adult	3.9	71	0.23	57	18	316	0	546
Un	Adult	3.3	83	0.27	73	25	303	0	345
Ik	Adult	5.2	88	0.27	52	17	328	0	clumped
Ik	Adult	1.89	41	0.13	67	22	327	26	896
Ik	Adult	1.27	32	0.09	74	25	338	13	clumped
Ik	Adult	1.32	33	0.1	77	25	327	109	624
Ik	Adult	1.5	41	0.15	100	28	281	44	clumped
Ik	Adult	1.8	50	0.18	102	28	279	77	clumped

Ik	Adult	1.7	29	0.1	63	18	279	66	clumped
Ik	Adult	4.2	75	0.23	56	18	326	2	clumped
Ik	Adult	1.7	42	0.16	95	25	266	21	clumped
Ik	Adult	2.3	61	0.2	86	26	302	28	clumped
Ik	Adult	1.32	29	0.08	61	22	356	15	396
Ik	Adult	1.57	39	0.11	83	25	355	33	561
Ik	Adult	1.3	32	0.11	84	26	305	53	clumped
Un	Adult	5.43	91	0.28	52	17	322	0	
Ik	Adult	5.43	91	0.28	52	17	322	0	
Ik	Adult	3.4	66	0.21	62	19	308		clumped
Ik	Adult	4.09	80	0.21	51	20	381	1	Clumped
Ik	Adult	4.06	77	0.21	52	19	367		Clumped
Ik	Adult	7.6	153	0.42	55	20	369		494
Un	Adult	6.22	105	0.29	47	17	362		432
neg	Adult	6.21	111	0.3	48	18	370		391
neg	Adult	6.69	112	0.31	47	17	361		clumped
Ik	Adult	1	26	0.09	85	25	295	19	clumped
Un	Adult	6.79	100	0.27	40	15	370	0	clumped
Un	Adult	6.21	88	0.23	37	14	383	0	clumped
neg	Adult	2.92	72	0.21	72	25	343	0	clumped
neg	Adult	2.04	50	0.15	74	25	333	2	clumped
Un	Adult	6.4	113	0.31	48	18	365	0	clumped
Un	Adult	5.6	94	0.25	45	17	376	0	clumped
Un	Adult	6.06	103	0.28	46	17	368	0	clumped
Un	Adult	6.19	96	0.25	40	16	384	0	clumped
neg	Adult	3.53	78	0.24	68	22	325	0	clumped
Ik	Adult	1.4	32	0.1	69	22	323	1	
Ik	Adult	1.8	49	0.19	103	27	265	13	435
Ik	Adult	6.9	98	0.29	42	14	340		
Ik	Adult	3	68	0.22	72	23	315		
Ik	Adult	5.1	80	0.22	44	16	360		497
Ik	Adult	1.3	35	0.12	93	27	287	13	516
Ik	Adult	1.7	36	0.12	71	22	308	14	457
Ik	Adult	1.1	28	0.09	86	26	298	41	clumped
Ik	Adult	1.4	39	0.13	93	27	293	3	704
Ik	Adult	1.6	45	0.16	101	29	285	147	264
Ik	Adult	1	30	0.11	110	29	263	41	clumped
Un	Adult	6.22	99	0.27	43	16	367	0	clumped
Un	Adult	6.73	122	0.33	49	18	370	0	333
Ik	Adult	4.8	87	0.23	48	18	378	0	clumped
Ik	Adult	5.66	106	0.29	51	19	366	1	clumped
Un	Adult	6.1	111	0.31	51	18	358	0	clumped
Un	Adult	7.08	107	0.28	40	15	382	0	clumped
Un	Adult	6.79	111	0.31	45	16	358	0	clumped
Un	Adult	6.62	116	0.32	48	18	363	0	437
Ik	Adult	5.99	105	0.28	47	18	375	0	clumped

Ik	Adult	6.8	130	0.38	56	19	340		clumped
Ik	Adult	5.6	101	0.29	51	18	351		clumped
Ik	Adult	5.58	110	0.31	56	20	355	0	clumped
Ik	Adult	2.27	46	0.14	60	20	329	1	clumped
Un	Adult	3.25	63	0.18	54	19	359	86	503
Ik	Adult	1.25	37	0.12	92	29	319	52	396
Ik	Adult	1.1	29	0.11	99	26	266	18	clumped
Un	Adult	10.6	177	0.53	49	17	337	0	347
Ik	Adult	9.4	164	0.48	51	17	342		419
Ik	Adult	6.7	115	0.34	51	17	336		clumped
Ik	Adult	1.4	35	0.11	81	25	307	1	clumped
Ik	Adult	1.8	47	0.16	92	26	288	3	clumped
neg	Adult	1.82	37	0.12	63	21	325	6	636
Ik	Adult	1.2	26	0.1	84	23	271	30	clumped
Ik	Adult	2.2	60	0.2	91	28	303	4	clumped
Ik	Adult	1.4	32	0.14	96	23	237	51	clumped
Ik	Adult	0.9	28	0.09	94	30	318	46	clumped
Ik	Adult	0.8	22	0.08	104	28	272	160	clumped
Ik	Adult	1.4	28	0.09	64	20	315	8	427
Ik	Unknown	4.6	90	0.29	62	19	316		clumped
Ik	Unknown	1.5	34	0.14	95	23	238	57	clumped
Ik	Unknown	1.53	34	0.1	65	22	340	6	clumped
Ik	Unknown	1.8	50	0.19	108	29	265	90	286
Ik	Unknown	2.5	62	0.2	79	25	312	6	312
Ik	Unknown	1	23	0.07	75	23	329	11	clumped
Ik	Unknown	1.5	34	0.11	77	23	304	14	clumped
Un	Unknown	1.9	38	0.12	65	20	309	7	278
Ik	Unknown	1.3	29	0.1	74	22	293		clumped
Ik	Unknown	1.3	28	0.09	67	21	318	4	335
Ik	Unknown	1.2	34	0.13	107	28	258	65	750
neg	Unknown	2.9	45	0.15	51	16	308		229
Ik	Unknown	1.11	30	0.08	76	27	355	12	clumped
Ik	Unknown	1.3	32	0.12	91	25	278	17	350
Ik	Unknown	1.4	42	0.15	103	29	284	45	214
Ik	Unknown	1.6	43	0.16	103	27	267	15	515
Ik	Unknown	1.5	43	0.16	109	29	264	6	397
Ik	Unknown	4.5	90	0.27	60	20	328		clumped
Ik	Unknown	5.1	104	0.32	63	21	326		clumped
Ik	Unknown	4.2	90	0.29	70	22	307		clumped
Un	Unknown	2.4	48	0.15	62	20	322		
Ik	Unknown	1.3	35	0.11	84	26	310	8	clumped
Ik	Unknown	1.2	29	0.11	86	23	271	44	235
Ik	Unknown	1.1	31	0.11	96	27	287		
Un	Unknown	5.2	104	0.37	71	20	280		clumped
neg	Unknown	7	132	0.38	55	19	346		clumped
Un	Unknown	6.8	119	0.33	49	17	356		310

Ik	Unknown	1.3	30	0.1	71	23	316		
Ik	Unknown	1.4	32	0.11	84	24	281		
Ik	Unknown	1.9	37	0.15	78	20	253	2	425
Ik	Unknown	4.4	91	0.27	62	21	336		325
Ik	Unknown	3.4	78	0.26	77	23	298		clumped
Un	Unknown	7.2	117	0.34	47	16	346		546
Un	Unknown	8.7	122	0.34	39	14	364		428
Un	Unknown	5.3	91	0.28	53	17	325		clumped
Ik	Unknown	1.53	30	0.09	64	20	333	7	537
Ik	Unknown	1.17	28	0.08	84	24	350	76	clumped
Ik	Unknown	1	26	0.1	101	27	268	72	clumped
Ik	Unknown	2.4	50	0.17	71	21	299	14	Clumped
Ik	Unknown	1.2	29	0.09	82	25	309	150	Clumped
Ik	Unknown	7.3	134	0.39	54	18	343		clumped
Ik	Unknown	7.8	131	0.41	53	17	320		clumped
Ik	Unknown	1.6	36	0.13	76	22	288	26	clumped
Ik	Unknown	1.5	41	0.16	109	28	259	35	380
Ik	Unknown	2.86	48	0.15	53	17	319	2	
Ik	Unknown	2.86	48	0.15	53	17	319	2	
neg	Unknown	2.86	48	0.15	53	17	319	2	
neg	Unknown	2.86	48	0.15	53	17	319	2	
Ik	Unknown	3.3	72	0.23	70	22	319		215
Ik	Unknown	3.4	76	0.23	68	22	325		460
Ik	Unknown	1.9	58	0.21	108	30	280	2	476
Un	Unknown	3.6	64	0.2	56	18	323	0	496
Ik	Unknown	2.2	56	0.21	93	25	273	82	clumped
Ik	Unknown	1.22	35	0.12	94	28	300	113	clumped
Ik	Unknown	1	30	0.1	104	31	294	50	clumped
Ik	unknown	1.2	28	0.09	75	23	301	74	clumped
Ik	Unknown	1.5	35	0.12	77	23	297	8	356
Ik	Unknown	2	41	0.15	74	21	283	13	clumped
Ik	Unknown	1.21	27	0.08	72	22	338	59	clumped
Ik	Unknown	3.3	58	0.17	53	18	335	2	clumped
neg	Unknown	1.8	37	0.12	67	21	314	2	clumped
Ik	Unknown	0.9	29	0.11	115	31	271	25	clumped
Ik	Unknown	3.6	61	0.2	54	17	319		clumped
Ik	Unknown	3.6	61	0.2	54	17	319		clumped
Ik	Unknown	1.4	39	0.15	106	28	262	272	clumped
Ik	Unknown	1	28	0.1	96	28	286	197	734
Un	Unknown	3.2	49	0.15	46	15	331		clumped
Un	Unknown	7.7	126	0.37	48	17	345		clumped
Ik	Unknown	1	30	0.09	90	30	333	56	clumped
Ik	Unknown	1.6	35	0.13	79	22	290	6	clumped
Ik	Unknown	1	27	0.1	108	28	260	110	clumped
Ik	Unknown	1.25	31	0.09	72	25	344	104	clumped
Ik	Unknown	2.5	54	0.18	72	22	300	3	clumped

Ik	Unknown	1.61	40	0.12	80	25	333	6	Clumped
Ik	Unknown	1.01	26	0.09	89	26	289	21	457
Ik	Unknown	1.2	31	0.1	81	25	313	3	clumped
Ik	Unknown	3	73	0.24	81	24	300		395
Ik	Unknown	1.4	40	0.15	102	28	272		
Ik	Unknown	1.4	38	0.14	98	27	273		
Ik	Unknown	1.4	28	0.09	66	20	311	5	clumped
Ik	Unknown	3.4	79	0.25	74	23	311		354
Ik	Unknown	5.2	92	0.28	54	18	330		544
Ik	Unknown	6.5	100	0.28	43	15	358		clumped
Ik	Unknown	4	77	0.23	59	19	332		259
Un	Unknown	7.1	107	0.31	44	15	342		clumped
Ik	Unknown	1.4	28	0.09	60	19	326	4	296
Ik	Unknown	1	26	0.09	92	26	383	4	533
Ik	Unknown	1.2	36	0.13	106	29	275	41	106
Ik	Unknown	1.8	46	0.17	96	26	269	24	clumped
Ik	Unknown	1.47	34	0.1	65	23	340	11	clumped
Ik	Unknown	6.3	102	0.3	48	16	339		261
Ik	Unknown	1	26	0.1	105	27	257	98	clumped
Ik	Unknown	4.1	67	0.2	49	16	332		
Ik	Unknown	1.5	29	0.1	68	20	296	12	clumped
Un	Unknown	4.1	70	0.2	50	17	347	2	clumped
Ik	Unknown	5.8	95	0.28	48	16	342		266
Ik	Unknown	5.7	88	0.25	44	16	352		258
Ik	Unknown	4.4	87	0.27	61	20	323		565
Ik	Unknown	4.3	77	0.22	51	18	350	0	465
Ik	Unknown	1.7	40	0.15	91	24	260	67	668
Ik	Unknown	5.3	91	0.28	55	17	325		
neg	Unknown	5.1	111	0.32	64	22	343		clumped
Ik	Unknown	5.4	96	0.3	56	18	320		409
Ik	Unknown	1.6	40	0.14	91	26	280	119	223
Ik	unknown	4.6	75	0.23	50	16	326		clumped
Ik	Unknown	3.1	64	0.21	67	21	312	0	clumped
Ik	Unknown	2.2	48	0.15	71	22	314	3	clumped
Ik	Unknown	2	45	0.17	86	23	266		clumped
Ik	Unknown	3.5	77	0.26	74	22	300	0	clumped
Ik	Unknown	2	51	0.17	88	26	295	109	clumped
Ik	Unknown	4.7	86	0.27	57	18	321		277
Ik	Unknown	3.2	82	0.26	80	25	318		231
Ik	Unknown	4.2	82	0.25	58	20	335		524
Ik	Unknown	2.9	73	0.23	78	25	322	21	405
Ik	Unknown	2.4	58	0.2	83	24	290		clumped
Ik	Unknown		33	0.09				53	clumped
Un	Unknown	5.9	118	0.36	61	20	328		482
Ik	Unknown	1.15	27	0.08	80	23	338	124	504
Ik	Unknown	1.18	34	0.1	85	29	344	14	clumped

lk	Unknown	1.7	48	0.17	103	29	277	26	clumped
lk	Unknown	1.15	27	0.08	78	23	338	52	
lk	Unknown	1.36	26	0.08	59	19	325		
lk	Unknown	4.52	94	0.3	65	21	319	4	

Table 8. Individual case data from suspected cases of *Theileria* associated bovine anaemia reported up to November 2014, **Chapter 6.**

Date	Animal ID	HCT	<i>Theileria</i> count per 1000 RBC	Strain type	Easting	Northing	Farm
30/10/2012	186	0.35	1	Ik	1674083.5	6113985.3	Beef
30/10/2012	189	0.27	2	Ik	1674083.5	6113985.3	Beef
30/10/2012	195	0.29	3	Ik	1674083.5	6113985.3	Beef
30/10/2012	175	0.35	1	Ik	1674083.5	6113985.3	Beef
30/10/2012	180	0.3	3	Ik	1674083.5	6113985.3	Beef
30/10/2012	193	0.28	0.9	Ik	1674083.5	6113985.3	Beef
30/10/2012	197	0.31	2	Ik	1674083.5	6113985.3	Beef
30/10/2012	181	0.29	3	Ik	1674083.5	6113985.3	Beef
30/10/2012	191	0.3	3	Ik	1674083.5	6113985.3	Beef
19/10/2012	272	0.12	1	Ik	1698720.4	6002366	Beef
30/10/2012	Big	0.12	1	Ik	1705731.7	6034079.1	Beef
30/10/2012	Little	0.09	1	Ik	1705731.7	6034079.1	Beef
12/12/2012	nt	0.07	280	Ik	1723939.3	6029238.9	Beef
1/11/2012	A140	0.25	0	Ik	1686467.2	5996217.2	Beef
1/11/2012	XB199	0.23	54	Ik	1686467.2	5996217.2	Beef
29/10/2012		0.08	0	Ik	1800258	5804659.6	Beef
21/10/2013	29	0.12	38	Ik	1688446.3	6107913.6	Beef
21/10/2013	184	0.12	340	Ik	1688446.3	6107913.6	Beef
26/10/2013		0.09		Ik	1846155.8	5849580.1	Beef
30/10/2013		0.08		Ik	1779574.2	5756728.3	Beef
30/10/2013	1316	0.17		Ik	1718747.1	6065046.9	Beef
8/05/2013	4302	0.18	1	Ik	1622739.1	6123592.9	Beef
19/03/2013	97195	0.21		Ik	1807695.5	5854089.1	Beef
28/03/2013	97078	0.29		Ik	1807695.5	5854089.1	Beef
28/03/2013	97107	0.31		Ik	1807695.5	5854089.1	Beef
28/03/2013	97115	0.31		Ik	1807695.5	5854089.1	Beef
28/03/2013	97237	0.3		Ik	1807695.5	5854089.1	Beef
28/03/2013	97154	0.35		Ik	1807695.5	5854089.1	Beef
28/03/2013	97169	0.26		Ik	1807695.5	5854089.1	Beef
28/03/2013	97171	0.24		Ik	1807695.5	5854089.1	Beef
28/03/2013	97204	0.27		Ik	1807695.5	5854089.1	Beef
28/03/2013	97208	0.31		Ik	1807695.5	5854089.1	Beef
28/03/2013	97234	0.27		Ik	1807695.5	5854089.1	Beef
11/04/2013	97195	0.31		Ik	1807695.5	5854089.1	Beef
29/08/2013	shaggy	0.08	9	Ik	1806339.1	5803784.6	Beef
27/08/2013	Fausett	0.18	4	Ik	1765557.4	5881662.8	Beef
26/08/2013	530	0.12	5	Ik	1755202.6	5849248.3	Beef
19/06/2013		0.18	125	Ik	1857756.2	5840785.2	Beef
8/07/2013	NA	0.22	1	Ik	1776532.9	5861048.9	Beef
25/07/2013	43	0.21	95	Ik	1716171.1	6005359	Beef
25/07/2013	69	0.21	14	Ik	1716171.1	6005359	Beef

19/08/2013	67	0.08	56	Ik	1779033.7	5811396.6	Beef
3/09/2013	NO ID	0.19	4	Ik	1755202.6	5849248.3	Beef
10/09/2013	NO ID	0.07	460	Ik	1714905.1	6032044.7	Beef
31/10/2013	NO ID	0.36		Ik	1757086.7	5727851.7	Beef
24/09/2013	4	0.23		Ik	2047380.7	5721481	Beef
24/09/2013	1	0.22		Ik	2047380.7	5721481	Beef
24/09/2013	2	0.25		Ik	2047380.7	5721481	Beef
27/09/2013	1	0.22		Ik	1842624.4	5924708.1	Beef
27/09/2013	2	0.21		Ik	1842624.4	5924708.1	Beef
28/09/2013		0.21		Ik	1714198.1	6015043.8	Beef
24/09/2013		0.36	17	Ik	1842624.4	5924708.1	Beef
26/09/2013	calf50	0.1		Ik	1623701.3	6101780.5	Beef
24/09/2013	Calf	0.22		Ik	1718747.1	6065046.9	Beef
27/09/2013		0.11		Ik	1846799.4	5815065.8	Beef
30/10/2013		0.41		Ik	1846799.4	5815065.8	Beef
4/10/2013	J194	0.33		Ik	2049739.7	5715974	Beef
4/10/2013	J249	0.27		Ik	2049739.7	5715974	Beef
4/10/2013	J250	0.32		Ik	2049739.7	5715974	Beef
27/09/2013	205	0.26	20	Ik	1693765.9	6012719.2	Beef
27/09/2013	348	0.27	27	Ik	1693765.9	6012719.2	Beef
25/09/2013	350	0.12	52	Ik	1698720.4	6002366	Beef
2/10/2013	103	0.12	79	Ik	1645808	6094936.3	Beef
2/10/2013	157	0.09	12	Ik	1645808	6094936.3	Beef
3/10/2013	Beef R1	0.24		Ik	1842624.4	5924708.1	Beef
1/10/2013	49	0.32		Ik	1789951.2	5775108.6	Beef
1/10/2013	86	0.21		Ik	1789951.2	5775108.6	Beef
2/10/2013	PTQB 7	0.23		Ik	1776221.8	5841466	Beef
7/10/2013	calf	0.09		Ik	1661187.9	6030909.1	Beef
8/10/2013	No Tag	0.08		Ik	1761410.8	5839551.5	Beef
8/10/2013	326	0.06		Ik	1761410.8	5839551.5	Beef
10/10/2013	1	0.08	78	Ik	1705731.7	6034079.1	Beef
10/10/2013	2	0.09	25	Ik	1705731.7	6034079.1	Beef
8/10/2013	344	0.08		Ik	1800258	5804659.6	Beef
7/10/2013		0.31		Ik	1716246	6049771	Beef
10/10/2013		0.39		Ik	1744528	5983268	Beef
4/10/2013	62	0.09		Ik	1716099.3	5972716.5	Beef
7/10/2013	41	0.21		Ik	1734007.5	5980492.1	Beef
10/10/2013		0.28		Ik	1834506.4	5910827	Beef
26/09/2013	calf	0.09		Ik	1741097.3	5987802	Beef
29/09/2013		0.4		Ik	1742822	5976183	Beef
10/10/2013	142	0.18		Ik	1744030.7	5994297.6	Beef
10/10/2013	NO iD	0.2		Ik	1777678.1	5739600.7	Beef
10/10/2013	14	0.07		Ik	1800258	5804659.6	Beef
10/10/2013	329	0.19		Ik	1800258	5804659.6	Beef
10/10/2013	polled	0.2		Ik	1775168.2	5753307	Beef
10/10/2013	horned	0.37		Ik	1775168.2	5753307	Beef

14/10/2013		0.14		Ik	1779848.4	5743712.2	Beef
14/10/2013	calf	0.31		Ik	1625022.8	6113021	Beef
15/10/2013	8	0.39		Ik	1903617.4	5812444.1	Beef
18/10/2013	93	0.33		Ik	1763395.6	5823132.6	Beef
16/10/2013	349	0.31		Ik	1693765.9	6012719.2	Beef
16/10/2013	350	0.38		Ik	1693765.9	6012719.2	Beef
16/10/2013	341	0.35		Ik	1693765.9	6012719.2	Beef
16/10/2013	344	0.38		Ik	1693765.9	6012719.2	Beef
16/10/2013	347	0.4		Ik	1693765.9	6012719.2	Beef
16/10/2013	348	0.32		Ik	1693765.9	6012719.2	Beef
11/10/2013	9	0.28		Ik	1839809.1	5929890.9	Beef
11/10/2013	33	0.25		Ik	1839809.1	5929890.9	Beef
11/10/2013	49	0.25		Ik	1839809.1	5929890.9	Beef
21/10/2013	big	0.07		Ik	1723354.2	5941237.2	Beef
21/10/2013	small	0.09		Ik	1723354.2	5941237.2	Beef
16/10/2013		0.07	8	Ik	1683072.5	6114935.4	Beef
16/10/2013		0.11	5	Ik	1665469.2	6111461.1	Beef
24/10/2013	15	0.11		Ik	1872024.8	5783452.4	Beef
24/10/2013	202	0.1		Ik	1872024.8	5783452.4	Beef
24/10/2013	366	0.09		Ik	1872024.8	5783452.4	Beef
24/10/2013	648	0.1		Ik	1872024.8	5783452.4	Beef
23/10/2013	311	0.3	170	Ik	1693765.9	6012719.2	Beef
23/10/2013	349	0.26	120	Ik	1693765.9	6012719.2	Beef
23/10/2013	359	0.18	12	Ik	1698720.4	6002366	Beef
23/10/2013		0.57		Ik	1772131.2	5814913.2	Beef
29/10/2013	09 466	0.11		Ik	1799551.2	5737596	Beef
1/11/2013		0.1		Ik	1806362.9	5696480.2	Beef
6/11/2013	NO ID	0.24		Ik	1665419	6029822.4	Beef
8/11/2013	356/13	0.2		Ik	2012158	5672285	Beef
7/11/2013	latham	0.36		Ik	1785200.9	5883216.9	Beef
4/11/2013	19	0.16		Ik	1787585.9	5842224.1	Beef
6/11/2013	wood	0.28		Ik	1704848	5976833	Beef
8/11/2013	Calf1	0.12		Ik	1693765.9	6012719.2	Beef
8/11/2013	Calf2	0.15		Ik	1693765.9	6012719.2	Beef
8/11/2013	Calf3	0.13	4	Ik	1693765.9	6012719.2	Beef
4/11/2013	pad	0.08		Ik	1762616.9	5802593.1	Beef
4/11/2013	yard	0.37		Ik	1762616.9	5802593.1	Beef
13/11/2013	35	0.22		Ik	1782611	5852883	Beef
14/11/2013	133	0.44		Ik	2012158	5672285	Beef
14/11/2013	356	0.37		Ik	2012158	5672285	Beef
14/11/2013	390	0.38		Ik	2012158	5672285	Beef
14/11/2013	444	0.35		Ik	2012158	5672285	Beef
14/11/2013	456	0.33		Ik	2012158	5672285	Beef
11/12/2013	593	0.12		Ik	2012158	5672285	Beef
11/11/2013	NO iD	0.32		Ik	1671118.3	6021756.7	Beef
15/11/2013		0.38		Ik	1832561.8	5792254.9	Beef

15/11/2013		0.35		Ik	1832561.8	5792254.9	Beef
11/11/2013	269	0.21	71	Ik	1713321.1	5957199.8	Beef
12/11/2013	calf	0.12	3	Ik	1695057.2	6007730.7	Beef
13/11/2013	Calf	0.36		Ik	1718747.1	6065046.9	Beef
18/11/2013	calf	0.22	2	Ik	1725899.7	5937957.5	Beef
12/11/2013		0.15		Ik	2000584	5735086	Beef
11/11/2013		0.3		Ik	1834912.4	5552634.3	Beef
13/11/2013	NO ID	0.3		Ik	2026990.6	5738109	Beef
13/11/2013	J45	0.17		Ik	2049739.7	5715974	Beef
1/11/2013	BIZZ	0.27		Ik	2049739.7	5715974	Beef
15/11/2013	411	0.32		Ik	1910732.7	5596094.1	Beef
12/11/2013	H24	0.32		Ik	2049739.7	5715974	Beef
12/11/2013	H31	0.45		Ik	2049739.7	5715974	Beef
12/11/2013	H114	0.38		Ik	2049739.7	5715974	Beef
12/11/2013	H225	0.39		Ik	2049739.7	5715974	Beef
12/11/2013	H307	0.37		Ik	2049739.7	5715974	Beef
12/11/2013	H333	0.36		Ik	2049739.7	5715974	Beef
18/11/2013	H70	0.37		Ik	2049739.7	5715974	Beef
18/11/2013	2453	0.17		Ik	1865868.4	5733753.5	Beef
18/11/2013	2615	0.09		Ik	1865868.4	5733753.5	Beef
20/11/2013	858	0.12		Ik	1865868.4	5733753.5	Beef
20/11/2013	892	0.32		Ik	1865868.4	5733753.5	Beef
20/11/2013	1759	0.1		Ik	1865868.4	5733753.5	Beef
20/11/2013	2288	0.14		Ik	1865868.4	5733753.5	Beef
20/11/2013	28	0.17		Ik	1819583.8	5761691.7	Beef
20/11/2013	73	0.19		Ik	1819583.8	5761691.7	Beef
21/11/2013	332	0.13		Ik	1903617.4	5812444.1	Beef
21/11/2013	185	0.19		Ik	1903617.4	5812444.1	Beef
23/11/2013	1	0.13		Ik	1633918.3	6106789.8	Beef
23/11/2013	2	0.1		Ik	1633918.3	6106789.8	Beef
18/11/2013	719	0.27		Ik	1781973	5893341.9	Beef
19/11/2013	NO ID	0.41		Ik	1779048	5874243	Beef
21/11/2013	NO ID	0.35		Ik	1770535	5850793.6	Beef
18/11/2013	14	0.44		Ik	1750170.4	5981919.3	Beef
20/11/2013		0.28		Ik	2004243	5668568.3	Beef
21/11/2013	Nov-45	0.22	49	Ik	1652883.9	6111584.6	Beef
21/11/2013	12-NO TAG	0.23	2	Ik	1652883.9	6111584.6	Beef
19/11/2013		0.34		Ik	1838801	5851797	Beef
14/11/2013		0.29		Ik	2000320.2	5679351.1	Beef
18/11/2013	H133	0.31		Ik	2049739.7	5715974	Beef
18/11/2013	H203	0.37		Ik	2049739.7	5715974	Beef
18/11/2013	H205	0.2		Ik	2049739.7	5715974	Beef
28/11/2013	117	0.1		Ik	1707435.8	6042145.4	Beef
22/11/2013	5	0.34		Ik	1819583.8	5761691.7	Beef
22/11/2013	7	0.38		Ik	1819583.8	5761691.7	Beef
22/11/2013	No ID	0.42		Ik	1819583.8	5761691.7	Beef

29/11/2013	352	0.2	Ik	1785800.6	5890155.6	Beef
25/11/2013	No ID	0.3	Ik	1763550	5811058	Beef
26/11/2013	111	0.39	Ik	1618697.9	6117349.6	Beef
26/11/2013	Bull	0.4	Ik	1618697.9	6117349.6	Beef
26/11/2013	cow 271	0.37	Ik	1618697.9	6117349.6	Beef
26/11/2013	calf 289	0.34	Ik	1618697.9	6117349.6	Beef
26/11/2013	calf 373	0.43	Ik	1618697.9	6117349.6	Beef
26/11/2013	calf 242	0.48	Ik	1618697.9	6117349.6	Beef
29/11/2013	calf	0.26	Ik	1622075.7	6115692.2	Beef
28/11/2013	58	0.4	Ik	1618697.9	6117349.6	Beef
28/11/2013	blue dot	0.53	Ik	1618697.9	6117349.6	Beef
29/11/2013	215	0.4	Ik	1766742	5685119	Beef
29/11/2013	241	0.39	Ik	1766742	5685119	Beef
29/11/2013	242	0.4	Ik	1766742	5685119	Beef
29/11/2013	243	0.34	Ik	1766742	5685119	Beef
29/11/2013	246	0.38	Ik	1766742	5685119	Beef
18/11/2013	angus	0.28	Ik	1955769.7	5776840	Beef
28/11/2013		0.23	Ik	1955769.7	5776840	Beef
28/11/2013		0.23	Ik	1955769.7	5776840	Beef
23/11/2013	R2	0.11	Ik	1838801	5851797	Beef
27/11/2013	415/10	0.31	Ik	2047655.6	5726432.8	Beef
28/11/2013	304	0.37	Ik	2026990.6	5738109	Beef
28/11/2013	186	0.28	Ik	2026181.3	5698143.4	Beef
29/11/2013	6074	0.33	Ik	1698616.7	6035490.8	Beef
29/11/2013	5929	0.28	Ik	1698616.7	6035490.8	Beef
29/11/2013	6233	0.3	Ik	1698616.7	6035490.8	Beef
29/11/2013	6183	0.31	Ik	1698616.7	6035490.8	Beef
4/12/2013	NO ID	0.2	Ik	2022112.8	5738196.9	Beef
5/12/2013	NO ID	0.31	Ik	2018541	5741475	Beef
5/12/2013	186	0.32	Ik	2055784.1	5727746.4	Beef
11/12/2013	NO ID	0.07	Ik	2012158	5672285	Beef
6/12/2013	110	0.14	Ik	1606915	6150117.7	Beef
6/12/2013	376	0.15	Ik	1606915	6150117.7	Beef
6/12/2013	Bull	0.15	Ik	1606915	6150117.7	Beef
11/12/2013	NO ID	0.11	Ik	1837306.7	5806105.3	Beef
5/12/2013	56	0.33	Ik	1974042.1	5669969.8	Beef
10/12/2013	skinny	0.21	Ik	1732464.2	5977674.4	Beef
9/12/2013		0.07	Ik	1737826.8	5960902.9	Beef
16/12/2013	calf	0.31	Ik	1693921.5	6020288.9	Beef
18/12/2013	60	0.31	Ik	1844137.4	5915022.7	Beef
18/12/2013	179	0.23	Ik	1972707.3	5687870.4	Beef
19/12/2013	111	0.31	Ik	1773198.7	5912042.9	Beef
20/12/2013		0.28	Ik	1662577.2	6030127.4	Beef
22/12/2013	No ID	0.25	Ik	1693456.7	6017777.7	Beef
22/12/2013	No ID	0.36	Ik	1693456.7	6017777.7	Beef
27/12/2013	1	0.32	Ik	1629897.3	6118616	Beef

27/12/2013	2	0.29		Ik	1629897.3	6118616	Beef
27/12/2013		0.26		Ik	1629897.3	6118616	Beef
3/01/2014	10	0.38		Ik	1790346.3	5750576.6	Beef
3/01/2014	19	0.39		Ik	1790346.3	5750576.6	Beef
3/01/2014	40	0.31		Ik	1790346.3	5750576.6	Beef
20/12/2013	1	0.09		Ik	1639049	6125764	Beef
20/12/2013	2	0.09		Ik	1639049	6125764	Beef
20/12/2013	3	0.07		Ik	1639049	6125764	Beef
7/01/2014	89	0.14		Ik	1822178.9	5866883.3	Beef
9/12/2013	No ID	0.18		Ik	1976919.9	5684264.8	Beef
7/01/2014	sick	0.34		Ik	1618697.9	6117349.6	Beef
9/01/2014	live2	0.48		Ik	1757525.8	5760174.2	Beef
7/01/2013		0.19		Ik	2047380.7	5721481	Beef
13/01/2014	No ID	0.09		Ik	1778583.5	5757688.3	Beef
14/01/2014	1	0.13	37	Ik	1845898.8	5887277.3	Beef
14/01/2014	2	0.26	7	Ik	1845898.8	5887277.3	Beef
14/01/2014	4	0.28	14	Ik	1845898.8	5887277.3	Beef
14/01/2014	3	0.31	72	Ik	1845898.8	5887277.3	Beef
14/01/2014	5	0.34	23	Ik	1845898.8	5887277.3	Beef
14/01/2014	6	0.29	25	Ik	1845898.8	5887277.3	Beef
14/01/2014	sick	0.46	9	Ik	1845898.8	5887277.3	Beef
15/01/2014	bull	0.49		Ik	1749814.2	5870172.8	Beef
10/01/2014	9	0.36		Ik	1721389.1	5990758.9	Beef
8/01/2014	23	0.35		Ik	1745255.6	5982103.2	Beef
23/01/2014	heifer	0.2		Ik	1976919.9	5684264.8	Beef
16/01/2014	31	0.24		Ik	1747004.2	5971492.7	Beef
20/01/2014	Brownie	0.35		Ik	1726342	5981179	Beef
20/01/2014	Charalais	0.3		Ik	1726342	5981179	Beef
20/01/2014	Blackie	0.22		Ik	1726342	5981179	Beef
22/01/2014	Nice	0.49		Ik	1787972	5726772	Beef
22/01/2014	F Bull	0.35		Ik	1778886	5856203	Beef
16/01/2014	10-191	0.28		Ik	2058738	5797266	Beef
12/02/2014	202	0.11		Ik	1888083.1	5802959.9	Beef
5/02/2014	A24231	0.21		Ik	1789144.3	5908269.5	Beef
5/02/2014	A23303	0.21		Ik	1789144.3	5908269.5	Beef
5/02/2014	A24153	0.22		Ik	1789144.3	5908269.5	Beef
5/02/2014	A24138	0.2		Ik	1789144.3	5908269.5	Beef
5/02/2014	23236	0.21		Ik	1789144.3	5908269.5	Beef
5/02/2014	23245	0.23		Ik	1789144.3	5908269.5	Beef
5/02/2014	23244	0.22		Ik	1789144.3	5908269.5	Beef
13/02/2014	SHOWCOW	0.12		Ik	1871165.5	5783274	Beef
28/02/2014	2-Sep	0.1		Ik	1787223	5488643	Beef
28/02/2014	208	0.39		Ik	2012174	5672258	Beef
12/03/2014	604	0.17		Ik	1787223	5488643	Beef
14/04/2014	666	0.1		Ik	1777766	5736070	Beef
22/04/2014	Bellvue	0.1		Ik	1813540	5812936	Beef

19/04/2014	Heifer	0.08	Ik	1789583	5765875	Beef
16/04/2014	774	0.07	Ik	1813906	5861788	Beef
28/04/2014	250	0.18	Ik	1807176	5800825	Beef
1/05/2014	260	0.28	Ik	1816595	5809727	Beef
1/05/2014	1035	0.19	Ik	1816595	5809727	Beef
1/05/2014	567	0.24	Ik	1816595	5809727	Beef
1/05/2014	14	0.23	Ik	1816595	5809727	Beef
1/05/2014	209	0.2	Ik	1816595	5809727	Beef
15/04/2014	320 12	0.11	Ik	1821224	5776412	Beef
13/05/2014	220	0.23	Ik	1795350	5871543	Beef
15/05/2014	C4	0.34	Ik	2012759	5668742	Beef
15/05/2014	C42	0.3	Ik	2012759	5668742	Beef
15/05/2014	C176	0.27	Ik	2012759	5668742	Beef
15/05/2014	C153	0.31	Ik	2012759	5668742	Beef
15/05/2014	C232	0.35	Ik	2012759	5668742	Beef
16/05/2014	Bull	0.23	Ik	2009751	5670268	Beef
7/05/2014	146	0.12	Ik	1777085	5843791	Beef
13/05/2014	DJX 57 12 01	0.12	Ik	1946966	5771890	Beef
1/07/2014	Deserae	0.21	Ik	1853256	5805132	Beef
20/06/2014	1	0.38	Ik	2026882	5656526	Beef
20/06/2014	2	0.4	Ik	2026882	5656526	Beef
13/08/2014	206	0.21	Ik	1783784	5906066	Beef
25/08/2014	9-Dec	0.1	Ik	1717274	5612514	Beef
25/08/2014	Sep-33	0.09	Ik	1717274	5612514	Beef
27/08/2014	NO ID	0.13	Ik	1775706	5475695	Beef
21/08/2014	WF596	0.22	Ik	1771771	5893783	Beef
21/08/2014	Down Ang Steer	0.23	Ik	1771771	5893783	Beef
21/08/2014	51	0.22	Ik	1863641	5809471	Beef
21/08/2014	BS2	0.11	Ik	1760892	5766593	Beef
2/09/2014	Dec-51	0.11	Ik	1889459	5568038	Beef
2/09/2014	26	0.14	Ik	2003759	5734573	Beef
2/09/2014	NT1	0.12	Ik	1787591	5726187	Beef
2/09/2014	NT2	0.11	Ik	1787591	5726187	Beef
9/09/2014	820	0.23	Ik	1770645	5730845	Beef
9/09/2014	10000	0.18	Ik	1804210	5805216	Beef
4/09/2014	Aiken	0.15	Ik	1707023	6043494	Beef
8/09/2014	110	0.23	Ik	1813695	5839209	Beef
8/09/2014	Waimaha	0.16	Ik	1765482	5833911	Beef
10/09/2014	Calf	0.08	Ik	1735809	5982674	Beef
17/09/2014	423	0.22	Ik	1761385	5752933	Beef
18/09/2014	126	0.1	Ik	1791634	5754959	Beef
18/09/2014	410	0.1	Ik	1791634	5754959	Beef
18/09/2014	123	0.08	Ik	1799555	5737410	Beef
16/09/2014	8 BEEF	0.12	Ik	1831913	5762587	Beef
25/09/2014	376	0.1	Ik	1747019	5593429	Beef
1/10/2014	SKC	0.23	Ik	2052962	5733773	Beef

16/09/2014	12/126	0.16		Ik	1791589	5555738	Beef
16/09/2014	2176	0.12		Ik	1791589	5555738	Beef
23/09/2014	302	0.18		Ik	1783703	5759912	Beef
19/09/2014	Houghton	0.11		Ik	1821672	5809081	Beef
12/09/2014	NO ID	0.09		Ik	1784689	5888182	Beef
17/09/2014	NO TAG A	0.23		Ik	1770855	5785657	Beef
17/09/2014	209 A	0.23		Ik	1770855	5785657	Beef
15/09/2014	1	0.1		Ik	1779594	5781989	Beef
23/10/2014	BM8	0.17		Ik	1782223	5728245	Beef
16/10/2014	calf	0.06		Ik	1799381	5805612	Beef
15/10/2014	Badgers	0.14		Ik	1844905	5554520	Beef
23/10/2014	3 corner	0.12		Ik	1844905	5554520	Beef
15/10/2014	39	0.12		Ik	1783703	5759912	Beef
15/10/2014	379	0.17		Ik	1783703	5759912	Beef
16/10/2014	309	0.1		Ik	1810877	5696548	Beef
16/10/2014	314	0.09		Ik	1810877	5696548	Beef
16/10/2014	342	0.09		Ik	1810877	5696548	Beef
19/08/2013	GRAY	0.23	1	neg	1831531.7	5861799.6	Beef
22/10/2013		0.3		neg	1857433.5	5856564.3	Beef
13/11/2013		0.4		neg	2048732.5	5720744.4	Beef
25/11/2013		0.15		neg	1708581.5	5673883.1	Beef
27/12/2013		0.2		neg	1901882	5795537.9	Beef
24/01/2014	105	0.38		neg	1841684	5805258	Beef
24/01/2014	342	0.29		neg	1841684	5805258	Beef
5/02/2014	A23273	0.26		neg	1789144.3	5908269.5	Beef
5/02/2014	A24223	0.25		neg	1789144.3	5908269.5	Beef
5/02/2014	A16241	0.3		neg	1789144.3	5908269.5	Beef
5/02/2014	24781	0.31		neg	1789144.3	5908269.5	Beef
5/02/2014	23352	0.24		neg	1789144.3	5908269.5	Beef
5/02/2014	10460	0.29		neg	1789144.3	5908269.5	Beef
28/04/2014	251	0.3		neg	1807176	5800825	Beef
28/04/2014	Brown	0.29		neg	1807176	5800825	Beef
15/05/2014	SC63	0.2		neg	2012759	5668742	Beef
10/05/2014	H41 12	0.21		neg	1799382	5800617	Beef
16/05/2014	248	0.21		neg	1803202	5698930	Beef
7/06/2014	162	0.15		neg	1844905	5554520	Beef
10/09/2014	Steer	0.21		neg	1759987	5728572	Beef
11/09/2014	4400	0.23		neg	1785648	5739497	Beef
11/09/2014	127	0.23		neg	1785648	5739497	Beef
2/05/2014	Pink 150	0.18		other	2028139	5660669	Beef
2/05/2014	Big No Tag	0.14		other	2028139	5660669	Beef
29/10/2013	12139	0.32		un	2013125.5	5720988.1	Beef
24/07/2013	GVV942	0.25	2	un	1878832.2	5817954.3	Beef
24/09/2013	3	0.26		un	2047380.7	5721481	Beef
27/09/2013	M1	0.23		un	1842624.4	5924708.1	Beef
27/09/2013	M2	0.28		un	1842624.4	5924708.1	Beef

27/09/2013	M3	0.26	un	1842624.4	5924708.1	Beef
24/09/2013	5	0.26	un	2047380.7	5721481	Beef
24/09/2013	6	0.31	un	2047380.7	5721481	Beef
5/10/2013		0.39	un	1756584.5	5882430	Beef
10/10/2013	5	0.35	un	1920571	5790013.3	Beef
10/10/2013	30	0.35	un	1920571	5790013.3	Beef
10/10/2013	1186	0.35	un	1920571	5790013.3	Beef
10/10/2013	1293	0.34	un	1920571	5790013.3	Beef
15/10/2013	32	0.43	un	1788157.8	5719194.7	Beef
15/10/2013	H87	0.37	un	1788157.8	5719194.7	Beef
15/10/2013	T12	0.41	un	1788157.8	5719194.7	Beef
15/10/2013	H81	0.4	un	1788157.8	5719194.7	Beef
15/10/2013	T59	0.43	un	1788157.8	5719194.7	Beef
15/10/2013	R5	0.38	un	1788157.8	5719194.7	Beef
15/10/2013	T127	0.41	un	1788157.8	5719194.7	Beef
15/10/2013	H46	0.38	un	1788157.8	5719194.7	Beef
15/10/2013	189	0.39	un	1788157.8	5719194.7	Beef
15/10/2013	244	0.44	un	1788157.8	5719194.7	Beef
15/10/2013	R108	0.38	un	1788157.8	5719194.7	Beef
15/10/2013	R27	0.42	un	1788157.8	5719194.7	Beef
15/10/2013	R57	0.37	un	1788157.8	5719194.7	Beef
15/10/2013	158R	0.39	un	1788157.8	5719194.7	Beef
15/10/2013	R153	0.36	un	1788157.8	5719194.7	Beef
15/10/2013	215	0.37	un	1788157.8	5719194.7	Beef
15/10/2013	R152	0.41	un	1788157.8	5719194.7	Beef
15/10/2013	H241	0.38	un	1788157.8	5719194.7	Beef
23/10/2013	352	0.18	un	1698720.4	6002366	Beef
22/10/2013	979	0.31	un	1835162.9	5852452.4	Beef
4/11/2013	NO ID	0.33	un	1775222.2	5740447	Beef
6/11/2013	745	0.28	un	1872030	5712580	Beef
7/11/2013	25	0.27	un	1840691	5910604	Beef
7/11/2013	81	0.2	un	1840691	5910604	Beef
7/11/2013	JB	0.26	un	1840691	5910604	Beef
11/11/2013	walker	0.22	un	1863777	5821468.5	Beef
16/11/2013	882	0.39	un	1977894.7	5669623.5	Beef
16/11/2013	900	0.42	un	1977894.7	5669623.5	Beef
16/11/2013	904	0.43	un	1977894.7	5669623.5	Beef
16/11/2013	910	0.44	un	1977894.7	5669623.5	Beef
20/11/2013	22	0.37	un	1832971.9	5751251.3	Beef
29/11/2013	121	0.4	un	1869403.7	5808597.8	Beef
29/11/2013	209	0.35	un	1766742	5685119	Beef
27/11/2013		0.17	un	1858309.8	5840626	Beef
10/12/2013	Dry 1	0.39	un	2001734.6	5682756.5	Beef
10/12/2013	Dry 2	0.38	un	2001734.6	5682756.5	Beef
10/12/2013	Dry 3	0.38	un	2001734.6	5682756.5	Beef
10/12/2013	Dryx4	0.4	un	2001734.6	5682756.5	Beef

10/12/2013	Dry 5	0.37		un	2001734.6	5682756.5	Beef
10/12/2013	Dry 6	0.38		un	2001734.6	5682756.5	Beef
13/12/2013	4269	0.42		un	2044786.8	5726131.1	Beef
13/12/2013	2409	0.42		un	2044786.8	5726131.1	Beef
13/12/2013	3837	0.46		un	2044786.8	5726131.1	Beef
17/12/2013	5	0.13		un	1774418.8	5810305.7	Beef
27/12/2013	carol	0.36		un	1986140.4	5677413.8	Beef
7/01/2014	571	0.25		un	1822178.9	5866883.3	Beef
7/01/2014	1	0.34		un	1873097.3	5814720.2	Beef
7/01/2014	2	0.34		un	1873097.3	5814720.2	Beef
14/01/2014	155	0.45		un	1846799.4	5815065.8	Beef
28/01/2014	4533	0.23		un	2021521.8	5659823.1	Beef
28/01/2014	5010	0.25		un	2021521.8	5659823.1	Beef
28/01/2014	4090	0.18		un	2021521.8	5659823.1	Beef
28/01/2014	4504	0.16		un	2021521.8	5659823.1	Beef
1/05/2014	677	0.16		un	1816595	5809727	Beef
1/05/2014	1394	0.13		un	1816595	5809727	Beef
1/05/2014	150	0.16		un	1816595	5809727	Beef
1/05/2014	646	0.35		un	1816595	5809727	Beef
1/05/2014	183	0.14		un	1816595	5809727	Beef
2/05/2014	No Tag Horns	0.39		un	2028139	5660669	Beef
2/05/2014	Pink 051	0.36		un	2028139	5660669	Beef
9/09/2014	327	0.29		un	1770645	5730845	Beef
9/09/2014	9824	0.15		un	1804210	5805216	Beef
8/09/2014	69	0.27		un	1813695	5839209	Beef
16/09/2014	852	0.15		un	1831913	5762587	Beef
23/09/2014	323	0.38		un	1783703	5759912	Beef
17/09/2014	104 A	0.19		un	1770855	5785657	Beef
11/09/2014	4311	0.23		un	1785648	5739497	Beef
11/09/2014	86	0.25		un	1785648	5739497	Beef
11/09/2014	32	0.26		un	1785648	5739497	Beef
11/09/2014	4346	0.23		un	1785648	5739497	Beef
11/09/2014	HORNS	0.25		un	1785648	5739497	Beef
11/04/2013	95	0.31	0	un	1788480.8	5852743.8	Dairy
12/04/2013	99	0.34	0	un	1788480.8	5852743.8	Dairy
14/04/2013	107	0.39	0	un	1788480.8	5852743.8	Dairy
2/05/2013	12	0.32	0	un	1788480.8	5852743.8	Dairy
13/05/2013	353	0.32	2	un	1788480.8	5852743.8	Dairy
9/04/2013	92	0.35	1	un	1788480.8	5852743.8	Dairy
3/05/2013	19	0.27	0	un	1788480.8	5852743.8	Dairy
4/05/2013	22	0.29	0	un	1788480.8	5852743.8	Dairy
5/05/2013	72	0.29	0	un	1788480.8	5852743.8	Dairy
6/05/2013	94	0.28	0	un	1788480.8	5852743.8	Dairy
8/05/2013	291	0.24	0	un	1788480.8	5852743.8	Dairy
5/04/2013	Hickey	0.13	4	Ik	1798494.4	5861409.6	Dairy
27/03/2013	78	0.18	23	Ik	1788480.8	5852743.8	Dairy

16/04/2013	18	0.26	0	Ik	1798494.4	5861409.6	Dairy
16/04/2013	20	0.34	2	Ik	1798494.4	5861409.6	Dairy
16/04/2013	105	0.29	0.9	Ik	1798494.4	5861409.6	Dairy
16/04/2013	391	0.32	0.9	Ik	1798494.4	5861409.6	Dairy
16/04/2013	432	0.31	3	Ik	1798494.4	5861409.6	Dairy
16/04/2013	475	0.31	1	Ik	1798494.4	5861409.6	Dairy
16/04/2013	584	0.26	0	Ik	1798494.4	5861409.6	Dairy
16/04/2013	653	0.39	0	Ik	1798494.4	5861409.6	Dairy
16/04/2013	665	0.22	57	Ik	1798494.4	5861409.6	Dairy
16/04/2013	674	0.3	0	Ik	1798494.4	5861409.6	Dairy
27/03/2013	31	0.3	1	Ik	1788480.8	5852743.8	Dairy
28/03/2013	38	0.27	5	Ik	1788480.8	5852743.8	Dairy
29/03/2013	39	0.33	3	Ik	1788480.8	5852743.8	Dairy
30/03/2013	45	0.33	0.9	Ik	1788480.8	5852743.8	Dairy
31/03/2013	51	0.24	2	Ik	1788480.8	5852743.8	Dairy
1/04/2013	64	0.24	0.9	Ik	1788480.8	5852743.8	Dairy
2/04/2013	94	0.25	6	Ik	1788480.8	5852743.8	Dairy
7/04/2013	84	0.33	8	Ik	1788480.8	5852743.8	Dairy
8/04/2013	91	0.31	0	Ik	1788480.8	5852743.8	Dairy
10/04/2013	94	0.35	0	Ik	1788480.8	5852743.8	Dairy
13/04/2013	106	0.32	0	Ik	1788480.8	5852743.8	Dairy
15/04/2013	115	0.4	0	Ik	1788480.8	5852743.8	Dairy
9/05/2013	304	0.28	0	Ik	1788480.8	5852743.8	Dairy
11/05/2013	133	0.13	22	Ik	1788480.8	5852743.8	Dairy
12/05/2013	201	0.3	72	Ik	1788480.8	5852743.8	Dairy
14/05/2013	360	0.2	1	Ik	1788480.8	5852743.8	Dairy
15/05/2013	452	0.19	24	Ik	1788480.8	5852743.8	Dairy
16/05/2013	18 (T)	0.26	27	Ik	1788480.8	5852743.8	Dairy
17/05/2013	214 (T)	0.17	7	Ik	1788480.8	5852743.8	Dairy
18/05/2013	368 (T)	0.25	12	Ik	1788480.8	5852743.8	Dairy
19/05/2013	463 (T)	0.14	46	Ik	1788480.8	5852743.8	Dairy
20/05/2013	477 (T)	0.29	35	Ik	1788480.8	5852743.8	Dairy
1/08/2013	309	0.12	15	Ik	1788480.8	5852743.8	Dairy
1/08/2013	319	0.11	9	Ik	1788480.8	5852743.8	Dairy
16/04/2013	18 (A)	0.27	0	neg	1788480.8	5852743.8	Dairy
17/04/2013	21	0.21	0	neg	1788480.8	5852743.8	Dairy
18/04/2013	23	0.24	0	neg	1788480.8	5852743.8	Dairy
19/04/2013	25	0.32	0	neg	1788480.8	5852743.8	Dairy
20/04/2013	30	0.2	0	neg	1788480.8	5852743.8	Dairy
21/04/2013	32	0.24	0	neg	1788480.8	5852743.8	Dairy
22/04/2013	35	0.33	0	neg	1788480.8	5852743.8	Dairy
23/04/2013	37 (A)	0.41	0	neg	1788480.8	5852743.8	Dairy
24/04/2013	39	0.34	0	neg	1788480.8	5852743.8	Dairy
25/04/2013	40	0.43	0	neg	1788480.8	5852743.8	Dairy
26/04/2013	35	0.3	1	neg	1788480.8	5852743.8	Dairy
7/05/2013	246	0.32	0	neg	1788480.8	5852743.8	Dairy

10/05/2013	352	0.3	0	neg	1788480.8	5852743.8	Dairy
29/08/2014	74	0.11		Ik	1794978	5494840	Dairy
12/04/2013	100	0.29	1	un	1933739.8	5787643.1	Dairy
12/04/2013	105	0.27	1	un	1933739.8	5787643.1	Dairy
19/04/2013	109	0.23	1	un	1763908.2	5874080.3	Dairy
12/04/2013	117	0.27	1	un	1933739.8	5787643.1	Dairy
19/04/2013	90	0.26	8	un	1763908.2	5874080.3	Dairy
19/04/2013	198	0.36	1	un	1763908.2	5874080.3	Dairy
17/10/2012	nt	0.1	10	Ik	1822924.5	5494879	Dairy
30/08/2012	900	0.09	18	Ik	1896071	5741325.4	Dairy
30/08/2012	522	0.12	1	Ik	1896071	5741325.4	Dairy
5/04/2013	20	0.08		Ik	1933739.8	5787643.1	Dairy
11/04/2013	206	0.09		Ik	1813560.8	5792036.2	Dairy
29/10/2013	637	0.19		Ik	1792918.3	5850973	Dairy
29/10/2013	74	0.15		Ik	1943236.7	5789286.9	Dairy
29/10/2013	77	0.14		Ik	1943236.7	5789286.9	Dairy
29/10/2013	167	0.14		Ik	1943236.7	5789286.9	Dairy
29/10/2013	218	0.27		Ik	1943236.7	5789286.9	Dairy
29/10/2013	229	0.1		Ik	1943236.7	5789286.9	Dairy
31/10/2013		0.22		Ik	1837068.9	5795590.1	Dairy
24/10/2013		0.09		Ik	1849071.9	5850645	Dairy
28/10/2013	664	0.29		Ik	1827641.3	5840050	Dairy
28/10/2013	1020	0.09		Ik	1827641.3	5840050	Dairy
30/10/2013	40	0.08		Ik	1700892.7	5662527.9	Dairy
30/10/2013	220	0.1		Ik	1700892.7	5662527.9	Dairy
30/10/2013	99	0.1		Ik	1813762.3	5864426.1	Dairy
30/10/2013	203	0.22		Ik	1813762.3	5864426.1	Dairy
30/10/2013		0.1		Ik	1803454.5	5893909.1	Dairy
30/10/2013		0.08		Ik	1843413.2	5828965.9	Dairy
31/10/2013		0.08		Ik	1807760.2	5759221.5	Dairy
1/11/2013		0.12		Ik	1839271.7	5868318.6	Dairy
25/10/2013		0.27		Ik	1984842	5784868	Dairy
1/11/2013	70	0.26		Ik	1843413.2	5828965.9	Dairy
1/11/2013	134	0.29		Ik	1843413.2	5828965.9	Dairy
1/11/2013	132	0.31		Ik	1843413.2	5828965.9	Dairy
30/10/2013	195	0.14		Ik	1788169.7	5815808.4	Dairy
30/10/2013	408	0.11		Ik	1812900.2	5825724.2	Dairy
1/11/2013	25	0.14		Ik	1814913.2	5797028.8	Dairy
12/04/2013	55	0.29	3	Ik	1933739.8	5787643.1	Dairy
12/04/2013	98	0.22	35	Ik	1933739.8	5787643.1	Dairy
12/04/2013	156	0.11	19	Ik	1933739.8	5787643.1	Dairy
12/04/2013	104	0.27		Ik	1712294.6	6039804.8	Dairy
12/04/2013	131	0.26	0.9	Ik	1712294.6	6039804.8	Dairy
12/04/2013	179	0.33	0.9	Ik	1712294.6	6039804.8	Dairy
12/04/2013	313	0.27	0.9	Ik	1712294.6	6039804.8	Dairy
12/04/2013	335	0.29	0.9	Ik	1712294.6	6039804.8	Dairy

12/04/2013	433	0.24	4	Ik	1712294.6	6039804.8	Dairy
15/04/2013	84	0.08	80	Ik	1763908.2	5874080.3	Dairy
15/04/2013	96	0.11	20	Ik	1763908.2	5874080.3	Dairy
18/04/2013	7	0.13	7	Ik	1819122.8	5856980.6	Dairy
18/04/2013	15	0.13	1	Ik	1819122.8	5856980.6	Dairy
18/04/2013	105	0.2	0	Ik	1819122.8	5856980.6	Dairy
18/04/2013	195	0.3	0	Ik	1819122.8	5856980.6	Dairy
18/04/2013	296	0.14	3	Ik	1819122.8	5856980.6	Dairy
15/05/2013	124	0.3		Ik	1555532	5201629.4	Dairy
15/05/2013	91	0.32		Ik	1555532	5201629.4	Dairy
15/05/2013	85	0.35		Ik	1555532	5201629.4	Dairy
15/05/2013	115	0.27		Ik	1555532	5201629.4	Dairy
15/05/2013	151	0.3		Ik	1555532	5201629.4	Dairy
15/05/2013	119	0.32		Ik	1555532	5201629.4	Dairy
15/05/2013	86	0.28		Ik	1555532	5201629.4	Dairy
2/05/2013	60	0.23	56	Ik	1839115.2	5813130.4	Dairy
2/05/2013	336	0.24	22	Ik	1839115.2	5813130.4	Dairy
2/05/2013	208	0.33	3	Ik	1839115.2	5813130.4	Dairy
2/05/2013	91	0.12	15	Ik	1839115.2	5813130.4	Dairy
2/05/2013	264	0.18	76	Ik	1839115.2	5813130.4	Dairy
2/05/2013	327	0.23	36	Ik	1839115.2	5813130.4	Dairy
2/05/2013	325	0.18	16	Ik	1839115.2	5813130.4	Dairy
2/05/2013	118	0.33	2	Ik	1839115.2	5813130.4	Dairy
2/05/2013	314	0.31	1	Ik	1839115.2	5813130.4	Dairy
15/05/2013	52	0.13	4	Ik	1763110.4	5807538.4	Dairy
14/05/2013	198	0.12	5	Ik	1823555.4	5840708.8	Dairy
9/05/2013	58	0.08	10	Ik	1816771.2	5810158	Dairy
9/05/2013	1167	0.16	3	Ik	1837687.6	5807338.5	Dairy
9/05/2013	1278	0.21	1	Ik	1837687.6	5807338.5	Dairy
9/05/2013	1374	0.25	1	Ik	1837687.6	5807338.5	Dairy
9/05/2013	1169	0.21	11	Ik	1837687.6	5807338.5	Dairy
9/05/2013	1012	0.31	2	Ik	1837687.6	5807338.5	Dairy
9/05/2013	G1069	0.21	12	Ik	1837687.6	5807338.5	Dairy
14/05/2013	82	0.3	1	Ik	1850563.1	5859415.4	Dairy
14/06/2013	H1	0.4	4	Ik	1813560.8	5792036.2	Dairy
14/06/2013	H2	0.35	2	Ik	1813560.8	5792036.2	Dairy
14/06/2013	H3	0.37	4	Ik	1813560.8	5792036.2	Dairy
14/06/2013	H4	0.34	1	Ik	1813560.8	5792036.2	Dairy
14/06/2013	H5	0.4	6	Ik	1813560.8	5792036.2	Dairy
14/06/2013	H6	0.39	2	Ik	1813560.8	5792036.2	Dairy
14/06/2013	H7	0.35	2	Ik	1813560.8	5792036.2	Dairy
6/06/2013	677	0.22	20	Ik	1805870.1	5847607.7	Dairy
29/05/2013		0.11	9	Ik	1754185.8	5872151.1	Dairy
18/04/2013	319	0.19	8	Ik	1819122.8	5856980.6	Dairy
18/04/2013	397	0.23	0	Ik	1819122.8	5856980.6	Dairy
18/04/2013	dead	0.09	5	Ik	1819122.8	5856980.6	Dairy

22/04/2013	32	0.13	7	Ik	1788969.8	5821848.5	Dairy
15/04/2013	donor	0.09		Ik	1555532	5201629.4	Dairy
19/04/2013	52	0.2	6	Ik	1763908.2	5874080.3	Dairy
19/04/2013	57	0.24	1	Ik	1763908.2	5874080.3	Dairy
19/04/2013	82	0.25	7	Ik	1763908.2	5874080.3	Dairy
19/04/2013	113	0.27	5	Ik	1763908.2	5874080.3	Dairy
19/04/2013	131	0.28	9	Ik	1763908.2	5874080.3	Dairy
19/04/2013	220	0.16	4	Ik	1763908.2	5874080.3	Dairy
12/04/2013	R4	0.19	10	Ik	1748648.6	5871756.6	Dairy
12/04/2013	R69	0.15	35	Ik	1748648.6	5871756.6	Dairy
12/04/2013	R85	0.26	3	Ik	1748648.6	5871756.6	Dairy
12/04/2013	R85(2)	0.18	91	Ik	1748648.6	5871756.6	Dairy
12/04/2013	R134	0.22	3	Ik	1748648.6	5871756.6	Dairy
12/04/2013	R219	0.19	4	Ik	1748648.6	5871756.6	Dairy
12/04/2013	R275	0.19	14	Ik	1748648.6	5871756.6	Dairy
12/04/2013	R337	0.24	6	Ik	1748648.6	5871756.6	Dairy
12/04/2013	81	0.31	0.9	Ik	1748648.6	5871756.6	Dairy
12/04/2013	111	0.24	2	Ik	1748648.6	5871756.6	Dairy
12/04/2013	139	0.32	1	Ik	1748648.6	5871756.6	Dairy
23/04/2013	52	0.29	13	Ik	1837068.9	5795590.1	Dairy
23/04/2013	274	0.23	10	Ik	1837068.9	5795590.1	Dairy
30/04/2013	77	0.37	1	Ik	1789247.7	5820159.5	Dairy
30/04/2013	90	0.36	35	Ik	1789247.7	5820159.5	Dairy
30/04/2013	91	0.31	3	Ik	1789247.7	5820159.5	Dairy
30/04/2013	92	0.24	22	Ik	1789247.7	5820159.5	Dairy
30/04/2013	108	0.34	1	Ik	1789247.7	5820159.5	Dairy
30/04/2013	110	0.37	0	Ik	1789247.7	5820159.5	Dairy
30/04/2013	120	0.28	6	Ik	1789247.7	5820159.5	Dairy
30/04/2013	141	0.27	4	Ik	1789247.7	5820159.5	Dairy
30/04/2013	150	0.31	3	Ik	1789247.7	5820159.5	Dairy
30/04/2013	164	0.33	1	Ik	1789247.7	5820159.5	Dairy
30/04/2013	25	0.31	1	Ik	1788969.8	5821848.5	Dairy
30/04/2013	157	0.35	1	Ik	1788969.8	5821848.5	Dairy
30/04/2013	160	0.36	1	Ik	1788969.8	5821848.5	Dairy
30/04/2013	180	0.16	1	Ik	1788969.8	5821848.5	Dairy
30/04/2013	205	0.35	7	Ik	1788969.8	5821848.5	Dairy
30/04/2013	238	0.29	101	Ik	1788969.8	5821848.5	Dairy
30/04/2013	264	0.2	42	Ik	1788969.8	5821848.5	Dairy
30/04/2013	4	0.37	0	Ik	1762630.9	5886658.1	Dairy
30/04/2013	52	0.3	2	Ik	1762630.9	5886658.1	Dairy
30/04/2013	54	0.34	2	Ik	1762630.9	5886658.1	Dairy
30/04/2013	86	0.3	1	Ik	1762630.9	5886658.1	Dairy
30/04/2013	113	0.28	2	Ik	1762630.9	5886658.1	Dairy
30/04/2013	122	0.29	0	Ik	1762630.9	5886658.1	Dairy
30/04/2013	160	0.28	1	Ik	1762630.9	5886658.1	Dairy
30/04/2013	185	0.3	1	Ik	1762630.9	5886658.1	Dairy

30/04/2013	253	0.3	0	Ik	1762630.9	5886658.1	Dairy
30/04/2013	258	0.35	1	Ik	1762630.9	5886658.1	Dairy
30/04/2013	79	0.09	1	Ik	1839115.2	5813130.4	Dairy
30/04/2013	159	0.08	9	Ik	1839115.2	5813130.4	Dairy
7/05/2013		0.14	1	Ik	1788514.3	5800695	Dairy
7/05/2013	167	0.09	26	Ik	1769935.1	5812283.3	Dairy
7/05/2013	5	0.28	1	Ik	1788514.3	5800695	Dairy
7/05/2013	49	0.19	12	Ik	1788514.3	5800695	Dairy
7/05/2013	56	0.19	96	Ik	1788514.3	5800695	Dairy
7/05/2013	69	0.25	5	Ik	1788514.3	5800695	Dairy
7/05/2013	265	0.24	11	Ik	1788514.3	5800695	Dairy
7/05/2013	320	0.22	131	Ik	1788514.3	5800695	Dairy
7/05/2013	369	0.23	80	Ik	1788514.3	5800695	Dairy
7/05/2013	32	0.1	22	Ik	1788514.3	5800695	Dairy
7/05/2013	19	0.24	33	Ik	1788514.3	5800695	Dairy
7/05/2013	301	0.26	4	Ik	1788514.3	5800695	Dairy
10/05/2013	76	0.31	1	Ik	1769935.1	5812283.3	Dairy
10/05/2013	11	0.31	1	Ik	1769935.1	5812283.3	Dairy
10/05/2013	93	0.26	1	Ik	1769935.1	5812283.3	Dairy
10/05/2013	101	0.23	6	Ik	1769935.1	5812283.3	Dairy
10/05/2013	112	0.32	1	Ik	1769935.1	5812283.3	Dairy
10/05/2013	3	0.27	1	Ik	1769935.1	5812283.3	Dairy
10/05/2013	24	0.28	4	Ik	1769935.1	5812283.3	Dairy
10/05/2013	94	0.3	4	Ik	1769935.1	5812283.3	Dairy
10/05/2013	131	0.29	12	Ik	1769935.1	5812283.3	Dairy
19/08/2013	2556	0.2	85	Ik	1688136	6019595.3	Dairy
10/08/2013	NoID	0.08	18	Ik	1821942.5	5877304.1	Dairy
17/08/2013	51	0.27	4	Ik	1950217.4	5780713.7	Dairy
17/08/2013	68	0.28		Ik	1950217.4	5780713.7	Dairy
17/08/2013	111	0.24	4	Ik	1950217.4	5780713.7	Dairy
17/08/2013	116	0.29		Ik	1950217.4	5780713.7	Dairy
17/08/2013	135	0.25		Ik	1950217.4	5780713.7	Dairy
17/08/2013	368	0.24		Ik	1950217.4	5780713.7	Dairy
17/08/2013	374	0.27		Ik	1950217.4	5780713.7	Dairy
17/08/2013	376	0.22	76	Ik	1950217.4	5780713.7	Dairy
17/08/2013	377	0.25		Ik	1950217.4	5780713.7	Dairy
26/08/2013	315	0.1	31	Ik	1812738.3	5873648.8	Dairy
27/08/2013	NT	0.1	129	Ik	1978002.2	5784344.3	Dairy
27/08/2013	2	0.09	171	Ik	1812318.4	5801047.9	Dairy
27/08/2013	376	0.08	26	Ik	1812318.4	5801047.9	Dairy
27/08/2013	82	0.11	4	Ik	1812318.4	5801047.9	Dairy
28/08/2013	53	0.07	61	Ik	1813495.2	5875848.4	Dairy
23/08/2013	436	0.1	50	Ik	1756896.3	5589811.7	Dairy
23/08/2013	45	0.09	20	Ik	1756896.3	5589811.7	Dairy
23/08/2013	131	0.1		Ik	1794738.6	5873927	Dairy
23/08/2013	99MG	0.24	3	Ik	1780223.5	5783791.1	Dairy

