THE IMPACT OF AGE AT FIRST CALVING ON FIRST LACTATION PERFORMANCE OF DAIRY HEIFERS WITHIN THE UNITED KINGDOM

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LIST OF ABBREVIATIONS

AFC	Age at first calving
BRD	Bovine respiratory disease
BW	Bodyweight
CR	Conception rate
DLWG	Daily liveweight gain
DIM	Days in milk
FCE	Feed conversion efficiency
KPI	Key performance indicator
SCC	Somatic cell count

ABSTRACT

The objective of this research was to evaluate the performance and survival of first lactation heifers within a large sample of herds across United Kingdom and specifically to assess the association between age at first calving (AFC) on their survival. Data from 437 herds were re-structured for analysis. Descriptive statistics were calculated, and multilevel logistic regression models were used to explore factors associated with the risk of first lactation culling, fertility performance and milk production. The mean within-herd culling rate for the primiparous heifers was 15.9%. The mean within-herd AFC was 29.6 months, with 35.9% of heifers having an AFC >30 months of age. Multivariable analysis revealed a negative association between survival rate of primiparous heifers and increasing AFC, and also associations with herd culling rate in older cows and calving season. This study highlights the importance of AFC for survival of primiparous heifers, as well as the need to address heifer wastage in herds with high culling rates. The fertility performance analysis, as measured by 100 day and 200 day in calf rates, showed a negative association between being in calf by 100 days and 200 days in milk and increasing AFC. The production performance however showed a positive association between 305 day yield and increasing AFC, however the clinical relevance of this was debatable.

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A large section of this work has been published as Sherwin et al., 2016. The association between age at first calving and survival of first lactation heifers within dairy herds, *Animal* 10 (11), 1877-1882.

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1. Chapter 1: Introduction

Age at first calving (AFC) has been quoted as a key performance indicator (KPI) within the dairy industry for monitoring heifer performance, in terms of both rearing and past fertility, as well as future production (Cooke and Wathes, 2014). AFC is considered to be a KPI because it can reflect the efficiency of the heifer rearing programme as well as highlighting the time taken for new heifers to enter the adult herd. AFC is inherently correlated to the adult herd culling rate and will be the same if there is a requirement for a consistent number of animals within the adult herd; they will not be the same if the herd is increasing in numbers (e.g. expanding) or decreasing in number (e.g. selling the herd). Research has shown that in order to achieve optimal lifetime performance, it is important for heifers to remain healthy and meet target growth rates to ensure that they are well-grown before they calve for the first time (Le Cozler, Lollivier, Lacasse, & Disenhaus, 2008). With less than a quarter of herds in the UK achieving a mean AFC of 24 months in 2015 (Hanks and Kossaibati, 2015), there is a great potential for improvement. This chapter describes literature relating to the performance of heifers across the world in terms of AFC and how AFC correlates with future production, culling rates within the milking herd and survival of animals.

1.1 Culling Rates

The replacement rate, and therefore the need for heifers to come into a herd, is directly linked to the number of animals leaving the herd, i.e. the culling rate, in order to maintain a constant number of animals within the herd (Kristensen, 1992). Culls have traditionally been classified as voluntary or involuntary, however another classification is "forced culls" and "economic culls". Forced culls are those cows for which no possible productive future exists and economic culls are those cows for which a decision has been made that replacing them with another cow is a sensible economic option (Fetrow, Nordlund, & Norman, 2006). Since the majority of culls on farm are economic (Orpin &

Esslemont, 2010), this indicates that the incoming replacement animal needs to be a better financial option for the farm. Previous research highlights that the costs of rearing a replacement are generally not recovered until the second lactation (Archer, Mc Coy, Wapenaar, & Green, 2013), therefore it is economically important for most dairies that replacement heifers survive to their second lactation.

The herd culling rate has been quoted as a KPI within the dairy industry (Compton et al., 2017; de Vries et al., 2011) and can be used to benchmark other farms against. Whilst culling cows is inevitable, a high culling rate has been quoted as a poor welfare indicator (de Vries et al., 2011); however the dynamics of herd culling rate are not that simple. The risk of culling can be reason-specific and will vary depending upon multiple factors, such as stage of lactation, parity, pregnancy, season, herd characteristics, and other concurrent conditions affecting individual cows (Pinedo et al., 2014). Other reasons that would influence the risk of being culled would include whether the farm was aiming to increase the number of animals, the milk price compared to the cull cow price, as well as the availability of the an economical viable replacement. In some herds, such as a flying herd, the culling rate may be low if the price of replacement heifers is high and the milk price is low, whilst a herd which raises their own heifers of high genetic merit may have a higher culling rate at times of a high milk price, as they aim to increase the genetic merit of the herd by introducing the replacement heifers as soon as possible. Therefore the dynamics of culling within a herd is fluid and will alter depending upon the market value of cows.

1.1.1 HERD CULLING RATES

The mean herd culling rate has been quoted between 22% and 25% in the past 20 years (Bell et al., 2010; Esslemont & Kossaibati, 1997; Orpin & Esslemont, 2010; Randall et al., 2015). A study investigating the deaths and disposals of 50 herds between 1990 and 1992 reported an mean culling rate of 23.8%, with a variation of 11.8% to 32.9%

between herds (Esslemont & Kossaibati, 1997). These results were similar to those reported by Bell et al. (2010) for the culling rates at the University of Edinburgh's Langhill farm and the SAC Dairy Research Centre for the time period 1990 to 2008; the mean culling rate was approximately 25.0% over the 18 year period (Bell et al., 2010). A more recent study based on 500 milk recording herds within the UK reported an unchanged culling rate within the milking herd of 24% for 2010 to 2015, with the "best" 25% of herds achieving 20% (Hanks & Kossabaiti, 2015).

1.1.2 CULLING RATES WITHIN FIRST LACTATION HEIFERS

With research highlighting that an increasing proportion of cows surviving beyond the first lactation was associated with increasing the profit of the farm (Jagannatha et al. 1998), it is important to investigate the culling rate of first lactation heifers, for both economic and welfare reasons. In a study of 18 farms within south east England, there was an mean culling rate of first lactation heifers of 19% (range 7.1% to 25.0%). These herds consisted of 15 to 30 first lactation heifers, born in 2003 and 2004 (Brickell & Wathes 2011). The mean DIM prior to being culled was 322 DIM (±29 days) suggesting many of these were for failure to conceive.

A study in Ireland that investigated the survival of 192,404 first lactation Holstein-Friesian heifers, reported that only 76% of the heifers survived to second lactation, an exit rate of 24%. This was a higher culling rate than reported in Florida of 17.6% (Ettema & Santos 2004), which was based on three herds and a total of 1,933 first lactation heifers. These results were all lower than those reported for 601 heifers born in China, where only 68% survived to second lactation (n=409) and 93 heifers exiting the herd between first calving and second lactation (Wu et al. 2012). All of these studies report a higher culling rate than that reported for a study in Spain on one external contract heifer rearer for 133 different dairy farms; in this study there were 8.4% (n=655) heifers that were culled prior to second lactation from a starting population at birth of 7,768 heifers (Bach 2011).

TIMING OF CULLING OF FIRST LACTATION HEIFERS

The timing of culling has the potential to influence the profitability of the cull, in terms of the milk production in the first lactation and the potential for weight gain at the end of the lactation, when there is less of a demand on energy from milk production.

In an English study of 18 farms, a mean lactation length of 322 days (±29 days) was reported for the 79 first lactation heifers, suggesting that the majority of heifers completed a full lactation (based on a 365 day calving interval and 60 day dry period). A comparison in culling rate between first lactation, the rearing period (pre-calving) and second lactation for this cohort of animals is shown in Figure 1 (Brickell & Wathes, 2011). First lactation heifers had a mean survival time of 322DIM in this study, with very few heifers being culled prior to 200 DIM. The first lactation heifers had an increased mean DIM prior to culling than lactation 2. These findings were different to those in a study in Spain, where 31.5% of heifers that did not survive the first lactation exited the herd before 50DIM (Bach, 2011).

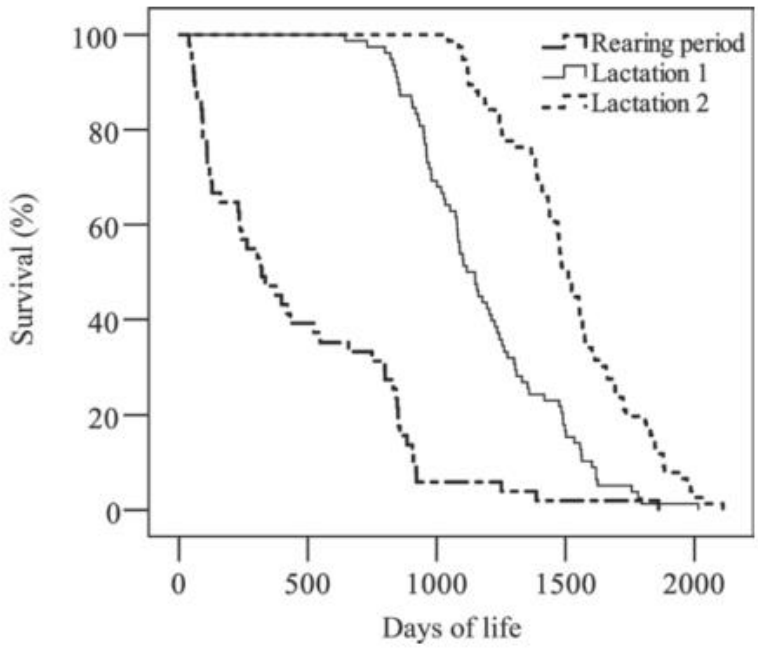


Figure 1 : Kaplan-Meier curves showing the survival time in days of animals culled at different lifetime phases before third calving (rearing period, n=53, lactation 1 n=79, lactation 2 = 79). Taken from Brickell et al. 2011.

Reasons for Culling First Lactation Heifers

There are few studies that describe the reasons for culling of heifers during first lactation. One study (Brickell et al 2011), showed that infertility was the greatest risk for removal. The breakdown of the reasons for removal is shown in Figure 2 with infertility being the prime reason for culling in 40% of the 79 culled first lactation heifers, which is suggestive of fertility management problems on these 18 farms. This is not surprising as fertility is one of the most commonly reported reasons for culling on dairy farms (Ahlman, Berglund, Rydhmer, & Strandberg, 2011; Pinedo et al., 2014) The lack of information within the literature regarding reasons for culling could potentially reflect the lack of recording on farms of this data or the potential difficulty in allocating a reason as to why the animal was culled.

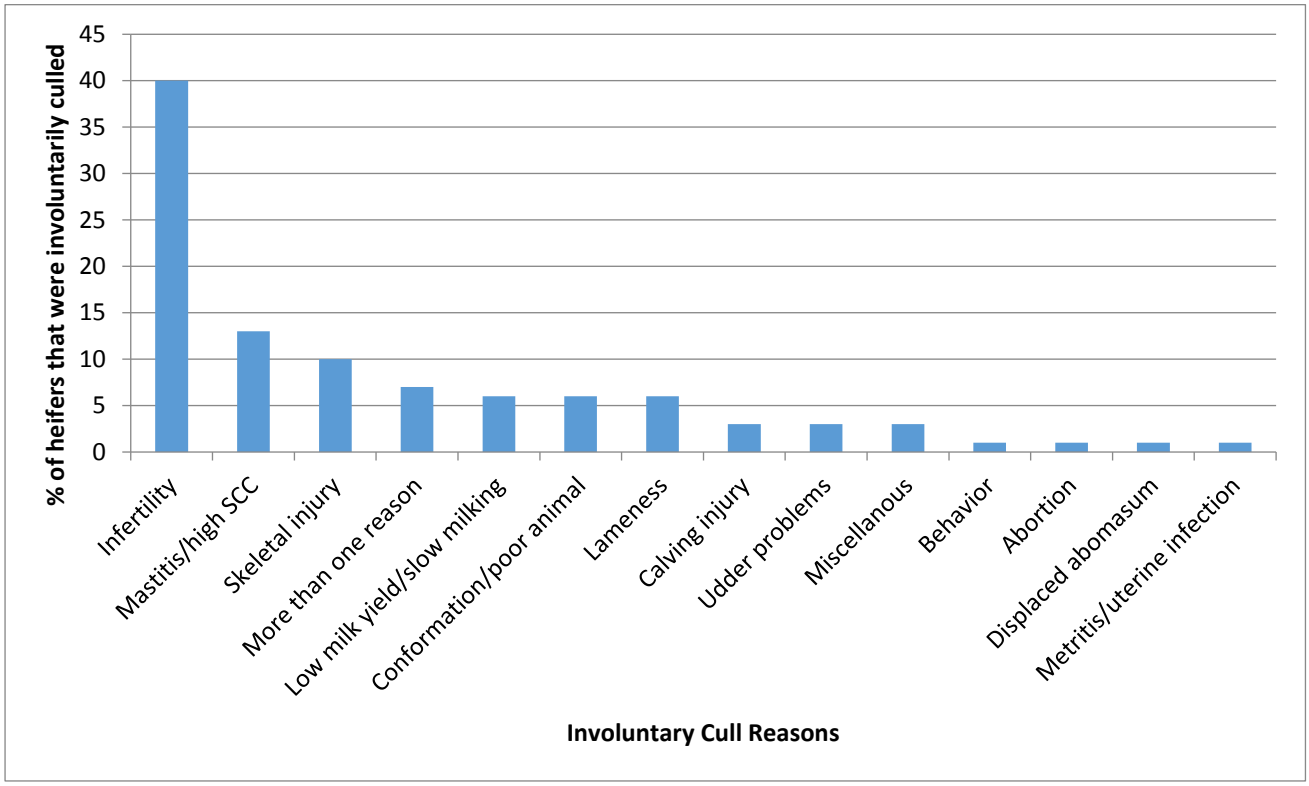


Figure 2 Reasons for involuntary cull of first lactation heifers from 18 herds in England. Data taken from Brickell et al. 2011.

Predisposing Factors that Influence Survival during First Lactation

There are multiple factors that have been reported to influence the risk of a heifer being culled during the first lactation. One study (Bach, 2011) identified daily liveweight gain (DLWG), abortion rate, bovine respiratory disease (BRD), season of calving and nulliparous heifer conception rates as risk factors for culling risk as follows. Increased DLWG from birth to weaning at 2 months was significantly associated with survival to second lactation (Bach, 2011). No relationships were found between bodyweight (BW) at calving or BW at breeding with survivability to second lactation (Bach, 2011). The effects of AFC and BW are difficult to separate because they are intrinsically linked by DLWG, as highlighted by Van Amburgh et al 1998; heifers with 1.0kg/d DLWG had fewer removals (n=60/85), compared to the lower DLWG group at 0.6kg/d, which had 40% of the first lactation heifers removed prior to second lactation (n=50/84) (Van Amburgh et al., 1998). Heifers which aborted prior to calving for the first time were 2.73 times more likely to be culled prior to second lactation, as well as being more likely to exit the herd within the first 50 DIM (Bach, 2011), potentially reflecting that the longer AFC were due to the abortion. Pre-weaning disease was shown to have an effect on survival to first lactation, with BRD having a significant effect, whilst diarrhoea in the pre-weaned period did not (Bach 2011). It was shown that there was a significant interaction of increasing BRD cases and delayed AFC, which resulted in having decreased odds of survival, compared to heifers with a delayed AFC but no/low incidence of BRD, as shown in Figure 3 and Figure 4. This could be related to a delay in AFC due to the number of incidences of BRD, which has previously been reported by Rossini in 2004, who reported a significant delay in mean AFC of 0.53 months for multiple BRD cases, when compared to no treatments (Rossini, 2004). The influence of disease on heifer performance on AFC had previously been identified with heifers experiencing BRD in the first 3 months of life having a delayed median AFC of 6 months (Correa, Curtis, Erb, & White, 1988).

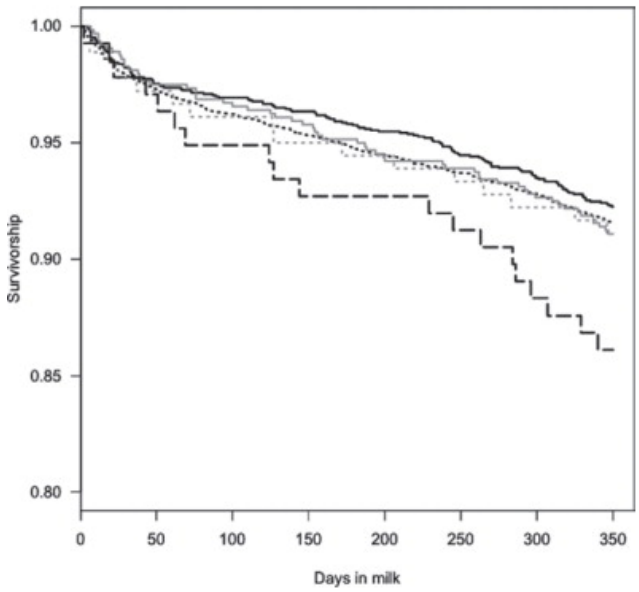


Figure 3: Evolution of survivorship throughout first lactation as influenced by the number of bovine respiratory disease episodes before first calving. Curves indicate the number of BRD cases: solid black line = 0, solid grey line = 1, dotted black line = 2, dotted grey line = 3, dashed black line = ≥4. Taken from Bach 2011.

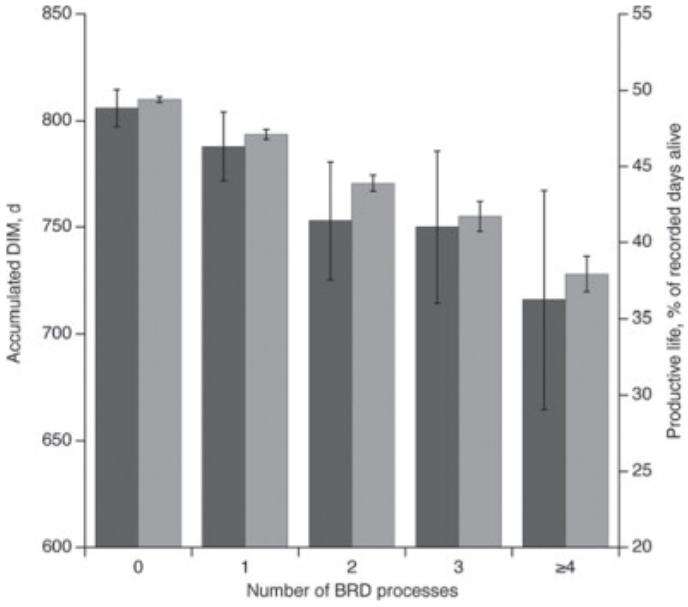


Figure 4 Accumulated days in milk (dark bars) and productive life (as a proportion of productive days out of those recorded as alive; light bars) of cows as affected by the number of bovine respiratory disease incidences experienced prior to first calving. Error lines depict standard errors. Taken from Bach, 2011.

There are numerous studies that have investigated conception rate of nulliparous heifers and their survival prior to calving for the first time, as well as the impact of conception rate on AFC (Brickell, Bourne, McGowan, & Wathes, 2009; Kuhn, Hutchison, & Wiggans, 2006; Mohd Nor, Steeneveld, Mourits, & Hogeveen, 2014; Wathes, Pollott, Johnson, Richardson, & Cooke, 2014), however there is very limited literature on the impact of nulliparous heifer fertility on future survival in the adult herd. It has been shown that nulliparous heifer conception rate was significantly associated with survival to second lactation, with heifers that only required one AI having the greatest chance of survival (Bach, 2011). It was reported that nulliparous heifers requiring ≥4 serves to become pregnant were culled more aggressively after 100 DIM, compared with cows that required fewer serves to conceive (Bach, 2011).

Season of first calving was also significantly associated with first lactation survival, with heifers born in winter (odds ratio: 1.25) and spring (odds ratio: 1.37) having greater odds of survival than summer and autumn (Bach, 2011). No association was identified between season of calving and time of culling during the first lactation. These findings were similar to those of a study in Florida, where there was a higher risk of heifers being culled when calving in the summer compared to other seasons; it was concluded in this study that this increased risk could be related to the increased probability of heat stress, which may exacerbate losses of milk and thus increase the risk of culling (Ettema & Santos, 2004).

Therefore, the scientific literature suggests that one of the main factors associated with survival of first lactation heifers is AFC and that this in turn is affected by various factors during the rearing and breeding period. These factors will not only affect the chance of survival, but will also have welfare and economic implications for the heifers during this time period.

1.2 Economics of Heifer Rearing

The importance of monitoring the AFC at a herd level includes maximising welfare by reducing the incidence of disease but also for optimising the efficiency of heifer rearing and maximising first lactation production for maximum profitability. Economics of heifer rearing is dynamic and will depend upon farm management decisions (for example whether sexed semen is used, whether heifers are reared by someone else) as well as other factors, which the farmer has no/less control over. These other factors include factors such as the strength of the British pound, the price of cull cows, the market value of dairy-beef cross calves, feed costs and the price of milk. To the author's knowledge, there have not been any research studies quantifying what impact these different factors have on the cost of heifer rearing and what impact they have on the overall economics of heifer rearing in different situations, for example what the impact of a milk price of 20p/L has on heifer rearing compared to 24p/L for a 250 cow herd. With this in mind, the economics discussed below are generalised and will differ from farm to farm, as well as for different economic situations.