26/08/2013	58G	0.24	47	Ik	1780223.5	5783791.1	Dairy
26/08/2013	245G	0.17	111	Ik	1780223.5	5783791.1	Dairy
28/08/2013	381	0.17	16	Ik	1774483.9	5904089.9	Dairy
28/08/2013	390	0.12	2	Ik	1774483.9	5904089.9	Dairy
20/06/2013	114B	0.22	7	Ik	1827331.8	5800155.3	Dairy
2/07/2013	316	0.29	16	Ik	1810571.4	5774512.4	Dairy
2/07/2013	334	0.27	10	Ik	1810571.4	5774512.4	Dairy
2/07/2013	354	0.27	7	Ik	1810571.4	5774512.4	Dairy
2/07/2013	491	0.26	5	Ik	1810571.4	5774512.4	Dairy
11/10/2013		0.1		Ik	1810571.4	5774512.4	Dairy
5/07/2013	NA	0.23	4	Ik	1841990.3	5799473.8	Dairy
2/07/2013	NA	0.24	6	Ik	1802395.8	5856941.5	Dairy
29/06/2013	436	0.22	2	Ik	1831787.7	5798816.2	Dairy
10/07/2013	167	0.23	5	Ik	1812042.8	5794343.6	Dairy
10/07/2013	198	0.16	1	Ik	1812042.8	5794343.6	Dairy
9/07/2013	106	0.08	18	Ik	1718569.4	5953236.1	Dairy
6/08/2013	52	0.08	20	Ik	1718569.4	5953236.1	Dairy
31/07/2013	261	0.21	23	Ik	1616439.5	6136072.1	Dairy
29/07/2013	17	0.13	3	Ik	1785008.2	5850906.6	Dairy
31/07/2013	47	0.11	27	Ik	1769310.5	5884079.7	Dairy
29/07/2013	244	0.1	325	Ik	1692861.8	6048808.3	Dairy
3/08/2013	50	0.11	18	Ik	1828772.5	5873784.9	Dairy
26/07/2013	1207	0.1	60	Ik	1690042.7	6096358.1	Dairy
31/07/2013	120	0.1	20	Ik	1746448.3	5946722.4	Dairy
15/07/2013	63	0.09	250	Ik	1737497	5945019.8	Dairy
26/07/2013	231	0.27	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	232	0.29	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	260	0.28	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	261	0.25	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	262	0.27	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	264	0.25	2	Ik	1731454.9	5952386.6	Dairy
26/07/2013	275	0.24	2	Ik	1731454.9	5952386.6	Dairy
26/07/2013	276	0.29	2	Ik	1731454.9	5952386.6	Dairy
26/07/2013	277	0.29	2	Ik	1731454.9	5952386.6	Dairy
26/07/2013	294	0.28	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	298	0.28	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	450	0.3	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	451	0.3	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	452	0.32	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	455	0.31	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	457	0.3	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	458	0.28	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	459	0.25	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	461	0.27	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	466	0.3	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	469	0.28	1	Ik	1731454.9	5952386.6	Dairy

26/07/2013	481	0.28	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	486	0.3	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	489	0.3	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	490	0.26	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	492	0.3	1	Ik	1731454.9	5952386.6	Dairy
26/07/2013	507	0.32	1	Ik	1731454.9	5952386.6	Dairy
12/08/2013	10	0.11	60	Ik	1791079	5792000.2	Dairy
9/08/2013	94	0.2	89	Ik	1835574	5857690.6	Dairy
20/08/2013	317	0.12		Ik	1737497	5945019.8	Dairy
20/08/2013	23	0.1	7	Ik	1726298.1	5986720	Dairy
20/08/2013	67	0.08	180	Ik	1726298.1	5986720	Dairy
20/08/2013	82	0.1	3	Ik	1726298.1	5986720	Dairy
23/08/2013	20	0.11	2	Ik	1741159.5	5984849.5	Dairy
18/08/2013	448	0.09	91	Ik	1881826.5	5795706.4	Dairy
18/08/2013	495	0.09	23	Ik	1881826.5	5795706.4	Dairy
13/08/2013	158	0.13	15	Ik	1821002.1	5816033.6	Dairy
13/08/2013	312	0.08	31	Ik	1951310	5781567.7	Dairy
13/08/2013	350	0.12	86	Ik	1788955.7	5847505.6	Dairy
20/08/2013	6214	0.12	45	Ik	1688136	6019595.3	Dairy
19/08/2013	193	0.1	22	Ik	1765440.6	5870739.2	Dairy
17/08/2013	NT	0.09	2	Ik	1792051.4	5798806.6	Dairy
16/08/2013	593	0.1	13	Ik	1770533.8	5813749.1	Dairy
16/08/2013	418	0.1	11	Ik	1797039.4	5769052.1	Dairy
23/08/2013	24	0.13	1	Ik	1756896.3	5589811.7	Dairy
20/08/2013	563	0.1	2	Ik	1770533.8	5813749.1	Dairy
20/08/2013	1524	0.1	61	Ik	1791982.4	5759952.4	Dairy
20/08/2013	21	0.09	22	Ik	1764640.3	5807590.5	Dairy
20/08/2013	64	0.15		Ik	1764640.3	5807590.5	Dairy
20/08/2013	310	0.18	2	Ik	1764640.3	5807590.5	Dairy
20/08/2013	323	0.14	1	Ik	1764640.3	5807590.5	Dairy
20/08/2013	325	0.23	1	Ik	1764640.3	5807590.5	Dairy
21/08/2013	163	0.1	1	Ik	1795894.6	5762984.9	Dairy
21/08/2013	2523	0.12	40	Ik	1688136	6019595.3	Dairy
21/08/2013	2559	0.11	88	Ik	1688136	6019595.3	Dairy
21/08/2013	40	0.08	38	Ik	1808897.7	5798812.8	Dairy
23/08/2013	cow	0.12	8	Ik	1671557.6	6032075.9	Dairy
23/08/2013	332	0.13	11	Ik	1780223.5	5783791.1	Dairy
28/08/2013	1	0.25	39	Ik	1795894.6	5762984.9	Dairy
28/08/2013	5	0.27	2	Ik	1795894.6	5762984.9	Dairy
28/08/2013	18	0.27	1	Ik	1795894.6	5762984.9	Dairy
28/08/2013	31	0.24	5	Ik	1795894.6	5762984.9	Dairy
28/08/2013	37	0.18	48	Ik	1795894.6	5762984.9	Dairy
28/08/2013	43	0.23	51	Ik	1795894.6	5762984.9	Dairy
28/08/2013	52	0.22	10	Ik	1795894.6	5762984.9	Dairy
28/08/2013	63	0.3	7	Ik	1795894.6	5762984.9	Dairy
28/08/2013	83	0.24	6	Ik	1795894.6	5762984.9	Dairy

28/08/2013	92	0.24	21	Ik	1795894.6	5762984.9	Dairy
28/08/2013	102	0.18	30	Ik	1795894.6	5762984.9	Dairy
28/08/2013	103	0.35	0	Ik	1795894.6	5762984.9	Dairy
28/08/2013	121	0.2	29	Ik	1795894.6	5762984.9	Dairy
28/08/2013	125	0.25	5	Ik	1795894.6	5762984.9	Dairy
28/08/2013	132	0.26	11	Ik	1795894.6	5762984.9	Dairy
28/08/2013	141	0.25	1	Ik	1795894.6	5762984.9	Dairy
28/08/2013	175	0.25	27	Ik	1795894.6	5762984.9	Dairy
28/08/2013	177	0.3	5	Ik	1795894.6	5762984.9	Dairy
28/08/2013	178	0.21	24	Ik	1795894.6	5762984.9	Dairy
28/08/2013	S27	0.22	24	Ik	1795894.6	5762984.9	Dairy
28/08/2013	S33	0.22	1	Ik	1795894.6	5762984.9	Dairy
28/08/2013	S64	0.17	8	Ik	1795894.6	5762984.9	Dairy
28/08/2013	S87	0.14	6	Ik	1795894.6	5762984.9	Dairy
28/08/2013	S93	0.23	1	Ik	1795894.6	5762984.9	Dairy
28/08/2013	S98	0.25	2	Ik	1795894.6	5762984.9	Dairy
28/08/2013	S107	0.2	1	Ik	1795894.6	5762984.9	Dairy
28/08/2013	S126	0.16	2	Ik	1795894.6	5762984.9	Dairy
6/09/2013	410	0.1	37	Ik	1803782.8	5686967.9	Dairy
6/09/2013	452	0.18	1	Ik	1803782.8	5686967.9	Dairy
6/09/2013	454	0.11	20	Ik	1803782.8	5686967.9	Dairy
6/09/2013	478	0.09	14	Ik	1803782.8	5686967.9	Dairy
6/09/2013	563	0.1	19	Ik	1803782.8	5686967.9	Dairy
6/09/2013	591	0.11	38	Ik	1803782.8	5686967.9	Dairy
6/09/2013	593	0.12	12	Ik	1803782.8	5686967.9	Dairy
6/09/2013	708	0.19	6	Ik	1803782.8	5686967.9	Dairy
6/09/2013	737	0.15	15	Ik	1803782.8	5686967.9	Dairy
6/09/2013	771	0.1	11	Ik	1803782.8	5686967.9	Dairy
6/09/2013	877	0.11	25	Ik	1803782.8	5686967.9	Dairy
6/09/2013	968	0.11	1	Ik	1803782.8	5686967.9	Dairy
6/09/2013	1284	0.19	23	Ik	1803782.8	5686967.9	Dairy
6/09/2013	1456	0.15	4	Ik	1803782.8	5686967.9	Dairy
6/09/2013	79	0.15	5	Ik	1836748.9	5841374.7	Dairy
1/09/2013	493	0.12	1	Ik	1870409.6	5746471.4	Dairy
30/08/2013	NO ID	0.1	8	Ik	1787953	5844723.4	Dairy
31/08/2013	106	0.17	10	Ik	1808574.3	5839040.3	Dairy
31/08/2013	130	0.09	71	Ik	1808574.3	5839040.3	Dairy
3/09/2013	48	0.09	47	Ik	1837068.9	5795590.1	Dairy
2/09/2013	451	0.14	0	Ik	1803782.8	5686967.9	Dairy
2/09/2013	954NT	0.09	10	Ik	1803782.8	5686967.9	Dairy
2/09/2013	1463	0.08	74	Ik	1803782.8	5686967.9	Dairy
2/09/2013	NO ID	0.13	1	Ik	1792837.4	5859012.4	Dairy
3/09/2013	183	0.2	6	Ik	1766375.6	5887988.6	Dairy
3/09/2013	100	0.08	2	Ik	1766375.6	5887988.6	Dairy
3/09/2013	150	0.21	34	Ik	1789827.9	5874053.5	Dairy
4/09/2013	39	0.1	3	Ik	1821268.3	5773214.9	Dairy

4/09/2013	26	0.16	0	Ik	1790374.3	5776886.7	Dairy
4/09/2013	50	0.08	275	Ik	1790374.3	5776886.7	Dairy
5/09/2013	NO ID	0.13	5	Ik	1778712.1	5743978.2	Dairy
5/09/2013	337	0.1	6	Ik	1778712.1	5743978.2	Dairy
5/09/2013	AU 253	0.09	102	Ik	1836748.9	5841374.7	Dairy
6/09/2013	98	0.1	7	Ik	1807931.4	5778453.3	Dairy
6/09/2013	506	0.2	5	Ik	1807931.4	5778453.3	Dairy
6/09/2013	94	0.21	17	Ik	1836748.9	5841374.7	Dairy
6/09/2013	554	0.15	25	Ik	1836748.9	5841374.7	Dairy
16/09/2013	159	0.18	11	Ik	1836748.9	5841374.7	Dairy
5/09/2013	472	0.15	99	Ik	1865853.6	5746226.7	Dairy
29/08/2013	90	0.1	215	Ik	1741159.5	5984849.5	Dairy
6/09/2013	9	0.1	70	Ik	1801460.1	5780278.4	Dairy
6/09/2013	502	0.11	110	Ik	1801460.1	5780278.4	Dairy
5/09/2013	NO ID	0.09	100	Ik	1751195	5590312	Dairy
3/09/2013	158	0.12	47	Ik	1789827.9	5874053.5	Dairy
3/09/2013	324	0.25	3	Ik	1789827.9	5874053.5	Dairy
3/09/2013	328	0.11	7	Ik	1789827.9	5874053.5	Dairy
3/09/2013	349	0.19	8	Ik	1789827.9	5874053.5	Dairy
3/09/2013	358	0.21	10	Ik	1789827.9	5874053.5	Dairy
12/09/2013	479	0.08	70	Ik	1783376.9	5568760.3	Dairy
12/09/2013	119	0.09	7	Ik	1818799.9	5858722	Dairy
12/09/2013	237	0.13	4	Ik	1818799.9	5858722	Dairy
11/09/2013	66	0.1	2	Ik	1787646.6	5802292.3	Dairy
16/09/2013	630	0.1	6	Ik	1836748.9	5841374.7	Dairy
12/09/2013	508	0.1	9	Ik	1787781	5799705.9	Dairy
12/09/2013	136	0.16	4	Ik	1818799.9	5858722	Dairy
12/09/2013		0.13	4	Ik	1783108.1	5875626.7	Dairy
12/09/2013	314	0.17	1	Ik	1824845.9	5838312.5	Dairy
9/09/2013	426	0.11	12	Ik	1798860.1	5861533.1	Dairy
9/09/2013	124	0.13	8	Ik	1834406.8	5817286.8	Dairy
9/09/2013	65	0.12	78	Ik	1826485.8	5819726	Dairy
9/09/2013	108	0.11	31	Ik	1826485.8	5819726	Dairy
9/09/2013	119	0.18	1	Ik	1826485.8	5819726	Dairy
10/09/2013	60	0.08	76	Ik	1804335.6	5801420.4	Dairy
10/09/2013	AU777	0.11	4	Ik	1836748.9	5841374.7	Dairy
10/09/2013	AU 502	0.16	96	Ik	1836748.9	5841374.7	Dairy
11/09/2013	231	0.11	70	Ik	1818008.8	5830392.2	Dairy
12/09/2013	85	0.12	4	Ik	1783758.3	5752844.5	Dairy
30/10/2013	80	0.28		Ik	1808894.4	5821400	Dairy
31/10/2013	137	0.39		Ik	1621129.7	6116327.4	Dairy
1/11/2013	NO ID	0.36		Ik	1809496.9	5792912.3	Dairy
29/10/2013	19	0.27		Ik	1933739.8	5787643.1	Dairy
29/10/2013	24	0.27		Ik	1933739.8	5787643.1	Dairy
29/10/2013	99	0.24		Ik	1933739.8	5787643.1	Dairy
29/10/2013	125	0.27		Ik	1933739.8	5787643.1	Dairy

29/10/2013	134	0.26		Ik	1933739.8	5787643.1	Dairy
29/10/2013	144	0.29		Ik	1933739.8	5787643.1	Dairy
29/10/2013	152	0.27		Ik	1933739.8	5787643.1	Dairy
29/10/2013	173	0.28		Ik	1933739.8	5787643.1	Dairy
29/10/2013	177	0.19		Ik	1933739.8	5787643.1	Dairy
29/10/2013	186	0.24		Ik	1933739.8	5787643.1	Dairy
29/10/2013	208	0.24		Ik	1933739.8	5787643.1	Dairy
29/10/2013	168	0.26		Ik	1933739.8	5787643.1	Dairy
29/10/2013	341	0.15		Ik	1928892.1	5745726.6	Dairy
29/10/2013	jeffrey	0.09		Ik	1822372.2	5819587.6	Dairy
29/10/2013	542	0.09		Ik	1850470.7	5818752.7	Dairy
30/10/2013	16	0.2		Ik	1928892.1	5745726.6	Dairy
31/10/2013	656	0.24		Ik	1832029	5867235.6	Dairy
31/10/2013	56	0.14		Ik	1791875	5796089.4	Dairy
31/10/2013	NO ID	0.09		Ik	1787143.4	5868795.4	Dairy
4/11/2013	NO ID	0.11		Ik	1766607.4	5881999.4	Dairy
5/11/2013	370	0.08		Ik	1821982.9	5816186.3	Dairy
12/09/2013	86	0.09	3	Ik	1783758.3	5752844.5	Dairy
18/09/2013	196	0.17	6	Ik	1828473.7	5862407.9	Dairy
18/09/2013	170	0.16	4	Ik	1787781	5799705.9	Dairy
18/09/2013	245	0.12	2	Ik	1787781	5799705.9	Dairy
17/09/2013	281	0.2	1	Ik	1813907	5782890	Dairy
17/09/2013	47	0.13	10	Ik	1801099.8	5794386.6	Dairy
17/09/2013	405	0.11	1	Ik	1801099.8	5794386.6	Dairy
17/09/2013	138	0.12	3	Ik	1801099.8	5794386.6	Dairy
18/09/2013	367	0.15	6	Ik	1817036.1	5768025.7	Dairy
18/09/2013	17	0.14	6	Ik	1817036.1	5768025.7	Dairy
16/09/2013	437	0.09	12	Ik	1788891.1	5757164.6	Dairy
16/09/2013	224	0.13	5	Ik	1839115.2	5813130.4	Dairy
9/09/2013	786	0.14	8	Ik	1803782.8	5686967.9	Dairy
17/09/2013	NO ID	0.09	10	Ik	1683488.7	6031366.8	Dairy
17/09/2013	404	0.1	80	Ik	1893009	5817381.1	Dairy
3/09/2013	36	0.06	401	Ik	1950498.9	5775731.6	Dairy
4/09/2013	36	0.12	106	Ik	1808450.8	5870991.1	Dairy
5/09/2013	31	0.11	31	Ik	1813492.8	5870248.1	Dairy
5/09/2013	388	0.11	59	Ik	1813492.8	5870248.1	Dairy
6/09/2013	90	0.1	22	Ik	1823563.9	5878214.2	Dairy
12/09/2013	257	0.08	61	Ik	1808548.6	5777175	Dairy
9/09/2013	178	0.31	4	Ik	1808450.8	5870991.1	Dairy
9/09/2013	275	0.14		Ik	1808450.8	5870991.1	Dairy
9/09/2013	DQRW23	0.12		Ik	1808450.8	5870991.1	Dairy
9/09/2013	21	0.25		Ik	1808450.8	5870991.1	Dairy
9/09/2013	106	0.14		Ik	1808450.8	5870991.1	Dairy
9/09/2013	108	0.23		Ik	1808450.8	5870991.1	Dairy
9/09/2013	160	0.3		Ik	1808450.8	5870991.1	Dairy
9/09/2013	175	0.15		Ik	1808450.8	5870991.1	Dairy

9/09/2013	233	0.3		Ik	1808450.8	5870991.1	Dairy
9/09/2013	239	0.23		Ik	1808450.8	5870991.1	Dairy
9/09/2013	252	0.22		Ik	1808450.8	5870991.1	Dairy
9/09/2013	272	0.34		Ik	1808450.8	5870991.1	Dairy
9/09/2013	286	0.36		Ik	1808450.8	5870991.1	Dairy
9/09/2013	342	0.29		Ik	1808450.8	5870991.1	Dairy
9/09/2013	928	0.27		Ik	1808450.8	5870991.1	Dairy
9/09/2013	194	0.13		Ik	1808450.8	5870991.1	Dairy
19/09/2013	106	0.18	19	Ik	1808450.8	5870991.1	Dairy
12/09/2013	838	0.1	144	Ik	1801099.8	5794386.6	Dairy
12/09/2013	2	0.23	105	Ik	1814831.4	5869818.5	Dairy
16/09/2013		0.08	342	Ik	1790739.1	5765051.1	Dairy
18/09/2013	dizzy	0.11	2	Ik	1820574.8	5875087.7	Dairy
20/09/2013	26	0.12		Ik	1783296.8	5845214.6	Dairy
17/09/2013	41	0.28		Ik	1634192.7	6098119.7	Dairy
17/09/2013	26	0.23		Ik	1634192.7	6098119.7	Dairy
12/09/2013	232	0.13	3	Ik	1793392.7	5871084.3	Dairy
16/09/2013	15	0.18	18	Ik	1836748.9	5841374.7	Dairy
16/09/2013	527	0.13	45	Ik	1836748.9	5841374.7	Dairy
16/09/2013	139	0.18	5	Ik	1828473.7	5862407.9	Dairy
26/09/2013	17	0.24		Ik	1846663.5	5892146.9	Dairy
16/09/2013	270	0.15	26	Ik	1783758.3	5752844.5	Dairy
17/09/2013	331	0.15	1	Ik	1798802.8	5787340.7	Dairy
17/09/2013	470	0.21	32	Ik	1836748.9	5841374.7	Dairy
20/09/2013	176	0.16		Ik	1783758.3	5752844.5	Dairy
18/09/2013	187	0.2	16	Ik	1797663	5840228	Dairy
18/09/2013	183	0.2	5	Ik	1797663	5840228	Dairy
18/09/2013	NO ID	0.1	6	Ik	1756464.9	5871137.1	Dairy
19/09/2013	50	0.16	24	Ik	1914047.1	5802731.2	Dairy
19/09/2013	41	0.1	4	Ik	1801995.3	5773729.1	Dairy
19/09/2013	140	0.22		Ik	1801995.3	5773729.1	Dairy
19/09/2013	437	0.27		Ik	1801995.3	5773729.1	Dairy
19/09/2013	905	0.29		Ik	1801995.3	5773729.1	Dairy
19/09/2013	103	0.31		Ik	1626734.4	6110852	Dairy
19/09/2013	110J	0.36		Ik	1626734.4	6110852	Dairy
19/09/2013	114F	0.37		Ik	1626734.4	6110852	Dairy
19/09/2013	115F	0.34		Ik	1626734.4	6110852	Dairy
19/09/2013	118F	0.38		Ik	1626734.4	6110852	Dairy
19/09/2013	21	0.26	0	Ik	1808450.8	5870991.1	Dairy
19/09/2013	342	0.2	52	Ik	1808450.8	5870991.1	Dairy
19/09/2013	275	0.15	82	Ik	1808450.8	5870991.1	Dairy
19/09/2013	178	0.25	76	Ik	1808450.8	5870991.1	Dairy
19/09/2013	108	0.16	37	Ik	1808450.8	5870991.1	Dairy
19/09/2013	272	0.22	32	Ik	1808450.8	5870991.1	Dairy
19/09/2013	160	0.18	25	Ik	1808450.8	5870991.1	Dairy
19/09/2013	23	0.25	1	Ik	1808450.8	5870991.1	Dairy

19/09/2013	21A	0.22	0	Ik	1808450.8	5870991.1	Dairy
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18/09/2013	NO ID	0.17	2	Ik	1844628.2	5856115.7	Dairy
18/09/2013	361	0.15	41	Ik	1858880.2	5852739	Dairy
18/09/2013	372	0.19	25	Ik	1858880.2	5852739	Dairy
18/09/2013	402	0.15	30	Ik	1858880.2	5852739	Dairy
18/09/2013	405	0.18	22	Ik	1858880.2	5852739	Dairy
18/09/2013	413	0.15	27	Ik	1858880.2	5852739	Dairy
18/09/2013		0.07		Ik	1836690.9	5792263.4	Dairy
19/09/2013		0.11	42	Ik	1836690.9	5792263.4	Dairy
20/09/2013	NO iD	0.09		Ik	1795361.8	5771474.4	Dairy
20/09/2013	71	0.1	19	Ik	1880658	5804176.6	Dairy
20/09/2013	542	0.11	36	Ik	1880658	5804176.6	Dairy
16/09/2013	1191	0.1	2	Ik	1751195	5590312	Dairy
16/09/2013	NO ID	0.15	140	Ik	1751195	5590312	Dairy
20/09/2013	NO ID	0.11		Ik	1848302.7	5807178.2	Dairy
25/09/2013	208	0.1		Ik	1828473.7	5862407.9	Dairy
26/09/2013	211	0.12		Ik	1828473.7	5862407.9	Dairy
24/09/2013	81	0.12		Ik	1756464.9	5871137.1	Dairy
24/09/2013	543	0.1		Ik	1756464.9	5871137.1	Dairy
25/09/2013	442	0.09		Ik	1788891.1	5757164.6	Dairy
26/09/2013	141	0.11		Ik	1792918.3	5850973	Dairy
26/09/2013	Charbelle	0.07		Ik	1818431.6	5817861.9	Dairy
16/09/2013	168	0.09	30	Ik	1783296.8	5845214.6	Dairy
26/09/2013	160	0.24		Ik	1846663.5	5892146.9	Dairy
26/09/2013	271	0.1		Ik	1902805.4	5734801.7	Dairy
25/09/2013	NO ID	0.13		Ik	1792837.4	5859012.4	Dairy
26/09/2013	19	0.16		Ik	1778986.7	5805959.4	Dairy
26/09/2013	37	0.22		Ik	1778986.7	5805959.4	Dairy
25/09/2013		0.23		Ik	1766324	5892447	Dairy
24/09/2013	283	0.09		Ik	1783758.3	5752844.5	Dairy
24/09/2013	34	0.08		Ik	1891699.4	5817555.9	Dairy
24/09/2013	78	0.09		Ik	1692861.8	6048808.3	Dairy
23/09/2013	93	0.16		Ik	1831631.2	5810595.2	Dairy
24/09/2013	532	0.11		Ik	1785508	5838679.4	Dairy
24/09/2013	549	0.18		Ik	1785508	5838679.4	Dairy
24/09/2013	615	0.1		Ik	1785508	5838679.4	Dairy
23/09/2013	263	0.14		Ik	1831631.2	5810595.2	Dairy
25/09/2013	NO ID	0.1		Ik	1755296.6	5589875.2	Dairy
27/09/2013	98	0.14		Ik	1837068.9	5795590.1	Dairy
27/09/2013	552	0.31		Ik	1837068.9	5795590.1	Dairy
24/09/2013		0.12	86	Ik	1787707.6	5800509.4	Dairy
27/09/2013	NO ID	0.16	1	Ik	1827491.1	5869834	Dairy
26/09/2013		0.14	6	Ik	1815791	5863590.1	Dairy
26/09/2013	95	0.09		Ik	1793809.7	5807260.7	Dairy
28/09/2013		0.09	109	Ik	1838963.4	5847026.7	Dairy

26/09/2013	181	0.1	83	Ik	1804412.1	5783450.1	Dairy
27/09/2013	67	0.27		Ik	1804412.1	5783450.1	Dairy
27/09/2013	472	0.25		Ik	1804412.1	5783450.1	Dairy
27/09/2013	1344	0.25		Ik	1804412.1	5783450.1	Dairy
26/09/2013	123	0.1		Ik	1804857.5	5766402	Dairy
26/09/2013	67	0.12		Ik	1784226.9	5751287	Dairy
30/09/2013		0.1		Ik	1825676.9	5777632.9	Dairy
27/09/2013	180	0.31	17	Ik	1837068.9	5795590.1	Dairy
27/09/2013	232	0.3	3	Ik	1837068.9	5795590.1	Dairy
28/09/2013		0.24		Ik	1839792.8	5911861.9	Dairy
25/09/2013	88	0.27		Ik	1739704.1	5989736.1	Dairy
27/09/2013	31	0.17		Ik	1804412.1	5783450.1	Dairy
27/09/2013	67	0.29		Ik	1804412.1	5783450.1	Dairy
27/09/2013	72	0.26		Ik	1804412.1	5783450.1	Dairy
27/09/2013	130	0.2		Ik	1804412.1	5783450.1	Dairy
27/09/2013	135	0.29		Ik	1804412.1	5783450.1	Dairy
27/09/2013	186	0.26		Ik	1804412.1	5783450.1	Dairy
27/09/2013		0.28		Ik	1795361.8	5771474.4	Dairy
27/09/2013	325	0.26		Ik	1804412.1	5783450.1	Dairy
27/09/2013	398	0.26		Ik	1804412.1	5783450.1	Dairy
27/09/2013	495	0.2		Ik	1804412.1	5783450.1	Dairy
27/09/2013	529	0.3		Ik	1804412.1	5783450.1	Dairy
27/09/2013	641	0.27		Ik	1804412.1	5783450.1	Dairy
27/09/2013	646	0.27		Ik	1804412.1	5783450.1	Dairy
27/09/2013	664	0.24		Ik	1804412.1	5783450.1	Dairy
27/09/2013	952	0.25		Ik	1804412.1	5783450.1	Dairy
27/09/2013	1022	0.29		Ik	1804412.1	5783450.1	Dairy
27/09/2013	1089	0.29		Ik	1804412.1	5783450.1	Dairy
27/09/2013	1104	0.23		Ik	1804412.1	5783450.1	Dairy
27/09/2013	1248	0.32		Ik	1804412.1	5783450.1	Dairy
27/09/2013	1276	0.29		Ik	1804412.1	5783450.1	Dairy
27/09/2013	1344	0.27		Ik	1804412.1	5783450.1	Dairy
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27/09/2013	26	0.16		Ik	1783296.8	5845214.6	Dairy
27/09/2013	166	0.07		Ik	1797779.9	5842871.4	Dairy
27/09/2013	44	0.11		Ik	1809888.9	5809291.2	Dairy
27/09/2013	NOID	0.15		Ik	1805870.1	5847607.7	Dairy
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27/09/2013	1812	0.2		Ik	1840681.9	5734678	Dairy
27/09/2013	NO ID	0.17		Ik	1823842.9	5848158	Dairy
27/09/2013	450	0.09		Ik	1838318.7	5790527.9	Dairy
30/09/2013	277	0.14		Ik	1821949.9	5838454.8	Dairy
1/10/2013	76	0.23		Ik	1840681.9	5734678	Dairy
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1/10/2013	1845	0.21		Ik	1840681.9	5734678	Dairy

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2/10/2013	197	0.1		Ik	1838318.7	5790527.9	Dairy
30/09/2013	731	0.15		Ik	1805870.1	5847607.7	Dairy
30/09/2013	75	0.17		Ik	1818008.8	5830392.2	Dairy
30/09/2013	32	0.1		Ik	1818008.8	5830392.2	Dairy
30/09/2013	5	0.13		Ik	1819705.4	5824061.3	Dairy
30/09/2013	1	0.19		Ik	1819854.6	5848892.9	Dairy
30/09/2013	2	0.24		Ik	1819854.6	5848892.9	Dairy
30/09/2013	3	0.11		Ik	1819854.6	5848892.9	Dairy
30/09/2013	4	0.07		Ik	1819854.6	5848892.9	Dairy
30/09/2013	5	0.18		Ik	1819854.6	5848892.9	Dairy
30/09/2013	93	0.11		Ik	1818008.8	5830392.2	Dairy
30/09/2013	240	0.14		Ik	1813029.3	5846530.5	Dairy
30/09/2013	280	0.23		Ik	1813029.3	5846530.5	Dairy
30/09/2013	64	0.16		Ik	1783296.8	5845214.6	Dairy
29/09/2013	430	0.17		Ik	1836748.9	5841374.7	Dairy
30/09/2013	122	0.11		Ik	1802006	5798717.3	Dairy
30/09/2013	339	0.12		Ik	1797125.9	5774861.5	Dairy
30/09/2013		0.18		Ik	1786423.7	5801575.3	Dairy
1/10/2013	269	0.12		Ik	1762229.1	5874307	Dairy
2/10/2013	626	0.12		Ik	1796387.8	5849953.5	Dairy
2/10/2013	632	0.15		Ik	1796387.8	5849953.5	Dairy
2/10/2013	51	0.17		Ik	1788935.8	5802143.1	Dairy
1/10/2013	80	0.09		Ik	1809487.5	5821528.2	Dairy
1/10/2013	10	0.12		Ik	1820876.1	5834912.3	Dairy
1/10/2013	39	0.1		Ik	1820876.1	5834912.3	Dairy
1/10/2013	68	0.1		Ik	1820876.1	5834912.3	Dairy
1/10/2013	117	0.2		Ik	1820876.1	5834912.3	Dairy
1/10/2013	126	0.15		Ik	1820876.1	5834912.3	Dairy
1/10/2013	158	0.08		Ik	1891975	5806598	Dairy
30/09/2013	471	0.11		Ik	1821949.9	5838454.8	Dairy
1/10/2013	KTVG1	0.28		Ik	1814335.9	5780783.2	Dairy
30/09/2013	94	0.26		Ik	1836748.9	5841374.7	Dairy
27/09/2013		0.1		Ik	1780711.6	5752321.5	Dairy
24/09/2013	430	0.39		Ik	1621265.1	6121479.6	Dairy
25/09/2013	52	0.32		Ik	1816771.2	5810158	Dairy
3/09/2013		0.45	9	Ik	1852568.3	5796803	Dairy
14/09/2013	108	0.28	5	Ik	1815127	5875198.3	Dairy
14/09/2013	23	0.28	1	Ik	1815127	5875198.3	Dairy
1/10/2013	886	0.11		Ik	1749365.7	5587856.6	Dairy
4/10/2013	82	0.1		Ik	1755296.6	5589875.2	Dairy
23/09/2013	446	0.12	11	Ik	1797144.3	5881072	Dairy
1/10/2013		0.13	16	Ik	1828796.1	5878258.7	Dairy
2/10/2013		0.12	195	Ik	1823912.2	5868504.8	Dairy
2/10/2013	348	0.16		Ik	1880717.6	5805470.3	Dairy

2/10/2013	1118	0.11	Ik	1880717.6	5805470.3	Dairy
3/10/2013		0.14	Ik	1817953.6	5817256.8	Dairy
5/10/2013	77	0.23	Ik	1801944.3	5890615.8	Dairy
5/10/2013	90	0.16	Ik	1801944.3	5890615.8	Dairy
5/10/2013		0.21	Ik	1806777	5878073.9	Dairy
2/10/2013		0.36	Ik	1791772.9	5808572	Dairy
1/10/2013	341	0.29	Ik	1814065.9	5850032.7	Dairy
5/10/2013	102	0.3	Ik	1813740.8	5865256.2	Dairy
5/10/2013	160	0.27	Ik	1813740.8	5865256.2	Dairy
7/10/2013		0.26	Ik	1951239.2	5773527	Dairy
2/10/2013	297	0.18	Ik	1807579.3	5829619.3	Dairy
2/10/2013	470	0.17	Ik	1836748.9	5841374.7	Dairy
2/10/2013	192	0.23	Ik	1783296.8	5845214.6	Dairy
4/10/2013	3052	0.05	Ik	1730471.9	6060116.1	Dairy
4/10/2013	3083	0.26	Ik	1730471.9	6060116.1	Dairy
3/10/2013	mills	0.1	Ik	1820164.1	5843300.8	Dairy
3/10/2013	691	0.15	Ik	1809487.5	5821528.2	Dairy
3/10/2013	695	0.16	Ik	1809487.5	5821528.2	Dairy
3/10/2013	721	0.16	Ik	1809487.5	5821528.2	Dairy
4/10/2013	151	0.12	Ik	1809487.5	5821528.2	Dairy
3/10/2013	255	0.1	Ik	1832385.3	5825539.3	Dairy
3/10/2013	No tag1	0.11	Ik	1677113.3	6012204.2	Dairy
3/10/2013	No tag2	0.07	Ik	1677113.3	6012204.2	Dairy
4/10/2013	359	0.11	Ik	1792185.1	5784232.1	Dairy
4/10/2013	534	0.2	Ik	1792185.1	5784232.1	Dairy
4/10/2013	245	0.09	Ik	1847381.4	5824925.1	Dairy
3/10/2013	24	0.15	Ik	1826581.3	5838703.8	Dairy
4/10/2013	160	0.19	Ik	1764640.3	5807590.5	Dairy
4/10/2013		0.09	Ik	1806866.3	5844969.1	Dairy
4/10/2013	19	0.24	Ik	1767703.5	5799626.8	Dairy
4/10/2013	45	0.29	Ik	1767703.5	5799626.8	Dairy
4/10/2013	62	0.31	Ik	1767703.5	5799626.8	Dairy
2/10/2013	217	0.09	Ik	1800545.2	5841203.7	Dairy
2/10/2013	140	0.22	Ik	1836748.9	5841374.7	Dairy
3/10/2013	stu	0.2	Ik	1797779.9	5842871.4	Dairy
4/10/2013	352	0.09	Ik	1798804.9	5863089.4	Dairy
4/10/2013	6	0.1	Ik	1787728	5754675.9	Dairy
4/10/2013	146	0.09	Ik	1793091.5	5738426.4	Dairy
7/10/2013	917	0.19	Ik	1786703.4	5875035.6	Dairy
4/10/2013	182	0.22	Ik	1802204	5860569.6	Dairy
4/10/2013	255	0.16	Ik	1802204	5860569.6	Dairy
4/10/2013	257	0.13	Ik	1802204	5860569.6	Dairy
4/10/2013	295	0.13	Ik	1785508	5838679.4	Dairy
6/10/2013	4	0.12	Ik	1815839.4	5848373.3	Dairy
4/10/2013	340	0.24	Ik	1812366.5	5775577	Dairy
5/10/2013	987	0.21	Ik	1792185.1	5784232.1	Dairy

5/10/2013	930	0.09		Ik	1792185.1	5784232.1	Dairy
5/10/2013	193	0.1		Ik	1803950.9	5842079.1	Dairy
6/10/2013	325	0.13		Ik	1893009	5817381.1	Dairy
7/10/2013	63	0.14		Ik	1782778.6	5895907.6	Dairy
7/10/2013	121	0.11		Ik	1782778.6	5895907.6	Dairy
7/10/2013	43	0.28		Ik	1783771.4	5780018	Dairy
7/10/2013	112	0.26		Ik	1783771.4	5780018	Dairy
7/10/2013	128	0.21		Ik	1783771.4	5780018	Dairy
7/10/2013	106	0.14		Ik	1633367	6106673.4	Dairy
7/10/2013	208	0.11		Ik	1633367	6106673.4	Dairy
7/10/2013	702	0.17		Ik	1633367	6106673.4	Dairy
8/10/2013	227	0.1		Ik	1768305.1	5808893.3	Dairy
7/10/2013	415	0.17		Ik	1828804.5	5785021	Dairy
9/10/2013	calf	0.07	2	Ik	1688068.1	6003567.8	Dairy
8/10/2013	57	0.19		Ik	1794689.2	5836782.3	Dairy
9/10/2013	NO ID	0.17		Ik	1850289.4	5805612.8	Dairy
9/10/2013	387	0.2		Ik	1795093.7	5800952	Dairy
9/10/2013	53	0.18		Ik	1809487.5	5821528.2	Dairy
9/10/2013	29	0.09		Ik	1809487.5	5821528.2	Dairy
7/10/2013		0.08		Ik	1857844.6	5854884.6	Dairy
10/10/2013		0.14		Ik	1828804.5	5785021	Dairy
16/09/2013		0.1	119	Ik	1844868.6	5854225.8	Dairy
10/10/2013		0.11		Ik	1795067.5	5763067.2	Dairy
10/10/2013	147	0.28		Ik	1815235.6	5862825.1	Dairy
10/10/2013	458	0.09		Ik	1815235.6	5862825.1	Dairy
7/10/2013	1610	0.27		Ik	1786703.4	5875035.6	Dairy
9/10/2013	218	0.25		Ik	1788955.7	5847505.6	Dairy
9/10/2013	290	0.28		Ik	1794689.2	5836782.3	Dairy
8/10/2013	60	0.34		Ik	1782786	5751467	Dairy
9/10/2013	146	0.09		Ik	1802021.4	5844961.6	Dairy
8/10/2013		0.31		Ik	1918298.2	5804728.6	Dairy
30/09/2013	125	0.33		Ik	1731715.6	5981923.5	Dairy
3/10/2013	NO ID	0.03		Ik	1794135.5	5820433	Dairy
9/10/2013	119	0.37		Ik	1933856.8	5656908.3	Dairy
9/10/2013	149	0.38		Ik	1933856.8	5656908.3	Dairy
9/10/2013	159	0.35		Ik	1933856.8	5656908.3	Dairy
26/09/2013	443	0.34		Ik	1751441.5	5988037.6	Dairy
10/10/2013	156	0.21		Ik	1915410.6	5643400.7	Dairy
10/10/2013	556	0.12		Ik	1915410.6	5643400.7	Dairy
11/10/2013	124	0.12		Ik	1814189.5	5827490	Dairy
10/10/2013	166	0.09		Ik	1799536.6	5800476.3	Dairy
14/10/2013	93	0.1		Ik	1846511.6	5852132.1	Dairy
15/10/2013	64	0.14		Ik	1839945.8	5838059.1	Dairy
16/10/2013	235	0.14		Ik	1808766.4	5841877.4	Dairy
14/10/2013	38	0.15		Ik	1692401.5	6075290.7	Dairy
15/10/2013	26	0.09		Ik	1692401.5	6075290.7	Dairy

15/10/2013	103	0.35		Ik	1692401.5	6075290.7	Dairy
15/10/2013	24	0.09		Ik	1692401.5	6075290.7	Dairy
11/10/2013	653	0.14		Ik	1786182.1	5744173.7	Dairy
14/10/2013	69	0.12		Ik	1790306.9	5757492.9	Dairy
16/10/2013	96	0.14		Ik	1790306.9	5757492.9	Dairy
14/10/2013	379	0.18		Ik	1768789.6	5809889	Dairy
15/10/2013	160	0.24		Ik	1845637.7	5770699.4	Dairy
14/10/2013	269	0.12		Ik	1788935.8	5802143.1	Dairy
17/10/2013	150	0.14		Ik	1783296.8	5845214.6	Dairy
16/10/2013	11	0.13		Ik	1783296.8	5845214.6	Dairy
17/10/2013	427	0.11		Ik	1850470.7	5818752.7	Dairy
17/10/2013	465	0.16		Ik	1817771	5795180	Dairy
17/10/2013	190	0.11		Ik	1805022.1	5838077.2	Dairy
18/10/2013	182	0.15		Ik	1820876.1	5834912.3	Dairy
18/10/2013	127	0.16		Ik	1820164.1	5843300.8	Dairy
17/10/2013	284	0.09		Ik	1806692.5	5842959	Dairy
18/10/2013	3	0.17		Ik	1793939.3	5789190.2	Dairy
18/10/2013	188	0.13		Ik	1798002.5	5802297.9	Dairy
10/10/2013	200	0.32		Ik	1810585.5	5800214.5	Dairy
11/10/2013	302	0.33		Ik	1821026.1	5774283	Dairy
10/10/2013		0.31		Ik	1786182.1	5744173.7	Dairy
15/10/2013	297	0.37		Ik	1768353.4	5813374.6	Dairy
12/10/2013	14	0.41		Ik	1675044.7	6012135.9	Dairy
17/10/2013	94	0.27		Ik	1836748.9	5841374.7	Dairy
15/10/2013	F38	0.37		Ik	1945149.4	5663238.2	Dairy
15/10/2013	F62	0.36		Ik	1945149.4	5663238.2	Dairy
15/10/2013	J148	0.34		Ik	1945149.4	5663238.2	Dairy
18/10/2013	731	0.27		Ik	1805870.1	5847607.7	Dairy
11/10/2013	359	0.23		Ik	1828804.5	5785021	Dairy
14/10/2013		0.38		Ik	1918298.2	5804728.6	Dairy
14/10/2013	132	0.14		Ik	1829355.9	5847957.8	Dairy
14/10/2013	144	0.1		Ik	1829355.9	5847957.8	Dairy
14/10/2013	188	0.15		Ik	1829355.9	5847957.8	Dairy
14/10/2013		0.1		Ik	1838312.3	5917601	Dairy
16/10/2013		0.15		Ik	1943236.7	5789286.9	Dairy
14/10/2013		0.04		Ik	1806868.7	5817109.4	Dairy
31/07/2013	61	0.25	74	Ik	1839115.2	5813130.4	Dairy
2/09/2013	100	0.12	7	Ik	1839115.2	5813130.4	Dairy
2/09/2013	243	0.14	6	Ik	1839115.2	5813130.4	Dairy
27/09/2013	46	0.09		Ik	1839115.2	5813130.4	Dairy
15/05/2013		0.11	8	Ik	1808574.3	5839040.3	Dairy
12/08/2013	03/288	0.1	3	Ik	1783771.4	5780018	Dairy
9/09/2013	296	0.08	13	Ik	1788955.7	5847505.6	Dairy
26/08/2013	184	0.11	24	Ik	1820876.1	5834912.3	Dairy
26/09/2013		0.15	20	Ik	1813740.8	5865256.2	Dairy
11/10/2013	472	0.28		Ik	1734161.3	5985179.4	Dairy

23/10/2013	64	0.12	Ik	1714245.6	5636859.6	Dairy
22/10/2013	233	0.1	Ik	1795689.6	5834987.2	Dairy
22/10/2013	292	0.23	Ik	1795689.6	5834987.2	Dairy
23/10/2013	28	0.19	Ik	1813495.2	5875848.4	Dairy
23/10/2013	305	0.14	Ik	1813495.2	5875848.4	Dairy
18/10/2013		0.09	Ik	1813029.3	5846530.5	Dairy
17/10/2013		0.1	Ik	1810567.9	5874013.2	Dairy
23/10/2013		0.11	Ik	1798201.3	5762139.4	Dairy
23/10/2013		0.15	Ik	1822846.3	5843999.8	Dairy
25/10/2013	685	0.27	Ik	1809487.5	5821528.2	Dairy
25/10/2013	691	0.32	Ik	1809487.5	5821528.2	Dairy
25/10/2013	721	0.29	Ik	1809487.5	5821528.2	Dairy
25/10/2013	352	0.25	Ik	1798804.9	5863089.4	Dairy
21/10/2013	no id	0.38	Ik	1785508	5838679.4	Dairy
22/10/2013	430	0.25	Ik	1836748.9	5841374.7	Dairy
22/10/2013	470	0.26	Ik	1836748.9	5841374.7	Dairy
21/10/2013	139	0.07	Ik	1780223.5	5783791.1	Dairy
22/10/2013	30	0.09	Ik	1803419.3	5805329.9	Dairy
21/10/2013	304	0.11	Ik	1825782.1	5818297.7	Dairy
22/10/2013	06 17	0.08	Ik	1820794.4	5839091.7	Dairy
22/10/2013		0.17	Ik	1825299.3	5837800	Dairy
25/10/2013	185	0.12	Ik	1928892.1	5745726.6	Dairy
22/10/2013	26	0.1	Ik	1802788.2	5843777.5	Dairy
22/10/2013	46	0.21	Ik	1799969.6	5774636.6	Dairy
22/10/2013	216	0.1	Ik	1906095.4	5810565.5	Dairy
23/10/2013	NO ID	0.12	Ik	1777313.2	5746411.9	Dairy
24/10/2013	82	0.24	Ik	1820164.1	5843300.8	Dairy
24/10/2013	297	0.23	Ik	1807217.8	5828752	Dairy
24/10/2013	64	0.23	Ik	1783296.8	5845214.6	Dairy
24/10/2013	107	0.31	Ik	1945149.4	5663238.2	Dairy
24/10/2013	137	0.42	Ik	1945149.4	5663238.2	Dairy
24/10/2013	464	0.34	Ik	1945149.4	5663238.2	Dairy
24/10/2013	147	0.09	Ik	1849618.9	5774560.7	Dairy
25/10/2013	889	0.15	Ik	1833163.6	5764676.4	Dairy
25/10/2013	324	0.11	Ik	1751877.1	5869978.7	Dairy
21/10/2013	214	0.33	Ik	1696359.1	6047781.3	Dairy
22/10/2013	231	0.11	Ik	1830740.6	5869715.5	Dairy
22/10/2013	243	0.15	Ik	1911496.1	5805617	Dairy
25/10/2013	454	0.09	Ik	1796395	5837739.4	Dairy
23/10/2013	68	0.37	Ik	1675600.9	6026046.4	Dairy
24/10/2013	10	0.26	Ik	1820876.1	5834912.3	Dairy
24/10/2013	117	0.27	Ik	1820876.1	5834912.3	Dairy
29/10/2013		0.15	Ik	1777159.5	5724118.7	Dairy
29/10/2013		0.13	Ik	1794536.7	5804140.4	Dairy
29/10/2013	64	0.14	Ik	1825782.1	5818297.7	Dairy
29/10/2013		0.14	Ik	1846133.9	5835441.8	Dairy

29/10/2013	122	0.24	Ik	1758982	5870368.2	Dairy
31/10/2013		0.15	Ik	1803303.2	5799284.8	Dairy
6/11/2013		0.14	Ik	1794084.4	5783624.3	Dairy
6/11/2013	166	0.11	Ik	1831108.9	5841162.1	Dairy
6/11/2013	239	0.08	Ik	1837316.3	5868446.9	Dairy
5/11/2013	56	0.1	Ik	1804087.9	5834808.4	Dairy
6/11/2013	Dead heifer	0.08	Ik	1778192.5	5724895.2	Dairy
6/11/2013	203	0.08	Ik	1839945.8	5838059.1	Dairy
8/11/2013	239	0.11	Ik	1799726.6	5844407.5	Dairy
7/11/2013	Char Hfr	0.08	Ik	1644618.4	6124568.4	Dairy
7/11/2013	Black Hfr	0.1	Ik	1644618.4	6124568.4	Dairy
7/11/2013	Friesian Bull	0.2	Ik	1644618.4	6124568.4	Dairy
7/11/2013	2502	0.35	Ik	1808574.3	5839040.3	Dairy
7/11/2013	2151	0.3	Ik	1808574.3	5839040.3	Dairy
4/11/2013	108	0.25	Ik	1867423	5817727.6	Dairy
4/11/2013	110	0.11	Ik	1867423	5817727.6	Dairy
5/11/2013		0.23	Ik	1814065.9	5850032.7	Dairy
7/11/2013		0.17	Ik	1814204.5	5873957.2	Dairy
4/11/2013	954	0.17	Ik	1827641.3	5840050	Dairy
4/11/2013	1148	0.14	Ik	1827641.3	5840050	Dairy
4/11/2013		0.16	Ik	1809999.9	5877344.7	Dairy
8/11/2013	62	0.11	Ik	1729195.4	5685822.5	Dairy
8/11/2013	188	0.11	Ik	1729195.4	5685822.5	Dairy
6/11/2013		0.29	Ik	1837068.9	5795590.1	Dairy
12/11/2013	15902	0.25	Ik	1778192.5	5724895.2	Dairy
12/11/2013	15737	0.31	Ik	1778192.5	5724895.2	Dairy
12/11/2013	15678	0.3	Ik	1778192.5	5724895.2	Dairy
12/11/2013	15937	0.29	Ik	1778192.5	5724895.2	Dairy
12/11/2013	15876	0.3	Ik	1778192.5	5724895.2	Dairy
12/11/2013	15943	0.18	Ik	1778192.5	5724895.2	Dairy
12/11/2013	15909	0.3	Ik	1778192.5	5724895.2	Dairy
12/11/2013	15963	0.28	Ik	1778192.5	5724895.2	Dairy
12/11/2013	15842	0.27	Ik	1778192.5	5724895.2	Dairy
12/11/2013	15725	0.28	Ik	1778192.5	5724895.2	Dairy
12/11/2013	15665	0.3	Ik	1778192.5	5724895.2	Dairy
12/11/2013	15869	0.31	Ik	1778192.5	5724895.2	Dairy
12/11/2013	15894	0.32	Ik	1778192.5	5724895.2	Dairy
11/11/2013	64	0.09	Ik	1814628.9	5793645.5	Dairy
12/11/2013	478	0.14	Ik	1846133.9	5835441.8	Dairy
13/11/2013	601	0.14	Ik	1811548.9	5836046.7	Dairy
13/11/2013	165	0.09	Ik	1936651.5	5760084	Dairy
14/11/2013	101	0.13	Ik	1811475.9	5841605	Dairy
14/11/2013	1355	0.09	Ik	1801544.9	5785992.9	Dairy
14/11/2013	227	0.09	Ik	1834051.8	5805021.2	Dairy
15/11/2013		0.09	Ik	1811033.4	5839432.3	Dairy
11/11/2013	355	0.25	Ik	1736364.4	5989931.1	Dairy

12/11/2013	65	0.26	Ik	1842376.1	5814486.9	Dairy
12/11/2013	64	0.38	Ik	1842376.1	5814486.9	Dairy
12/11/2013	No tag	0.25	Ik	1789138.3	5851393.8	Dairy
13/11/2013	524	0.25	Ik	1816771.2	5810158	Dairy
13/11/2013	72	0.25	Ik	1825090.7	5818450.5	Dairy
15/11/2013		0.34	Ik	1618190.1	6133921.2	Dairy
13/11/2013	Calf	0.2	Ik	1692401.5	6075290.7	Dairy
11/11/2013		0.14	Ik	1817788.5	5871774.4	Dairy
12/11/2013	102	0.28	Ik	1837068.9	5795590.1	Dairy
12/11/2013	184	0.21	Ik	1837068.9	5795590.1	Dairy
12/11/2013	246	0.26	Ik	1837068.9	5795590.1	Dairy
12/11/2013	349	0.19	Ik	1837068.9	5795590.1	Dairy
12/11/2013	504	0.27	Ik	1837068.9	5795590.1	Dairy
12/11/2013	506	0.25	Ik	1837068.9	5795590.1	Dairy
13/11/2013		0.1	Ik	1823820.4	5868169.8	Dairy
13/11/2013		0.12	Ik	1827585	5872035.8	Dairy
11/11/2013	7	0.08	Ik	1714245.6	5636859.6	Dairy
15/11/2013	32	0.12	Ik	1825090.7	5818450.5	Dairy
18/11/2013	131	0.12	Ik	1831151.2	5853334	Dairy
20/11/2013	327	0.11	Ik	1821982.9	5816186.3	Dairy
20/11/2013		0.1	Ik	1845267.8	5759560	Dairy
21/11/2013	31	0.16	Ik	1838809.6	5836721.5	Dairy
21/11/2013	113	0.22	Ik	1786703.4	5875035.6	Dairy
22/11/2013	19	0.13	Ik	1814760.1	5789041.7	Dairy
19/11/2013		0.29	Ik	1714145.9	6059347.8	Dairy
18/11/2013	177	0.38	Ik	1785989.4	5804420.2	Dairy
18/11/2013	318	0.4	Ik	1785989.4	5804420.2	Dairy
19/11/2013	285	0.25	Ik	1843208	5822922.6	Dairy
19/11/2013	372	0.2	Ik	1729673.2	5978432.9	Dairy
25/11/2013	NO ID	0.09	Ik	1690777.3	5667420.7	Dairy
15/11/2013	71	0.13	Ik	1867423	5817727.6	Dairy
16/11/2013		0.12	Ik	1816902.5	5860301.6	Dairy
1/11/2013		0.12	Ik	1832444.9	5833147.4	Dairy
15/11/2013		0.09	Ik	1848279.7	5855294.9	Dairy
25/11/2013	194	0.22	Ik	1801824.6	5806169.6	Dairy
25/11/2013	40	0.12	Ik	1801824.6	5806169.6	Dairy
25/11/2013	379	0.22	Ik	1801824.6	5806169.6	Dairy
26/11/2013	425	0.12	Ik	1801824.6	5806169.6	Dairy
27/11/2013	286	0.12	Ik	1810992	5840945.8	Dairy
27/11/2013	171	0.1	Ik	1798950.2	5848596.6	Dairy
27/11/2013	7	0.13	Ik	1801217.1	5843330.6	Dairy
27/11/2013	270	0.15	Ik	1801217.1	5843330.6	Dairy
28/11/2013	588	0.13	Ik	1865853.6	5746226.7	Dairy
28/11/2013	227	0.12	Ik	1804048	5831400.6	Dairy
27/09/2013	666	0.19	Ik	1789827.9	5874053.5	Dairy
28/11/2013	387	0.09	Ik	1788880.4	5798458.3	Dairy

29/11/2013	80	0.11		Ik	1818569.8	5809421.1	Dairy
25/11/2013	526	0.31		Ik	1774483.9	5904089.9	Dairy
26/11/2013	82	0.39		Ik	1758982	5870368.2	Dairy
25/11/2013	NO iD	0.44		Ik	1634751.2	6108363.1	Dairy
26/11/2013	241	0.32		Ik	1748427.2	5883051.2	Dairy
28/11/2013	97	0.46		Ik	1707211.8	6045637.5	Dairy
28/11/2013	109	0.35		Ik	1707211.8	6045637.5	Dairy
28/11/2013	FHWV	0.3		Ik	1775068.4	5863454.9	Dairy
28/11/2013	44650	0.28		Ik	1775068.4	5863454.9	Dairy
29/11/2013	No ID	0.28		Ik	1752951.6	5886135.2	Dairy
23/11/2013		0.14		Ik	1840868.5	5781620.5	Dairy
2/12/2013	170	0.12		Ik	1832100.5	5814765.6	Dairy
3/12/2013		0.09		Ik	1808631	5835085.3	Dairy
2/12/2013	63	0.28		Ik	1801931.9	5829600.3	Dairy
5/12/2013	3340	0.35		Ik	1730471.9	6060116.1	Dairy
3/12/2013	144	0.11		Ik	1821101.4	5855278.8	Dairy
5/12/2013		0.18		Ik	1727318.9	6004913.3	Dairy
1/12/2013		0.23		Ik	1835833.5	5831061.5	Dairy
9/12/2013		0.27		Ik	1945494.4	5776348.3	Dairy
2/12/2013		0.3		Ik	1846918.4	5793586.1	Dairy
30/11/2013		0.27		Ik	1795689.6	5834987.2	Dairy
2/12/2013		0.29		Ik	1949971.8	5771616.5	Dairy
10/12/2013	No tag	0.09		Ik	1675669.3	6100584.6	Dairy
9/12/2013	22	0.36	4	Ik	1695199.3	6011318.6	Dairy
9/12/2013	27	0.29	6	Ik	1695199.3	6011318.6	Dairy
9/12/2013	42	0.32	1	Ik	1695199.3	6011318.6	Dairy
9/12/2013	60	0.3	15	Ik	1695199.3	6011318.6	Dairy
8/12/2013	149	0.07		Ik	1791220.3	5769236.9	Dairy
10/12/2013	80	0.13		Ik	1834013.3	5854141.5	Dairy
12/12/2013	366	0.1		Ik	1811909.4	5845195.5	Dairy
10/12/2013	NO ID	0.24		Ik	1818569.8	5809421.1	Dairy
11/12/2013	39	0.14		Ik	1753255.1	5871292.9	Dairy
12/12/2013	45	0.14		Ik	1821563.4	5853946	Dairy
13/12/2013	396	0.15		Ik	1833166.6	5812990.2	Dairy
6/12/2013	351	0.29		Ik	1707980.1	6040755.4	Dairy
9/12/2013	97	0.3		Ik	1800314.4	5839533	Dairy
11/12/2013	91	0.28		Ik	1789891.8	5761791.6	Dairy
10/12/2013	131	0.28		Ik	1798641	5773566.6	Dairy
11/12/2013	107	0.23		Ik	1735252.1	5959151.4	Dairy
19/12/2013	208	0.13		Ik	1938597.3	5794627.3	Dairy
19/12/2013	No ID	0.07		Ik	1777782.9	5756150.1	Dairy
19/12/2013	3	0.09		Ik	1710195.5	6069712.6	Dairy
16/12/2013	450	0.34		Ik	1802788.2	5843777.5	Dairy
16/12/2013	2	0.38		Ik	1690724.8	6029423.4	Dairy
16/12/2013	118	0.29		Ik	1690724.8	6029423.4	Dairy
16/12/2013	100	0.28		Ik	1905769.9	5801342.7	Dairy

18/12/2013	107	0.39	Ik	1806692.5	5842959	Dairy
30/12/2013	209	0.2	Ik	1807938.3	5840763.5	Dairy
19/12/2013	WF Licc	0.28	Ik	1807059.4	5829654.6	Dairy
19/12/2013	IVF 2	0.32	Ik	1807059.4	5829654.6	Dairy
21/12/2013	58	0.36	Ik	1826415.8	5832923.5	Dairy
20/12/2013	247	0.26	Ik	1784655.9	5856882.4	Dairy
23/12/2013	43599	0.28	Ik	1800027.9	5785540.4	Dairy
23/12/2013	43484	0.23	Ik	1800027.9	5785540.4	Dairy
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24/12/2013	No ID	0.31	Ik	1836870.2	5914797.7	Dairy
20/12/2013	186	0.3	Ik	1707137.1	6043706.5	Dairy
20/12/2013	173	0.3	Ik	1707137.1	6043706.5	Dairy
30/12/2013	1	0.31	Ik	1684975.7	6008936.5	Dairy
30/12/2013	2	0.27	Ik	1684975.7	6008936.5	Dairy
31/12/2013	2505	0.31	Ik	1808574.3	5839040.3	Dairy
20/12/2013	54	0.23	Ik	1791020.1	5798622	Dairy
23/12/2013	No ID	0.17	Ik	1834754	5875858.4	Dairy
23/12/2013	200	0.23	Ik	1911507.5	5806494.6	Dairy
27/12/2013	375	0.11	Ik	1831462.7	5767749.1	Dairy
30/12/2013	820	0.1	Ik	1803530.3	5804500	Dairy
30/12/2013	332	0.24	Ik	1786099.2	5758165.9	Dairy
30/12/2013	64	0.12	Ik	1820603.1	5809388.3	Dairy
30/12/2013	271	0.1	Ik	1820603.1	5809388.3	Dairy
27/12/2013	447	0.1	Ik	1895678.5	5816473	Dairy
3/01/2014	9	0.08	Ik	1799423.6	5839251.9	Dairy
11/12/2013		0.12	Ik	1840868.5	5781620.5	Dairy
11/12/2013		0.12	Ik	1847385.1	5828064.8	Dairy
17/12/2013		0.18	Ik	1831441.5	5874250.8	Dairy
31/12/2013		0.19	Ik	1823170.1	5867968.4	Dairy
3/01/2014		0.1	Ik	1801605.5	5793985.9	Dairy
7/01/2014		0.17	Ik	1949465.4	5782186	Dairy
19/12/2013		0.25	Ik	1866318.3	5821922.1	Dairy
30/12/2013		0.32	Ik	1935547.5	5788198.9	Dairy
16/12/2013	110	0.31	Ik	1731658.5	5984768.1	Dairy
19/12/2013	413	0.34	Ik	1714414	5976447.8	Dairy
6/01/2014	837	0.24	Ik	1835937.4	5737547	Dairy
6/01/2014	No ID	0.28	Ik	1779803.7	5846978.5	Dairy
9/01/2014	6	0.12	Ik	1796447.1	5835886.4	Dairy
9/01/2014	193	0.09	Ik	1813865.9	5822844	Dairy
8/01/2014	1	0.1	Ik	1796689.1	5800221.6	Dairy
8/01/2014	129	0.19	Ik	1796689.1	5800221.6	Dairy
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8/01/2014	No ID	0.31		Ik	1799226.8	5865408.1	Dairy
8/01/2014	683	0.34		Ik	1738630.7	6036855.9	Dairy
10/01/2013	233	0.45		Ik	1788049.6	5761333.6	Dairy
14/01/2014	Gibson4	0.13		Ik	1675434.5	5664058.6	Dairy
7/01/2014	45	0.25		Ik	1677070.1	6099718	Dairy
7/01/2014	97	0.26		Ik	1677070.1	6099718	Dairy
11/01/2014	NoID	0.08		Ik	1890554.9	5736433.4	Dairy
13/01/2014	327	0.36		Ik	1835652.1	5849602.5	Dairy
8/01/2014	bull	0.24		Ik	1831441.5	5874250.8	Dairy
14/01/2014		0.08		Ik	1708408.2	5669303.9	Dairy
13/01/2014	98	0.05		Ik	1845185.9	5820566.2	Dairy
10/01/2014	177	0.1		Ik	1836674.4	5825437.9	Dairy
7/01/2014	203	0.1		Ik	1797885.3	5770233.8	Dairy
9/01/2014	437	0.26		Ik	2021565	5668427.2	Dairy
10/01/2014	417	0.11		Ik	1957790.6	5770016.2	Dairy
13/01/2014	116	0.18		Ik	1836072.9	5865264.3	Dairy
16/01/2014	100	0.13		Ik	1787143.4	5868795.4	Dairy
16/01/2014	229	0.17		Ik	1787143.4	5868795.4	Dairy
16/01/2014	105	0.08		Ik	1804663	5841540.9	Dairy
16/01/2014	6	0.3		Ik	1797926.4	5792949.6	Dairy
17/01/2014	calf	0.37		Ik	1685310	6015189	Dairy
14/01/2014	15	0.11	15	Ik	1931966.6	5789479.7	Dairy
17/01/2014	287	0.09		Ik	1938763.4	5787841.9	Dairy
17/01/2014	550	0.1		Ik	1938763.4	5787841.9	Dairy
15/01/2014	188	0.36		Ik	1840868.5	5781620.5	Dairy
24/01/2014	NoID	0.08		Ik	1819930.4	5869640	Dairy
22/01/2014		0.07	36	Ik	1844531.8	5793121.5	Dairy
22/01/2014		0.11	78	Ik	1930130.1	5793343.1	Dairy
25/01/2014	147	0.12		Ik	1836360.3	5768302.1	Dairy
25/01/2014	175	0.23		Ik	1833849.2	5780655.9	Dairy
24/01/2014	158	0.26		Ik	1800696.8	5825408.7	Dairy
24/01/2014	165	0.22		Ik	1831441.5	5874250.8	Dairy
24/01/2014	1 (R1)	0.3		Ik	1831441.5	5874250.8	Dairy
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22/01/2014	89	0.25		Ik	1802204	5860569.6	Dairy
22/01/2014	309	0.17		Ik	1802204	5860569.6	Dairy
22/01/2014	322	0.29		Ik	1815832	5781326	Dairy
24/01/2014	25	0.24		Ik	1808377	5789884	Dairy
24/01/2014	5	0.37		Ik	1821439	5774284	Dairy
21/01/2014	97	0.32		Ik	1858766.1	5717780.6	Dairy
29/01/2014	138	0.19		Ik	1790497.9	5756780	Dairy
29/01/2014	36	0.1		Ik	1790497.9	5756780	Dairy
30/01/2014	192	0.12		Ik	1799955.9	5530328.1	Dairy
30/01/2014	327	0.12		Ik	1816067	5865958	Dairy

28/01/2014	163	0.23	Ik	1712619	5956241	Dairy
3/02/2014	NO ID	0.1	Ik	1829047.9	5847339.8	Dairy
3/02/2014	96	0.1	Ik	1810301	5835006	Dairy
30/01/2014	383	0.1	Ik	1816067	5865958	Dairy
8/02/2014	50	0.14	Ik	1821356.2	5832268	Dairy
14/02/2014	499	0.14	Ik	1801805	5806555	Dairy
12/02/2014	957	0.13	Ik	1804087	5804529	Dairy
3/03/2014	33	0.16	Ik	1845379	5829351	Dairy
12/02/2014	82	0.22	Ik	1805623	5879287	Dairy
13/02/2014	770	0.09	Ik	1937336	5797537	Dairy
6/03/2014	255	0.11	Ik	1814627	5843528	Dairy
17/02/2014	161	0.11	Ik	1791024	5824504	Dairy
17/02/2014	192	0.13	Ik	1806594	5825576	Dairy
5/03/2014	MV199	0.1	Ik	1791051	5802871	Dairy
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26/02/2014	30	0.11	Ik	1820609	5845771	Dairy
21/02/2014	110	0.09	Ik	1840177	5812250	Dairy
18/02/2014	100	0.07	Ik	1790887	5877255	Dairy
5/03/2014	Orange	0.09	Ik	1890698	5816209	Dairy
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3/03/2014	389	0.12	Ik	1823526	5819548	Dairy
19/02/2014	8	0.1	Ik	1813425	5843880	Dairy
28/02/2014	60	0.17	Ik	1814913	5797028	Dairy
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7/03/2014	433	0.22	Ik	1838318	5790527	Dairy
10/03/2014	76	0.08	Ik	1833879	5862579	Dairy
10/03/2014	48	0.27	Ik	1766386	5871193	Dairy
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12/03/2014	117	0.09	Ik	1801492	5850219	Dairy
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28/02/2014	194	0.11	Ik	1794885	5836859	Dairy
28/02/2014	290	0.1	Ik	1794885	5836859	Dairy
20/03/2014	938	0.09	Ik	1893265	5818243	Dairy
19/03/2014	161	0.14	Ik	1790216	5798912	Dairy
21/03/2014	186	0.09	Ik	1835605	5831486	Dairy
20/03/2014	147	0.1	Ik	1902784	5812440	Dairy
17/03/2014	37	0.17	Ik	1834698	5874085	Dairy
17/03/2014	87	0.23	Ik	1831710	5810583	Dairy
26/03/2014	Stables	0.19	Ik	1784324	5839927	Dairy
27/03/2014	8	0.14	Ik	1831551	5824916	Dairy
26/03/2014	420	0.12	Ik	1889827	5814033	Dairy
26/03/2014	NO ID	0.12	Ik	1823808	5847723	Dairy
26/03/2014	117	0.1	Ik	1794870	5808239	Dairy
25/03/2014	460	0.16	Ik	1816186	5832585	Dairy

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28/03/2014	930	0.13	Ik	1806323	5839249	Dairy
17/03/2014	339	0.1	Ik	1895430	5813076	Dairy
26/03/2014	4039097	0.09	Ik	1818099	5547765	Dairy
11/03/2014	147	0.23	Ik	1820907	5864838	Dairy
21/03/2014	174	0.17	Ik	1832318	5869150	Dairy
11/03/2014	226	0.11	Ik	1797877	5790597	Dairy
21/03/2014	491	0.08	Ik	1809675	5798638	Dairy
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10/03/2014	76	0.08	Ik	1833879	5862579	Dairy
1/04/2014	430	0.07	Ik	1815666	5812800	Dairy
2/04/2014	14	0.07	Ik	1821546	5836783	Dairy
7/04/2014	37	0.14	Ik	1795572	5767090	Dairy
6/04/2014	196	0.23	Ik	1841338	5837572	Dairy
10/04/2014	171	0.12	Ik	1852473	5853963	Dairy
8/04/2014	385	0.09	Ik	1798945	5863480	Dairy
8/04/2014	432	0.1	Ik	1798945	5863480	Dairy
10/04/2014	297	0.1	Ik	1824193	5879173	Dairy
11/04/2014	11/344	0.08	Ik	1791543	5804559	Dairy
10/04/2014	743	0.12	Ik	1798945	5863480	Dairy
10/04/2014	749	0.12	Ik	1798945	5863480	Dairy
10/04/2014	452	0.09	Ik	1798945	5863480	Dairy
14/04/2014	261	0.1	Ik	1792998	5806725	Dairy
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1/03/2014	51	0.11	Ik	1831551	5824916	Dairy
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1/03/2014	124	0.11	Ik	1831551	5824916	Dairy
1/03/2014	146	0.16	Ik	1831551	5824916	Dairy
1/03/2014	218	0.22	Ik	1831551	5824916	Dairy
1/03/2014	247	0.15	Ik	1831551	5824916	Dairy
1/03/2014	389	0.17	Ik	1831551	5824916	Dairy
7/04/2014	445	0.13	Ik	1809675	5798638	Dairy
2/04/2014	120	0.12	Ik	1804464	5766177	Dairy
31/03/2014	108	0.11	Ik	1895372	5815888	Dairy
14/04/2014	97	0.08	Ik	1843892	5791526	Dairy
14/04/2014	136	0.12	Ik	1843892	5791526	Dairy
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6/04/2014	275	0.13	Ik	1831225	5785016	Dairy
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3/04/2014	MT 58	0.13	Ik	1843961	5837133	Dairy

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9/04/2014	221	0.1	Ik	1902630	5809963	Dairy
3/04/2014	485	0.11	Ik	1833511	5789672	Dairy
7/04/2014	NO ID	0.13	Ik	1768334	5895160	Dairy
2/04/2014	31	0.09	Ik	1783818	5843546	Dairy
14/04/2014	NO ID	0.13	Ik	1801045	5863178	Dairy
16/04/2014	242	0.1	Ik	1825200	5877445	Dairy
24/04/2014	Hanna	0.18	Ik	1838112	5792361	Dairy
16/04/2014	226	0.06	Ik	1960514	5768854	Dairy
22/04/2014	168	0.1	Ik	1814280	5794309	Dairy
22/04/2014	294	0.14	Ik	1809675	5798638	Dairy
23/04/2014	134	0.21	Ik	1828366	5867574	Dairy
23/04/2014	192	0.14	Ik	1828366	5867574	Dairy
28/04/2014	244	0.09	Ik	1798544	5839259	Dairy
28/04/2014	95	0.15	Ik	1823943	5873071	Dairy
28/04/2014	166	0.09	Ik	1924376	5793588	Dairy
29/04/2014	78	0.08	Ik	1831590	5863123	Dairy
29/04/2014	169	0.11	Ik	1806226	5797855	Dairy
30/04/2014	Orchard	0.17	Ik	1855431	5858532	Dairy
1/05/2014	124	0.1	Ik	1805282	5798997	Dairy
6/05/2014	234	0.15	Ik	1803741	5808631	Dairy
2/05/2014	274	0.14	Ik	1893265	5818243	Dairy
2/05/2014	9	0.11	Ik	1856818	5760082	Dairy
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5/05/2014	01 24	0.1	Ik	1821492	5840439	Dairy
6/05/2014	24	0.15	Ik	1840958	5793531	Dairy
16/04/2014	242	0.1	Ik	1825200	5877445	Dairy
23/04/2014	164	0.09	Ik	1839478	5815800	Dairy
30/04/2014	171	0.1	Ik	1841140	5813117	Dairy
26/04/2014	78	0.06	Ik	1847742	5852142	Dairy
23/04/2014	101	0.22	Ik	1836459	5864330	Dairy
28/04/2014	276	0.13	Ik	1836459	5864330	Dairy
24/04/2014	175	0.11	Ik	1793420	5765127	Dairy
1/05/2014	18	0.12	Ik	1843086	5790296	Dairy
1/05/2014	11	0.11	Ik	1845008	5798625	Dairy
28/04/2014	41	0.1	Ik	1840607	5814965	Dairy
8/05/2014	345	0.12	Ik	1836716	5826658	Dairy
1/05/2014	540	0.09	Ik	1840958	5793531	Dairy
1/05/2014	VA51	0.13	Ik	1836393	5839727	Dairy
24/04/2014	21	0.19	Ik	1803472	5871795	Dairy
1/05/2014	258	0.1	Ik	1804413	5828428	Dairy
8/05/2014	328	0.15	Ik	1786141	5820080	Dairy
6/05/2014	168	0.24	Ik	1786141	5820080	Dairy
6/05/2014	290	0.12	Ik	1786141	5820080	Dairy
6/05/2014	330	0.14	Ik	1786141	5820080	Dairy

6/05/2014	379	0.09	Ik	1786141	5820080	Dairy
30/04/2014	247	0.07	Ik	1856818	5760082	Dairy
1/04/2014	118	0.22	Ik	1842658	5838208	Dairy
8/05/2014	No ID	0.13	Ik	1825413	5539197	Dairy
8/05/2014	A	0.09	Ik	1825413	5539197	Dairy
14/05/2014	1	0.09	Ik	1937636	5794330	Dairy
6/05/2014	656	0.16	Ik	1810717	5836982	Dairy
6/05/2014	381	0.21	Ik	1810717	5836982	Dairy
7/05/2014	336	0.09	Ik	1929129	5746774	Dairy
8/05/2014	95	0.1	Ik	1929129	5746774	Dairy
14/05/2014	78	0.11	Ik	1790228	5810266	Dairy
13/05/2014	14	0.12	Ik	1813881	5778851	Dairy
15/05/2014	1	0.21	Ik	1831852	5856608	Dairy
12/05/2014	72	0.17	Ik	1815248	5876655	Dairy
19/05/2014	4	0.11	Ik	1817916	5832670	Dairy
17/05/2014	238	0.23	Ik	1830918	5816730	Dairy
14/05/2014	5	0.14	Ik	1843961	5837133	Dairy
14/05/2014	25	0.11	Ik	1790884	5817786	Dairy
8/05/2014	NO ID	0.07	Ik	1816025	5769967	Dairy
8/05/2014	329	0.09	Ik	1793668	5811240	Dairy
27/05/2014	60	0.21	Ik	1762689	5868246	Dairy
7/05/2014	199	0.08	Ik	1792745	5780347	Dairy
27/05/2014	152	0.23	Ik	1810026	5799775	Dairy
23/05/2014	27	0.23	Ik	1814834	5528162	Dairy
9/06/2014	574	0.11	Ik	1718568	5608227	Dairy
9/06/2014	4	0.11	Ik	1791516	5781394	Dairy
6/06/2014	349	0.13	Ik	1846194	5802737	Dairy
25/06/2014	291	0.07	Ik	1821335	5867705	Dairy
10/07/2014	Hereford	0.21	Ik	1831883	5768145	Dairy
9/07/2014	42	0.08	Ik	1815934	5846433	Dairy
1/07/2014	342	0.18	Ik	1797600	5881749	Dairy
4/07/2014	10	0.1	Ik	1823711	5872195	Dairy
14/07/2014	121	0.23	Ik	1796893	5765724	Dairy
21/07/2014	41	0.18	Ik	1913012	5806083	Dairy
18/07/2014	464	0.12	Ik	1895430	5813076	Dairy
7/07/2014	188	0.16	Ik	1848974	5794359	Dairy
18/07/2014	242	0.1	Ik	1617464	6129901	Dairy
11/07/2014	NO ID	0.12	Ik	1827174	5819072	Dairy
19/07/2014	153	0.2	Ik	1690097	6095874	Dairy
30/07/2014	405/12	0.1	Ik	1796156	5804178	Dairy
7/08/2014	175	0.09	Ik	1937675	5793262	Dairy
30/07/2014	1072	0.12	Ik	1695354	6004833	Dairy
5/08/2014	113	0.09	Ik	1764637	5807175	Dairy
4/08/2014	376	0.12	Ik	1783487	5776225	Dairy
2/08/2014	359	0.11	Ik	1899388	5815488	Dairy
2/08/2014	362	0.07	Ik	1899388	5815488	Dairy

25/07/2014	64	0.22	Ik	1750500	5867311	Dairy
23/07/2014	126	0.18	Ik	1745754	5880083	Dairy
1/08/2014	4	0.13	Ik	1880360	5757451	Dairy
1/08/2014	533	0.11	Ik	1880360	5757451	Dairy
31/07/2014	223	0.16	Ik	1695800	5635797	Dairy
7/08/2014	317	0.08	Ik	1844287	5805070	Dairy
14/08/2014	270	0.1	Ik	1809675	5798638	Dairy
11/08/2014	181	0.22	Ik	1719216	5951802	Dairy
6/08/2014	77	0.17	Ik	1799301	5791562	Dairy
6/08/2014	Robson Cow	0.09	Ik	1832177	5926353	Dairy
11/08/2014	558	0.12	Ik	1805453	5828225	Dairy
7/08/2014	222	0.13	Ik	1695354	6004833	Dairy
8/08/2014	211	0.21	Ik	1974281	5778947	Dairy
8/08/2014	617	0.21	Ik	1974281	5778947	Dairy
8/08/2014	359	0.1	Ik	1974281	5778947	Dairy
14/08/1977	12 10	0.1	Ik	1816751	5835701	Dairy
1/08/2014	56	0.12	Ik	1899587	5800176	Dairy
11/08/2014	James	0.14	Ik	1941242	5790748	Dairy
28/07/2014	63	0.1	Ik	1785569	5837351	Dairy
6/08/2014	117B	0.18	Ik	1850418	5800855	Dairy
25/07/2014	NO2	0.1	Ik	1617464	6129901	Dairy
31/07/2014	Kalma	0.12	Ik	1764742	5802888	Dairy
22/07/2014	NO ID	0.07	Ik	2032646	5823578	Dairy
15/08/2014	88	0.09	Ik	1798580	5786039	Dairy
15/08/2014	COW	0.11	Ik	1846289	5893193	Dairy
28/08/2014	285	0.18	Ik	1858112	5547027	Dairy
28/08/2014	192	0.09	Ik	1858112	5547027	Dairy
28/08/2014	281	0.16	Ik	1858112	5547027	Dairy
12/08/2014	418	0.09	Ik	1838099	5855695	Dairy
14/08/2014	200	0.21	Ik	1811831	5801158	Dairy
14/08/2014	223	0.13	Ik	1811831	5801158	Dairy
14/08/2014	438	0.08	Ik	1811831	5801158	Dairy
13/08/2014	306	0.11	Ik	1794588	5864221	Dairy
13/08/2014	26	0.16	Ik	1794588	5864221	Dairy
18/08/2014	67	0.09	Ik	1758404	5872721	Dairy
28/08/2014	544	0.09	Ik	1698180	5628994	Dairy
18/08/2014	COW	0.11	Ik	1801082	5842503	Dairy
27/08/2014	96	0.11	Ik	1718568	5608227	Dairy
27/08/2014	638	0.12	Ik	1718568	5608227	Dairy
22/08/2014	146	0.08	Ik	1687303	5634223	Dairy
26/08/2014	163	0.15	Ik	1687303	5634223	Dairy
29/08/2014	59	0.11	Ik	1799955	5530328	Dairy
15/08/2014	767	0.23	Ik	1732570	5985328	Dairy
13/08/2014	Prout	0.09	Ik	1930961	5789628	Dairy
13/08/2014	179	0.12	Ik	1822989	5819890	Dairy
13/08/2014	13	0.11	Ik	1913802	5807698	Dairy

13/08/2014	802 sick	0.1	Ik	1934404	5792746	Dairy
15/08/2014	1	0.09	Ik	1926531	5742187	Dairy
18/08/2014	395	0.15	Ik	1819520	5792705	Dairy
19/08/2014	477	0.16	Ik	1789145	5798774	Dairy
18/08/2014	111	0.16	Ik	1976283	5778408	Dairy
19/08/2014	9	0.1	Ik	1843289	5888960	Dairy
26/08/2014	154	0.09	Ik	2022340	5711139	Dairy
22/08/2014	695	0.11	Ik	1830918	5816730	Dairy
25/08/2014	34	0.16	Ik	1851809	5853272	Dairy
25/08/2014	225	0.11	Ik	1851809	5853272	Dairy
21/08/2014	2	0.04	Ik	1856486	5863159	Dairy
25/08/2014	Clayton	0.11	Ik	1831387	5794369	Dairy
19/08/2014	340	0.09	Ik	1826164	5792494	Dairy
25/08/2014	82	0.22	Ik	1794048	5786380	Dairy
25/08/2014	106	0.15	Ik	1794048	5786380	Dairy
25/08/2014	233	0.11	Ik	1794048	5786380	Dairy
25/08/2014	443	0.14	Ik	1794048	5786380	Dairy
25/08/2014	Bayliss12	0.09	Ik	1812850	5794045	Dairy
26/08/2014	710	0.1	Ik	1809287	5774908	Dairy
25/08/2014	813	0.12	Ik	1832464	5794138	Dairy
25/08/2014	170	0.1	Ik	1851217	5796599	Dairy
20/08/2014	49	0.1	Ik	1695354	6004833	Dairy
20/08/2014	138	0.21	Ik	1695354	6004833	Dairy
20/08/2014	209	0.18	Ik	1695354	6004833	Dairy
20/08/2014	700	0.2	Ik	1695354	6004833	Dairy
20/08/2014	898	0.18	Ik	1695354	6004833	Dairy
20/08/2014	1369	0.21	Ik	1695354	6004833	Dairy
20/08/2014	1539	0.13	Ik	1695354	6004833	Dairy
25/08/2014	91	0.09	Ik	1788941	5764247	Dairy
25/08/2014	253	0.08	Ik	1788941	5764247	Dairy
21/08/2014	34	0.13	Ik	1778204	5725617	Dairy
25/08/2014	321	0.11	Ik	1899286	5802953	Dairy
1/09/2014	167	0.11	Ik	1846182	5535058	Dairy
2/09/2014	107	0.087	Ik	1810624	5785986	Dairy
2/09/2014	240	0.1	Ik	1810624	5785986	Dairy
5/09/2014	256 31T	0.1	Ik	1816718	5860626	Dairy
5/09/2014	200T	0.14	Ik	1816718	5860626	Dairy
1/09/2014	696	0.05	Ik	1807192	5794875	Dairy
1/09/2014	449	0.07	Ik	1811059	5763785	Dairy
5/09/2014	105	0.12	Ik	1792803	5794798	Dairy
5/09/2014	264	0.11	Ik	1792803	5794798	Dairy
23/08/2014	359	0.11	Ik	1785226	5776229	Dairy
20/08/2014	NO ID	0.13	Ik	1986281	5785345	Dairy
4/09/2014	148	0.11	Ik	1849014	5894539	Dairy
4/09/2014	419	0.12	Ik	1849014	5894539	Dairy
20/08/2014	AU 556	0.11	Ik	1836378	5841394	Dairy

5/09/2014	120	0.11	Ik	1790018	5500711	Dairy
1/09/2014	137	0.21	Ik	1653528	6047523	Dairy
1/09/2014	175	0.23	Ik	1653528	6047523	Dairy
8/09/2014	231	0.1	Ik	1782930	5894538	Dairy
29/08/2014	12	0.1	Ik	1818064	5793774	Dairy
3/09/2014	137	0.11	Ik	1796581	5763404	Dairy
29/08/2014	118	0.16	Ik	1795295	5760290	Dairy
29/08/2014	256	0.1	Ik	1795295	5760290	Dairy
8/09/2014	110	0.09	Ik	1848058	5809677	Dairy
5/09/2014	145	0.12	Ik	1814627	5843528	Dairy
9/09/2014	21	0.11	Ik	1792130	5788209	Dairy
28/08/2014	526	0.1	Ik	1797299	5774932	Dairy
29/08/2014	NO ID	0.08	Ik	1773261	5749948	Dairy
29/08/2014	30	0.09	Ik	1775579	5738530	Dairy
29/08/2014	338	0.11	Ik	1775579	5738530	Dairy
28/08/2014	185	0.09	Ik	1808947	5782631	Dairy
2/09/2014	62	0.23	Ik	1844287	5805070	Dairy
2/09/2014	88	0.16	Ik	1844287	5805070	Dairy
2/09/2014	279	0.2	Ik	1844287	5805070	Dairy
2/09/2014	286	0.23	Ik	1844287	5805070	Dairy
26/08/2014	178	0.09	Ik	1847478	5799593	Dairy
4/09/2014	349	0.2	Ik	1779339	5487342	Dairy
4/09/2014	30	0.1	Ik	1779339	5487342	Dairy
3/09/2014	411	0.09	Ik	1811121	5775532	Dairy
2/09/2014	215	0.13	Ik	1939810	5793458	Dairy
5/09/2014	NO ID	0.1	Ik	1820090	5791035	Dairy
5/09/2014	440	0.09	Ik	1801123	5807025	Dairy
6/09/2014	918	0.11	Ik	1695354	6004833	Dairy
6/09/2014	128	0.16	Ik	1814191	5768639	Dairy
8/09/2014	25	0.12	Ik	1928022	5745444	Dairy
8/09/2014	173	0.13	Ik	1928022	5745444	Dairy
5/09/2014	13	0.14	Ik	1812850	5794045	Dairy
5/09/2014	47	0.14	Ik	1821492	5840439	Dairy
5/09/2014	53	0.12	Ik	1824099	5793793	Dairy
5/09/2014	210	0.11	Ik	1824099	5793793	Dairy
5/09/2014	341	0.09	Ik	1824099	5793793	Dairy
4/09/2014	27	0.13	Ik	1796936	5797619	Dairy
3/09/2014	107	0.1	Ik	1795295	5760290	Dairy
4/09/2014	46	0.12	Ik	1947231	5788311	Dairy
4/09/2014	326	0.1	Ik	1799649	5796725	Dairy
5/09/2014	63	0.2	Ik	1791483	5828248	Dairy
5/09/2014	254	0.11	Ik	1838112	5792361	Dairy
3/09/2014	530	0.1	Ik	1855993	5736636	Dairy
29/08/2014	92	0.09	Ik	1802465	5831327	Dairy
29/08/2014	T19	0.23	Ik	1788295	5800109	Dairy
29/08/2014	200	0.09	Ik	1836796	5747356	Dairy

29/08/2014	239	0.1	Ik	1755687	5870176	Dairy
2/09/2014	24	0.14	Ik	1856067	5763989	Dairy
2/09/2014	172	0.11	Ik	1856067	5763989	Dairy
30/08/2014	26	0.12	Ik	1853404	5858918	Dairy
2/09/2014	189	0.07	Ik	1980304	5781071	Dairy
1/09/2014	566	0.13	Ik	1806718	5773564	Dairy
2/09/2014	354	0.12	Ik	1932816	5796716	Dairy
8/09/2014	240	0.1	Ik	1829209	5823101	Dairy
9/09/2014	163	0.11	Ik	1822134	5781275	Dairy
9/09/2014	181	0.14	Ik	1808354	5804136	Dairy
27/08/2014	88	0.1	Ik	1832611	5507297	Dairy
27/08/2014	Anaemic Cow	0.09	Ik	1932816	5796716	Dairy
27/08/2014	190	0.15	Ik	1812850	5794045	Dairy
1/09/2014	243	0.07	Ik	1927792	5785290	Dairy
2/09/2014	538	0.11	Ik	1927792	5785290	Dairy
30/08/2014	534	0.09	Ik	1927792	5785290	Dairy
27/08/2014	956	0.11	Ik	1810970	5523929	Dairy
29/08/2014	243	0.12	Ik	1810970	5523929	Dairy
29/08/2014	410	0.11	Ik	1810970	5523929	Dairy
29/08/2014	928	0.12	Ik	1810970	5523929	Dairy
29/08/2014	1018	0.12	Ik	1810970	5523929	Dairy
4/09/2014	491	0.14	Ik	1810970	5523929	Dairy
5/09/2014	256	0.13	Ik	1807966	5820816	Dairy
5/09/2014	73	0.1	Ik	1807966	5820816	Dairy
3/09/2014	36	0.09	Ik	1807966	5820816	Dairy
2/09/2014	118	0.17	Ik	1846218	5858218	Dairy
30/08/2014	156	0.11	Ik	1846218	5858218	Dairy
11/09/2014	98	0.2	Ik	1711241	5670729	Dairy
15/09/2014	850	0.09	Ik	1810970	5523929	Dairy
9/09/2014	NO TAG	0.13	Ik	1663450	6072955	Dairy
6/09/2014	605	0.08	Ik	1927190	5787976	Dairy
2/09/2014	157	0.08	Ik	1713095	5634649	Dairy
2/09/2014	181	0.1	Ik	1713095	5634649	Dairy
4/09/2014	153	0.12	Ik	1811675	5542889	Dairy
16/09/2014	111	0.16	Ik	1803168	5789047	Dairy
22/09/2014	623	0.12	Ik	1792532	5512443	Dairy
10/09/2014	248	0.23	Ik	1830918	5816730	Dairy
10/09/2014	514	0.12	Ik	1830918	5816730	Dairy
10/09/2014	233	0.17	Ik	1801837	5773533	Dairy
13/09/2014	NO ID	0.11	Ik	1832157	5845444	Dairy
18/09/2014	151	0.13	Ik	1800921	5766101	Dairy
19/09/2014	521	0.12	Ik	1840069	5818167	Dairy
19/09/2014	LD304	0.22	Ik	1846253	5831829	Dairy
23/09/2014	756	0.1	Ik	1819218	5779325	Dairy
16/09/2014	141	0.11	Ik	1846194	5802737	Dairy
17/09/2014	2	0.09	Ik	1798125	5764515	Dairy

23/09/2014	18	0.1	Ik	1811326	5791042	Dairy
23/09/2014	162	0.11	Ik	1838112	5792361	Dairy
20/09/2014	195	0.11	Ik	1908993	5810419	Dairy
15/09/2014	81	0.11	Ik	1847512	5803070	Dairy
22/09/2014	280	0.21	Ik	1790995	5762390	Dairy
19/09/2014	Heifer	0.21	Ik	1766846	5807893	Dairy
17/09/2014	365	0.11	Ik	1825347	5820415	Dairy
22/09/2014	74	0.12	Ik	1802909	5825266	Dairy
9/09/2014	133	0.22	Ik	1726816	6004557	Dairy
9/09/2014	JM79	0.1	Ik	1727359	5601564	Dairy
15/09/2014	17	0.09	Ik	1825774	5805540	Dairy
15/09/2014	208	0.1	Ik	1808354	5804136	Dairy
1/10/2014	55	0.12	Ik	1729049	5607132	Dairy
1/10/2014	222	0.18	Ik	1729049	5607132	Dairy
1/10/2014	15	0.12	Ik	1729049	5607132	Dairy
12/09/2014	125	0.13	Ik	1940178	5791145	Dairy
15/09/2014	134	0.12	Ik	1805354	5840992	Dairy
12/09/2014	209	0.1	Ik	1944496	5792949	Dairy
15/09/2014	229	0.13	Ik	1788295	5800109	Dairy
15/09/2014	145	0.1	Ik	1794407	5826957	Dairy
16/09/2014	138	0.14	Ik	1932531	5796047	Dairy
16/09/2014	373	0.1	Ik	1929453	5747199	Dairy
16/09/2014	349	0.13	Ik	1833179	5780891	Dairy
30/09/2014	179	0.17	Ik	1933518	5656813	Dairy
11/09/2014	70	0.12	Ik	1937024	5791140	Dairy
9/09/2014	303	0.08	Ik	1810198	5827350	Dairy
10/09/2014	99	0.13	Ik	1930275	5789168	Dairy
10/09/2014	351	0.12	Ik	1933152	5790065	Dairy
15/09/2014	618	0.13	Ik	1831896	5769805	Dairy
19/09/2014	8	0.11	Ik	1787907	5494713	Dairy
17/09/2014	Pedley 65	0.09	Ik	1794978	5494840	Dairy
15/09/2014	352	0.12	Ik	1794043	5511747	Dairy
15/09/2014	429	0.1	Ik	1794043	5511747	Dairy
22/09/2014	418	0.11	Ik	1794043	5511747	Dairy
22/09/2014	792	0.1	Ik	1794043	5511747	Dairy
30/09/2014	99	0.087	Ik	1867690	5818760	Dairy
3/10/2014	26	0.1	Ik	1846880	5800786	Dairy
1/10/2014	118	0.1	Ik	1794043	5511747	Dairy
1/10/2014	890	0.24	Ik	2017521	5717715	Dairy
30/09/2014	246	0.13	Ik	1904904	5634814	Dairy
30/09/2014	778	0.14	Ik	1904904	5634814	Dairy
30/09/2014	385	0.17	Ik	1904904	5634814	Dairy
2/10/2014	443	0.14	Ik	1904904	5634814	Dairy
6/10/2014	41	0.11	Ik	1801431	5533578	Dairy
6/10/2014	43	0.11	Ik	1801431	5533578	Dairy
6/10/2014	132	0.08	Ik	1801431	5533578	Dairy

1/10/2014	Clausen	0.08	Ik	1803960	5832580	Dairy
7/10/2014	NO ID	0.09	Ik	1718502	5613550	Dairy
4/10/2014	Unlabelled	0.16	Ik	1890979	5736403	Dairy
23/09/2014	679	0.11	Ik	1783553	5568487	Dairy
24/09/2014	415	0.11	Ik	1680492	5630422	Dairy
23/09/2014	56	0.09	Ik	1822250	5553614	Dairy
16/09/2014	QK	0.11	Ik	1845968	5856706	Dairy
16/09/2014	146	0.09	Ik	1841978	5781524	Dairy
19/09/2014	NO ID	0.14	Ik	1785385	5846227	Dairy
20/09/2014	439	0.1	Ik	1842657	5798556	Dairy
17/09/2014	2423	0.11	Ik	1869758	5781916	Dairy
10/09/2014	220	0.09	Ik	1845342	5829626	Dairy
12/09/2014	15	0.14	Ik	1845342	5829626	Dairy
23/09/2014	388	0.11	Ik	1928845	5749761	Dairy
12/09/2014	168	0.1	Ik	1791746	5868244	Dairy
18/09/2014	45	0.13	Ik	1846253	5831829	Dairy
15/09/2014	91	0.11	Ik	1915495	5806052	Dairy
10/09/2014	326	0.23	Ik	1817811	5827157	Dairy
22/09/2014	151	0.15	Ik	1836060	5811465	Dairy
2/10/2014	191 FR	0.17	Ik	1695800	5635797	Dairy
4/10/2014	281	0.23	Ik	1695800	5635797	Dairy
11/09/2014	192	0.12	Ik	1810072	5793005	Dairy
16/09/2014	88	0.13	Ik	1802285	5788624	Dairy
24/09/2014	1094	0.09	Ik	1794044	5541868	Dairy
15/09/2014	172	0.12	Ik	1790559	5510880	Dairy
17/09/2014	417	0.09	Ik	1790559	5510880	Dairy
23/09/2014	353	0.12	Ik	1790559	5510880	Dairy
22/09/2014	325	0.12	Ik	1798125	5764515	Dairy
1/10/2014	82	0.082	Ik	1764742	5802888	Dairy
1/10/2014	338	0.088	Ik	1764742	5802888	Dairy
1/10/2014	Kent1069	0.11	Ik	1751194	5590309	Dairy
22/09/2014	133	0.07	Ik	1798141	5763434	Dairy
23/09/2014	266 08	0.11	Ik	1790228	5810266	Dairy
10/09/2014	WA	0.08	Ik	1775137	5735032	Dairy
23/09/2014	Dennis 1	0.16	Ik	1778138	5726302	Dairy
15/09/2014	Y328	0.11	Ik	1841518	5839138	Dairy
11/09/2014	333	0.1	Ik	1807082	5776377	Dairy
15/09/2014	209	0.19	Ik	1846673	5833268	Dairy
15/09/2014	Laurence	0.09	Ik	1826301	5837476	Dairy
12/09/2014	50	0.15	Ik	1831434	5874514	Dairy
12/09/2014	17	0.1	Ik	1856214	5855704	Dairy
22/09/2014	57	0.11	Ik	1847771	5802842	Dairy
22/09/2014	140	0.13	Ik	1847771	5802842	Dairy
11/09/2014	372	0.11	Ik	1939810	5793458	Dairy
15/09/2014	Duckpond	0.18	Ik	1840958	5793531	Dairy
11/09/2014	225	0.08	Ik	1945360	5792009	Dairy

11/10/2014	570	0.09		Ik	1782214	5487234	Dairy
10/10/2014	327	0.12		Ik	1808447	5551889	Dairy
9/10/2014	Apr-90	0.18		Ik	1853175	5761751	Dairy
9/10/2014	08/255	0.05		Ik	1853175	5761751	Dairy
10/10/2014	143	0.13		Ik	1482457	5275164	Dairy
8/10/2014	NO ID	0.12		Ik	1811675	5542889	Dairy
24/10/2014	31	0.08		Ik	1851417	5811316	Dairy
23/10/2014	39	0.11		Ik	1821094	5865133	Dairy
23/10/2014	74	0.19		Ik	1821094	5865133	Dairy
23/10/2014	Kite47	0.16		Ik	1807217	5803855	Dairy
23/10/2014	79	0.12		Ik	1938269	5794082	Dairy
23/10/2014	118	0.1		Ik	1938269	5794082	Dairy
23/10/2014	124	0.14		Ik	1935401	5790526	Dairy
23/10/2014	28	0.12		Ik	1776361	5725527	Dairy
23/10/2014	124	0.13		Ik	1791952	5780814	Dairy
23/10/2014	45	0.15		Ik	1810159	5835718	Dairy
23/10/2014	121	0.13		Ik	1810159	5835718	Dairy
23/10/2014	138	0.18		Ik	1810159	5835718	Dairy
24/10/2014	NO ID	0.08		Ik	1790424	5734274	Dairy
17/10/2014	117	0.22		Ik	1956611	5782772	Dairy
21/10/2014	Calf1	0.2		Ik	1972854	5782644	Dairy
22/10/2014	58	0.1		Ik	1819910	5834484	Dairy
22/10/2014	76	0.13		Ik	1819910	5834484	Dairy
20/10/2014	75	0.17		Ik	1847311	5829228	Dairy
20/10/2014	111	0.2		Ik	1821492	5840439	Dairy
20/10/2014	102	0.09		Ik	1940935	5794859	Dairy
17/10/2014	62	0.11		Ik	1802505	5793742	Dairy
20/10/2014	NO ID	0.11		Ik	1805597	5781743	Dairy
17/10/2014	166	0.1		Ik	1845008	5798625	Dairy
17/10/2014	51	0.11		Ik	1818598	5815848	Dairy
14/10/2014	53	0.11		Ik	1787992	5800588	Dairy
14/10/2014	51	0.19		Ik	1787992	5800588	Dairy
15/10/2014	151	0.13		Ik	1808302	5790039	Dairy
20/10/2014	217	0.14		Ik	1814645	5845203	Dairy
17/10/2014	434	0.11		Ik	1801805	5806555	Dairy
13/10/2014	39	0.1		Ik	1673698	5658783	Dairy
10/10/2014	128	0.11		Ik	1835230	5802075	Dairy
17/10/2012	nt	0.22	1	neg	1825178.2	5553857	Dairy
31/10/2013	44	0.31		neg	1682981.5	5631368.9	Dairy
31/10/2013	175	0.26		neg	1682981.5	5631368.9	Dairy
1/11/2013	709	0.38		neg	1861141.2	5768746.3	Dairy
29/10/2013		0.13		neg	1828818.6	5793483.4	Dairy
12/04/2013	11	0.32	1	neg	1933739.8	5787643.1	Dairy
15/05/2013	M40	0.29		neg	1555532	5201629.4	Dairy
15/05/2013	M153	0.3		neg	1555532	5201629.4	Dairy
15/05/2013	M101	0.27		neg	1555532	5201629.4	Dairy

15/05/2013	M71	0.27		neg	1555532	5201629.4	Dairy
15/05/2013	M317	0.28		neg	1555532	5201629.4	Dairy
15/05/2013	M63	0.32		neg	1555532	5201629.4	Dairy
15/05/2013	M32	0.31		neg	1555532	5201629.4	Dairy
14/05/2013	124	0.24	5	neg	1850563.1	5859415.4	Dairy
22/05/2013	121	0.2	1	neg	1816902.5	5860301.6	Dairy
14/06/2013	47	0.27	0.9	neg	1813560.8	5792036.2	Dairy
14/06/2013	10 29	0.29	0	neg	1813560.8	5792036.2	Dairy
14/06/2013	99	0.23	0	neg	1813560.8	5792036.2	Dairy
19/04/2013	124	0.25	0	neg	1763908.2	5874080.3	Dairy
23/04/2013	4	0.3	0	neg	1837068.9	5795590.1	Dairy
23/04/2013	121	0.31	0	neg	1837068.9	5795590.1	Dairy
23/04/2013	166	0.31	0	neg	1837068.9	5795590.1	Dairy
23/04/2013	228	0.33	0	neg	1837068.9	5795590.1	Dairy
23/04/2013	327	0.35	1	neg	1837068.9	5795590.1	Dairy
23/04/2013	447	0.3	1	neg	1837068.9	5795590.1	Dairy
23/04/2013	475	0.32	0	neg	1837068.9	5795590.1	Dairy
23/04/2013	524	0.39	0	neg	1837068.9	5795590.1	Dairy
23/04/2013	543	0.29	0	neg	1837068.9	5795590.1	Dairy
26/04/2013	26	0.3	0	neg	1864539	5820923.4	Dairy
26/04/2013	191	0.33	0	neg	1864539	5820923.4	Dairy
24/04/2013	25	0.34	0	neg	1873413.2	5801388.7	Dairy
24/04/2013	45	0.29	0	neg	1873413.2	5801388.7	Dairy
24/04/2013	183	0.29	0	neg	1873413.2	5801388.7	Dairy
24/04/2013	276	0.32	0	neg	1873413.2	5801388.7	Dairy
24/04/2013	279	0.26	0	neg	1873413.2	5801388.7	Dairy
24/04/2013	283	0.32	0	neg	1873413.2	5801388.7	Dairy
24/04/2013	364	0.32	0	neg	1873413.2	5801388.7	Dairy
30/04/2013	64	0.31	0	neg	1788969.8	5821848.5	Dairy
30/04/2013	94	0.36	0	neg	1788969.8	5821848.5	Dairy
7/05/2013	333	0.35	0	neg	1788514.3	5800695	Dairy
10/05/2013	114	0.3	0	neg	1769935.1	5812283.3	Dairy
16/08/2013	158	0.21	0	neg	1830838.1	5821613.1	Dairy
16/08/2013	210	0.15	0	neg	1830838.1	5821613.1	Dairy
17/08/2013	G	0.32		neg	1950217.4	5780713.7	Dairy
17/08/2013	P	0.36		neg	1950217.4	5780713.7	Dairy
17/08/2013	6	0.25		neg	1950217.4	5780713.7	Dairy
17/08/2013	79C	0.36		neg	1950217.4	5780713.7	Dairy
17/08/2013	329	0.28		neg	1950217.4	5780713.7	Dairy
17/08/2013	342	0.28		neg	1950217.4	5780713.7	Dairy
17/08/2013	372	0.29		neg	1950217.4	5780713.7	Dairy
20/06/2013	129	0.13	2	neg	1789134.8	5783310.2	Dairy
2/07/2013	298	0.3	1	neg	1810571.4	5774512.4	Dairy
16/08/2013	603	0.12	0	neg	1797039.4	5769052.1	Dairy
6/09/2013	374	0.22	0	neg	1803782.8	5686967.9	Dairy
12/09/2013	162	0.08	1	neg	1690156.4	5623814.4	Dairy

31/10/2013	277	0.27		neg	1837526.2	5802132.5	Dairy
13/09/2013	HFD Bull	0.23	4	neg	1801099.8	5794386.6	Dairy
10/09/2013	NO ID	0.21	4	neg	1980176.4	5780983.3	Dairy
20/09/2013	684	0.27	0	neg	1880658	5804176.6	Dairy
27/09/2013	292	0.29		neg	1804412.1	5783450.1	Dairy
27/09/2013	2156	0.28		neg	1804412.1	5783450.1	Dairy
26/09/2013	205	0.36		neg	1804857.5	5766402	Dairy
24/09/2013		0.36	17	neg	1824774.2	5877261.2	Dairy
29/09/2013		0.32	2	neg	1823387.3	5879647.6	Dairy
30/09/2013		0.31	3	neg	1808562.6	5817286.8	Dairy
25/09/2013	998	0.32		neg	1851646.2	5728792.7	Dairy
25/09/2013		0.11	0	neg	1935547.5	5788198.9	Dairy
27/09/2013	262	0.31		neg	1804412.1	5783450.1	Dairy
1/10/2013	NO ID	0.1		neg	1836861.4	5814800.5	Dairy
30/09/2013	191	0.22		neg	1822728.5	5839752	Dairy
25/09/2013	251	0.11		neg	1801824.6	5806169.6	Dairy
7/10/2013	2	0.12		neg	1794730	5776810	Dairy
14/10/2013		0.1		neg	1823157.8	5866059.1	Dairy
23/10/2013	129	0.18		neg	1714245.6	5636859.6	Dairy
24/10/2013	118	0.12		neg	1711683.4	5647890	Dairy
18/10/2013	665	0.31		neg	1804412.1	5783450.1	Dairy
23/10/2013	30	0.34		neg	1839990.9	5826565.6	Dairy
25/10/2013	387	0.24		neg	1803895.6	5785328.3	Dairy
23/10/2013	479	0.24		neg	1821949.9	5838454.8	Dairy
1/11/2013	17	0.24		neg	1850029	5816754.3	Dairy
4/11/2013	228	0.28		neg	1827641.3	5840050	Dairy
2/11/2013		0.27		neg	1698006.2	5658169.1	Dairy
12/11/2013	15	0.29		neg	1837068.9	5795590.1	Dairy
12/11/2013	79	0.27		neg	1837068.9	5795590.1	Dairy
12/11/2013	223	0.25		neg	1837068.9	5795590.1	Dairy
12/11/2013	34	0.26		neg	1837068.9	5795590.1	Dairy
12/11/2013		0.3		neg	1865853.6	5746226.7	Dairy
12/11/2013		0.23		neg	1870428.1	5809092.6	Dairy
18/11/2013	738	0.25		neg	1821967.2	5546500.9	Dairy
18/11/2013	197	0.09		neg	1711509	5614986.6	Dairy
15/11/2013	174	0.13		neg	1867423	5817727.6	Dairy
19/11/2013		0.11		neg	1682283.1	5634938.7	Dairy
21/11/2013		0.36		neg	1799969.6	5774636.6	Dairy
15/11/2013		0.25		neg	1825221.1	5836466.5	Dairy
28/11/2013	146	0.22		neg	1813534	5778593.1	Dairy
3/12/2013	330	0.15		neg	1679290	5652088.2	Dairy
9/12/2013	NO ID	0.12		neg	1690777.3	5667420.7	Dairy
10/12/2013		0.11		neg	1682395.5	5632417.7	Dairy
11/12/2013	buttercup	0.16		neg	1805792.2	5805457.6	Dairy
16/12/2013	228	0.24		neg	1796395	5837739.4	Dairy
16/12/2013	No ID	0.08		neg	1776858.3	5735153.6	Dairy

19/12/2013	159	0.15	neg	1802389.7	5794367.9	Dairy
27/12/2013	157	0.1	neg	1895501.6	5738749	Dairy
24/12/2013	53	0.48	neg	1945149.4	5663238.2	Dairy
20/12/2013	237	0.29	neg	1821949.9	5838454.8	Dairy
13/01/2014	59	0.08	neg	1700175.4	5633351.4	Dairy
10/01/2014	70	0.26	neg	1817015.5	5876919.6	Dairy
8/01/2014	choc calf	0.25	neg	1831441.5	5874250.8	Dairy
8/01/2014	hereford	0.31	neg	1831441.5	5874250.8	Dairy
11/01/2014	ed	0.19	neg	1842655.9	5835663.8	Dairy
7/01/2014	NT	0.23	neg	1833749.3	5843310.3	Dairy
16/01/2014	308	0.1	neg	1864132.1	5761716.8	Dairy
16/01/2014	4	0.28	neg	1714141.5	5677762	Dairy
14/01/2014	84	0.33	neg	1800955.3	5827688.7	Dairy
24/01/2014	337	0.26	neg	1835662.7	5783999.8	Dairy
21/01/2014	No ID	0.23	neg	1761912	5890145	Dairy
21/01/2014	33	0.38	neg	1769243	5888326	Dairy
21/01/2014	138	0.31	neg	1675446	5664017	Dairy
21/01/2014	147	0.33	neg	1675446	5664017	Dairy
21/01/2014	459	0.34	neg	1858766.1	5717780.6	Dairy
21/01/2014	559	0.37	neg	1858766.1	5717780.6	Dairy
21/01/2014	613	0.36	neg	1858766.1	5717780.6	Dairy
21/01/2014	No Tag Blue	0.28	neg	1858766.1	5717780.6	Dairy
21/01/2014	B2326	0.32	neg	1858766.1	5717780.6	Dairy
21/01/2014	B3571	0.38	neg	1858766.1	5717780.6	Dairy
21/01/2014	B2294	0.35	neg	1858766.1	5717780.6	Dairy
21/01/2014	B1005	0.35	neg	1858766.1	5717780.6	Dairy
12/02/2014	1	0.12	neg	1801805.4	5806555.6	Dairy
30/01/2014	472	0.27	neg	1816067	5865958	Dairy
18/02/2014	388	0.22	neg	1922831	5733439	Dairy
28/02/2014	227	0.35	neg	1814913	5797028	Dairy
28/02/2014	289	0.23	neg	1814913	5797028	Dairy
28/02/2014	432	0.32	neg	1814913	5797028	Dairy
28/02/2014	583	0.3	neg	1814913	5797028	Dairy
28/02/2014	593	0.26	neg	1814913	5797028	Dairy
10/03/2014	48	0.27	neg	1766386	5871193	Dairy
8/04/2014	189	0.08	neg	1819269	5790360	Dairy
7/04/2014	34	0.11	neg	1828300	5833998	Dairy
2/04/2014	GR359	0.18	neg	1724645	5604416	Dairy
7/04/2014	13 60	0.22	neg	1917040	5806473	Dairy
2/04/2014	09 4	0.09	neg	1750512	5877872	Dairy
5/03/2014	NO ID	0.19	neg	1878425	5782880	Dairy
24/04/2014	458	0.21	neg	1813881	5778851	Dairy
28/04/2014	JH	0.17	neg	1728082	5611778	Dairy
22/04/2014	443	0.19	neg	1814280	5794309	Dairy
29/04/2014	561	0.23	neg	1813802	5785777	Dairy
2/05/2014	111	0.29	neg	1893265	5818243	Dairy

2/05/2014	268	0.16		neg	1893265	5818243	Dairy
28/02/2014	223	0.16		neg	1807195	5775466	Dairy
28/03/2014	500	0.24		neg	1473488	5152738	Dairy
15/05/2014	64	0.23		neg	1794240	5532061	Dairy
6/05/2014	505	0.13		neg	1810717	5836982	Dairy
27/05/2014	58	0.3		neg	1762689	5868246	Dairy
13/06/2014	no id	0.23		neg	1836176	5794784	Dairy
25/07/2014	114	0.16		neg	1833833	5859135	Dairy
11/06/2014	28	0.23		neg	1802864	5759212	Dairy
27/06/2014	NO ID	0.22		neg	1831935	5832828	Dairy
26/06/2014	23	0.15		neg	1849115	5818099	Dairy
5/09/2014	Smeaton	0.11		neg	1852843	5852705	Dairy
3/09/2014	Meredith	0.1		neg	1795593	5762551	Dairy
1/09/2014	600	0.13		neg	1857530	5756913	Dairy
23/09/2014	1030	0.14		neg	1893525	5735991	Dairy
12/09/2014	21	0.1		neg	1794909	5497412	Dairy
3/03/2014	34	0.28		other	1845379	5829351	Dairy
3/03/2014	35	0.26		other	1845379	5829351	Dairy
4/04/2014	10	0.14		other	1840746	5814491	Dairy
12/05/2014	161	0.39		other	1815248	5876655	Dairy
11/09/2012	355W	0.31	2	un	1896071	5741325.4	Dairy
29/10/2013	159	0.27		un	1943236.7	5789286.9	Dairy
17/10/2013		0.22		un	1856818.4	5833228.2	Dairy
30/10/2013		0.12		un	1936212.1	5765031.9	Dairy
1/11/2013		0.21		un	1985762.8	5785760.7	Dairy
4/11/2013	17	0.31		un	1843413.2	5828965.9	Dairy
12/04/2013	45	0.25	37	Un	1933739.8	5787643.1	Dairy
15/05/2013	M249	0.29		un	1555532	5201629.4	Dairy
15/05/2013	114	0.32		un	1555532	5201629.4	Dairy
2/05/2013	254	0.27	1	un	1839115.2	5813130.4	Dairy
29/05/2013	431	0.23	2	un	1831787.7	5798816.2	Dairy
12/04/2013	5	0.26	0	un	1748648.6	5871756.6	Dairy
12/04/2013	15	0.22	0	un	1748648.6	5871756.6	Dairy
12/04/2013	78	0.27	1	un	1748648.6	5871756.6	Dairy
12/04/2013	160	0.31	3	un	1748648.6	5871756.6	Dairy
12/04/2013	164	0.26	0	un	1748648.6	5871756.6	Dairy
12/04/2013	198	0.26	0.9	un	1748648.6	5871756.6	Dairy
12/04/2013	267	0.26	0.9	un	1748648.6	5871756.6	Dairy
26/04/2013	4	0.32	0	un	1864539	5820923.4	Dairy
26/04/2013	17	0.31	2	un	1864539	5820923.4	Dairy
26/04/2013	64	0.29	1	un	1864539	5820923.4	Dairy
26/04/2013	73	0.32	2	un	1864539	5820923.4	Dairy
26/04/2013	214	0.33	1	un	1864539	5820923.4	Dairy
26/04/2013	266	0.34	1	un	1864539	5820923.4	Dairy
26/04/2013	272	0.31	5	un	1864539	5820923.4	Dairy
26/04/2013	297	0.28	0	un	1864539	5820923.4	Dairy

24/04/2013	19	0.29	0	un	1873413.2	5801388.7	Dairy
24/04/2013	51	0.33	0	un	1873413.2	5801388.7	Dairy
24/04/2013	372	0.3	0	un	1873413.2	5801388.7	Dairy
30/04/2013	274	0.34	0	un	1788969.8	5821848.5	Dairy
16/08/2013	106	0.27	0	un	1830838.1	5821613.1	Dairy
16/08/2013	113	0.23	1	un	1830838.1	5821613.1	Dairy
16/08/2013	232	0.31	0	un	1830838.1	5821613.1	Dairy
16/08/2013	300	0.25	0	un	1830838.1	5821613.1	Dairy
16/08/2013	301	0.28	0	un	1830838.1	5821613.1	Dairy
16/08/2013	344	0.25	0	un	1830838.1	5821613.1	Dairy
16/08/2013	NT	0.24	0	un	1830838.1	5821613.1	Dairy
17/08/2013	276	0.27		un	1950217.4	5780713.7	Dairy
17/08/2013	324	0.27		un	1950217.4	5780713.7	Dairy
17/08/2013	367	0.29		un	1950217.4	5780713.7	Dairy
17/06/2013	NA	0.22	11	un	1835652.1	5849602.5	Dairy
26/07/2013	143	0.24	1	un	1913067.7	5804146.8	Dairy
29/07/2013	353	0.18	1	un	1837127.3	5854689	Dairy
6/08/2013		0.11	1	un	1783108.1	5875626.7	Dairy
8/08/2013	39	0.12	0	un	1778830.7	5902447.4	Dairy
31/10/2013	18	0.24		un	1804335.6	5801420.4	Dairy
5/11/2013	446	0.24		un	1813534	5778593.1	Dairy
17/09/2013	892	0.11	22	un	1801099.8	5794386.6	Dairy
14/09/2013	178	0.13	1	un	1622571.1	6112316.3	Dairy
16/09/2013	76	0.09	40	un	1747057.7	5589744.1	Dairy
28/09/2013		0.22		un	2004641.1	5798704.3	Dairy
26/09/2013	179	0.26		un	1784226.9	5751287	Dairy
24/09/2013		0.36	1	un	1941178.5	5792304.5	Dairy
27/09/2013	485	0.28		un	1804412.1	5783450.1	Dairy
27/09/2013	828	0.33		un	1804412.1	5783450.1	Dairy
27/09/2013	146	0.3		un	1804412.1	5783450.1	Dairy
2/10/2013	262	0.21		un	1838318.7	5790527.9	Dairy
2/10/2013	528	0.25		un	1838318.7	5790527.9	Dairy
2/10/2013	806	0.25		un	1838318.7	5790527.9	Dairy
2/10/2013	220	0.34		un	1835574	5857690.6	Dairy
1/10/2013	323	0.32		un	1814335.9	5780783.2	Dairy
30/09/2013	614	0.53		un	1834043.7	5845408.6	Dairy
20/09/2013		0.42		un	1832227.6	5856942.3	Dairy
18/09/2013		0.26	2	un	1822178.9	5866883.3	Dairy
24/09/2013	131	0.12		un	1779356.7	5748920.8	Dairy
2/10/2013		0.31		un	1798247	5838339.2	Dairy
1/10/2013	110	0.27		un	1814065.9	5850032.7	Dairy
10/10/2013	445	0.32		un	1815235.6	5862825.1	Dairy
7/10/2013		0.11		un	1835462.5	5844403.5	Dairy
11/10/2013		0.25		un	1968759.5	5781187.7	Dairy
8/10/2013		0.26		un	1976889.9	5777574.6	Dairy
8/10/2013	757	0.31		un	1814065.9	5850032.7	Dairy

8/10/2013	998	0.33	un	1814065.9	5850032.7	Dairy
8/10/2013		0.33	un	1938010.5	5785903.3	Dairy
2/10/2013	233	0.2	un	1876018.9	5731385.8	Dairy
3/10/2013	963	0.36	un	1804412.1	5783450.1	Dairy
14/10/2013	309	0.17	un	1790010.9	5809777.9	Dairy
9/10/2013	Ngutinui	0.37	un	1790653.8	5768598	Dairy
15/10/2013	F8	0.33	un	1945149.4	5663238.2	Dairy
11/10/2013	248	0.3	un	1828804.5	5785021	Dairy
15/10/2013	232	0.22	un	1842460.4	5911663.9	Dairy
15/10/2013	363	0.22	un	1842460.4	5911663.9	Dairy
15/10/2013	272	0.24	un	1842460.4	5911663.9	Dairy
16/10/2013		0.22	un	1830919.4	5874819.9	Dairy
23/10/2013		0.24	un	1808562.6	5817286.8	Dairy
21/10/2013		0.11	un	1837296.6	5918093.2	Dairy
24/10/2013		0.37	un	1826404	5871055.3	Dairy
18/10/2013	917	0.29	un	1804412.1	5783450.1	Dairy
18/10/2013	65	0.29	un	1804412.1	5783450.1	Dairy
18/10/2013	555	0.28	un	1804412.1	5783450.1	Dairy
18/10/2013	816	0.23	un	1804412.1	5783450.1	Dairy
18/10/2013	382	0.3	un	1804412.1	5783450.1	Dairy
18/10/2013	798	0.3	un	1804412.1	5783450.1	Dairy
18/10/2013	860	0.28	un	1804412.1	5783450.1	Dairy
18/10/2013	184	0.33	un	1804412.1	5783450.1	Dairy
18/10/2013	346	0.33	un	1804412.1	5783450.1	Dairy
18/10/2013	341	0.32	un	1804412.1	5783450.1	Dairy
18/10/2013	889	0.33	un	1804412.1	5783450.1	Dairy
18/10/2013	NO ID	0.31	un	1804412.1	5783450.1	Dairy
22/10/2013	216	0.36	un	1791537.6	5773866.7	Dairy
21/10/2013	235	0.11	un	1910686.4	5806045.7	Dairy
25/10/2013	249	0.28	un	1813480.9	5867468.2	Dairy
25/10/2013	462	0.44	un	1794603.5	5774705.5	Dairy
29/10/2013		0.1	un	1830643	5797323	Dairy
1/11/2013	844	0.16	un	1831462.7	5767749.1	Dairy
6/11/2013	51	0.25	un	1834410	5870697.7	Dairy
9/11/2013	14	0.09	un	1826523.2	5795372.6	Dairy
8/11/2013		0.27	un	1821563.4	5853946	Dairy
6/11/2013	1	0.27	un	1784883.1	5776243.6	Dairy
4/11/2013	101	0.15	un	1809884	5785235	Dairy
13/11/2013	121	0.25	un	1813425.4	5843880.6	Dairy
13/11/2013	H2	0.37	un	1884146.9	5751434.2	Dairy
22/11/2013	602	0.23	un	1801544.9	5785992.9	Dairy
22/11/2013	236	0.15	un	1831362.6	5794610.2	Dairy
18/11/2013	125	0.3	un	1809825.2	5787896.3	Dairy
19/11/2013	154	0.42	un	1824506.9	5834808.1	Dairy
19/11/2013	57	0.33	un	1851247.7	5819388.8	Dairy
21/11/2013		0.19	un	1839502.4	5772585	Dairy

18/11/2013		0.43	un	1854882.8	5840124.6	Dairy
28/11/2013	325	0.23	un	1789827.9	5874053.5	Dairy
25/11/2013	96	0.3	un	1810992	5840945.8	Dairy
22/11/2013		0.37	un	1834691.8	5854445.5	Dairy
6/12/2013	80	0.25	un	1818066.7	5780899.6	Dairy
9/12/2013	11	0.26	un	1800314.4	5839533	Dairy
11/12/2013	36	0.27	un	1842758.1	5829581.4	Dairy
11/12/2013	554	0.4	un	1912584.7	5800210.9	Dairy
13/12/2013	412	0.28	un	1806866.3	5844969.1	Dairy
16/12/2013		0.44	un	1829722.7	5840669.4	Dairy
19/12/2013	166	0.24	un	1752851.1	5868658.1	Dairy
31/12/2013	229	0.24	un	1763921	5803566.1	Dairy
31/12/2013		0.35	un	1836898.9	5832017.6	Dairy
9/12/2013		0.28	un	1944387.2	5791858	Dairy
9/01/2014	305	0.3	un	1790268.6	5798698.7	Dairy
13/01/2014	290	0.29	un	1809891.2	5783035.2	Dairy
13/01/2014	93	0.11	un	1820306.8	5838294.4	Dairy
13/01/2014	5	0.33	un	1823526.3	5819548.5	Dairy
14/01/2014	674	0.37	un	1968759.5	5781187.7	Dairy
14/01/2014	513	0.33	un	1863533.4	5729350.2	Dairy
17/01/2014	715	0.3	un	1968759.5	5781187.7	Dairy
21/01/2014	127	0.28	un	1988121.7	5785992.4	Dairy
21/01/2014	357	0.26	un	1988121.7	5785992.4	Dairy
23/01/2014	67	0.24	un	1840268.6	5798055.3	Dairy
24/01/2014	7 (R1)	0.28	un	1831441.5	5874250.8	Dairy
24/01/2014	1215 (R1)	0.36	un	1831441.5	5874250.8	Dairy
24/04/2014	189	0.36	un	1813881	5778851	Dairy
24/04/2014	385	0.31	un	1813881	5778851	Dairy
23/04/2014	14	0.2	un	1828366	5867574	Dairy
1/05/2014	25	0.29	un	1805282	5798997	Dairy
1/05/2014	309	0.29	un	1805282	5798997	Dairy
2/05/2014	149	0.3	un	1856818	5760082	Dairy
23/04/2014	152	0.26	un	1836459	5864330	Dairy
8/05/2014	1789	0.33	un	1786141	5820080	Dairy
19/05/2014	BROWN	0.3	un	1817916	5832670	Dairy
19/05/2014	BLACK	0.28	un	1817916	5832670	Dairy
1/07/2014	476	0.25	un	1797600	5881749	Dairy
19/07/2014	271	0.34	un	1690097	6095874	Dairy
5/08/2014	114	0.34	un	1764637	5807175	Dairy
5/08/2014	240	0.34	un	1764637	5807175	Dairy
23/07/2014	36	0.36	un	1745754	5880083	Dairy
7/08/2014	341	0.48	un	1695354	6004833	Dairy
6/08/2014	117A	0.35	un	1850418	5800855	Dairy
6/08/2014	101	0.34	un	1850418	5800855	Dairy
6/08/2014	115	0.26	un	1850418	5800855	Dairy
6/08/2014	122	0.29	un	1850418	5800855	Dairy

14/08/2014	281	0.28	un	1811831	5801158	Dairy
25/08/2014	291	0.12	un	1851809	5853272	Dairy
20/08/2014	420	0.32	un	1695354	6004833	Dairy
20/08/2014	486	0.31	un	1695354	6004833	Dairy
20/08/2014	885	0.27	un	1695354	6004833	Dairy
20/08/2014	1173	0.28	un	1695354	6004833	Dairy
2/09/2014	326	0.14	un	1810624	5785986	Dairy
5/09/2014	39	0.33	un	1816718	5860626	Dairy
4/09/2014	495	0.29	un	1849014	5894539	Dairy
4/09/2014	160	0.29	un	1849014	5894539	Dairy
4/09/2014	497	0.34	un	1849014	5894539	Dairy
1/09/2014	56	0.079	un	1849014	5894539	Dairy
1/09/2014	55	0.26	un	1653528	6047523	Dairy
1/09/2014	82N	0.26	un	1653528	6047523	Dairy
1/09/2014	134N	0.28	un	1653528	6047523	Dairy
1/09/2014	162N	0.27	un	1653528	6047523	Dairy
5/09/2014	318	0.44	un	1814627	5843528	Dairy
2/09/2014	210	0.21	un	1844287	5805070	Dairy
2/09/2014	367	0.27	un	1844287	5805070	Dairy
5/09/2014	143	0.3	un	1838112	5792361	Dairy
29/08/2014	T334	0.3	un	1788295	5800109	Dairy
29/08/2014	T250	0.29	un	1788295	5800109	Dairy
1/09/2014	367	0.19	un	1806718	5773564	Dairy
2/09/2014	287	0.29	un	1932816	5796716	Dairy
2/09/2014	12	0.43	un	1932816	5796716	Dairy
30/09/2014	123	0.14	un	1933518	5656813	Dairy
23/09/2014	952	0.31	un	1893525	5735991	Dairy
30/09/2014	416	0.42	un	1904904	5634814	Dairy
2/10/2014	117	0.31	un	1904904	5634814	Dairy
2/10/2014	268	0.28	un	1904904	5634814	Dairy
2/10/2014	322	0.35	un	1904904	5634814	Dairy
2/10/2014	444	0.32	un	1904904	5634814	Dairy
2/10/2014	510	0.33	un	1904904	5634814	Dairy
2/10/2014	749	0.34	un	1904904	5634814	Dairy
17/09/2014	2260	0.44	un	1869758	5781916	Dairy
10/09/2014	118	0.36	un	1845342	5829626	Dairy
12/09/2014	277	0.29	un	1845342	5829626	Dairy
10/09/2014	160	0.31	un	1817811	5827157	Dairy
2/10/2014	131	0.28	un	1695800	5635797	Dairy
22/09/2014	130	0.32	un	1798125	5764515	Dairy
9/10/2014	07/234	0.42	un	1853175	5761751	Dairy
10/10/2014	27	0.33	un	1482457	5275164	Dairy
10/10/2014	227	0.32	un	1482457	5275164	Dairy
23/10/2014	950	0.31	un	1776361	5725527	Dairy
23/10/2014	108	0.29	un	1810159	5835718	Dairy
17/10/2014	25	0.16	un	1845008	5798625	Dairy

12/12/2012	709	0.11	40	Ik	1729464.1	6016816.7	Dairy
5/04/2013	MICKELSON	0.09	41	Ik	1805100.3	5853159.9	Dairy
4/04/2013	1	0.07	9	Ik	1747239.4	5885474.3	Dairy
9/11/2013	H13 008015	0.11	12	Ik	1779950	5869647	Dairy
11/04/2013	R24	0.12	4	Ik	1747239.4	5885474.3	Dairy
11/04/2013	R34	0.21	38	Ik	1747239.4	5885474.3	Dairy
11/04/2013	R37	0.12	17	Ik	1747239.4	5885474.3	Dairy
11/04/2013	R57	0.23	3	Ik	1747239.4	5885474.3	Dairy
11/04/2013	R73	0.1	40	Ik	1747239.4	5885474.3	Dairy
11/04/2013	R77	0.21	24	Ik	1747239.4	5885474.3	Dairy
11/04/2013	R87	0.28	0	Ik	1747239.4	5885474.3	Dairy
11/04/2013	R121	0.04	0	Ik	1747239.4	5885474.3	Dairy
11/04/2013	R126	0.17	20	Ik	1747239.4	5885474.3	Dairy
11/04/2013	R128	0.18	3	Ik	1747239.4	5885474.3	Dairy
11/04/2013	R133	0.21	5	Ik	1747239.4	5885474.3	Dairy
11/04/2013	11	0.29	0	Ik	1747239.4	5885474.3	Dairy
11/04/2013	74	0.3	10	Ik	1747239.4	5885474.3	Dairy
11/04/2013	86	0.37	1	Ik	1747239.4	5885474.3	Dairy
11/04/2013	172	0.32	0	Ik	1747239.4	5885474.3	Dairy
11/04/2013	193	0.31	2	Ik	1747239.4	5885474.3	Dairy
11/04/2013	198	0.24	5	Ik	1747239.4	5885474.3	Dairy
11/04/2013	200	0.29	1	Ik	1747239.4	5885474.3	Dairy
11/04/2013	202	0.28	0.9	Ik	1747239.4	5885474.3	Dairy
11/04/2013	250	0.35	0.9	Ik	1747239.4	5885474.3	Dairy
11/04/2013	229	0.3	0	Ik	1747239.4	5885474.3	Dairy
11/04/2013	113B	0.19	10	Ik	1779950	5869647	Dairy
11/04/2013	6B	0.14	2	Ik	1779950	5869647	Dairy
11/04/2013	109B	0.12	3	Ik	1779950	5869647	Dairy
11/04/2013	184B	0.27	8	Ik	1779950	5869647	Dairy
11/04/2013	16B	0.23	0	Ik	1779950	5869647	Dairy
11/04/2013	25B	0.15	0.9	Ik	1779950	5869647	Dairy
11/04/2013	38B	0.15	19	Ik	1779950	5869647	Dairy
11/04/2013	72B	0.11	10	Ik	1779950	5869647	Dairy
11/04/2013	220	0.27	0.9	Ik	1779950	5869647	Dairy
11/04/2013	370	0.25	11	Ik	1779950	5869647	Dairy
11/04/2013	239	0.32	0	Ik	1779950	5869647	Dairy
11/04/2013	256	0.26	4	Ik	1779950	5869647	Dairy
11/04/2013	122	0.31	1	Ik	1779950	5869647	Dairy
11/04/2013	172	0.22	0.9	Ik	1779950	5869647	Dairy
11/04/2013	290	0.26	0	Ik	1779950	5869647	Dairy
11/04/2013	541	0.26	5	Ik	1779950	5869647	Dairy
11/04/2013	313	0.24	0	Ik	1779950	5869647	Dairy
29/04/2013	487s	0.3	1	Ik	1787228.4	5857626.4	Dairy
29/04/2013	33	0.28	1	Ik	1787228.4	5857626.4	Dairy
29/04/2013	253	0.23	0	Ik	1787228.4	5857626.4	Dairy
29/04/2013	143s	0.28	1	Ik	1787228.4	5857626.4	Dairy

29/04/2013	113s	0.2	1	Ik	1787228.4	5857626.4	Dairy
29/04/2013	139a	0.19	10	Ik	1787228.4	5857626.4	Dairy
29/04/2013	45a	0.26	1	Ik	1787228.4	5857626.4	Dairy
29/04/2013	154s	0.31	1	Ik	1787228.4	5857626.4	Dairy
29/04/2013	10a	0.3	3	Ik	1787228.4	5857626.4	Dairy
29/04/2013	138a	0.23	1	Ik	1787228.4	5857626.4	Dairy
29/04/2013	51a	0.24	1	Ik	1787228.4	5857626.4	Dairy
29/04/2013	688	0.34	1	Ik	1787228.4	5857626.4	Dairy
17/05/2013	193	0.09	1	Ik	1795099.6	5778604.3	Dairy
15/05/2013	NT	0.22	7	Ik	1795099.6	5778604.3	Dairy
9/05/2013	232	0.1	4	Ik	1761950.4	5890056.5	Dairy
16/04/2013	34	0.29	0	Ik	1805100.3	5853159.9	Dairy
16/04/2013	52	0.3	11	Ik	1805100.3	5853159.9	Dairy
16/04/2013	145	0.25	5	Ik	1805100.3	5853159.9	Dairy
16/04/2013	148	0.25	0.9	Ik	1805100.3	5853159.9	Dairy
16/04/2013	198	0.21	1	Ik	1805100.3	5853159.9	Dairy
16/04/2013	204	0.27	1	Ik	1805100.3	5853159.9	Dairy
16/04/2013	225	0.25	4	Ik	1805100.3	5853159.9	Dairy
16/04/2013	257	0.25	2	Ik	1805100.3	5853159.9	Dairy
16/04/2013	274	0.31	0.9	Ik	1805100.3	5853159.9	Dairy
16/04/2013	NT	0.26	8	Ik	1805100.3	5853159.9	Dairy
26/04/2013	353	0.12	160	Ik	1817868.3	5861542.2	Dairy
26/04/2013	288	0.1	8	Ik	1787228.4	5857626.4	Dairy
26/04/2013	171	0.11	0	Ik	1787228.4	5857626.4	Dairy
26/04/2013	510	0.09	115	Ik	1817868.3	5861542.2	Dairy
29/04/2013	64	0.32	1	Ik	1817868.3	5861542.2	Dairy
29/04/2013	114	0.25	1	Ik	1817868.3	5861542.2	Dairy
29/04/2013	164	0.27	1	Ik	1817868.3	5861542.2	Dairy
29/04/2013	226	0.24	1	Ik	1817868.3	5861542.2	Dairy
29/04/2013	352	0.26	10	Ik	1817868.3	5861542.2	Dairy
29/04/2013	450	0.19	1	Ik	1817868.3	5861542.2	Dairy
13/08/2013	NoID	0.14	57	Ik	1787228.4	5857626.4	Dairy
1/10/2013	73	0.21		Ik	1787228.4	5857626.4	Dairy
1/10/2013	57	0.19		Ik	1787228.4	5857626.4	Dairy
1/10/2013	268	0.19		Ik	1787228.4	5857626.4	Dairy
7/10/2013	497	0.26		Ik	1787228.4	5857626.4	Dairy
10/06/2013	114	0.23	3	Ik	1817868.3	5861542.2	Dairy
10/06/2013	160	0.29	1	Ik	1817868.3	5861542.2	Dairy
10/06/2013	721	0.33	1	Ik	1817868.3	5861542.2	Dairy
11/04/2013	90B	0.26	0	neg	1779950	5869647	Dairy
29/04/2013	373s	0.32	0	neg	1787228.4	5857626.4	Dairy
29/04/2013	516	0.27	0	neg	1787228.4	5857626.4	Dairy
29/04/2013	244s	0.3	0	neg	1787228.4	5857626.4	Dairy
29/04/2013	459s	0.31	0	neg	1787228.4	5857626.4	Dairy
29/04/2013	236s	0.31	1	neg	1787228.4	5857626.4	Dairy
29/04/2013	275s	0.33	0	neg	1787228.4	5857626.4	Dairy