1.2.1 Number of Replacement Heifers Reared

The number of replacement heifers reared on a dairy farm depends upon several factors within the adult milking herd, including the voluntary and involuntary culling rates, calving interval and live calving rate of the dairy herd. The number of replacements within the replacement heifer population is also affected by factors within the replacement heifers including mortality rates, AFC, reproductive performance of nulliparous heifers and involuntary heifer culling rate (Tozer & Heinrichs, 2001). An external factor which may influence the decision upon the number of heifer replacements reared would be the market value and demand for replacement heifers, which would allow the farmer an extra income from any surplus heifers.

As herd sizes increase within the UK, there is an increased demand for replacement heifers, which will increase the value of heifers and also has the potential to increase the pressure on housing and labour.

1.2.2 COST OF HEIFER REARING

The cost of rearing heifers is variable between farms, with a recently reported mean in the UK of £1,819.01 (range £1,073.36 to £3,070.46) (Boulton et al 2015). Replacement heifers cost around 2.6p per litre of herd production, with some herds having rearing costs as high as 3.2 p per litre of milk produced. These figures were estimated from a questionnaire based study from 124 farms in the UK, based on farmer reported results alongside with some standardised depreciation costs (Boulton, 2015). The wide range of costs reported could reflect either large differences between rearing systems on farms or that the results were inaccurately reported or a combination of both. Other research indicates that heifer rearing contributes 15% to 20% of total dairy production costs (Heinrichs, 1993). It was recently reported that most farmers should be able to reduce the cost of rearing replacements to 2.0p per litre, which could result in a financial benefit of £14,400 per annum for a 160 cow herd (Bazeley, Barrett, Williams, & Reyher, 2016). Factors affecting the cost of rearing heifers are discussed below and an example of a heifer rearing cost calculation is given in Table 1.

FEED COMPONENT OF THE REARING COST

The daily cost of rearing heifers depends upon the DLWG of the heifers because faster growing heifers require more to feed on a daily basis; increased energy and protein are needed in the ration. However a higher daily cost may not result in a higher total feed cost because there will a shorter rearing period to reach a specified body weight (Tozer, 2000). Feed costs have been shown to be a major component of rearing costs, with one study in Holland showing that feed costs accounted for 44.5% of rearing costs up to first calving at 25 months (Mohd Nor, Steeneveld, Mourits, & Hogeveen, 2012). In the USA it was estimated that feed was just less than 73% of total costs for rearing on 44 farms

Table 1 An example of a heifer rearing calculation with additional detail provided for the first 12 weeks: source DairyCo heifer rearing cost calculator. Taken from Breen et al. 2012

	Notes	Unit Cost (£)
Initial value of the calf		250.00
Birth to 12 weeks old		
Milk powder (@£1500/t)	Calf requires approximately 5L/d fed at approximately 10% concentration (colostrum for first 3 days); total fed 23kg (weaned at 7 weeks)	34.50
Calf Starter Mix (@ £230/t)	Fed from 3 days of age; average 0.75kg/d until weaning; 2.5kg/d until 12 weeks; total amount fed 120kg	27.60
Barley straw (£80/t)	Feeding and bedding; assume 100kg/calf until 12 weeks	8.00
Vet and medical spend (e.g. vaccination)	May be increased with other treatments	8.00
Other (e.g. water heating for milk)	-	10.00
Mortality Rate	Most calf deaths are neonatal/first week of life: 4% mortality rate and £250 calf value	10.00
Labour (@ £10/h)	Includes feeding, bedding and cleaning out: 3.5h/calf until weaning for twice daily bucket feeding; 1.5h/calf until 12 weeks	50.00
Total cost (birth to 12 weeks of age		398.10
12 weeks to 7 months	Includes grass silage, concentrates, bedding straw, vet/medical (e.g. lungworm vaccine) and labour	133.50
7 to 14 months	Includes grazing (land opportunity cots), fertiliser applications, vet/medical (e.g. antihelmintics) and labour	144.62
14 to 19 months	Includes grass silage *ad lib.*, wheat straw bedding, vet/medical (e.g. antihelmintics at housing), artificial insemination (@£18 per straw assuming 55% conception rate) and labour	301.22
19 to 25 months	Includes grazing (land opportunity costs), fertiliser applications, vet/medical (e.g. antihelmintics) and labour	188.16
Total cost (birth to 25 months)		1165.60

(Heinrichs et al., 2013). In a study in 2013 in the UK, feed was shown to be the most costly component of rearing between birth and weaning, costing on mean of £3.14 per day, compared to weaning to conception and conception to calving, which were on mean £1.65 and £1.64 per day respectively (Boulton et al 2015b). With feed costs being increased for the pre-weaning period, one method of reducing feed costs would be to limit feed during the pre-weaning period. However this has been shown to be

counterproductive, due to the feed conversion efficiency (FCE) altering during the development of gastrointestinal tract of the heifer (Table 2). In fact, accelerating the growth of pre-weaned heifers has been shown to allow breeding size to be achieved earlier and therefore has a potential to decrease age at first calving and rearing costs (Davis Rincker et al., 2008; Raeth-Knight et al., 2009). This was confirmed by another study which showed that an increase in BW and girth measurements at 1 month of age were associated with a lower AFC (Brickell, McGowan, Pfeiffer, & Wathes, 2009).

	Diet	**Estimated Feed Conversion Efficiency (DMI:DLWG)**
Pre-weaned calves	Milk	2:1 to 2.5:1
Weaned calves	25% forage	3:1 to 4:1
Young heifers	50% high quality forage	4:1
Older Heifers	Total Mixed Ration	6:1 to 7:1
Older Heifers	Poor quality forage	8:1 to 15:1

Table 2 : Feed Conversion Efficiency for Heifers at different rearing stages, taken from Heinrichs et al. (2011b). DMI = dry matter intake. DLWG = daily liveweight gain

Pre-weaned Heifer Mortality Rate

A study using dynamic programming to investigate the cost of heifer replacement programs concluded that the impact of pre-weaned heifer mortality rate was minimal, unless it exceeded 15%. Once 15% was exceeded, then a producer would not have enough replacement heifers to maintain the herd size (assumed culling rate of 25%, AFC 25 months of age, calving interval 13 months) (Tozer & Heinrichs, 2001).

Other Factors

Other key contributing factors to the economics of heifer rearing are labour, reproductive performance, health and housing. The true costs of poor health are difficult to estimate due to the hidden costs such as loss of future production and decreased DWLG, as well as under-detection and therefore treatment of disease. In a UK study, it was concluded

that after feed, labour was the largest component of heifer rearing throughout the process (Boulton et al 2015b).

1.2.3 INFLUENCE OF AGE AT FIRST CALVING ON ECONOMICS

AFC has been shown to have a large influence on total rearing costs (Tozer & Heinrichs, 2001), with a relatively low AFC reducing the rearing costs because heifers are kept for a shorter period of time. A lower AFC also resulted in fewer replacements being required (Tozer & Heinrichs, 2001).

The impact of AFC on the economics of heifer rearing has been explored in two studies using different modelling approaches. The first used a Markov process model used for multiple scenarios for heifer rearing in Holland. This concluded that the optimal economic AFC was 22.6 months of age, with a calving weight of 564kg (Mourits, Huirne, Dijkhuizen, Kristensen, & Galligan, 1999). However this model had limited information on the interrelationships of rearing strategies with the future production of the heifer, and therefore relied upon the sensitivity analyses to provide information on the key components of heifer rearing. The other study used a dynamic programme model, based on data from the USA. It concluded that reducing the mean AFC by 1 month old could reduce the costs of the rearing program by $1400 (£950) for a 100 cow herd (Tozer & Heinrichs, 2001); the reference mean AFC was 25 months of age. The findings of both of these models were reiterated in a study in Korea, using data from between 2000 and 2010 from milk recording data from National Agricultural Co-operative Federation (Do et al., 2013). This study showed an increased lifetime profit of approximately 2,600,000 Won (£1534) from 800,000 Won (£472) when age at first calving decreased to 22.3 months from 32.8 month.

1.2.4 FARMER CONTROL OVER ECONOMICS

WITHIN THE REPLACEMENT HERD

One method of altering the economics of a farm is to alter the rate at which replacements enter the herd, with the aim of reducing the number of non-profitable days (i.e. days not milking) and maximising future performance. AFC has been shown to be a benchmark that should be properly managed in order to achieve the highest economic return and longer productive life (Do et al., 2013). Two of the major control points in the economics of heifer rearing are the plane of nutrition and the moment of insemination (Mourits et al., 1999). As discussed above, feed costs are a considerable proportion of the rearing costs and it has been shown that manipulation of the feeding regimen has the potential to reduce the AFC to 18 months of age (Hoffman & Funk, 1992). However, such a low AFC is not optimal because of the negative impact that an AFC of 18 months of age has on future performance including decreased milk yield and impaired fertility performance (Ettema & Santos, 2004; Nilforooshan & Edriss, 2004), possibly related to the fact that the heifer requires more energy for growth, compared to heifers calving in at a later age. It does demonstrate that farmers have the potential to manipulate heifer BW, to ensure that the heifer is at the required BW at a chosen time point, to allow AFB at the most economically beneficial time point.

WITHIN THE ADULT HERD

As described previously, the culling rate of the adult herd has a large impact on the replacement rate, with the replacement rate and therefore costs increasing with an increase in culling rate. Culling rates beyond those available within the heifer replacement herd could result in additional heifers needing to be purchased (Tozer & Heinrichs, 2001). A lower culling rate could lead to the possibility of selling surplus heifers and generating revenue, or replacing less profitable cows within the adult herd sooner; however within in different economic markets, it is possible for farmers to sell their heifers for less than the rearing costs and therefore selling heifers is not always

profitable. The impact of herd culling rate was evaluated using a dynamic programme model, and the research concluded that the costs of rearing replacements could be reduced by approximately $1000 to $1500 (£678 to £1018) per 1% reduction in the milking herd culling rate for a 100 cow herd.

1.2.5 BREAKEVEN POINT

In the UK, the average farmer invests £1,819 per heifer in heifer rearing programs, it is important to understand where the breakeven point is in terms of the survival of replacement heifers (Boulton et al., 2015). In one study investigating the longevity of Irish heifers it was calculated that 8,535kg of milk would be required to break even, based on an mean margin over variable cost of €0.17/kg and the approximate cost of rearing a heifer of €1,451 per heifer (Archer et al., 2013). This would therefore take a minimum of one lactation and generally more. This study concluded that increased longevity of cows would reduce the demand for replacement heifers and therefore would provide economic benefits including opportunity costs of producing more beef calves, selling surplus heifers, increasing the size of the milking herd, or leasing resources (Archer et al., 2013). This finding was echoed in an UK based study, where the mean number of days after first calving to breakeven point was 530 days, which were approximately 1.5 lactations before profit is made (Boulton et al 2015). In this study there was a large amount of variation between the heifers on the 102 farms (range 168 days to 2,321 days; 1 to 6 lactations), suggesting a large amount of on farm variability. The factors identified as having the largest effect on rearing were AFC, calving pattern, herd size, breed of cattle and the amount of time that heifers spent at grass (Boulton et al 2015). However no of these studies consider the influence of differing market prices for different variables, including milk price and the differences in milk yield between the first lactation heifer and the cow she is replacing and the price of the cull cow, as well as the economic difference between rearing the replacement heifers and purchasing a heifer around the time of calving. These factors impact will upon where the breakeven point is

and will vary between farms. However from the limited research, it could be suggested that it is important for both welfare and economic reasons that first lactation heifers survive to at least second lactation.

1.3 Age at First Calving; A Global Perspective

The accepted industry target for AFC is 24.0 months to ensure maximum profitability of the heifer rearing programme (Drackley, 2008; Duplessis et al., 2015; Wathes et al., 2014).

In this section, the mean AFC reported for different countries will be discussed. However a comparison between studies is difficult, with various parameters being used to evaluate AFC, including both median and mean. With the potential for the mean result to be skewed by a right sided distribution, it was decided to use the median and range to evaluate AFC, to reduce the potential bias from outlying values.

1.3.1 UNITED KINGDOM

Recently published data from 500 milk recorded dairy herds within the UK reported that the median AFC in 2015 was 2.3 years (27.6 months), which was one month less than reported from the same cohort of farms five years previously; unfortunately the exact number of first lactation heifers within this dataset was not reported. The "best" 25% of herds within this dataset achieved a median of 2.2 years of age (26.4 months) at time of first calving (Hanks and Kossaibati, 2015). These results were similar to those described in a study based in the United Kingdom in 2011 (Brickell & Wathes, 2011) that reported a mean AFC of 27 months for 18 dairy herds in the south east of England (there was no information regarding the range or median for AFC). However, these herds were selected on the basis that they had a targeted herd mean AFC of 24 months. Another study reported a similar mean AFC of 25.8 months (range: 20.5 to 37.8 months) from a database of an eight year period (2003 to 2011) of Scotland's Rural College's Research

Farm (Dumfries, Scotland), from 724 Holstein-Friesian cows (Randall et al., 2015), again a median AFC was not reported. A study based on 102 farms in the UK reported a mean AFC of 25.5 months for heifers calving in 2013, with no range or median reported (Boulton et al. 2015).

1.3.2 IRELAND

A study in Ireland reported that the mean AFC was 26.0 months, similar to the UK herds (Evans, Wallace, Shalloo, Garrick, & Dillon, 2006); however this study investigated the AFC in 14 spring-calving seasonal herds and heifers (n= 313,722 heifers between 1990 and 2004) were only included if the AFC was between 20 and 40 months of age. This could result in a potential bias due to the management system of seasonal block calving herds, where it is crucial to have the nulliparous heifers calving around the same time point as the adult herd.

Seasonality of calving was reflected in another Irish study (Berry & Cromie, 2009), investigating the AFC of 192,404 heifers, taken from the Irish Breeding Federation database, from herds containing 30 or more cows and which were spring seasonal calving (15th December to 31st May). AFC had a bimodal peak at approximately 24 months and 36 months, as shown in Figure 5.

1.3.1 THE REST OF THE WORLD

The reported AFC from the literature are summarised in Table 3. Within the reported distributions of AFC, there appears to be a wide variation at the level of both the individual animal and at the herd in all countries, including the UK and Ireland. Over the past 30 years, there has been a trend for a decrease in the AFC as reported by Hare et al. in a study using data from across the United States of America from 1993 to 2003 for 13.8 million heifers (Figure 6 and 7).

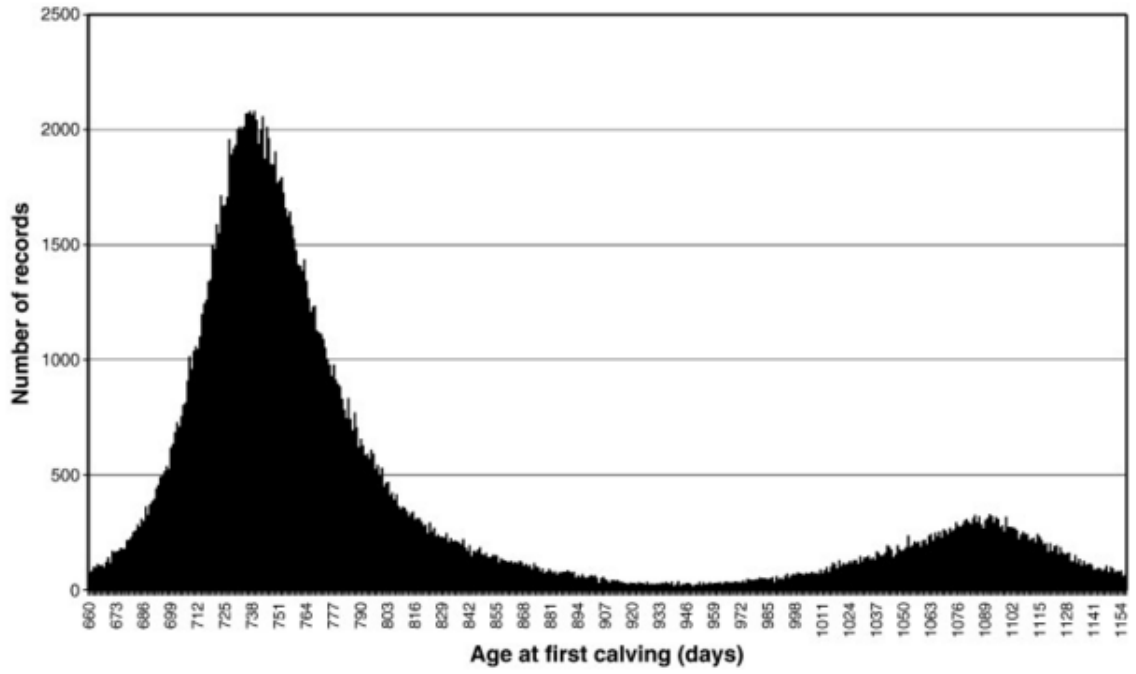


Figure 5 The distribution of age at first calving for 192,404 Irish Heifers from 2000-2006 (taken from Berry & Cromie 2009)

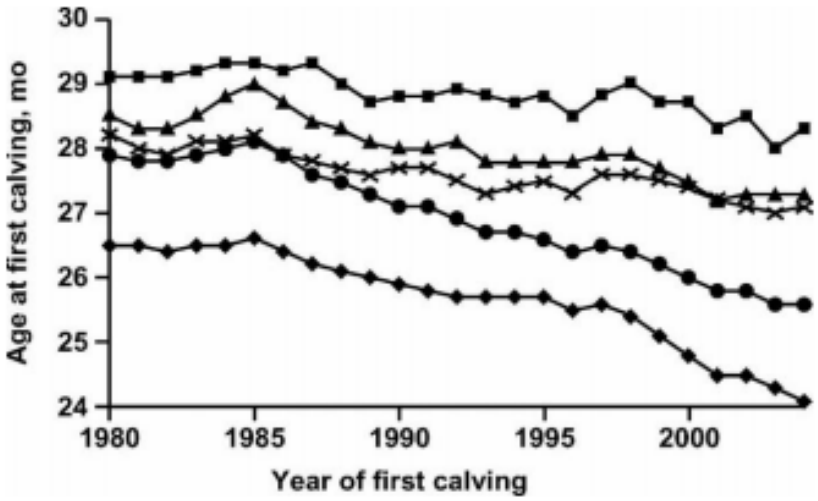


Figure 6 Trend in age at first calving by year of first calving for Ayrshire (squares), Brown Swiss (triangles), Guernsey (X), Holsteins (circles) and Jerseys (diamonds) in the USA. Taken from (Hare et al. 2006).

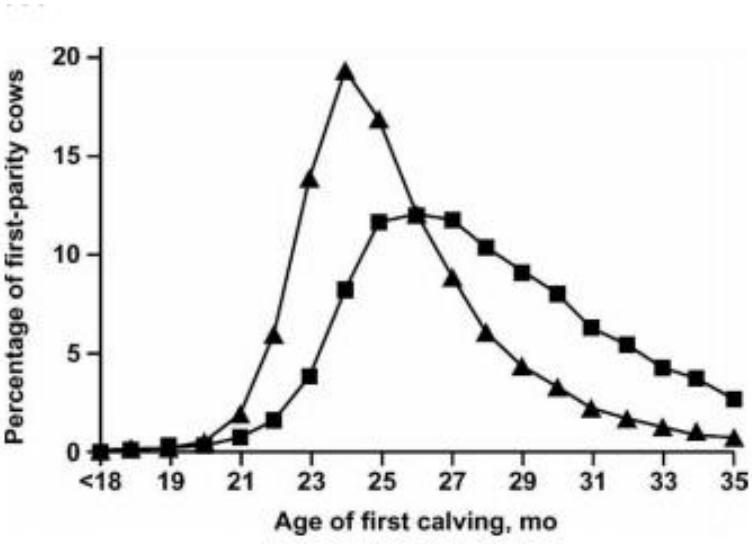


Figure 7 The distribution of age at first calving for first lactation Holstein heifers for 2004 (triangles) and 1980 (squares). Taken from Hare et al. 2006b.

Despite the trend for a decreasing AFC and decreased variation between heifer cohorts, none of the countries have reported a median AFC of 24.0 months, which is considered the industry target. This suggests that there are potential management factors that affect the AFC for the individual animal, as well as at herd level and these are discussed below.