29/04/2013	225	0.27	1	neg	1817868.3	5861542.2	Dairy
11/04/2013	156	0.28	1	un	1747239.4	5885474.3	Dairy
29/04/2013	655s	0.31	1	un	1787228.4	5857626.4	Dairy
29/04/2013	108	0.28	0	un	1787228.4	5857626.4	Dairy
29/04/2013	9a heifer	0.3	2	un	1787228.4	5857626.4	Dairy
29/04/2013	19	0.28	1	un	1817868.3	5861542.2	Dairy
29/04/2013	107	0.28	1	un	1817868.3	5861542.2	Dairy
29/04/2013	223	0.28	1	un	1817868.3	5861542.2	Dairy
23/07/2013	331	0.13	252	un	1787228.4	5857626.4	Dairy
10/06/2013	57	0.27	1	un	1817868.3	5861542.2	Dairy
10/06/2013	229	0.31	2	un	1817868.3	5861542.2	Dairy
10/06/2013	258	0.28	1	un	1817868.3	5861542.2	Dairy
10/06/2013	408	0.31	1	un	1817868.3	5861542.2	Dairy
10/06/2013	545	0.32	1	un	1817868.3	5861542.2	Dairy
10/06/2013	899	0.28	1	un	1817868.3	5861542.2	Dairy
20/11/2012	1	0.32		Ik	1693705	6050484.3	Dry
3/05/2013	70	0.1	40	Ik	1759278.1	5801319.1	Dry
8/05/2013	10	0.39	0	Ik	1759278.1	5801319.1	Dry
8/05/2013	15	0.35	0	Ik	1759278.1	5801319.1	Dry
8/05/2013	16	0.32	1	Ik	1759278.1	5801319.1	Dry
8/05/2013	26	0.34	7	Ik	1759278.1	5801319.1	Dry
8/05/2013	28	0.35	3	Ik	1759278.1	5801319.1	Dry
8/05/2013	38	0.33	0	Ik	1759278.1	5801319.1	Dry
8/05/2013	62	0.38	1	Ik	1759278.1	5801319.1	Dry
8/05/2013	65	0.37	5	Ik	1759278.1	5801319.1	Dry
16/09/2013	JQMR1218	0.34	0	Ik	1817449.5	5852025	Dry
16/09/2013	JQMR1214	0.13	0	Ik	1817449.5	5852025	Dry
16/09/2013	HYC1237	0.34	0	Ik	1817449.5	5852025	Dry
16/09/2013	HYC1238	0.29	0	Ik	1817449.5	5852025	Dry
16/09/2013	TALL280	0.11	3	Ik	1817449.5	5852025	Dry
19/09/2013		0.17	7	Ik	1797079.5	5905148.6	Dry
30/09/2013	calf	0.1		Ik	1817449.5	5852025	Dry
3/10/2013	calf	0.11		Ik	1817449.5	5852025	Dry
16/10/2013		0.15		Ik	1848743.1	5785656.7	Dry
14/10/2103	R1	0.13		Ik	1817449.5	5852025	Dry
22/11/2013	R1	0.27		Ik	1817449.5	5852025	Dry
23/01/2014	87	0.3		Ik	1959598	5771435	Dry
23/01/2014	24178	0.38		Ik	1789251	5908341	Dry
22/01/2014	KYUT 123	0.36		Ik	1789251	5908341	Dry
5/03/2014	342	0.12		Ik	1819269	5790360	Dry
25/03/2014	244	0.09		Ik	1803469	5821626	Dry
28/03/2014	Heifer	0.17		Ik	1790123	5787912	Dry
31/03/2014	D Knight	0.19		Ik	1813648	5818363	Dry
16/04/2014	NO ID	0.2		Ik	1823785	5825068	Dry
2/05/2014	114	0.23		Ik	1790123	5787912	Dry
15/05/2014	366	0.13		Ik	1841514	5805049	Dry

4/07/2014	851	0.22		Ik	1798152	5793868	Dry
13/08/2014	1554	0.16		Ik	1841328	5734265	Dry
22/08/2014	NO ID	0.09		Ik	1816309	5833270	Dry
20/08/2014	57	0.1		Ik	1830553	5788832	Dry
19/08/2014	368	0.1		Ik	1842080	5736115	Dry
19/08/2014	2401	0.1		Ik	1842080	5736115	Dry
8/09/2014	244	0.12		Ik	1873649	5781818	Dry
8/09/2014	879	0.15		Ik	1873649	5781818	Dry
5/09/2014	1416	0.1		Ik	1820104	5778548	Dry
2/09/2014	177	0.17		Ik	1825036	5814457	Dry
28/08/2014	Ward	0.07		Ik	1789108	5822777	Dry
27/08/2014	1561	0.13		Ik	1841328	5734265	Dry
27/08/2014	1460	0.12		Ik	1841328	5734265	Dry
29/08/2014	2015	0.11		Ik	1841328	5734265	Dry
29/08/2014	2350	0.18		Ik	1841328	5734265	Dry
13/09/2014	Hayward	0.1		Ik	1830968	5778100	Dry
12/09/2014	16	0.2		Ik	1754669	5881213	Dry
15/09/2014	145	0.12		Ik	1813259	5805459	Dry
16/09/2014	106	0.09		Ik	1827456	5797719	Dry
11/09/2014	1	0.08		Ik	1822680	5776039	Dry
11/09/2014	2	0.1		Ik	1822680	5776039	Dry
21/10/2014	NO ID	0.09		Ik	1799571	5693054	Dry
21/10/2014	NO ID	0.05		Ik	1830610	5549125	Dry
17/10/2014	163 08	0.23		Ik	1792147	5814478	Dry
8/05/2013	43	0.36	0	neg	1759278.1	5801319.1	Dry
6/06/2013	TD	0.09	2	un	1830536.8	5793625.8	Dry
8/05/2013	55	0.34	2	un	1759278.1	5801319.1	Dry
8/09/2014	204	0.23		un	1873649	5781818	Dry
7/11/2012	AU12_23572	0.33		Ik	1671244.5	6082281.6	
10/11/2012	AU12_23883/1	0.41		Ik	1660197.6	6113971.7	
24/09/2013	118	0.28		Ik	1760950	5829428	
24/09/2013	521	0.25		Ik	1760950	5829428	
20/12/2013	196	0.31		Ik	1748049.3	5989276.8	
11/01/2014	139	0.35		Ik	1707586.7	6050760.3	
12/04/2013	253	0.28	0	neg	1887314.6	5720617.7	
12/04/2013	362	0.31	0	neg	1887314.6	5720617.7	
6/11/2012	AU12_23536	0.43		un	1700484.7	6043946.7	
10/11/2012	AU12_23883/1	0.42		un	1660197.6	6113971.7	
7/11/2012	AU12_23572	0.32		un	1671244.5	6082281.6	
28/10/2013	409	0.35		un	1806223.1	5675726.3	
23/09/2013	29	0.28		un	1829239.7	5872319.9	
24/09/2013	140	0.46		un	1760749.6	5873148.7	
8/10/2013	NO ID	0.39		un	1786419.6	5755077.9	

Table 9. Cartesian coordinates of 921 farms which had at least one Ikeda PCR positive case of *Theileria* associated bovine anaemia (TABA) up to November 2014, **Chapter 7.**

Species	Easting	Northing	Species	Easting	Northing	Species	Easting	Northing
HL	1896071	5741325.4	HL	1872024.8	5783452.4	HL	1946966	5771890
HL	1712294.6	6039804.8	HL	1849618.9	5774560.7	HL	1831852	5856608
HL	1626155.4	6097386.4	HL	1849071.9	5850645	HL	1790884	5817786
HL	1723961.3	5943544.3	HL	1928892.1	5745726.6	HL	1795350	5871543
HL	1693765.9	6012719.2	HL	1833163.6	5764676.4	HL	1937636	5794330
HL	1822924.5	5494879	HL	1751877.1	5869978.7	HL	1813881	5778851
HL	1698720.4	6002366	HL	1634555.4	6128020.4	HL	2012759	5668742
HL	1686467.2	5996217.2	HL	1846155.8	5849580.1	HL	1790228	5810266
HL	1705731.7	6034079.1	HL	1827641.3	5840050	HL	1841514	5805049
HL	1674083.5	6113985.3	HL	1846133.9	5835441.8	HL	1810248	5835630
HL	1720314.2	5994568	HL	1777159.5	5724118.7	HL	2009751	5670268
HL	1713055.5	6038887.6	HL	1794536.7	5804140.4	HL	1783878	5831154
HL	1794827.3	5880306	HL	1799551.2	5737596	HL	1830918	5816730
HL	1660067.9	6127957.8	HL	1758982	5870368.2	HL	1817916	5832670
HL	1800258	5804659.6	HL	1822372.2	5819587.6	HL	1814834	5528162
HL	1671118.3	6021756.7	HL	1779574.2	5756728.3	HL	1762689	5868246
HL	1665419	6029822.4	HL	1700892.7	5662527.9	HL	1821429	5865255
HL	1723939.3	6029238.9	HL	1813762.3	5864426.1	HL	1810026	5799775
HL	1729464.1	6016816.7	HL	1803454.5	5893909.1	HL	1828993	5867434
HL	1658696	6035291	HL	1843413.2	5828965.9	HL	1824060	5875776
HL	1622428.1	6116069.5	HL	1803303.2	5799284.8	HL	1816162	5871467
HL	1658694.3	6033616.3	HL	1807760.2	5759221.5	HL	2043924	5726406
HL	1679462	6030562	HL	1832029	5867235.6	HL	1846194	5802737
HL	1788514.3	5800695	HL	1791875	5796089.4	HL	1718568	5608227
HL	1807695.5	5854089.1	HL	1787143.4	5868795.4	HL	1819933	5833208
HL	1788480.8	5852743.8	HL	1806362.9	5696480.2	HL	1794865	5793531
HL	1805100.3	5853159.9	HL	1839271.7	5868318.6	HL	2026882	5656526
HL	1798494.4	5861409.6	HL	1814913.2	5797028.8	HL	1853256	5805132
HL	1813560.8	5792036.2	HL	1832444.9	5833147.4	HL	1797600	5881749
HL	1933739.8	5787643.1	HL	1766607.4	5881999.4	HL	1798152	5793868
HL	1747239.4	5885474.3	HL	1867423	5817727.6	HL	1823711	5872195
HL	1779950	5869647	HL	1762616.9	5802593.1	HL	1844651	5787751
HL	1748648.6	5871756.6	HL	1809999.9	5877344.7	HL	1848974	5794359
HL	1555532	5201629.4	HL	1821982.9	5816186.3	HL	1815934	5846433
HL	1819122.8	5856980.6	HL	1804087.9	5834808.4	HL	1796893	5765724
HL	1763908.2	5874080.3	HL	1762538.3	5804024.3	HL	1827174	5819072
HL	1837068.9	5795590.1	HL	1794084.4	5783624.3	HL	1695800	5635797
HL	1788969.8	5821848.5	HL	1831108.9	5841162.1	HL	1617464	6129901
HL	1789247.7	5820159.5	HL	1837316.3	5868446.9	HL	1913012	5806083
HL	1817868.3	5861542.2	HL	1778192.5	5724895.2	HL	1745754	5880083
HL	1787228.4	5857626.4	HL	1644618.4	6124568.4	HL	2032646	5823578
HL	1762630.9	5886658.1	HL	1814204.5	5873957.2	HL	1985769	5675769
HL	1839115.2	5813130.4	HL	1799726.6	5844407.5	HL	1830028	5874049

HL	1759278.1	5801319.1	HL	2012158	5672285	HL	1750500	5867311
HL	1769935.1	5812283.3	HL	1729195.4	5685822.5	HL	1785569	5837351
HL	1761950.4	5890056.5	HL	1814628.9	5793645.5	HL	1844287	5805070
HL	1622739.1	6123592.9	HL	1713321.1	5957199.8	HL	1796156	5804178
HL	1816771.2	5810158	HL	1817788.5	5871774.4	HL	1937675	5793262
HL	1837687.6	5807338.5	HL	1695057.2	6007730.7	HL	1764742	5802888
HL	1823555.4	5840708.8	HL	2000584	5735086	HL	1782223	5728245
HL	1850563.1	5859415.4	HL	1782611	5852883	HL	1899587	5800176
HL	1763110.4	5807538.4	HL	1811548.9	5836046.7	HL	1880360	5757451
HL	1808574.3	5839040.3	HL	1936651.5	5760084	HL	1899388	5815488
HL	1795099.6	5778604.3	HL	1823820.4	5868169.8	HL	1783487	5776225
HL	1754185.8	5872151.1	HL	1827585	5872035.8	HL	1698226	5620049
HL	1831787.7	5798816.2	HL	1811475.9	5841605	HL	1799301	5791562
HL	1805870.1	5847607.7	HL	1801544.9	5785992.9	HL	1832177	5926353
HL	1827331.8	5800155.3	HL	1834051.8	5805021.2	HL	1850418	5800855
HL	1857756.2	5840785.2	HL	1811033.4	5839432.3	HL	1974281	5778947
HL	1810571.4	5774512.4	HL	1848279.7	5855294.9	HL	1660992	6077527
HL	1802395.8	5856941.5	HL	1725899.7	5937957.5	HL	1816751	5835701
HL	1841990.3	5799473.8	HL	1865868.4	5733753.5	HL	1839039	5786525
HL	1737497	5945019.8	HL	1831151.2	5853334	HL	1719216	5951802
HL	1776532.9	5861048.9	HL	1955769.7	5776840	HL	1805453	5828225
HL	1718569.4	5953236.1	HL	1838801	5851797	HL	1941242	5790748
HL	1812042.8	5794343.6	HL	1845267.8	5759560	HL	1838099	5855695
HL	1704812.3	6032289.2	HL	1819583.8	5761691.7	HL	1783784	5906066
HL	1716171.1	6005359	HL	1838809.6	5836721.5	HL	1808738	5828000
HL	1690042.7	6096358.1	HL	1652883.9	6111584.6	HL	1930961	5789628
HL	1785008.2	5850906.6	HL	1814760.1	5789041.7	HL	1794588	5864221
HL	1692861.8	6048808.3	HL	1633918.3	6106789.8	HL	1913802	5807698
HL	1616439.5	6136072.1	HL	1840868.5	5781620.5	HL	1934404	5792746
HL	1769310.5	5884079.7	HL	1690777.3	5667420.7	HL	1926531	5742187
HL	1746448.3	5946722.4	HL	1748427.2	5883051.2	HL	1798580	5786039
HL	1828772.5	5873784.9	HL	1810992	5840945.8	HL	1722622	5987360
HL	1783108.1	5875626.7	HL	1798950.2	5848596.6	HL	1732570	5985328
HL	1835574	5857690.6	HL	1801217.1	5843330.6	HL	1699131	5632743
HL	1821942.5	5877304.1	HL	1804048	5831400.6	HL	1819520	5792705
HL	1791079	5792000.2	HL	1788880.4	5798458.3	HL	1976283	5778408
HL	1783771.4	5780018	HL	1707435.8	6042145.4	HL	1758404	5872721
HL	1821002.1	5816033.6	HL	1818569.8	5809421.1	HL	1843289	5888960
HL	1951310	5781567.7	HL	1785800.6	5890155.6	HL	1842080	5736115
HL	1788955.7	5847505.6	HL	1835833.5	5831061.5	HL	1830553	5788832
HL	1770533.8	5813749.1	HL	1832100.5	5814765.6	HL	1826164	5792494
HL	1797039.4	5769052.1	HL	1808631	5835085.3	HL	1856486	5863159
HL	1792051.4	5798806.6	HL	2022112.8	5738196.9	HL	1760892	5766593
HL	1950217.4	5780713.7	HL	1727318.9	6004913.3	HL	1849428	5887756
HL	1881826.5	5795706.4	HL	1805460.8	5865040.2	HL	1687303	5634223
HL	1765440.6	5870739.2	HL	1606915	6150117.7	HL	1771771	5893783

HL	1779033.7	5811396.6	HL	1791220.3	5769236.9	HL	1863641	5809471
HL	1726298.1	5986720	HL	1737826.8	5960902.9	HL	1932944	5796804
HL	1688136	6019595.3	HL	1976919.9	5684264.8	HL	1818630	5781809
HL	1791982.4	5759952.4	HL	1834013.3	5854141.5	HL	1794048	5786380
HL	1764640.3	5807590.5	HL	1732464.2	5977674.4	HL	1899286	5802953
HL	1795894.6	5762984.9	HL	1753255.1	5871292.9	HL	1785226	5776229
HL	1808897.7	5798812.8	HL	1837306.7	5806105.3	HL	1812850	5794045
HL	1741159.5	5984849.5	HL	1735252.1	5959151.4	HL	1717274	5612514
HL	1756896.3	5589811.7	HL	1847385.1	5828064.8	HL	2022340	5711139
HL	1671557.6	6032075.9	HL	1811909.4	5845195.5	HL	1851809	5853272
HL	1780223.5	5783791.1	HL	1699802.2	6048190.4	HL	1809287	5774908
HL	1794738.6	5873927	HL	1833166.6	5812990.2	HL	1832464	5794138
HL	1812738.3	5873648.8	HL	1831441.5	5874250.8	HL	1851217	5796599
HL	1755202.6	5849248.3	HL	1972707.3	5687870.4	HL	1788941	5764247
HL	1820876.1	5834912.3	HL	1938597.3	5794627.3	HL	1775706	5475695
HL	1978002.2	5784344.3	HL	1777782.9	5756150.1	HL	1831387	5794369
HL	1812318.4	5801047.9	HL	1710195.5	6069712.6	HL	1847478	5799593
HL	1765557.4	5881662.8	HL	1639049	6125764	HL	1932816	5796716
HL	1813495.2	5875848.4	HL	1791020.1	5798622	HL	1698180	5628994
HL	1774483.9	5904089.9	HL	1800027.9	5785540.4	HL	1808947	5782631
HL	1806339.1	5803784.6	HL	1834754	5875858.4	HL	1832611	5507297
HL	1787953	5844723.4	HL	1911507.5	5806494.6	HL	1810970	5523929
HL	1870409.6	5746471.4	HL	1824501.6	5847426.6	HL	1858112	5547027
HL	1792837.4	5859012.4	HL	1825328.9	5847145.3	HL	1818064	5793774
HL	1766375.6	5887988.6	HL	1831462.7	5767749.1	HL	1795295	5760290
HL	1789827.9	5874053.5	HL	1895678.5	5816473	HL	1773261	5749948
HL	1950498.9	5775731.6	HL	1803530.3	5804500	HL	1775579	5738530
HL	1821268.3	5773214.9	HL	1786099.2	5758165.9	HL	1755687	5870176
HL	1790374.3	5776886.7	HL	1820603.1	5809388.3	HL	1789108	5822777
HL	1808450.8	5870991.1	HL	1823170.1	5867968.4	HL	1768150	5581015
HL	1778712.1	5743978.2	HL	1799423.6	5839251.9	HL	1653528	6047523
HL	1865853.6	5746226.7	HL	1801605.5	5793985.9	HL	1802465	5831327
HL	1751195	5590312	HL	1835937.4	5737547	HL	1836796	5747356
HL	1813492.8	5870248.1	HL	1822178.9	5866883.3	HL	1853404	5858918
HL	1803782.8	5686967.9	HL	1949465.4	5782186	HL	1794978	5494840
HL	1836748.9	5841374.7	HL	1833749.3	5843310.3	HL	1927792	5785290
HL	1807931.4	5778453.3	HL	1796689.1	5800221.6	HL	1807192	5794875
HL	1801460.1	5780278.4	HL	1796447.1	5835886.4	HL	1846182	5535058
HL	1799208	5906890	HL	1813865.9	5822844	HL	1810624	5785986
HL	1823563.9	5878214.2	HL	1792165.7	5781972.3	HL	1811059	5763785
HL	1783376.9	5568760.3	HL	1836674.4	5825437.9	HL	1806718	5773564
HL	1834406.8	5817286.8	HL	1890554.9	5736433.4	HL	2003759	5734573
HL	1826485.8	5819726	HL	1842655.9	5835663.8	HL	1713095	5634649
HL	1714905.1	6032044.7	HL	1845185.9	5820566.2	HL	1787591	5726187
HL	1804335.6	5801420.4	HL	1836072.9	5865264.3	HL	1980304	5781071
HL	1787646.6	5802292.3	HL	1778583.5	5757688.3	HL	1825036	5814457

HL	1818008.8	5830392.2	HL	1675434.5	5664058.6	HL	1846218	5858218
HL	1818799.9	5858722	HL	1708408.2	5669303.9	HL	1889459	5568038
HL	1787781	5799705.9	HL	1845898.8	5887277.3	HL	1796581	5763404
HL	1824845.9	5838312.5	HL	1931966.6	5789479.7	HL	1811675	5542889
HL	1783758.3	5752844.5	HL	1804663	5841540.9	HL	1939810	5793458
HL	1808548.6	5777175	HL	1747004.2	5971492.7	HL	1855993	5736636
HL	1814831.4	5869818.5	HL	2058738	5797266	HL	1856067	5763989
HL	1793392.7	5871084.3	HL	1797246.5	5886927.3	HL	1849014	5894539
HL	1788891.1	5757164.6	HL	1938763.4	5787841.9	HL	1779339	5487342
HL	1790739.1	5765051.1	HL	1726342	5981179	HL	1811121	5775532
HL	1817449.5	5852025	HL	1831662.3	5815757.8	HL	1796936	5797619
HL	1844868.6	5854225.8	HL	1858766.1	5717780.6	HL	1947231	5788311
HL	1813907	5782890	HL	1844531.8	5793121.5	HL	1799649	5796725
HL	1801099.8	5794386.6	HL	1930130.1	5793343.1	HL	1707023	6043494
HL	1683488.7	6031366.8	HL	1789251	5908341	HL	1791483	5828248
HL	1893009	5817381.1	HL	1778886	5856203	HL	1807966	5820816
HL	1634192.7	6098119.7	HL	1840268.6	5798055.3	HL	1816718	5860626
HL	1798802.8	5787340.7	HL	1959598	5771435	HL	1790018	5500711
HL	1797663	5840228	HL	1819930.4	5869640	HL	1928022	5745444
HL	1828473.7	5862407.9	HL	1803918.4	5869636.1	HL	1792803	5794798
HL	1817036.1	5768025.7	HL	1808377	5789884	HL	1820090	5791035
HL	1820574.8	5875087.7	HL	1836360.3	5768302.1	HL	1801123	5807025
HL	1756464.9	5871137.1	HL	1833849.2	5780655.9	HL	1814191	5768639
HL	1844628.2	5856115.7	HL	2021521.8	5659823.1	HL	1824099	5793793
HL	1858880.2	5852739	HL	1712619	5956241	HL	1820104	5778548
HL	1836690.9	5792263.4	HL	1855180.9	5839458	HL	1782930	5894538
HL	1673866.8	6104213.5	HL	1941618	5792952.3	HL	1848058	5809677
HL	1914047.1	5802731.2	HL	1871652.5	5784309.3	HL	1927190	5787976
HL	1801995.3	5773729.1	HL	1799955.9	5530328.1	HL	1813695	5839209
HL	1797079.5	5905148.6	HL	1816067	5865958	HL	1727359	5601564
HL	1783296.8	5845214.6	HL	1805623	5879287	HL	1792130	5788209
HL	1795361.8	5771474.4	HL	1801805.4	5806555.6	HL	1822134	5781275
HL	1880658	5804176.6	HL	1810301	5835006	HL	1810198	5827350
HL	1848302.7	5807178.2	HL	1888083.1	5802959.9	HL	1935353	5614112
HL	1831631.2	5810595.2	HL	1821356.2	5832268	HL	1873649	5781818
HL	1797144.3	5881072	HL	1937336	5797537	HL	1765482	5833911
HL	1891699.4	5817555.9	HL	1718842	5996540	HL	1663450	6072955
HL	1785508	5838679.4	HL	1855051	5832568	HL	1770645	5730845
HL	2047380.7	5721481	HL	1806594	5825576	HL	1804210	5805216
HL	1787707.6	5800509.4	HL	1791024	5824504	HL	1829209	5823101
HL	1718747.1	6065046.9	HL	1795840	5777997	HL	1879016	5764113
HL	1766324	5892447	HL	1790887	5877255	HL	1735809	5982674
HL	1755296.6	5589875.2	HL	1938269	5794082	HL	1808354	5804136
HL	1846663.5	5892146.9	HL	1872123	5820999	HL	1930275	5789168
HL	1792918.3	5850973	HL	1813425	5843880	HL	1933152	5790065
HL	1818431.6	5817861.9	HL	1728144	6028239	HL	1817811	5827157

HL	1902805.4	5734801.7	HL	1840177	5812250	HL	1775137	5735032
HL	1778986.7	5805959.4	HL	1820609	5845771	HL	1950139	5668896
HL	1804412.1	5783450.1	HL	1798386	5829655	HL	1937024	5791140
HL	1815791	5863590.1	HL	1787223	5488643	HL	1845342	5829626
HL	1793809.7	5807260.7	HL	1791051	5802871	HL	1810072	5793005
HL	1804857.5	5766402	HL	1823526	5819548	HL	1822680	5776039
HL	1784226.9	5751287	HL	1985762	5785760	HL	1945360	5792009
HL	1623701.3	6101780.5	HL	1845379	5829351	HL	1711241	5670729
HL	1813740.8	5865256.2	HL	1854047	5873222	HL	1807082	5776377
HL	1741097.3	5987802	HL	1890698	5816209	HL	1856214	5855704
HL	1842624.4	5924708.1	HL	2034767	5713033	HL	1832157	5845444
HL	1827491.1	5869834	HL	1819269	5790360	HL	1940178	5791145
HL	1846799.4	5815065.8	HL	1814627	5843528	HL	1805354	5840992
HL	1797779.9	5842871.4	HL	1833879	5862579	HL	1944496	5792949
HL	1809888.9	5809291.2	HL	1790216	5798912	HL	1754669	5881213
HL	1840681.9	5734678	HL	1769498	5821922	HL	1791746	5868244
HL	1823842.9	5848158	HL	1801492	5850219	HL	1784689	5888182
HL	1838318.7	5790527.9	HL	1714957	6003371	HL	1830968	5778100
HL	1714198.1	6015043.8	HL	1853820	5856815	HL	1846185	5785380
HL	1838963.4	5847026.7	HL	1848271	5827685	HL	1915495	5806052
HL	1825676.9	5777632.9	HL	1813648	5818363	HL	1846673	5833268
HL	1821949.9	5838454.8	HL	1768334	5895160	HL	1845968	5856706
HL	1819705.4	5824061.3	HL	1821546	5836783	HL	1825774	5805540
HL	1819854.6	5848892.9	HL	1842658	5838208	HL	1794407	5826957
HL	1813029.3	5846530.5	HL	1804464	5766177	HL	1813259	5805459
HL	1802006	5798717.3	HL	1833511	5789672	HL	1932531	5796047
HL	1797125.9	5774861.5	HL	1783818	5843546	HL	1929453	5747199
HL	1786423.7	5801575.3	HL	1843961	5837133	HL	1827456	5797719
HL	1762229.1	5874307	HL	1831551	5824916	HL	1831896	5769805
HL	1847167.8	5892723.4	HL	1834698	5874085	HL	1794043	5511747
HL	1802204	5860569.6	HL	1695354	6004833	HL	1848995	5778200
HL	1809487.5	5821528.2	HL	1831225	5785016	HL	1699281	5661310
HL	1891975	5806598	HL	1841338	5837572	HL	1790559	5510880
HL	1828796.1	5878258.7	HL	1766386	5871193	HL	1841518	5839138
HL	1789951.2	5775108.6	HL	1825075	5925009	HL	1826301	5837476
HL	1814065.9	5850032.7	HL	1795572	5767090	HL	1779594	5781989
HL	1796387.8	5849953.5	HL	1828300	5833998	HL	1803168	5789047
HL	1788935.8	5802143.1	HL	1902630	5809963	HL	1820256	5541525
HL	1645808	6094936.3	HL	1851552	5790565	HL	1800921	5766101
HL	1823912.2	5868504.8	HL	1661282	6094226	HL	1761385	5752933
HL	1807579.3	5829619.3	HL	1852473	5853963	HL	1798125	5764515
HL	1776221.8	5841466	HL	1824193	5879173	HL	1825347	5820415
HL	1814189.5	5827490	HL	1839478	5815800	HL	1866448	5826580
HL	1800545.2	5841203.7	HL	1791543	5804559	HL	1851301	5853791
HL	1817953.6	5817256.8	HL	1795801	5544780	HL	1793308	5830322
HL	1773123.9	5820272.2	HL	1832811	5827595	HL	1791589	5555738

HL	1820164.1	5843300.8	HL	1794885	5836859	HL	1841978	5781524
HL	1832385.3	5825539.3	HL	1809217	5873134	HL	1869758	5781916
HL	1677113.3	6012204.2	HL	1937333	5794377	HL	1802285	5788624
HL	1826581.3	5838703.8	HL	1793900	5773305	HL	1932452	5747388
HL	1794135.5	5820433	HL	1815573	5872536	HL	1798697	5836897
HL	2049739.7	5715974	HL	1833525	5864120	HL	1835230	5802075
HL	1730471.9	6060116.1	HL	1902784	5812440	HL	1846253	5831829
HL	1792185.1	5784232.1	HL	1836906	5862859	HL	1770855	5785657
HL	1847381.4	5824925.1	HL	1784324	5839927	HL	1791634	5754959
HL	1806866.3	5844969.1	HL	1889827	5814033	HL	1789404	5824794
HL	1767703.5	5799626.8	HL	1794870	5808239	HL	1840069	5818167
HL	1798804.9	5863089.4	HL	1816186	5832585	HL	1908993	5810419
HL	1787728	5754675.9	HL	1830530	5790828	HL	1787907	5494713
HL	1793091.5	5738426.4	HL	1803469	5821626	HL	1813737	5835776
HL	1812366.5	5775577	HL	1790123	5787912	HL	1785385	5846227
HL	1716099.3	5972716.5	HL	1869302	5818429	HL	1821672	5809081
HL	1801944.3	5890615.8	HL	1843892	5791526	HL	1842657	5798556
HL	1806777	5878073.9	HL	1801045	5863178	HL	1792532	5512443
HL	1803950.9	5842079.1	HL	1761040	5872860	HL	1696783	5664933
HL	1815839.4	5848373.3	HL	1792998	5806725	HL	1900317	5795131
HL	1786703.4	5875035.6	HL	1777766	5736070	HL	1836357	5787184
HL	1782778.6	5895907.6	HL	1895430	5813076	HL	1847512	5803070
HL	1633367	6106673.4	HL	1792589	5778489	HL	1816639	5859409
HL	1661187.9	6030909.1	HL	1821324	5537291	HL	1819218	5779325
HL	1828804.5	5785021	HL	1818099	5547765	HL	1790995	5762390
HL	1857844.6	5854884.6	HL	1820907	5864838	HL	1802909	5825266
HL	1734007.5	5980492.1	HL	1832318	5869150	HL	1783703	5759912
HL	1768305.1	5808893.3	HL	1797877	5790597	HL	1928845	5749761
HL	1794689.2	5836782.3	HL	2013837	5671414	HL	1836060	5811465
HL	1761410.8	5839551.5	HL	1821224	5776412	HL	1798141	5763434
HL	1688068.1	6003567.8	HL	1825200	5877445	HL	1896951	5814022
HL	1850289.4	5805612.8	HL	1838112	5792361	HL	1862389	5808498
HL	1795093.7	5800952	HL	1823785	5825068	HL	1811834	5772954
HL	1795067.5	5763067.2	HL	1960514	5768854	HL	1811326	5791042
HL	1815235.6	5862825.1	HL	1813906	5861788	HL	1680492	5630422
HL	1915410.6	5643400.7	HL	1789583	5765875	HL	1822250	5553614
HL	1799536.6	5800476.3	HL	1813540	5812936	HL	1859365	5837201
HL	1777678.1	5739600.7	HL	1814280	5794309	HL	1778138	5726302
HL	1775168.2	5753307	HL	1828366	5867574	HL	1794044	5541868
HL	1786182.1	5744173.7	HL	1836393	5839727	HL	1789688	5766691
HL	1846511.6	5852132.1	HL	1836459	5864330	HL	1747019	5593429
HL	1692401.5	6075290.7	HL	1793420	5765127	HL	1847683	5789845
HL	1790306.9	5757492.9	HL	1806599	5837826	HL	1838521	5778943
HL	1768789.6	5809889	HL	1847742	5852142	HL	1933518	5656813
HL	1779848.4	5743712.2	HL	1803472	5871795	HL	1867690	5818760
HL	1829355.9	5847957.8	HL	1840607	5814965	HL	2052962	5733773

HL	1838312.3	5917601	HL	1798544	5839259	HL	1904904	5634814
HL	1806868.7	5817109.4	HL	1807176	5800825	HL	2017521	5717715
HL	1839945.8	5838059.1	HL	1823943	5873071	HL	1729049	5607132
HL	1845637.7	5770699.4	HL	1924376	5793588	HL	1803960	5832580
HL	1903617.4	5812444.1	HL	1831590	5863123	HL	1822335	5875992
HL	1808766.4	5841877.4	HL	1843086	5790296	HL	1846880	5800786
HL	1788169.7	5815808.4	HL	1845008	5798625	HL	1801431	5533578
HL	1665469.2	6111461.1	HL	1855431	5858532	HL	1718502	5613550
HL	1683072.5	6114935.4	HL	1710024	5618103	HL	1812533	5821018
HL	1848743.1	5785656.7	HL	2059279	5742591	HL	1853175	5761751
HL	1943236.7	5789286.9	HL	1816309	5833270	HL	1821923	5879629
HL	1796225.2	5809832.8	HL	1806226	5797855	HL	1782214	5487234
HL	1850470.7	5818752.7	HL	1836716	5826658	HL	1808447	5551889
HL	1817771	5795180	HL	1856818	5760082	HL	1482457	5275164
HL	1805022.1	5838077.2	HL	1805282	5798997	HL	1673698	5658783
HL	1806692.5	5842959	HL	1841140	5813117	HL	1844905	5554520
HL	1810567.9	5874013.2	HL	2028139	5660669	HL	1810877	5696548
HL	1793939.3	5789190.2	HL	1874416	5815653	HL	1956611	5782772
HL	1798002.5	5802297.9	HL	1753562	5590265	HL	1802505	5793742
HL	1723354.2	5941237.2	HL	1815666	5812800	HL	1818598	5815848
HL	1825782.1	5818297.7	HL	1840958	5793531	HL	1792147	5814478
HL	1688446.3	6107913.6	HL	1804413	5828428	HL	1847311	5829228
HL	1795689.6	5834987.2	HL	1821492	5840439	HL	1940935	5794859
HL	1803419.3	5805329.9	HL	1803741	5808631	HL	1805597	5781743
HL	1820794.4	5839091.7	HL	1786141	5820080	HL	1814645	5845203
HL	1825299.3	5837800	HL	1929129	5746774	HL	1972854	5782644
HL	1802788.2	5843777.5	HL	1825413	5539197	HL	1799571	5693054
HL	1799969.6	5774636.6	HL	1810717	5836982	HL	1830610	5549125
HL	1906095.4	5810565.5	HL	1777085	5843791	HL	1807217	5803855
HL	1714245.6	5636859.6	HL	1792745	5780347	HL	1935401	5790526
HL	1798201.3	5762139.4	HL	1816025	5769967	HL	1791952	5780814
HL	1822846.3	5843999.8	HL	1793668	5811240	HL	1819910	5834484
HL	1777313.2	5746411.9	HL	1815248	5876655	HL	1810159	5835718
HL	1821094	5865133	HL	1790424	5734274	HL	1851417	5811316

Table 10. HCT and organisms/ μ L, by cow and month, for Farm A, **Chapter 9.**

Farm	cowno	age	sampledate	month	HCT	herd	organisms/ μ L
Farm A	1	3	3/08/2014	Aug	28	Thin	59924.3
Farm A	1	3	2/09/2014	Sep	33.5	Thin	4030.0
Farm A	1	3	6/10/2014	Oct	29.5	Thin	350.4
Farm A	1	3	6/11/2014	Nov	30	Thin	21551.7
Farm A	1	3	9/12/2014	Dec	32.5	Thin	350.4
Farm A	1	3	13/01/2015	Jan	29	Normal	438.0
Farm A	1	3	11/02/2015	Feb	28	Normal	30838.2
Farm A	1	3	3/03/2015	Mar	31	Normal	569.5
Farm A	1	3	16/04/2015	Apr	39	Normal	9286.5
Farm A	3	3	3/08/2014	Aug	27.5	Normal	28472.8
Farm A	3	3	2/09/2014	Sep	29	Normal	31626.7
Farm A	3	3	6/10/2014	Oct	30.5	Thin	1752.2
Farm A	3	3	6/11/2014	Nov	31	Thin	81826.5
Farm A	3	3	9/12/2014	Dec	32	Thin	4292.8
Farm A	3	3	13/01/2015	Jan	29.5	Thin	2715.9
Farm A	3	3	11/02/2015	Feb	26.5	Thin	1927.4
Farm A	3	3	3/03/2015	Mar	26	Normal	876.1
Farm A	3	3	16/04/2015	Apr	31	Normal	788.5
Farm A	4	3	3/08/2014	Aug	29	Thin	NA
Farm A	4	3	2/09/2014	Sep	30	Thin	350.4
Farm A	4	3	6/10/2014	Oct	30.5	Thin	613.3
Farm A	4	3	6/11/2014	Nov	28	Thin	87.6
Farm A	4	3	9/12/2014	Dec	33	Thin	3592.0
Farm A	4	3	13/01/2015	Jan	32.5	Thin	613.3
Farm A	4	3	11/02/2015	Feb	30	Thin	613.3
Farm A	4	3	16/04/2015	Apr	28	Thin	NA
Farm A	8	3	3/08/2014	Aug	31	Thin	28297.6
Farm A	8	3	2/09/2014	Sep	28	Thin	87.6
Farm A	8	3	6/10/2014	Oct	30	Thin	3679.6
Farm A	8	3	6/11/2014	Nov	28	Thin	26107.4
Farm A	8	3	9/12/2014	Dec	31.5	Thin	87.6
Farm A	8	3	13/01/2015	Jan	31	Thin	6921.1
Farm A	8	3	16/04/2015	Apr	30	Thin	788.5
Farm A	14	3	3/08/2014	Aug	25.5	Normal	3416.7
Farm A	14	3	2/09/2014	Sep	33	Normal	2277.8
Farm A	14	3	6/10/2014	Oct	34.5	Normal	NA
Farm A	14	3	6/11/2014	Nov	35.5	Normal	NA
Farm A	14	3	9/12/2014	Dec	33.5	Normal	87.6
Farm A	14	3	13/01/2015	Jan	33	Thin	NA
Farm A	14	3	11/02/2015	Feb	30.5	Thin	141049.9
Farm A	14	3	3/03/2015	Mar	31.5	Thin	963.7
Farm A	14	3	16/04/2015	Apr	35	Thin	1401.7
Farm A	16	3	3/08/2014	Aug	26.5	Thin	9724.6

Farm A	16	3	2/09/2014	Sep	32	Thin	5607.0
Farm A	16	3	6/10/2014	Oct	31	Thin	27333.9
Farm A	16	3	6/11/2014	Nov	26.5	Thin	350.4
Farm A	16	3	9/12/2014	Dec	31	Thin	8760.9
Farm A	16	3	13/01/2015	Jan	30	Thin	2102.6
Farm A	16	3	11/02/2015	Feb	27.5	Thin	6658.3
Farm A	16	3	3/03/2015	Mar	30	Normal	175.2
Farm A	16	3	16/04/2015	Apr	33	Normal	175.2
Farm A	19	3	3/08/2014	Aug	28.5	Thin	9374.1
Farm A	19	3	2/09/2014	Sep	28	Thin	5431.7
Farm A	19	3	6/10/2014	Oct	29.5	Thin	NA
Farm A	19	3	6/11/2014	Nov	33	Thin	NA
Farm A	19	3	9/12/2014	Dec	30	Thin	1401.7
Farm A	19	3	13/01/2015	Jan	30	Thin	45994.5
Farm A	19	3	11/02/2015	Feb	30	Normal	4555.7
Farm A	30	3	3/08/2014	Aug	29.5	Normal	44330.0
Farm A	30	3	2/09/2014	Sep	33.5	Normal	350.4
Farm A	30	3	6/10/2014	Oct	32.5	Thin	70612.6
Farm A	30	3	6/11/2014	Nov	30	Thin	NA
Farm A	30	3	13/01/2015	Jan	26.5	Thin	12703.3
Farm A	30	3	11/02/2015	Feb	26.5	Normal	6745.9
Farm A	30	3	3/03/2015	Mar	29.5	Normal	32327.6
Farm A	30	3	16/04/2015	Apr	29.5	Normal	13754.6
Farm A	44	3	3/08/2014	Aug	23.5	Normal	60362.4
Farm A	44	3	2/09/2014	Sep	27	Normal	1489.3
Farm A	44	3	6/10/2014	Oct	32	Normal	15068.7
Farm A	44	3	6/11/2014	Nov	32.5	Normal	20850.9
Farm A	44	3	9/12/2014	Dec	31.5	Normal	128083.9
Farm A	44	3	13/01/2015	Jan	31	Thin	218233.2
Farm A	44	3	11/02/2015	Feb	28.5	Normal	18222.6
Farm A	44	3	3/03/2015	Mar	26.5	Normal	21420.3
Farm A	44	3	16/04/2015	Apr	35	Normal	7271.5
Farm A	67	4	6/11/2014	Nov	25.5	Thin	6570.6
Farm A	67		9/12/2014	Dec	27	Thin	18573.0
Farm A	84	6	3/08/2014	Aug	26	Thin	48535.2
Farm A	84	6	2/09/2014	Sep	29	Thin	28998.5
Farm A	84	6	6/10/2014	Oct	30.5	Thin	175.2
Farm A	84	6	6/11/2014	Nov	30.5	Thin	15944.8
Farm A	84	6	9/12/2014	Dec	32	Thin	9637.0
Farm A	84	6	13/01/2015	Jan	30	Thin	14192.6
Farm A	84	6	11/02/2015	Feb	30.5	Thin	54667.8
Farm A	84	6	3/03/2015	Mar	30.5	Thin	50769.2
Farm A	84	6	16/04/2015	Apr	32.5	Thin	2102.6
Farm A	91	2	3/08/2014	Aug	29	Thin	4555.7
Farm A	91	2	2/09/2014	Sep	30	Thin	29173.7
Farm A	91	2	6/11/2014	Nov	30	Normal	2803.5

Farm A	91	2	9/12/2014	Dec	32	Normal	173903.2
Farm A	91	2	13/01/2015	Jan	26	Thin	65443.7
Farm A	91	2	11/02/2015	Feb	26.5	Thin	22778.3
Farm A	91	2	3/03/2015	Mar	27	Thin	20500.4
Farm A	91	2	16/04/2015	Apr	32.5	Thin	7271.5
Farm A	102	4	3/08/2014	Aug	30.5	Thin	54930.6
Farm A	102	4	2/09/2014	Sep	28	Thin	262.8
Farm A	102	4	6/10/2014	Oct	29.5	Thin	1577.0
Farm A	102	4	6/11/2014	Nov	33	Normal	87.6
Farm A	102	4	9/12/2014	Dec	31.5	Normal	NA
Farm A	102	4	13/01/2015	Jan	28	Thin	12878.5
Farm A	102	4	11/02/2015	Feb	27.5	Thin	68597.6
Farm A	102	4	3/03/2015	Mar	29	Thin	700.9
Farm A	120	5	3/08/2014	Aug	25	Normal	69298.4
Farm A	120	5	2/09/2014	Sep	30	Normal	350.4
Farm A	120	5	6/10/2014	Oct	32	Normal	9637.0
Farm A	120	5	6/11/2014	Nov	33.5	Normal	87.6
Farm A	120	5	9/12/2014	Dec	32	Normal	4117.6
Farm A	120	5	13/01/2015	Jan	28.5	Normal	1752.2
Farm A	120	5	16/04/2015	Apr	34	Normal	6658.3
Farm A	138	2	3/08/2014	Aug	31.5	Thin	9374.1
Farm A	138	2	2/09/2014	Sep	24	Thin	73503.7
Farm A	138	2	6/10/2014	Oct	28	Thin	95931.5
Farm A	138	2	6/11/2014	Nov	28	Normal	NA
Farm A	138	2	9/12/2014	Dec	30	Normal	231900.1
Farm A	138	2	13/01/2015	Jan	25	Normal	NA
Farm A	138	2	11/02/2015	Feb	26	Normal	24618.0
Farm A	138	2	3/03/2015	Mar	25	Normal	919.9
Farm A	138	2	16/04/2015	Apr	33	Normal	10250.2
Farm A	140	8	3/08/2014	Aug	26.5	Normal	6045.0
Farm A	140	8	2/09/2014	Sep	28	Normal	14718.3
Farm A	140	8	6/10/2014	Oct	30.5	Normal	2277.8
Farm A	140	8	6/11/2014	Nov	31	Thin	NA
Farm A	140	8	9/12/2014	Dec	31	Thin	4468.0
Farm A	140	8	13/01/2015	Jan	28.5	Thin	21814.6
Farm A	140	8	11/02/2015	Feb	30	Thin	23041.1
Farm A	140	8	3/03/2015	Mar	31	Normal	87.6
Farm A	140	8	16/04/2015	Apr	35	Normal	NA
Farm A	162	2	3/08/2014	Aug	30	Normal	394.2
Farm A	162	2	2/09/2014	Sep	31.5	Normal	350.4
Farm A	162	2	6/10/2014	Oct	29.5	Normal	2102.6
Farm A	183	4	3/08/2014	Aug	28.5	Thin	9374.1
Farm A	183	4	2/09/2014	Sep	27	Thin	700.9
Farm A	183	4	6/10/2014	Oct	30	Thin	9461.7
Farm A	183	4	6/11/2014	Nov	31.5	Thin	4205.2
Farm A	183	4	9/12/2014	Dec	30.5	Thin	350.4

Farm A	183	4	13/01/2015	Jan	29	Thin	1664.6
Farm A	183	4	11/02/2015	Feb	30.5	Thin	2102.6
Farm A	183	4	3/03/2015	Mar	30	Thin	10951.1
Farm A	183	4	16/04/2015	Apr	24	Thin	87.6
Farm A	188	4	3/08/2014	Aug	29.5	Thin	19799.6
Farm A	188	4	2/09/2014	Sep	29	Thin	262.8
Farm A	188	4	6/10/2014	Oct	32.5	Thin	175.2
Farm A	188	4	6/11/2014	Nov	35	Normal	262.8
Farm A	188	4	9/12/2014	Dec	32.5	Normal	6132.6
Farm A	188	4	13/01/2015	Jan	28	Thin	13404.1
Farm A	188	4	11/02/2015	Feb	26.5	Thin	5081.3
Farm A	188	4	3/03/2015	Mar	28	Normal	131.4
Farm A	188	4	16/04/2015	Apr	35	Normal	1577.0
Farm A	190	10	3/08/2014	Aug	28.5	Thin	73591.3
Farm A	190	10	2/09/2014	Sep	30	Thin	2015.0
Farm A	190	10	6/10/2014	Oct	31.5	Thin	1577.0
Farm A	190	10	6/11/2014	Nov	32	Normal	NA
Farm A	190	10	9/12/2014	Dec	32	Thin	9286.5
Farm A	190	10	13/01/2015	Jan	32	Normal	963.7
Farm A	190	10	11/02/2015	Feb	30.5	Normal	6658.3
Farm A	190	10	3/03/2015	Mar	29	Normal	788.5
Farm A	190	10	16/04/2015	Apr	33	Normal	175.2
Farm A	196	7	3/08/2014	Aug	25.5	Thin	1138.9
Farm A	196	7	2/09/2014	Sep	29	Thin	87.6
Farm A	196	7	6/10/2014	Oct	31	Thin	NA
Farm A	196	7	6/11/2014	Nov	27	Thin	175.2
Farm A	196	7	9/12/2014	Dec	31	Thin	2715.9
Farm A	196	7	13/01/2015	Jan	32.5	Thin	NA
Farm A	196	7	11/02/2015	Feb	27	Thin	16382.8
Farm A	196	7	3/03/2015	Mar	29	Normal	2234.0
Farm A	196	7	16/04/2015	Apr	39	Normal	1577.0
Farm A	197	7	3/08/2014	Aug	24	Thin	44330.0
Farm A	197	7	2/09/2014	Sep	24	Thin	262.8
Farm A	197	7	6/10/2014	Oct	25.5	Thin	125017.6
Farm A	197	7	6/11/2014	Nov	27	Normal	8848.5
Farm A	197	7	9/12/2014	Dec	25	Thin	788.5
Farm A	197	7	13/01/2015	Jan	26.5	Thin	17083.7
Farm A	197	7	11/02/2015	Feb	26	Normal	14893.5
Farm A	198	2	3/08/2014	Aug	32	Thin	51075.8
Farm A	198	2	2/09/2014	Sep	30	Thin	4030.0
Farm A	198	2	6/10/2014	Oct	27.5	Thin	262.8
Farm A	198	2	6/11/2014	Nov	26	Thin	NA
Farm A	198	2	9/12/2014	Dec	26	Thin	1489.3
Farm A	198	2	13/01/2015	Jan	26	Thin	8936.1
Farm A	198	2	11/02/2015	Feb	26	Thin	84980.4
Farm A	198	2	16/04/2015	Apr	29.5	Thin	26107.4

Farm A	205	3	3/08/2014	Aug	33	Thin	6132.6
Farm A	205	3	2/09/2014	Sep	29	Thin	525.7
Farm A	205	3	6/10/2014	Oct	31	Thin	2102.6
Farm A	205	3	6/11/2014	Nov	29.5	Thin	175.2
Farm A	205	3	9/12/2014	Dec	30	Thin	87.6
Farm A	205	3	13/01/2015	Jan	31.5	Thin	7709.6
Farm A	205	3	11/02/2015	Feb	30	Thin	1051.3
Farm A	205	3	3/03/2015	Mar	30	Normal	350.4
Farm A	205	3	16/04/2015	Apr	30	Normal	438.0
Farm A	208	3	3/08/2014	Aug	26.5	Thin	152088.6
Farm A	208	3	2/09/2014	Sep	30	Thin	17346.5
Farm A	208	3	6/10/2014	Oct	31	Thin	1401.7
Farm A	208	3	6/11/2014	Nov	28	Thin	26107.4
Farm A	208	3	9/12/2014	Dec	30	Thin	48447.6
Farm A	208	3	13/01/2015	Jan	29.5	Thin	96281.9
Farm A	208	3	11/02/2015	Feb	28	Thin	16120.0
Farm A	208	3	3/03/2015	Mar	26.5	Normal	5431.7
Farm A	208	3	16/04/2015	Apr	27.5	Normal	613.3
Farm A	211	3	3/08/2014	Aug	34	Thin	6833.5
Farm A	211	3	2/09/2014	Sep	31	Thin	1051.3
Farm A	211	3	6/10/2014	Oct	32.5	Thin	25669.3
Farm A	211	3	6/11/2014	Nov	28	Thin	16032.4
Farm A	211	3	9/12/2014	Dec	33	Normal	160937.1
Farm A	211	3	13/01/2015	Jan	30	Normal	NA
Farm A	211	3	11/02/2015	Feb	28.5	Normal	47396.3
Farm A	211	3	3/03/2015	Mar	28.5	Normal	43.8
Farm A	233	3	3/08/2014	Aug	31	Thin	11652.0
Farm A	233	3	2/09/2014	Sep	34	Thin	175.2
Farm A	233	3	6/10/2014	Oct	35.5	Thin	13228.9
Farm A	233	3	6/11/2014	Nov	38.5	Normal	2628.3
Farm A	233	3	9/12/2014	Dec	38	Normal	5782.2
Farm A	233	3	13/01/2015	Jan	32.5	Normal	1927.4
Farm A	233	3	11/02/2015	Feb	31.5	Normal	17696.9
Farm A	233	3	3/03/2015	Mar	32	Normal	1226.5
Farm A	233	3	16/04/2015	Apr	19.5	Normal	NA
Farm A	248	3	3/08/2014	Aug	32.5	Normal	5344.1
Farm A	248	3	2/09/2014	Sep	34	Normal	1577.0
Farm A	248	3	6/10/2014	Oct	33	Thin	5957.4
Farm A	248	3	6/11/2014	Nov	33	Normal	262.8
Farm A	248	3	9/12/2014	Dec	35.5	Normal	23128.7
Farm A	248	3	13/01/2015	Jan	30.5	Normal	525.7
Farm A	248	3	11/02/2015	Feb	31.5	Normal	8498.0
Farm A	248	3	3/03/2015	Mar	30	Thin	87.6
Farm A	248	3	16/04/2015	Apr	24.5	Thin	NA
Farm A	259	3	3/08/2014	Aug	33	Thin	2190.2
Farm A	259	3	2/09/2014	Sep	32	Thin	3854.8

Farm A	259	3	6/10/2014	Oct	32	Thin	700.9
Farm A	259	3	6/11/2014	Nov	31	Thin	16295.2
Farm A	259	3	9/12/2014	Dec	30.5	Thin	6132.6
Farm A	259	3	13/01/2015	Jan	32.5	Thin	3329.1
Farm A	259	3	11/02/2015	Feb	29.5	Thin	2978.7
Farm A	259	3	3/03/2015	Mar	28	Thin	788.5
Farm A	259	3	16/04/2015	Apr	35.5	Thin	87.6
Farm A	261	3	3/08/2014	Aug	33.5	Thin	350.4
Farm A	261	3	2/09/2014	Sep	30	Thin	175.2
Farm A	261	3	6/10/2014	Oct	33.5	Thin	262.8
Farm A	261	3	6/11/2014	Nov	32	Thin	NA
Farm A	261	3	9/12/2014	Dec	29.5	Thin	963.7
Farm A	261	3	13/01/2015	Jan	30.5	Normal	262.8
Farm A	261	3	11/02/2015	Feb	31	Normal	3679.6
Farm A	261	3	3/03/2015	Mar	31.5	Thin	39861.9
Farm A	261	3	16/04/2015	Apr	35.5	Thin	613.3
Farm A	263	3	3/08/2014	Aug	33	Normal	44680.4
Farm A	263	3	2/09/2014	Sep	34.5	Normal	3854.8
Farm A	263	3	6/10/2014	Oct	36	Normal	20500.4
Farm A	263	3	6/11/2014	Nov	35	Normal	788.5
Farm A	263	3	9/12/2014	Dec	35	Normal	175.2
Farm A	263	3	13/01/2015	Jan	32	Normal	137107.5
Farm A	263	3	11/02/2015	Feb	34	Normal	4730.9
Farm A	263	3	16/04/2015	Apr	35.5	Normal	12703.3
Farm A	265	3	3/08/2014	Aug	30	Normal	5256.5
Farm A	265	3	2/09/2014	Sep	33	Normal	1489.3
Farm A	265	3	6/10/2014	Oct	34	Normal	963.7
Farm A	265	3	6/11/2014	Nov	34	Normal	NA
Farm A	265	3	9/12/2014	Dec	33.5	Normal	2453.0
Farm A	265	3	13/01/2015	Jan	29.5	Normal	1839.8
Farm A	265	3	11/02/2015	Feb	28.5	Normal	1839.8
Farm A	265	3	3/03/2015	Mar	29.5	Normal	1314.1
Farm A	265	3	16/04/2015	Apr	35	Normal	1051.3
Farm A	266	3	3/08/2014	Aug	29.5	Thin	59048.2
Farm A	266	3	2/09/2014	Sep	28	Thin	4468.0
Farm A	266	3	6/10/2014	Oct	30	Thin	438.0
Farm A	266	3	6/11/2014	Nov	29	Thin	3241.5
Farm A	266	3	9/12/2014	Dec	28	Thin	7797.2
Farm A	266	3	13/01/2015	Jan	25	Normal	79373.4
Farm A	266	3	11/02/2015	Feb	25	Normal	39248.7
Farm A	266	3	3/03/2015	Mar	24	Normal	175.2
Farm A	266	3	16/04/2015	Apr	28.5	Normal	34693.0
Farm A	267	3	3/08/2014	Aug	33	Thin	34255.0
Farm A	267	3	2/09/2014	Sep	29	Thin	1051.3
Farm A	267	3	6/10/2014	Oct	31.5	Thin	13842.2
Farm A	267	3	6/11/2014	Nov	30	Thin	19711.9

Farm A	267	3	9/12/2014	Dec	33.5	Normal	2026913.9
Farm A	267	3	13/01/2015	Jan	28.5	Normal	1927.4
Farm A	267	3	16/04/2015	Apr	36.5	Thin	1664.6
Farm A	268	3	3/08/2014	Aug	30.5	Thin	127032.6
Farm A	268	3	2/09/2014	Sep	30.5	Thin	1577.0
Farm A	268	3	6/10/2014	Oct	34	Thin	262.8
Farm A	268	3	6/11/2014	Nov	33	Thin	63866.7
Farm A	268	3	9/12/2014	Dec	32	Thin	20500.4
Farm A	268	3	13/01/2015	Jan	30	Thin	19624.3
Farm A	268	3	11/02/2015	Feb	27.5	Thin	4555.7
Farm A	268	3	3/03/2015	Mar	30	Normal	6395.4
Farm A	270	3	3/08/2014	Aug	31	Thin	525.7
Farm A	270	3	2/09/2014	Sep	28	Thin	87.6
Farm A	270	3	6/10/2014	Oct	28	Thin	2453.0
Farm A	270	3	6/11/2014	Nov	29	Thin	700.9
Farm A	270	3	9/12/2014	Dec	28	Thin	4030.0
Farm A	270	3	13/01/2015	Jan	28	Thin	16207.6
Farm A	270	3	11/02/2015	Feb	28.5	Thin	613.3
Farm A	270	3	3/03/2015	Mar	30.5	Thin	175.2
Farm A	270	3	16/04/2015	Apr	35.5	Thin	2453.0
Farm A	274	3	3/08/2014	Aug	28	Thin	10600.6
Farm A	274	3	2/09/2014	Sep	30	Thin	613.3
Farm A	274	3	6/10/2014	Oct	30	Thin	342024.2
Farm A	274	3	6/11/2014	Nov	29	Thin	1401.7
Farm A	274	3	9/12/2014	Dec	29.5	Thin	3942.4
Farm A	274	3	13/01/2015	Jan	27.5	Thin	21464.1
Farm A	274	3	11/02/2015	Feb	27.5	Thin	45994.5
Farm A	274	3	3/03/2015	Mar	27	Thin	2628.3
Farm A	275	3	3/08/2014	Aug	28.5	Thin	24442.8
Farm A	275	3	2/09/2014	Sep	28	Thin	8848.5
Farm A	275	3	6/10/2014	Oct	30	Thin	NA
Farm A	275	3	6/11/2014	Nov	30	Thin	6132.6
Farm A	275	3	13/01/2015	Jan	27	Normal	8936.1
Farm A	275	3	11/02/2015	Feb	26.5	Normal	156469.1
Farm A	275	3	3/03/2015	Mar	26.5	Thin	87.6
Farm A	280	3	3/08/2014	Aug	36	Thin	16558.0
Farm A	280	3	2/09/2014	Sep	34	Thin	262.8
Farm A	280	3	6/10/2014	Oct	30.5	Thin	19974.8
Farm A	280	3	6/11/2014	Nov	30.5	Thin	NA
Farm A	280	3	9/12/2014	Dec	31	Thin	2891.1
Farm A	280	3	13/01/2015	Jan	31	Thin	19449.1
Farm A	280	3	11/02/2015	Feb	34.5	Thin	64217.1
Farm A	280	3	3/03/2015	Mar	31	Thin	3110.1
Farm A	280	3	16/04/2015	Apr	33	Thin	13316.5
Farm A	282	3	3/08/2014	Aug	35	Thin	1752.2
Farm A	282	3	2/09/2014	Sep	31	Thin	175.2

Farm A	282	3	6/10/2014	Oct	32	Thin	700.9
Farm A	282	3	6/11/2014	Nov	30	Thin	9286.5
Farm A	282	3	9/12/2014	Dec	31.5	Thin	175.2
Farm A	282	3	13/01/2015	Jan	32	Thin	10513.0
Farm A	282	3	11/02/2015	Feb	29.5	Thin	113891.3
Farm A	282	3	3/03/2015	Mar	29	Normal	87.6
Farm A	282	3	16/04/2015	Apr	22	Normal	NA
Farm A	283	3	3/08/2014	Aug	31	Thin	219.0
Farm A	283	3	2/09/2014	Sep	33	Thin	262.8
Farm A	283	3	6/10/2014	Oct	34	Thin	1839.8
Farm A	283	3	6/11/2014	Nov	32	Thin	87.6
Farm A	283	3	9/12/2014	Dec	36	Thin	350.4
Farm A	283	3	13/01/2015	Jan	32	Thin	963.7
Farm A	283	3	11/02/2015	Feb	29.5	Thin	963.7
Farm A	283	3	3/03/2015	Mar	31.5	Thin	438.0
Farm A	283	3	16/04/2015	Apr	21.5	Thin	87.6
Farm A	290	3	3/08/2014	Aug	30	Thin	56858.0
Farm A	290	3	2/09/2014	Sep	28.5	Thin	87.6
Farm A	290	3	6/10/2014	Oct	30	Thin	87.6
Farm A	290	3	6/11/2014	Nov	28.5	Thin	43191.1
Farm A	290	3	9/12/2014	Dec	30.5	Thin	525.7
Farm A	290	3	13/01/2015	Jan	29	Normal	175.2
Farm A	290	3	11/02/2015	Feb	27	Normal	7972.4
Farm A	290	3	3/03/2015	Mar	29.5	Normal	1095.1
Farm A	290	3	16/04/2015	Apr	31.5	Normal	87.6
Farm A	296	3	3/08/2014	Aug	29	Normal	99611.0
Farm A	296	3	2/09/2014	Sep	31	Normal	175.2
Farm A	296	3	6/10/2014	Oct	30	Thin	NA
Farm A	296	3	6/11/2014	Nov	31	Thin	15243.9
Farm A	296	3	9/12/2014	Dec	30	Thin	10951.1
Farm A	296	3	13/01/2015	Jan	27.5	Normal	262.8
Farm A	296	3	11/02/2015	Feb	27.5	Normal	32152.4
Farm A	296	3	3/03/2015	Mar	27.5	Normal	700.9
Farm A	296	3	16/04/2015	Apr	35.5	Normal	3153.9
Farm A	301	3	3/08/2014	Aug	27	Thin	18923.5
Farm A	301	3	2/09/2014	Sep	27	Thin	175.2
Farm A	301	3	6/10/2014	Oct	30	Thin	350.4
Farm A	301	3	6/11/2014	Nov	28.5	Thin	2803.5
Farm A	301	3	9/12/2014	Dec	29	Thin	1752.2
Farm A	301	3	13/01/2015	Jan	27	Thin	14280.2
Farm A	301	3	11/02/2015	Feb	25	Thin	57821.7
Farm A	301	3	3/03/2015	Mar	25	Thin	963.7
Farm A	303	3	3/08/2014	Aug	34.5	Thin	16295.2
Farm A	303	3	2/09/2014	Sep	30	Thin	788.5
Farm A	303	3	6/10/2014	Oct	31	Thin	NA
Farm A	303	3	6/11/2014	Nov	34	Thin	NA

Farm A	303	3	9/12/2014	Dec	35	Thin	30838.2
Farm A	303	3	13/01/2015	Jan	28	Thin	3854.8
Farm A	303	3	11/02/2015	Feb	30	Thin	5431.7
Farm A	303	3	3/03/2015	Mar	33	Thin	438.0
Farm A	312	3	3/08/2014	Aug	28	Thin	262.8
Farm A	312	3	6/10/2014	Oct	31	Thin	87.6
Farm A	312	3	6/11/2014	Nov	32	Thin	9812.2
Farm A	312	3	9/12/2014	Dec	32.5	Thin	7534.3
Farm A	312	3	13/01/2015	Jan	30.5	Thin	2190.2
Farm A	312	3	11/02/2015	Feb	30	Thin	5957.4
Farm A	312	3	3/03/2015	Mar	26	Thin	3854.8
Farm A	312	3	16/04/2015	Apr	32.5	Thin	3592.0
Farm A	321	2	3/08/2014	Aug	34	Thin	438.0
Farm A	321	2	2/09/2014	Sep	29	Thin	6570.6
Farm A	321	2	6/10/2014	Oct	29.5	Thin	438.0
Farm A	321	2	6/11/2014	Nov	30.5	Thin	NA
Farm A	321	2	9/12/2014	Dec	32.5	Normal	NA
Farm A	321	2	13/01/2015	Jan	30.5	Normal	700.9
Farm A	321	2	11/02/2015	Feb	26	Normal	788.5
Farm A	321	2	3/03/2015	Mar	25	Thin	175.2
Farm A	326	9	3/08/2014	Aug	29.5	Normal	16996.1
Farm A	326	9	2/09/2014	Sep	35	Normal	262.8
Farm A	326	9	6/10/2014	Oct	37.5	Normal	876.1
Farm A	326	9	6/11/2014	Nov	33	Thin	18923.5
Farm A	326	9	9/12/2014	Dec	31.5	Thin	11739.6
Farm A	326	9	13/01/2015	Jan	33	Thin	8498.0
Farm A	326	9	11/02/2015	Feb	31	Thin	156556.7
Farm A	326	9	3/03/2015	Mar	29.5	Normal	1182.7
Farm A	326	9	16/04/2015	Apr	31.5	Normal	525.7
Farm A	354	4	3/08/2014	Aug	30	Normal	71225.8
Farm A	354	4	2/09/2014	Sep	32	Normal	6658.3
Farm A	354	4	6/10/2014	Oct	34	Normal	21726.9
Farm A	354	4	6/11/2014	Nov	32	Normal	17083.7
Farm A	354	4	9/12/2014	Dec	30.5	Normal	2803.5
Farm A	354	4	13/01/2015	Jan	28	Normal	1489.3
Farm A	354	4	11/02/2015	Feb	27	Normal	262650.8
Farm A	354	4	3/03/2015	Mar	28.5	Thin	1138.9
Farm A	354	4	16/04/2015	Apr	29.5	Thin	262.8
Farm A	356	8	3/08/2014	Aug	28.5	Normal	262.8
Farm A	356	8	6/10/2014	Oct	31.5	Thin	87.6
Farm A	356	8	6/11/2014	Nov	31	Thin	254503.1
Farm A	356	8	9/12/2014	Dec	32.5	Thin	87.6
Farm A	356	8	13/01/2015	Jan	26.5	Normal	5869.8
Farm A	356	8	11/02/2015	Feb	28.5	Normal	18135.0
Farm A	365	6	3/08/2014	Aug	26.5	Thin	202025.6
Farm A	365	6	2/09/2014	Sep	30.5	Thin	9724.6

Farm A	365	6	6/10/2014	Oct	33.5	Normal	13141.3
Farm A	365	6	6/11/2014	Nov	31	Thin	36708.0
Farm A	365	6	9/12/2014	Dec	32	Thin	175.2
Farm A	365	6	13/01/2015	Jan	28	Thin	39073.5
Farm A	365	6	11/02/2015	Feb	29	Thin	525.7
Farm A	365	6	3/03/2015	Mar	33.5	Normal	43.8
Farm A	365	6	16/04/2015	Apr	32	Normal	NA
Farm A	374	7	3/08/2014	Aug	27	Normal	46345.0
Farm A	374	7	2/09/2014	Sep	32	Normal	2102.6
Farm A	374	7	6/10/2014	Oct	34.5	Normal	18485.4
Farm A	374	7	6/11/2014	Nov	33.5	Normal	525.7
Farm A	374	7	9/12/2014	Dec	34.5	Normal	156994.7
Farm A	374	7	13/01/2015	Jan	29	Normal	NA
Farm A	374	7	11/02/2015	Feb	30	Normal	4205.2
Farm A	374	7	3/03/2015	Mar	29	Normal	2715.9
Farm A	374	7	16/04/2015	Apr	32	Normal	NA
Farm A	395	7	3/08/2014	Aug	22	Normal	5431.7
Farm A	395	7	2/09/2014	Sep	29	Normal	2015.0
Farm A	395	7	6/10/2014	Oct	29	Normal	8936.1
Farm A	395	7	6/11/2014	Nov	29	Thin	350.4
Farm A	395	7	9/12/2014	Dec	26.5	Thin	23041.1
Farm A	395	7	13/01/2015	Jan	26.5	Thin	2102.6
Farm A	395	7	11/02/2015	Feb	26.5	Thin	3679.6
Farm A	395	7	3/03/2015	Mar	23	Thin	262.8
Farm A	395	7	16/04/2015	Apr	18	Thin	NA
Farm A	396	9	3/08/2014	Aug	29.5	Normal	92777.6
Farm A	396	9	2/09/2014	Sep	29.5	Normal	NA
Farm A	396	9	6/10/2014	Oct	32	Normal	14105.0
Farm A	396	9	6/11/2014	Nov	30	Normal	NA
Farm A	396	9	9/12/2014	Dec	33	Normal	2453.0
Farm A	396	9	13/01/2015	Jan	30	Normal	2190.2
Farm A	396	9	16/04/2015	Apr	29	Normal	27071.1
Farm A	424	5	3/08/2014	Aug	34	Thin	25844.6
Farm A	424	5	2/09/2014	Sep	33	Thin	19273.9
Farm A	424	5	6/10/2014	Oct	32	Thin	1839.8
Farm A	424	5	9/12/2014	Dec	32.5	Thin	23829.6
Farm A	432	8	3/08/2014	Aug	33	Thin	18310.2
Farm A	432	8	2/09/2014	Sep	32	Thin	876.1
Farm A	432	8	6/10/2014	Oct	32	Thin	NA
Farm A	432	8	6/11/2014	Nov	31	Thin	1051.3
Farm A	432	8	9/12/2014	Dec	30	Thin	262.8
Farm A	432	8	13/01/2015	Jan	35	Thin	350.4
Farm A	432	8	11/02/2015	Feb	29.5	Thin	3241.5
Farm A	432	8	3/03/2015	Mar	29.5	Normal	1489.3
Farm A	432	8	16/04/2015	Apr	36	Normal	NA
Farm A	434	2	3/08/2014	Aug	32.5	Thin	213151.9

Farm A	434	2	2/09/2014	Sep	31	Thin	9724.6
Farm A	434	2	6/10/2014	Oct	31	Thin	NA
Farm A	434	2	6/11/2014	Nov	31	Thin	NA
Farm A	434	2	9/12/2014	Dec	30.5	Normal	613.3
Farm A	434	2	13/01/2015	Jan	26	Normal	NA
Farm A	434	2	11/02/2015	Feb	28.5	Normal	788.5
Farm A	434	2	3/03/2015	Mar	27	Normal	43.8
Farm A	439	6	3/08/2014	Aug	32.5	Thin	105042.8
Farm A	439	6	2/09/2014	Sep	30	Thin	175.2
Farm A	439	6	6/10/2014	Oct	30.5	Thin	4117.6
Farm A	439	6	6/11/2014	Nov	34	Normal	4205.2
Farm A	439	6	9/12/2014	Dec	35	Normal	NA
Farm A	439	6	13/01/2015	Jan	30	Normal	3416.7
Farm A	439	6	11/02/2015	Feb	30	Normal	30487.8
Farm A	439	6	3/03/2015	Mar	30	Normal	1664.6
Farm A	439	6	16/04/2015	Apr	32.5	Normal	10513.0
Farm A	451	7	3/08/2014	Aug	22.5	Normal	252137.7
Farm A	451	7	2/09/2014	Sep	28	Normal	1051.3
Farm A	451	7	6/10/2014	Oct	28.5	Normal	613.3
Farm A	451	7	6/11/2014	Nov	28	Normal	438.0
Farm A	451	7	9/12/2014	Dec	27	Normal	487016.5
Farm A	451	7	13/01/2015	Jan	24.5	Normal	262.8
Farm A	451	7	11/02/2015	Feb	23	Normal	5256.5
Farm A	451	7	3/03/2015	Mar	25	Normal	87.6
Farm A	451	7	16/04/2015	Apr	27	Normal	3854.8
Farm A	452	2	6/11/2014	Nov	28	Thin	43366.3
Farm A	489	10	9/12/2014	Dec	30.5	Thin	10775.9
Farm A	492	10	3/08/2014	Aug	27.5	Normal	91726.3
Farm A	492	10	2/09/2014	Sep	34	Normal	87.6
Farm A	492	10	6/10/2014	Oct	34.5	Normal	613.3
Farm A	492	10	6/11/2014	Nov	35	Thin	6745.9
Farm A	492	2	9/12/2014	Dec	33	Thin	62552.6
Farm A	492	10	13/01/2015	Jan	30	Thin	25143.7
Farm A	492	10	11/02/2015	Feb	26	Thin	2891.1
Farm A	492	10	3/03/2015	Mar	26.5	Normal	262.8
Farm A	492	10	16/04/2015	Apr	36	Normal	1752.2
Farm A	499	2	3/08/2014	Aug	28.5	Thin	13228.9
Farm A	499	2	2/09/2014	Sep	29	Thin	2540.7
Farm A	499	2	6/10/2014	Oct	28.5	Thin	13141.3
Farm A	499	2	6/11/2014	Nov	28	Thin	963.7
Farm A	499	5	9/12/2014	Dec	27	Thin	700.9
Farm A	499	2	13/01/2015	Jan	25.5	Thin	11038.7
Farm A	499	2	11/02/2015	Feb	24.5	Thin	4730.9
Farm A	526	7	3/08/2014	Aug	23	Normal	9987.4
Farm A	526	7	2/09/2014	Sep	30	Normal	13929.8
Farm A	526	7	6/10/2014	Oct	31	Normal	2277.8

Farm A	526	7	6/11/2014	Nov	32	Normal	NA
Farm A	526	7	9/12/2014	Dec	28.5	Normal	8585.6
Farm A	526	7	13/01/2015	Jan	26	Normal	10425.4
Farm A	526	7	11/02/2015	Feb	25	Normal	744147.9
Farm A	526	7	3/03/2015	Mar	27	Thin	NA
Farm A	526	7	16/04/2015	Apr	30	Thin	11213.9
Farm A	544	2	3/08/2014	Aug	23	Thin	412899.6
Farm A	544	2	2/09/2014	Sep	29	Thin	1577.0
Farm A	544	2	6/10/2014	Oct	31.5	Thin	175.2
Farm A	544	2	6/11/2014	Nov	26	Thin	53528.9
Farm A	544	2	9/12/2014	Dec	32.5	Thin	250210.3
Farm A	544	2	13/01/2015	Jan	28.5	Thin	302249.9
Farm A	544	2	11/02/2015	Feb	26	Thin	NA
Farm A	544	2	3/03/2015	Mar	26	Thin	48973.2
Farm A	544	2	16/04/2015	Apr	33	Thin	10250.2
Farm A	547	7	3/08/2014	Aug	26	Normal	4292.8
Farm A	547	7	2/09/2014	Sep	33	Normal	262.8
Farm A	547	7	6/10/2014	Oct	32.5	Normal	6658.3
Farm A	547	7	6/11/2014	Nov	33.5	Thin	8322.8
Farm A	547	7	9/12/2014	Dec	29	Thin	10688.3
Farm A	547	7	13/01/2015	Jan	33	Thin	15857.2
Farm A	547	7	11/02/2015	Feb	31	Thin	1138.9
Farm A	547	7	3/03/2015	Mar	32	Thin	613.3
Farm A	547	7	16/04/2015	Apr	37.5	Thin	1051.3
Farm A	550	5	3/08/2014	Aug	28	Normal	142889.7
Farm A	550	5	2/09/2014	Sep	33.5	Normal	7534.3
Farm A	550	5	6/10/2014	Oct	35	Normal	9023.7
Farm A	550	5	6/11/2014	Nov	33.5	Normal	2015.0
Farm A	550	5	9/12/2014	Dec	33	Normal	19186.3
Farm A	550	5	13/01/2015	Jan	32	Thin	45381.3
Farm A	550	5	11/02/2015	Feb	29	Thin	213239.5
Farm A	550	5	3/03/2015	Mar	29	Normal	131.4
Farm A	550	5	16/04/2015	Apr	32	Normal	5431.7
Farm A	570	4	3/08/2014	Aug	32.5	Normal	3854.8
Farm A	570	4	2/09/2014	Sep	34	Normal	438.0
Farm A	570	4	6/10/2014	Oct	33.5	Normal	12177.6
Farm A	570	4	6/11/2014	Nov	35	Normal	262.8
Farm A	570	4	9/12/2014	Dec	36.5	Normal	14718.3
Farm A	570	4	13/01/2015	Jan	31.5	Normal	1489.3
Farm A	570	4	11/02/2015	Feb	30.5	Normal	2102.6
Farm A	570	4	16/04/2015	Apr	36	Normal	438.0
Farm A	587	8	3/08/2014	Aug	30	Normal	131325.4
Farm A	587	8	2/09/2014	Sep	29	Normal	8498.0
Farm A	587	8	6/10/2014	Oct	28	Normal	1839.8
Farm A	587	8	6/11/2014	Nov	29	Normal	43.8
Farm A	587	8	9/12/2014	Dec	27.5	Normal	NA

Farm A	587	8	13/01/2015	Jan	26.5	Normal	43366.3
Farm A	587	8	11/02/2015	Feb	26	Normal	5519.3
Farm A	587	8	3/03/2015	Mar	25.5	Thin	87.6
Farm A	587	8	16/04/2015	Apr	26	Thin	1051.3
Farm A	592	6	3/08/2014	Aug	28	Normal	12440.4
Farm A	592	6	2/09/2014	Sep	30	Normal	4468.0
Farm A	592	6	6/10/2014	Oct	31	Normal	9023.7
Farm A	592	6	6/11/2014	Nov	34	Normal	NA
Farm A	592	6	9/12/2014	Dec	32.5	Normal	3592.0
Farm A	592	6	13/01/2015	Jan	26	Normal	78935.4
Farm A	592	6	11/02/2015	Feb	25.5	Normal	10250.2
Farm A	592	6	3/03/2015	Mar	30.5	Normal	613.3
Farm A	592	6	16/04/2015	Apr	32	Normal	9637.0
Farm A	597	3	3/08/2014	Aug	27	Normal	695963.2
Farm A	597	3	6/11/2014	Nov	31	Normal	87.6
Farm A	597	3	9/12/2014	Dec	32	Thin	14455.4
Farm A	597	3	13/01/2015	Jan	28.5	Thin	1051.3
Farm A	597	3	11/02/2015	Feb	28.5	Thin	3241.5
Farm A	597	3	3/03/2015	Mar	24.5	Normal	481.8
Farm A	597	3	16/04/2015	Apr	29	Normal	350.4
Farm A	615	3	3/08/2014	Aug	33	Thin	9724.6
Farm A	615	3	2/09/2014	Sep	31.5	Thin	1489.3
Farm A	615	3	6/10/2014	Oct	30.5	Thin	175.2
Farm A	615	3	6/11/2014	Nov	32	Thin	1314.1
Farm A	615	3	9/12/2014	Dec	30	Thin	35481.5
Farm A	615	3	13/01/2015	Jan	29	Normal	788.5
Farm A	615	3	11/02/2015	Feb	28.5	Normal	6307.8
Farm A	615	3	3/03/2015	Mar	28	Thin	876.1
Farm A	615	3	16/04/2015	Apr	33.5	Thin	175.2
Farm A	627	7	3/08/2014	Aug	28.5	Normal	3416.7
Farm A	627	7	2/09/2014	Sep	29.5	Normal	525.7
Farm A	627	7	6/10/2014	Oct	32	Normal	1752.2
Farm A	627	7	6/11/2014	Nov	32.5	Normal	963.7
Farm A	627	7	9/12/2014	Dec	34	Normal	162251.2
Farm A	627	7	13/01/2015	Jan	30	Normal	613.3
Farm A	627	7	11/02/2015	Feb	30	Normal	23128.7
Farm A	627	7	3/03/2015	Mar	29.5	Normal	1445.5
Farm A	627	7	16/04/2015	Apr	33	Normal	1752.2
Farm A	640	5	3/08/2014	Aug	34	Thin	438.0
Farm A	640	5	2/09/2014	Sep	29	Thin	87.6
Farm A	640	5	6/10/2014	Oct	34	Thin	2628.3
Farm A	640	5	6/11/2014	Nov	33.5	Thin	788.5
Farm A	640	5	9/12/2014	Dec	33	Thin	3767.2
Farm A	640	5	13/01/2015	Jan	34	Thin	525.7
Farm A	640	5	11/02/2015	Feb	30.5	Thin	258620.8
Farm A	640	5	3/03/2015	Mar	32	Normal	11389.1

Farm A	644	5	3/08/2014	Aug	30.5	Thin	262.8
Farm A	644	5	2/09/2014	Sep	31	Thin	12878.5
Farm A	644	5	6/10/2014	Oct	29.5	Thin	NA
Farm A	644	5	6/11/2014	Nov	25.5	Thin	2978.7
Farm A	644	5	9/12/2014	Dec	31.5	Normal	NA
Farm A	644	5	13/01/2015	Jan	25.5	Thin	7534.3
Farm A	644	5	11/02/2015	Feb	23	Thin	17346.5
Farm A	645	5	3/08/2014	Aug	27	Thin	24311.4
Farm A	645	5	2/09/2014	Sep	30	Thin	438.0
Farm A	645	5	6/10/2014	Oct	34.5	Thin	350.4
Farm A	645	5	6/11/2014	Nov	35	Thin	10337.8
Farm A	645	5	9/12/2014	Dec	34.5	Thin	18660.6
Farm A	645	5	13/01/2015	Jan	34	Thin	1138.9
Farm A	645	5	16/04/2015	Apr	37	Thin	8936.1
Farm A	652	3	3/08/2014	Aug	28	Thin	68159.5
Farm A	652	3	2/09/2014	Sep	28	Thin	262.8
Farm A	652	3	6/10/2014	Oct	30	Thin	1927.4
Farm A	652	3	6/11/2014	Nov	30	Normal	NA
Farm A	652	3	9/12/2014	Dec	29.5	Normal	175.2
Farm A	652	3	13/01/2015	Jan	25	Normal	613.3
Farm A	652	3	11/02/2015	Feb	24	Normal	2365.4
Farm A	652	3	3/03/2015	Mar	27	Thin	350.4
Farm A	652	3	16/04/2015	Apr	28	Thin	1839.8
Farm A	653	5	3/08/2014	Aug	31	Normal	130624.5
Farm A	653	5	2/09/2014	Sep	31	Normal	4030.0
Farm A	653	5	6/10/2014	Oct	33.5	Normal	2628.3
Farm A	653	5	6/11/2014	Nov	31	Thin	16733.3
Farm A	653	5	9/12/2014	Dec	32.5	Thin	28472.8
Farm A	653	5	13/01/2015	Jan	29	Thin	2281504.6
Farm A	653	5	11/02/2015	Feb	29	Thin	22515.4
Farm A	653	5	3/03/2015	Mar	28.5	Normal	438.0
Farm A	653	5	16/04/2015	Apr	32.5	Normal	17434.1
Farm A	654	3	3/08/2014	Aug	30	Thin	197031.9
Farm A	654	3	2/09/2014	Sep	31	Thin	4030.0
Farm A	654	3	6/10/2014	Oct	34	Thin	87.6
Farm A	654	3	6/11/2014	Nov	33	Thin	NA
Farm A	654	3	9/12/2014	Dec	32.5	Thin	6220.2
Farm A	654	3	13/01/2015	Jan	32	Thin	8717.1
Farm A	654	3	11/02/2015	Feb	30	Thin	2453.0
Farm A	654	3	3/03/2015	Mar	34	Thin	2015.0
Farm A	660	5	3/08/2014	Aug	28	Thin	94442.1
Farm A	660	5	2/09/2014	Sep	29	Thin	6307.8
Farm A	660	5	6/10/2014	Oct	33	Thin	1752.2
Farm A	660	5	6/11/2014	Nov	30	Thin	80775.2
Farm A	660	5	9/12/2014	Dec	31	Thin	27071.1
Farm A	660	5	13/01/2015	Jan	29	Normal	97946.5

Farm A	666	4	3/08/2014	Aug	27	Thin	1401.7
Farm A	666	4	2/09/2014	Sep	29	Thin	438.0
Farm A	666	4	6/10/2014	Oct	31.5	Thin	7972.4
Farm A	666	4	6/11/2014	Nov	31.5	Thin	62289.8
Farm A	666	4	9/12/2014	Dec	29.5	Thin	525.7
Farm A	666	4	13/01/2015	Jan	28.5	Thin	1927.4
Farm A	666	4	11/02/2015	Feb	28.5	Thin	109335.6
Farm A	666	4	3/03/2015	Mar	28.5	Thin	1401.7
Farm A	666	4	16/04/2015	Apr	35.5	Thin	700.9
Farm A	674	6	3/08/2014	Aug	30	Thin	72452.4
Farm A	674	6	2/09/2014	Sep	29	Thin	350.4
Farm A	674	6	6/10/2014	Oct	29.5	Thin	26720.6
Farm A	674	6	6/11/2014	Nov	27.5	Thin	262.8
Farm A	674	6	9/12/2014	Dec	29	Thin	13316.5
Farm A	674	6	13/01/2015	Jan	28	Thin	56244.8
Farm A	674	6	11/02/2015	Feb	29	Thin	64567.6
Farm A	674	6	3/03/2015	Mar	28.5	Thin	525.7
Farm A	680	4	3/08/2014	Aug	31.5	Thin	42753.0
Farm A	680	4	2/09/2014	Sep	32	Thin	1664.6
Farm A	680	4	6/10/2014	Oct	36.5	Thin	175.2
Farm A	680	4	6/11/2014	Nov	35	Thin	110386.9
Farm A	680	4	9/12/2014	Dec	32.5	Thin	17959.8
Farm A	680	4	13/01/2015	Jan	30.5	Normal	2453.0
Farm A	680	4	11/02/2015	Feb	30.5	Normal	43191.1
Farm A	680	4	3/03/2015	Mar	29.5	Thin	4468.0
Farm A	680	4	16/04/2015	Apr	24.5	Thin	NA
Farm A	688	7	3/08/2014	Aug	30.5	Thin	141400.4
Farm A	688	7	2/09/2014	Sep	32	Thin	87.6
Farm A	688	7	6/10/2014	Oct	32	Thin	525.7
Farm A	688	7	6/11/2014	Nov	34	Thin	57996.9
Farm A	688	7	9/12/2014	Dec	33.5	Thin	438.0
Farm A	688	7	13/01/2015	Jan	30.5	Normal	525.7
Farm A	688	7	11/02/2015	Feb	30.5	Normal	9286.5
Farm A	688	7	3/03/2015	Mar	29	Normal	262.8
Farm A	688	7	16/04/2015	Apr	38.5	Normal	876.1
Farm A	692	5	3/08/2014	Aug	33	Thin	1203567.7
Farm A	692	5	2/09/2014	Sep	31.5	Thin	438.0
Farm A	692	5	6/10/2014	Oct	34	Thin	18310.2
Farm A	692	5	6/11/2014	Nov	30.5	Thin	1226.5
Farm A	692	5	9/12/2014	Dec	33	Normal	59924.3
Farm A	692	5	13/01/2015	Jan	27	Thin	2022883.9
Farm A	692	5	11/02/2015	Feb	26.5	Thin	49498.9
Farm A	692	5	3/03/2015	Mar	26.5	Normal	131.4
Farm A	692	5	16/04/2015	Apr	36.5	Normal	7972.4
Farm A	694	3	3/08/2014	Aug	28.5	Thin	293489.0
Farm A	694	3	2/09/2014	Sep	28	Thin	9899.8

Farm A	694	3	6/10/2014	Oct	30.5	Thin	175.2
Farm A	694	3	6/11/2014	Nov	31.5	Thin	31714.3
Farm A	694	3	9/12/2014	Dec	32.5	Normal	98822.6
Farm A	694	3	13/01/2015	Jan	30	Normal	87.6
Farm A	694	3	11/02/2015	Feb	28	Normal	10951.1
Farm A	694	3	3/03/2015	Mar	29	Normal	1752.2
Farm A	694	3	16/04/2015	Apr	40	Normal	613.3
Farm A	699	7	3/08/2014	Aug	31	Normal	9987.4
Farm A	699	7	2/09/2014	Sep	33	Normal	NA
Farm A	699	7	6/10/2014	Oct	37	Normal	876.1
Farm A	699	7	6/11/2014	Nov	35	Normal	87.6
Farm A	699	7	9/12/2014	Dec	35.5	Normal	58435.0
Farm A	699	7	13/01/2015	Jan	33	Normal	613.3
Farm A	699	7	16/04/2015	Apr	34	Normal	350.4
Farm A	707	2	3/08/2014	Aug	30	Normal	17346.5
Farm A	707	2	6/11/2014	Nov	35.5	Normal	525.7
Farm A	707	2	9/12/2014	Dec	34.5	Normal	1314.1
Farm A	707	2	13/01/2015	Jan	31	Normal	NA
Farm A	707	2	11/02/2015	Feb	29	Normal	51513.9
Farm A	707	2	3/03/2015	Mar	29	Normal	613.3
Farm A	707	2	16/04/2015	Apr	38	Normal	4818.5
Farm A	718	7	3/08/2014	Aug	30	Thin	52740.4
Farm A	718	7	6/11/2014	Nov	30.5	Thin	87.6
Farm A	718	7	9/12/2014	Dec	34.5	Thin	175.2
Farm A	718	7	13/01/2015	Jan	30	Thin	3592.0
Farm A	720	10	3/08/2014	Aug	31.5	Normal	102765.0
Farm A	720	10	2/09/2014	Sep	32	Normal	525.7
Farm A	720	10	6/10/2014	Oct	31	Normal	700.9
Farm A	720	10	6/11/2014	Nov	27.5	Thin	10951.1
Farm A	720	10	9/12/2014	Dec	31	Thin	87.6
Farm A	720	10	13/01/2015	Jan	31	Thin	30312.6
Farm A	720	10	11/02/2015	Feb	30.5	Thin	2540.7
Farm A	720	10	3/03/2015	Mar	26.5	Normal	10031.2
Farm A	720	10	16/04/2015	Apr	36.5	Normal	24530.4
Farm A	725	6	3/08/2014	Aug	25	Thin	4730.9
Farm A	725	6	2/09/2014	Sep	32.5	Thin	376016.4
Farm A	725	6	6/10/2014	Oct	31.5	Thin	350.4
Farm A	725	6	6/11/2014	Nov	33	Thin	21026.1
Farm A	725	6	9/12/2014	Dec	28.5	Thin	262.8
Farm A	725	6	13/01/2015	Jan	31.5	Thin	8585.6
Farm A	725	6	11/02/2015	Feb	29	Thin	2015.0
Farm A	725	6	3/03/2015	Mar	29	Thin	11213.9
Farm A	725	6	16/04/2015	Apr	36.5	Thin	175.2
Farm A	726	6	3/08/2014	Aug	31	Normal	686151.0
Farm A	726	6	2/09/2014	Sep	34	Normal	NA
Farm A	726	6	6/10/2014	Oct	36.5	Normal	87.6

Farm A	726	6	6/11/2014	Nov	35.5	Normal	NA
Farm A	726	6	9/12/2014	Dec	36	Normal	6745.9
Farm A	726	6	13/01/2015	Jan	30.5	Normal	67984.3
Farm A	726	6	11/02/2015	Feb	32	Normal	26195.0
Farm A	726	6	3/03/2015	Mar	32	Normal	8060.0
Farm A	726	6	16/04/2015	Apr	41.5	Normal	6395.4
Farm A	729	6	3/08/2014	Aug	32.5	Thin	22077.4
Farm A	729	6	2/09/2014	Sep	29	Thin	7534.3
Farm A	729	6	6/10/2014	Oct	30	Thin	5694.6
Farm A	729	6	6/11/2014	Nov	28	Thin	320910.5
Farm A	729	6	9/12/2014	Dec	31	Thin	1226.5
Farm A	729	6	13/01/2015	Jan	28	Thin	10688.3
Farm A	729	6	11/02/2015	Feb	26	Thin	3329.1
Farm A	729	6	3/03/2015	Mar	26	Normal	1226.5
Farm A	729	6	16/04/2015	Apr	30	Normal	4730.9
Farm A	742	4	3/08/2014	Aug	27	Thin	37058.5
Farm A	742	4	2/09/2014	Sep	32	Thin	NA
Farm A	742	4	6/10/2014	Oct	34	Thin	NA
Farm A	742	4	6/11/2014	Nov	34	Thin	1138.9
Farm A	742	4	9/12/2014	Dec	32	Thin	4468.0
Farm A	742	4	13/01/2015	Jan	28	Thin	NA
Farm A	742	4	11/02/2015	Feb	30.5	Thin	1051.3
Farm A	742	4	3/03/2015	Mar	29.5	Thin	175.2
Farm A	742	4	16/04/2015	Apr	36	Thin	87.6
Farm A	751	2	3/08/2014	Aug	18	Thin	1119638.6
Farm A	751	2	2/09/2014	Sep	27	Thin	87.6
Farm A	751	2	6/10/2014	Oct	27.5	Thin	NA
Farm A	751	2	6/11/2014	Nov	30	Thin	19186.3
Farm A	751	2	9/12/2014	Dec	28.5	Thin	10863.5
Farm A	751	2	13/01/2015	Jan	29	Thin	28560.4
Farm A	751	2	11/02/2015	Feb	26	Thin	89448.4
Farm A	751	2	3/03/2015	Mar	23.5	Thin	137633.2
Farm A	751	2	16/04/2015	Apr	31	Thin	2453.0
Farm A	757	6	3/08/2014	Aug	32.5	Thin	2277.8
Farm A	757	6	2/09/2014	Sep	33	Thin	2277.8
Farm A	757	6	6/10/2014	Oct	34.5	Thin	175.2
Farm A	757	6	6/11/2014	Nov	34	Thin	NA
Farm A	757	6	9/12/2014	Dec	32	Thin	NA
Farm A	757	6	13/01/2015	Jan	30.5	Normal	87.6
Farm A	757	6	11/02/2015	Feb	29	Normal	1664.6
Farm A	757	6	3/03/2015	Mar	29	Normal	1708.4
Farm A	757	6	16/04/2015	Apr	40.5	Normal	2190.2
Farm A	769	6	3/08/2014	Aug	28.5	Thin	178458.8
Farm A	769	6	2/09/2014	Sep	30	Thin	9111.3
Farm A	769	6	6/10/2014	Oct	29.5	Thin	11827.2
Farm A	769	6	6/11/2014	Nov	30	Thin	NA

Farm A	769	6	9/12/2014	Dec	34	Normal	258796.0
Farm A	769	6	13/01/2015	Jan	30	Normal	142276.5
Farm A	769	6	11/02/2015	Feb	30.5	Normal	10513.0
Farm A	769	6	3/03/2015	Mar	31.5	Normal	5300.3
Farm A	769	6	16/04/2015	Apr	35	Normal	7359.1
Farm A	770	5	3/08/2014	Aug	30	Thin	18047.4
Farm A	770	5	2/09/2014	Sep	32.5	Thin	525.7
Farm A	770	5	6/10/2014	Oct	33.5	Thin	87.6
Farm A	770	5	6/11/2014	Nov	32	Thin	87.6
Farm A	770	5	9/12/2014	Dec	29.5	Thin	23654.3
Farm A	770	5	13/01/2015	Jan	30.5	Thin	38723.0
Farm A	770	5	11/02/2015	Feb	28	Thin	46870.6
Farm A	770	5	3/03/2015	Mar	29.5	Thin	2190.2
Farm A	770	5	16/04/2015	Apr	30	Thin	12790.9
Farm A	799	4	3/08/2014	Aug	29.5	Thin	646464.3
Farm A	799	4	2/09/2014	Sep	29.5	Thin	23303.9
Farm A	799	4	6/10/2014	Oct	29.5	Thin	175.2
Farm A	799	4	6/11/2014	Nov	28	Thin	30137.4
Farm A	799	4	9/12/2014	Dec	28.5	Thin	8760.9
Farm A	799	4	13/01/2015	Jan	23.5	Normal	525.7
Farm A	799	4	11/02/2015	Feb	23	Normal	5168.9
Farm A	799	4	3/03/2015	Mar	26	Thin	7183.9
Farm A	799	4	16/04/2015	Apr	29.5	Thin	1927.4
Farm A	802	2	3/08/2014	Aug	33.5	Thin	2453.0
Farm A	802	2	2/09/2014	Sep	26	Thin	4030.0
Farm A	802	2	6/10/2014	Oct	31.5	Thin	20500.4
Farm A	802	2	6/11/2014	Nov	32.5	Normal	87.6
Farm A	802	2	9/12/2014	Dec	31.5	Normal	NA
Farm A	802	2	13/01/2015	Jan	28	Thin	1401.7
Farm A	802	2	11/02/2015	Feb	28.5	Thin	147007.3
Farm A	802	2	3/03/2015	Mar	28	Thin	12265.2
Farm A	802	2	16/04/2015	Apr	31.5	Thin	87.6
Farm A	806	4	3/08/2014	Aug	27.5	Thin	909290.2
Farm A	806	4	2/09/2014	Sep	28	Thin	NA
Farm A	806	4	6/10/2014	Oct	30	Thin	19974.8
Farm A	806	4	6/11/2014	Nov	26	Thin	3241.5
Farm A	806	4	9/12/2014	Dec	30	Thin	876.1
Farm A	806	4	13/01/2015	Jan	26	Normal	2365.4
Farm A	806	4	11/02/2015	Feb	24.5	Normal	8147.6
Farm A	806	4	3/03/2015	Mar	35	Normal	43.8
Farm A	806	4	16/04/2015	Apr	14.5	Normal	NA
Farm A	808	2	3/08/2014	Aug	32.5	Normal	7183.9
Farm A	808	2	2/09/2014	Sep	35	Normal	2891.1
Farm A	808	2	6/10/2014	Oct	29.5	Normal	NA
Farm A	808	2	6/11/2014	Nov	32	Normal	NA
Farm A	808	2	9/12/2014	Dec	34	Normal	83403.4

Farm A	808	2	13/01/2015	Jan	31	Normal	235492.1
Farm A	808	2	11/02/2015	Feb	25.5	Normal	256255.3
Farm A	808	2	3/03/2015	Mar	25	Normal	14543.0
Farm A	808	2	16/04/2015	Apr	33	Normal	1577.0
Farm A	811	3	3/08/2014	Aug	26	Normal	27859.6
Farm A	811	3	2/09/2014	Sep	32	Normal	5607.0
Farm A	811	3	6/10/2014	Oct	34	Normal	13491.7
Farm A	811	3	6/11/2014	Nov	35.5	Normal	NA
Farm A	811	3	9/12/2014	Dec	33	Normal	NA
Farm A	811	3	13/01/2015	Jan	30.5	Normal	87.6
Farm A	811	3	11/02/2015	Feb	29.5	Normal	17083.7
Farm A	811	3	3/03/2015	Mar	30	Normal	3548.2
Farm A	811	3	16/04/2015	Apr	30	Normal	262.8
Farm A	826	5	3/08/2014	Aug	27	Normal	220160.6
Farm A	826	5	2/09/2014	Sep	29	Normal	4993.7
Farm A	826	5	6/10/2014	Oct	32	Normal	12177.6
Farm A	826	5	6/11/2014	Nov	30	Thin	5782.2
Farm A	826	5	9/12/2014	Dec	29.5	Thin	5168.9
Farm A	826	5	13/01/2015	Jan	29	Normal	700.9
Farm A	826	5	11/02/2015	Feb	29.5	Normal	5344.1
Farm A	826	5	3/03/2015	Mar	30.5	Normal	1489.3
Farm A	826	5	16/04/2015	Apr	27	Normal	1051.3
Farm A	830	2	3/08/2014	Aug	30	Thin	37759.3
Farm A	830	2	2/09/2014	Sep	30	Thin	2803.5
Farm A	830	2	6/10/2014	Oct	30	Thin	10337.8
Farm A	830	2	6/11/2014	Nov	31.5	Thin	71401.1
Farm A	830	2	9/12/2014	Dec	28.5	Thin	5344.1
Farm A	830	2	13/01/2015	Jan	28	Thin	262.8
Farm A	830	2	11/02/2015	Feb	28.5	Thin	4205.2
Farm A	830	2	3/03/2015	Mar	26.5	Thin	3241.5
Farm A	830	2	16/04/2015	Apr	32	Thin	11038.7
Farm A	833	2	3/08/2014	Aug	30	Thin	59048.2
Farm A	833	2	2/09/2014	Sep	33	Thin	1577.0
Farm A	833	2	6/10/2014	Oct	34.5	Thin	700.9
Farm A	833	2	6/11/2014	Nov	26	Thin	525.7
Farm A	833	2	9/12/2014	Dec	31	Thin	6570.6
Farm A	833	2	13/01/2015	Jan	31.5	Thin	175.2
Farm A	833	2	11/02/2015	Feb	29.5	Thin	22690.6
Farm A	833	2	3/03/2015	Mar	26	Thin	2891.1
Farm A	833	2	16/04/2015	Apr	30	Thin	525.7

Table 11. HCT and organisms/ μ L, by cow and month, for Farm B, **Chapter 9.**

Farm	cowno	age	sampledate	month	HCT	Herd	organisms/ μ L
Farm B	1	3	11/08/2014	Aug	30.5	young	0.0
Farm B	1	3	9/09/2014	Sep	29.5	young	87.6
Farm B	1	3	9/10/2014	Oct	28.5	young	0.0
Farm B	1	3	10/11/2014	Nov	28	young	87.6
Farm B	1	3	10/12/2014	Dec	31	young	0.0
Farm B	1	3	8/01/2015	Jan	30.5	young	0.0
Farm B	1	3	8/02/2015	Feb	31	young	0.0
Farm B	1	3	9/03/2015	Mar	25	young	0.0
Farm B	1	3	9/04/2015	Apr	25	young	0.0
Farm B	1	3	19/05/2015	May	28	young	0.0
Farm B	4	3	11/08/2014	Aug	33.5	young	175.2
Farm B	4	3	9/09/2014	Sep	30.5	young	175.2
Farm B	4	3	9/10/2014	Oct	30.5	young	0.0
Farm B	4	3	10/11/2014	Nov	29.5	young	0.0
Farm B	4	3	10/12/2014	Dec	33	young	0.0
Farm B	4	3	8/01/2015	Jan	31	young	0.0
Farm B	4	3	8/02/2015	Feb	30.5	young	0.0
Farm B	4	3	9/03/2015	Mar	23.5	old	NA
Farm B	4	3	9/04/2015	Apr	29	young	3022.5
Farm B	4	3	19/05/2015	May	32	young	0.0
Farm B	7	3	11/08/2014	Aug	27	young	8936.1
Farm B	7	3	9/09/2014	Sep	30	young	4906.1
Farm B	7	3	9/10/2014	Oct	30	young	4468.0
Farm B	7	3	10/11/2014	Nov	31	young	5168.9
Farm B	7	3	10/12/2014	Dec	31.5	young	37671.7
Farm B	7	3	8/01/2015	Jan	33.5	young	700.9
Farm B	7	3	8/02/2015	Feb	31.5	young	14017.4
Farm B	7	3	9/03/2015	Mar	29	young	53791.7
Farm B	7	3	9/04/2015	Apr	29.5	young	16733.3
Farm B	7	3	19/05/2015	May	31.5	young	4993.7
Farm B	11	7	11/08/2014	Aug	30	old	48973.2
Farm B	11	7	9/10/2014	Oct	30	old	21201.3
Farm B	11	7	10/11/2014	Nov	27	old	4642.8
Farm B	11	7	10/12/2014	Dec	31.5	old	69824.1
Farm B	11	7	8/01/2015	Jan	30	old	87.6
Farm B	11	7	8/02/2015	Feb	32	old	7534.3
Farm B	11	7	9/03/2015	Mar	32	old	31626.7
Farm B	11	7	9/04/2015	Apr	29.5	old	NA
Farm B	11	7	19/05/2015	May	32.5	old	6483.0
Farm B	13	9	11/08/2014	Aug	29.5	old	3679.6
Farm B	13	9	9/09/2014	Sep	29	old	16382.8
Farm B	13	9	9/10/2014	Oct	29.5	old	14630.6
Farm B	13	9	10/11/2014	Nov	32.5	old	38460.2

Farm B	13	9	10/12/2014	Dec	31.5	old	3241.5
Farm B	13	9	8/01/2015	Jan	32	old	5081.3
Farm B	13	9	8/02/2015	Feb	32.5	old	75693.9
Farm B	13	9	9/03/2015	Mar	28.5	old	70700.2
Farm B	13	9	9/04/2015	Apr	27.5	old	55894.3
Farm B	13	9	19/05/2015	May	32	old	46607.8
Farm B	15	3	11/08/2014	Aug	36	young	0.0
Farm B	15	3	9/09/2014	Sep	34	young	175.2
Farm B	15	3	9/10/2014	Oct	29	young	NA
Farm B	15	3	10/11/2014	Nov	30.5	young	0.0
Farm B	15	3	10/12/2014	Dec	31	young	0.0
Farm B	15	3	8/01/2015	Jan	34	young	0.0
Farm B	15	3	8/02/2015	Feb	33	young	0.0
Farm B	15	3	9/03/2015	Mar	29	young	4205.2
Farm B	15	3	9/04/2015	Apr	26.5	young	0.0
Farm B	15	3	19/05/2015	May	30.5	young	NA
Farm B	16	3	11/08/2014	Aug	34	young	0.0
Farm B	16	3	9/09/2014	Sep	32	young	0.0
Farm B	16	3	9/10/2014	Oct	30	young	0.0
Farm B	16	3	10/11/2014	Nov	30.5	young	0.0
Farm B	16	3	10/12/2014	Dec	32.5	young	0.0
Farm B	16	3	8/01/2015	Jan	35	young	0.0
Farm B	16	3	8/02/2015	Feb	30	young	0.0
Farm B	16	3	9/03/2015	Mar	24	young	87.6
Farm B	16	3	9/04/2015	Apr	26	young	0.0
Farm B	16	3	19/05/2015	May	31.5	young	0.0
Farm B	25	3	11/08/2014	Aug	31	young	78146.9
Farm B	25	3	9/09/2014	Sep	31	young	4117.2
Farm B	25	3	9/10/2014	Oct	30.5	young	73503.7
Farm B	25	3	10/11/2014	Nov	29	young	350.4
Farm B	25	3	10/12/2014	Dec	31	young	262.8
Farm B	25	3	8/01/2015	Jan	31	young	788.5
Farm B	25	3	8/02/2015	Feb	36	young	67371.1
Farm B	25	3	9/03/2015	Mar	32.5	young	1752.2
Farm B	25	3	9/04/2015	Apr	30	young	21902.2
Farm B	25	3	19/05/2015	May	30.5	young	30487.8
Farm B	26	4	11/08/2014	Aug	34	old	0.0
Farm B	26	4	9/09/2014	Sep	32.5	old	0.0
Farm B	26	4	9/10/2014	Oct	30	old	87.6
Farm B	26	4	10/11/2014	Nov	31.5	old	0.0
Farm B	26	4	10/12/2014	Dec	32	old	963.7
Farm B	26	4	8/01/2015	Jan	34.5	old	NA
Farm B	26	4	8/02/2015	Feb	35	old	0.0
Farm B	26	4	9/03/2015	Mar	33	old	0.0
Farm B	26	4	9/04/2015	Apr	30	old	0.0
Farm B	26	4	19/05/2015	May	33.5	old	0.0

Farm B	27	3	11/08/2014	Aug	32.5	young	87.6
Farm B	27	3	9/09/2014	Sep	29.5	young	0.0
Farm B	27	3	9/10/2014	Oct	30	young	0.0
Farm B	27	3	10/11/2014	Nov	29	young	87.6
Farm B	27	3	10/12/2014	Dec	30.5	young	87.6
Farm B	27	3	8/01/2015	Jan	33	young	0.0
Farm B	27	3	8/02/2015	Feb	30.5	young	0.0
Farm B	27	3	9/03/2015	Mar	26	young	0.0
Farm B	27	3	9/04/2015	Apr	27.5	young	0.0
Farm B	27	3	19/05/2015	May	29.5	young	87.6
Farm B	33	4	11/08/2014	Aug	30	old	0.0
Farm B	33	4	9/09/2014	Sep	28	old	0.0
Farm B	33	4	9/10/2014	Oct	26	old	0.0
Farm B	33	4	10/11/2014	Nov	26.5	old	0.0
Farm B	33	4	10/12/2014	Dec	29	old	87.6
Farm B	33	4	8/01/2015	Jan	29	old	0.0
Farm B	33	4	8/02/2015	Feb	31.5	old	0.0
Farm B	33	4	9/03/2015	Mar	28	old	0.0
Farm B	33	4	9/04/2015	Apr	25	young	0.0
Farm B	33	4	19/05/2015	May	37.5	old	NA
Farm B	43	4	11/08/2014	Aug	32	old	2715.9
Farm B	43	4	9/09/2014	Sep	31	old	921555.5
Farm B	43	4	9/10/2014	Oct	31.5	old	5869.8
Farm B	43	4	10/11/2014	Nov	30.5	old	525.7
Farm B	43	4	10/12/2014	Dec	32	old	613.2
Farm B	43	4	8/01/2015	Jan	32	old	1226.5
Farm B	43	4	8/02/2015	Feb	34	old	20150.0
Farm B	43	4	9/03/2015	Mar	31	old	14105.0
Farm B	43	4	9/04/2015	Apr	30	old	963.7
Farm B	43	4	19/05/2015	May	30.5	old	20938.5
Farm B	45	6	11/08/2014	Aug	28	old	180911.9
Farm B	45	6	9/09/2014	Sep	29	old	9549.3
Farm B	45	6	9/10/2014	Oct	30.5	old	10075.0
Farm B	45	6	10/11/2014	Nov	29	old	1664.6
Farm B	45	6	10/12/2014	Dec	33	old	27071.1
Farm B	45	6	8/01/2015	Jan	32	old	53353.7
Farm B	45	6	8/02/2015	Feb	32	old	53266.1
Farm B	45	6	9/03/2015	Mar	28	old	22778.3
Farm B	45	6	9/04/2015	Apr	29.5	old	24092.4
Farm B	45	6	19/05/2015	May	31.5	old	2891.1
Farm B	53	6	11/08/2014	Aug	27.5	old	186694.0
Farm B	53	6	9/09/2014	Sep	29.5	old	6658.3
Farm B	53	6	10/11/2014	Nov	30.5	old	167770.6
Farm B	53	6	10/12/2014	Dec	32.5	old	9987.4
Farm B	53	6	8/01/2015	Jan	29	old	3592.0
Farm B	53	6	8/02/2015	Feb	30.5	old	53266.1

Farm B	53	6	9/03/2015	Mar	29	old	21376.5
Farm B	53	6	9/04/2015	Apr	28	old	6132.6
Farm B	53	6	19/05/2015	May	29	old	13053.7
Farm B	63	8	11/08/2014	Aug	32	young	3416.7
Farm B	63	8	9/09/2014	Sep	27.5	young	20412.8
Farm B	63	8	9/10/2014	Oct	25.5	young	262.8
Farm B	63	8	10/11/2014	Nov	25	young	262.8
Farm B	63	8	10/12/2014	Dec	30	young	3854.8
Farm B	63	8	8/01/2015	Jan	29	young	60888.0
Farm B	63	8	8/02/2015	Feb	26	young	16645.6
Farm B	63	8	9/03/2015	Mar	25.5	young	4468.0
Farm B	63	8	9/04/2015	Apr	26	young	3592.0
Farm B	63	8	19/05/2015	May	26.5	young	6220.2
Farm B	64	11	11/08/2014	Aug	25	old	613.3
Farm B	64	11	9/09/2014	Sep	23.5	old	13667.0
Farm B	64	11	9/10/2014	Oct	22	old	525.7
Farm B	64	11	10/11/2014	Nov	22.5	old	1752.2
Farm B	64	11	10/12/2014	Dec	25	old	350.4
Farm B	64	11	8/01/2015	Jan	24	old	1226.5
Farm B	64	11	8/02/2015	Feb	24	old	12878.5
Farm B	64	11	9/03/2015	Mar	23	old	5081.3
Farm B	64	11	9/04/2015	Apr	26	old	4643.3
Farm B	74	4	11/08/2014	Aug	30	old	87.6
Farm B	74	4	9/09/2014	Sep	28	old	0.0
Farm B	74	4	9/10/2014	Oct	31	old	0.0
Farm B	74	4	10/11/2014	Nov	31	old	0.0
Farm B	74	4	10/12/2014	Dec	32.5	old	175.2
Farm B	74	4	8/01/2015	Jan	30.5	old	0.0
Farm B	74	4	8/02/2015	Feb	32.5	old	0.0
Farm B	74	4	9/03/2015	Mar	28	old	NA
Farm B	74	4	9/04/2015	Apr	27	old	0.0
Farm B	74	4	19/05/2015	May	29.5	old	0.0
Farm B	79	6	11/08/2014	Aug	32	old	0.0
Farm B	79	6	9/09/2014	Sep	32	old	4380.4
Farm B	79	6	9/10/2014	Oct	31	old	87.6
Farm B	79	6	10/11/2014	Nov	34	old	7622.0
Farm B	79	6	10/12/2014	Dec	35	old	27246.3
Farm B	79	6	8/01/2015	Jan	33	old	438.0
Farm B	79	6	8/02/2015	Feb	34.5	old	21639.3
Farm B	79	6	9/03/2015	Mar	30.5	old	13228.9
Farm B	79	6	9/04/2015	Apr	29.5	old	1577.0
Farm B	79	6	19/05/2015	May	31	old	438.0
Farm B	82	6	10/11/2014	Nov	31	old	19711.9
Farm B	82	6	10/12/2014	Dec	34	old	700.9
Farm B	82	6	8/01/2015	Jan	31	old	4818.5
Farm B	82	6	8/02/2015	Feb	32	old	1839.8

Farm B	82	6	9/03/2015	Mar	29	old	27158.7
Farm B	82	6	9/04/2015	Apr	27	old	8147.6
Farm B	82	6	19/05/2015	May	30.5	old	26545.4
Farm B	90	3	11/08/2014	Aug	35	young	87.6
Farm B	90	3	9/09/2014	Sep	32	young	0.0
Farm B	90	3	9/10/2014	Oct	29	young	NA
Farm B	90	3	10/11/2014	Nov	27	young	0.0
Farm B	90	3	10/12/2014	Dec	31	young	NA
Farm B	90	3	8/01/2015	Jan	32	young	0.0
Farm B	90	3	8/02/2015	Feb	30.5	young	0.0
Farm B	90	3	9/03/2015	Mar	26	young	0.0
Farm B	90	3	9/04/2015	Apr	25	young	0.0
Farm B	90	3	19/05/2015	May	28	young	0.0
Farm B	91	8	11/08/2014	Aug	24	old	5957.4
Farm B	91	8	9/09/2014	Sep	24	old	8089860.0
Farm B	91	8	9/10/2014	Oct	25.5	old	963.7
Farm B	91	8	10/11/2014	Nov	24	old	20150.0
Farm B	91	8	10/12/2014	Dec	26.5	old	0.0
Farm B	91	8	8/01/2015	Jan	26	old	525.7
Farm B	91	8	8/02/2015	Feb	31	old	2891.1
Farm B	91	8	9/03/2015	Mar	26	old	24180.0
Farm B	91	8	9/04/2015	Apr	26	old	5431.7
Farm B	91	8	19/05/2015	May	26.5	old	1489.3
Farm B	100	4	11/08/2014	Aug	29	old	243201.6
Farm B	100	4	9/09/2014	Sep	30.5	old	1051.3
Farm B	100	4	9/10/2014	Oct	30	old	2453.0
Farm B	100	4	10/11/2014	Nov	30	old	24004.8
Farm B	100	4	10/12/2014	Dec	32.5	old	262.8
Farm B	100	4	8/01/2015	Jan	30.5	old	3329.1
Farm B	100	4	8/02/2015	Feb	31	old	43716.7
Farm B	100	4	9/03/2015	Mar	30	old	43366.3
Farm B	100	4	9/04/2015	Apr	31.5	old	5869.8
Farm B	100	4	19/05/2015	May	31	old	2715.9
Farm B	108		8/02/2015	Feb	31	old	1051.3
Farm B	116	6	11/08/2014	Aug	29.5	old	262.8
Farm B	116	6	9/09/2014	Sep	28	old	68328.0
Farm B	116	6	9/10/2014	Oct	31.5	old	2102.6
Farm B	116	6	10/11/2014	Nov	32	old	9637.0
Farm B	116	6	10/12/2014	Dec	34	old	18222.6
Farm B	116	6	8/01/2015	Jan	32	old	87.6
Farm B	116	6	8/02/2015	Feb	33	old	23654.3
Farm B	116	6	9/03/2015	Mar	33	old	10863.5
Farm B	116	6	9/04/2015	Apr	32.5	old	38547.8
Farm B	116	6	19/05/2015	May	34	old	13491.7
Farm B	118	4	11/08/2014	Aug	29.5	old	1664.6
Farm B	118	4	9/09/2014	Sep	29	old	9461.7

Farm B	118	4	9/10/2014	Oct	30	old	1314.1
Farm B	118	4	10/11/2014	Nov	30	old	700.9
Farm B	118	4	10/12/2014	Dec	30.5	old	75343.4
Farm B	118	4	8/01/2015	Jan	30	old	140173.8
Farm B	118	4	8/02/2015	Feb	30.5	old	9111.3
Farm B	118	4	9/03/2015	Mar	29	old	4205.2
Farm B	118	4	9/04/2015	Apr	27	old	156819.5
Farm B	118	4	19/05/2015	May	28.5	old	35744.3
Farm B	123	4	11/08/2014	Aug	27	old	18047.4
Farm B	123	4	9/09/2014	Sep	29.5	old	9724.6
Farm B	123	4	9/10/2014	Oct	30.5	old	1051.3
Farm B	123	4	10/11/2014	Nov	30	old	18748.3
Farm B	123	4	10/12/2014	Dec	32.5	old	17434.1
Farm B	123	4	8/01/2015	Jan	30	old	23391.5
Farm B	123	4	8/02/2015	Feb	30.5	old	21814.6
Farm B	123	4	9/03/2015	Mar	30	old	64480.0
Farm B	123	4	9/04/2015	Apr	30	old	37934.5
Farm B	123	4	19/05/2015	May	33	old	33466.5
Farm B	130	4	11/08/2014	Aug	31	old	262.8
Farm B	130	4	9/09/2014	Sep	22.5	old	1005835.0
Farm B	130	4	10/11/2014	Nov	31	old	72189.5
Farm B	130	4	10/12/2014	Dec	33	old	0.0
Farm B	130	4	8/01/2015	Jan	30	old	181262.3
Farm B	130	4	8/02/2015	Feb	33	old	NA
Farm B	130	4	9/03/2015	Mar	29	old	9374.1
Farm B	130	4	9/04/2015	Apr	29.5	old	262.8
Farm B	130	4	19/05/2015	May	31	old	15681.9
Farm B	141	3	11/08/2014	Aug	33	young	0.0
Farm B	141	3	9/09/2014	Sep	31	young	0.0
Farm B	141	3	9/10/2014	Oct	29.5	young	0.0
Farm B	141	3	10/11/2014	Nov	29	young	0.0
Farm B	141	3	10/12/2014	Dec	31	young	NA
Farm B	141	3	8/01/2015	Jan	32	young	0.0
Farm B	141	3	8/02/2015	Feb	30	young	NA
Farm B	141	3	9/03/2015	Mar	25	young	175.2
Farm B	141	3	9/04/2015	Apr	25	young	NA
Farm B	141	3	19/05/2015	May	28	young	0.0
Farm B	144	3	11/08/2014	Aug	31	young	0.0
Farm B	144	3	9/09/2014	Sep	29	young	87.6
Farm B	144	3	9/10/2014	Oct	29.5	young	0.0
Farm B	144	3	10/11/2014	Nov	29	young	87.6
Farm B	144	3	10/12/2014	Dec	30	young	0.0
Farm B	144	3	8/01/2015	Jan	32	young	0.0
Farm B	144	3	8/02/2015	Feb	30.5	young	0.0
Farm B	144	3	9/03/2015	Mar	26	young	NA
Farm B	144	3	9/04/2015	Apr	25.5	young	0.0

Farm B	144	3	19/05/2015	May	27	young	0.0
Farm B	145	4	11/08/2014	Aug	36	old	87.6
Farm B	145	4	9/09/2014	Sep	33	old	175.2
Farm B	145	4	9/10/2014	Oct	23.5	old	2849296.3
Farm B	145	4	10/11/2014	Nov	28	old	358845.1
Farm B	145	4	10/12/2014	Dec	35	old	1138.9
Farm B	145	4	8/01/2015	Jan	34.5	old	57296.1
Farm B	145	4	8/02/2015	Feb	36.5	old	2277.8
Farm B	145	4	9/03/2015	Mar	33	old	30838.2
Farm B	145	4	9/04/2015	Apr	26.5	old	87.6
Farm B	145	4	19/05/2015	May	31	old	11564.3
Farm B	146	7	11/08/2014	Aug	29	old	456353.5
Farm B	146	7	9/09/2014	Sep	28	old	4030.0
Farm B	146	7	9/10/2014	Oct	29	old	33988.8
Farm B	146	7	10/11/2014	Nov	27	old	24442.8
Farm B	146	7	10/12/2014	Dec	29	old	525.7
Farm B	146	7	8/01/2015	Jan	29	old	1839.8
Farm B	146	7	8/02/2015	Feb	30.5	old	8673.3
Farm B	146	7	9/03/2015	Mar	27	old	44154.8
Farm B	146	7	9/04/2015	Apr	29	old	4818.5
Farm B	146	7	19/05/2015	May	29.5	old	110386.9
Farm B	147	3	11/08/2014	Aug	38	young	175.2
Farm B	147	3	9/09/2014	Sep	33	young	0.0
Farm B	147	3	9/10/2014	Oct	33	young	0.0
Farm B	147	3	10/11/2014	Nov	27	young	87.6
Farm B	147	3	10/12/2014	Dec	26.5	young	0.0
Farm B	147	3	8/01/2015	Jan	28	young	0.0
Farm B	147	3	8/02/2015	Feb	30	young	0.0
Farm B	147	3	9/03/2015	Mar	29	young	1226.5
Farm B	147	3	9/04/2015	Apr	28.5	young	0.0
Farm B	147	3	19/05/2015	May	29.5	young	0.0
Farm B	148	6	11/08/2014	Aug	19	old	88660.0
Farm B	148	6	9/09/2014	Sep	25.5	old	72277.1
Farm B	148	6	9/10/2014	Oct	30	old	38547.8
Farm B	148	6	10/11/2014	Nov	32	old	62815.4
Farm B	148	6	10/12/2014	Dec	34.5	old	256518.1
Farm B	148	6	8/01/2015	Jan	32	old	525.6
Farm B	148	6	8/02/2015	Feb	30	old	409570.5
Farm B	148	6	9/03/2015	Mar	29	old	64742.8
Farm B	148	6	9/04/2015	Apr	28	old	788.5
Farm B	148	6	19/05/2015	May	32.5	old	525.7
Farm B	154	8	11/08/2014	Aug	30	old	805386.4
Farm B	154	8	9/09/2014	Sep	29	old	613.3
Farm B	154	8	9/10/2014	Oct	30	old	120724.7
Farm B	154	8	10/11/2014	Nov	32	old	3942.4
Farm B	154	8	10/12/2014	Dec	30.5	old	10688.3

Farm B	154	8	8/01/2015	Jan	30.5	old	613.2
Farm B	154	8	8/02/2015	Feb	32	old	168121.0
Farm B	154	8	9/03/2015	Mar	30.5	old	0.0
Farm B	154	8	9/04/2015	Apr	29.5	old	10513.0
Farm B	165	4	11/08/2014	Aug	29	old	142188.8
Farm B	165	4	9/09/2014	Sep	28	old	156381.5
Farm B	165	4	9/10/2014	Oct	29	old	232425.8
Farm B	165	4	10/11/2014	Nov	28.5	old	74116.9
Farm B	165	4	10/12/2014	Dec	30.5	old	70174.5
Farm B	165	4	8/01/2015	Jan	29.5	old	93916.5
Farm B	165	4	8/02/2015	Feb	31.5	old	5957.4
Farm B	165	4	9/03/2015	Mar	28	old	133428.0
Farm B	165	4	9/04/2015	Apr	26.5	old	3679.6
Farm B	165	4	19/05/2015	May	30.5	old	24968.5
Farm B	173	5	11/08/2014	Aug	27.5	old	165054.7
Farm B	173	5	9/09/2014	Sep	18.5	old	87.6
Farm B	173	5	9/10/2014	Oct	29	old	1839.8
Farm B	173	5	10/11/2014	Nov	30.5	old	1226.5
Farm B	173	5	10/12/2014	Dec	34	old	2365.2
Farm B	173	5	8/01/2015	Jan	34	old	31714.3
Farm B	173	5	8/02/2015	Feb	32.5	old	36270.0
Farm B	173	5	9/03/2015	Mar	27	old	1314.1
Farm B	173	5	9/04/2015	Apr	28	old	5607.0
Farm B	173	5	19/05/2015	May	32	old	14192.6
Farm B	189	3	11/08/2014	Aug	34.5	young	87.6
Farm B	189	3	9/09/2014	Sep	31	young	0.0
Farm B	189	3	9/10/2014	Oct	22.5	young	414739.4
Farm B	189	3	10/11/2014	Nov	24	young	49761.7
Farm B	189	3	10/12/2014	Dec	29	young	131588.2
Farm B	189	3	8/01/2015	Jan	31.5	young	301461.4
Farm B	189	3	8/02/2015	Feb	32.5	young	85768.9
Farm B	189	3	9/03/2015	Mar	28	young	21113.7
Farm B	189	3	9/04/2015	Apr	27	young	30750.6
Farm B	189	3	19/05/2015	May	34	young	36620.4
Farm B	192	6	11/08/2014	Aug	27.5	old	0.0
Farm B	192	6	9/09/2014	Sep	28	old	242237.9
Farm B	192	6	9/10/2014	Oct	31.5	old	438.0
Farm B	192	6	10/11/2014	Nov	32	old	4468.0
Farm B	192	6	10/12/2014	Dec	32	old	172939.5
Farm B	192	6	8/01/2015	Jan	30	old	8848.5
Farm B	192	6	8/02/2015	Feb	31	old	43541.5
Farm B	192	6	9/03/2015	Mar	29	old	0.0
Farm B	192	6	9/04/2015	Apr	29	old	109948.9
Farm B	192	6	19/05/2015	May	32	old	176005.8
Farm B	196	5	11/08/2014	Aug	32	old	4730.9
Farm B	196	5	9/09/2014	Sep	19	old	463011.7

Farm B	196	5	9/10/2014	Oct	29	old	70518.0
Farm B	196	5	10/11/2014	Nov	30	old	59223.5
Farm B	196	5	10/12/2014	Dec	32	old	57033.2
Farm B	196	5	8/01/2015	Jan	30	old	8410.4
Farm B	196	5	8/02/2015	Feb	30	old	84454.7
Farm B	196	5	9/03/2015	Mar	28	old	40124.8
Farm B	196	5	9/04/2015	Apr	30	old	57120.8
Farm B	196	5	19/05/2015	May	30	old	19536.7
Farm B	199	4	11/08/2014	Aug	29.5	old	87.6
Farm B	199	4	9/09/2014	Sep	30.5	old	0.0
Farm B	199	4	9/10/2014	Oct	33	old	0.0
Farm B	199	4	10/11/2014	Nov	29.5	old	0.0
Farm B	199	4	10/12/2014	Dec	31.5	old	0.0
Farm B	199	4	8/01/2015	Jan	32	old	NA
Farm B	199	4	8/02/2015	Feb	34	old	87.6
Farm B	199	4	9/03/2015	Mar	29	old	0.0
Farm B	199	4	9/04/2015	Apr	28	old	0.0
Farm B	199	4	19/05/2015	May	28	old	0.0
Farm B	201	3	11/08/2014	Aug	31.5	young	0.0
Farm B	201	3	9/09/2014	Sep	29	young	0.0
Farm B	201	3	9/10/2014	Oct	28	young	0.0
Farm B	201	3	10/11/2014	Nov	29	young	0.0
Farm B	201	3	10/12/2014	Dec	32	young	0.0
Farm B	201	3	8/01/2015	Jan	31	young	0.0
Farm B	201	3	8/02/2015	Feb	29	young	0.0
Farm B	201	3	9/03/2015	Mar	29	young	1051.3
Farm B	201	3	9/04/2015	Apr	28	young	0.0
Farm B	201	3	19/05/2015	May	31.5	young	0.0
Farm B	207	3	11/08/2014	Aug	31	young	0.0
Farm B	207	3	9/09/2014	Sep	29	young	0.0
Farm B	207	3	9/10/2014	Oct	28.5	young	0.0
Farm B	207	3	10/11/2014	Nov	30	young	0.0
Farm B	207	3	10/12/2014	Dec	30	young	NA
Farm B	207	3	8/01/2015	Jan	32	young	0.0
Farm B	207	3	8/02/2015	Feb	29.5	young	0.0
Farm B	207	3	9/03/2015	Mar	26.5	young	87.6
Farm B	207	3	9/04/2015	Apr	26.5	young	0.0
Farm B	221	3	11/08/2014	Aug	33	young	0.0
Farm B	221	3	9/09/2014	Sep	33	young	87.6
Farm B	221	3	9/10/2014	Oct	34.5	young	0.0
Farm B	221	3	10/11/2014	Nov	33	young	87.6
Farm B	221	3	10/12/2014	Dec	34.5	young	0.0
Farm B	221	3	8/01/2015	Jan	31.5	young	0.0
Farm B	221	3	8/02/2015	Feb	30.5	young	0.0
Farm B	221	3	9/03/2015	Mar	26	young	0.0
Farm B	221	3	9/04/2015	Apr	29	young	NA

Farm B	221	3	19/05/2015	May	34	young	NA
Farm B	224	4	11/08/2014	Aug	29	old	9111.3
Farm B	224	4	9/09/2014	Sep	30	old	4205.2
Farm B	224	4	9/10/2014	Oct	30.5	old	3767.2
Farm B	224	4	10/11/2014	Nov	31.5	old	19011.1
Farm B	224	4	10/12/2014	Dec	32	old	NA
Farm B	224	4	8/01/2015	Jan	31.5	old	20586.0
Farm B	224	4	8/02/2015	Feb	32	old	0.0
Farm B	224	4	9/03/2015	Mar	30	old	114592.1
Farm B	224	4	9/04/2015	Apr	29	old	10863.5
Farm B	224	4	19/05/2015	May	31.5	old	41701.7
Farm B	226	5	11/08/2014	Aug	28	old	41351.3
Farm B	226	5	9/09/2014	Sep	29	old	7183.9
Farm B	234	6	11/08/2014	Aug	27	old	491572.2
Farm B	234	6	9/09/2014	Sep	29	old	3679.6
Farm B	234	6	9/10/2014	Oct	31.5	old	18047.4
Farm B	234	6	10/11/2014	Nov	33	old	204741.4
Farm B	234	6	10/12/2014	Dec	34	old	70437.4
Farm B	234	6	8/01/2015	Jan	31	old	7008.7
Farm B	234	6	8/02/2015	Feb	33.5	old	99873.9
Farm B	234	6	9/03/2015	Mar	30.5	old	8060.0
Farm B	234	6	9/04/2015	Apr	29.5	old	56332.4
Farm B	234	6	19/05/2015	May	32.5	old	48710.4
Farm B	237	7	11/08/2014	Aug	28.5	old	NA
Farm B	237	7	9/09/2014	Sep	29.5	old	788.5
Farm B	237	7	9/10/2014	Oct	28.5	old	17784.6
Farm B	237	7	10/11/2014	Nov	32	old	4030.0
Farm B	237	7	10/12/2014	Dec	32	old	876.1
Farm B	237	7	8/01/2015	Jan	31	old	1664.6
Farm B	237	7	8/02/2015	Feb	30	old	2803.5
Farm B	237	7	9/03/2015	Mar	27	old	9023.7
Farm B	237	7	9/04/2015	Apr	31	old	6307.8
Farm B	237	7	19/05/2015	May	32.5	old	12440.4
Farm B	242	9	11/08/2014	Aug	27	old	175.2
Farm B	242	9	9/09/2014	Sep	28.5	old	2365.4
Farm B	242	9	9/10/2014	Oct	24.5	old	62552.6
Farm B	242	9	10/11/2014	Nov	27.5	old	9724.6
Farm B	242	9	10/12/2014	Dec	32	old	15331.5
Farm B	242	9	8/01/2015	Jan	32.5	old	10075.0
Farm B	242	9	8/02/2015	Feb	32	old	8410.4
Farm B	242	9	9/04/2015	Apr	27	old	2453.0
Farm B	242	9	19/05/2015	May	27	old	12878.5
Farm B	272	4	11/08/2014	Aug	34	old	87.6
Farm B	272	4	9/09/2014	Sep	31	old	0.0
Farm B	272	4	9/10/2014	Oct	29.5	old	NA
Farm B	272	4	10/11/2014	Nov	28	old	0.0

Farm B	272	4	10/12/2014	Dec	30	old	0.0
Farm B	272	4	8/01/2015	Jan	31	old	0.0
Farm B	272	4	8/02/2015	Feb	33.5	old	175.2
Farm B	272	4	9/03/2015	Mar	31	old	0.0
Farm B	272	4	9/04/2015	Apr	27.5	old	0.0
Farm B	272	4	19/05/2015	May	30	old	87.6
Farm B	273	5	11/08/2014	Aug	34	old	175.2
Farm B	273	5	9/09/2014	Sep	30.5	old	0.0
Farm B	273	5	9/10/2014	Oct	31	old	0.0
Farm B	273	5	10/11/2014	Nov	28	old	0.0
Farm B	273	5	10/12/2014	Dec	32	old	0.0
Farm B	273	5	8/01/2015	Jan	31.5	old	0.0
Farm B	273	5	8/02/2015	Feb	34.5	old	0.0
Farm B	273	5	9/03/2015	Mar	28.5	old	0.0
Farm B	273	5	9/04/2015	Apr	27.5	old	0.0
Farm B	273	5	19/05/2015	May	30.5	old	0.0
Farm B	284	4	11/08/2014	Aug	12.5	old	7660325.7
Farm B	284	4	9/09/2014	Sep	24	old	71050.6
Farm B	284	4	9/10/2014	Oct	30.5	old	29962.2
Farm B	284	4	10/11/2014	Nov	30	old	140874.7
Farm B	284	4	10/12/2014	Dec	30.5	old	1752.2
Farm B	284	4	8/01/2015	Jan	30	old	9549.3
Farm B	284	4	8/02/2015	Feb	30	old	5344.1
Farm B	284	4	9/03/2015	Mar	27.5	old	284552.9
Farm B	284	4	9/04/2015	Apr	30.5	old	16645.6
Farm B	284	4	19/05/2015	May	30	old	97858.9
Farm B	290	4	11/08/2014	Aug	34	old	0.0
Farm B	290	4	9/09/2014	Sep	30	old	0.0
Farm B	290	4	9/10/2014	Oct	30	old	0.0
Farm B	290	4	10/11/2014	Nov	28	old	159272.5
Farm B	290	4	10/12/2014	Dec	24.5	old	70875.4
Farm B	290	4	8/01/2015	Jan	29	old	243026.4
Farm B	290	4	8/02/2015	Feb	29	old	86206.9
Farm B	290	4	9/03/2015	Mar	29	old	788.5
Farm B	290	4	9/04/2015	Apr	30.5	old	9111.3
Farm B	290	4	19/05/2015	May	31	old	20763.3
Farm B	304	9	11/08/2014	Aug	29	old	613.3
Farm B	304	9	9/09/2014	Sep	31	old	1051.3
Farm B	304	9	9/10/2014	Oct	31.5	old	10688.3
Farm B	304	9	10/11/2014	Nov	31.5	old	6307.8
Farm B	304	9	10/12/2014	Dec	32	old	38810.6
Farm B	304	9	8/01/2015	Jan	32	old	438.0
Farm B	304	9	8/02/2015	Feb	33	old	28297.6
Farm B	304	9	9/03/2015	Mar	29.5	old	5607.0
Farm B	304	9	9/04/2015	Apr	29	old	613.3
Farm B	304	9	19/05/2015	May	29.5	old	65443.7