Table 3 Summary of Age at First Calving across the world

Paper	Country	Time period	Number of heifers	Number of herds	Source of data	Median AFC (months)	Mean AFC (months)	Range of AFC (months)	Exclusions
Pirlo et al. 2000	Italy	1992-1997	1,048,942	-	Italian Holstein-Freisian association	-	28.1		<20 months >36 months
Bach 2011	Spain	2011	7,768	133 farms of origin; one rearing unit	On farm data	-	-	20.5 to 34.4	
Mohd Nor et al. 2013	Holland		8,454	86 clients of Utrecht Farm Animal department	On farm data	25.4	-	23 to 30	
Hultgren & Svensson 2009	Sweden		2,429	121 in Skaraborg	On farm data	27.6		23.8 to 47.2	
Losinger & Heinrichs 1997	United States of America	1997		1,811	Questionnaire based	18 to 49 months per farm			
Ettema & Santos 2004	United States of America		1905	3 in California	On farm data	-	25.1		
Hare et al. 2006a	United States of America	1980 to 2004	13.8 million		Data from Animal Improvement Laboratory, USDA	-	26.9	-	<15 months >300 months
Pietersma et al. 2006	Canada	1993 to 2003	44,989				26.5 (Holsteins) 27.1 (Ayrshires)	19.9 to 32.9 (Holsteins) 22.6 to 32.8 (Ayrshires)	
Wu et al. 2012	China	2008	1,430	1	On farm data		29.3		
Nilforooshan & Edriss 2004	Iran	1991 to 2001	12,082	45 in Isfahan			26.8	21 to 39	

1.4 Factors Affecting Age at First Calving

Since AFC displays considerable variation both within and between farms, it is useful to examine the impact on AFC of different factors during the rearing period have. Factors that influence the AFC would include the time of conception and inherent fertility of the heifer, which in turn are affected by the bodyweight (BW) of the heifer at the time of service. The BW of the heifer at first service is determined by the daily liveweight gain (DLWG) of the heifer from birth. Therefore we shall discuss the fertility of nulliparous heifers and how this is affected by DLWG.

1.4.1 NULLIPAROUS HEIFER FERTILITY

The fertility performance of the nulliparous heifer has been linked to AFC, through conception rates (CR) and risks of abortion (Brickell, Bourne, et al., 2009). Conception rate is defined as the proportion of inseminations that result in conception, with the number of cows becoming pregnant being the numerator (Wapenaar, W et al. 2008). The overall conception rate of a nulliparous dairy heifer was reported to be 56.5% in America (Kuhn et al., 2006). This study also highlighted a relationship between age at first breeding (AFB) and CR, with maximum CR occurring at 15 to 16 months and decreasing to a minimum at 26 to 27 months. A Swedish study reported a higher CR of 65.0% from 109 herds, with an interquartile range of 50 to 73% (Hultgren & Svensson, 2009). These findings were similar to a study in the UK that showed there was a mean pregnancy rate to first serve of 67% (n=392) (pregnancy rate to first serve was defined as the number of animals pregnant to first AI divided by the total number of first inseminations given to animals that conceived) and that 6% of heifers required >2 inseminations to conceive (Brickell, McGowan, & Wathes, 2009). The mean age at first breeding was 473 days (range 357 to 936 days) and the mean AFC was 791 days (25.9 months) (range 636 to 1529 days) in this study.

There have been associations reported between fertility performance and DLWG of nulliparous heifers; heifers with lower DLWG tend to require more services per conception, calve later and are more likely to be culled early (Wathes et al., 2008). This is potentially related to the DLWG affecting the timing of puberty and therefore first serve. However there is research that does not support this hypothesis; a study investigating factors associated with CR in nulliparous Holstein heifers in Florida reported that pelivmetry, oestrus type (natural or prostaglandin induced) and modified live viral (MLV) vaccination used within 21 days of first AI did affect CR, whilst BW, body condition score (BCS), DLWG between 6 months and first service and AFB did not affect CR (Donovan, Bennett, & Springer, 2003). Pelvimetry is a measurement of the pelvic area of the heifer using calipers and from different standardised measurements (height, width and diagnol), ratios can be calculated which give an indication of whether the heifer is at a higher risk of dystocia due to a small pelvic canal (Van Donkersgoed, Ribble, Booker, McCartney, & Janzen, 1993). Pelvimetry is more commonly used in beef cattle in the United States of America, than in dairy heifers. The use of the MLV vaccine suggests that there could be an inflammatory response to the live antigen in the vaccine, which in has a negative impact on the recognition of the conceptus by the dam and thus could result in early embryonic death; this has been shown in another study (Chiang, Smith, Nusbaum, & Stringfellow, 1990).

There have been many studies investigating the impact of fertility synchronisation programmes (Atkins et al., 2013; Lopes Jr. et al., 2013; Stevenson, 2005; Wathes et al., 2014). However the conception rate (serves that result in a pregnancy) is commonly greater than 60% and therefore synchronisation programmes are often used to decrease the labour required for heat detection. It is considered common that inseminations are often based on both oestrus and detection and timed AI programs, followed by the use of sweeper bulls (Stevenson, 2005). An in-depth review of different synchronisation programmes used in nulliparous heifers is outside the remit of this literature review.

1.4.2 BODYWEIGHT AND DAILY LIVEWEIGHT GAIN

DLWG has been shown to be linked to AFC through the impact of heifer BW and thus the timing of puberty and breeding; this relationship has been highlighted in numerous studies, reporting that variation in DLWG leads to varying AFC within herds (Brickell, McGowan, & Wathes, 2009; Ettema & Santos, 2004). In a UK study, it was reported that sub-optimum growth of heifers was identified at an early age and resulted in animals reaching the start of breeding at an inadequate size (BW range 209–498 kg at 15 months) (Brickell, McGowan, & Wathes, 2009). It is widely accepted that nulliparous heifers should be bred for the first time at 55-60% mature BW, in order to be 85-95% of mature BW at calving (e.g. Marigerson and Downey 2005). These growth targets relate to the timing of puberty, which has shown to occur on mean at 9.5 months of age (range 7.5 to 13.5 months) in Holstein-Friesian heifers (Taylor 2001), with the biggest influence of timing of puberty relating to BW and age. In terms of BW, puberty does not occur until approximately 43% mature BW (Van Amburgh et al., 1998). Therefore the link between a higher BW at time of service (15 months old; ≥420kg) and a lower AFC is unsurprising (Krpálková et al., 2014). In this study, when herds were categorised based on a mean AFC (the groups were ≤749 days, 750 to 799 days and ≥800 days), there was a significant difference in terms of DLWG. However when herds were categorised based on a mean DLWG (the groups were ≤0.699kg/d, 0.700-0.799kg/d and >0.799kg/d), there was no significant difference between the groups for mean AFC, with the difference reported between 10 and 11 days (Krpálková et al. 2014).

DLWG is largely determined by voluntary feed intake above maintenance requirements for that animal (Wathes et al., 2014). In other words, the energy available for the heifer to grow is the total energy consumed minus the amount for maintenance energy requirements and extra losses. Extra losses here could include energy to keep warm (i.e. cold stress), energy used to mobilise the immune system during infection and energy used for inefficient conversion of food resources into energy. These extra energy losses

will vary within a group and with age (Wathes et al., 2014). In a study in 2005, it was shown on 18 commercial dairy farms in USA that there was an increased tendency for a higher AFC if there were poor calf housing facilities (increased humidity and temperature with an increased ammonia concentration), provision of poor quality forage and when a heifer was treated with antibiotics, especially over a prolonged period (Heinrichs, Heinrichs, Harel, Rogers, & Place, 2005). These factors may be associated with extra energy losses and therefore reduced DLWG.

In order to achieve an AFC of 24 months, age at conception must be 15 months of age. In a recent UK study, variation in DLWG was found to result in variation in BW at time of first service at 420 days (13.8 months), with the mean BW being 353kg (±43.5kg); (the target in this study was set at 374kg, Bazeley et al. 2016). This below target weight set for the start of breeding suggests that there could be a potential delay in time of breeding for the heifers. DLWG has also been shown to influence the future production of a heifer. For example one study reported that a 1kg increase in dry matter intake at weaning with an associated increased DWLG, led to an increase in production of 286.7kg milk in the first lactation (Heinrichs & Heinrichs, 2011).

1.5 The Impact of Age at First Calving on Subsequent Health and Production

The replacement rate should reflect the culling rate of the adult herd, as discussed above, but it is also important to ensure that the incoming replacement heifers will perform at maximum efficiency, both economically and in terms of health. AFC has been shown to have an impact on the future performance of heifers and this is discussed below.

1.5.1 MILK YIELD AND MAMMARY HEALTH

MILK YIELD

There is potential for AFC to affect future milk production because the majority of mammary gland development occurs prior to first calving (Coffey, Hickey, & Brotherstone, 2006), however the science is unclear. It has been suggested that accelerated pre-pubertal growth to ensure a lower AFC, leads to decreased mammary gland development (Capuco et al. 1995; Serjsen 2005). The impact of AFC on milk production has been reported within the literature, with conflicting results reported and these studies are summarised in Table 4. The studies in Table 4 highlight relationships between milk yield and AFC at an individual heifer level; however studies on a herd level have reported no interaction between mean herd AFC and milk yield (Ettema & Santos 2004; Losinger & Heinrichs 1997; Bewley et al. 2001). In America it was reported that there was a lower herd milk production with herds that had an mean AFC of >27 months, when compared to herds with an mean AFC of ≤27 months old (Losinger & Heinrichs, 1997). This differed from what was reported in an Australian study reported that there was no significant difference yield between cows with an AFC of 25.1 months, 29.9 months and 33.9 months. However there were different culling rates within these groups, which acted as a source of bias within the results as there were some lactations which were incomplete and therefore could skew the data (Dobos et al. 2004).

MAMMARY GLAND HEALTH

There have been studies investigating links between AFC and somatic cell count (SCC) in the first lactation. One study of 13,932 first lactation Irish heifers concluded that AFC did not affect the mean lactation SCC (Berry & Cromie, 2009), which was supported by further analysis of AFC on SCC during the first lactation of 7,537 Irish heifers (Archer et al., 2013). Mean lactation SCC could be considered to be a poor choice of metric to measure as the mean SCC could be skewed largely by one reading of over a million

Table 4 Summary of research on the impact of age at first calving on milk yield

Paper	Location	Number of Herds	Number of Heifers	Outcome: Milk yield	Variables Investigated	Outcome
Bach and Ahedo 2008	Spain	3	348	First lactation	Pre-calving bodyweight	• Increase in milk yield of 1000kg per first lactation when calving at 700kg (compared to 600kg) • Increase equivalent of an increase of 3.8kg/d during 0-150 DIM
Krpálková et al. 2014b	Czech Republic	33	18139	First lactation	DLWG at 5 to 14 months of age	• Significant difference found with higher milk yield with DLWG of 0.8-0.95kg/d (compared to <0.699 kg/d)
					AFC	• No significant difference overall • Significantly decreased yield during the first 100 DIM for animals with an AFC≤699 days (compared to ≥751 days)
Davis Rincker et al. 2011	USA	1	80	First lactation 305 day yield	Pre-weaning DLWG (0.45kg/d versus 0.68kg/d)	• No significant difference for energy-corrected, age-corrected 305 day yield • Tendency for increased milk production with 0.68kg/d DLWG once genetic variation between heifers was taken into account
Carson et al. 2000	USA	1	70	First lactation	DLWG at 3 to 10 months (0.7kg/d versus 0.95kg/d)	• No significant difference
					DLWG at 14 to 24 months (0.65kg/d versus 0.9kg/d)	• No significant difference
Van Amburgh et al. 1998	USA	1	234	First lactation 305 day yield	DLWG during rearing (0.6kg/d, 0.8kg/d, 1.0kg/d)	• Significant difference found with DLWG of 0.94kg/d (mean AFC 21.3 months) producing less milk than 0.68kg/d (mean AFC 24.5 months)

Paper	Location	Number of Herds	Number of Heifers	Outcome: Milk yield	Variables Investigated	Outcome
Ettema and Santos 2004	USA	3	1933	First lactation 310 day yield	AFC	• Significant difference found with AFC>751 days producing more milk than heifers with a younger AFC
Berry and Cromie 2009	Ireland	1,086	192,404	First lactation peak yield	AFC	• Significant difference with a linear relationship of increase in milk production of 0.007kg per day increase in AFC
				First lactation 305 day yield	AFC	• Significant difference with a linear relationship of increase in milk production of 1.82kg per day increase in AFC
Pirlo et al 2000	Italy	Not stated	1,048,942	First lactation 305 day yield	AFC	• Significant difference, with increased AFC producing more milk, but only significant when comparing to animals with an AFC of 20 to 22 months
Nilforooshan & Edriss 2004	Iran	45	12,082	First lactation 305 day yield	AFC	• Significant difference by increasing AFC from 21 to 24 months with a yield increased, • Significant difference for AFC >24 months compared to AFC 24 months, with yield decrease as increase AFC.

cells/ml, whilst the rest of the SCC readings could be <200,000 cells/ml. However these results indicate that SCC is more likely to be related to other factors such environment and milking routine, rather than age of the cow at calving. AFC has been shown to have no significant impact on the incidence of clinical mastitis in some studies (Ettema & Santos, 2004), but has in others, with an increase in AFC being associated with an increased risk of mastitis (Waage, Sviland, & Odegaard, 1998; Wanner, Rogers, Kehrli, & Cooper, 1999). The proposed cause was hypothesised as a longer period of exposure to pathogens prior to calving, which is possible; however just because there is an association between udder health and AFC, it does not mean it is a causal relationship. Another study reported that AFC had no-significant impact on incidence of mastitis cases, including timing of cases and number of cases in this study (Ettema & Santos, 2004).

1.5.2 FERTILITY

DYSTOCIA

There is concern that by decreasing the AFC, an animal might not reach the target bodyweight for calving (85% to 90% of mature bodyweight (Margerson & Downey 2005)) and therefore this extra nutritional demand for growth may occur at the expense of fertility. In addition, there is the potential for incomplete body frame development, leading to dystocia due to feto-maternal disproportion. Conversely, there is the possibility for older animals calving for the first time to have excess body fat and therefore have a higher risk for dystocia and ketosis due to fat mobilisation, which will then have a negative effect on fertility (Ingvartsen, Dewhurst, & Friggens, 2003; Raboisson, Mounié, & Maigné, 2014; Shin et al., 2015). AFC has been significantly associated with the need for calving assistance but not the extent of calving assistance (no assistance/unobserved; slight assistance; severe assistance; veterinary assistance (including caesarean)) in 23,931 heifer calvings (Berry & Cromie, 2009). In this study, heifers with an AFC of 22 months had increased odds of requiring calving assistance

compared to AFC of 24 months, whilst heifers 25 to 27 months old and 35 months old had lower odds of survival to second lactation. However not all studies have shown a significant relationship (Ettema & Santos, 2004).

SUBSEQUENT FERTILITY PERFORMANCE

First lactation heifers should calve at 85 to 90% of their mature BW and therefore need to continue to grow during their first lactation (Margerson & Downey 2005). It has been hypothesed that heifers with lower BW at calving would potentially have a lower AFC and therefore require more energy for growth and thus have less nutrition partitioned towards reproductive activities. In one study there was no significant association between AFC and either calving interval or calving to first service interval, however this may reflect the fact that 80% of the herds in this study were seasonal calving, and thus had a strict breeding season (Berry & Cromie, 2009). A study in Florida investigating the performance of first lactation heifers based on AFC reported that AFC had a significant impact on CR at first serve and the proportion of cows pregnant by 310 DIM, as well as the number of serves per conception and days open for first lactation heifers (Ettema & Santos, 2004). The results of this study are shown inTable 5. The conception rate for postpartum first AI was significantly associated with both AFC and season of calving (as well as the interaction between the two), with summer performance (25.9%) being worse than winter performance (42.5%).

1.5.1 HEALTH

Disease problems in adult dairy cows can lead to decreased milk production and a potential increased risk of removal from the herd, therefore it is essential to optimise the health of milking cows. There is little published information on the impact of AFC on subsequent health.

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Table 5 The impact of age at first calving on fertility parameters for three herds in Florida, taken from Ettema and Santos 2004. Non-significant variables included DIM at first AI, abortion rate, number of abortions per cow and days open for pregnant cows.
a,b,c Superscripts in the same row differ (P < 0.05).
d,e Superscripts in the same row differ (P ≤ 0.10).

	Age at first calving (days)		
	Low (≤700)	Medium (701-750)	High (>750)
Number	514	917	474
Conception Rate at first AI (%)	27.9[a]	36.9[b]	30.8[a]
Pregnant at 310 DIM (%)	77.9[d]	83.4[e]	80.5[de]
Number of AI/first lactation heifer	3.27[a]	2.85[b]	3.23[a]
Days open for all cows (days)	160.9[b]±4.5	148.6[b]±3.1	154.5[ab]±4.2

A study in Florida based on three herds highlighted relationships between AFC and retained fetal membranes (P=0.61) and incidences of left displaced abomasums (P=0.54) which had a trend towards clinical significance; however both of these variables had a low number of incidences during the study period which may reflect the P values. On mean 15% of the heifers had a recorded lameness incident (determined by visual observation during weekly or twice-monthly visits by the herd veterinarian, as well as detection of abnormal gait by herd personnel), with a significant seasonal effect observed but lameness was not associated with AFC. However, a recent UK study identified an increased long-term risk of lameness associated with an AFC >24 months as opposed to >24 months of age (Randall et al., 2015)

1.5.2 HEALTH

Disease problems in adult dairy cows can lead to decreased milk production and a potential increased risk of removal from the herd, therefore it is essential to optimise the health of milking cows. There is little published information on the impact of AFC on subsequent health.

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1.5.3 SURVIVAL

It has been hypothesed that with a lower AFC, there is a possibility to have an increased adult herd culling rate because there are effectively more heifers available to replace the less economically viable adult cows. There are some discrepancies in the literature in terms of the impact of AFC on first lactation culling rates. A study in the UK showed that AFC was associated with survival, as shown in Figure 8 (Cooke et al 2013). There were two study groups within this research. In study group 1, AFC >30 months had a decreased chance of survival compared to animals with the lowest AFC (Figure 8a), and in study group 2 (Figure 8b) no significant impacts of AFC were identified on culling rates. It should be noted that these studies had very small numbers of heifers (Study 1: n=117; Study 2: n=388), which means important differences might not have been identified due to Type II errors (false negative rate). The false negative rate (β) is the proportion of positive instances that were erroneously reported as negative. The "power" of the study then is equal to (1 –β) and is the probability of failing to detect a difference when actually there is a difference. The power of a study increases as the chances of committing a Type II error decrease (Kadam & Bhalerao, 2010). A smaller sample size will give a result which may not be sufficiently powered to detect a difference between the groups and the study may turn out to be falsely negative leading to a type II error (Nayak, 2010).

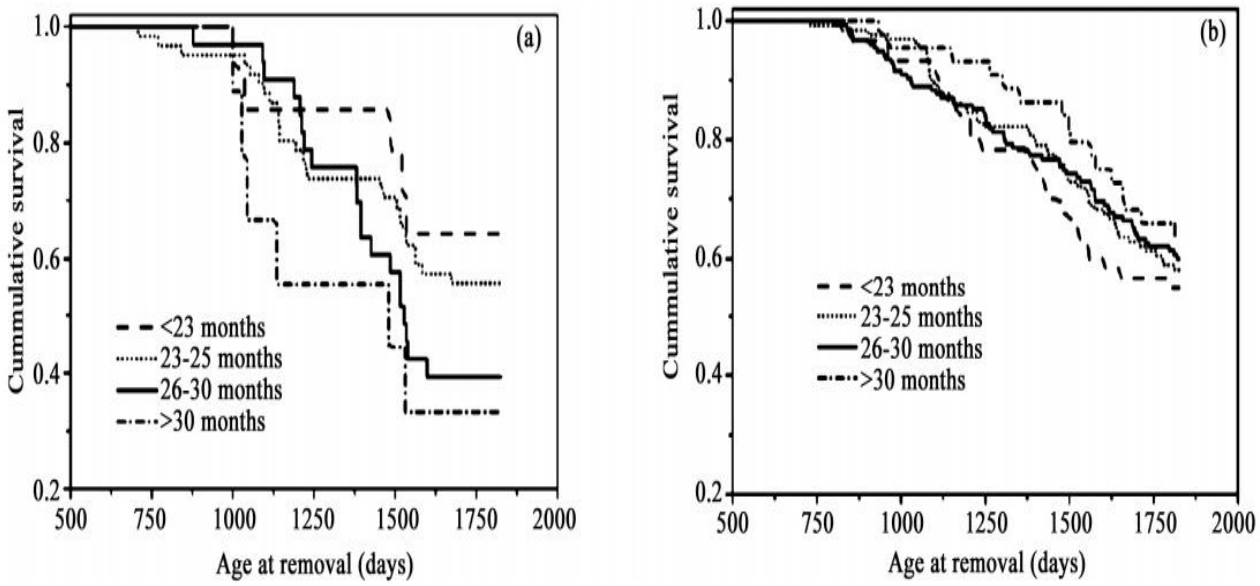


Figure 8 Survival curves up to 5 years of life according to age at first calving group in (a) study 1 and (b) study 2. The numbers of starting animals per age at first calving group were: Study 1: <23 months n=14; 23-25 months = 61; 26-30 months = 33 and >30 months n=9. Study 2: <23 months, n=60; 23-25 months n=129, 26-30 months n=155 and >30 months n=44. Taken from Cooke et al 2013.