Farm B	310	10	11/08/2014	Aug	31.5	old	398269.0
Farm B	310	10	9/09/2014	Sep	28.5	old	49586.5
Farm B	310	10	9/10/2014	Oct	27.5	old	4233688.3
Farm B	310	10	10/11/2014	Nov	28	old	21113.7
Farm B	310	10	10/12/2014	Dec	32	old	2978.7
Farm B	310	10	8/01/2015	Jan	32.5	old	106619.7
Farm B	310	10	8/02/2015	Feb	33.5	old	76394.7
Farm B	310	10	9/03/2015	Mar	29	old	118096.5
Farm B	310	10	9/04/2015	Apr	28	old	8235.2
Farm B	312	3	11/08/2014	Aug	35	old	87.6
Farm B	312	3	9/09/2014	Sep	29.5	young	1577.0
Farm B	312	3	9/10/2014	Oct	29.5	young	12177.6
Farm B	312	3	10/11/2014	Nov	29	young	63428.7
Farm B	312	3	10/12/2014	Dec	31.5	young	38285.0
Farm B	312	3	8/01/2015	Jan	31.5	young	8060.0
Farm B	312	3	8/02/2015	Feb	29.5	young	146744.5
Farm B	312	3	9/03/2015	Mar	23	young	46432.6
Farm B	312	3	9/04/2015	Apr	30.5	young	51426.3
Farm B	312	3	19/05/2015	May	35	young	30487.8
Farm B	318	11	10/11/2014	Nov	29	old	71050.6
Farm B	318	11	10/12/2014	Dec	34	old	12265.2
Farm B	318	11	8/01/2015	Jan	32	old	38460.2
Farm B	318	11	8/02/2015	Feb	36.5	old	15857.2
Farm B	318	11	9/03/2015	Mar	29	old	314427.5
Farm B	318	11	9/04/2015	Apr	27.5	old	4730.9
Farm B	320	4	11/08/2014	Aug	33	old	10075.0
Farm B	320	4	9/09/2014	Sep	23	old	60011.9
Farm B	320	4	9/10/2014	Oct	32.5	old	22252.6
Farm B	320	4	10/11/2014	Nov	30	old	9286.5
Farm B	320	4	10/12/2014	Dec	35	old	5849052.0
Farm B	320	4	8/01/2015	Jan	33.5	old	NA
Farm B	320	4	8/02/2015	Feb	32.5	old	35306.3
Farm B	320	4	9/03/2015	Mar	26.5	young	264490.5
Farm B	320	4	9/04/2015	Apr	26	old	65443.7
Farm B	320	4	19/05/2015	May	29	old	58697.8
Farm B	323	6	11/08/2014	Aug	30.5	old	109160.4
Farm B	323	6	9/09/2014	Sep	29	old	1489.3
Farm B	323	6	9/10/2014	Oct	28.5	old	43278.7
Farm B	323	6	10/11/2014	Nov	26	old	9111.3
Farm B	323	6	10/12/2014	Dec	28.5	old	175.2
Farm B	323	6	8/01/2015	Jan	29.5	old	438.0
Farm B	323	6	8/02/2015	Feb	30	old	18573.0
Farm B	323	6	9/03/2015	Mar	25.5	old	262.8
Farm B	323	6	9/04/2015	Apr	25	old	13316.5
Farm B	323	6	19/05/2015	May	27.5	old	2015.0
Farm B	327	4	11/08/2014	Aug	28	old	103903.9

Farm B	327	4	9/09/2014	Sep	28.5	old	2365.4
Farm B	327	4	9/10/2014	Oct	28	old	262.8
Farm B	327	4	10/11/2014	Nov	27.5	old	16558.0
Farm B	327	4	10/12/2014	Dec	30	old	281661.8
Farm B	327	4	8/01/2015	Jan	29	old	0.0
Farm B	327	4	8/02/2015	Feb	28.5	old	28034.8
Farm B	327	4	9/03/2015	Mar	24	old	34430.2
Farm B	327	4	9/04/2015	Apr	24	old	613.3
Farm B	339	4	11/08/2014	Aug	31	old	9899.8
Farm B	339	4	9/09/2014	Sep	29	old	350.4
Farm B	339	4	9/10/2014	Oct	31.5	old	86907.8
Farm B	339	4	10/11/2014	Nov	31.5	old	20512941.6
Farm B	339	4	10/12/2014	Dec	32	old	19011.1
Farm B	339	4	8/01/2015	Jan	30	old	1138.9
Farm B	339	4	8/02/2015	Feb	30	old	19887.2
Farm B	339	4	9/03/2015	Mar	28.5	old	NA
Farm B	339	4	9/04/2015	Apr	29	old	6395.4
Farm B	339	4	19/05/2015	May	34	old	14280.2
Farm B	348	6	11/08/2014	Aug	34	old	87.6
Farm B	348	6	9/09/2014	Sep	32.5	old	175.2
Farm B	348	6	9/10/2014	Oct	30	old	0.0
Farm B	348	6	10/11/2014	Nov	29.5	old	0.0
Farm B	348	6	10/12/2014	Dec	31	old	1051.3
Farm B	348	6	8/01/2015	Jan	32	old	0.0
Farm B	348	6	8/02/2015	Feb	33.5	old	0.0
Farm B	348	6	9/03/2015	Mar	32	old	0.0
Farm B	348	6	9/04/2015	Apr	29	old	0.0
Farm B	348	6	19/05/2015	May	32	old	0.0
Farm B	350	7	11/08/2014	Aug	28	old	71401.1
Farm B	350	7	9/09/2014	Sep	29	old	262.8
Farm B	350	7	9/10/2014	Oct	29.5	old	7183.9
Farm B	350	7	10/11/2014	Nov	30	old	0.0
Farm B	350	7	10/12/2014	Dec	32	old	498882.0
Farm B	350	7	8/01/2015	Jan	29	old	7359.1
Farm B	350	7	8/02/2015	Feb	30.5	old	3416.7
Farm B	350	7	9/03/2015	Mar	26	old	16295.2
Farm B	350	7	9/04/2015	Apr	28.5	old	1927.4
Farm B	357	4	11/08/2014	Aug	31	old	0.0
Farm B	357	4	9/09/2014	Sep	26	old	97771.3
Farm B	357	4	9/10/2014	Oct	28	old	60274.8
Farm B	357	4	10/11/2014	Nov	27.5	old	12265.2
Farm B	357	4	10/12/2014	Dec	30	old	56682.8
Farm B	357	4	8/01/2015	Jan	30	old	79548.7
Farm B	357	4	8/02/2015	Feb	30	old	613.2
Farm B	357	4	9/03/2015	Mar	27.5	old	31188.7
Farm B	357	4	9/04/2015	Apr	25	old	3066.3

Farm B	357	4	19/05/2015	May	28	old	5607.0
Farm B	360	5	11/08/2014	Aug	26	old	0.0
Farm B	360	5	9/09/2014	Sep	29	old	58347.4
Farm B	360	5	9/10/2014	Oct	20	old	446804.1
Farm B	360	5	10/11/2014	Nov	27	old	438.0
Farm B	360	5	10/12/2014	Dec	27.5	old	835173.3
Farm B	360	5	8/01/2015	Jan	34.5	old	9637.0
Farm B	360	5	8/02/2015	Feb	30	old	1314.1
Farm B	360	5	9/03/2015	Mar	27.5	old	12615.6
Farm B	360	5	9/04/2015	Apr	26	old	6921.1
Farm B	360	5	19/05/2015	May	29	old	30575.4
Farm B	375	3	11/08/2014	Aug	33.5	young	0.0
Farm B	375	3	9/09/2014	Sep	29	young	87.6
Farm B	375	3	9/10/2014	Oct	27	young	0.0
Farm B	375	3	10/11/2014	Nov	36	young	87.6
Farm B	375	3	10/12/2014	Dec	29.5	young	0.0
Farm B	375	3	8/01/2015	Jan	30	young	0.0
Farm B	375	3	8/02/2015	Feb	29	young	0.0
Farm B	375	3	9/03/2015	Mar	24	young	0.0
Farm B	375	3	9/04/2015	Apr	24.5	young	0.0
Farm B	377	6	11/08/2014	Aug	31	old	66933.0
Farm B	377	6	9/09/2014	Sep	30.5	old	6483.0
Farm B	377	6	9/10/2014	Oct	29.5	old	NA
Farm B	377	6	10/11/2014	Nov	29.5	old	38285.0
Farm B	377	6	10/12/2014	Dec	30	old	39248.7
Farm B	377	6	8/01/2015	Jan	28.5	old	2453.0
Farm B	377	6	8/02/2015	Feb	30	old	272375.3
Farm B	377	6	9/03/2015	Mar	28	old	76044.3
Farm B	377	6	9/04/2015	Apr	26	old	6132.6
Farm B	377	6	19/05/2015	May	28	old	6921.1
Farm B	393	7	11/08/2014	Aug	25	old	0.0
Farm B	393	7	9/09/2014	Sep	29	old	3942.4
Farm B	393	7	9/10/2014	Oct	31	old	13929.8
Farm B	393	7	10/11/2014	Nov	29.5	old	21989.8
Farm B	393	7	10/12/2014	Dec	31.5	old	2102.6
Farm B	393	7	8/01/2015	Jan	29	old	87.6
Farm B	393	7	8/02/2015	Feb	31	old	9374.1
Farm B	393	7	9/03/2015	Mar	30	old	35831.9
Farm B	393	7	9/04/2015	Apr	30	old	3942.4
Farm B	393	7	19/05/2015	May	30.5	old	8147.6
Farm B	398	6	11/08/2014	Aug	29.5	old	7446.7
Farm B	398	6	9/09/2014	Sep	32	old	350.4
Farm B	398	6	9/10/2014	Oct	31.5	old	525.7
Farm B	398	6	10/11/2014	Nov	32	old	438.0
Farm B	398	6	10/12/2014	Dec	32	old	175.2
Farm B	398	6	8/01/2015	Jan	30	old	87.6

Farm B	398	6	8/02/2015	Feb	35	old	175.2
Farm B	398	6	9/03/2015	Mar	30.5	old	1664.6
Farm B	398	6	9/04/2015	Apr	30.5	old	262.8
Farm B	404	3	11/08/2014	Aug	30.5	young	644361.7
Farm B	404	3	9/09/2014	Sep	23	young	42928.2
Farm B	404	3	9/10/2014	Oct	27.5	young	10047223.5
Farm B	404	3	10/11/2014	Nov	25	young	4730.9
Farm B	404	3	10/12/2014	Dec	26.5	young	65005.6
Farm B	404	3	8/01/2015	Jan	26	young	1927.4
Farm B	404	3	8/02/2015	Feb	24.5	young	112401.9
Farm B	404	3	9/03/2015	Mar	23	young	7359.1
Farm B	404	3	9/04/2015	Apr	25.5	young	31363.9
Farm B	404	3	19/05/2015	May	26.5	young	14280.2
Farm B	405	3	11/08/2014	Aug	30	young	87.6
Farm B	405	3	9/09/2014	Sep	27	young	87.6
Farm B	405	3	9/10/2014	Oct	22.5	young	0.0
Farm B	405	3	10/11/2014	Nov	38	young	87.6
Farm B	405	3	10/12/2014	Dec	33.5	young	1051.3
Farm B	405	3	8/01/2015	Jan	28	young	0.0
Farm B	405	3	8/02/2015	Feb	27	young	0.0
Farm B	405	3	9/03/2015	Mar	22.5	young	0.0
Farm B	405	3	9/04/2015	Apr	24	young	0.0
Farm B	405	3	19/05/2015	May	27.5	young	0.0
Farm B	413	5	11/08/2014	Aug	35	old	378644.6
Farm B	413	5	9/09/2014	Sep	26	old	156293.8
Farm B	413	5	9/10/2014	Oct	29	old	1752.2
Farm B	413	5	10/11/2014	Nov	28.5	old	46783.0
Farm B	413	5	10/12/2014	Dec	31	old	17959.8
Farm B	413	5	8/01/2015	Jan	30	old	2190.2
Farm B	413	5	8/02/2015	Feb	30	old	10162.6
Farm B	413	5	9/03/2015	Mar	26	old	9987.4
Farm B	413	5	9/04/2015	Apr	26	old	876.1
Farm B	413	5	19/05/2015	May	31.5	old	32678.0
Farm B	417	5	11/08/2014	Aug	33.5	old	0.0
Farm B	417	5	9/09/2014	Sep	32.5	old	0.0
Farm B	417	5	9/10/2014	Oct	30	old	NA
Farm B	417	5	10/11/2014	Nov	32	old	0.0
Farm B	417	5	10/12/2014	Dec	32.5	old	87.6
Farm B	417	5	8/01/2015	Jan	33.5	old	0.0
Farm B	417	5	8/02/2015	Feb	35	old	NA
Farm B	417	5	9/03/2015	Mar	30.5	old	NA
Farm B	417	5	9/04/2015	Apr	31	old	0.0
Farm B	417	5	19/05/2015	May	34	old	0.0
Farm B	418	3	11/08/2014	Aug	31	young	0.0
Farm B	418	3	9/09/2014	Sep	32	young	175.2
Farm B	418	3	9/10/2014	Oct	31.5	young	87.6

Farm B	418	3	10/11/2014	Nov	30.5	young	1314.0
Farm B	418	3	10/12/2014	Dec	31.5	young	87.6
Farm B	418	3	8/01/2015	Jan	31	young	NA
Farm B	418	3	8/02/2015	Feb	31	young	NA
Farm B	418	3	9/03/2015	Mar	30	young	1051.3
Farm B	418	3	9/04/2015	Apr	29.5	young	NA
Farm B	421	8	11/08/2014	Aug	27	old	17171.3
Farm B	421	8	9/09/2014	Sep	29.5	old	2365.4
Farm B	421	8	9/10/2014	Oct	29	old	757990.1
Farm B	421	8	10/11/2014	Nov	28	old	44768.0
Farm B	421	8	10/12/2014	Dec	31	old	3767.2
Farm B	421	8	8/01/2015	Jan	34	old	2015.0
Farm B	421	8	8/02/2015	Feb	31	old	13842.2
Farm B	421	8	9/03/2015	Mar	28	old	15594.3
Farm B	421	8	9/04/2015	Apr	28	old	5694.6
Farm B	421	8	19/05/2015	May	30	old	22690.6
Farm B	422	3	11/08/2014	Aug	32.5	young	0.0
Farm B	422	3	9/09/2014	Sep	30	young	0.0
Farm B	422	3	9/10/2014	Oct	28.5	young	0.0
Farm B	422	3	10/11/2014	Nov	28	young	87.6
Farm B	422	3	10/12/2014	Dec	31.5	young	0.0
Farm B	422	3	8/01/2015	Jan	34.5	young	0.0
Farm B	422	3	8/02/2015	Feb	32	young	0.0
Farm B	422	3	9/03/2015	Mar	27	young	0.0
Farm B	422	3	9/04/2015	Apr	28	young	0.0
Farm B	422	3	19/05/2015	May	31	young	0.0
Farm B	434	11	9/09/2014	Sep	31	old	5607.0
Farm B	434	11	9/10/2014	Oct	30	old	5431.7
Farm B	434	11	10/11/2014	Nov	29	old	16120.0
Farm B	434	11	10/12/2014	Dec	32	old	30225.0
Farm B	434	11	8/01/2015	Jan	32	old	438.0
Farm B	434	11	8/02/2015	Feb	31	old	21639.3
Farm B	434	11	9/03/2015	Mar	29.5	old	16996.1
Farm B	434	11	9/04/2015	Apr	27	old	6570.6
Farm B	466	5	11/08/2014	Aug	26	old	175.2
Farm B	466	5	9/09/2014	Sep	29.5	old	0.0
Farm B	466	5	9/10/2014	Oct	28.5	old	16733.3
Farm B	466	5	10/11/2014	Nov	30	old	14674226.4
Farm B	466	5	10/12/2014	Dec	30.5	old	19361.5
Farm B	466	5	8/01/2015	Jan	29.5	old	262.8
Farm B	466	5	8/02/2015	Feb	29	old	1138.9
Farm B	466	5	9/03/2015	Mar	27	old	3592.0
Farm B	466	5	9/04/2015	Apr	27	old	1839.8
Farm B	466	5	19/05/2015	May	30	old	788.5
Farm B	469	6	11/08/2014	Aug	31	old	23216.3
Farm B	469	6	9/09/2014	Sep	30	old	2102.6

Farm B	469	6	9/10/2014	Oct	31	old	18397.8
Farm B	469	6	10/11/2014	Nov	29.5	old	18748.3
Farm B	469	6	10/12/2014	Dec	31	old	3942.4
Farm B	469	6	8/01/2015	Jan	31.5	old	963.7
Farm B	469	6	8/02/2015	Feb	32	old	2277.8
Farm B	469	6	9/03/2015	Mar	29.5	old	2978.7
Farm B	469	6	9/04/2015	Apr	30	old	29086.1
Farm B	469	6	19/05/2015	May	30.5	old	12966.1
Farm B	471	4	11/08/2014	Aug	27	old	612296.9
Farm B	471	4	9/09/2014	Sep	25.5	old	136844.7
Farm B	471	4	9/10/2014	Oct	29	old	489995.2
Farm B	471	4	10/11/2014	Nov	31	old	7008.7
Farm B	471	4	10/12/2014	Dec	31.5	old	57821.7
Farm B	471	4	8/01/2015	Jan	30	old	390121.3
Farm B	471	4	8/02/2015	Feb	29.5	old	18047.4
Farm B	471	4	9/03/2015	Mar	28	old	32853.2
Farm B	471	4	9/04/2015	Apr	29.5	old	5869.8
Farm B	471	4	19/05/2015	May	31.5	old	14017.4
Farm B	472	3	11/08/2014	Aug	34	young	87.6
Farm B	472	3	9/09/2014	Sep	30.5	young	175.2
Farm B	472	3	9/10/2014	Oct	31	young	0.0
Farm B	472	3	10/11/2014	Nov	28	young	87.6
Farm B	472	3	10/12/2014	Dec	32.5	young	87.6
Farm B	472	3	8/01/2015	Jan	33	young	0.0
Farm B	472	3	8/02/2015	Feb	34	young	NA
Farm B	472	3	9/03/2015	Mar	27.5	young	0.0
Farm B	472	3	9/04/2015	Apr	25	young	0.0
Farm B	472	3	19/05/2015	May	29	young	0.0
Farm B	474	4	11/08/2014	Aug	30	old	175.2
Farm B	474	4	9/09/2014	Sep	23	old	470808.9
Farm B	474	4	9/10/2014	Oct	28.5	old	66933.0
Farm B	474	4	10/11/2014	Nov	29	old	2190.2
Farm B	474	4	10/12/2014	Dec	28.5	old	62465.0
Farm B	474	4	8/01/2015	Jan	29.5	old	19799.6
Farm B	474	4	8/02/2015	Feb	30	old	13667.0
Farm B	474	4	9/03/2015	Mar	30.5	old	51075.8
Farm B	474	4	9/04/2015	Apr	27.5	old	2015.0
Farm B	474	4	19/05/2015	May	31.5	old	2628.3
Farm B	479	5	11/08/2014	Aug	32	old	0.0
Farm B	479	5	9/09/2014	Sep	29	old	0.0
Farm B	479	5	9/10/2014	Oct	28.5	old	0.0
Farm B	479	5	10/11/2014	Nov	30	old	0.0
Farm B	479	5	10/12/2014	Dec	31.5	old	0.0
Farm B	479	5	8/01/2015	Jan	32.5	old	0.0
Farm B	479	5	8/02/2015	Feb	31.5	old	0.0
Farm B	479	5	9/03/2015	Mar	27	old	0.0

Farm B	479	5	9/04/2015	Apr	26.5	old	NA
Farm B	479	5	19/05/2015	May	30	old	NA
Farm B	486	4	11/08/2014	Aug	28	old	0.0
Farm B	486	4	9/09/2014	Sep	30	old	17083.7
Farm B	486	4	9/10/2014	Oct	30	old	108196.7
Farm B	486	4	10/11/2014	Nov	33	old	2015.0
Farm B	486	4	10/12/2014	Dec	32	old	34605.4
Farm B	486	4	8/01/2015	Jan	32.5	old	525.7
Farm B	486	4	8/02/2015	Feb	34	old	0.0
Farm B	486	4	9/03/2015	Mar	34.5	old	10513.0
Farm B	486	4	9/04/2015	Apr	30	old	43804.3
Farm B	486	4	19/05/2015	May	31	old	114942.6
Farm B	488	3	11/08/2014	Aug	34	young	87.6
Farm B	488	3	9/09/2014	Sep	31.5	young	154103.6
Farm B	488	3	9/10/2014	Oct	24.5	young	3482181.3
Farm B	488	3	10/11/2014	Nov	33	young	2102.6
Farm B	488	3	10/12/2014	Dec	35.5	young	29348.9
Farm B	488	3	8/01/2015	Jan	34	young	35481.5
Farm B	488	3	8/02/2015	Feb	35	young	48973.2
Farm B	488	3	9/03/2015	Mar	28	young	7972.4
Farm B	488	3	9/04/2015	Apr	29.5	young	19887.2
Farm B	488	3	19/05/2015	May	35	young	32064.8
Farm B	494	6	11/08/2014	Aug	29	old	56945.6
Farm B	494	6	9/09/2014	Sep	31.5	old	1226.5
Farm B	494	6	9/10/2014	Oct	30.5	old	3329.1
Farm B	494	6	10/11/2014	Nov	32	old	27684.3
Farm B	494	6	10/12/2014	Dec	32.5	old	290860.7
Farm B	494	6	8/01/2015	Jan	31.5	old	1401.7
Farm B	494	6	8/02/2015	Feb	33.5	old	9111.3
Farm B	494	6	9/03/2015	Mar	29.5	old	127733.4
Farm B	494	6	9/04/2015	Apr	29.5	old	20675.6
Farm B	494	6	19/05/2015	May	32.5	old	8410.4
Farm B	496	6	11/08/2014	Aug	26.5	old	7972.4
Farm B	496	6	9/09/2014	Sep	26.5	old	36094.8
Farm B	496	6	9/10/2014	Oct	29.5	old	4730.9
Farm B	496	6	10/11/2014	Nov	28	old	9023.7
Farm B	496	6	10/12/2014	Dec	29.5	old	262.8
Farm B	496	6	8/01/2015	Jan	29	old	1051.3
Farm B	496	6	8/02/2015	Feb	29	old	7183.9
Farm B	496	6	9/03/2015	Mar	29	old	1138.9
Farm B	496	6	9/04/2015	Apr	26	old	3854.8
Farm B	496	6	19/05/2015	May	29	old	14981.1
Farm B	499	4	11/08/2014	Aug	33	old	175.2
Farm B	499	4	9/09/2014	Sep	32	old	0.0
Farm B	499	4	9/10/2014	Oct	32.5	old	NA
Farm B	499	4	10/11/2014	Nov	29	old	0.0

Farm B	499	4	10/12/2014	Dec	32	old	0.0
Farm B	499	4	8/01/2015	Jan	29.5	old	87.6
Farm B	499	4	8/02/2015	Feb	31	old	0.0
Farm B	499	4	9/03/2015	Mar	30	old	NA
Farm B	499	4	9/04/2015	Apr	30.5	old	0.0
Farm B	499	4	19/05/2015	May	32.5	old	0.0
Farm B	503	5	11/08/2014	Aug	27.5	old	53441.3
Farm B	503	5	9/09/2014	Sep	28.5	old	10337.8
Farm B	503	5	9/10/2014	Oct	30	old	108722.3
Farm B	503	5	10/11/2014	Nov	31.5	old	14718.3
Farm B	503	5	10/12/2014	Dec	32	old	91113.0
Farm B	503	5	8/01/2015	Jan	30	old	2015.0
Farm B	503	5	8/02/2015	Feb	32	old	97420.8
Farm B	503	5	9/03/2015	Mar	28	old	7359.1
Farm B	503	5	9/04/2015	Apr	31	old	5869.8
Farm B	503	5	19/05/2015	May	34	old	18222.6
Farm B	505	5	11/08/2014	Aug	35	old	350.4
Farm B	505	5	9/09/2014	Sep	34	old	175.2
Farm B	505	5	10/11/2014	Nov	29	old	0.0
Farm B	505	5	10/12/2014	Dec	31.5	old	87.6
Farm B	505	5	8/01/2015	Jan	33.5	old	1577.0
Farm B	505	5	8/02/2015	Feb	14.5	old	708841.6
Farm B	514	5	11/08/2014	Aug	30	old	51513.9
Farm B	514	5	9/09/2014	Sep	30.5	old	1314.1
Farm B	514	5	10/11/2014	Nov	30	old	59135.8
Farm B	514	5	10/12/2014	Dec	30.5	old	8322.8
Farm B	514	5	8/01/2015	Jan	30.5	old	438.0
Farm B	514	5	8/02/2015	Feb	30.5	old	12528.0
Farm B	514	5	9/03/2015	Mar	27	old	18397.8
Farm B	514	5	9/04/2015	Apr	28	old	21551.7
Farm B	514	5	19/05/2015	May	31	old	10775.9
Farm B	515	7	11/08/2014	Aug	32	old	38022.2
Farm B	515	7	9/09/2014	Sep	30.5	old	1401.7
Farm B	515	7	9/10/2014	Oct	28.5	old	262.8
Farm B	515	7	10/11/2014	Nov	26	old	1138.9
Farm B	515	7	10/12/2014	Dec	29	old	1839.8
Farm B	515	7	8/01/2015	Jan	29.5	old	10775.9
Farm B	515	7	8/02/2015	Feb	28.5	old	2277.8
Farm B	515	7	9/03/2015	Mar	26	old	0.0
Farm B	515	7	9/04/2015	Apr	25	old	1839.8
Farm B	515	7	19/05/2015	May	28	old	5869.8
Farm B	530	4	11/08/2014	Aug	33	old	0.0
Farm B	530	4	9/09/2014	Sep	31	old	0.0
Farm B	530	4	9/10/2014	Oct	30.5	old	0.0
Farm B	530	4	10/12/2014	Dec	31.5	old	29786.9
Farm B	530	4	8/01/2015	Jan	34.5	old	0.0

Farm B	530	4	8/02/2015	Feb	34.5	old	175.2
Farm B	530	4	9/03/2015	Mar	31.5	old	NA
Farm B	530	4	9/04/2015	Apr	29	old	0.0
Farm B	531	5	11/08/2014	Aug	29	old	8760.9
Farm B	531	5	9/09/2014	Sep	30.5	old	171187.3
Farm B	531	5	9/10/2014	Oct	31	old	NA
Farm B	531	5	10/11/2014	Nov	30	old	18396.0
Farm B	531	5	10/12/2014	Dec	32.5	old	23479.1
Farm B	531	5	8/01/2015	Jan	31	old	175.2
Farm B	531	5	8/02/2015	Feb	32	old	2014.8
Farm B	531	5	9/03/2015	Mar	29	old	229271.9
Farm B	531	5	9/04/2015	Apr	29	old	0.0
Farm B	531	5	19/05/2015	May	29	old	8760.9
Farm B	536	3	11/08/2014	Aug	30.5	young	87.6
Farm B	536	3	9/10/2014	Oct	27.5	young	0.0
Farm B	536	3	10/11/2014	Nov	26.5	young	87.6
Farm B	536	3	10/12/2014	Dec	30.5	young	0.0
Farm B	536	3	8/01/2015	Jan	31	young	0.0
Farm B	536	3	8/02/2015	Feb	29	young	0.0
Farm B	536	3	9/03/2015	Mar	26	young	NA
Farm B	536	3	9/04/2015	Apr	24	young	0.0
Farm B	536	3	19/05/2015	May	28	young	0.0
Farm B	538	3	11/08/2014	Aug	30	young	0.0
Farm B	538	3	9/09/2014	Sep	28.5	young	262.8
Farm B	538	3	9/10/2014	Oct	29	young	0.0
Farm B	538	3	10/11/2014	Nov	28	young	87.6
Farm B	538	3	10/12/2014	Dec	30	young	NA
Farm B	538	3	8/01/2015	Jan	32	young	0.0
Farm B	538	3	8/02/2015	Feb	29.5	young	0.0
Farm B	538	3	9/03/2015	Mar	27	young	175.2
Farm B	538	3	9/04/2015	Apr	28	young	0.0
Farm B	538	3	19/05/2015	May	28.5	young	87.6
Farm B	543	9	11/08/2014	Aug	30	old	1314.1
Farm B	543	9	9/09/2014	Sep	24	old	0.0
Farm B	543	9	9/10/2014	Oct	30.5	old	21113.7
Farm B	543	9	10/11/2014	Nov	31	old	0.0
Farm B	543	9	10/12/2014	Dec	34.5	old	1752.2
Farm B	543	9	8/01/2015	Jan	31	old	87.6
Farm B	543	9	8/02/2015	Feb	31.5	old	87.6
Farm B	543	9	9/03/2015	Mar	28	old	2190.2
Farm B	543	9	9/04/2015	Apr	29	old	0.0
Farm B	543	9	19/05/2015	May	32	old	1226.5
Farm B	561	7	11/08/2014	Aug	27	old	876.1
Farm B	561	7	9/09/2014	Sep	25	old	0.0
Farm B	561	7	9/10/2014	Oct	29.5	old	NA
Farm B	561	7	10/11/2014	Nov	28	old	31539.1

Farm B	561	7	10/12/2014	Dec	30	old	0.0
Farm B	561	7	8/01/2015	Jan	28.5	old	788.5
Farm B	561	7	8/02/2015	Feb	32	old	4643.3
Farm B	561	7	9/03/2015	Mar	29	old	2015.0
Farm B	561	7	9/04/2015	Apr	28.5	old	4292.8
Farm B	561	7	19/05/2015	May	29	old	40825.6
Farm B	576	3	11/08/2014	Aug	28	young	87.6
Farm B	576	3	9/09/2014	Sep	26.5	young	4030.0
Farm B	576	3	9/10/2014	Oct	18	young	2277.8
Farm B	576	3	10/11/2014	Nov	26	young	1577.0
Farm B	576	3	10/12/2014	Dec	26	young	0.0
Farm B	576	3	8/01/2015	Jan	26	young	14630.6
Farm B	576	3	8/02/2015	Feb	25	young	40475.2
Farm B	576	3	9/03/2015	Mar	22.5	young	87.6
Farm B	576	3	9/04/2015	Apr	23	young	140436.7
Farm B	576	3	19/05/2015	May	27.5	young	3942.4
Farm B	580	8	11/08/2014	Aug	28.5	old	22077.4
Farm B	580	8	9/09/2014	Sep	29	old	4380.4
Farm B	580	8	9/10/2014	Oct	27	old	1927.2
Farm B	580	8	10/11/2014	Nov	27	old	63341.1
Farm B	580	8	10/12/2014	Dec	26.5	old	2978.7
Farm B	580	8	8/01/2015	Jan	29.5	old	5344.1
Farm B	580	8	8/02/2015	Feb	32	old	4906.1
Farm B	580	8	9/03/2015	Mar	27	old	14893.5
Farm B	580	8	9/04/2015	Apr	26	old	1664.6
Farm B	580	8	19/05/2015	May	29.5	old	15944.8
Farm B	592	3	11/08/2014	Aug	35	young	1226.5
Farm B	592	3	9/09/2014	Sep	31.5	young	0.0
Farm B	592	3	9/10/2014	Oct	32	young	0.0
Farm B	592	3	10/11/2014	Nov	32	young	87.6
Farm B	592	3	10/12/2014	Dec	32.5	young	0.0
Farm B	592	3	8/01/2015	Jan	34.5	young	0.0
Farm B	592	3	8/02/2015	Feb	32.5	young	NA
Farm B	592	3	9/03/2015	Mar	28.5	young	262.8
Farm B	592	3	9/04/2015	Apr	23	young	0.0
Farm B	592	3	19/05/2015	May	31.5	young	0.0
Farm B	594	3	11/08/2014	Aug	34	young	0.0
Farm B	594	3	9/09/2014	Sep	30.5	young	0.0
Farm B	594	3	9/10/2014	Oct	30.5	young	87.6
Farm B	594	3	10/11/2014	Nov	31	young	87.6
Farm B	594	3	10/12/2014	Dec	32	young	65531.3
Farm B	594	3	8/01/2015	Jan	32.5	young	0.0
Farm B	594	3	8/02/2015	Feb	32	young	0.0
Farm B	594	3	9/03/2015	Mar	26	young	NA
Farm B	594	3	9/04/2015	Apr	26	young	0.0
Farm B	594	3	19/05/2015	May	33	young	0.0

Farm B	599	3	11/08/2014	Aug	33	young	0.0
Farm B	599	3	9/09/2014	Sep	28.5	young	613.3
Farm B	599	3	9/10/2014	Oct	20.5	young	476153.0
Farm B	599	3	10/11/2014	Nov	29	young	2102.6
Farm B	599	3	10/12/2014	Dec	32	young	64918.0
Farm B	599	3	8/01/2015	Jan	34.5	young	262.8
Farm B	599	3	8/02/2015	Feb	30	young	0.0
Farm B	599	3	9/03/2015	Mar	21.5	young	0.0
Farm B	599	3	9/04/2015	Apr	25	young	262.8
Farm B	599	3	19/05/2015	May	30.5	young	87.6
Farm B	605	3	11/08/2014	Aug	33.5	young	0.0
Farm B	605	3	9/09/2014	Sep	30	young	175.2
Farm B	605	3	9/10/2014	Oct	30	young	87.6
Farm B	605	3	10/11/2014	Nov	30	young	0.0
Farm B	605	3	10/12/2014	Dec	32	young	87.6
Farm B	605	3	8/01/2015	Jan	31.5	young	0.0
Farm B	605	3	8/02/2015	Feb	30	young	NA
Farm B	605	3	9/03/2015	Mar	22.5	young	87.6
Farm B	605	3	9/04/2015	Apr	27.5	young	0.0
Farm B	605	3	19/05/2015	May	30	young	0.0

Table 12. HCT and organisms/ μL , by cow and month, for Farm C, **Chapter 9.**

Farm	cowno	age	Sample date	month	HCT	runoff	organisms/ μL
Farm C	1	2	22/09/2014	Sep	35.5	0	0.0
Farm C	1	2	15/12/2014	Dec	33.5	0	0.0
Farm C	1	2	4/03/2015	Mar	34.5	0	339.0
Farm C	1	2	7/05/2015	May	34.5	0	103.0
Farm C	2	3	22/09/2014	Sep	35.5	0	0.0
Farm C	2	3	15/12/2014	Dec	36	0	0.0
Farm C	2	3	4/03/2015	Mar	35	0	0.0
Farm C	2	3	7/05/2015	May	37.5	0	0.0
Farm C	3	3	22/09/2014	Sep	31	0	87.6
Farm C	3	3	15/12/2014	Dec	31	0	0.0
Farm C	3	3	4/03/2015	Mar	32	0	331.9
Farm C	3	3	7/05/2015	May	36	0	0.0
Farm C	4	7	22/09/2014	Sep	17	1	193878.0
Farm C	4	7	15/12/2014	Dec	34	1	1314.1
Farm C	4	7	4/03/2015	Mar	29	1	108.6
Farm C	6	5	22/09/2014	Sep	24	0	6552777.0
Farm C	6	5	15/12/2014	Dec	32.5	0	7271.5
Farm C	6	5	4/03/2015	Mar	33	0	774.0
Farm C	6	5	7/05/2015	May	40	0	8937.1
Farm C	7	6	22/09/2014	Sep	32	0	0.0
Farm C	7	6	15/12/2014	Dec	33	0	751.5
Farm C	7	6	4/03/2015	Mar	31	0	613.3
Farm C	8	2	22/09/2014	Sep	30.5	0	87.6
Farm C	8	2	15/12/2014	Dec	32	0	0.0
Farm C	8	2	4/03/2015	Mar	30.5	0	353.8
Farm C	8	2	7/05/2015	May	34	0	0.0
Farm C	9	9	22/09/2014	Sep	29	1	1489.3
Farm C	9	9	15/12/2014	Dec	33.5	1	7622.0
Farm C	9	9	4/03/2015	Mar	35	1	18310.2
Farm C	9	9	7/05/2015	May	44	1	1261.8
Farm C	10	4	22/09/2014	Sep	34	0	0.0
Farm C	10	4	15/12/2014	Dec	35	0	487805.0
Farm C	10	4	4/03/2015	Mar	34.5	0	934.5
Farm C	11	10	22/09/2014	Sep	28	0	87.6
Farm C	11	10	15/12/2014	Dec	27	0	262.8
Farm C	11	10	4/03/2015	Mar	26	0	291.2
Farm C	12	4	22/09/2014	Sep	32	0	0.0
Farm C	12	4	15/12/2014	Dec	30	0	0.0
Farm C	12	4	4/03/2015	Mar	31	0	280.7
Farm C	13	6	22/09/2014	Sep	32	0	87.6
Farm C	13	6	15/12/2014	Dec	32	0	175.2
Farm C	13	6	4/03/2015	Mar	33	0	285.4
Farm C	13	6	7/05/2015	May	37.5	0	294.5

Farm C	14	8	22/09/2014	Sep	30.5	0	0.0
Farm C	14	8	15/12/2014	Dec	33	0	350.4
Farm C	14	8	4/03/2015	Mar	31	0	0.0
Farm C	14	8	7/05/2015	May	35	0	304.3
Farm C	15	9	22/09/2014	Sep	27.5	0	788.5
Farm C	15	9	15/12/2014	Dec	31	0	175.2
Farm C	15	9	4/03/2015	Mar	27.5	0	23.8
Farm C	15	9	7/05/2015	May	32	0	114.6
Farm C	16	6	22/09/2014	Sep	31	0	0.5
Farm C	16	6	15/12/2014	Dec	34.5	0	175.2
Farm C	16	6	4/03/2015	Mar	32	0	52.0
Farm C	16	6	7/05/2015	May	34	0	0.0
Farm C	17	3	22/09/2014	Sep	33	0	87.6
Farm C	17	3	15/12/2014	Dec	31.5	0	0.0
Farm C	17	3	4/03/2015	Mar	31	0	192.2
Farm C	17	3	7/05/2015	May	36	0	84.4
Farm C	18	8	22/09/2014	Sep	25	1	5960279.7
Farm C	18	8	15/12/2014	Dec	31	1	5607.0
Farm C	18	8	4/03/2015	Mar	28.5	1	283.4
Farm C	19	4	22/09/2014	Sep	32	0	0.0
Farm C	19	4	15/12/2014	Dec	31	0	87.6
Farm C	19	4	4/03/2015	Mar	32	0	3.7
Farm C	19	4	7/05/2015	May	38	0	0.0
Farm C	20	10	22/09/2014	Sep	31	0	0.0
Farm C	20	10	15/12/2014	Dec	31	0	0.0
Farm C	20	10	4/03/2015	Mar	31	0	0.4
Farm C	20	10	7/05/2015	May	33.5	0	0.0
Farm C	21	6	22/09/2014	Sep	31.5	0	0.0
Farm C	21	6	15/12/2014	Dec	32	0	0.0
Farm C	21	6	4/03/2015	Mar	34.5	0	382.2
Farm C	21	6	7/05/2015	May	35	0	1.2
Farm C	22	9	22/09/2014	Sep	32	0	87.6
Farm C	22	9	15/12/2014	Dec	33.5	0	175.2
Farm C	22	9	4/03/2015	Mar	36.5	0	525.7
Farm C	23	4	22/09/2014	Sep	30	0	0.0
Farm C	23	4	15/12/2014	Dec	28.5	0	175.2
Farm C	23	4	4/03/2015	Mar	30.5	0	525.7
Farm C	23	4	7/05/2015	May	34.5	0	38.4
Farm C	25	3	22/09/2014	Sep	28.5	1	7534.3
Farm C	25	3	15/12/2014	Dec	33	1	262.8
Farm C	25	3	4/03/2015	Mar	34.5	1	22.4
Farm C	25	3	7/05/2015	May	31.5	1	600.9
Farm C	26	8	22/09/2014	Sep	31.5	0	0.0
Farm C	26	8	15/12/2014	Dec	30	0	175.2
Farm C	26	8	4/03/2015	Mar	32.5	0	277.3
Farm C	26	8	7/05/2015	May	35	0	88.6

Farm C	27	2	22/09/2014	Sep	32	0	0.0
Farm C	27	2	15/12/2014	Dec	35	0	175.2
Farm C	27	2	4/03/2015	Mar	38.5	0	438.0
Farm C	27	2	7/05/2015	May	40	0	87.3
Farm C	29	5	22/09/2014	Sep	29.5	1	477116.7
Farm C	29	5	15/12/2014	Dec	33	1	518.3
Farm C	29	5	4/03/2015	Mar	30	1	15384.0
Farm C	29	5	7/05/2015	May	37	1	15607.7
Farm C	30	6	22/09/2014	Sep	30	1	521096.3
Farm C	30	6	15/12/2014	Dec	30	1	262.8
Farm C	30	6	4/03/2015	Mar	28.5	1	231.1
Farm C	30	6	7/05/2015	May	35.5	1	5150.2
Farm C	31	3	22/09/2014	Sep	19	0	317669.0
Farm C	31	3	15/12/2014	Dec	32	0	296380.1
Farm C	31	3	4/03/2015	Mar	37	0	NA
Farm C	32	6	22/09/2014	Sep	31	0	87.6
Farm C	32	6	15/12/2014	Dec	35	0	0.0
Farm C	32	6	4/03/2015	Mar	37.5	0	310.3
Farm C	32	6	7/05/2015	May	37	0	0.4
Farm C	33	5	22/09/2014	Sep	31.5	0	0.0
Farm C	33	5	15/12/2014	Dec	29	0	350.4
Farm C	33	5	4/03/2015	Mar	30	0	281.9
Farm C	34	6	22/09/2014	Sep	32.5	0	0.0
Farm C	34	6	15/12/2014	Dec	32	0	87.6
Farm C	34	6	4/03/2015	Mar	34	0	0.0
Farm C	34	6	7/05/2015	May	36.5	0	0.0
Farm C	35	8	22/09/2014	Sep	29.5	0	0.0
Farm C	35	8	15/12/2014	Dec	31	0	87.6
Farm C	35	8	4/03/2015	Mar	29.5	0	385.7
Farm C	36	4	22/09/2014	Sep	32	0	87.6
Farm C	36	4	15/12/2014	Dec	32.5	0	0.0
Farm C	36	4	4/03/2015	Mar	30.5	0	0.0
Farm C	36	4	7/05/2015	May	37	0	0.0
Farm C	37	10	22/09/2014	Sep	28.5	1	600557.3
Farm C	37	10	15/12/2014	Dec	27.5	1	525.7
Farm C	37	10	4/03/2015	Mar	29	1	218.3
Farm C	37	10	7/05/2015	May	35.5	1	3.2
Farm C	38	8	22/09/2014	Sep	19	1	14017.4
Farm C	38	8	15/12/2014	Dec	28	1	65881.7
Farm C	38	8	4/03/2015	Mar	24.5	1	279.1
Farm C	39	4	22/09/2014	Sep	29	0	0.0
Farm C	39	4	15/12/2014	Dec	29	0	0.0
Farm C	39	4	4/03/2015	Mar	29.5	0	0.0
Farm C	39	4	7/05/2015	May	33.5	0	280.7
Farm C	40	5	22/09/2014	Sep	22	1	46695.4
Farm C	40	5	15/12/2014	Dec	30.5	1	15944.8

Farm C	40	5	4/03/2015	Mar	29	1	287.1
Farm C	40	5	7/05/2015	May	34	1	179.9
Farm C	41	2	22/09/2014	Sep	33.5	0	87.6
Farm C	41	2	15/12/2014	Dec	35	0	43.8
Farm C	41	2	4/03/2015	Mar	35	0	0.0
Farm C	42	5	22/09/2014	Sep	32.5	0	87.6
Farm C	42	5	15/12/2014	Dec	31.5	0	87.6
Farm C	42	5	4/03/2015	Mar	31	0	0.0
Farm C	42	5	7/05/2015	May	32	0	0.0
Farm C	43	3	22/09/2014	Sep	33.5	0	87.6
Farm C	43	3	15/12/2014	Dec	30.5	0	175.2
Farm C	43	3	4/03/2015	Mar	32	0	3.7
Farm C	43	3	7/05/2015	May	34.5	0	279.1
Farm C	44	4	22/09/2014	Sep	29.5	0	87.6
Farm C	44	4	15/12/2014	Dec	24	0	87.6
Farm C	44	4	4/03/2015	Mar	26.5	0	288.1
Farm C	44	4	7/05/2015	May	31	0	1.3
Farm C	45	4	22/09/2014	Sep	33	0	0.0
Farm C	45	4	15/12/2014	Dec	33.5	0	262.8
Farm C	45	4	4/03/2015	Mar	35	0	0.0
Farm C	45	4	7/05/2015	May	39	0	0.0
Farm C	46	6	22/09/2014	Sep	28	1	54755.4
Farm C	46	6	15/12/2014	Dec	32.5	1	350.4
Farm C	46	6	4/03/2015	Mar	34	1	295.8
Farm C	46	6	7/05/2015	May	36.5	1	311.1
Farm C	47	3	22/09/2014	Sep	32	0	87.6
Farm C	47	3	15/12/2014	Dec	32.5	0	2007.7
Farm C	47	3	4/03/2015	Mar	32	0	0.0
Farm C	47	3	7/05/2015	May	37	0	125.6
Farm C	48	11	22/09/2014	Sep	35.5	1	18310.2
Farm C	48	11	15/12/2014	Dec	33.5	1	2277.8
Farm C	48	11	4/03/2015	Mar	31	1	6838.5
Farm C	48	11	7/05/2015	May	35.5	1	21970.7
Farm C	49	3	22/09/2014	Sep	29	0	0.0
Farm C	49	3	15/12/2014	Dec	25	0	0.0
Farm C	49	3	4/03/2015	Mar	26	0	NA
Farm C	50	4	22/09/2014	Sep	31.5	0	0.0
Farm C	50	4	15/12/2014	Dec	30	0	350.4
Farm C	50	4	4/03/2015	Mar	30	0	295.2
Farm C	50	4	7/05/2015	May	33	0	100.8
Farm C	51	5	22/09/2014	Sep	30	1	52477.6
Farm C	51	5	15/12/2014	Dec	32.5	1	52039.5
Farm C	51	5	4/03/2015	Mar	30.5	1	232.3
Farm C	51	5	7/05/2015	May	36	1	5863.1
Farm C	52	6	22/09/2014	Sep	35	0	0.0
Farm C	52	6	15/12/2014	Dec	35	0	1051.3

Farm C	52	6	4/03/2015	Mar	33.5	0	278.9
Farm C	52	6	7/05/2015	May	36	0	0.0
Farm C	53	11	22/09/2014	Sep	29.5	0	0.0
Farm C	53	11	15/12/2014	Dec	33.5	0	43.8
Farm C	53	11	4/03/2015	Mar	32.5	0	282.0
Farm C	54	8	22/09/2014	Sep	24.5	1	683873.2
Farm C	54	8	15/12/2014	Dec	30	1	38723.0
Farm C	54	8	4/03/2015	Mar	24.5	1	261.6
Farm C	55	6	22/09/2014	Sep	29.5	0	0.0
Farm C	55	6	15/12/2014	Dec	29	0	262.8
Farm C	55	6	4/03/2015	Mar	30.5	0	7.3
Farm C	55	6	7/05/2015	May	32	0	59.3
Farm C	56	4	15/12/2014	Dec	32.5	0	87.6
Farm C	56	4	4/03/2015	Mar	33.5	0	876.1
Farm C	56	4	7/05/2015	May	34	0	207.7
Farm C	57	4	22/09/2014	Sep	26	1	13228.9
Farm C	57	4	15/12/2014	Dec	29	1	5694.6
Farm C	57	4	4/03/2015	Mar	28.5	1	876.1
Farm C	57	4	7/05/2015	May	35	1	76.8
Farm C	58	9	22/09/2014	Sep	30	0	87.6
Farm C	58	9	15/12/2014	Dec	30.5	0	175.2
Farm C	58	9	4/03/2015	Mar	33	0	525.7
Farm C	59	9	22/09/2014	Sep	33	0	87.6
Farm C	59	9	15/12/2014	Dec	32.5	0	438.0
Farm C	59	9	4/03/2015	Mar	34	0	316.4
Farm C	59	9	7/05/2015	May	36	0	122.8
Farm C	60	6	22/09/2014	Sep	34	0	0.0
Farm C	60	6	15/12/2014	Dec	31.5	0	87.6
Farm C	60	6	4/03/2015	Mar	28	0	257.7
Farm C	60	6	7/05/2015	May	34	0	13.1
Farm C	61	5	22/09/2014	Sep	24.5	1	25669.3
Farm C	61	5	15/12/2014	Dec	31.5	1	50199.8
Farm C	61	5	4/03/2015	Mar	27	1	268.8
Farm C	61	5	7/05/2015	May	33	1	1700.5
Farm C	62	2	15/12/2014	Dec	35.5	0	0.0
Farm C	62	2	4/03/2015	Mar	35	0	334.0
Farm C	62	2	7/05/2015	May	37	0	46.8
Farm C	63	5	22/09/2014	Sep	38	0	0.0
Farm C	63	5	22/09/2014	Sep	30.5	0	87.6
Farm C	63	5	15/12/2014	Dec	32	0	0.0
Farm C	63	5	4/03/2015	Mar	31.5	0	700.9
Farm C	63	5	7/05/2015	May	39.5	0	0.0
Farm C	64	NA	22/09/2014	Sep	34	0	87.6
Farm C	64	NA	15/12/2014	Dec	39.5	0	0.0
Farm C	64	NA	4/03/2015	Mar	39.5	0	315.5
Farm C	64	NA	7/05/2015	May	41	0	87.6

Farm C	65	6	22/09/2014	Sep	33	0	0.0
Farm C	65	6	15/12/2014	Dec	38	0	0.0
Farm C	65	6	4/03/2015	Mar	38	0	372.6
Farm C	65	6	7/05/2015	May	39	0	82.2
Farm C	66	4	22/09/2014	Sep	30.5	1	1138.9
Farm C	66	4	15/12/2014	Dec	25.5	1	438.0
Farm C	66	4	4/03/2015	Mar	27.5	1	6132.6
Farm C	66	4	7/05/2015	May	32	1	106.4
Farm C	67	5	22/09/2014	Sep	29	1	2255309.6
Farm C	67	5	15/12/2014	Dec	30.5	1	33422.7
Farm C	67	5	4/03/2015	Mar	29.5	1	46520.2
Farm C	67	5	7/05/2015	May	35	1	NA
Farm C	68	10	22/09/2014	Sep	28	1	5081.3
Farm C	68	10	15/12/2014	Dec	32	1	16470.4
Farm C	68	10	4/03/2015	Mar	29	1	281.0
Farm C	68	10	7/05/2015	May	32	1	9.4
Farm C	69	4	22/09/2014	Sep	34	0	0.0
Farm C	69	4	15/12/2014	Dec	30	0	175.2
Farm C	69	4	4/03/2015	Mar	32	0	0.4
Farm C	69	4	7/05/2015	May	37	0	2.5
Farm C	70	7	22/09/2014	Sep	24	1	574537.6
Farm C	70	7	15/12/2014	Dec	31	1	29348.9
Farm C	70	7	4/03/2015	Mar	32	1	8.4
Farm C	70	7	7/05/2015	May	37	1	2108.4
Farm C	71	3	22/09/2014	Sep	36.5	0	87.6
Farm C	71	3	15/12/2014	Dec	35	0	0.5
Farm C	71	3	4/03/2015	Mar	38	0	284.7
Farm C	71	3	7/05/2015	May	39	0	0.0
Farm C	72	7	22/09/2014	Sep	27	0	87.6
Farm C	72	7	15/12/2014	Dec	31.5	0	175.2
Farm C	72	7	4/03/2015	Mar	33	0	525.7
Farm C	72	7	7/05/2015	May	33	0	438.9
Farm C	73	2	22/09/2014	Sep	35	0	0.0
Farm C	73	2	15/12/2014	Dec	30	0	43.8
Farm C	73	2	4/03/2015	Mar	29	0	613.3
Farm C	73	2	7/05/2015	May	32.5	0	107.0
Farm C	74	2	22/09/2014	Sep	35.5	0	87.6
Farm C	74	2	15/12/2014	Dec	35.5	0	1.2
Farm C	74	2	4/03/2015	Mar	36.5	0	302.4
Farm C	74	2	7/05/2015	May	39.5	0	0.0
Farm C	75	3	22/09/2014	Sep	31	1	5797415.2
Farm C	75	3	15/12/2014	Dec	32	1	NA
Farm C	75	3	4/03/2015	Mar	30.5	1	934.5
Farm C	75	3	7/05/2015	May	35.5	1	5519.3
Farm C	76	4	22/09/2014	Sep	32.5	0	0.0
Farm C	76	4	15/12/2014	Dec	34	0	175.2

Farm C	76	4	4/03/2015	Mar	35	0	304.8
Farm C	76	4	7/05/2015	May	36.5	0	190.6
Farm C	77	2	22/09/2014	Sep	34	0	87.6
Farm C	77	2	15/12/2014	Dec	33.5	0	262.8
Farm C	77	2	4/03/2015	Mar	35	0	15.1
Farm C	77	2	7/05/2015	May	40	0	110.9
Farm C	78	6	22/09/2014	Sep	29	0	0.0
Farm C	78	6	15/12/2014	Dec	32.5	0	350.4
Farm C	78	6	4/03/2015	Mar	30	0	269.6
Farm C	78	6	7/05/2015	May	36	0	0.0
Farm C	79	7	22/09/2014	Sep	19	1	272112.5
Farm C	79	7	15/12/2014	Dec	29	1	5869.8
Farm C	79	7	4/03/2015	Mar	28	1	14893.5
Farm C	79	7	7/05/2015	May	29	1	1027.7
Farm C	80	7	22/09/2014	Sep	34	0	0.0
Farm C	80	7	15/12/2014	Dec	35	0	262.8
Farm C	80	7	4/03/2015	Mar	33	0	288.5
Farm C	80	7	7/05/2015	May	35	0	123.9
Farm C	81	3	22/09/2014	Sep	26.5	1	5256.5
Farm C	81	3	15/12/2014	Dec	34.5	1	26926.5
Farm C	81	3	4/03/2015	Mar	29.5	1	289.3
Farm C	81	3	7/05/2015	May	39	1	951.2
Farm C	82	2	22/09/2014	Sep	30	0	0.0
Farm C	82	2	15/12/2014	Dec	30	0	0.2
Farm C	82	2	4/03/2015	Mar	32	0	0.0
Farm C	82	2	7/05/2015	May	37	0	87.6
Farm C	83	5	22/09/2014	Sep	31.5	0	0.0
Farm C	83	5	15/12/2014	Dec	33	0	0.0
Farm C	83	5	4/03/2015	Mar	38	0	293.4
Farm C	84	3	22/09/2014	Sep	35.5	0	0.0
Farm C	84	3	15/12/2014	Dec	34	0	43.8
Farm C	84	3	4/03/2015	Mar	34.5	0	288.9
Farm C	84	3	7/05/2015	May	36.5	0	1.2
Farm C	85	NA	22/09/2014	Sep	37	0	0.0
Farm C	85	NA	15/12/2014	Dec	35.5	0	0.0
Farm C	86	4	22/09/2014	Sep	28.5	1	3026441.0
Farm C	86	4	15/12/2014	Dec	36	1	4292.8
Farm C	86	4	4/03/2015	Mar	35	1	257.7
Farm C	86	4	7/05/2015	May	40	1	4946.2
Farm C	87	4	22/09/2014	Sep	26	1	5344.1
Farm C	87	4	15/12/2014	Dec	31.5	1	36620.4
Farm C	87	4	4/03/2015	Mar	29	1	4257.9
Farm C	87	4	7/05/2015	May	34.5	1	38.7
Farm C	88	4	22/09/2014	Sep	24	1	922869.6
Farm C	88	4	15/12/2014	Dec	28.5	1	2453.0
Farm C	88	4	4/03/2015	Mar	28	1	288.6

Farm C	88	4	7/05/2015	May	29	1	NA
Farm C	89	4	22/09/2014	Sep	30	1	351836.4
Farm C	89	4	15/12/2014	Dec	29.5	1	57296.1
Farm C	89	4	4/03/2015	Mar	30	1	175.2
Farm C	91	4	22/09/2014	Sep	33	0	87.6
Farm C	91	4	15/12/2014	Dec	26.5	0	87.6
Farm C	91	4	4/03/2015	Mar	31	0	262.9
Farm C	91	4	7/05/2015	May	33	0	87.6
Farm C	92	6	22/09/2014	Sep	20	1	938814.4
Farm C	92	6	15/12/2014	Dec	29	1	2715.9
Farm C	92	6	4/03/2015	Mar	27	1	NA
Farm C	92	6	7/05/2015	May	31	1	12170.8
Farm C	93	6	22/09/2014	Sep	21.5	1	2238401.2
Farm C	93	6	15/12/2014	Dec	30	1	108459.5
Farm C	93	6	4/03/2015	Mar	29	1	192.2
Farm C	93	6	7/05/2015	May	33	1	13168.3
Farm C	94	6	22/09/2014	Sep	33	0	87.6
Farm C	94	6	15/12/2014	Dec	32	0	262.8
Farm C	94	6	4/03/2015	Mar	33	0	302.6
Farm C	94	6	7/05/2015	May	38	0	112.1
Farm C	96	4	22/09/2014	Sep	26	0	0.0
Farm C	96	4	22/09/2014	Sep	33.5	0	0.0
Farm C	96	4	15/12/2014	Dec	30	0	0.0
Farm C	96	4	4/03/2015	Mar	32.5	0	7.1
Farm C	96	4	7/05/2015	May	34	0	24.9
Farm C	97	6	22/09/2014	Sep	30.5	0	0.0
Farm C	97	6	15/12/2014	Dec	30	0	43.8
Farm C	97	6	4/03/2015	Mar	30	0	700.9
Farm C	97	6	7/05/2015	May	35.5	0	389.3
Farm C	98	6	22/09/2014	Sep	26	1	56157.1
Farm C	98	6	15/12/2014	Dec	34.5	1	1138.9
Farm C	98	6	4/03/2015	Mar	30.5	1	222.6
Farm C	98	6	7/05/2015	May	36.5	1	83.9
Farm C	99	4	22/09/2014	Sep	34	0	87.6
Farm C	99	4	15/12/2014	Dec	33	0	87.6
Farm C	99	4	4/03/2015	Mar	36.5	0	1787.7
Farm C	99	4	7/05/2015	May	40	0	0.0
Farm C	100	4	22/09/2014	Sep	32	0	0.0
Farm C	100	4	15/12/2014	Dec	34	0	0.0
Farm C	100	4	4/03/2015	Mar	35	0	0.0
Farm C	100	4	7/05/2015	May	39	0	266.2
Farm C	102	4	22/09/2014	Sep	30.5	0	87.6
Farm C	102	4	15/12/2014	Dec	36.5	0	0.0
Farm C	102	4	4/03/2015	Mar	32.5	0	700.9
Farm C	102	4	7/05/2015	May	38	0	87.6
Farm C	103	3	22/09/2014	Sep	30.5	0	0.0

Farm C	103	3	15/12/2014	Dec	21	0	87.6
Farm C	103	3	4/03/2015	Mar	28.5	0	336.7
Farm C	104	NA	22/09/2014	Sep	30	1	5519.3
Farm C	104	NA	15/12/2014	Dec	32	1	2102.6
Farm C	104	NA	4/03/2015	Mar	34	1	256.3
Farm C	105	3	22/09/2014	Sep	24	1	4292.8
Farm C	105	3	15/12/2014	Dec	29	1	25406.5
Farm C	105	3	4/03/2015	Mar	31	1	295.2
Farm C	105	3	7/05/2015	May	34	1	1096.4
Farm C	106	8	22/09/2014	Sep	30	1	1752.2
Farm C	106	8	15/12/2014	Dec	30	1	13053.7
Farm C	106	8	4/03/2015	Mar	26.5	1	NA
Farm C	106	8	7/05/2015	May	32	1	4638.0
Farm C	107	4	22/09/2014	Sep	38	0	0.0
Farm C	107	4	15/12/2014	Dec	34	0	175.2
Farm C	107	4	4/03/2015	Mar	37.5	0	372.9
Farm C	107	4	7/05/2015	May	42.5	0	307.1
Farm C	108	5	22/09/2014	Sep	30	1	2498423.7
Farm C	108	5	15/12/2014	Dec	32	1	6132.6
Farm C	108	5	4/03/2015	Mar	34.5	1	215.8
Farm C	108	5	7/05/2015	May	35.5	1	1438.0
Farm C	109	4	22/09/2014	Sep	33	0	87.6
Farm C	109	4	15/12/2014	Dec	32.5	0	0.0
Farm C	109	4	4/03/2015	Mar	33.5	0	298.7
Farm C	110	3	22/09/2014	Sep	30.5	0	0.0
Farm C	110	3	15/12/2014	Dec	31.5	0	175.2
Farm C	110	3	4/03/2015	Mar	33.5	0	0.1
Farm C	110	3	7/05/2015	May	34.5	0	0.0
Farm C	111	2	22/09/2014	Sep	33	0	87.6
Farm C	111	2	15/12/2014	Dec	29.5	0	87.6
Farm C	111	2	4/03/2015	Mar	27.5	0	295.6
Farm C	111	2	7/05/2015	May	38.5	0	0.0
Farm C	112	6	22/09/2014	Sep	30	0	0.0
Farm C	112	6	15/12/2014	Dec	29	0	0.0
Farm C	112	6	4/03/2015	Mar	31	0	256.3
Farm C	112	6	7/05/2015	May	31.5	0	4.9
Farm C	113	5	22/09/2014	Sep	30.5	0	0.0
Farm C	113	5	15/12/2014	Dec	30	0	0.0
Farm C	113	5	4/03/2015	Mar	29.5	0	371.3
Farm C	113	5	7/05/2015	May	34.5	0	86.2
Farm C	114	3	22/09/2014	Sep	32.5	0	0.0
Farm C	114	3	15/12/2014	Dec	32	0	87.6
Farm C	114	3	4/03/2015	Mar	38.5	0	10.1
Farm C	115	8	22/09/2014	Sep	29	0	87.6
Farm C	115	8	15/12/2014	Dec	25	0	0.0
Farm C	115	8	4/03/2015	Mar	26	0	290.8

Farm C	116	2	22/09/2014	Sep	34.5	0	0.0
Farm C	116	2	15/12/2014	Dec	39	0	43.8
Farm C	116	2	4/03/2015	Mar	36.5	0	283.3
Farm C	116	2	7/05/2015	May	36	0	442.2
Farm C	117	6	22/09/2014	Sep	31	0	87.6
Farm C	117	6	15/12/2014	Dec	30	0	87.6
Farm C	117	6	4/03/2015	Mar	29	0	613.3
Farm C	117	6	7/05/2015	May	39	0	0.0
Farm C	118	3	22/09/2014	Sep	31.5	0	87.6
Farm C	118	3	15/12/2014	Dec	33	0	43.8
Farm C	118	3	4/03/2015	Mar	34	0	291.6
Farm C	118	3	7/05/2015	May	37	0	335.0
Farm C	119	2	22/09/2014	Sep	33.5	0	87.6
Farm C	119	2	15/12/2014	Dec	31	0	525.7
Farm C	119	2	4/03/2015	Mar	33.5	0	0.0
Farm C	119	2	7/05/2015	May	38	0	57.5
Farm C	120	4	22/09/2014	Sep	32	0	87.6
Farm C	120	4	15/12/2014	Dec	30	0	0.0
Farm C	120	4	4/03/2015	Mar	33.5	0	0.0
Farm C	120	4	7/05/2015	May	36.5	0	299.7
Farm C	121	5	22/09/2014	Sep	29	0	0.0
Farm C	121	5	15/12/2014	Dec	29.5	0	175.2
Farm C	121	5	4/03/2015	Mar	28.5	0	367.1
Farm C	121	5	7/05/2015	May	31	0	267.9
Farm C	122	9	22/09/2014	Sep	31	0	0.0
Farm C	122	9	15/12/2014	Dec	30	0	43.8
Farm C	122	9	4/03/2015	Mar	31	0	525.7
Farm C	123	5	22/09/2014	Sep	31.5	0	0.0
Farm C	123	5	15/12/2014	Dec	30	0	0.0
Farm C	123	5	4/03/2015	Mar	30	0	306.5
Farm C	123	5	7/05/2015	May	39	0	0.0
Farm C	124	3	22/09/2014	Sep	32	0	0.0
Farm C	124	3	15/12/2014	Dec	25.5	0	0.0
Farm C	124	3	4/03/2015	Mar	29	0	262.8
Farm C	125	2	22/09/2014	Sep	31	0	0.0
Farm C	125	2	15/12/2014	Dec	29.5	0	43.8
Farm C	125	2	4/03/2015	Mar	28.5	0	20.3
Farm C	125	2	7/05/2015	May	31.5	0	0.0
Farm C	126	2	22/09/2014	Sep	34	0	87.6
Farm C	126	2	15/12/2014	Dec	32	0	43.8
Farm C	126	2	4/03/2015	Mar	33	0	267.7
Farm C	126	2	7/05/2015	May	36	0	0.5
Farm C	127	4	22/09/2014	Sep	35.5	0	0.0
Farm C	127	4	15/12/2014	Dec	35	0	0.0
Farm C	127	4	4/03/2015	Mar	36.5	0	6.5
Farm C	128	3	22/09/2014	Sep	35	0	87.6

Farm C	128	3	15/12/2014	Dec	34.5	0	0.0
Farm C	128	3	4/03/2015	Mar	35	0	525.7
Farm C	128	3	7/05/2015	May	39	0	0.0
Farm C	129	8	22/09/2014	Sep	35.5	1	5694.6
Farm C	129	8	15/12/2014	Dec	31.5	1	1226.5
Farm C	129	8	4/03/2015	Mar	27.5	1	258.8
Farm C	130	8	22/09/2014	Sep	30	0	0.0
Farm C	130	8	15/12/2014	Dec	30.5	0	43.8
Farm C	130	8	4/03/2015	Mar	30	0	438.0
Farm C	130	8	7/05/2015	May	32	0	0.4
Farm C	131	2	22/09/2014	Sep	33.5	0	87.6
Farm C	131	2	15/12/2014	Dec	34	0	0.0
Farm C	131	2	4/03/2015	Mar	35	0	263.3
Farm C	131	2	7/05/2015	May	36	0	3.2
Farm C	132	8	22/09/2014	Sep	28.5	1	1624176.9
Farm C	132	8	15/12/2014	Dec	29	1	9023.7
Farm C	132	8	4/03/2015	Mar	28	1	23.8
Farm C	133	5	22/09/2014	Sep	30.5	0	87.6
Farm C	133	5	15/12/2014	Dec	28	0	87.6
Farm C	133	5	4/03/2015	Mar	29	0	0.0
Farm C	133	5	7/05/2015	May	29	0	1.0
Farm C	134	3	22/09/2014	Sep	24.5	1	29962.2
Farm C	134	3	15/12/2014	Dec	33	1	876.1
Farm C	134	3	4/03/2015	Mar	33	1	263.9
Farm C	134	3	7/05/2015	May	33	1	972.8
Farm C	135	5	22/09/2014	Sep	32.5	0	0.0
Farm C	135	5	15/12/2014	Dec	31.5	0	6.7
Farm C	135	5	4/03/2015	Mar	32	0	308.8
Farm C	135	5	7/05/2015	May	39	0	71.3
Farm C	136	4	22/09/2014	Sep	32	0	87.6
Farm C	136	4	15/12/2014	Dec	32	0	1138.9
Farm C	136	4	4/03/2015	Mar	37	0	0.0
Farm C	136	4	7/05/2015	May	36	0	0.0
Farm C	137	7	22/09/2014	Sep	33	0	0.0
Farm C	137	7	15/12/2014	Dec	31.5	0	525.7
Farm C	137	7	4/03/2015	Mar	35	0	293.0
Farm C	137	7	7/05/2015	May	33.5	0	4.6
Farm C	138	8	22/09/2014	Sep	35	0	0.0
Farm C	138	8	15/12/2014	Dec	26	0	262.8
Farm C	138	8	4/03/2015	Mar	26	0	269.6
Farm C	139	3	22/09/2014	Sep	33	0	0.0
Farm C	139	3	15/12/2014	Dec	33	0	0.0
Farm C	139	3	4/03/2015	Mar	37	0	283.7
Farm C	139	3	7/05/2015	May	36.5	0	0.0
Farm C	140	4	22/09/2014	Sep	29.5	1	1750420.9
Farm C	140	4	15/12/2014	Dec	31	1	3416.7

Farm C	140	4	4/03/2015	Mar	25	1	8060.0
Farm C	141	2	22/09/2014	Sep	35	0	0.0
Farm C	141	2	4/03/2015	Mar	34.5	0	283.2
Farm C	141	2	7/05/2015	May	36	0	2.3
Farm C	142	5	22/09/2014	Sep	29	0	87.6
Farm C	142	5	15/12/2014	Dec	26	0	87.6
Farm C	142	5	4/03/2015	Mar	25	0	262.8
Farm C	142	5	7/05/2015	May	31.5	0	7104.1
Farm C	143	8	22/09/2014	Sep	25	1	392224.0
Farm C	143	8	15/12/2014	Dec	33	1	175.2
Farm C	143	8	4/03/2015	Mar	32	1	1.5
Farm C	143	8	7/05/2015	May	35	1	171.3
Farm C	144	8	22/09/2014	Sep	30	0	0.0
Farm C	145	3	22/09/2014	Sep	32	0	0.0
Farm C	145	3	15/12/2014	Dec	30	0	350.4
Farm C	145	3	4/03/2015	Mar	30	0	350.4
Farm C	145	3	7/05/2015	May	33	0	0.0
Farm C	147	8	22/09/2014	Sep	30	0	0.0
Farm C	147	8	15/12/2014	Dec	31.5	0	438.0
Farm C	147	8	4/03/2015	Mar	30	0	3.7
Farm C	147	8	7/05/2015	May	33.5	0	301.7
Farm C	148	3	22/09/2014	Sep	33.5	0	0.0
Farm C	148	3	15/12/2014	Dec	39	0	876.1
Farm C	148	3	4/03/2015	Mar	36	0	0.0
Farm C	148	3	7/05/2015	May	40	0	61.1
Farm C	149	11	22/09/2014	Sep	32.5	0	0.0
Farm C	149	11	15/12/2014	Dec	29	0	87.6
Farm C	149	11	4/03/2015	Mar	32.5	0	0.0
Farm C	149	11	7/05/2015	May	33	0	8.1
Farm C	150	7	22/09/2014	Sep	30.5	0	0.0
Farm C	150	7	15/12/2014	Dec	28.5	0	43.8
Farm C	150	7	4/03/2015	Mar	31.5	0	297.4
Farm C	150	7	7/05/2015	May	35	0	86.0
Farm C	151	2	22/09/2014	Sep	30	0	87.6
Farm C	151	2	15/12/2014	Dec	33	0	0.0
Farm C	151	2	4/03/2015	Mar	32.5	0	438.0
Farm C	151	2	7/05/2015	May	34.5	0	336.4
Farm C	152	7	22/09/2014	Sep	31	0	87.6
Farm C	152	7	15/12/2014	Dec	33	0	0.0
Farm C	152	7	4/03/2015	Mar	30.5	0	267.7
Farm C	152	7	7/05/2015	May	32	0	312.4
Farm C	153	5	22/09/2014	Sep	33.5	0	87.6
Farm C	153	5	15/12/2014	Dec	35.5	0	0.0
Farm C	153	5	4/03/2015	Mar	36	0	373.2
Farm C	153	5	7/05/2015	May	36.5	0	103.1
Farm C	154	2	22/09/2014	Sep	31	0	0.7

Farm C	154	2	15/12/2014	Dec	32	0	0.3
Farm C	154	2	4/03/2015	Mar	30	0	0.0
Farm C	154	2	7/05/2015	May	31	0	0.0
Farm C	155	5	22/09/2014	Sep	33.5	0	0.0
Farm C	155	5	15/12/2014	Dec	34	0	262.8
Farm C	155	5	4/03/2015	Mar	35	0	350.4
Farm C	155	5	7/05/2015	May	38	0	104.0
Farm C	157	2	22/09/2014	Sep	30	0	87.6
Farm C	157	2	15/12/2014	Dec	28	0	262.8
Farm C	157	2	4/03/2015	Mar	33	0	306.5
Farm C	157	2	7/05/2015	May	33.5	0	332.2
Farm C	158	2	22/09/2014	Sep	32	0	87.6
Farm C	158	2	15/12/2014	Dec	30.5	0	175.2
Farm C	158	2	4/03/2015	Mar	28.5	0	288.9
Farm C	158	2	7/05/2015	May	38	0	0.0
Farm C	159	2	22/09/2014	Sep	31.5	0	87.6
Farm C	159	2	15/12/2014	Dec	31	0	175.2
Farm C	159	2	4/03/2015	Mar	31.5	0	350.4
Farm C	159	2	7/05/2015	May	38	0	282.3
Farm C	160	2	22/09/2014	Sep	26.5	0	0.0
Farm C	160	2	15/12/2014	Dec	25.5	0	2.0
Farm C	160	2	4/03/2015	Mar	28.5	0	0.0
Farm C	161	2	22/09/2014	Sep	30.5	0	87.6
Farm C	161	2	15/12/2014	Dec	34	0	525.7
Farm C	161	2	4/03/2015	Mar	34.5	0	322.5
Farm C	161	2	7/05/2015	May	44.5	0	142.2
Farm C	162	2	22/09/2014	Sep	30.5	0	87.6
Farm C	162	2	15/12/2014	Dec	32	0	0.0
Farm C	162	2	4/03/2015	Mar	31.5	0	280.7
Farm C	162	2	7/05/2015	May	30.5	0	0.0

Table 13. ECM production data, by cow and herd test, for Farm A, **Chapter 9.**

Farm	cowno	age	herd	ECM/kg	Herd.Test.Date	Calving.date	dim
Farm A	1	3	Thin	19.18	1/10/2014	24/07/2014	69
Farm A	1	3	Thin	18.91	27/11/2014	24/07/2014	126
Farm A	1	3	Normal	10.03	8/02/2015	24/07/2014	199
Farm A	3	3	Thin	18.67	1/10/2014	28/07/2014	65
Farm A	3	3	Thin	14.89	27/11/2014	28/07/2014	122
Farm A	3	3	Thin	11.12	8/02/2015	28/07/2014	195
Farm A	4	3	Thin	17.25	1/10/2014	19/07/2014	74
Farm A	4	3	Thin	14.26	27/11/2014	19/07/2014	131
Farm A	4	3	Thin	11.24	8/02/2015	19/07/2014	204
Farm A	8	3	Thin	20.56	1/10/2014	19/07/2014	74
Farm A	8	3	Thin	13.58	27/11/2014	19/07/2014	131
Farm A	14	3	Normal	16.60	1/10/2014	28/07/2014	65
Farm A	14	3	Normal	17.33	27/11/2014	28/07/2014	122
Farm A	14	3	Thin	10.42	8/02/2015	28/07/2014	195
Farm A	16	3	Thin	18.60	1/10/2014	21/07/2014	72
Farm A	16	3	Thin	16.06	27/11/2014	21/07/2014	129
Farm A	16	3	Thin	10.71	8/02/2015	21/07/2014	202
Farm A	19	3	Thin	19.61	1/10/2014	NA	NA
Farm A	19	3	Thin	21.96	27/11/2014	NA	NA
Farm A	19	3	Normal	11.78	8/02/2015	NA	NA
Farm A	30	3	Thin	24.11	1/10/2014	29/07/2014	64
Farm A	30	3	Thin	19.21	27/11/2014	29/07/2014	121
Farm A	30	3	Normal	12.01	8/02/2015	29/07/2014	194
Farm A	44	3	Normal	19.61	1/10/2014	28/07/2014	65
Farm A	44	3	Normal	16.35	27/11/2014	28/07/2014	122
Farm A	44	3	Normal	7.59	8/02/2015	28/07/2014	195
Farm A	67	4	Thin	9.56	27/11/2014	21/07/2014	129
Farm A	84	6	Thin	21.50	1/10/2014	15/07/2014	78
Farm A	84	6	Thin	18.58	27/11/2014	15/07/2014	135
Farm A	84	6	Thin	14.05	8/02/2015	15/07/2014	208
Farm A	91	2	Normal	12.37	27/11/2014	18/07/2014	132
Farm A	91	2	Thin	9.19	8/02/2015	18/07/2014	205
Farm A	102	4	Thin	20.24	1/10/2014	27/07/2014	66
Farm A	102	4	Normal	20.25	27/11/2014	27/07/2014	123
Farm A	102	4	Thin	11.77	8/02/2015	27/07/2014	196
Farm A	120	5	Normal	19.92	1/10/2014	23/07/2014	70
Farm A	120	5	Normal	20.70	27/11/2014	23/07/2014	127
Farm A	138	2	Thin	15.52	1/10/2014	28/07/2014	65
Farm A	138	2	Normal	13.14	27/11/2014	28/07/2014	122
Farm A	138	2	Normal	9.26	8/02/2015	28/07/2014	195
Farm A	140	8	Normal	26.80	1/10/2014	25/07/2014	68
Farm A	140	8	Thin	20.22	27/11/2014	25/07/2014	125
Farm A	140	8	Thin	13.05	8/02/2015	25/07/2014	198

Farm A	162	2	Normal	15.50	1/10/2014	NA	NA
Farm A	183	4	Thin	18.93	1/10/2014	19/07/2014	74
Farm A	183	4	Thin	17.83	27/11/2014	19/07/2014	131
Farm A	183	4	Thin	5.60	8/02/2015	19/07/2014	204
Farm A	188	4	Thin	16.17	1/10/2014	19/07/2014	74
Farm A	188	4	Normal	17.79	27/11/2014	19/07/2014	131
Farm A	188	4	Thin	9.93	8/02/2015	19/07/2014	204
Farm A	190	10	Thin	11.38	1/10/2014	22/07/2014	71
Farm A	190	10	Normal	19.19	27/11/2014	22/07/2014	128
Farm A	190	10	Normal	10.55	8/02/2015	22/07/2014	201
Farm A	196	7	Thin	15.19	1/10/2014	17/07/2014	76
Farm A	196	7	Thin	9.08	27/11/2014	17/07/2014	133
Farm A	196	7	Thin	10.22	8/02/2015	17/07/2014	206
Farm A	197	7	Thin	6.80	1/10/2014	24/07/2014	69
Farm A	197	7	Normal	7.52	27/11/2014	24/07/2014	126
Farm A	197	7	Normal	3.17	8/02/2015	24/07/2014	199
Farm A	198	2	Thin	22.08	1/10/2014	19/07/2014	74
Farm A	198	2	Thin	12.14	27/11/2014	19/07/2014	131
Farm A	198	2	Thin	7.60	8/02/2015	19/07/2014	204
Farm A	205	3	Thin	13.14	1/10/2014	28/07/2014	65
Farm A	205	3	Thin	13.11	27/11/2014	28/07/2014	122
Farm A	205	3	Thin	7.11	8/02/2015	28/07/2014	195
Farm A	208	3	Thin	17.34	1/10/2014	30/07/2014	63
Farm A	208	3	Thin	14.34	27/11/2014	30/07/2014	120
Farm A	208	3	Thin	10.06	8/02/2015	30/07/2014	193
Farm A	211	3	Thin	22.03	1/10/2014	30/07/2014	63
Farm A	211	3	Thin	19.89	27/11/2014	30/07/2014	120
Farm A	211	3	Normal	11.94	8/02/2015	30/07/2014	193
Farm A	233	3	Thin	14.72	1/10/2014	18/07/2014	75
Farm A	233	3	Normal	14.94	27/11/2014	18/07/2014	132
Farm A	233	3	Normal	7.36	8/02/2015	18/07/2014	205
Farm A	248	3	Thin	17.20	1/10/2014	19/07/2014	74
Farm A	248	3	Normal	14.00	27/11/2014	19/07/2014	131
Farm A	248	3	Normal	9.04	8/02/2015	19/07/2014	204
Farm A	259	3	Thin	18.66	1/10/2014	21/07/2014	72
Farm A	259	3	Thin	16.53	27/11/2014	21/07/2014	129
Farm A	259	3	Thin	10.52	8/02/2015	21/07/2014	202
Farm A	261	3	Thin	23.42	1/10/2014	24/07/2014	69
Farm A	261	3	Thin	20.15	27/11/2014	24/07/2014	126
Farm A	261	3	Normal	15.00	8/02/2015	24/07/2014	199
Farm A	263	3	Normal	17.80	1/10/2014	16/07/2014	77
Farm A	263	3	Normal	5.49	27/11/2014	16/07/2014	134
Farm A	263	3	Normal	0.48	8/02/2015	16/07/2014	207
Farm A	265	3	Normal	22.60	1/10/2014	20/07/2014	73
Farm A	265	3	Normal	17.54	27/11/2014	20/07/2014	130
Farm A	265	3	Normal	10.10	8/02/2015	20/07/2014	203

Farm A	266	3	Thin	16.14	1/10/2014	27/07/2014	66
Farm A	266	3	Thin	14.75	27/11/2014	27/07/2014	123
Farm A	266	3	Normal	7.64	8/02/2015	27/07/2014	196
Farm A	267	3	Thin	19.34	1/10/2014	25/07/2014	68
Farm A	267	3	Thin	14.87	27/11/2014	25/07/2014	125
Farm A	268	3	Thin	15.32	1/10/2014	NA	NA
Farm A	268	3	Thin	15.54	27/11/2014	NA	NA
Farm A	268	3	Thin	11.53	8/02/2015	NA	NA
Farm A	270	3	Thin	18.99	1/10/2014	22/07/2014	71
Farm A	270	3	Thin	15.53	27/11/2014	22/07/2014	128
Farm A	270	3	Thin	10.81	8/02/2015	22/07/2014	201
Farm A	274	3	Thin	13.24	1/10/2014	NA	NA
Farm A	274	3	Thin	14.94	27/11/2014	NA	NA
Farm A	274	3	Thin	10.61	8/02/2015	NA	NA
Farm A	275	3	Thin	11.98	1/10/2014	NA	NA
Farm A	275	3	Thin	13.33	27/11/2014	NA	NA
Farm A	275	3	Normal	7.35	8/02/2015	NA	NA
Farm A	280	3	Thin	18.38	1/10/2014	18/07/2014	75
Farm A	280	3	Thin	17.42	27/11/2014	18/07/2014	132
Farm A	280	3	Thin	13.69	8/02/2015	18/07/2014	205
Farm A	282	3	Thin	22.49	1/10/2014	30/07/2014	63
Farm A	282	3	Thin	21.04	27/11/2014	30/07/2014	120
Farm A	282	3	Thin	11.20	8/02/2015	30/07/2014	193
Farm A	283	3	Thin	19.09	1/10/2014	20/07/2014	73
Farm A	283	3	Thin	16.26	27/11/2014	20/07/2014	130
Farm A	283	3	Thin	9.72	8/02/2015	20/07/2014	203
Farm A	290	3	Thin	20.37	1/10/2014	24/07/2014	69
Farm A	290	3	Thin	18.53	27/11/2014	24/07/2014	126
Farm A	290	3	Normal	14.68	8/02/2015	24/07/2014	199
Farm A	296	3	Thin	18.48	1/10/2014	5/07/2014	88
Farm A	296	3	Thin	16.33	27/11/2014	5/07/2014	145
Farm A	296	3	Normal	10.22	8/02/2015	5/07/2014	218
Farm A	301	3	Thin	17.18	1/10/2014	NA	NA
Farm A	301	3	Thin	15.06	27/11/2014	NA	NA
Farm A	301	3	Thin	11.00	8/02/2015	NA	NA
Farm A	303	3	Thin	18.14	1/10/2014	30/07/2014	63
Farm A	303	3	Thin	17.05	27/11/2014	30/07/2014	120
Farm A	303	3	Thin	9.63	8/02/2015	30/07/2014	193
Farm A	312	3	Thin	15.59	1/10/2014	19/07/2014	74
Farm A	312	3	Thin	11.68	27/11/2014	19/07/2014	131
Farm A	312	3	Thin	8.74	8/02/2015	19/07/2014	204
Farm A	321	2	Thin	14.84	1/10/2014	13/07/2014	80
Farm A	321	2	Thin	15.44	27/11/2014	13/07/2014	137
Farm A	321	2	Normal	11.08	8/02/2015	13/07/2014	210
Farm A	326	9	Normal	22.88	1/10/2014	25/07/2014	68
Farm A	326	9	Thin	17.31	27/11/2014	25/07/2014	125

Farm A	326	9	Thin	12.58	8/02/2015	25/07/2014	198
Farm A	354	4	Normal	21.36	1/10/2014	25/07/2014	68
Farm A	354	4	Normal	18.63	27/11/2014	25/07/2014	125
Farm A	354	4	Normal	8.34	8/02/2015	25/07/2014	198
Farm A	356	8	Thin	22.22	1/10/2014	NA	NA
Farm A	356	8	Thin	18.39	27/11/2014	NA	NA
Farm A	356	8	Normal	7.20	8/02/2015	NA	NA
Farm A	365	6	Normal	21.55	1/10/2014	19/07/2014	74
Farm A	365	6	Thin	18.54	27/11/2014	19/07/2014	131
Farm A	365	6	Thin	11.42	8/02/2015	19/07/2014	204
Farm A	374	7	Normal	35.36	1/10/2014	26/07/2014	67
Farm A	374	7	Normal	24.71	27/11/2014	26/07/2014	124
Farm A	374	7	Normal	8.50	8/02/2015	26/07/2014	197
Farm A	395	7	Normal	27.61	1/10/2014	29/07/2014	64
Farm A	395	7	Thin	19.74	27/11/2014	29/07/2014	121
Farm A	395	7	Thin	10.21	8/02/2015	29/07/2014	194
Farm A	396	9	Normal	25.61	1/10/2014	16/07/2014	77
Farm A	396	9	Normal	21.21	27/11/2014	16/07/2014	134
Farm A	424	5	Thin	23.64	1/10/2014	NA	NA
Farm A	432	8	Thin	25.74	1/10/2014	26/07/2014	67
Farm A	432	8	Thin	20.06	27/11/2014	26/07/2014	124
Farm A	432	8	Thin	14.89	8/02/2015	26/07/2014	197
Farm A	434	2	Thin	15.30	1/10/2014	NA	NA
Farm A	434	2	Thin	5.20	27/11/2014	NA	NA
Farm A	434	2	Normal	8.63	8/02/2015	NA	NA
Farm A	439	6	Thin	24.15	1/10/2014	26/07/2014	67
Farm A	439	6	Normal	20.00	27/11/2014	26/07/2014	124
Farm A	439	6	Normal	8.94	8/02/2015	26/07/2014	197
Farm A	451	7	Normal	26.42	1/10/2014	29/07/2014	64
Farm A	451	7	Normal	20.62	27/11/2014	29/07/2014	121
Farm A	451	7	Normal	11.87	8/02/2015	29/07/2014	194
Farm A	452	2	Thin	15.27	27/11/2014	4/08/2014	115
Farm A	492	10	Normal	15.66	1/10/2014	20/07/2014	73
Farm A	492	10	Thin	12.58	27/11/2014	20/07/2014	130
Farm A	492	10	Thin	5.24	8/02/2015	20/07/2014	203
Farm A	499	2	Thin	16.65	1/10/2014	15/07/2014	78
Farm A	499	2	Thin	12.96	27/11/2014	15/07/2014	135
Farm A	499	2	Thin	8.52	8/02/2015	15/07/2014	208
Farm A	526	7	Normal	25.55	1/10/2014	26/07/2014	67
Farm A	526	7	Normal	13.71	27/11/2014	26/07/2014	124
Farm A	526	7	Normal	8.95	8/02/2015	26/07/2014	197
Farm A	544	2	Thin	19.18	1/10/2014	13/07/2014	80
Farm A	544	2	Thin	13.70	27/11/2014	13/07/2014	137
Farm A	544	2	Thin	3.52	8/02/2015	13/07/2014	210
Farm A	547	7	Normal	23.13	1/10/2014	21/07/2014	72
Farm A	547	7	Thin	18.22	27/11/2014	21/07/2014	129

Farm A	547	7	Thin	13.60	8/02/2015	21/07/2014	202
Farm A	550	5	Normal	23.15	1/10/2014	24/07/2014	69
Farm A	550	5	Normal	19.83	27/11/2014	24/07/2014	126
Farm A	550	5	Thin	11.73	8/02/2015	24/07/2014	199
Farm A	570	4	Normal	22.55	1/10/2014	27/07/2014	66
Farm A	570	4	Normal	17.78	27/11/2014	27/07/2014	123
Farm A	570	4	Normal	8.16	8/02/2015	27/07/2014	196
Farm A	587	8	Normal	23.49	1/10/2014	27/07/2014	66
Farm A	587	8	Normal	19.57	27/11/2014	27/07/2014	123
Farm A	587	8	Normal	9.66	8/02/2015	27/07/2014	196
Farm A	592	6	Normal	27.71	1/10/2014	3/08/2014	59
Farm A	592	6	Normal	22.07	27/11/2014	3/08/2014	116
Farm A	592	6	Normal	11.51	8/02/2015	3/08/2014	189
Farm A	597	3	Normal	12.70	27/11/2014	24/07/2014	126
Farm A	597	3	Thin	5.67	8/02/2015	24/07/2014	199
Farm A	615	3	Thin	20.10	1/10/2014	29/07/2014	64
Farm A	615	3	Thin	18.20	27/11/2014	29/07/2014	121
Farm A	615	3	Normal	14.91	8/02/2015	29/07/2014	194
Farm A	627	7	Normal	23.91	1/10/2014	20/07/2014	73
Farm A	627	7	Normal	19.78	27/11/2014	20/07/2014	130
Farm A	627	7	Normal	10.77	8/02/2015	20/07/2014	203
Farm A	640	5	Thin	17.94	1/10/2014	20/07/2014	73
Farm A	640	5	Thin	13.94	27/11/2014	20/07/2014	130
Farm A	640	5	Thin	8.74	8/02/2015	20/07/2014	203
Farm A	644	5	Thin	21.24	1/10/2014	NA	NA
Farm A	644	5	Thin	19.45	27/11/2014	NA	NA
Farm A	644	5	Thin	9.35	8/02/2015	NA	NA
Farm A	645	5	Thin	21.69	1/10/2014	21/07/2014	72
Farm A	645	5	Thin	13.38	27/11/2014	21/07/2014	129
Farm A	652	3	Thin	17.70	1/10/2014	23/07/2014	70
Farm A	652	3	Normal	16.21	27/11/2014	23/07/2014	127
Farm A	652	3	Normal	10.22	8/02/2015	23/07/2014	200
Farm A	653	5	Normal	19.82	1/10/2014	21/07/2014	72
Farm A	653	5	Thin	15.24	27/11/2014	21/07/2014	129
Farm A	653	5	Thin	8.17	8/02/2015	21/07/2014	202
Farm A	654	3	Thin	20.68	1/10/2014	31/07/2014	62
Farm A	654	3	Thin	16.20	27/11/2014	31/07/2014	119
Farm A	654	3	Thin	10.64	8/02/2015	31/07/2014	192
Farm A	660	5	Thin	21.47	1/10/2014	NA	NA
Farm A	660	5	Thin	16.02	27/11/2014	NA	NA
Farm A	666	4	Thin	21.36	1/10/2014	23/07/2014	70
Farm A	666	4	Thin	17.71	27/11/2014	23/07/2014	127
Farm A	666	4	Thin	11.59	8/02/2015	23/07/2014	200
Farm A	674	6	Thin	17.15	1/10/2014	NA	NA
Farm A	674	6	Thin	13.14	27/11/2014	NA	NA
Farm A	674	6	Thin	10.20	8/02/2015	NA	NA

Farm A	680	4	Thin	17.38	1/10/2014	29/07/2014	64
Farm A	680	4	Thin	14.48	27/11/2014	29/07/2014	121
Farm A	680	4	Normal	8.90	8/02/2015	29/07/2014	194
Farm A	688	7	Thin	15.19	1/10/2014	23/07/2014	70
Farm A	688	7	Thin	13.55	27/11/2014	23/07/2014	127
Farm A	688	7	Normal	11.32	8/02/2015	23/07/2014	200
Farm A	692	5	Thin	22.51	1/10/2014	29/07/2014	64
Farm A	692	5	Thin	19.67	27/11/2014	29/07/2014	121
Farm A	692	5	Thin	11.06	8/02/2015	29/07/2014	194
Farm A	694	3	Thin	20.05	1/10/2014	21/07/2014	72
Farm A	694	3	Thin	19.16	27/11/2014	21/07/2014	129
Farm A	694	3	Normal	12.09	8/02/2015	21/07/2014	202
Farm A	699	7	Normal	17.63	1/10/2014	21/07/2014	72
Farm A	699	7	Normal	12.04	27/11/2014	21/07/2014	129
Farm A	707	2	Normal	18.96	27/11/2014	16/08/2014	103
Farm A	707	2	Normal	9.22	8/02/2015	16/08/2014	176
Farm A	718	7	Thin	20.35	27/11/2014	NA	NA
Farm A	720	10	Normal	22.48	1/10/2014	29/07/2014	64
Farm A	720	10	Thin	18.26	27/11/2014	29/07/2014	121
Farm A	720	10	Thin	11.14	8/02/2015	29/07/2014	194
Farm A	725	6	Thin	19.70	1/10/2014	21/07/2014	72
Farm A	725	6	Thin	16.70	27/11/2014	21/07/2014	129
Farm A	725	6	Thin	7.48	8/02/2015	21/07/2014	202
Farm A	726	6	Normal	22.36	1/10/2014	30/07/2014	63
Farm A	726	6	Normal	16.85	27/11/2014	30/07/2014	120
Farm A	726	6	Normal	12.47	8/02/2015	30/07/2014	193
Farm A	729	6	Thin	23.06	1/10/2014	30/07/2014	63
Farm A	729	6	Thin	19.55	27/11/2014	30/07/2014	120
Farm A	729	6	Thin	9.89	8/02/2015	30/07/2014	193
Farm A	742	4	Thin	23.54	1/10/2014	30/07/2014	63
Farm A	742	4	Thin	19.60	27/11/2014	30/07/2014	120
Farm A	742	4	Thin	12.41	8/02/2015	30/07/2014	193
Farm A	751	2	Thin	14.46	1/10/2014	17/07/2014	76
Farm A	751	2	Thin	13.03	27/11/2014	17/07/2014	133
Farm A	751	2	Thin	7.79	8/02/2015	17/07/2014	206
Farm A	757	6	Thin	16.53	1/10/2014	26/07/2014	67
Farm A	757	6	Thin	16.73	27/11/2014	26/07/2014	124
Farm A	757	6	Normal	9.25	8/02/2015	26/07/2014	197
Farm A	769	6	Thin	14.01	1/10/2014	23/07/2014	70
Farm A	769	6	Thin	14.10	27/11/2014	23/07/2014	127
Farm A	769	6	Normal	6.56	8/02/2015	23/07/2014	200
Farm A	770	5	Thin	18.44	1/10/2014	26/07/2014	67
Farm A	770	5	Thin	15.32	27/11/2014	26/07/2014	124
Farm A	770	5	Thin	7.97	8/02/2015	26/07/2014	197
Farm A	799	4	Thin	20.74	1/10/2014	26/07/2014	67
Farm A	799	4	Thin	22.03	27/11/2014	26/07/2014	124

Farm A	799	4	Normal	10.89	8/02/2015	26/07/2014	197
Farm A	802	2	Thin	14.13	1/10/2014	16/07/2014	77
Farm A	802	2	Normal	14.28	27/11/2014	16/07/2014	134
Farm A	802	2	Thin	8.63	8/02/2015	16/07/2014	207
Farm A	806	4	Thin	20.13	1/10/2014	31/07/2014	62
Farm A	806	4	Thin	15.07	27/11/2014	31/07/2014	119
Farm A	806	4	Normal	10.67	8/02/2015	31/07/2014	192
Farm A	808	2	Normal	15.87	1/10/2014	1/07/2014	92
Farm A	808	2	Normal	15.14	27/11/2014	1/07/2014	149
Farm A	808	2	Normal	11.70	8/02/2015	1/07/2014	222
Farm A	811	3	Normal	24.60	1/10/2014	16/07/2014	77
Farm A	811	3	Normal	20.12	27/11/2014	16/07/2014	134
Farm A	811	3	Normal	8.62	8/02/2015	16/07/2014	207
Farm A	826	5	Normal	23.59	1/10/2014	NA	NA
Farm A	826	5	Thin	21.57	27/11/2014	NA	NA
Farm A	826	5	Normal	10.48	8/02/2015	NA	NA
Farm A	830	2	Thin	15.97	1/10/2014	26/07/2014	67
Farm A	830	2	Thin	14.03	27/11/2014	26/07/2014	124
Farm A	830	2	Thin	10.21	8/02/2015	26/07/2014	197
Farm A	833	2	Thin	15.09	1/10/2014	17/07/2014	76
Farm A	833	2	Thin	14.08	27/11/2014	17/07/2014	133
Farm A	833	2	Thin	7.99	8/02/2015	17/07/2014	206

Table 14. ECM production data, by cow and herd test, for Farm B, **Chapter 9.**

Farm	cowno	age	Herd	ECM/kg	Herd.Test.Date	Calving.date	dim
Farm B	1	3	young	23.41	29/09/2014	27/07/2014	64
Farm B	1	3	young	22.86	12/11/2014	27/07/2014	108
Farm B	1	3	young	22.59	7/12/2014	27/07/2014	133
Farm B	1	3	young	16.49	2/02/2015	27/07/2014	190
Farm B	1	3	young	14.89	1/04/2015	27/07/2014	248
Farm B	4	3	young	29.09	29/09/2014	2/08/2014	58
Farm B	4	3	young	24.76	12/11/2014	2/08/2014	102
Farm B	4	3	young	24.67	7/12/2014	2/08/2014	127
Farm B	4	3	young	15.57	2/02/2015	2/08/2014	184
Farm B	4	3	young	15.98	1/04/2015	2/08/2014	242
Farm B	7	3	young	23.17	29/09/2014	26/07/2014	65
Farm B	7	3	young	20.11	12/11/2014	26/07/2014	109
Farm B	7	3	young	21.15	7/12/2014	26/07/2014	134
Farm B	7	3	young	13.69	2/02/2015	26/07/2014	191
Farm B	7	3	young	16.07	1/04/2015	26/07/2014	249
Farm B	11	7	old	21.46	12/11/2014	30/07/2014	105
Farm B	11	7	old	25.56	7/12/2014	30/07/2014	130
Farm B	11	7	old	18.25	2/02/2015	30/07/2014	187
Farm B	11	7	old	16.26	1/04/2015	30/07/2014	245
Farm B	13	9	old	33.08	29/09/2014	3/08/2014	57
Farm B	13	9	old	29.39	12/11/2014	3/08/2014	101
Farm B	13	9	old	25.35	7/12/2014	3/08/2014	126
Farm B	13	9	old	17.88	2/02/2015	3/08/2014	183
Farm B	13	9	old	14.71	1/04/2015	3/08/2014	241
Farm B	15	3	young	21.70	29/09/2014	23/07/2014	68
Farm B	15	3	young	19.27	12/11/2014	23/07/2014	112
Farm B	15	3	young	21.08	7/12/2014	23/07/2014	137
Farm B	15	3	young	14.47	2/02/2015	23/07/2014	194
Farm B	15	3	young	13.38	1/04/2015	23/07/2014	252
Farm B	16	3	young	28.28	29/09/2014	28/07/2014	63
Farm B	16	3	young	26.80	12/11/2014	28/07/2014	107
Farm B	16	3	young	23.87	7/12/2014	28/07/2014	132
Farm B	16	3	young	17.98	2/02/2015	28/07/2014	189
Farm B	16	3	young	15.18	1/04/2015	28/07/2014	247
Farm B	25	3	young	26.31	29/09/2014	2/08/2014	58
Farm B	25	3	young	25.14	12/11/2014	2/08/2014	102
Farm B	25	3	young	25.08	7/12/2014	2/08/2014	127
Farm B	25	3	young	12.69	2/02/2015	2/08/2014	184
Farm B	25	3	young	17.22	1/04/2015	2/08/2014	242
Farm B	26	4	old	30.87	29/09/2014	31/07/2014	60
Farm B	26	4	old	34.93	12/11/2014	31/07/2014	104
Farm B	26	4	old	26.92	7/12/2014	31/07/2014	129
Farm B	26	4	old	17.77	2/02/2015	31/07/2014	186

Farm B	26	4	old	17.17	1/04/2015	31/07/2014	244
Farm B	27	3	young	25.99	29/09/2014	30/07/2014	61
Farm B	27	3	young	22.60	12/11/2014	30/07/2014	105
Farm B	27	3	young	22.61	7/12/2014	30/07/2014	130
Farm B	27	3	young	21.45	2/02/2015	30/07/2014	187
Farm B	27	3	young	17.50	1/04/2015	30/07/2014	245
Farm B	33	4	old	27.45	29/09/2014	4/08/2014	56
Farm B	33	4	old	28.44	12/11/2014	4/08/2014	100
Farm B	33	4	old	27.82	7/12/2014	4/08/2014	125
Farm B	33	4	old	18.75	2/02/2015	4/08/2014	182
Farm B	33	4	young	18.26	1/04/2015	4/08/2014	240
Farm B	43	4	old	25.92	29/09/2014	22/07/2014	69
Farm B	43	4	old	23.42	12/11/2014	22/07/2014	113
Farm B	43	4	old	25.28	7/12/2014	22/07/2014	138
Farm B	43	4	old	15.42	2/02/2015	22/07/2014	195
Farm B	43	4	old	13.09	1/04/2015	22/07/2014	253
Farm B	45	6	old	24.69	29/09/2014	2/08/2014	58
Farm B	45	6	old	24.47	12/11/2014	2/08/2014	102
Farm B	45	6	old	26.19	7/12/2014	2/08/2014	127
Farm B	45	6	old	19.76	2/02/2015	2/08/2014	184
Farm B	45	6	old	17.20	1/04/2015	2/08/2014	242
Farm B	53	6	old	28.20	29/09/2014	31/07/2014	60
Farm B	53	6	old	26.17	12/11/2014	31/07/2014	104
Farm B	53	6	old	25.40	7/12/2014	31/07/2014	129
Farm B	53	6	old	16.89	2/02/2015	31/07/2014	186
Farm B	53	6	old	13.24	1/04/2015	31/07/2014	244
Farm B	63	8	young	29.40	29/09/2014	27/07/2014	64
Farm B	63	8	young	27.42	12/11/2014	27/07/2014	108
Farm B	63	8	young	26.49	7/12/2014	27/07/2014	133
Farm B	63	8	young	17.23	2/02/2015	27/07/2014	190
Farm B	63	8	young	17.29	1/04/2015	27/07/2014	248
Farm B	64	11	old	23.61	29/09/2014	29/07/2014	62
Farm B	64	11	old	22.15	12/11/2014	29/07/2014	106
Farm B	64	11	old	24.09	7/12/2014	29/07/2014	131
Farm B	64	11	old	13.31	2/02/2015	29/07/2014	188
Farm B	64	11	old	9.06	1/04/2015	29/07/2014	246
Farm B	74	4	old	28.33	29/09/2014	30/07/2014	61
Farm B	74	4	old	22.97	12/11/2014	30/07/2014	105
Farm B	74	4	old	25.05	7/12/2014	30/07/2014	130
Farm B	74	4	old	17.84	2/02/2015	30/07/2014	187
Farm B	74	4	old	16.88	1/04/2015	30/07/2014	245
Farm B	79	6	old	28.47	29/09/2014	24/07/2014	67
Farm B	79	6	old	26.96	12/11/2014	24/07/2014	111
Farm B	79	6	old	27.69	7/12/2014	24/07/2014	136
Farm B	79	6	old	18.50	2/02/2015	24/07/2014	193
Farm B	79	6	old	15.91	1/04/2015	24/07/2014	251

Farm B	82	6	old	30.40	12/11/2014	24/07/2014	111
Farm B	82	6	old	27.71	7/12/2014	24/07/2014	136
Farm B	82	6	old	17.89	2/02/2015	24/07/2014	193
Farm B	82	6	old	14.74	1/04/2015	24/07/2014	251
Farm B	90	3	young	28.94	29/09/2014	1/08/2014	59
Farm B	90	3	young	26.01	12/11/2014	1/08/2014	103
Farm B	90	3	young	25.84	7/12/2014	1/08/2014	128
Farm B	90	3	young	17.14	2/02/2015	1/08/2014	185
Farm B	90	3	young	18.47	1/04/2015	1/08/2014	243
Farm B	91	8	old	31.55	29/09/2014	3/08/2014	57
Farm B	91	8	old	27.84	12/11/2014	3/08/2014	101
Farm B	91	8	old	27.55	7/12/2014	3/08/2014	126
Farm B	91	8	old	20.81	2/02/2015	3/08/2014	183
Farm B	91	8	old	15.72	1/04/2015	3/08/2014	241
Farm B	100	4	old	30.34	29/09/2014	26/07/2014	65
Farm B	100	4	old	26.59	12/11/2014	26/07/2014	109
Farm B	100	4	old	25.27	7/12/2014	26/07/2014	134
Farm B	100	4	old	17.34	2/02/2015	26/07/2014	191
Farm B	100	4	old	11.62	1/04/2015	26/07/2014	249
Farm B	108	NA	old	18.14	2/02/2015	7/08/2014	179
Farm B	116	6	old	31.98	29/09/2014	2/08/2014	58
Farm B	116	6	old	28.71	12/11/2014	2/08/2014	102
Farm B	116	6	old	27.35	7/12/2014	2/08/2014	127
Farm B	116	6	old	15.80	2/02/2015	2/08/2014	184
Farm B	116	6	old	15.95	1/04/2015	2/08/2014	242
Farm B	118	4	old	28.76	29/09/2014	27/07/2014	64
Farm B	118	4	old	26.23	12/11/2014	27/07/2014	108
Farm B	118	4	old	26.51	7/12/2014	27/07/2014	133
Farm B	118	4	old	17.22	2/02/2015	27/07/2014	190
Farm B	118	4	old	16.31	1/04/2015	27/07/2014	248
Farm B	123	4	old	27.69	29/09/2014	27/07/2014	64
Farm B	123	4	old	25.39	12/11/2014	27/07/2014	108
Farm B	123	4	old	24.58	7/12/2014	27/07/2014	133
Farm B	123	4	old	18.28	2/02/2015	27/07/2014	190
Farm B	123	4	old	17.41	1/04/2015	27/07/2014	248
Farm B	130	4	old	23.55	29/09/2014	31/07/2014	60
Farm B	130	4	old	19.93	12/11/2014	31/07/2014	104
Farm B	130	4	old	18.99	7/12/2014	31/07/2014	129
Farm B	130	4	old	14.52	2/02/2015	31/07/2014	186
Farm B	130	4	old	10.27	1/04/2015	31/07/2014	244
Farm B	141	3	young	25.85	29/09/2014	26/07/2014	65
Farm B	141	3	young	26.10	12/11/2014	26/07/2014	109
Farm B	141	3	young	24.03	7/12/2014	26/07/2014	134
Farm B	141	3	young	16.92	2/02/2015	26/07/2014	191
Farm B	141	3	young	15.32	1/04/2015	26/07/2014	249
Farm B	144	3	young	23.83	29/09/2014	24/07/2014	67

Farm B	144	3	young	23.18	12/11/2014	24/07/2014	111
Farm B	144	3	young	23.56	7/12/2014	24/07/2014	136
Farm B	144	3	young	15.63	2/02/2015	24/07/2014	193
Farm B	144	3	young	9.55	1/04/2015	24/07/2014	251
Farm B	145	4	old	27.94	29/09/2014	1/08/2014	59
Farm B	145	4	old	21.50	12/11/2014	1/08/2014	103
Farm B	145	4	old	26.06	7/12/2014	1/08/2014	128
Farm B	145	4	old	15.27	2/02/2015	1/08/2014	185
Farm B	145	4	old	14.15	1/04/2015	1/08/2014	243
Farm B	146	7	old	33.81	29/09/2014	3/08/2014	57
Farm B	146	7	old	23.28	12/11/2014	3/08/2014	101
Farm B	146	7	old	25.96	7/12/2014	3/08/2014	126
Farm B	146	7	old	15.85	2/02/2015	3/08/2014	183
Farm B	146	7	old	14.11	1/04/2015	3/08/2014	241
Farm B	147	3	young	26.72	29/09/2014	28/07/2014	63
Farm B	147	3	young	19.82	12/11/2014	28/07/2014	107
Farm B	147	3	young	18.20	7/12/2014	28/07/2014	132
Farm B	147	3	young	13.24	2/02/2015	28/07/2014	189
Farm B	147	3	young	15.07	1/04/2015	28/07/2014	247
Farm B	148	6	old	30.05	29/09/2014	2/08/2014	58
Farm B	148	6	old	29.23	12/11/2014	2/08/2014	102
Farm B	148	6	old	29.03	7/12/2014	2/08/2014	127
Farm B	148	6	old	20.01	2/02/2015	2/08/2014	184
Farm B	148	6	old	17.92	1/04/2015	2/08/2014	242
Farm B	154	8	old	26.40	29/09/2014	1/08/2014	59
Farm B	154	8	old	26.72	12/11/2014	1/08/2014	103
Farm B	154	8	old	27.48	7/12/2014	1/08/2014	128
Farm B	154	8	old	15.82	2/02/2015	1/08/2014	185
Farm B	154	8	old	12.77	1/04/2015	1/08/2014	243
Farm B	165	4	old	29.18	29/09/2014	3/08/2014	57
Farm B	165	4	old	24.52	12/11/2014	3/08/2014	101
Farm B	165	4	old	24.35	7/12/2014	3/08/2014	126
Farm B	165	4	old	15.87	2/02/2015	3/08/2014	183
Farm B	165	4	old	13.89	1/04/2015	3/08/2014	241
Farm B	173	5	old	32.19	29/09/2014	29/07/2014	62
Farm B	173	5	old	24.41	12/11/2014	29/07/2014	106
Farm B	173	5	old	27.58	7/12/2014	29/07/2014	131
Farm B	173	5	old	18.21	2/02/2015	29/07/2014	188
Farm B	173	5	old	17.81	1/04/2015	29/07/2014	246
Farm B	189	3	young	27.90	29/09/2014	5/08/2014	55
Farm B	189	3	young	22.48	12/11/2014	5/08/2014	99
Farm B	189	3	young	25.17	7/12/2014	5/08/2014	124
Farm B	189	3	young	17.47	2/02/2015	5/08/2014	181
Farm B	189	3	young	15.00	1/04/2015	5/08/2014	239
Farm B	192	6	old	32.83	29/09/2014	25/07/2014	66
Farm B	192	6	old	29.56	12/11/2014	25/07/2014	110

Farm B	192	6	old	28.89	7/12/2014	25/07/2014	135
Farm B	192	6	old	17.70	2/02/2015	25/07/2014	192
Farm B	192	6	old	18.87	1/04/2015	25/07/2014	250
Farm B	196	5	old	31.98	29/09/2014	5/08/2014	55
Farm B	196	5	old	31.04	12/11/2014	5/08/2014	99
Farm B	196	5	old	29.55	7/12/2014	5/08/2014	124
Farm B	196	5	old	21.71	2/02/2015	5/08/2014	181
Farm B	196	5	old	20.73	1/04/2015	5/08/2014	239
Farm B	199	4	old	35.04	29/09/2014	31/07/2014	60
Farm B	199	4	old	26.37	12/11/2014	31/07/2014	104
Farm B	199	4	old	24.94	7/12/2014	31/07/2014	129
Farm B	199	4	old	17.26	2/02/2015	31/07/2014	186
Farm B	199	4	old	14.99	1/04/2015	31/07/2014	244
Farm B	201	3	young	23.75	29/09/2014	28/07/2014	63
Farm B	201	3	young	22.80	12/11/2014	28/07/2014	107
Farm B	201	3	young	22.53	7/12/2014	28/07/2014	132
Farm B	201	3	young	16.72	2/02/2015	28/07/2014	189
Farm B	201	3	young	18.56	1/04/2015	28/07/2014	247
Farm B	207	3	young	18.31	29/09/2014	30/07/2014	61
Farm B	207	3	young	17.17	12/11/2014	30/07/2014	105
Farm B	207	3	young	13.23	7/12/2014	30/07/2014	130
Farm B	207	3	young	12.21	2/02/2015	30/07/2014	187
Farm B	207	3	young	13.63	1/04/2015	30/07/2014	245
Farm B	221	3	young	26.44	29/09/2014	30/07/2014	61
Farm B	221	3	young	24.25	12/11/2014	30/07/2014	105
Farm B	221	3	young	24.33	7/12/2014	30/07/2014	130
Farm B	221	3	young	13.94	2/02/2015	30/07/2014	187
Farm B	221	3	young	13.83	1/04/2015	30/07/2014	245
Farm B	224	4	old	27.72	29/09/2014	31/07/2014	60
Farm B	224	4	old	23.39	12/11/2014	31/07/2014	104
Farm B	224	4	old	22.11	7/12/2014	31/07/2014	129
Farm B	224	4	old	17.16	2/02/2015	31/07/2014	186
Farm B	224	4	old	14.84	1/04/2015	31/07/2014	244
Farm B	226	5	old	32.95	29/09/2014	NA	NA
Farm B	234	6	old	33.83	29/09/2014	22/07/2014	69
Farm B	234	6	old	26.67	12/11/2014	22/07/2014	113
Farm B	234	6	old	32.51	7/12/2014	22/07/2014	138
Farm B	234	6	old	18.88	2/02/2015	22/07/2014	195
Farm B	234	6	old	16.52	1/04/2015	22/07/2014	253
Farm B	237	7	old	30.35	29/09/2014	24/07/2014	67
Farm B	237	7	old	30.50	12/11/2014	24/07/2014	111
Farm B	237	7	old	26.79	7/12/2014	24/07/2014	136
Farm B	237	7	old	18.22	2/02/2015	24/07/2014	193
Farm B	237	7	old	12.84	1/04/2015	24/07/2014	251
Farm B	242	9	old	36.67	29/09/2014	29/07/2014	62
Farm B	242	9	old	30.42	12/11/2014	29/07/2014	106

Farm B	242	9	old	27.41	7/12/2014	29/07/2014	131
Farm B	242	9	old	18.29	2/02/2015	29/07/2014	188
Farm B	242	9	old	18.04	1/04/2015	29/07/2014	246
Farm B	272	4	old	29.23	29/09/2014	30/07/2014	61
Farm B	272	4	old	26.66	12/11/2014	30/07/2014	105
Farm B	272	4	old	25.83	7/12/2014	30/07/2014	130
Farm B	272	4	old	16.34	2/02/2015	30/07/2014	187
Farm B	272	4	old	13.90	1/04/2015	30/07/2014	245
Farm B	273	5	old	32.69	29/09/2014	29/07/2014	62
Farm B	273	5	old	29.39	12/11/2014	29/07/2014	106
Farm B	273	5	old	28.58	7/12/2014	29/07/2014	131
Farm B	273	5	old	14.08	2/02/2015	29/07/2014	188
Farm B	273	5	old	15.77	1/04/2015	29/07/2014	246
Farm B	284	4	old	18.88	29/09/2014	2/08/2014	58
Farm B	284	4	old	26.49	12/11/2014	2/08/2014	102
Farm B	284	4	old	24.30	7/12/2014	2/08/2014	127
Farm B	284	4	old	19.09	2/02/2015	2/08/2014	184
Farm B	284	4	old	13.60	1/04/2015	2/08/2014	242
Farm B	304	9	old	31.86	29/09/2014	31/07/2014	60
Farm B	304	9	old	25.07	12/11/2014	31/07/2014	104
Farm B	304	9	old	28.05	7/12/2014	31/07/2014	129
Farm B	304	9	old	18.70	2/02/2015	31/07/2014	186
Farm B	304	9	old	18.19	1/04/2015	31/07/2014	244
Farm B	310	10	old	21.89	29/09/2014	5/08/2014	55
Farm B	310	10	old	23.99	12/11/2014	5/08/2014	99
Farm B	310	10	old	21.91	7/12/2014	5/08/2014	124
Farm B	310	10	old	16.43	2/02/2015	5/08/2014	181
Farm B	310	10	old	12.72	1/04/2015	5/08/2014	239
Farm B	312	3	young	29.10	29/09/2014	30/07/2014	61
Farm B	312	3	young	18.93	12/11/2014	30/07/2014	105
Farm B	312	3	young	26.46	7/12/2014	30/07/2014	130
Farm B	312	3	young	15.92	2/02/2015	30/07/2014	187
Farm B	312	3	young	17.64	1/04/2015	30/07/2014	245
Farm B	318	11	old	25.35	12/11/2014	24/07/2014	111
Farm B	318	11	old	25.54	7/12/2014	24/07/2014	136
Farm B	318	11	old	16.79	2/02/2015	24/07/2014	193
Farm B	318	11	old	13.98	1/04/2015	24/07/2014	251
Farm B	320	4	old	24.40	29/09/2014	1/08/2014	59
Farm B	320	4	old	21.11	12/11/2014	1/08/2014	103
Farm B	320	4	old	22.21	7/12/2014	1/08/2014	128
Farm B	320	4	old	15.69	2/02/2015	1/08/2014	185
Farm B	320	4	old	13.83	1/04/2015	1/08/2014	243
Farm B	323	6	old	36.65	29/09/2014	3/08/2014	57
Farm B	323	6	old	32.38	12/11/2014	3/08/2014	101
Farm B	323	6	old	30.06	7/12/2014	3/08/2014	126
Farm B	323	6	old	19.89	2/02/2015	3/08/2014	183

Farm B	323	6	old	19.69	1/04/2015	3/08/2014	241
Farm B	327	4	old	29.89	29/09/2014	22/07/2014	69
Farm B	327	4	old	23.70	12/11/2014	22/07/2014	113
Farm B	327	4	old	24.39	7/12/2014	22/07/2014	138
Farm B	327	4	old	20.07	2/02/2015	22/07/2014	195
Farm B	327	4	old	15.31	1/04/2015	22/07/2014	253
Farm B	339	4	old	24.64	29/09/2014	31/07/2014	60
Farm B	339	4	old	24.47	12/11/2014	31/07/2014	104
Farm B	339	4	old	25.07	7/12/2014	31/07/2014	129
Farm B	339	4	old	14.23	2/02/2015	31/07/2014	186
Farm B	339	4	old	12.68	1/04/2015	31/07/2014	244
Farm B	348	6	old	29.43	29/09/2014	5/08/2014	55
Farm B	348	6	old	25.36	12/11/2014	5/08/2014	99
Farm B	348	6	old	25.98	7/12/2014	5/08/2014	124
Farm B	348	6	old	17.54	2/02/2015	5/08/2014	181
Farm B	348	6	old	14.31	1/04/2015	5/08/2014	239
Farm B	350	7	old	28.58	29/09/2014	26/07/2014	65
Farm B	350	7	old	29.40	12/11/2014	26/07/2014	109
Farm B	350	7	old	27.57	7/12/2014	26/07/2014	134
Farm B	350	7	old	20.12	2/02/2015	26/07/2014	191
Farm B	350	7	old	16.78	1/04/2015	26/07/2014	249
Farm B	357	4	old	30.55	29/09/2014	3/08/2014	57
Farm B	357	4	old	25.45	12/11/2014	3/08/2014	101
Farm B	357	4	old	25.33	7/12/2014	3/08/2014	126
Farm B	357	4	old	15.56	2/02/2015	3/08/2014	183
Farm B	357	4	old	10.91	1/04/2015	3/08/2014	241
Farm B	360	5	old	24.61	29/09/2014	28/07/2014	63
Farm B	360	5	old	27.36	12/11/2014	28/07/2014	107
Farm B	360	5	old	28.73	7/12/2014	28/07/2014	132
Farm B	360	5	old	18.09	2/02/2015	28/07/2014	189
Farm B	360	5	old	17.09	1/04/2015	28/07/2014	247
Farm B	375	3	young	22.66	29/09/2014	3/08/2014	57
Farm B	375	3	young	21.20	12/11/2014	3/08/2014	101
Farm B	375	3	young	19.90	7/12/2014	3/08/2014	126
Farm B	375	3	young	16.03	2/02/2015	3/08/2014	183
Farm B	375	3	young	14.85	1/04/2015	3/08/2014	241
Farm B	377	6	old	36.35	29/09/2014	5/08/2014	55
Farm B	377	6	old	27.70	12/11/2014	5/08/2014	99
Farm B	377	6	old	30.76	7/12/2014	5/08/2014	124
Farm B	377	6	old	18.65	2/02/2015	5/08/2014	181
Farm B	377	6	old	17.61	1/04/2015	5/08/2014	239
Farm B	393	7	old	29.42	29/09/2014	29/07/2014	62
Farm B	393	7	old	27.93	12/11/2014	29/07/2014	106
Farm B	393	7	old	24.30	7/12/2014	29/07/2014	131
Farm B	393	7	old	16.63	2/02/2015	29/07/2014	188
Farm B	393	7	old	11.03	1/04/2015	29/07/2014	246

Farm B	398	6	old	24.60	29/09/2014	25/07/2014	66
Farm B	398	6	old	22.43	12/11/2014	25/07/2014	110
Farm B	398	6	old	22.33	7/12/2014	25/07/2014	135
Farm B	398	6	old	14.67	2/02/2015	25/07/2014	192
Farm B	398	6	old	11.90	1/04/2015	25/07/2014	250
Farm B	404	3	young	24.60	29/09/2014	30/07/2014	61
Farm B	404	3	young	22.10	12/11/2014	30/07/2014	105
Farm B	404	3	young	22.55	7/12/2014	30/07/2014	130
Farm B	404	3	young	13.20	2/02/2015	30/07/2014	187
Farm B	404	3	young	15.85	1/04/2015	30/07/2014	245
Farm B	405	3	young	20.78	29/09/2014	28/07/2014	63
Farm B	405	3	young	22.04	12/11/2014	28/07/2014	107
Farm B	405	3	young	22.37	7/12/2014	28/07/2014	132
Farm B	405	3	young	11.19	2/02/2015	28/07/2014	189
Farm B	405	3	young	15.32	1/04/2015	28/07/2014	247
Farm B	413	5	old	24.79	29/09/2014	27/07/2014	64
Farm B	413	5	old	24.72	12/11/2014	27/07/2014	108
Farm B	413	5	old	25.33	7/12/2014	27/07/2014	133
Farm B	413	5	old	17.50	2/02/2015	27/07/2014	190
Farm B	413	5	old	13.50	1/04/2015	27/07/2014	248
Farm B	417	5	old	34.26	29/09/2014	26/07/2014	65
Farm B	417	5	old	26.91	12/11/2014	26/07/2014	109
Farm B	417	5	old	28.62	7/12/2014	26/07/2014	134
Farm B	417	5	old	16.36	2/02/2015	26/07/2014	191
Farm B	417	5	old	12.49	1/04/2015	26/07/2014	249
Farm B	418	3	young	28.50	29/09/2014	28/07/2014	63
Farm B	418	3	young	25.42	12/11/2014	28/07/2014	107
Farm B	418	3	young	26.03	7/12/2014	28/07/2014	132
Farm B	418	3	young	18.87	2/02/2015	28/07/2014	189
Farm B	418	3	young	18.63	1/04/2015	28/07/2014	247
Farm B	421	8	old	32.70	29/09/2014	26/07/2014	65
Farm B	421	8	old	22.75	12/11/2014	26/07/2014	109
Farm B	421	8	old	20.27	7/12/2014	26/07/2014	134
Farm B	421	8	old	15.01	2/02/2015	26/07/2014	191
Farm B	421	8	old	12.74	1/04/2015	26/07/2014	249
Farm B	422	3	young	26.12	29/09/2014	27/07/2014	64
Farm B	422	3	young	21.22	12/11/2014	27/07/2014	108
Farm B	422	3	young	18.68	7/12/2014	27/07/2014	133
Farm B	422	3	young	16.28	2/02/2015	27/07/2014	190
Farm B	422	3	young	17.56	1/04/2015	27/07/2014	248
Farm B	434	11	old	27.61	29/09/2014	31/07/2014	60
Farm B	434	11	old	22.94	12/11/2014	31/07/2014	104
Farm B	434	11	old	18.96	7/12/2014	31/07/2014	129
Farm B	434	11	old	13.55	2/02/2015	31/07/2014	186
Farm B	434	11	old	10.01	1/04/2015	31/07/2014	244
Farm B	466	5	old	34.06	29/09/2014	27/07/2014	64

Farm B	466	5	old	26.77	12/11/2014	27/07/2014	108
Farm B	466	5	old	24.81	7/12/2014	27/07/2014	133
Farm B	466	5	old	17.10	2/02/2015	27/07/2014	190
Farm B	466	5	old	13.62	1/04/2015	27/07/2014	248
Farm B	469	6	old	24.09	29/09/2014	1/08/2014	59
Farm B	469	6	old	25.99	12/11/2014	1/08/2014	103
Farm B	469	6	old	23.49	7/12/2014	1/08/2014	128
Farm B	469	6	old	16.98	2/02/2015	1/08/2014	185
Farm B	469	6	old	20.27	1/04/2015	1/08/2014	243
Farm B	471	4	old	28.58	29/09/2014	23/07/2014	68
Farm B	471	4	old	26.71	12/11/2014	23/07/2014	112
Farm B	471	4	old	26.24	7/12/2014	23/07/2014	137
Farm B	471	4	old	19.36	2/02/2015	23/07/2014	194
Farm B	471	4	old	16.21	1/04/2015	23/07/2014	252
Farm B	472	3	young	23.13	29/09/2014	29/07/2014	62
Farm B	472	3	young	18.40	12/11/2014	29/07/2014	106
Farm B	472	3	young	23.46	7/12/2014	29/07/2014	131
Farm B	472	3	young	16.31	2/02/2015	29/07/2014	188
Farm B	472	3	young	16.61	1/04/2015	29/07/2014	246
Farm B	474	4	old	27.43	29/09/2014	23/07/2014	68
Farm B	474	4	old	24.09	12/11/2014	23/07/2014	112
Farm B	474	4	old	24.59	7/12/2014	23/07/2014	137
Farm B	474	4	old	19.74	2/02/2015	23/07/2014	194
Farm B	474	4	old	16.35	1/04/2015	23/07/2014	252
Farm B	479	5	old	30.11	29/09/2014	29/07/2014	62
Farm B	479	5	old	24.36	12/11/2014	29/07/2014	106
Farm B	479	5	old	27.01	7/12/2014	29/07/2014	131
Farm B	479	5	old	15.21	2/02/2015	29/07/2014	188
Farm B	479	5	old	16.74	1/04/2015	29/07/2014	246
Farm B	486	4	old	30.46	29/09/2014	10/08/2014	50
Farm B	486	4	old	28.42	12/11/2014	10/08/2014	94
Farm B	486	4	old	25.75	7/12/2014	10/08/2014	119
Farm B	486	4	old	18.35	2/02/2015	10/08/2014	176
Farm B	486	4	old	14.79	1/04/2015	10/08/2014	234
Farm B	488	3	young	20.47	29/09/2014	24/07/2014	67
Farm B	488	3	young	21.76	12/11/2014	24/07/2014	111
Farm B	488	3	young	21.50	7/12/2014	24/07/2014	136
Farm B	488	3	young	14.78	2/02/2015	24/07/2014	193
Farm B	488	3	young	14.01	1/04/2015	24/07/2014	251
Farm B	494	6	old	40.25	29/09/2014	23/07/2014	68
Farm B	494	6	old	30.76	12/11/2014	23/07/2014	112
Farm B	494	6	old	29.48	7/12/2014	23/07/2014	137
Farm B	494	6	old	14.95	2/02/2015	23/07/2014	194
Farm B	494	6	old	15.92	1/04/2015	23/07/2014	252
Farm B	496	6	old	37.26	29/09/2014	27/07/2014	64
Farm B	496	6	old	31.84	12/11/2014	27/07/2014	108

Farm B	496	6	old	25.83	7/12/2014	27/07/2014	133
Farm B	496	6	old	17.04	2/02/2015	27/07/2014	190
Farm B	496	6	old	16.76	1/04/2015	27/07/2014	248
Farm B	499	4	old	35.94	29/09/2014	4/08/2014	56
Farm B	499	4	old	24.21	12/11/2014	4/08/2014	100
Farm B	499	4	old	21.16	7/12/2014	4/08/2014	125
Farm B	499	4	old	14.59	2/02/2015	4/08/2014	182
Farm B	499	4	old	14.31	1/04/2015	4/08/2014	240
Farm B	503	5	old	28.56	29/09/2014	3/08/2014	57
Farm B	503	5	old	24.83	12/11/2014	3/08/2014	101
Farm B	503	5	old	27.83	7/12/2014	3/08/2014	126
Farm B	503	5	old	20.65	2/02/2015	3/08/2014	183
Farm B	503	5	old	17.37	1/04/2015	3/08/2014	241
Farm B	514	5	old	32.07	29/09/2014	30/07/2014	61
Farm B	514	5	old	29.14	12/11/2014	30/07/2014	105
Farm B	514	5	old	27.99	7/12/2014	30/07/2014	130
Farm B	514	5	old	19.31	2/02/2015	30/07/2014	187
Farm B	514	5	old	16.85	1/04/2015	30/07/2014	245
Farm B	515	7	old	30.65	29/09/2014	31/07/2014	60
Farm B	515	7	old	27.74	12/11/2014	31/07/2014	104
Farm B	515	7	old	26.01	7/12/2014	31/07/2014	129
Farm B	515	7	old	16.69	2/02/2015	31/07/2014	186
Farm B	515	7	old	16.07	1/04/2015	31/07/2014	244
Farm B	530	4	old	25.81	29/09/2014	29/07/2014	62
Farm B	530	4	old	24.20	7/12/2014	29/07/2014	131
Farm B	530	4	old	14.84	2/02/2015	29/07/2014	188
Farm B	530	4	old	15.25	1/04/2015	29/07/2014	246
Farm B	531	5	old	32.32	29/09/2014	22/07/2014	69
Farm B	531	5	old	32.88	12/11/2014	22/07/2014	113
Farm B	531	5	old	29.13	7/12/2014	22/07/2014	138
Farm B	531	5	old	19.61	2/02/2015	22/07/2014	195
Farm B	531	5	old	18.16	1/04/2015	22/07/2014	253
Farm B	536	3	young	25.06	12/11/2014	27/07/2014	108
Farm B	536	3	young	21.93	7/12/2014	27/07/2014	133
Farm B	536	3	young	17.49	2/02/2015	27/07/2014	190
Farm B	536	3	young	16.30	1/04/2015	27/07/2014	248
Farm B	538	3	young	25.88	29/09/2014	27/07/2014	64
Farm B	538	3	young	19.16	12/11/2014	27/07/2014	108
Farm B	538	3	young	19.33	7/12/2014	27/07/2014	133
Farm B	538	3	young	13.57	2/02/2015	27/07/2014	190
Farm B	538	3	young	12.26	1/04/2015	27/07/2014	248
Farm B	543	9	old	31.99	29/09/2014	25/07/2014	66
Farm B	543	9	old	28.64	12/11/2014	25/07/2014	110
Farm B	543	9	old	28.59	7/12/2014	25/07/2014	135
Farm B	543	9	old	17.81	2/02/2015	25/07/2014	192
Farm B	543	9	old	15.34	1/04/2015	25/07/2014	250

Farm B	561	7	old	32.07	29/09/2014	29/07/2014	62
Farm B	561	7	old	29.10	12/11/2014	29/07/2014	106
Farm B	561	7	old	29.07	7/12/2014	29/07/2014	131
Farm B	561	7	old	16.46	2/02/2015	29/07/2014	188
Farm B	561	7	old	18.86	1/04/2015	29/07/2014	246
Farm B	576	3	young	23.43	29/09/2014	30/07/2014	61
Farm B	576	3	young	22.86	12/11/2014	30/07/2014	105
Farm B	576	3	young	22.03	7/12/2014	30/07/2014	130
Farm B	576	3	young	17.05	2/02/2015	30/07/2014	187
Farm B	576	3	young	16.77	1/04/2015	30/07/2014	245
Farm B	580	8	old	28.95	29/09/2014	31/07/2014	60
Farm B	580	8	old	24.09	12/11/2014	31/07/2014	104
Farm B	580	8	old	27.28	7/12/2014	31/07/2014	129
Farm B	580	8	old	17.51	2/02/2015	31/07/2014	186
Farm B	580	8	old	14.93	1/04/2015	31/07/2014	244
Farm B	592	3	young	27.30	29/09/2014	25/07/2014	66
Farm B	592	3	young	17.33	12/11/2014	25/07/2014	110
Farm B	592	3	young	26.24	7/12/2014	25/07/2014	135
Farm B	592	3	young	14.65	2/02/2015	25/07/2014	192
Farm B	592	3	young	11.94	1/04/2015	25/07/2014	250
Farm B	594	3	young	23.95	29/09/2014	29/07/2014	62
Farm B	594	3	young	23.02	12/11/2014	29/07/2014	106
Farm B	594	3	young	23.80	7/12/2014	29/07/2014	131
Farm B	594	3	young	16.71	2/02/2015	29/07/2014	188
Farm B	594	3	young	15.63	1/04/2015	29/07/2014	246
Farm B	599	3	young	25.43	29/09/2014	30/07/2014	61
Farm B	599	3	young	23.22	12/11/2014	30/07/2014	105
Farm B	599	3	young	22.71	7/12/2014	30/07/2014	130
Farm B	599	3	young	18.05	2/02/2015	30/07/2014	187
Farm B	599	3	young	18.14	1/04/2015	30/07/2014	245
Farm B	605	3	young	23.79	29/09/2014	26/07/2014	65
Farm B	605	3	young	21.50	12/11/2014	26/07/2014	109
Farm B	605	3	young	21.42	7/12/2014	26/07/2014	134
Farm B	605	3	young	12.59	2/02/2015	26/07/2014	191
Farm B	605	3	young	14.26	1/04/2015	26/07/2014	249

Table 15. ECM production data, by cow and herd test, for Farm C, **Chapter 9.**

Farm	cowno	age	ECM/kg	Herd.Test.Date	Calving.date	dim
Farm C	1	2	16.69	19/10/2014	19/08/2014	61
Farm C	1	2	13.03	15/12/2014	19/08/2014	118
Farm C	1	2	10.11	8/02/2015	19/08/2014	173
Farm C	1	2	7.97	7/04/2015	19/08/2014	231
Farm C	2	3	20.75	19/10/2014	26/08/2014	54
Farm C	2	3	17.72	15/12/2014	26/08/2014	111
Farm C	2	3	12.88	8/02/2015	26/08/2014	166
Farm C	2	3	11.08	7/04/2015	26/08/2014	224
Farm C	3	3	24.81	19/10/2014	18/08/2014	62
Farm C	3	3	18.42	15/12/2014	18/08/2014	119
Farm C	3	3	12.12	8/02/2015	18/08/2014	174
Farm C	3	3	9.78	7/04/2015	18/08/2014	232
Farm C	4	7	25.99	19/10/2014	NA	NA
Farm C	4	7	23.06	15/12/2014	NA	NA
Farm C	4	7	13.64	8/02/2015	NA	NA
Farm C	5	12	27.61	19/10/2014	NA	NA
Farm C	6	5	22.55	19/10/2014	24/08/2014	56
Farm C	6	5	20.25	15/12/2014	24/08/2014	113
Farm C	6	5	13.48	8/02/2015	24/08/2014	168
Farm C	6	5	14.10	7/04/2015	24/08/2014	226
Farm C	7	6	24.90	19/10/2014	NA	NA
Farm C	7	6	21.08	15/12/2014	NA	NA
Farm C	7	6	12.46	8/02/2015	NA	NA
Farm C	8	2	19.79	19/10/2014	8/08/2014	72
Farm C	8	2	15.49	15/12/2014	8/08/2014	129
Farm C	8	2	9.35	8/02/2015	8/08/2014	184
Farm C	8	2	9.73	7/04/2015	8/08/2014	242
Farm C	9	9	20.23	19/10/2014	9/09/2014	40
Farm C	9	9	20.44	15/12/2014	9/09/2014	97
Farm C	9	9	11.92	8/02/2015	9/09/2014	152
Farm C	9	9	10.84	7/04/2015	9/09/2014	210
Farm C	10	4	26.00	19/10/2014	NA	NA
Farm C	10	4	20.51	15/12/2014	NA	NA
Farm C	10	4	14.01	8/02/2015	NA	NA
Farm C	11	10	25.55	19/10/2014	NA	NA
Farm C	11	10	19.91	15/12/2014	NA	NA
Farm C	11	10	12.47	8/02/2015	NA	NA
Farm C	12	4	23.73	19/10/2014	NA	NA
Farm C	12	4	20.09	15/12/2014	NA	NA
Farm C	12	4	13.01	8/02/2015	NA	NA
Farm C	13	6	30.01	19/10/2014	30/08/2014	50
Farm C	13	6	20.76	15/12/2014	30/08/2014	107
Farm C	13	6	12.76	8/02/2015	30/08/2014	162