Other studies have shown an association between decreased AFC and a lower culling rate of first lactation heifers. In a study of mainly seasonal calving Irish herds, it was reported that there were significantly lower odds of surviving to higher lactations of first lactation heifers with an AFC ≥36 months of age when compared to 24 months, with an 8% lower probability of survival to second lactation (Berry & Cromie 2009). These findings were in agreement with another study that investigated the survival of Irish first lactation heifers, in which a decrease in AFC from 27 to 24 months of age was associated with a 10% reduction in the odds of removal (median odds ratio = 0.90; 95% confidence interval = 0.93-0.88) (Archer et al. 2013). These findings were also in agreement with a Spanish study investigating survival to the second lactation of 7,992 heifers, which showed that heifers that completed their first lactation had significantly lower mean AFC (724.3 ± 2.3 d) than those that did not (737.4 ± 3.4 d) (Bach 2011). The same study concluded that an AFC as early as 21.7 months was not associated with compromised future cow survivorship, and that as mean AFC increased, survivorship decreased (Bach

2011). In a Canadian study analysing the genetics of 331,147 first lactation heifers registered in the Programme d'Analyse des Troupeaux Laitiers du Quebec and calving between 1981 and 1995, it was concluded that AFC >24 months of age resulted in an increased risk of culling, as shown in Figure 9 (Dürr et al. 1999). The results of this study showed that there was a linear increase in relative culling risk observed as AFC increased. These results were comparable to results found by Lin et al in 1988 (Lin et al. 1988).

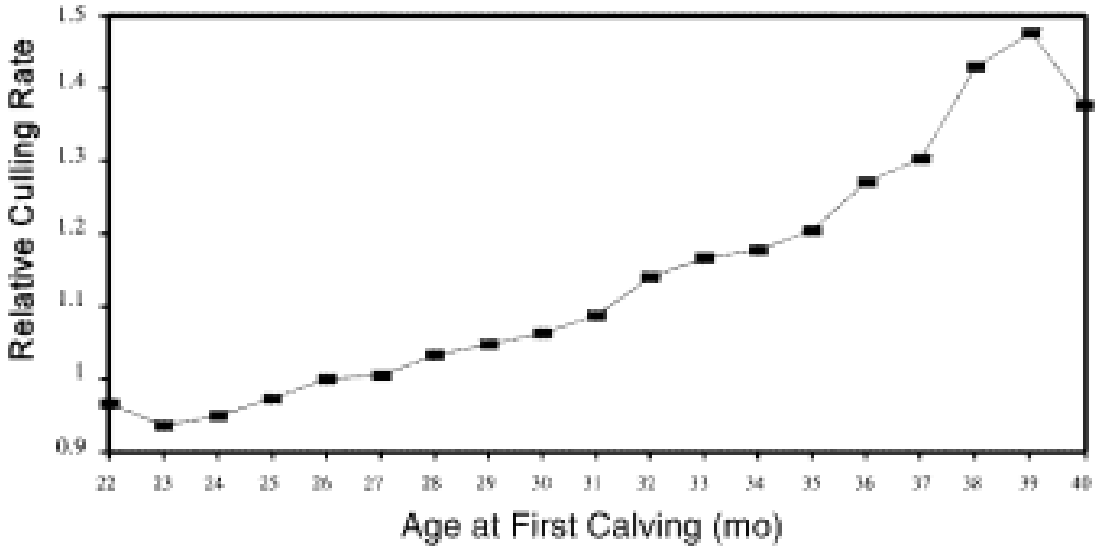


Figure 9 Estimates of the effect of age at first calving (first age class combined heifers calving from 17 to 22 months of age months of age). Taken from Dürr et al. 1999.

The results of this study vary slightly to a study analysing the survival of Holstein-Friesian cows in Kenya on 4 large scale farms between 1985 and 1997, where it was reported that animals calving early (21 to 27 months of age; relative risk = 1.34) and late (>38 months of age; relative risk = 1.45) had a higher risk of being culled compared to heifers which had an AFC between 28 and 32 months of age (Ojango et al. 2005). A recent study analysed associations between AFC, DLWG, herd milk yield and dairy herd production, using data from 33 commercial herds with a total of 18,139 heifers in Czech Republic over a 5 year period. This study showed varying culling rates

for different AFC categories, with an increased risk of culling with a decreased mean herd AFC; herds with an mean AFC of ≤749 days (24.6 months of age) had a herd culling rate of 40.59±4.36%, compared to 33.42±3.60% and 31.01±3.20% for an mean AFC of 750-799 days and ≥800 days (26.3 months of age) respectively (Krpálková et al. 2014).

Conversely, a study on three commercial dairy units in Florida, with a mean culling rate for heifers of 17.6%, reported that AFC was not significantly associated with culling rate, (Ettema & Santos 2004). However, the study groups were possibly not ideally categorised; the group with the highest AFC had heifers with an AFC >750 days (24.6 months) whereas the low and medium AFC group had AFCs of <700 days (23 months) and 701 to 750 days respectively (Ettema & Santos 2004). Considering that the mean AFC for United States of America is >25 months the findings of this study may not relevant to a realistic clinical scenario. Similarly, findings in a study in Normande analysing cow records for a ten year period (1979 to 1989) concluded that AFC did not impact on survival of first lactation heifers (Ducrocq 1994).

Time of Culling of First Lactation Heifers

The time of culling of first lactation heifers has been discussed above, with the majority of heifers being culled near to the end of lactation (Bach, 2011; Brickell & Wathes, 2011). A study in Ireland investigated the impact of AFC upon the timing of culling, which reported a significant difference between survival times and AFC, as shown in Figure 10. Median days in milk to culling in heifers calving at 24 months of age was 187 days longer than heifers calving for the first time at 36 months of age (Berry & Cromie, 2009).

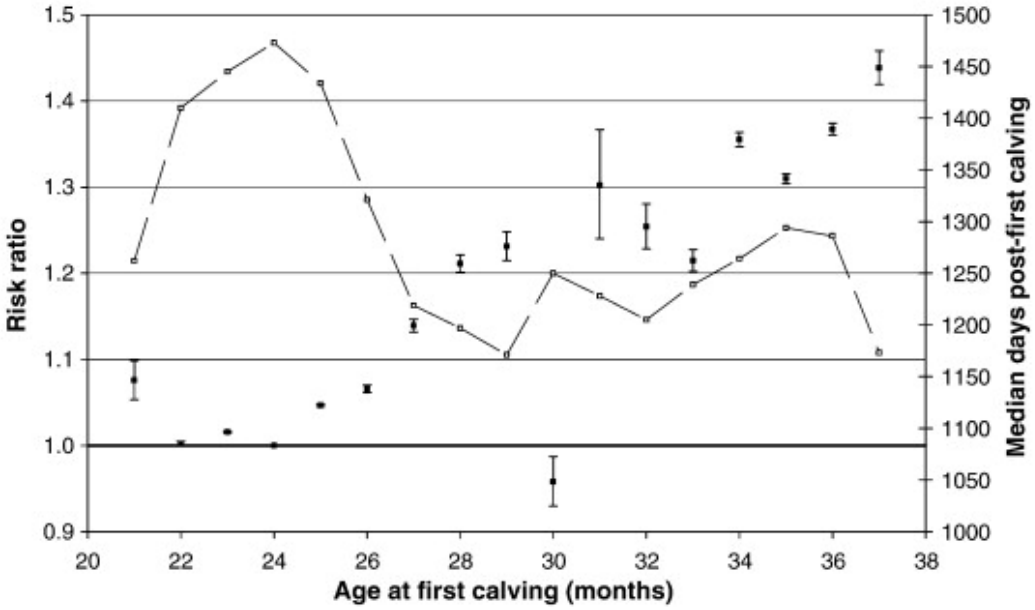


Figure 10 The risk (95% confidence intervals represented by vertical bars) of being culled (filled squares), derived from survival analysis and median days post-first calving at culling (broken line and open squares; days post-calving when 50% of animals were culled) for different ages at first calving. Age at first calving of 24 months was taken as the referent category. Taken from Berry & Cromie 2009.

1.5.4 WELFARE

However one area that should be discussed alongside factors affecting AFC would be the welfare of heifers during the rearing process. Unfortunately to the author's knowledge, there is no research investigating the impact of AFC on the welfare of heifers during the rearing process, as well as subsequent welfare after calving. Whilst this literature review has concentrated on the economic aspects of heifer rearing, the welfare of the heifers is of upmost importance. Welfare concerns are often defined as three questions; is the animal functioning well (e.g., good health, productivity, etc.), is the animal feeling well (e.g., absence of pain, etc.), and is the animal able to live according to its nature (e.g., perform natural behaviours that are thought to be important to it,) (von Keyserlingk et al., 2009). The easiest concern to monitor is if the animal is functioning well, in terms of production and health outputs. Morbidity or mortality are considered only as a crude indicator of health and welfare. Therefore a very crude idea of

welfare can be gained from the survival of heifers through the rearing process and the first lactation. A more sensitive indicator of welfare could relate to the AFC as a delay in AFC could potentially be related to poor welfare, for example due to disease, poor nutrition or poor housing conditions. A potential indicator for first lactation welfare could potentially be the fertility performance of the first lactation heifer, as an extended calving interval could indicate poor adaption to the milking cow environment or bullying, resulting in an increased risk of diseases such as ketosis and lameness. However none of the above indicators have been investigated as potential welfare indicators and therefore the sensitivity of these indicators are unknown and could possibly vary from farm to farm.

1.6 CONCLUSION

There is an economic need for first lactation heifers to calve for a second time in order to recuperate the financial expense of rearing the heifer (Boulton et al. 2015; Archer et al. 2013). There are also potential welfare implications associated with the culling of heifers prior to second lactation. In order to survive the first lactation, the heifer must produce a profitable amount of milk as well as becoming pregnant; therefore the production and fertility performance of first lactation heifers are important performance parameters to monitor. The review of the literature has highlighted the presence conflicting evidence of the impact of AFC on first lactation survival and performance. A large number of these studies were based on a small number of animals and herds, resulting in potential population bias, as well as influencing the power of the study (Nayak, 2010). Other larger studies were based outside of the UK and therefore the populations of animals used in these studies may not apply to the UK dairy industry, because of different management systems and climates, as well as genetics of the cows. Therefore there appears to be gap in the literature as to the impact of AFC across a large number of herds on herd performance in the UK, in terms of milk production and fertility as well as survival. Whilst there is currently no link between these production parameters and welfare, the percentage of first lactation heifers surviving to the second lactation could

possibly be a crude and general indicator for welfare in the dairy industry and is another hole in the knowledge.

Another gap in our knowledge is what the median AFC and the range of AFCs for first lactation heifers is in the UK, as well as true representation of the range of herd level AFC across the UK. These parameters would give an indication as to the performance of heifers and potentially highlight either potential insufficiencies in heifer rearing, which in turn could result in poorer welfare conditions and increase the costs of heifer rearing, or highlight poor knowledge transfer within the industry of the importance of AFC.

Therefore the objective of this study was to evaluate the impact that AFC had on the survival of the first lactation heifers to second calving, and also the production and fertility performance of heifers during the first lactation, as well as investigate the AFC of heifers across a large number of herds.

2. CHAPTER 2: MATERIALS AND METHODS

Substantial amounts of this research have recently been published, see Sherwin et al. (2016), in Appendix, Section 8.

2.1 DATA COLLECTION AND ORGANISATION

Herd management data were collected as part of a larger project (Hudson et al. 2012), with anonymized herd databases being requested from 20 veterinary surgeons across England and Wales, with an acknowledged interest in dairy herd health management and data analysis. Data came from a variety of sources, including on-farm recording software, veterinary practice bureau-recording services and records of national milk recording organisations. Although not a probabilistic sampling method, this convenience sample was used because high-quality data were essential for the analyses. The data set included 468 herds from across the United Kingdom. The data was extracted for all animals that calved within each herd between 1st January 2008 and 31st December 2008, using Microsoft Access 2010 (Microsoft Corporation, Redmond, WA).

2.1.1 INITIAL DATA QUALITY ASSESSMENT

Data quality was assessed at both an individual cow and herd level, with the following criteria used for removal of herds

- Herds which contained no first lactation heifers
- Herds without any 305 day yield information

These exclusion criteria resulted in the final dataset containing 437 herds.
Any animals without a date of birth and without an initial calving date were removed from the dataset, resulting in a total of 73,277 animals, of which 18,413 were first lactation heifers.

2.1.2 CLASSIFICATION OF SURVIVAL

The definition of exiting the herd before their next calving was either the animal exiting the herd before the next calving (n=17 404) or the animal having not re-calved for a

minimum of 760 days at the end of the study period (n=139). Exit dates were available within the data, sometimes alongside exit reasons. A binary indicator was used to represent the removal of an animal from the herd, either due to death, being sold or culled. Removal from the herd (defined as a cull) was denoted as 1, and survival to the next lactation as 0. The age at the point of being culled was calculated from the birth dates, alongside the days in milk at the time of culling.

2.1.3 CALCULATED PARAMETERS

The following parameters were calculated for each individual animal:

- Calving Interval: for all animals which survived to the next lactation, a calving interval was calculated using the difference between the two calving dates.
- Calving to Conception Interval (CCI): a calving to conception interval was calculated for all animals that had a recorded conception date, based on PD+ results. A minimum voluntary waiting period of 21 days was assumed and all animals with a calving to conception <21 days were excluded.
- Age at first calving (AFC): this was calculated for first lactation heifers only; this was calculated using the first calving date and the birth date of the animal. Any animals with an AFC of less than 12 months were removed from the data.
- Season of calving was divided into Spring (March, April, May), Summer (June, July, August), Autumn (September, October, November) and Winter (December, January and February).

The following parameters were calculated for herd level indices:

- Herd size and the percentage of first lactation heifers within each herd were calculated. The herd size defined as the sum of all of the animals that calved from 01.01.2008 to 31.12.2008. This estimation was based on the theory the target calving interval is 365 days, resulting in each cow in the herd calving at least once in 12 months; in reality the herd average calving interval is greater than 365 days and therefore these approximations of herd size are likely to be

underestimates. The percentage of first lactation heifers was calculated from the total number of heifers calving during this time period divided by the herd size.

- Mean herd 305 day yield: The mean 305 day yield was taken from all of the animals that were not culled during that lactation (to prevent bias from animals which did not reach 305 days post-partum). The data was taken from monthly milk recordings and therefore was an estimation of the 305 day yield as daily milk yields were not collected.
- Mean herd calving interval: All individual cows with a calving interval less than 261 days were excluded as these were considered to be potential abortions (using the definition of abortion as being between 42 and 260 days of gestation, (Thurmond & Picanso, 1990)). This excluded 477 animals from the calving interval data.
- Herd Culling Rate: this was calculated for the overall herd and for the adult herd as follows. The overall herd culling rate was defined as the number of cows of any lactation that calved in 2008 but exited the herd prior to their next calving. The adult herd culling rate was defined as the number of cows equal to or above 2 lactations that exited the herd before their next calving.
- Herd calving patterns were denoted as AYR (all year round) or SC (seasonal calving), with SC herds having >50% of the herd calving within 3 consecutive months of the year. This analysis was performed by calculating the percentage of animals calving per month for each herd. A rolling 3 month mean across the 12 months of 2008 was calculated and if any of these 3 month rolling means were >50% of the herd, then the herd was denoted SC.
- The mean and median herd age at first calving was calculated, alongside a herd value for the 25^{th} and 75^{th} percentile. The interquartile range (IQR) was calculated as the difference in AFC between the 75^{th} percentile and 25^{th} percentile.

Data restructuring was carried out in Microsoft Excel 2010 and Microsoft Access 2010 (Microsoft Corporation, Redmond, WA).

2.2 DESCRIPTIVE ANALYSIS

Initial analysis was carried out to evaluate the general features and performance of the 437 herds and how performance indices compared between the herds. Performance of the first lactation heifers was investigated, both in terms of overall performance of the individual heifers, but also within their respective herds. Herd variation was analysed, alongside performance of heifers within their herds compared to adult cows (lactation 2 or above).

2.2.1 SURVIVAL ANALYSIS

Appraisal of the patterns of timing of the removal of animals from the herds was performed using Kaplan-Meier survival curves (Kaplan & Meier, 1958).

2.2.2 FERTILITY PERFORMANCE

A chi-squared test was used to evaluate the impact of AFC on 100 day and 200 day in calf rate (Petrie and Watson, 2006). The 100 day in calf rate was defined as the proportion of eligible cows (all cows that have calved) that were in calf within 100 days of calving (Wapenaar et al 2008). The 200 day in calf rate was defined as the proportion of eligible cows that were in calf within 200 days of calving. Although these calculations should ignore cows that are not intended for re-breeding (Wapenaar et al 2008), it was unknown which cows were intended to be bred, so the denominator population was all animals for each herd. The chi-squared test was undertaken using the Turner Faculty Online chi-squared calculator, using both 2x2 tables (for each AFC category individually) and 2x6 tables (to compare all AFC categories) to investigate the impact of AFC on 100 day in calf rate and 200 day in calf rate (available at turner.faculty.swau.edu/mathematics/math241/materials/contablecalc) .

Descriptive statistics were calculated using Minitab 17 Statistical Software (Minitab Inc. 2013).

2.3 STATISTICAL ANALYSIS

Multilevel logistic regression models were used to evaluate the impact of AFC and other variables on different outcomes of first lactation performance and survival, which are discussed in detail below. The models were 2-level hierarchical models in order to account for correlations between primiparous heifers within herds. Model building was carried out in MLwiN version 2.31 (Rabash, 2012). Initial model building was performed by forward selection and explanatory variables were retained in the model where the estimated coefficient was greater than twice the standard error (such that the 95% confidence interval for the estimate did not include zero); all rejected variables were re-offered to the final model and retained if they now met these criteria. This equated to a significance of $P<0.05$.

2.3.1 FACTORS AFFECTING SURVIVAL TO SECOND LACTATION

A multilevel logistic regression model was used to evaluate the association between the probability of a first lactation heifer exiting the herd prior to the second lactation (i.e. failing to calve for a second time) and a variety of potential explanatory variables. These included AFC, calving season, adult herd culling rate, herd size, herd mean 305d yield and herd mean calving interval.

The model specification took the form:

$$\text{Exit Herd}_{ij} \sim \text{Bernoulli}\ (\pi_{ij})$$

$$(\text{logit}= \pi_{ij}) = \alpha + \beta_1 X_{ij} + \beta_2 X_j + u_j$$

$$[u_j] \sim N\ (0, \Omega_u)$$

where subscripts i and j denoted the ith primiparous heifer of the jth herd, respectively. π_{ij} was the probability of a heifer exiting before the start of her 2nd lactation for the ith heifer of the jth herd, α the intercept value and X_{ij} and X_j were explanatory covariates at

heifer and herd levels respectively, with β_1 and β_2 being the corresponding coefficients for covariates X_{ij} and X_j respectively. u_j was the random effect to account for residual variation between herds (assumed to be normally distributed with mean = 0 and variance = σ^2_v)

2.3.2 FACTORS AFFECTING IN CALF RATES

Multilevel logistic regression models were used to evaluate the association between the probability of a first lactation heifer being in calf by two time points; 100DIM and 200DIM. The explanatory variables were AFC, survival to second lactation and calving season.

The model specification took the form:

$$\text{In Calf Rate}_{ij} \sim \text{Bernoulli}\ (\pi_{ij})$$

$$(\text{logit}= \pi_{ij}) = \alpha + \beta_1 X_{ij} + \beta_2 X_j + u_j$$

$$[u_j] \sim N\ (0, \Omega_u)$$

where subscripts i and j denoted the ith primiparous heifer of the jth herd, respectively. π_{ij} was the probability of a heifer being in calf by a certain time point for the ith heifer of the jth herd, α the intercept value and X_{ij} and X_j were explanatory covariates at heifer and herd levels respectively, with β_1 and β_2 being the corresponding coefficients for covariates X_{ij} and X_j respectively. u_j was the random effect to account for residual variation between herds (assumed to be normally distributed with mean = 0 and variance = σ^2_v)

2.3.3 FACTORS AFFECTING MILK PRODUCTION

A continuous multilevel linear regression model was used to evaluate the association between the 305 day milk yield of a first lactation heifer and different explanatory variables including AFC, seasonality of calving and survival to second lactation.

The model took the form:

$$305 \text{ day milk yield (kg)}_{ij} = \beta_{0ij} + \beta_{1ij} X_{ij} + \beta_2 X_j$$

$$\beta_{0ij} = \beta_0 + \mu_{0j} + e_{0ij}$$

$$\mu_{0j} \sim N(0, \sigma^2_{u0})$$

$$e_{0ij} \sim N(0, \sigma^2_{e0})$$

where 305 day milk yield_{ij} is the milk yield for the ith heifer in the jth herd. β_{0ij} is the model intercept, composed of β0 the overall intercept, u_{0j} the herd-level residual for the jth herd, and e_{0ij} the heifer-level residual for the ith heifer; residuals were assumed to be normally distributed (~N) with mean 0 and variance σ^2_{u0} and σ^2_{e0} respectively. X_{ij} and X_i were explanatory coefficients at the heifer and herd level respectively and β_1 and β_2 their respective coefficients.