Farm C	13	6	13.64	7/04/2015	30/08/2014	220
Farm C	14	8	31.03	19/10/2014	29/08/2014	51
Farm C	14	8	23.55	15/12/2014	29/08/2014	108
Farm C	14	8	12.81	8/02/2015	29/08/2014	163
Farm C	14	8	13.08	7/04/2015	29/08/2014	221
Farm C	15	9	25.32	19/10/2014	10/08/2014	70
Farm C	15	9	19.42	15/12/2014	10/08/2014	127
Farm C	15	9	12.67	8/02/2015	10/08/2014	182
Farm C	15	9	9.65	7/04/2015	10/08/2014	240
Farm C	16	6	27.13	19/10/2014	20/08/2014	60
Farm C	16	6	20.63	15/12/2014	20/08/2014	117
Farm C	16	6	13.06	8/02/2015	20/08/2014	172
Farm C	16	6	10.80	7/04/2015	20/08/2014	230
Farm C	17	3	20.15	19/10/2014	10/08/2014	70
Farm C	17	3	16.28	15/12/2014	10/08/2014	127
Farm C	17	3	9.75	8/02/2015	10/08/2014	182
Farm C	17	3	7.98	7/04/2015	10/08/2014	240
Farm C	18	8	30.64	19/10/2014	NA	NA
Farm C	18	8	16.72	15/12/2014	NA	NA
Farm C	18	8	16.68	8/02/2015	NA	NA
Farm C	19	4	27.47	19/10/2014	6/08/2014	74
Farm C	19	4	20.27	15/12/2014	6/08/2014	131
Farm C	19	4	12.07	8/02/2015	6/08/2014	186
Farm C	19	4	10.43	7/04/2015	6/08/2014	244
Farm C	20	10	23.60	19/10/2014	25/08/2014	55
Farm C	20	10	18.70	15/12/2014	25/08/2014	112
Farm C	20	10	11.53	8/02/2015	25/08/2014	167
Farm C	20	10	9.25	7/04/2015	25/08/2014	225
Farm C	21	6	29.42	19/10/2014	14/08/2014	66
Farm C	21	6	23.63	15/12/2014	14/08/2014	123
Farm C	21	6	13.05	8/02/2015	14/08/2014	178
Farm C	21	6	13.70	7/04/2015	14/08/2014	236
Farm C	22	9	27.26	19/10/2014	NA	NA
Farm C	22	9	21.91	15/12/2014	NA	NA
Farm C	22	9	11.62	8/02/2015	NA	NA
Farm C	23	4	28.31	19/10/2014	19/08/2014	61
Farm C	23	4	21.45	15/12/2014	19/08/2014	118
Farm C	23	4	11.90	8/02/2015	19/08/2014	173
Farm C	23	4	11.27	7/04/2015	19/08/2014	231
Farm C	25	3	19.72	19/10/2014	25/08/2014	55
Farm C	25	3	17.54	15/12/2014	25/08/2014	112
Farm C	25	3	11.49	8/02/2015	25/08/2014	167
Farm C	25	3	11.31	7/04/2015	25/08/2014	225
Farm C	26	8	24.54	19/10/2014	14/08/2014	66
Farm C	26	8	23.97	15/12/2014	14/08/2014	123
Farm C	26	8	10.63	8/02/2015	14/08/2014	178

Farm C	26	8	9.28	7/04/2015	14/08/2014	236
Farm C	27	2	16.13	19/10/2014	27/08/2014	53
Farm C	27	2	9.84	15/12/2014	27/08/2014	110
Farm C	27	2	9.35	8/02/2015	27/08/2014	165
Farm C	27	2	7.58	7/04/2015	27/08/2014	223
Farm C	29	5	28.66	19/10/2014	22/09/2014	27
Farm C	29	5	24.18	15/12/2014	22/09/2014	84
Farm C	29	5	13.88	8/02/2015	22/09/2014	139
Farm C	29	5	13.97	7/04/2015	22/09/2014	197
Farm C	30	6	31.18	19/10/2014	17/09/2014	32
Farm C	30	6	23.84	15/12/2014	17/09/2014	89
Farm C	30	6	13.67	8/02/2015	17/09/2014	144
Farm C	30	6	14.49	7/04/2015	17/09/2014	202
Farm C	31	3	16.53	19/10/2014	NA	NA
Farm C	31	3	14.48	15/12/2014	NA	NA
Farm C	31	3	10.72	8/02/2015	NA	NA
Farm C	32	6	23.47	19/10/2014	19/08/2014	61
Farm C	32	6	17.67	15/12/2014	19/08/2014	118
Farm C	32	6	11.61	8/02/2015	19/08/2014	173
Farm C	32	6	10.31	7/04/2015	19/08/2014	231
Farm C	33	5	31.93	19/10/2014	NA	NA
Farm C	33	5	25.60	15/12/2014	NA	NA
Farm C	33	5	13.30	8/02/2015	NA	NA
Farm C	34	6	29.23	19/10/2014	15/08/2014	65
Farm C	34	6	22.83	15/12/2014	15/08/2014	122
Farm C	34	6	13.05	8/02/2015	15/08/2014	177
Farm C	34	6	11.14	7/04/2015	15/08/2014	235
Farm C	35	8	33.53	19/10/2014	NA	NA
Farm C	35	8	28.19	15/12/2014	NA	NA
Farm C	35	8	11.65	8/02/2015	NA	NA
Farm C	36	4	21.52	19/10/2014	24/08/2014	56
Farm C	36	4	18.31	15/12/2014	24/08/2014	113
Farm C	36	4	13.71	8/02/2015	24/08/2014	168
Farm C	36	4	11.97	7/04/2015	24/08/2014	226
Farm C	37	10	31.12	19/10/2014	6/10/2014	13
Farm C	37	10	23.39	15/12/2014	6/10/2014	70
Farm C	37	10	12.82	8/02/2015	6/10/2014	125
Farm C	37	10	15.08	7/04/2015	6/10/2014	183
Farm C	38	8	27.28	19/10/2014	NA	NA
Farm C	38	8	22.84	15/12/2014	NA	NA
Farm C	38	8	13.13	8/02/2015	NA	NA
Farm C	39	4	28.32	19/10/2014	11/08/2014	69
Farm C	39	4	20.29	15/12/2014	11/08/2014	126
Farm C	39	4	12.00	8/02/2015	11/08/2014	181
Farm C	39	4	11.51	7/04/2015	11/08/2014	239
Farm C	40	5	28.28	19/10/2014	1/09/2014	48

Farm C	40	5	23.31	15/12/2014	1/09/2014	105
Farm C	40	5	12.83	8/02/2015	1/09/2014	160
Farm C	40	5	9.39	7/04/2015	1/09/2014	218
Farm C	41	2	20.67	19/10/2014	NA	NA
Farm C	41	2	17.00	15/12/2014	NA	NA
Farm C	41	2	11.68	8/02/2015	NA	NA
Farm C	42	5	24.19	19/10/2014	2/09/2014	47
Farm C	42	5	12.04	15/12/2014	2/09/2014	104
Farm C	42	5	14.41	8/02/2015	2/09/2014	159
Farm C	42	5	16.02	7/04/2015	2/09/2014	217
Farm C	43	3	22.99	19/10/2014	11/08/2014	69
Farm C	43	3	19.95	15/12/2014	11/08/2014	126
Farm C	43	3	12.33	8/02/2015	11/08/2014	181
Farm C	43	3	9.29	7/04/2015	11/08/2014	239
Farm C	44	4	29.91	19/10/2014	31/08/2014	49
Farm C	44	4	18.58	15/12/2014	31/08/2014	106
Farm C	44	4	13.24	8/02/2015	31/08/2014	161
Farm C	44	4	16.73	7/04/2015	31/08/2014	219
Farm C	45	4	24.27	19/10/2014	9/08/2014	71
Farm C	45	4	17.07	15/12/2014	9/08/2014	128
Farm C	45	4	14.62	8/02/2015	9/08/2014	183
Farm C	45	4	10.20	7/04/2015	9/08/2014	241
Farm C	46	6	24.41	19/10/2014	8/09/2014	41
Farm C	46	6	17.53	15/12/2014	8/09/2014	98
Farm C	46	6	11.72	8/02/2015	8/09/2014	153
Farm C	46	6	11.12	7/04/2015	8/09/2014	211
Farm C	47	3	25.82	19/10/2014	16/08/2014	64
Farm C	47	3	21.09	15/12/2014	16/08/2014	121
Farm C	47	3	13.52	8/02/2015	16/08/2014	176
Farm C	47	3	13.00	7/04/2015	16/08/2014	234
Farm C	48	11	29.78	19/10/2014	9/10/2014	10
Farm C	48	11	26.17	15/12/2014	9/10/2014	67
Farm C	48	11	14.54	8/02/2015	9/10/2014	122
Farm C	48	11	16.84	7/04/2015	9/10/2014	180
Farm C	49	3	17.26	19/10/2014	NA	NA
Farm C	49	3	17.37	15/12/2014	NA	NA
Farm C	49	3	11.80	8/02/2015	NA	NA
Farm C	50	4	29.85	19/10/2014	18/08/2014	62
Farm C	50	4	22.15	15/12/2014	18/08/2014	119
Farm C	50	4	13.50	8/02/2015	18/08/2014	174
Farm C	50	4	11.89	7/04/2015	18/08/2014	232
Farm C	51	5	27.51	19/10/2014	14/09/2014	35
Farm C	51	5	20.71	15/12/2014	14/09/2014	92
Farm C	51	5	15.11	8/02/2015	14/09/2014	147
Farm C	51	5	12.42	7/04/2015	14/09/2014	205
Farm C	52	6	25.33	19/10/2014	7/09/2014	42

Farm C	52	6	10.37	15/12/2014	7/09/2014	99
Farm C	52	6	10.06	8/02/2015	7/09/2014	154
Farm C	52	6	12.70	7/04/2015	7/09/2014	212
Farm C	53	11	18.24	19/10/2014	NA	NA
Farm C	53	11	15.61	15/12/2014	NA	NA
Farm C	53	11	12.84	8/02/2015	NA	NA
Farm C	54	8	32.99	19/10/2014	NA	NA
Farm C	54	8	26.77	15/12/2014	NA	NA
Farm C	54	8	16.13	8/02/2015	NA	NA
Farm C	55	6	28.58	19/10/2014	14/08/2014	66
Farm C	55	6	21.45	15/12/2014	14/08/2014	123
Farm C	55	6	12.48	8/02/2015	14/08/2014	178
Farm C	55	6	9.79	7/04/2015	14/08/2014	236
Farm C	56	4	22.97	19/10/2014	6/08/2014	74
Farm C	56	4	17.29	15/12/2014	6/08/2014	131
Farm C	56	4	10.95	8/02/2015	6/08/2014	186
Farm C	56	4	8.47	7/04/2015	6/08/2014	244
Farm C	57	4	25.64	19/10/2014	8/09/2014	41
Farm C	57	4	18.91	15/12/2014	8/09/2014	98
Farm C	57	4	11.17	8/02/2015	8/09/2014	153
Farm C	57	4	9.82	7/04/2015	8/09/2014	211
Farm C	58	9	27.34	19/10/2014	NA	NA
Farm C	58	9	19.35	15/12/2014	NA	NA
Farm C	58	9	10.83	8/02/2015	NA	NA
Farm C	59	9	28.92	19/10/2014	6/08/2014	74
Farm C	59	9	23.28	15/12/2014	6/08/2014	131
Farm C	59	9	14.72	8/02/2015	6/08/2014	186
Farm C	59	9	14.20	7/04/2015	6/08/2014	244
Farm C	60	6	35.00	19/10/2014	1/10/2014	18
Farm C	60	6	26.70	15/12/2014	1/10/2014	75
Farm C	60	6	15.59	8/02/2015	1/10/2014	130
Farm C	60	6	12.92	7/04/2015	1/10/2014	188
Farm C	61	5	28.10	19/10/2014	14/09/2014	35
Farm C	61	5	26.51	15/12/2014	14/09/2014	92
Farm C	61	5	14.28	8/02/2015	14/09/2014	147
Farm C	61	5	8.78	7/04/2015	14/09/2014	205
Farm C	62	2	16.04	19/10/2014	1/08/2014	79
Farm C	62	2	10.56	15/12/2014	1/08/2014	136
Farm C	62	2	7.84	8/02/2015	1/08/2014	191
Farm C	62	2	6.54	7/04/2015	1/08/2014	249
Farm C	63	5	22.90	19/10/2014	17/08/2014	63
Farm C	63	5	19.40	15/12/2014	17/08/2014	120
Farm C	63	5	13.79	8/02/2015	17/08/2014	175
Farm C	63	5	12.92	7/04/2015	17/08/2014	233
Farm C	65	6	0.00	19/10/2014	NA	NA
Farm C	66	4	22.07	19/10/2014	15/09/2014	34

Farm C	66	4	19.04	15/12/2014	15/09/2014	91
Farm C	66	4	11.03	8/02/2015	15/09/2014	146
Farm C	66	4	11.06	7/04/2015	15/09/2014	204
Farm C	67	5	19.49	15/12/2014	21/10/2014	55
Farm C	67	5	13.54	8/02/2015	21/10/2014	110
Farm C	67	5	12.57	7/04/2015	21/10/2014	168
Farm C	68	10	25.07	19/10/2014	11/09/2014	38
Farm C	68	10	20.73	15/12/2014	11/09/2014	95
Farm C	68	10	11.90	8/02/2015	11/09/2014	150
Farm C	68	10	9.23	7/04/2015	11/09/2014	208
Farm C	69	4	30.42	19/10/2014	28/08/2014	52
Farm C	69	4	20.42	15/12/2014	28/08/2014	109
Farm C	69	4	12.58	8/02/2015	28/08/2014	164
Farm C	69	4	12.08	7/04/2015	28/08/2014	222
Farm C	70	7	31.26	19/10/2014	17/09/2014	32
Farm C	70	7	19.21	15/12/2014	17/09/2014	89
Farm C	70	7	11.80	8/02/2015	17/09/2014	144
Farm C	70	7	11.35	7/04/2015	17/09/2014	202
Farm C	71	3	19.18	19/10/2014	6/08/2014	74
Farm C	71	3	12.24	15/12/2014	6/08/2014	131
Farm C	71	3	9.32	8/02/2015	6/08/2014	186
Farm C	71	3	5.85	7/04/2015	6/08/2014	244
Farm C	72	7	20.82	19/10/2014	16/08/2014	64
Farm C	72	7	15.48	15/12/2014	16/08/2014	121
Farm C	72	7	9.45	8/02/2015	16/08/2014	176
Farm C	72	7	8.44	7/04/2015	16/08/2014	234
Farm C	73	2	19.91	19/10/2014	22/08/2014	58
Farm C	73	2	15.47	15/12/2014	22/08/2014	115
Farm C	73	2	10.85	8/02/2015	22/08/2014	170
Farm C	73	2	11.17	7/04/2015	22/08/2014	228
Farm C	74	2	18.39	19/10/2014	1/08/2014	79
Farm C	74	2	14.00	15/12/2014	1/08/2014	136
Farm C	74	2	9.55	8/02/2015	1/08/2014	191
Farm C	74	2	8.05	7/04/2015	1/08/2014	249
Farm C	75	3	29.69	19/10/2014	14/10/2014	5
Farm C	75	3	24.70	15/12/2014	14/10/2014	62
Farm C	75	3	15.40	8/02/2015	14/10/2014	117
Farm C	75	3	17.25	7/04/2015	14/10/2014	175
Farm C	76	4	16.44	19/10/2014	15/08/2014	65
Farm C	76	4	17.51	15/12/2014	15/08/2014	122
Farm C	76	4	12.68	8/02/2015	15/08/2014	177
Farm C	76	4	8.26	7/04/2015	15/08/2014	235
Farm C	77	2	19.27	19/10/2014	1/08/2014	79
Farm C	77	2	17.71	15/12/2014	1/08/2014	136
Farm C	77	2	11.62	8/02/2015	1/08/2014	191
Farm C	77	2	11.26	7/04/2015	1/08/2014	249

Farm C	78	6	25.34	19/10/2014	19/08/2014	61
Farm C	78	6	20.25	15/12/2014	19/08/2014	118
Farm C	78	6	11.90	8/02/2015	19/08/2014	173
Farm C	78	6	11.08	7/04/2015	19/08/2014	231
Farm C	79	7	23.00	19/10/2014	1/09/2014	48
Farm C	79	7	19.24	15/12/2014	1/09/2014	105
Farm C	79	7	12.01	8/02/2015	1/09/2014	160
Farm C	79	7	10.53	7/04/2015	1/09/2014	218
Farm C	80	7	29.81	19/10/2014	30/08/2014	50
Farm C	80	7	19.15	15/12/2014	30/08/2014	107
Farm C	80	7	13.53	8/02/2015	30/08/2014	162
Farm C	80	7	14.79	7/04/2015	30/08/2014	220
Farm C	81	3	23.37	19/10/2014	12/09/2014	37
Farm C	81	3	19.14	15/12/2014	12/09/2014	94
Farm C	81	3	13.24	8/02/2015	12/09/2014	149
Farm C	81	3	11.80	7/04/2015	12/09/2014	207
Farm C	82	2	16.48	19/10/2014	8/08/2014	72
Farm C	82	2	15.64	15/12/2014	8/08/2014	129
Farm C	82	2	9.23	8/02/2015	8/08/2014	184
Farm C	82	2	9.89	7/04/2015	8/08/2014	242
Farm C	83	5	23.89	19/10/2014	NA	NA
Farm C	83	5	15.78	15/12/2014	NA	NA
Farm C	83	5	12.62	8/02/2015	NA	NA
Farm C	84	3	26.34	19/10/2014	24/08/2014	56
Farm C	84	3	21.05	15/12/2014	24/08/2014	113
Farm C	84	3	12.40	8/02/2015	24/08/2014	168
Farm C	84	3	10.97	7/04/2015	24/08/2014	226
Farm C	86	4	17.92	19/10/2014	7/10/2014	12
Farm C	86	4	18.04	15/12/2014	7/10/2014	69
Farm C	86	4	11.81	8/02/2015	7/10/2014	124
Farm C	86	4	9.42	7/04/2015	7/10/2014	182
Farm C	87	4	25.38	19/10/2014	9/09/2014	40
Farm C	87	4	10.05	15/12/2014	9/09/2014	97
Farm C	87	4	13.15	8/02/2015	9/09/2014	152
Farm C	87	4	13.45	7/04/2015	9/09/2014	210
Farm C	88	4	25.50	19/10/2014	25/08/2014	55
Farm C	88	4	20.06	15/12/2014	25/08/2014	112
Farm C	88	4	10.23	8/02/2015	25/08/2014	167
Farm C	88	4	11.34	7/04/2015	25/08/2014	225
Farm C	89	4	25.32	19/10/2014	NA	NA
Farm C	89	4	24.27	15/12/2014	NA	NA
Farm C	89	4	13.79	8/02/2015	NA	NA
Farm C	91	4	27.56	19/10/2014	18/08/2014	62
Farm C	91	4	18.92	15/12/2014	18/08/2014	119
Farm C	91	4	12.74	8/02/2015	18/08/2014	174
Farm C	91	4	9.47	7/04/2015	18/08/2014	232

Farm C	92	6	24.36	19/10/2014	22/09/2014	27
Farm C	92	6	22.85	15/12/2014	22/09/2014	84
Farm C	92	6	14.54	8/02/2015	22/09/2014	139
Farm C	92	6	14.22	7/04/2015	22/09/2014	197
Farm C	93	6	26.95	19/10/2014	21/09/2014	28
Farm C	93	6	24.13	15/12/2014	21/09/2014	85
Farm C	93	6	15.19	8/02/2015	21/09/2014	140
Farm C	93	6	13.66	7/04/2015	21/09/2014	198
Farm C	94	6	31.00	19/10/2014	21/08/2014	59
Farm C	94	6	9.83	15/12/2014	21/08/2014	116
Farm C	94	6	14.13	8/02/2015	21/08/2014	171
Farm C	94	6	12.84	7/04/2015	21/08/2014	229
Farm C	96	4	25.48	19/10/2014	2/09/2014	47
Farm C	96	4	21.00	15/12/2014	2/09/2014	104
Farm C	96	4	14.21	8/02/2015	2/09/2014	159
Farm C	96	4	15.54	7/04/2015	2/09/2014	217
Farm C	97	6	24.05	19/10/2014	27/08/2014	53
Farm C	97	6	21.48	15/12/2014	27/08/2014	110
Farm C	97	6	12.73	8/02/2015	27/08/2014	165
Farm C	97	6	13.20	7/04/2015	27/08/2014	223
Farm C	98	6	26.72	19/10/2014	6/09/2014	43
Farm C	98	6	19.38	15/12/2014	6/09/2014	100
Farm C	98	6	12.39	8/02/2015	6/09/2014	155
Farm C	98	6	12.13	7/04/2015	6/09/2014	213
Farm C	99	4	20.08	19/10/2014	21/08/2014	59
Farm C	99	4	19.03	15/12/2014	21/08/2014	116
Farm C	99	4	11.13	8/02/2015	21/08/2014	171
Farm C	99	4	12.52	7/04/2015	21/08/2014	229
Farm C	100	4	26.95	19/10/2014	6/08/2014	74
Farm C	100	4	18.03	15/12/2014	6/08/2014	131
Farm C	100	4	13.35	8/02/2015	6/08/2014	186
Farm C	100	4	12.78	7/04/2015	6/08/2014	244
Farm C	102	4	27.35	19/10/2014	31/08/2014	49
Farm C	102	4	20.24	15/12/2014	31/08/2014	106
Farm C	102	4	13.62	8/02/2015	31/08/2014	161
Farm C	102	4	14.48	7/04/2015	31/08/2014	219
Farm C	103	3	25.42	19/10/2014	NA	NA
Farm C	103	3	17.60	15/12/2014	NA	NA
Farm C	103	3	7.59	8/02/2015	NA	NA
Farm C	105	3	20.22	19/10/2014	9/09/2014	40
Farm C	105	3	17.29	15/12/2014	9/09/2014	97
Farm C	105	3	11.22	8/02/2015	9/09/2014	152
Farm C	105	3	12.17	7/04/2015	9/09/2014	210
Farm C	106	8	24.91	15/12/2014	18/10/2014	58
Farm C	106	8	13.43	8/02/2015	18/10/2014	113
Farm C	106	8	12.32	7/04/2015	18/10/2014	171

Farm C	107	4	0.00	19/10/2014	9/09/2014	40
Farm C	107	4	17.09	15/12/2014	9/09/2014	97
Farm C	107	4	10.85	8/02/2015	9/09/2014	152
Farm C	107	4	10.13	7/04/2015	9/09/2014	210
Farm C	108	5	27.90	19/10/2014	15/10/2014	4
Farm C	108	5	24.95	15/12/2014	15/10/2014	61
Farm C	108	5	17.41	8/02/2015	15/10/2014	116
Farm C	108	5	15.66	7/04/2015	15/10/2014	174
Farm C	109	4	20.35	19/10/2014	NA	NA
Farm C	109	4	15.60	15/12/2014	NA	NA
Farm C	109	4	12.90	8/02/2015	NA	NA
Farm C	110	3	26.97	19/10/2014	9/08/2014	71
Farm C	110	3	18.87	15/12/2014	9/08/2014	128
Farm C	110	3	10.67	8/02/2015	9/08/2014	183
Farm C	110	3	10.09	7/04/2015	9/08/2014	241
Farm C	111	2	19.97	19/10/2014	1/09/2014	48
Farm C	111	2	15.42	15/12/2014	1/09/2014	105
Farm C	111	2	12.46	8/02/2015	1/09/2014	160
Farm C	111	2	11.64	7/04/2015	1/09/2014	218
Farm C	112	6	28.94	19/10/2014	12/08/2014	68
Farm C	112	6	23.56	15/12/2014	12/08/2014	125
Farm C	112	6	14.01	8/02/2015	12/08/2014	180
Farm C	112	6	8.19	7/04/2015	12/08/2014	238
Farm C	113	5	26.38	19/10/2014	26/08/2014	54
Farm C	113	5	20.70	15/12/2014	26/08/2014	111
Farm C	113	5	13.52	8/02/2015	26/08/2014	166
Farm C	113	5	14.49	7/04/2015	26/08/2014	224
Farm C	114	3	23.80	19/10/2014	NA	NA
Farm C	114	3	17.76	15/12/2014	NA	NA
Farm C	114	3	11.73	8/02/2015	NA	NA
Farm C	115	8	28.98	19/10/2014	NA	NA
Farm C	115	8	24.95	15/12/2014	NA	NA
Farm C	115	8	14.05	8/02/2015	NA	NA
Farm C	116	2	13.21	19/10/2014	1/08/2014	79
Farm C	116	2	5.17	15/12/2014	1/08/2014	136
Farm C	116	2	10.83	8/02/2015	1/08/2014	191
Farm C	116	2	8.32	7/04/2015	1/08/2014	249
Farm C	117	6	20.55	19/10/2014	17/08/2014	63
Farm C	117	6	18.49	15/12/2014	17/08/2014	120
Farm C	117	6	13.14	8/02/2015	17/08/2014	175
Farm C	117	6	8.67	7/04/2015	17/08/2014	233
Farm C	118	3	23.73	19/10/2014	22/08/2014	58
Farm C	118	3	20.20	15/12/2014	22/08/2014	115
Farm C	118	3	13.38	8/02/2015	22/08/2014	170
Farm C	118	3	11.89	7/04/2015	22/08/2014	228
Farm C	119	2	21.88	19/10/2014	11/08/2014	69

Farm C	119	2	14.24	15/12/2014	11/08/2014	126
Farm C	119	2	12.25	8/02/2015	11/08/2014	181
Farm C	119	2	9.69	7/04/2015	11/08/2014	239
Farm C	120	4	24.54	19/10/2014	12/08/2014	68
Farm C	120	4	17.66	15/12/2014	12/08/2014	125
Farm C	120	4	13.18	8/02/2015	12/08/2014	180
Farm C	120	4	11.99	7/04/2015	12/08/2014	238
Farm C	121	5	31.97	19/10/2014	21/08/2014	59
Farm C	121	5	23.65	15/12/2014	21/08/2014	116
Farm C	121	5	12.74	8/02/2015	21/08/2014	171
Farm C	121	5	15.20	7/04/2015	21/08/2014	229
Farm C	122	9	28.75	19/10/2014	NA	NA
Farm C	122	9	20.89	15/12/2014	NA	NA
Farm C	122	9	11.16	8/02/2015	NA	NA
Farm C	123	5	24.56	19/10/2014	16/08/2014	64
Farm C	123	5	23.84	15/12/2014	16/08/2014	121
Farm C	123	5	13.80	8/02/2015	16/08/2014	176
Farm C	123	5	11.87	7/04/2015	16/08/2014	234
Farm C	124	3	21.93	19/10/2014	NA	NA
Farm C	124	3	20.46	15/12/2014	NA	NA
Farm C	124	3	13.03	8/02/2015	NA	NA
Farm C	125	2	19.42	19/10/2014	8/09/2014	41
Farm C	125	2	17.20	15/12/2014	8/09/2014	98
Farm C	125	2	11.65	8/02/2015	8/09/2014	153
Farm C	125	2	9.75	7/04/2015	8/09/2014	211
Farm C	126	2	25.14	19/10/2014	10/08/2014	70
Farm C	126	2	13.69	15/12/2014	10/08/2014	127
Farm C	126	2	9.51	8/02/2015	10/08/2014	182
Farm C	126	2	8.72	7/04/2015	10/08/2014	240
Farm C	127	4	27.22	19/10/2014	NA	NA
Farm C	127	4	19.83	15/12/2014	NA	NA
Farm C	127	4	11.76	8/02/2015	NA	NA
Farm C	128	3	20.09	19/10/2014	14/08/2014	66
Farm C	128	3	14.93	15/12/2014	14/08/2014	123
Farm C	128	3	10.74	8/02/2015	14/08/2014	178
Farm C	128	3	10.73	7/04/2015	14/08/2014	236
Farm C	129	8	26.77	19/10/2014	NA	NA
Farm C	129	8	26.02	15/12/2014	NA	NA
Farm C	129	8	15.88	8/02/2015	NA	NA
Farm C	130	8	28.99	19/10/2014	19/08/2014	61
Farm C	130	8	22.29	15/12/2014	19/08/2014	118
Farm C	130	8	10.53	8/02/2015	19/08/2014	173
Farm C	130	8	10.14	7/04/2015	19/08/2014	231
Farm C	131	2	20.13	19/10/2014	14/08/2014	66
Farm C	131	2	14.54	15/12/2014	14/08/2014	123
Farm C	131	2	8.63	8/02/2015	14/08/2014	178

Farm C	131	2	9.23	7/04/2015	14/08/2014	236
Farm C	132	8	26.59	19/10/2014	NA	NA
Farm C	132	8	20.87	15/12/2014	NA	NA
Farm C	132	8	8.99	8/02/2015	NA	NA
Farm C	133	5	22.79	19/10/2014	29/08/2014	51
Farm C	133	5	22.96	15/12/2014	29/08/2014	108
Farm C	133	5	14.95	8/02/2015	29/08/2014	163
Farm C	133	5	13.44	7/04/2015	29/08/2014	221
Farm C	134	3	22.07	19/10/2014	1/09/2014	48
Farm C	134	3	8.41	15/12/2014	1/09/2014	105
Farm C	134	3	12.18	8/02/2015	1/09/2014	160
Farm C	134	3	12.02	7/04/2015	1/09/2014	218
Farm C	135	5	25.59	19/10/2014	27/08/2014	53
Farm C	135	5	22.23	15/12/2014	27/08/2014	110
Farm C	135	5	9.32	8/02/2015	27/08/2014	165
Farm C	135	5	13.09	7/04/2015	27/08/2014	223
Farm C	136	4	17.98	19/10/2014	30/08/2014	50
Farm C	136	4	19.95	15/12/2014	30/08/2014	107
Farm C	136	4	11.02	8/02/2015	30/08/2014	162
Farm C	136	4	9.53	7/04/2015	30/08/2014	220
Farm C	137	7	31.65	19/10/2014	24/08/2014	56
Farm C	137	7	26.48	15/12/2014	24/08/2014	113
Farm C	137	7	12.53	8/02/2015	24/08/2014	168
Farm C	137	7	13.49	7/04/2015	24/08/2014	226
Farm C	138	8	24.69	19/10/2014	NA	NA
Farm C	138	8	18.50	15/12/2014	NA	NA
Farm C	138	8	11.16	8/02/2015	NA	NA
Farm C	139	3	21.83	19/10/2014	13/08/2014	67
Farm C	139	3	18.40	15/12/2014	13/08/2014	124
Farm C	139	3	10.90	8/02/2015	13/08/2014	179
Farm C	139	3	8.69	7/04/2015	13/08/2014	237
Farm C	140	4	29.38	19/10/2014	NA	NA
Farm C	140	4	24.82	15/12/2014	NA	NA
Farm C	140	4	13.91	8/02/2015	NA	NA
Farm C	141	2	21.21	19/10/2014	6/08/2014	74
Farm C	141	2	17.00	15/12/2014	6/08/2014	131
Farm C	141	2	11.59	8/02/2015	6/08/2014	186
Farm C	141	2	9.22	7/04/2015	6/08/2014	244
Farm C	142	5	26.58	19/10/2014	6/08/2014	74
Farm C	142	5	24.36	15/12/2014	6/08/2014	131
Farm C	142	5	12.83	8/02/2015	6/08/2014	186
Farm C	142	5	13.42	7/04/2015	6/08/2014	244
Farm C	143	8	24.49	19/10/2014	27/09/2014	22
Farm C	143	8	21.82	15/12/2014	27/09/2014	79
Farm C	143	8	14.17	8/02/2015	27/09/2014	134
Farm C	143	8	13.10	7/04/2015	27/09/2014	192

Farm C	144	8	30.33	19/10/2014	NA	NA
Farm C	145	3	21.32	19/10/2014	29/08/2014	51
Farm C	145	3	19.37	15/12/2014	29/08/2014	108
Farm C	145	3	12.64	8/02/2015	29/08/2014	163
Farm C	145	3	11.12	7/04/2015	29/08/2014	221
Farm C	147	8	25.39	19/10/2014	23/08/2014	57
Farm C	147	8	10.22	15/12/2014	23/08/2014	114
Farm C	147	8	13.70	8/02/2015	23/08/2014	169
Farm C	147	8	10.32	7/04/2015	23/08/2014	227
Farm C	148	3	21.45	19/10/2014	26/08/2014	54
Farm C	148	3	15.56	15/12/2014	26/08/2014	111
Farm C	148	3	10.08	8/02/2015	26/08/2014	166
Farm C	148	3	9.75	7/04/2015	26/08/2014	224
Farm C	149	11	28.24	19/10/2014	23/08/2014	57
Farm C	149	11	21.29	15/12/2014	23/08/2014	114
Farm C	149	11	10.96	8/02/2015	23/08/2014	169
Farm C	149	11	8.60	7/04/2015	23/08/2014	227
Farm C	150	7	26.85	19/10/2014	25/08/2014	55
Farm C	150	7	22.62	15/12/2014	25/08/2014	112
Farm C	150	7	11.11	8/02/2015	25/08/2014	167
Farm C	150	7	11.15	7/04/2015	25/08/2014	225
Farm C	151	2	17.18	19/10/2014	17/08/2014	63
Farm C	151	2	13.29	15/12/2014	17/08/2014	120
Farm C	151	2	10.64	8/02/2015	17/08/2014	175
Farm C	151	2	9.63	7/04/2015	17/08/2014	233
Farm C	152	7	30.33	19/10/2014	9/08/2014	71
Farm C	152	7	20.71	15/12/2014	9/08/2014	128
Farm C	152	7	14.20	8/02/2015	9/08/2014	183
Farm C	152	7	11.45	7/04/2015	9/08/2014	241
Farm C	153	5	25.44	19/10/2014	6/08/2014	74
Farm C	153	5	22.62	15/12/2014	6/08/2014	131
Farm C	153	5	12.29	8/02/2015	6/08/2014	186
Farm C	153	5	8.03	7/04/2015	6/08/2014	244
Farm C	154	2	16.24	19/10/2014	14/08/2014	66
Farm C	154	2	14.84	15/12/2014	14/08/2014	123
Farm C	154	2	10.59	8/02/2015	14/08/2014	178
Farm C	154	2	8.91	7/04/2015	14/08/2014	236
Farm C	155	5	32.09	19/10/2014	6/08/2014	74
Farm C	155	5	23.32	15/12/2014	6/08/2014	131
Farm C	155	5	15.21	8/02/2015	6/08/2014	186
Farm C	155	5	16.64	7/04/2015	6/08/2014	244
Farm C	157	2	18.65	19/10/2014	5/09/2014	44
Farm C	157	2	16.57	15/12/2014	5/09/2014	101
Farm C	157	2	11.83	8/02/2015	5/09/2014	156
Farm C	157	2	11.32	7/04/2015	5/09/2014	214
Farm C	158	2	18.59	19/10/2014	10/08/2014	70

Farm C	158	2	16.39	15/12/2014	10/08/2014	127
Farm C	158	2	11.01	8/02/2015	10/08/2014	182
Farm C	158	2	11.24	7/04/2015	10/08/2014	240
Farm C	159	2	15.20	19/10/2014	3/09/2014	46
Farm C	159	2	12.62	15/12/2014	3/09/2014	103
Farm C	159	2	10.75	8/02/2015	3/09/2014	158
Farm C	159	2	9.53	7/04/2015	3/09/2014	216
Farm C	160	2	9.12	19/10/2014	NA	NA
Farm C	160	2	8.16	15/12/2014	NA	NA
Farm C	160	2	7.23	8/02/2015	NA	NA
Farm C	161	2	18.15	19/10/2014	17/08/2014	63
Farm C	161	2	15.35	15/12/2014	17/08/2014	120
Farm C	161	2	10.07	8/02/2015	17/08/2014	175
Farm C	161	2	0.00	7/04/2015	17/08/2014	233
Farm C	162	2	13.22	19/10/2014	24/08/2014	56
Farm C	162	2	17.24	15/12/2014	24/08/2014	113
Farm C	162	2	11.96	8/02/2015	24/08/2014	168
Farm C	162	2	8.42	7/04/2015	24/08/2014	226

Table 16. Data from prevalence study conducted by MPI in 2013, **Chapter 10.**

Farm	visit	Farm type	Date	Animal ID	HCT	Theileria count	Strain type
C1	1	Dairy town supply	4/04/2013	1	0.07	9	Ch Ik
C1	2	Dairy town supply	11/04/2013	11	0.29	0	Ik
C1	2	Dairy town supply	11/04/2013	74	0.3	10	Ik
C1	2	Dairy town supply	11/04/2013	86	0.37	1	Ik
C1	2	Dairy town supply	11/04/2013	156	0.28	1	un
C1	2	Dairy town supply	11/04/2013	172	0.32	0	Ik
C1	2	Dairy town supply	11/04/2013	193	0.31	2	Ik
C1	2	Dairy town supply	11/04/2013	198	0.24	5	Ik
C1	2	Dairy town supply	11/04/2013	200	0.29	1	Ik
C1	2	Dairy town supply	11/04/2013	202	0.28	0.9	Ik
C1	2	Dairy town supply	11/04/2013	250	0.35	0.9	Ik
C1	2	Dairy town supply	11/04/2013	229	0.3	0	Ik
C1	3	Dairy town supply	11/04/2013	R24	0.12	4	Ik
C1	3	Dairy town supply	11/04/2013	R34	0.21	38	Ik
C1	3	Dairy town supply	11/04/2013	R37	0.12	17	Ik
C1	3	Dairy town supply	11/04/2013	R57	0.23	3	Ik
C1	3	Dairy town supply	11/04/2013	R73	0.1	40	Ik
C1	3	Dairy town supply	11/04/2013	R77	0.21	24	Ik
C1	3	Dairy town supply	11/04/2013	R87	0.28	0	Ik
C1	3	Dairy town supply	11/04/2013	R121	0.04	0	Ik
C1	3	Dairy town supply	11/04/2013	R126	0.17	20	Ik
C1	3	Dairy town supply	11/04/2013	R128	0.18	3	Ik
C1	3	Dairy town supply	11/04/2013	R133	0.21	5	Ik
D1	2	Dairy town supply	11/04/2013	113B	0.19	10	Ik
D1	2	Dairy town supply	11/04/2013	31B	NA	0.9	Ik
D1	2	Dairy town supply	11/04/2013	109B	0.12	3	Ik
D1	2	Dairy town supply	11/04/2013	90B	0.26	0	neg
D1	2	Dairy town supply	11/04/2013	184B	0.27	8	Ik
D1	2	Dairy town supply	11/04/2013	16B	0.23	0	Ik
D1	2	Dairy town supply	11/04/2013	25B	0.15	0.9	Ik
D1	2	Dairy town supply	11/04/2013	38B	0.15	19	Ik
D1	2	Dairy town supply	11/04/2013	72B	0.11	10	Ik
D1	3	Dairy town supply	11/04/2013	220	0.27	0.9	Ik
D1	3	Dairy town supply	11/04/2013	370	0.25	11	Ik
D1	3	Dairy town supply	11/04/2013	239	0.32	0	Ik
D1	3	Dairy town supply	11/04/2013	256	0.26	4	Ik
D1	3	Dairy town supply	11/04/2013	122	0.31	1	Ik
D1	3	Dairy town supply	11/04/2013	172	0.22	0.9	Ik
D1	3	Dairy town supply	11/04/2013	290	0.26	0	Ik
D1	3	Dairy town supply	11/04/2013	541	0.26	5	Ik
D1	3	Dairy town supply	11/04/2013	313	0.24	0	Ik
D1	3	Dairy town supply	11/04/2013	6B	0.14	2	Ik
D1	3	Dairy town supply	11/04/2013	27	NA	0.9	Ik

D2	1	Dairy town supply	27/03/2013	78	0.18	23	Ik
D2	2	Dairy town supply	9/04/2013	31	0.3	1	Ch Ik
D2	2	Dairy town supply	9/04/2013	38	0.27	5	Ch Ik
D2	2	Dairy town supply	9/04/2013	39	0.33	3	Ch Ik
D2	2	Dairy town supply	9/04/2013	45	0.33	0.9	Ch Ik
D2	2	Dairy town supply	9/04/2013	51	0.24	2	Ch Ik
D2	2	Dairy town supply	9/04/2013	64	0.24	0.9	Ch Ik
D2	2	Dairy town supply	9/04/2013	94	0.25	6	Ch Ik
D2	2	Dairy town supply	9/04/2013	58		4	Ch Ik
D2	2	Dairy town supply	9/04/2013	69		0.9	Ch Ik
D2	2	Dairy town supply	9/04/2013	110		5	Ch Ik
D2	3	Dairy town supply	9/04/2013	78	0.38	0	Ik
D2	3	Dairy town supply	9/04/2013	84	0.33	8	Ch Ik
D2	3	Dairy town supply	9/04/2013	91	0.31	0	Ik
D2	3	Dairy town supply	9/04/2013	92	0.35	1	Ch
D2	3	Dairy town supply	9/04/2013	94	0.35	0	Ik
D2	3	Dairy town supply	9/04/2013	95	0.31	0	Buf
D2	3	Dairy town supply	9/04/2013	99	0.34	0	Buf
D2	3	Dairy town supply	9/04/2013	106	0.32	0	Ik
D2	3	Dairy town supply	9/04/2013	107	0.39	0	Buf
D2	3	Dairy town supply	9/04/2013	115	0.4	0	Ch Ik
D2	4	Dairy town supply	9/04/2013	18 (A)	0.27	0	neg
D2	4	Dairy town supply	9/04/2013	21	0.21	0	neg
D2	4	Dairy town supply	9/04/2013	23	0.24	0	neg
D2	4	Dairy town supply	9/04/2013	25	0.32	0	neg
D2	4	Dairy town supply	9/04/2013	30	0.2	0	neg
D2	4	Dairy town supply	9/04/2013	32	0.24	0	neg
D2	4	Dairy town supply	9/04/2013	35	0.33	0	neg
D2	4	Dairy town supply	9/04/2013	37 (A)	0.41	0	neg
D2	4	Dairy town supply	9/04/2013	39	0.34	0	neg
D2	4	Dairy town supply	9/04/2013	40	0.43	0	neg
D2	5	Dairy town supply	22/04/2013	12	0.32	0	Buf
D2	5	Dairy town supply	22/04/2013	19	0.27	0	Ch
D2	5	Dairy town supply	22/04/2013	22	0.29	0	Ch
D2	5	Dairy town supply	22/04/2013	72	0.29	0	Ch
D2	5	Dairy town supply	22/04/2013	94	0.28	0	Ch
D2	5	Dairy town supply	22/04/2013	246	0.32	0	neg
D2	5	Dairy town supply	22/04/2013	291	0.24	0	Ch
D2	5	Dairy town supply	22/04/2013	304	0.28	0	Ik
D2	5	Dairy town supply	22/04/2013	352	0.3	0	neg
D2	6	Dairy town supply	22/04/2013	133	0.13	22	Ch Ik
D2	6	Dairy town supply	22/04/2013	201	0.3	72	Ch Ik
D2	6	Dairy town supply	22/04/2013	353	0.32	2	Buf
D2	6	Dairy town supply	22/04/2013	360	0.2	1	Ch Ik
D2	6	Dairy town supply	22/04/2013	452	0.19	24	Ch Ik
D2	6	Dairy town supply	22/04/2013	18 (T)	0.26	27	Ch Ik

D2	6	Dairy town supply	22/04/2013	214 (T)	0.17	7	Ch Ik
D2	6	Dairy town supply	22/04/2013	368 (T)	0.25	12	Ch Ik
D2	6	Dairy town supply	22/04/2013	463 (T)	0.14	46	Ch Ik
D2	6	Dairy town supply	22/04/2013	477 (T)	0.29	35	Ch Ik
F1	1	Dairy spring calving	2/09/2013	451	0.14	0	Ik
F1	1	Dairy spring calving	2/09/2013	954NT	0.09	10	Ik
F1	1	Dairy spring calving	2/09/2013	1463	0.08	74	Ik
F1	2	Dairy spring calving	6/09/2013	374	0.22	0	neg
F1	2	Dairy spring calving	6/09/2013	410	0.1	37	Ik
F1	2	Dairy spring calving	6/09/2013	452	0.18	1	Ik
F1	2	Dairy spring calving	6/09/2013	454	0.11	20	Ik
F1	2	Dairy spring calving	6/09/2013	478	0.09	14	Ik
F1	2	Dairy spring calving	6/09/2013	563	0.1	19	Ik
F1	2	Dairy spring calving	6/09/2013	591	0.11	38	Ik
F1	2	Dairy spring calving	6/09/2013	593	0.12	12	Ik
F1	2	Dairy spring calving	6/09/2013	708	0.19	6	Ik
F1	2	Dairy spring calving	6/09/2013	737	0.15	15	Ik
F1	2	Dairy spring calving	6/09/2013	771	0.1	11	Ik
F1	2	Dairy spring calving	6/09/2013	877	0.11	25	Ik
F1	2	Dairy spring calving	6/09/2013	968	0.11	1	Ik
F1	2	Dairy spring calving	6/09/2013	1284	0.19	23	Ik
F1	2	Dairy spring calving	6/09/2013	1456	0.15	4	Ik
G1	1	Dairy spring calving	8/04/2013	206	0.09		Ik
G1	2	Dairy spring calving	11/04/2013	H11			neg
G1	2	Dairy spring calving	11/04/2013	H22			Ik
G1	2	Dairy spring calving	11/04/2013	H26			neg
G1	2	Dairy spring calving	11/04/2013	H27			Ik
G1	2	Dairy spring calving	11/04/2013	H29			neg
G1	2	Dairy spring calving	11/04/2013	H38			neg
G1	2	Dairy spring calving	11/04/2013	Cow99			neg
G1	2	Dairy spring calving	11/04/2013	Cow225			Ik
G1	2	Dairy spring calving	11/04/2013	Cow103			Ik
G1	2	Dairy spring calving	11/04/2013	C0w160			neg
H1	1	Dairy spring calving	7/05/2013	167	0.09	26	Ik
H1	2	Dairy spring calving	10/05/2013	114	0.3	0	neg
H1	2	Dairy spring calving	10/05/2013	76	0.31	1	Ik
H1	2	Dairy spring calving	10/05/2013	11	0.31	1	Ik
H1	2	Dairy spring calving	10/05/2013	93	0.26	1	Ik
H1	2	Dairy spring calving	10/05/2013	101	0.23	6	Ik
H1	2	Dairy spring calving	10/05/2013	112	0.32	1	Ik
H1	2	Dairy spring calving	10/05/2013	3	0.27	1	Ik
H1	2	Dairy spring calving	10/05/2013	24	0.28	4	Ik
H1	2	Dairy spring calving	10/05/2013	94	0.3	4	Ik
H1	2	Dairy spring calving	10/05/2013	131	0.29	12	Ik
H2	2	Dairy spring calving	26/04/2013	4	0.32	0	un
H2	2	Dairy spring calving	26/04/2013	17	0.31	2	un

H2	2	Dairy spring calving	26/04/2013	26	0.3	0	neg
H2	2	Dairy spring calving	26/04/2013	64	0.29	1	un
H2	2	Dairy spring calving	26/04/2013	73	0.32	2	un
H2	2	Dairy spring calving	26/04/2013	191	0.33	0	neg
H2	2	Dairy spring calving	26/04/2013	214	0.33	1	un
H2	2	Dairy spring calving	26/04/2013	266	0.34	1	un
H2	2	Dairy spring calving	26/04/2013	272	0.31	5	un
H2	2	Dairy spring calving	26/04/2013	297	0.28	0	un
H3	1	Dairy spring calving	5/04/2013	20	0.08		Ik
H3	2	Dairy spring calving	12/04/2013	11	0.32	1	neg
H3	2	Dairy spring calving	12/04/2013	45	0.25	37	Un
H3	2	Dairy spring calving	12/04/2013	55	0.29	3	Ik
H3	2	Dairy spring calving	12/04/2013	98	0.22	35	Ik
H3	2	Dairy spring calving	12/04/2013	100	0.29	1	Buf
H3	2	Dairy spring calving	12/04/2013	105	0.27	1	Buf
H3	2	Dairy spring calving	12/04/2013	117	0.27	1	Ch
H3	2	Dairy spring calving	12/04/2013	156	0.11	19	Ik
H3	2	Dairy spring calving	12/04/2013	174	NA	1	Ik
H4	1	Dairy autumn calving	5/04/2013		0.13	4	Ik
H4	2	Dairy autumn calving	16/04/2013	18	0.26	0	Ik
H4	2	Dairy autumn calving	16/04/2013	20	0.34	2	Ik
H4	2	Dairy autumn calving	16/04/2013	105	0.29	0.9	Ik
H4	2	Dairy autumn calving	16/04/2013	391	0.32	0.9	Ik
H4	2	Dairy autumn calving	16/04/2013	432	0.31	3	Ik
H4	2	Dairy autumn calving	16/04/2013	475	0.31	1	Ik
H4	2	Dairy autumn calving	16/04/2013	584	0.26	0	Ik
H4	2	Dairy autumn calving	16/04/2013	653	0.39	0	Ik
H4	2	Dairy autumn calving	16/04/2013	665	0.22	57	Ik
H4	2	Dairy autumn calving	16/04/2013	674	0.3	0	Ik
H5	1	Dairy spring calving	16/04/2013	7	0.13	7	Ik
H5	2	Dairy spring calving	18/04/2013	15	0.13	1	Ik
H5	2	Dairy spring calving	18/04/2013	105	0.2	0	Ik
H5	2	Dairy spring calving	18/04/2013	195	0.3	0	Ik
H5	2	Dairy spring calving	18/04/2013	296	0.14	3	Ik
H5	2	Dairy spring calving	18/04/2013	319	0.19	8	Ik
H5	2	Dairy spring calving	18/04/2013	397	0.23	0	Ik
H5	2	Dairy spring calving	18/04/2013	dead	0.09	5	Ik
K1	1	Dairy town supply	26/04/2013	288	0.1	8	Ik
K1	1	Dairy town supply	26/04/2013	171	0.11	0	Ik
K1	2	Dairy town supply	29/04/2013	373s	0.32	0	neg
K1	2	Dairy town supply	29/04/2013	655s	0.31	1	un
K1	2	Dairy town supply	29/04/2013	487s	0.3	1	Ik
K1	2	Dairy town supply	29/04/2013	244s	0.3	0	neg
K1	2	Dairy town supply	29/04/2013	143s	0.28	1	Ik
K1	2	Dairy town supply	29/04/2013	113s	0.2	1	Ik
K1	2	Dairy town supply	29/04/2013	154s	0.31	1	Ik

K1	2	Dairy town supply	29/04/2013	459s	0.31	0	neg
K1	2	Dairy town supply	29/04/2013	236s	0.31	1	neg
K1	2	Dairy town supply	29/04/2013	275s	0.33	0	neg
K1	3	Dairy town supply	29/04/2013	108	0.28	0	un
K1	3	Dairy town supply	29/04/2013	516	0.27	0	neg
K1	3	Dairy town supply	29/04/2013	33	0.28	1	lk
K1	3	Dairy town supply	29/04/2013	253	0.23	0	lk
K1	3	Dairy town supply	29/04/2013	139a	0.19	10	lk
K1	3	Dairy town supply	29/04/2013	45a	0.26	1	lk
K1	3	Dairy town supply	29/04/2013	9a heifer	0.3	2	un
K1	3	Dairy town supply	29/04/2013	10a	0.3	3	lk
K1	3	Dairy town supply	29/04/2013	138a	0.23	1	lk
K1	3	Dairy town supply	29/04/2013	51a	0.24	1	lk
K1	3	Dairy town supply	29/04/2013	688	0.34	1	lk
L1	1	Dairy spring calving	4/03/2013	298	0.08	2	lk
L1	2	Dairy spring calving	7/05/2013		0.14	1	lk
L1	2	Dairy spring calving	7/05/2013	5	0.28	1	lk
L1	2	Dairy spring calving	7/05/2013	49	0.19	12	lk
L1	2	Dairy spring calving	7/05/2013	56	0.19	96	lk
L1	2	Dairy spring calving	7/05/2013	69	0.25	5	lk
L1	2	Dairy spring calving	7/05/2013	265	0.24	11	lk
L1	2	Dairy spring calving	7/05/2013	320	0.22	131	lk
L1	2	Dairy spring calving	7/05/2013	333	0.35	0	neg
L1	2	Dairy spring calving	7/05/2013	369	0.23	80	lk
L1	2	Dairy spring calving	7/05/2013	32	0.1	22	lk
L1	2	Dairy spring calving	7/05/2013	19	0.24	33	lk
L1	2	Dairy spring calving	7/05/2013	301	0.26	4	lk
L2	1	Dairy spring calving	15/04/2013	84	0.08	80	lk
L3	1	Dairy spring calving	15/04/2013	96	0.11	20	lk
L4	2	Dairy spring calving	19/04/2013	52	0.2	6	lk
L5	2	Dairy spring calving	19/04/2013	57	0.24	1	lk
L6	2	Dairy spring calving	19/04/2013	82	0.25	7	lk
L7	2	Dairy spring calving	19/04/2013	90	0.26	8	Ch
L8	2	Dairy spring calving	19/04/2013	109	0.23	1	Buf
L9	2	Dairy spring calving	19/04/2013	113	0.27	5	lk
L10	2	Dairy spring calving	19/04/2013	131	0.28	9	lk
L11	2	Dairy spring calving	19/04/2013	124	0.25	0	neg
L12	2	Dairy spring calving	19/04/2013	198	0.36	1	Ch
L13	2	Dairy spring calving	19/04/2013	220	0.16	4	lk
M1	1	Dairy spring calving	22/04/2013	88	0.09		lk
M1	2	Dairy spring calving	23/04/2013	4	0.3	0	neg
M1	2	Dairy spring calving	23/04/2013	52	0.29	13	lk
M1	2	Dairy spring calving	23/04/2013	121	0.31	0	neg
M1	2	Dairy spring calving	23/04/2013	166	0.31	0	neg
M1	2	Dairy spring calving	23/04/2013	228	0.33	0	neg
M1	2	Dairy spring calving	23/04/2013	274	0.23	10	lk

M1	2	Dairy spring calving	23/04/2013	327	0.35	1	neg
M1	2	Dairy spring calving	23/04/2013	447	0.3	1	neg
M1	2	Dairy spring calving	23/04/2013	475	0.32	0	neg
M1	2	Dairy spring calving	23/04/2013	524	0.39	0	neg
M1	2	Dairy spring calving	23/04/2013	543	0.29	0	neg
M2	1	Dairy spring calving	24/04/2013	135	0.13	1	Ik
M2	2	Dairy spring calving	30/04/2013	4	0.37	0	Ik
M2	2	Dairy spring calving	30/04/2013	52	0.3	2	Ik
M2	2	Dairy spring calving	30/04/2013	54	0.34	2	Ik
M2	2	Dairy spring calving	30/04/2013	86	0.3	1	Ik
M2	2	Dairy spring calving	30/04/2013	113	0.28	2	Ik
M2	2	Dairy spring calving	30/04/2013	122	0.29	0	Ik
M2	2	Dairy spring calving	30/04/2013	160	0.28	1	Ik
M2	2	Dairy spring calving	30/04/2013	185	0.3	1	Ik
M2	2	Dairy spring calving	30/04/2013	253	0.3	0	Ik
M2	2	Dairy spring calving	30/04/2013	258	0.35	1	Ik
M3	1	Dairy town supply	26/04/2013	353	0.12	160	Ik
M3	1	Dairy town supply	26/04/2013	510	0.09	115	Ik
M3	2	Dairy town supply	29/04/2013	19	0.28	1	un
M3	2	Dairy town supply	29/04/2013	64	0.32	1	Ik
M3	2	Dairy town supply	29/04/2013	107	0.28	1	un
M3	2	Dairy town supply	29/04/2013	114	0.25	1	Ik
M3	2	Dairy town supply	29/04/2013	164	0.27	1	Ik
M3	2	Dairy town supply	29/04/2013	223	0.28	1	un
M3	2	Dairy town supply	29/04/2013	225	0.27	1	neg
M3	2	Dairy town supply	29/04/2013	226	0.24	1	Ik
M3	2	Dairy town supply	29/04/2013	352	0.26	10	Ik
M3	2	Dairy town supply	29/04/2013	450	0.19	1	Ik
M4	1	Dairy town supply	5/04/2013		0.09	41	Ch Ik
M4	2	Dairy town supply	16/04/2013	34	0.29	0	Ik
M4	2	Dairy town supply	16/04/2013	52	0.3	11	Ik
M4	2	Dairy town supply	16/04/2013	145	0.25	5	Ik
M4	2	Dairy town supply	16/04/2013	148	0.25	0.9	Ik
M4	2	Dairy town supply	16/04/2013	198	0.21	1	Ik
M4	2	Dairy town supply	16/04/2013	204	0.27	1	Ik
M4	2	Dairy town supply	16/04/2013	225	0.25	4	Ik
M4	2	Dairy town supply	16/04/2013	257	0.25	2	Ik
M4	2	Dairy town supply	16/04/2013	274	0.31	0.9	Ik
M4	2	Dairy town supply	16/04/2013	NT	0.26	8	Ik
M5	2	Dairy spring calving	12/04/2013	R4	0.19	10	Ik
M5	2	Dairy spring calving	12/04/2013	R69	0.15	35	Ik
M5	2	Dairy spring calving	12/04/2013	R85	0.26	3	Ik
M5	2	Dairy spring calving	12/04/2013	R85(2)	0.18	91	Ik
M5	2	Dairy spring calving	12/04/2013	R134	0.22	3	Ik
M5	2	Dairy spring calving	12/04/2013	R219	0.19	4	Ik
M5	2	Dairy spring calving	12/04/2013	R275	0.19	14	Ik

M5	2	Dairy spring calving	12/04/2013	R337	0.24	6	Ik
M5	3	Dairy spring calving	12/04/2013	5	0.26	0	un
M5	3	Dairy spring calving	12/04/2013	15	0.22	0	un
M5	3	Dairy spring calving	12/04/2013	78	0.27	1	un
M5	3	Dairy spring calving	12/04/2013	81	0.31	0.9	Ik
M5	3	Dairy spring calving	12/04/2013	111	0.24	2	Ik
M5	3	Dairy spring calving	12/04/2013	139	0.32	1	Ik
M5	3	Dairy spring calving	12/04/2013	160	0.31	3	un
M5	3	Dairy spring calving	12/04/2013	164	0.26	0	un
M5	3	Dairy spring calving	12/04/2013	198	0.26	0.9	un
M5	3	Dairy spring calving	12/04/2013	267	0.26	0.9	un
M6	1	Dry	3/05/2013	70	0.1	40	Ik
M6	2	Dry	8/05/2013	10	0.39	0	Ik
M6	2	Dry	8/05/2013	15	0.35	0	Ik
M6	2	Dry	8/05/2013	16	0.32	1	Ik
M6	2	Dry	8/05/2013	26	0.34	7	Ik
M6	2	Dry	8/05/2013	28	0.35	3	Ik
M6	2	Dry	8/05/2013	38	0.33	0	Ik
M6	2	Dry	8/05/2013	43	0.36	0	neg
M6	2	Dry	8/05/2013	55	0.34	2	un
M6	2	Dry	8/05/2013	62	0.38	1	Ik
M6	2	Dry	8/05/2013	65	0.37	5	Ik
P1	1	Dairy spring calving	21/08/2013	163	0.1	1	Ik
P1	2	Dairy spring calving	28/08/2013	1	0.25	39	Ik
P1	2	Dairy spring calving	28/08/2013	5	0.27	2	Ik
P1	2	Dairy spring calving	28/08/2013	18	0.27	1	Ik
P1	2	Dairy spring calving	28/08/2013	31	0.24	5	Ik
P1	2	Dairy spring calving	28/08/2013	37	0.18	48	Ik
P1	2	Dairy spring calving	28/08/2013	43	0.23	51	Ik
P1	2	Dairy spring calving	28/08/2013	52	0.22	10	Ik
P1	2	Dairy spring calving	28/08/2013	63	0.3	7	Ik
P1	2	Dairy spring calving	28/08/2013	83	0.24	6	Ik
P1	2	Dairy spring calving	28/08/2013	92	0.24	21	Ik
P1	2	Dairy spring calving	28/08/2013	102	0.18	30	Ik
P1	2	Dairy spring calving	28/08/2013	103	0.35	0	Ik
P1	2	Dairy spring calving	28/08/2013	121	0.2	29	Ik
P1	2	Dairy spring calving	28/08/2013	125	0.25	5	Ik
P1	2	Dairy spring calving	28/08/2013	132	0.26	11	Ik
P1	2	Dairy spring calving	28/08/2013	141	0.25	1	Ik
P1	2	Dairy spring calving	28/08/2013	175	0.25	27	Ik
P1	2	Dairy spring calving	28/08/2013	177	0.3	5	Ik
P1	2	Dairy spring calving	28/08/2013	178	0.21	24	Ik
P1	2	Dairy spring calving	28/08/2013	S27	0.22	24	Ik
P1	2	Dairy spring calving	28/08/2013	S33	0.22	1	Ik
P1	2	Dairy spring calving	28/08/2013	S64	0.17	8	Ik
P1	2	Dairy spring calving	28/08/2013	S87	0.14	6	Ik

P1	2	Dairy spring calving	28/08/2013	S93	0.23	1	Ik
P1	2	Dairy spring calving	28/08/2013	S98	0.25	2	Ik
P1	2	Dairy spring calving	28/08/2013	S107	0.2	1	Ik
P1	2	Dairy spring calving	28/08/2013	S126	0.16	2	Ik
P1	2	Dairy spring calving	28/08/2013	148		40	Ik
S1	1	Dairy spring calving	22/04/2013	32	0.13	7	Ik
S1	2	Dairy spring calving	30/04/2013	25	0.31	1	Ik
S1	2	Dairy spring calving	30/04/2013	64	0.31	0	neg
S1	2	Dairy spring calving	30/04/2013	94	0.36	0	neg
S1	2	Dairy spring calving	30/04/2013	157	0.35	1	Ik
S1	2	Dairy spring calving	30/04/2013	160	0.36	1	Ik
S1	2	Dairy spring calving	30/04/2013	180	0.16	1	Ik
S1	2	Dairy spring calving	30/04/2013	205	0.35	7	Ik
S1	2	Dairy spring calving	30/04/2013	238	0.29	101	Ik
S1	2	Dairy spring calving	30/04/2013	264	0.2	42	Ik
S1	2	Dairy spring calving	30/04/2013	274	0.34	0	un
S2	2	Dairy spring calving	30/04/2013	77	0.37	1	Ik
S2	2	Dairy spring calving	30/04/2013	90	0.36	35	Ik
S2	2	Dairy spring calving	30/04/2013	91	0.31	3	Ik
S2	2	Dairy spring calving	30/04/2013	92	0.24	22	Ik
S2	2	Dairy spring calving	30/04/2013	108	0.34	1	Ik
S2	2	Dairy spring calving	30/04/2013	110	0.37	0	Ik
S2	2	Dairy spring calving	30/04/2013	120	0.28	6	Ik
S2	2	Dairy spring calving	30/04/2013	141	0.27	4	Ik
S2	2	Dairy spring calving	30/04/2013	150	0.31	3	Ik
S2	2	Dairy spring calving	30/04/2013	164	0.33	1	Ik
W1	1	Dairy spring calving	15/04/2013	donor	0.09		Ik
W1	2	Dairy spring calving	15/05/2013	M40	0.29		neg
W1	2	Dairy spring calving	15/05/2013	M153	0.3		neg
W1	2	Dairy spring calving	15/05/2013	M101	0.27		neg
W1	2	Dairy spring calving	15/05/2013	M71	0.27		neg
W1	2	Dairy spring calving	15/05/2013	M317	0.28		neg
W1	2	Dairy spring calving	15/05/2013	M63	0.32		neg
W1	2	Dairy spring calving	15/05/2013	M249	0.29		un
W1	2	Dairy spring calving	15/05/2013	M16			neg
W1	2	Dairy spring calving	15/05/2013	M32	0.31		neg
W1	2	Dairy spring calving	15/05/2013	M324			neg
W1	3	Beef heifers	15/05/2013	124	0.3		Ik
W1	3	Beef heifers	15/05/2013	91	0.32		Ik
W1	3	Beef heifers	15/05/2013	85	0.35		Ik
W1	3	Beef heifers	15/05/2013	103			Ik
W1	3	Beef heifers	15/05/2013	115	0.27		Ik
W1	3	Beef heifers	15/05/2013	151	0.3		Ik
W1	3	Beef heifers	15/05/2013	190			un
W1	3	Beef heifers	15/05/2013	119	0.32		Ik
W1	3	Beef heifers	15/05/2013	86	0.28		Ik

W1	3	Beef heifers	15/05/2013	114	0.32		un
W2	1	Dairy spring calving	30/04/2013	79	0.09	1	Ik
W2	1	Dairy spring calving	30/04/2013	159	0.08	9	Ik
W2	2	Dairy spring calving	2/05/2013	60	0.23	56	Ik
W2	2	Dairy spring calving	2/05/2013	336	0.24	22	Ik
W2	2	Dairy spring calving	2/05/2013	254	0.27	1	un
W2	2	Dairy spring calving	2/05/2013	208	0.33	3	Ik
W2	2	Dairy spring calving	2/05/2013	91	0.12	15	Ik
W2	2	Dairy spring calving	2/05/2013	264	0.18	76	Ik
W2	2	Dairy spring calving	2/05/2013	327	0.23	36	Ik
W2	2	Dairy spring calving	2/05/2013	325	0.18	16	Ik
W2	2	Dairy spring calving	2/05/2013	118	0.33	2	Ik
W2	2	Dairy spring calving	2/05/2013	314	0.31	1	Ik
W3	1	Beef	19/03/2013	97195	0.21		Ch Ik
W3	2	Beef	28/03/2013	97078	0.29		Ch Ik
W3	2	Beef	28/03/2013	97107	0.31		Ch Ik
W3	2	Beef	28/03/2013	97115	0.31		Ch Ik
W3	2	Beef	28/03/2013	97237	0.3		Ch Ik
W3	2	Beef	28/03/2013	97154	0.35		Ch Ik
W3	2	Beef	28/03/2013	97169	0.26		Ch Ik
W3	2	Beef	28/03/2013	97171	0.24		Ch Ik
W3	2	Beef	28/03/2013	97204	0.27		Ch Ik
W3	2	Beef	28/03/2013	97208	0.31		Ch Ik
W3	2	Beef	28/03/2013	97234	0.27		Ch Ik
W4	2	Dairy spring calving	24/04/2013	19	0.29	0	un
W4	2	Dairy spring calving	24/04/2013	25	0.34	0	neg
W4	2	Dairy spring calving	24/04/2013	45	0.29	0	neg
W4	2	Dairy spring calving	24/04/2013	51	0.33	0	un
W4	2	Dairy spring calving	24/04/2013	183	0.29	0	neg
W4	2	Dairy spring calving	24/04/2013	276	0.32	0	neg
W4	2	Dairy spring calving	24/04/2013	279	0.26	0	neg
W4	2	Dairy spring calving	24/04/2013	283	0.32	0	neg
W4	2	Dairy spring calving	24/04/2013	364	0.32	0	neg
W4	2	Dairy spring calving	24/04/2013	372	0.3	0	un

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