3. CHAPTER 3: RESULTS

3.1 HERD LEVEL DESCRIPTIVE RESULTS

3.1.1 DATA ORGANISATION: EXCLUSIONS

The following exclusions were made during the data organisation process:

- Herd Level Exclusions
    - Herds which contained no first lactation heifers (n = 25)
    - Herds without any 305 day yield information (n=6)
- Animal Level Exclusions
    - Any animals without a date of birth (n=25,749)
    - Any animals without an initial calving date (n=15)
    - Any animals with an AFC <12 months (n=7)

3.1.2 HERD SIZE

In the final dataset, there were 437 herds, containing 18,406 heifers and 54,871 lactation two and above animals. The number of animals that calved during 2008 in each herd varied between 25 and 848, with the median number per herd being 144 (mean: 168). The within herd frequencies of different parities is shown in Table 6. The median percentage of first lactation heifers calving in the herd was 23.9% (mean: 24.3%), with an inter-quartile range of 18.5% to 30%. The distribution of the percentage of primiparous heifers by herd is illustrated in Figure 11.

Table 6 The distribution of different parities between the herds

	Number in Data Set	Mean (%)	Median (%)	Interquartile Range (%)	Range (%)
Parity 1	18,406	24.3	23.9	18.5-29.9	1.0-93.5
Parity 2	17,129	23.0	22.2	18.4-26.6	4.0-98.6
Parity 3	12,959	17.5	17.4	14.3-20.8	0.0-43.7
Parity 4	8,764	12.0	11.9	9.2-12.0	0.0-33.0
Parity 5 and above	15,740	20.9	20.3	15.6-20.9	0.0-50.0

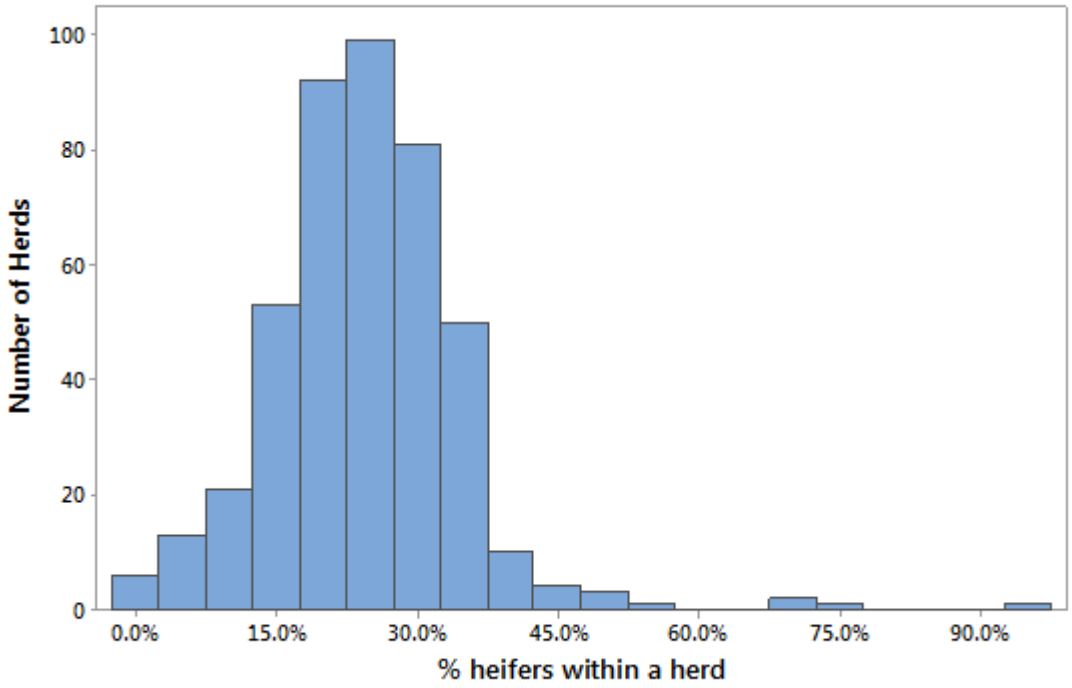


Figure 11 Histogram of the percentage of primiparous dairy heifers within the 437 study herds

3.1.3 HERD PRODUCTION CHARACTERISTICS

The median 305 day yield at an individual animal level was 7,382kg (mean: 7,159kg), with an interquartile range of 6,437kg to 8,197kg. The median 305 day yield for first lactation heifers was 7,208kg (mean 7,179kg), which was 1,300kg lower compared to the median 305 day yield for second lactation and above animals (median 8,508kg, mean 8,397kg). These figures excluded animals that were culled and therefore the number of animals included were 15,096 heifers and 40,017 parity two and above respectively. The mean herd 305 day yield for all year round calving herds was 466 kg greater than that of seasonal calving herds, at 7,255kg and 6,789kg respectively.

There was no clear association between 305 day yield and herd size, as illustrated in Figure 12. There was a tendency for herds consisting of 25 to 35% first lactation heifers

to produce more milk than herds containing either <15% and >35% of first lactation heifers, for both AYR and SC herds, as shown in Table 7.

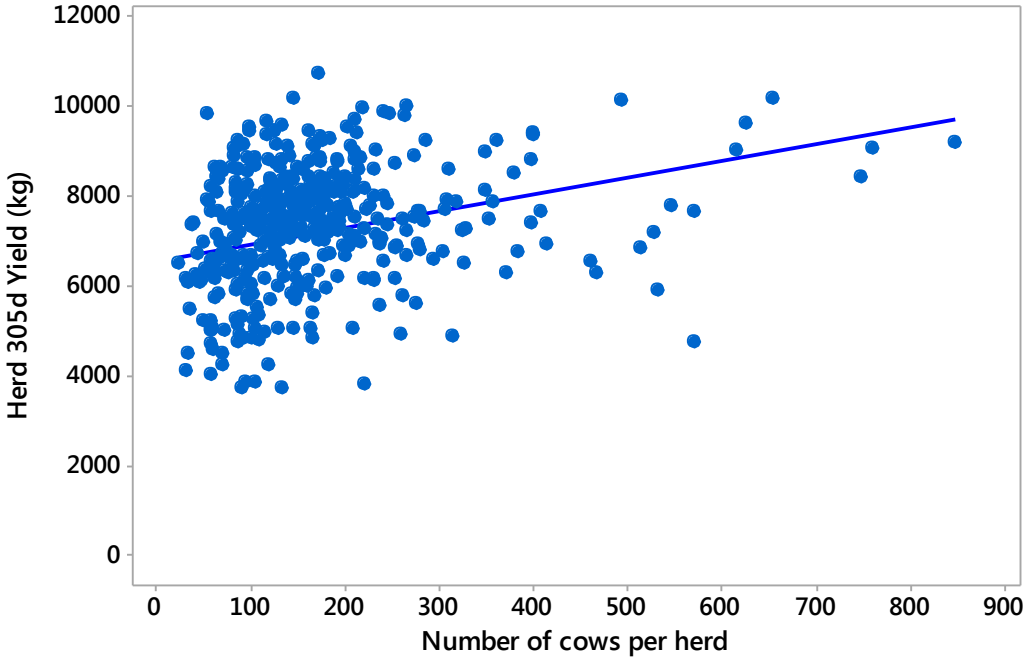


Figure 12 The relationship between herd size on the mean herd milk yield (kg).

Table 7 The relationship between the percentage of first lactation heifers within a herd and the herd mean 305 day yield, for seasonal calving, all year round and all herds.

% of Lactation 1 Heifers within herd	Number of Herds included	Mean Herd 305 day yield (kg)		
		All year round calving herds	Seasonal Calving herds	All herds
≤15%	60	6582	6433	6552
15.1 to 20.0%	76	7194	6746	7117
20.1 to 25.0%	98	7051	7064	7054
25.1 to 30.0%	112	7597	7247	7541
30.1 to 35.0%	53	7655	7093	7559
>35.0%	38	7319	5081	6907

3.1.4 HERD FERTILITY

The median individual animal calving interval was 421 days (mean 448 days), with an interquartile range of 375-519 days for all parities (n=55,113). On a herd level, the mean calving interval for the median herd was 411 days (for the mean herd was 414 days), with the distribution shown in

Figure 13. The median herd calving interval for all year round calving herds and seasonal calving herds were 412 days and 406 days respectively. The distribution of the mean herd calving intervals is shown in

Figure 13, with 8.9% of the herds having a mean calving interval of less than 386 days. Less than a quarter of the herds had an mean calving interval of less than 400 days (n=126; 23.8%), with 7.8% of the herds having a mean calving interval of longer than 450 days. The median days of calving to conception, assuming a 21 day voluntary wait period, was 114 days (mean 139 days), with an interquartile range of 78-175 days postpartum (n=57,693 cows). The median number of serves per conception was 2.0 serves (mean 2.3 serves; interquartile range 1 to 3 serves; range 1 to 9 serves) (n= 57,693cows).

The percentage of cows calving per season is shown in Table 8, with slightly more cows calving in autumn (September/October/November) compared to the other seasons, with the fewest number of calvings occurring in the spring (March/April/May). Eighteen percent of the herds within the data set were SC herds (n=79), with the remainder being classified as AYR.

Table 8 The number of calvings per season for all study animals

Calving Season	Number of calvings	Percentage of total calvings
Spring (March/April/May)	14893	20%
Summer (June/July/August)	19123	26%
Autumn (September/October/November)	22719	31%
Winter (December/January/February)	16492	23%
All Seasons	73227	100%

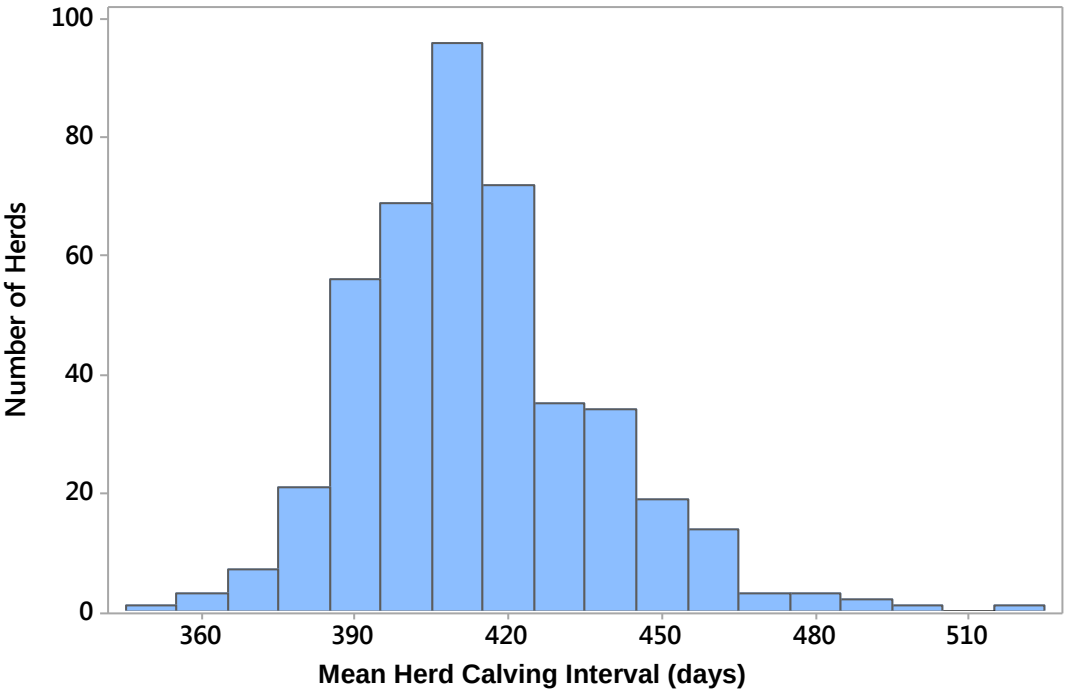


Figure 13 A histogram of the distribution of the mean herd calving intervals for the 437 study herds

The overall 100 day in calf rate and 200 day in calf rate for all animals were 36.2% and 62.0% respectively. The variation between herds is shown in Table 9, with the median herd having a 100 day in calf rate of 35.7% and a 200 day in calf rate of 63.1%.

Table 9 The variation of 100 day and 200 day in calf rates across 437 study herds.

	Average	Median	Interquartile Range	Range
100 day in calf rate (%)	35.4	35.7	28.3-42.1	0.0-76.9
200 day in calf rate (%)	62.2	63.1	56.5-68.0	25.0-100.0

3.1.5 HERD CULLING RATES

The overall culling rate for all parities was 23.9%, with 17,534 animals being culled prior to their next lactation. A total of 16.9% of all first lactation heifers were culled

(n=3,110), which was lower than the 26.3% culling rate of animals 2nd lactation and above (n=14,424). The median within herd overall culling rate was 25.6% (mean 25.7%). The descriptive analysis of herd size and culling rate is shown in Table 10. There was no clear trend between herd culling rate and herd size.

3.1.6 HERD SURVIVAL ANALYSIS

A survival plot for all of the animals within the data was plotted using a Kaplan-Meier survival curve, shown in Figure 14. The culling rate within the first 100 days in milk was 5.7% of all animals (23.9% of all animals which did not survive to the next lactation), which then decreased to 3.5% of all animals (14.9% of all animals which did not survive to the next lactation) for 100 to 200 days in milk. Of animals that did not survive to the next lactation, 56.4% were culled prior to 300 days in milk, suggesting that they did not survive the full time period of the final lactation.

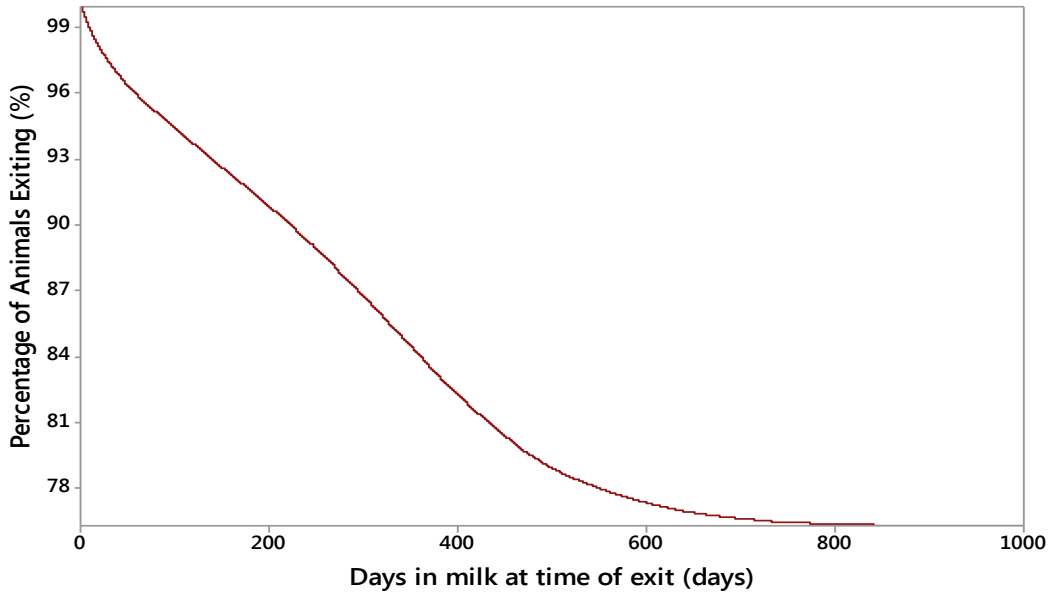


Figure 14 The Kaplan- Meyer survival curve of all study animals over the lactation during 2008 (n=73,227)

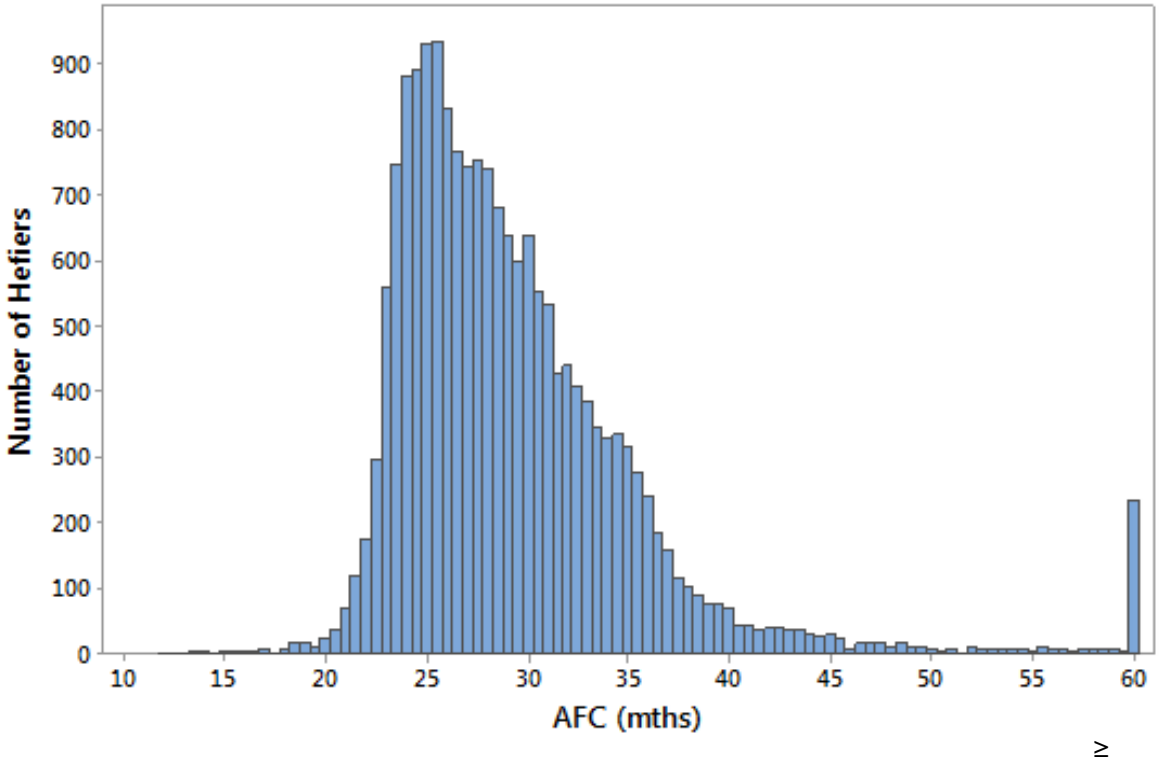
Table 10 The culling rates for different parities, categorised by herd size.

		Herd Size (animals per herd)							All Herds
		0-70	**71-100**	**101-130**	**131-160**	**161-190**	**191-250**	**>250**	
	Number of Herds	53	65	70	63	62	65	59	437
Total Overall Herd Culling Rate	Number of animals survived	2183	4255	6270	7006	8287	10757	16810	55693
	Number of animals culled	572	1351	1851	2267	2543	3207	5725	17534
	Total	2755	5606	8121	9273	10830	13964	22535	73227
	% Culled	20.8%	24.1%	22.8%	24.4%	23.5%	23.0%	25.4%	23.9%
1st Lactation Heifers Culling Rate	Number of heifers survived	468	1102	1588	1902	2337	2990	4888	15296
	Number of heifers culled	90	239	320	382	406	627	1043	3110
	Total	558	1341	1908	2284	2743	3617	5931	18406
	% Culled	16.1%	17.8%	16.8%	16.7%	14.8%	17.3%	17.6%	16.9%
2nd Lactation and above Culling Rate	Number of animals survived	1715	3153	4682	5104	5950	7767	11922	40397
	Number of animals culled	482	1112	1531	1885	2137	2580	4682	14424
	Total	2197	4265	6213	6989	8087	10347	16604	54821
	% Culled	21.9%	26.1%	24.6%	27.0%	26.4%	24.9%	28.2%	26.3%

3.2 PERFORMANCE OF FIRST LACTATION HEIFERS

3.2.1 AGE AT FIRST CALVING

he median AFC was 28.0 months, with a mean of 29.6 months, indicating that 50.1% of heifers calved for the first time at ≥28 months of age. There was a right skew in the distribution of AFC; with 35.9% calved for the first time older than 30 months, and 9.8% older than 36 months of age. The distribution of AFC is shown in Figure 15.



≥

Figure 15 Distribution of the age of first calving for primiparous dairy heifers (n=18,406)

The herd mean AFC varied between 22.7 and 96.3 months, with the interquartile range being 27.1 to 38.1 months. The distribution of the herd mean AFC is shown in Figure 16, highlighting that 43% of the herds (n= 188 herds) had a mean AFC greater than 30 months of age and that 8.5% (n= 37 herds) with a mean AFC greater than 36 months of age. The median herd had a mean AFC of 29.2 months, whilst the mean herd had a mean AFC of 30.5 months.

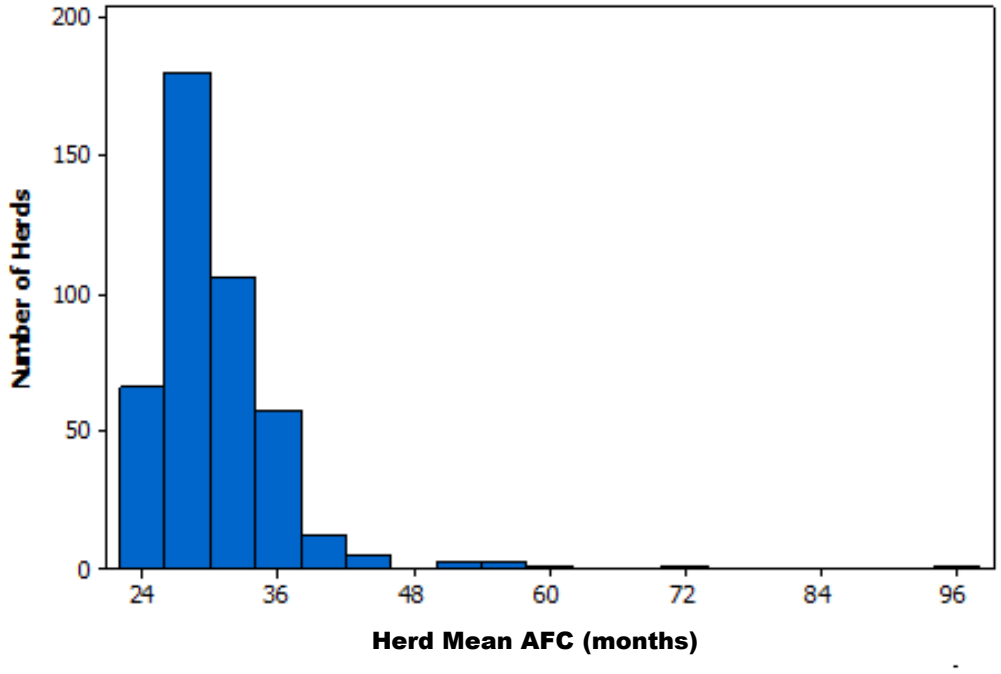


Figure 16 A histogram of the distribution of the herd mean age at first calving across 437 study herds.

The variation within each herd for AFC was measured by the IQR, which consisted of the middle 50% of heifers within the herd, as shown in Figure 17. There was an IQR of less than 3 months in 37.3% of herds (n=129 herds), whilst 18.5% of herds had an IQR greater than five months (n=81 herds). The relationship between the mean herd AFC and the IQR for AFC of the herd for herds with a mean herd AFC <45 months (n=429) is illustrated in Figure 18.

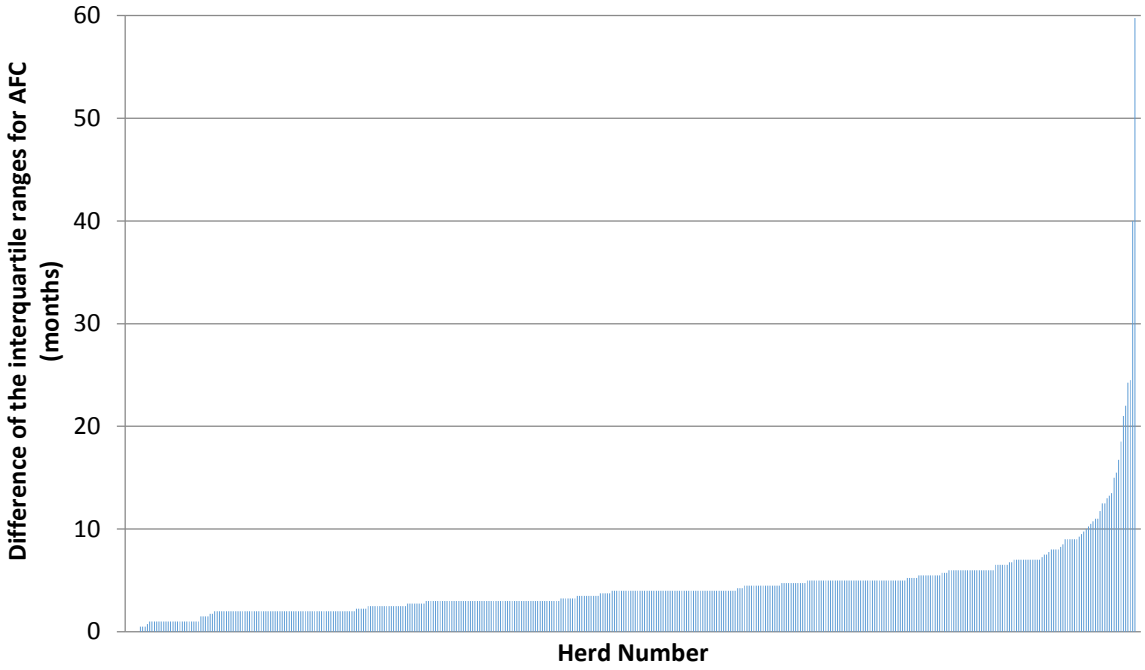


Figure 17 A bar chart of the interquartile range for the age at first calving for the 437 study herds.

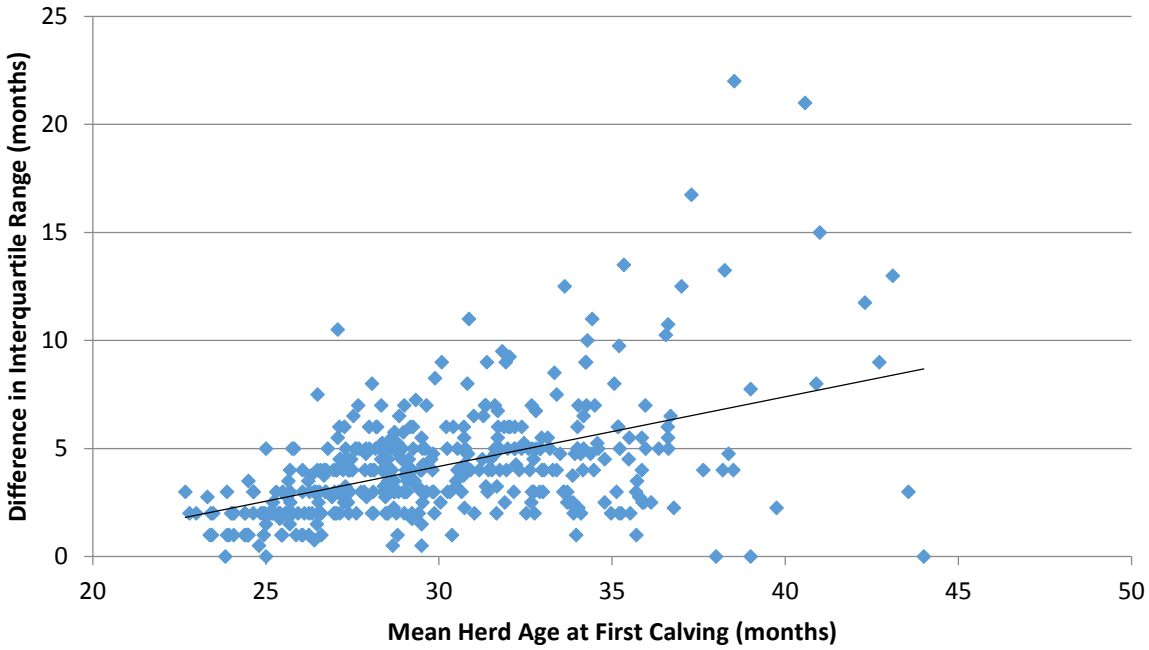


Figure 18 The relationship between the mean age at first calving for the herd and the interquartile range difference for age at first calving for the 429 study herds, with a mean age at first calving of <45 months

3.2.2 FIRST LACTATION HEIFER FERTILITY PERFORMANCE

Of the heifers calving in for the first time, the largest proportion (33.6%) calved in autumn (September-November) and the smallest proportion (18.0%) calved in spring (March-May). Twenty two percent calved in winter (December-February) and 26.5% in summer (June-August).

The median calving interval of the 15,296 heifers that re-calved was 385 days (mean 409 days), which was similar to the median calving interval of 389 days (mean 410 days) for animals in lactation 2 and above, shown in
Figure 19. Ten percent of the primiparous heifers had calving intervals <330 days and 53% of the heifers had calving intervals >380 days. A third of primiparous heifers had a calving interval greater than 420 days.

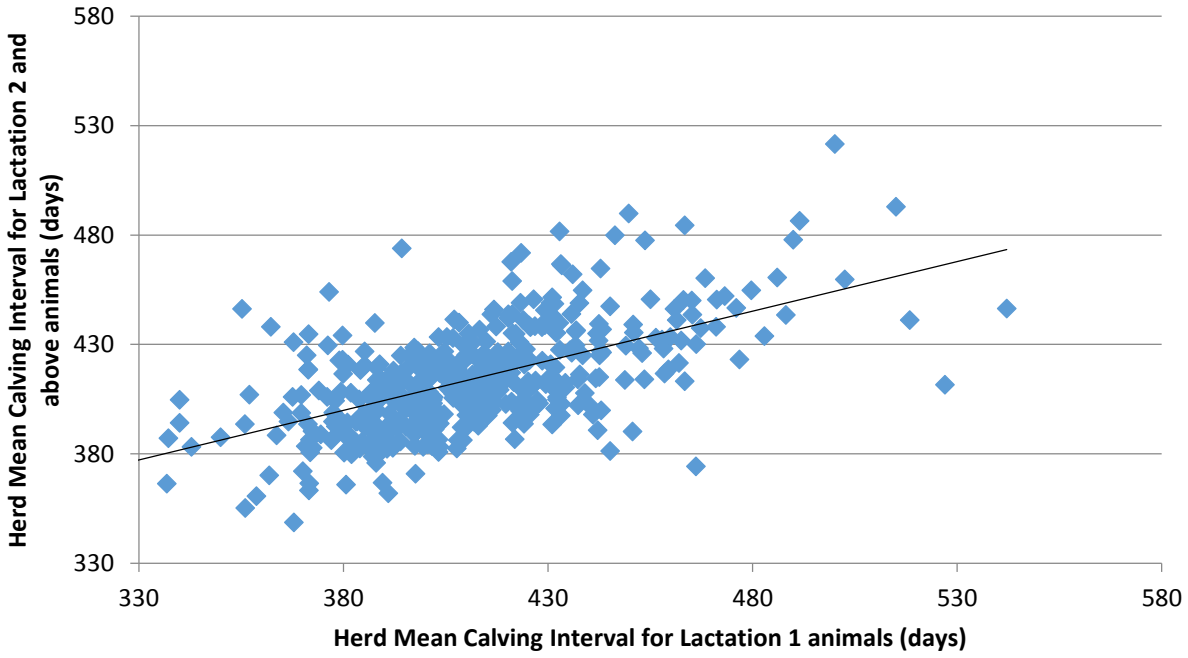


Figure 19 A scatterplot of the herd mean calving intervals for lactation 1 and lactation 2 and above

The median CCI was 112 days (mean 138 days; range 21 to 791 days). The median number of serves was 2.0 (mean 2.3 serves; range 1 to 21 serves).

The 100 day in calf rate and 200 day in calf rate were calculated for all heifers at 40.8% and 68.2% respectively. The median herd had a 100 day in calf rate for first lactation heifers of 40.7% and 200 day in calf rate for first lactation heifers of 70.2% (means: 40.6% and 68.3% respectively).

3.2.3 PRODUCTION PERFORMANCE

The median first lactation 305 day yield for heifers that were not culled (n=15,008) was 7,208kg (mean 7,179 kg), with an inter-quartile range of 6,035kg to 8,397kg. On a herd level, the median 305 day yield for only first lactation heifers was 6,995kg, with a mean of 6,796kg (interquartile range: 6,158kg to 7,726kg).

3.2.4 SURVIVAL TO SECOND LACTATION

A total of 16.9% of all of the primiparous heifers within the study population were culled prior to second lactation. The median primiparous heifer herd culling rate was 14.3% (mean 15.7%); the distribution is shown in Figure 20. Of the 16.9% (n=3,110) exiting the herd prior to 2nd lactation, 6 % (n=175) were sold, 69% were culled (n=2,151) and 25% died (n=784).

3.2.4.1 SURVIVAL ANALYSIS

Survival analysis indicated that of those primiparous heifers culled, 31% were culled before 100 DIM (n=955), which was 5% of all primiparous heifers. This cull rate slowed to 14% (2% of all heifers) between 100 days to 400 days after calving as shown in Figure 22. First lactation heifers were removed at a faster rate during the first 150 DIM, compared to lactation 2 or 3, but overall had a lower culling rate than older parities, as shown in Figure 23. Lactation 4 and above cows were removed at a greater rate than all other parities at all time points.

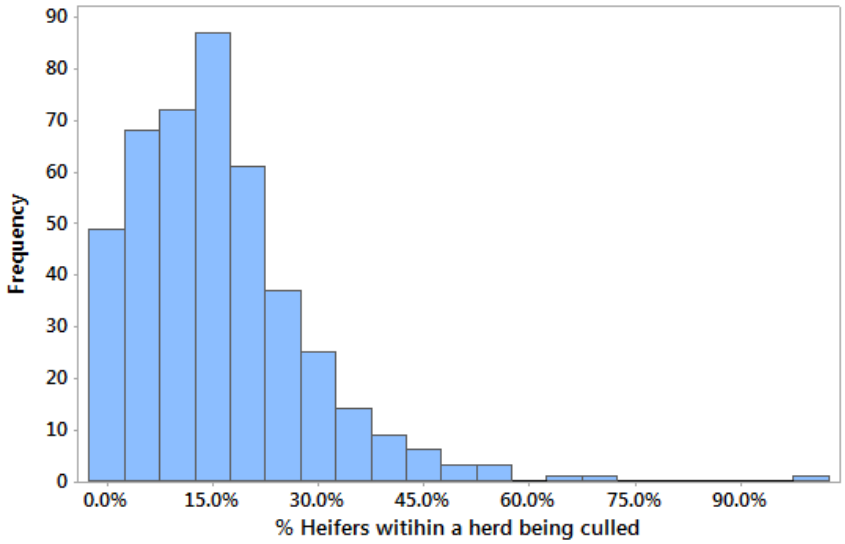


Figure 20 Histogram of the percentage of primiparous dairy heifers culled per herd in the 437 study herds

The relationship between total number of heifers within a herd and the culling rate is shown in Figure 21.

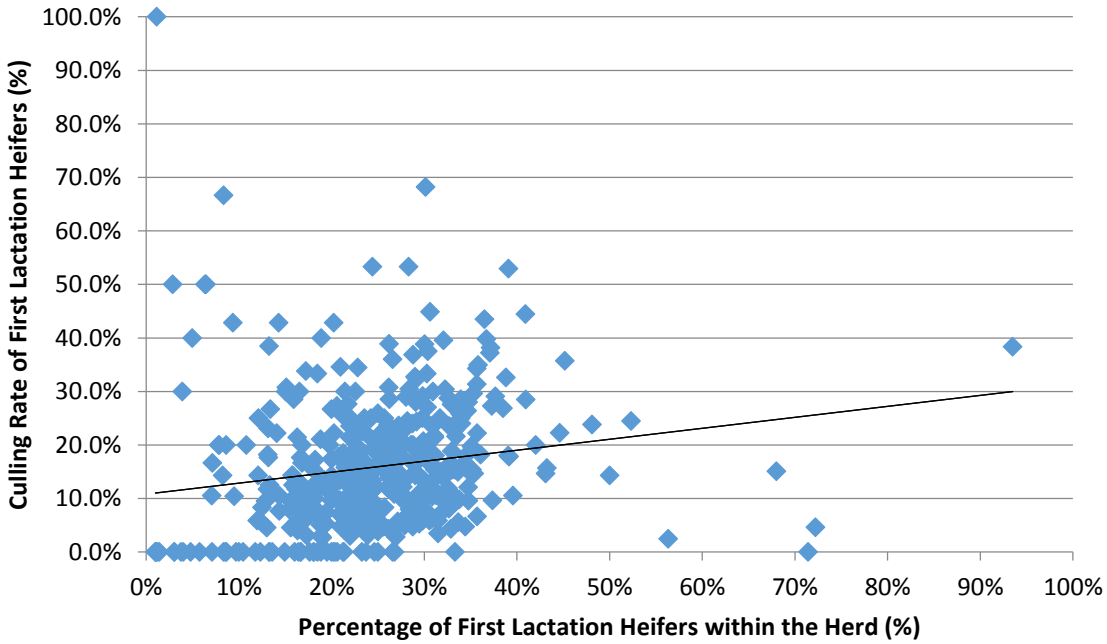


Figure 21 Comparison of proportion of first lactation heifers within the herd and the culling rate of first lactation heifers within 437 study herds

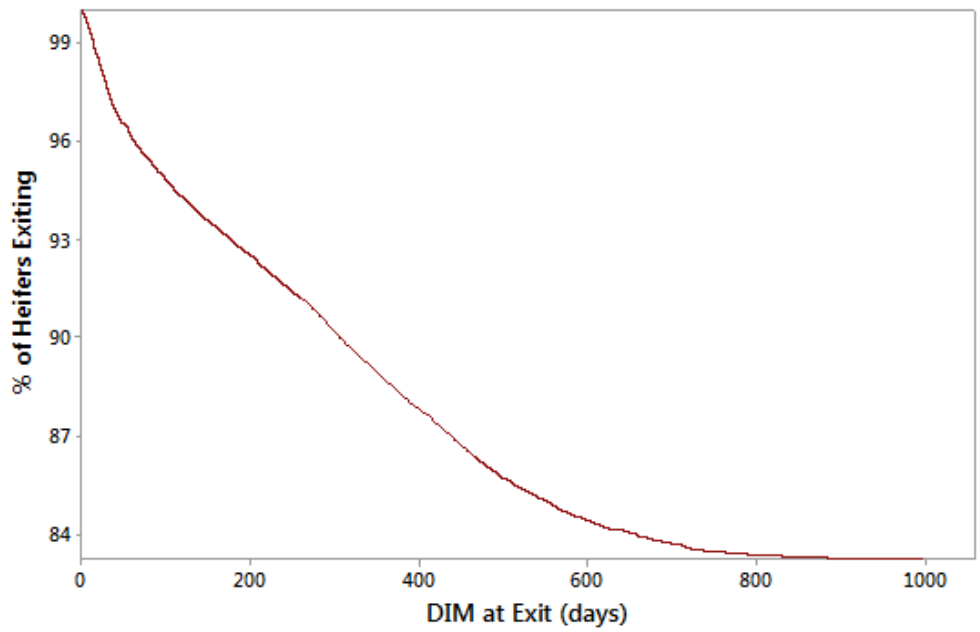


Figure 22 Kaplan-Meier survival analysis of survival of first lactation heifers over time in the 437 study herds.

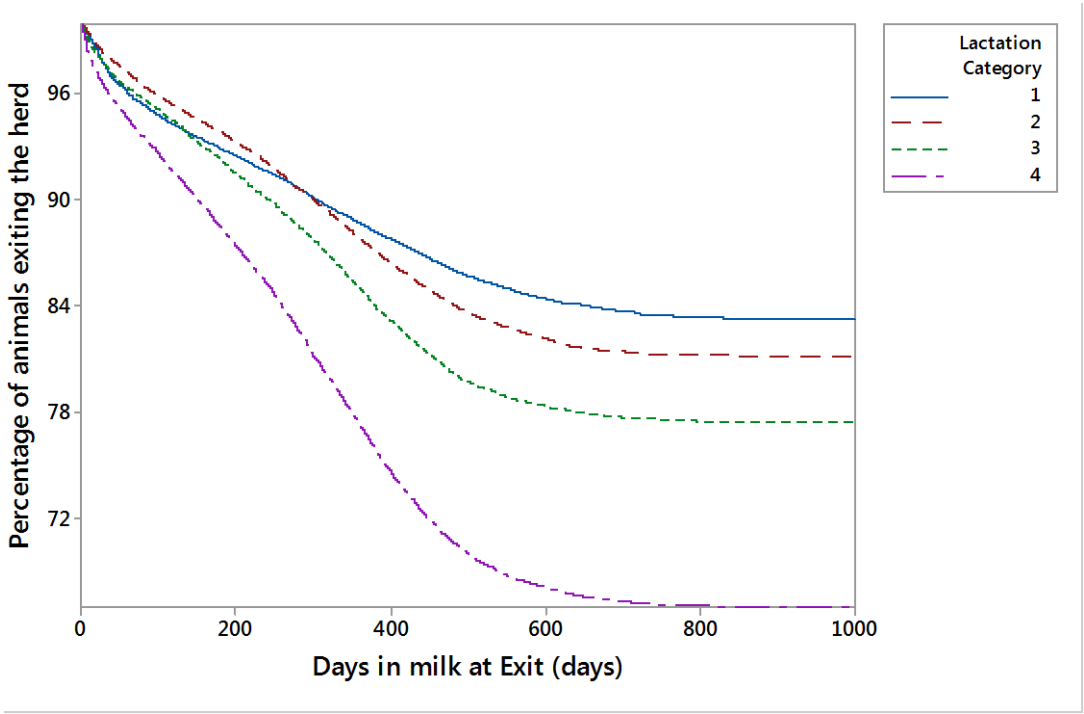


Figure 23 Kaplan-Meier survival plot for overall survival for all cows by lactation category. Lactation categories were 1: lactation 1, 2: lactation 2, 3: lactation 3, 4: lactation 4 and above.

3.2.4.2 Statistical Model for Survival of First Lactation Heifers

The survival of first lactation heifers was shown to be significantly associated with AFC, adult culling rate and season of calving, as shown in Table 11. The effect of AFC on survival is discussed below (section 3.3.3). Adult herd culling rate was shown in the statistical model to have a significant correlation with the survival of first lactation heifers, with an increase of the odds 1.5 when the herd adult culling rate was >23%, compared to <15%. The significant increase of odds of removal with increasing adult herd culling rate occurred once the adult culling rate was >20%, with <15% culling rate as the reference category. The season of calving was shown to effect survival of first lactation heifers, with summer calvings significantly associated with decreased odds of removal when compared to Spring (OR=0.85), compared to other seasons of calving.

Table 11 Parameter estimates from the final multilevel logistic regression model with the binary outcome variable being a primiparous dairy heifer culled (yes or no) during their first lactation. N/S = non-significant, AFC = age of first calving, Season = season of the first calving date for the heifers, Herd Cull Rate = the estimated overall herd culling rate

Model Term	**Number**	**Odds Ratio**	**95% Confidence interval**	**P value**
AFC <23 months	626	1.12	0.87-1.28	N/S
AFC 23-24 months	2812	Reference		
AFC 25-26 months	3558	1.19	1.04-1.40	<0.05
AFC 27-28 months	2883	1.36	1.17-1.57	<0.05
AFC 29-30 months	2506	1.37	1.18-1.60	<0.05
AFC >30 months	6021	1.71	1.55-1.94	<0.05
Season: March-May	3305	Reference		
Season: June-August	4871	0.85	0.76-0.96	<0.05
Season: September-November	6178	0.94	0.84-1.19	N/S
Season: December-February	4052	0.96	0.85-1.08	N/S
Herd Cull Rate <15%	1274 (59 herds)	Reference		
Herd Cull Rate 16-18%	913 (54 herds)	1.46	1.13-1.91	<0.05
Herd Cull Rate 19-20%	1462 (39 herds)	1.13	0.89-1.44	N/S
Herd Cull Rate 21-22%	1405 (53 herds)	1.50	1.13-1.90	<0.05
Herd Cull Rate 23-24%	1838 (55 herds)	1.81	1.12-2.26	<0.05
Herd Cull Rate 25-26%	2218 (41 herds)	1.51	1.21-1.88	<0.05
Herd Cull Rate 27-30%	3709 (62 herds)	1.94	1.58-2.37	<0.05
Herd Cull Rate >30%	5580 (72 herds)	2.67	2.20-3.24	<0.05

3.3 Impact of Age at First Calving on First Lactation Heifer Performance

3.3.1 Impact of AFC on Fertility Performance during First Lactation

When stratified in terms of AFC, 23 and 24 months AFC was associated with a lower median calving interval and CCI than the other AFC categories, as shown in Table 12.

Table 12 Table 12 Fertility Performance of First Lactation Heifers stratified by age at first calving

		Age at First Calving (months)					
		<23	**23 + 24**	**25 + 26**	**27 + 28**	**29 + 30**	**>30**
Calving Interval (days)	Number of heifers	512	2370	2923	2338	2001	4621
	Median	381	377	381	390	389	390
	Mean	401	399	404	413	414	414
	Range	261-822	261 - 797	271-953	264-894	262-847	261-971
Calving to Conception (days)	Number of heifers	544	2496	3114	2476	2134	4923
	Median	106.5	104	105.5	115	115	116
	Mean	129	128	131	140	143	144
	Range	21-538	21- 620	21-713	21-791	21-739	21-725
Number of serves	Number of heifers	619	2806	3548	2874	2491	5968
	Median	1	2	2	2	1	1
	Mean	2.0	2.1	2.2	2.1	2.0	1.8
	Range	1-15	1-21	1-19	1-20	1-16	1-20
% of heifers in calf by 100 DIM	Number of heifers	619	2806	3546	2874	2491	5968
	% in calf by 100 DIM	43.6%	46.3%	42.9%	38.1%	38.1%	36.1%
% of heifers not in calf by 200DIM	Number of heifers	619	2806	3546	2874	2491	5968
	% in calf by 200DIM	73.7%	74.6%	70.0%	67.4%	66.1%	64.0%

There appeared to be an association between AFC and 100 day in calf rate, with 100 day in calf rate decreasing as AFC increased. This relationship was echoed with the 200 day in calf rate. A Chi-Squared test was performed on the data for 100 day in calf rate and

200 day not in calf rates. The results of the 2 x 2 tables are shown in Table 13, with the reference category of an AFC of 23 and 24 months.

Table 13 Chi-squared test of 100 day in calf rate and 200 day not in calf rate for each age at first calving category (reference category 23 and 24 months of age). * significant result.

	100day In Calf Rate		**200day Not In Calf Rate**	
AFC (months)	In calf rate (%)	P value	In calf rate (%)	P value
<23	43.6	0.2206	73.7	0.67
23+24	46.3	Reference	74.6	Reference
25+26	42.9	0.0063*	70.0	0.0001*
27+28	38.1	0.0001*	67.4	0.0001*
29+30	38.1	0.0001*	66.1	0.017*
>30	36.1	0.0001*	64.0	0.0001*

The statistical model showed that the odds of a heifers being pregnant by 100DIM and 200DIM was significantly associated with AFC and whether the heifer survived to second lactation or not. The optimal AFC was <27 months of age and the risk of not being in calf by both 100DIM and 200DIM was with increased AFC; the odds of being in calf by 100DIM were 0.834 times less for heifers calving over 30 months of age, compared with those calving at 23-24 months ($P<0.05$). The results of the statistical model are shown in Table 14.

Table 14 Parameter estimates from the final multilevel logistic regression model with the binary outcome variable being in calf by 100 days in milk or 200 days in milk. N/S = non-significant, AFC = age of first calving

Outcome	Variable	Odds Ratio	95% Confidence Interval	Significance
100 day in calf rate	AFC <23 months	0.934	0.77-1.13	N/S
	AFC 23 + 24 months	Reference		
	AFC 25 + 26 months	1.046	0.94-1.17	N/S
	AFC 27 + 28 months	0.887	0.79-1.00	N/S
	AFC 29 + 30 months	0.913	0.81-1.04	N/S
	AFC >30 months	0.834	0.75-0.93	P<0.05
	Culled prior during 1st lactation	0.109	0.10-0.13	P<0.05
	Survived to 2nd lactation	Reference		
200 day in calf rate	AFC <23 months	1.015	0.80-1.29	N/S
	AFC 23 + 24 months	Reference		
	AFC 25 + 26 months	0.955	0.83-1.10	N/S
	AFC 27 + 28 months	0.824	0.71-0.95	P<0.05
	AFC 29 + 30 months	0.791	0.68-0.92	P<0.05
	AFC >30 months	0.723	0.63-0.83	P<0.05
	Culled prior during 1st lactation	0.044	0.04-0.05	P<0.05
	Survived to 2nd lactation	Reference		

3.3.2 IMPACT OF AFC ON PRODUCTION DURING FIRST LACTATION

The results of the linear regression model for the impact of AFC on milk yield are shown in Table 15. There was a significant impact of AFC on 305 day milk yield, with heifers with an AFC <23 months of age producing 186L less than heifers with an AFC of 23 + 24 months of age. Heifers that survived until second lactation producing 2,686L more milk (per 305 day yield), than those that did not.

Table 15 Parameter estimates from the final multilevel linear regression model with the continuous outcome variable 305 day milk yield. N/S = non-significant, AFC = age of first calving.

Model Term	Coefficient	Standard Error	Significance
Intercept	6406.6	103.4	
Fixed Effects			
AFC <23 months	Reference		
AFC 23 + 24 months	185.5	81.9	P<0.05
AFC 25 + 26 months	357.4	83.0	P<0.05
AFC 27+ 28 months	467.4	85.9	P<0.05
AFC 29 + 30 months	487.7	87.5	P<0.05
AFC >30 months	632.0	84.6	P<0.05
Survived until 2nd lactation	Reference		
Culled during 1st lactation	-2685.5	36.8	P<0.05

3.3.3 IMPACT OF AFC ON SURVIVAL

AFC was shown to have an impact upon the survival of first lactation heifers, as shown in Figure 24, with the survival times decreased as AFC increased. The survival curves in Figure 24 show that heifers that calved between 23-24 months of age were most likely to calve for a 2nd time and those that calved >30 months were least likely to calve again. In terms of culling rate in the first 150 DIM, heifers with AFC >30 months of age were culled more rapidly.

The statistical model showed that the odds of a heifers calving for a second time was significantly associated with AFC, season of calving and adult herd culling rate as follows. The optimal AFC was 23-24 months of age and the risk of culling increased with increased AFC; the odds of being culled were 1.71 times greater for heifers calving over 30 months of age, compared with those calving at 23-24 months (P<0.05). The results of the statistical model are shown in Table 11.

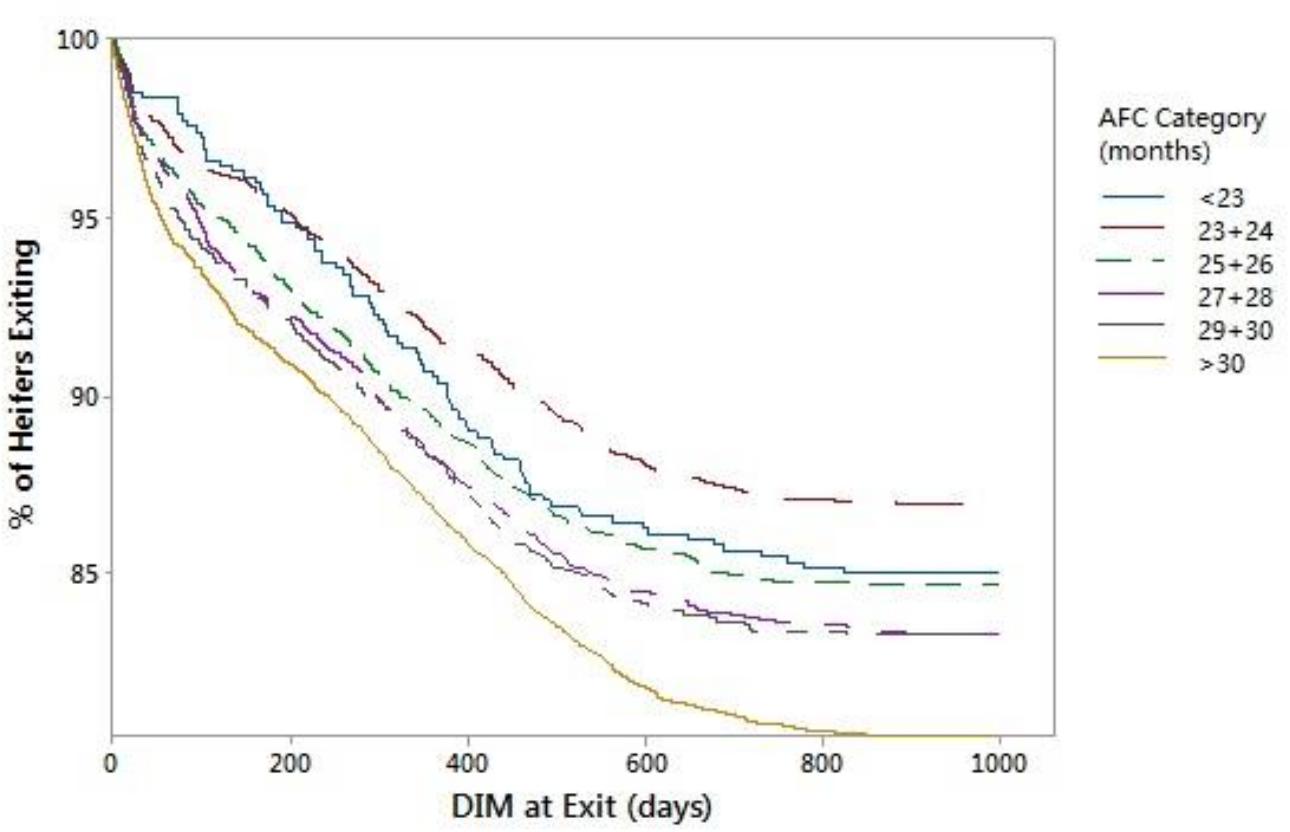


Figure 24 Kaplan-Meier Survival Plot of primiparous dairy heifers exiting the herd in terms of age at first calving (AFC). AFC <23 months (n=626), AFC 23+24 months (n=2812), AFC 25+26 months (n=3558), AFC 27 + 28 months (n=2883), AFC 29+30 months (n=2506), AFC >30 months (n=6021)

4. Discussion

4.1 First Lactation Performance: Impact of AFC

4.1.1 First Lactation Heifer Fertility Performance

AFC was shown to have a significant impact on the fertility performance of first lactation heifers, in terms of 100 day in calf rate and 200 day not in calf rate in this study, with heifers with an AFC > 24 months of age having a decreased chance of being in calf by 100DIM and 200 DIM. This was shown to be significant in the multivariate model (Table 14) and this has not previously been reported within the literature to the author's knowledge. The impact of AFC on 100 day in calf rate was only significant when the AFC was >30 months (compared to 23 + 24 months old), with the significance of AFC becoming more clinically relevant for 200 days in calf rate, with a statistical significance found for AFC >26 months. This may indicate that one of the primary reasons that first lactation heifers are culled is due to infertility, as previously shown by Cooke et al (2013). The impact of AFC on other fertility parameters has been reported (Wathes et al. 2014; Găvan et al, 2014; Krpálková et al. 2014) . This study showed an increase in the CCI for heifers with an AFC >27 months of age, compared to heifers 23-26 months old at first calving. The increase in CCI with an increasing AFC was identified in a previous UK study where there was a trend for heifers >30 months of age at first calving to have an increased first lactation CCI, compared to heifers <30 months of age (Cooke et al. 2013). The finding of a significant relationship between AFC and first lactation fertility agrees with findings of an American study (Ettema & Santos, 2004), but not with the findings in an Irish study (Berry & Cromie, 2009). In the Irish study there were significant differences for calving interval, with heifers calving at 24, 25, 29 and 34 months having shorter calving intervals than heifers with AFC 22 months ($P<0.05$); however there was no significant linear association in either calving interval or calving to first service interval with changing age at first calving (Berry & Cromie, 2009). This may be related to the seasonal calving system that was predominant in this study and thus

reflect the need for uniformity in the AFC of the heifers, which results in a bimodal AFC grouping as shown in Figure 5. However the measurements of calving to conception and calving interval do not take into account the animals which are subsequently culled and therefore can be skewed by culling policies as only cows that are confirmed pregnant are included (Wapenaar et al. 2008).

4.1.2 MILK PRODUCTION OF FIRST LACTATION HEIFERS

The results showed that there was a significant impact of AFC on the 305 day yield of first lactation heifers, with heifers with an AFC <23 months of age producing less milk than the other AFC categories. This impact of an early AFC impacting on milk production could be related to the lack of time for complete mammary development prior to calving in animals, compared to older animals (Coffey et al., 2006), with AFC <23 months of age having been shown to have a negative impact on milk yield in other studies (Krpálková et al., 2014; Van Amburgh et al., 1998). However this negative impact in one study was reported to have only lasted for the first 100 DIM (Krpálková et al., 2014), whilst in this study, it was reflected over the whole lactation. Other research has shown no significant difference, with one study highlighting no advantages of increasing the mean AFC from 724 days (23.7 months) to 791 days (26.0 months) (Ettema & Santos, 2004); however this study was based on three farms and may not be reflective of the whole population. The lack of association between AFC and milk production was also reported in a UK based study (Cooke et al. 2013); however there were only 117 heifers in Study 1 (n= 1 herd) and 353 heifers in Study 2 (n=16 herds). This suggests that the sample size may not have been large enough for a significant result and no power calculation was provided in the study design.

Heifers with an AFC >30 months were more likely to produce 632L more milk during the first 305 days of the first lactation than heifers with an AFC <23 months of age, which equates to 2.07L/day. This extra income from the extra milk sold per heifer per day would be less than £1.00 per day (based on a milk price <48p/L; cost would be 49.68p

for 25p/L milk contract), which is less income compared to the extra £1.64 per day (range £0.56 to 2.86 per day) that it costs to rear pregnant heifers. Therefore despite the increase in the milk yield, it does not make economic sense currently in the UK to calve heifers at a later age for economic reasons.

4.1.3 SURVIVAL DURING FIRST LACTATION

This study showed that there was a significant increase in the odds of a heifer being culled in the first lactation with an increasing AFC, which was the same finding as other studies in Ireland (Archer et al., 2013; Berry & Cromie, 2009), Spain (Bach, 2011) and Canada (Dürr, Monardes, & Cue, 1999). A decrease in AFC from 27 to 24 months of age was associated with a 10% reduction in the odds of removal from the herd (Archer et al., 2013), which was reflected in the current study with heifers with an AFC 27-28 months having a significant increase in odds of removal of 1.36, compared to heifers with an AFC of 23-24 months. The main reason discussed within the literature for the removal of first lactation heifers from a herd is due to poor fertility performance (Evans et al., 2006; Brickell and Wathes, 2011); first lactation fertility performance has been linked to AFC (see above) (Krpálková et al. 2014; Cooke et al. 2013). This relationship was highlighted by the model for the 100 day in calf rate and 200 day in calf rate, where heifers had an increased odds of not being in calf if they were culled during that lactation (OR: -2.216 for 100 day in calf rate, OR: -3.120 for 200 day in calf rate). This potential explanatory variable was included in the model to control for other potential reasons for culling of first lactation heifers.

4.2 First Lactation Heifer Performance: Summary

4.2.1 Age at First Calving

The median AFC was 28.0 months of age, with a mean AFC of 29.6 months of age, which is higher than previously reported means of 27 months of age (Brickell & Wathes 2011; Hanks & Kossabati 2015) and 25.8 months of age (Randall et al., 2015) for the UK. This may reflect that a small number of herds were evaluated in these two of the studies, as the management on these herds may not reflect the true population of UK dairy heifers (Brickell & Wathes, 2011; Randall et al., 2015), or the time period chosen, with more recent evidence highlighting the trend for decreasing AFC at a herd level over time (Hanks & Kossabati 2015;Hare et al. 2006). There was a wide distribution of AFC for individual heifers within a herd, as highlighted by Figure 15, as well as at a herd level, which agrees with findings of previous research within the UK (Cooke et al. 2013), as well as in the United States of America (Hare et al., 2006a). The variation within the herds suggests potential lack of uniformity within the groups of heifers on the one farm. A lack of uniformity could indicate that there may be management factors which affect the development of some heifers but not others or potential nulliparous heifer fertility problems. The variation between farms implies that there are possibly variable management factors and decisions between farms, which influence the AFC of the herd and the heifers within the herd. Further research into this is required.

4.2.2 Fertility Performance of First Lactation Heifer

In this study, 40.8% of first lactation heifers were pregnant by 100 DIM, which was lower than the target of 50% (Hudson et al. 2012b). The 100 day ICR is a measure of the proportion of eligible cows that are in-calf within 100 days of calving and includes any cows that were culled. It is also affected by the voluntary wait period on the farm and therefore the 200 day in calf rate could potentially be a better parameter (Wapenaar et al. 2008). In this study the 200 day in calf rate was 70.2%, which was also below the

quoted target of >85% (for all parity animals) (Hudson et al. 2012b). The first lactation heifers had higher in calf rates than the overall in calf rates, suggesting that first lactation heifer fertility outperformed the older cows within the herd.

The median calving interval of the surviving heifers was 385 days (mean 409days). The mean calving interval in this study was shorter than that previously reported in a Canadian study of 33,312 heifers of 395 days (Muir, Fatehi, & Schaeffer, 2004), but the same as the reported mean of 385 days for 56,577 Dutch heifers (Veerkamp, Koenen, & De Jong, 2001). The similarities in the calving interval suggests that a calving interval target of 365 days is achievable, with half of the herds already achieving a calving interval of <385 days.

4.2.3 MILK PRODUCTION DURING THE FIRST LACTATION

The median 305 day yield was 7,208kg (mean 7,179 kg), which varies from what has previously been reported. It is approximately 500kg less than previously reported in two studies investigating the effects of genetic parameters and DLWG on 305 day yields in first lactation (Muir et al., 2004; Van Amburgh et al., 1998); however these studies could have a selection bias and therefore may not be truly representative of the dairy industry. The median and mean reported 305 day yields in this study were higher than the reported mean of 6928.5kg in a study in USA for 122,715 lactation records of Holsteins in 1996. However this may reflect the difference in genetics of animals, time period and management systems between the two studies. To the author's knowledge, there is not a reported median or mean 305 day yield for first lactation heifers and therefore it is difficult to compare the 305 day yield results in this study to other results.

4.2.4 SURVIVAL OF FIRST LACTATION HEIFERS

The overall culling rate was 16.9%, with the median herd culling 14.3% for first lactation heifers. The mean culling rate of heifers was 2.1 percentage points lower in this study

than previously reported within the UK (Brickell & Wathes, 2011) and 0.7% lower than a study in California (Ettema & Santos, 2004). This may reflect the small number of herds used in the previous studies, compared to the larger number of herds used in the current study, as there was a wide variation between herds, suggesting the possibility of selection bias if only a few herds are sampled. There was a change over time as both of the previous studies mentioned collected data from animals between 2000 and 2005, whilst this data is from 2008 to 2011, which could represent differences in the population management and genetics. Across the world, there have been other first lactation culling rates reported of 32% in China (n=93 out of 502) (Wu et al., 2012) and 8.4% (n=655 out of 7,768; one farm), which differ from the results from this study. The distribution of within-herd culling had a right-sided skew and showed a large variation between herds. The large variation between herds was shown to be similar to previous findings (Archer et al., 2013; Brickell & Wathes, 2011), with Brickell reporting a range of herd culling rates of 7.1% to 33% from 18 herds in the UK. This large variation could reflect the impact of different farm management systems.

Survival analysis indicated that of those primiparous heifers culled, 31% were culled before 100 DIM (n=955), which was 5% of all primiparous heifers. In this study 21% of heifers that did not survive were culled within 50 DIM, which differed from the findings of Bach et al., where 31.5% of culled first lactation heifers did not survive to 51DIM (Bach, 2011). First lactation heifers were removed at a faster rate during the first 150 DIM, compared to lactation 2 or 3, but overall had a lower culling rate than older parities, as shown in Figure 23. Lactation 4 and above cows were removed at a greater rate than all other parities at all time points. This suggests that there were more forced culls of first lactation heifers during the first 150 DIM compared to lactation 2 and 3, whilst first lactation heifers had fewer economic culls than other parities. The higher culling rate of first lactation heifers in the first 100 DIM compared to multiparous cows has been reported previously in France, with 8% of multiparous culled cows being culled in the

first 100 DIM, compared to 13.8% of first lactation culled heifers (Seegers, Bareille, & Beaudeau, 1998).

Survival of heifers was shown to be significantly associated with season of calving, which has shown to be significant in previous studies (Bach, 2011; Ettema & Santos, 2004); however these studies have found different seasons to have an increased risk of removal. In a Californian study, there was an increased risk of removal if the calving occurred in the summer and was suggested to be related to heat stress (Ettema & Santos, 2004), whilst in a Spanish study, winter and spring had a significant decreased risk of removal when compared to summer (Bach, 2011). These findings differ from the result in the current study, where summer was protective compared to spring. This may reflect the differences in summer temperatures between the countries as well as the impact of different farming systems, in terms of management and reasons for culling.

The culling rate of first lactation heifers was significantly associated with adult herd culling rate, with an increased risk of being culled if there was a high adult culling rate. This suggests that herds with high culling rates were not culling for economic reasons (i.e. with the aim of replacing the culled cow with a more profitable heifer), but that the culls were forced culls and occurred across all parities of cows. This would indicate that there might have been management factors that caused an elevated culling rate on the farm, which could have had welfare implications.

4.3 HERD PERFORMANCE OF THE STUDY HERDS

4.3.1 STUDY POPULATION SIZE

Despite having a sample size of 73, 227 cows, this dataset only represented 3.88% of the total population of more than 1.8 million dairy cows in the United Kingdom in 2008, from 2.56% of registered UK dairy herds (n=437 out of 17,060 herds). The mean herd size in the study was 168 cows (median: 144), which was a larger than the reported

national mean United Kingdom herd size of 115 cows per herd in 2008 (Bate, 2016). The population of herds were selected from across the country, with the aim of representing the numerous different farming systems across United Kingdom. However there was a selection bias within this observational study, because the participating herds all used a form of data recording (for example milk recording, on farm computer software). Therefore this dataset may not be a true representation of the population.

4.3.2 MILK PRODUCTION

The mean 305 day yield of the study herds was 7,382kg per cow (median 7,159kg), which was higher than previously reported by the UK levy board, AHDB of 6,974 litres per cow per annum for 2008; however the parameter from AHDB was calculated by dividing the total milk production recorded by the size of the dairy herd (AHDB, 2015) and therefore is a different measurement of milk production and is difficult to compare to 305 day yield.

It has previously been reported that first lactation heifers produce less milk than multiparous cows (Cavestany et al., 2005; Wathes et al., 2007). It has been hypothesed that this could be attributed to the first lactation heifers not being mature at the point of calving, as well as being in a different metabolic state, resulting in higher concentrations of insulin growth factor-1 (IGF-1) and lower concentrations of insulin, in comparison to older cows (Coffey et al., 2006; Wathes et al., 2007). This association was echoed in this study, with multiparous cows producing a mean of 1,200kg per cow per 305 day yield more than first lactation heifers. There was also an association between herd 305 day milk yield and varying proportions of first lactation heifers within the herd; 25 to 35% of heifers produced significantly more milk than herds with <15% heifers and >35% heifers. Both all year round and seasonal calving herds had a median of 24% first lactation heifers within the herds, suggesting that the difference in 305 day yield between calving systems was not related to the percentage of first lactation heifers within the herd. However it was found in the current study that all year round calving

herds produced a median of 264kg more milk per 305 day yield than seasonal calvings. This may reflect the management systems of these farms, including nutritional management and cow genetics. There was no influence of herd size upon mean 305 day yield in this study.

4.3.3 HERD FERTILITY PERFORMANCE

The mean calving interval for the mean herd was 414 days, whilst it was 448 days for individual animals. The reported mean calving interval for the mean herd was 424 days in 2010 for 500 milk recorded herds in the UK (median not reported) (Hanks & Kossabati, 2015), with the best 25% of these herds achieving 409 days. That study reported a mean calving interval 10 days longer than the one found in this study, in a similar number of herds. However both studies have a potential for bias, because only data recorded herds were used as a convenience sample. The 100 day in calf rate of the mean herd in this study was 35.4%, which was higher than that reported for the mean herd in the UK in 2010 of 26% for 500 herds. The 25th percentile of herds achieved a 100 day in calf rate of less than 40% from 2010 to 2015 (Hanks & Kossabati 2015). The in calf rates within this study and reported by Hanks and Kossabati were below the reported target of >50% (Hudson, 2012b). This may reflect that the target is difficult to reach or that there were inherent fertility problems on these farms, which could be reflected in the wide variation of in calf rates between farms. The in calf rate fertility targets are not widely reported within the literature and therefore further work is required investigating the in calf rates within different countries and cohorts of cows to allow benchmarking of herds.

4.3.4 HERD CULLING RATES

The overall culling rate was 23.9% in this study, which was similar to previous studies which reported culling rates of 22% to 25% (Esslemont & Kossaibati 1997; Bell et al.

2010; Hanks & Kossabati 2015). Out of the animals that did not survive to the next lactation, 23.9% of those were culled in the first 100 DIM, which is a similar finding to Pinedo et al., whom reported that the highest risk of culling was in the first 60 DIM (Pinedo et al., 2014). In the current study, over 50% of the animals culled were removed from the herd prior to 300 DIM, resulting in an incomplete 305 day lactation. This suggests that there would have been associated economic losses including loss of milk as well as a decreased carcass weight at point of culling, as previously shown by Seegers et al (Seegers et al., 1998). Seegers et al showed that there was a significant association between time of culling and carcass weight, with cows culled in the first 100 DIM having a significantly lower carcass weight than those which were culled at greater than 249 DIM.

4.4 Study Design

This observational study was designed to give an indication of the AFC of heifers across a large number of herds within the UK, as the performance of the first lactation heifers and how this is potentially impacted on by AFC. The sample selected for this study was based upon a dataset of farms used in a previous study, with data obtained from farms with a good record keeping. This therefore biases the sample of the population as it excludes farms that do not record data accurately.

This study had a large number of animals within the study, which meant that the study had an adequate power to detect differences between the different outcomes (for example differences in milk yield, differences in survival). However with such a large number of animals within the study, it meant that the ability of the model to detect small differences between the groups was high and therefore some of statistically significant results that were found may not be clinically significant, for example the difference in milk yield between 23+24 months AFC and <23 months AFC was 185L per 305 day yield and was statistically significant ($P<0.05$), however the clinical relevance of this finding is most likely negligible.

The aim of this study was to evaluate the impact that AFC had on the survival of the first lactation heifers to second calving, and also the production and fertility performance of heifers during the first lactation, as well as investigate the AFC of heifers across a large number of herds. This was achieved by using the study design selected, however the relationships discovered may not be causal and thus gives scope for future work into investigating potential biological reasons as to why AFC has this impact.

4.5 Future Work

This research has highlighted the importance of the AFC as a KPI for farms in terms of future of survival and performance of first lactation heifers, however it has also highlighted the lack of key performance indicators for first lactation performance and a comparison to the rest of the adult of the herd. This work has suggested that there is a wide range in performance within and between different farms during the first lactation and therefore suggests that further work investigating potential KPIs for first lactation heifers could benefit benchmarking the performance of first lactation heifers and indicate how well a herd is performing at integrating the heifers into the milking herd. This research has also shown that there are still gaps within our knowledge of the impact of AFC on first lactation heifer performance, especially in terms of reasons for first lactation heifers leaving the herd. This data would be difficult to obtain over a large number herds due to a lack of recording on farm, multiple reasons/factors for why heifers leave the herd and the potential need for a standardised recording reason to allow a comparison across many different farms and systems.

Another large gap within the research is the impact of AFC on the performance of beef heifers, in terms of calving ease, calf vitality, survival and future fertility performance. To the author's knowledge, there have been no studies that have investigated the impact of different AFCs and its impact on the beef heifer's first lactation performance across a large number of herds and different systems, alongside a survey of what the median AFC

is for beef heifers within the UK. Further studies into the applicability of the presumption that the best AFC for beef heifers of different breeds within different farm systems is the same as for dairy heifers.

5. CONCLUSIONS

Age at first calving had a significant impact on various aspects of the performance of first lactation heifers, including fertility performance, milk production and survival to second lactation. The optimum AFC was found to be 23-24 months, in terms of ensuring a profitable milk yield, more efficient fertility performance and increased odds of survival to the second lactation. Within the study herds, there was shown to be large variation in AFC, which suggests that there are farm factors which result in a lack of uniformity of the heifers. This variation in AFC was echoed between farms and suggests that there are management decisions and factors that influence the AFC between the farms. More research is required to investigate the factors which have a potential impact on AFC, both between farms and heifers within a farm. This is of particular importance since the mean AFC within this study was reported to be higher than target, agreeing with previous studies. With the AFC being greater than target, there are both welfare and economic implications.

Heifer rearing has become a hot topic within the dairy industry in the previous five years, with a push in knowledge transfer to producers and other industry members. Despite research, including the outcomes of this study, highlighting the importance of AFC to be 23 to 24 months of age, there is currently no country reporting a mean or median AFC of <25 months of age. This suggests that clinically there is still a large amount of work to be done in terms of the heifer rearing process and knowledge transfer to producers. The veterinary profession needs to take responsibility for the herd health management, including the welfare, of calves on their client's farm as there are still some farms that raise their calves in unsuitable conditions. The lack of uniformity of AFC between heifers within single farms suggests that the heifer rearing process is not robust and has the potential for a large amount of variability from calf to calf. Another area of concern in the author's mind is the transition of the heifers into the adult milking herd. Unfortunately often in GB herds, once the heifer has calved, she is placed in a new group

of older milking cows, introduced to a new housing and feeding system, as well as a milking parlour in a short period of time. This is a large number of different stresses for the heifer to deal with. Currently there are no monitoring methods for how effectively this transition to a milking cow occurs, with no key performance indices developed for their fertility performance, health or production, in comparison to their herd mates. These would be useful to figures to obtain, in order to optimise the transition period for the heifer.

There is an enormous number of unknowns in terms of heifer rearing and first lactation performance, however it is encouraging to see an increasing interest within the dairy industry in terms of heifer rearing and the knowledge transfer that has started with farmers. It highlights how important heifer rearing is and that the key to a successful future is to look after the future herd, the youngstock.

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7. Appendix: Table of Herd Characteristics

Herd Number	Calving Pattern	Number of Animals	Number of First Lactation Heifers	Herd Mean AFC (months)	Herd Calving Interval (days)	Herd 305 day yield (kg)	Herd Culling Rate (%)
1	AYR	87	1	38.0	422	9117	25.3%
4	AYR	188	43	25.8	392	7424	23.4%
5	AYR	625	256	32.7	414	9615	37.8%
6	AYR	183	42	24.5	394	8122	20.8%
7	AYR	211	66	27.1	425	8978	24.6%
8	AYR	273	63	25.2	396	8895	22.7%
9	SC	139	27	27.1	388	8423	20.1%
10	SC	213	60	27.2	430	9380	17.4%
11	SC	175	41	25.2	418	7249	16.0%
12	SC	155	28	36.8	416	8120	21.9%
13	AYR	155	31	26.7	421	8583	23.2%
14	SC	157	36	25.6	388	6567	23.6%
15	SC	184	48	24.9	385	6739	19.0%
16	AYR	614	158	25.4	401	9025	24.1%
17	SC	163	38	25.4	386	8089	23.3%
18	SC	157	40	33.0	398	7723	29.3%
19	AYR	103	14	28.7	427	5235	23.3%
20	AYR	154	48	29.5	391	5968	29.2%
22	AYR	119	30	35.0	396	8128	28.6%
23	SC	116	22	27.2	425	8074	19.0%
24	AYR	170	20	28.5	409	8825	21.8%
25	SC	97	20	33.7	442	6301	16.5%
26	AYR	108	27	34.0	411	7209	24.1%
27	SC	133	33	25.7	408	8015	27.1%
28	SC	203	2	29.5	419	6880	16.7%
29	AYR	70	2	29.5	422	8632	22.9%
30	AYR	99	3	27.7	407	9424	19.2%
33	AYR	177	38	29.0	413	7418	26.6%
34	AYR	135	42	27.1	417	9569	28.1%
36	AYR	185	32	33.5	456	8420	23.2%
37	AYR	115	23	30.0	438	6147	20.9%
39	AYR	121	27	33.3	429	5678	14.9%
40	AYR	458	133	30.7	401	6355	20.1%
41	AYR	174	49	29.2	418	8293	32.8%
42	AYR	212	58	28.6	450	9679	23.6%
43	AYR	241	64	29.5	414	7993	29.5%
44	AYR	131	63	28.0	455	8616	27.5%

Herd Number	Calving Pattern	Number of Animals	Number of First Lactation Heifers	Herd Mean AFC (months)	Herd Calving Interval (days)	Herd 305 day yield (kg)	Herd Culling Rate (%)
45	AYR	118	39	29.1	406	7918	22.0%
46	AYR	197	53	28.6	438	8077	31.5%
47	AYR	160	42	29.5	432	7552	28.1%
48	AYR	174	75	25.8	433	8399	24.7%
49	AYR	231	81	28.4	396	8567	22.1%
50	AYR	219	63	26.6	414	9935	13.2%
51	AYR	216	47	34.8	400	6986	20.8%
52	SC	185	20	33.4	406	7065	19.5%
53	AYR	202	48	33.2	400	6665	23.3%
54	AYR	128	22	30.3	405	8213	18.8%
55	AYR	203	56	29.0	429	9503	23.2%
56	AYR	128	29	24.5	415	7938	20.3%
57	AYR	160	49	26.7	435	5964	48.1%
58	AYR	91	31	27.0	412	8019	23.1%
59	AYR	234	79	28.4	421	8992	36.8%
60	AYR	129	38	33.0	430	9145	27.1%
61	SC	81	23	35.1	410	7621	30.9%
62	AYR	281	82	32.4	437	6792	27.4%
63	SC	119	40	23.4	408	8789	27.7%
64	SC	84	30	24.1	410	7508	25.0%
65	AYR	173	55	32.0	412	7880	22.0%
66	AYR	160	30	35.2	391	7426	18.1%
67	AYR	86	14	35.5	438	7010	27.9%
68	AYR	189	41	27.3	395	8483	15.3%
69	AYR	761	200	38.5	392	9041	38.9%
70	SC	167	52	24.4	401	7616	26.3%
71	AYR	412	71	29.1	422	6919	29.4%
72	SC	139	40	25.0	399	7217	19.4%
73	SC	258	10	33.7	382	4905	14.7%
74	AYR	33	7	33.3	409	4091	33.3%
75	AYR	141	10	28.5	440	7227	18.4%
76	AYR	178	52	24.9	411	7382	21.3%
77	SC	102	30	25.2	405	6488	31.4%
78	AYR	264	65	26.6	411	9785	12.1%
79	SC	199	46	25.5	386	6874	17.6%
80	AYR	126	45	28.1	400	7407	27.8%
81	AYR	80	19	24.6	406	8721	26.3%
82	AYR	133	31	29.3	424	8315	30.8%
83	SC	136	18	23.8	369	7259	5.9%
84	AYR	348	77	28.1	439	8974	23.3%

Herd Number	Calving Pattern	Number of Animals	Number of First Lactation Heifers	Herd Mean AFC (months)	Herd Calving Interval (days)	Herd 305 day yield (kg)	Herd Culling Rate (%)
85	AYR	394	94	25.6	405	8838	25.9%
86	AYR	153	35	32.2	446	7164	24.2%
87	AYR	185	33	26.2	438	9272	21.6%
88	AYR	197	43	25.7	396	8335	18.8%
89	AYR	190	35	28.7	360	7259	14.2%
90	AYR	153	27	29.8	407	7640	21.6%
91	AYR	172	43	28.0	404	10735	16.3%
92	AYR	211	65	28.8	416	8777	15.6%
93	AYR	199	49	31.4	414	8367	23.6%
94	AYR	101	16	31.6	418	8807	16.8%
95	AYR	211	61	33.6	399	8115	25.1%
96	AYR	255	68	26.0	417	8717	27.1%
97	SC	167	51	26.5	404	9135	19.8%
98	AYR	568	185	27.4	385	7646	21.0%
101	AYR	86	25	31.4	446	5876	31.4%
102	AYR	59	14	33.9	419	4005	16.9%
103	AYR	72	25	28.5	413	8561	33.3%
104	AYR	101	32	34.0	436	7719	26.7%
105	SC	132	29	24.0	372	7435	27.3%
106	AYR	95	16	31.0	428	6164	20.0%
107	AYR	122	23	25.9	447	8363	21.3%
108	AYR	95	33	30.2	419	3836	17.9%
109	SC	61	22	38.4	442	4583	27.9%
110	SC	58	7	34.4	386	5120	17.2%
111	AYR	188	50	27.0	414	8057	28.7%
112	AYR	97	31	26.2	393	8246	21.6%
113	AYR	200	42	27.1	394	7687	11.0%
114	AYR	36	3	29.0	429	5476	22.2%
115	AYR	248	24	28.2	395	6899	21.8%
116	SC	79	18	32.7	395	6600	32.9%
117	AYR	178	44	27.8	407	7912	21.9%
118	AYR	93	27	31.5	410	6658	25.8%
119	AYR	87	19	25.2	423	8584	17.2%
120	AYR	78	26	36.6	434	6286	38.5%
121	AYR	67	18	30.8	481	8351	25.4%
122	AYR	64	9	43.6	391	5703	17.2%
123	AYR	165	28	28.4	408	9138	30.3%
124	AYR	181	59	30.7	426	5945	48.1%
125	SC	105	30	27.5	406	3873	21.0%
126	AYR	149	39	31.9	413	6454	28.9%

Herd Number	Calving Pattern	Number of Animals	Number of First Lactation Heifers	Herd Mean AFC (months)	Herd Calving Interval (days)	Herd 305 day yield (kg)	Herd Culling Rate (%)
127	AYR	166	62	35.3	476	5406	10.8%
128	SC	57	17	35.5	405	4975	28.1%
129	AYR	132	31	32.9	435	7757	21.2%
130	SC	135	28	25.9	442	3715	25.9%
131	AYR	47	4	34.5	402	6065	17.0%
132	AYR	407	120	28.1	385	7663	23.1%
133	AYR	72	13	32.4	460	4496	19.4%
134	AYR	150	30	28.4	359	5802	38.0%
135	AYR	112	15	29.9	406	3167	25.0%
136	AYR	199	53	26.7	413	8251	26.6%
137	AYR	111	18	29.2	381	7240	13.5%
138	AYR	140	46	28.8	406	7991	22.1%
139	AYR	105	17	26.1	414	8846	19.0%
140	AYR	266	65	29.5	437	10011	19.9%
141	AYR	128	50	36.6	396	7915	31.3%
142	AYR	73	15	26.5	409	6899	15.1%
143	AYR	86	20	28.8	416	8292	14.0%
144	AYR	165	56	27.9	419	8225	40.0%
145	AYR	122	42	27.4	428	7225	15.6%
146	AYR	324	72	30.4	408	6506	14.8%
147	AYR	178	53	26.2	409	6716	28.7%
148	AYR	129	17	29.4	442	6741	12.4%
149	AYR	86	1	44.0	406	1983	20.9%
150	AYR	167	34	26.9	408	7251	21.6%
151	AYR	52	3	27.3	434	2198	21.2%
152	AYR	87	25	27.0	417	7862	29.9%
153	AYR	102	17	31.9	430	4825	13.7%
154	AYR	130	30	38.5	443	5986	19.2%
155	AYR	110	23	35.5	461	5339	31.8%
156	AYR	146	55	32.7	413	7769	26.0%
157	AYR	237	72	32.3	423	6934	31.2%
158	AYR	50	15	28.5	397	6949	12.0%
159	AYR	147	50	28.9	434	8357	28.6%
160	AYR	294	72	31.8	403	6565	19.4%
161	AYR	122	37	25.5	391	7013	32.8%
162	AYR	223	67	30.5	426	7686	26.5%
163	SC	192	47	30.2	416	7196	21.4%
164	AYR	70	20	31.7	433	6633	42.9%
165	AYR	44	18	32.2	413	6121	34.1%
166	AYR	63	20	36.6	420	6160	33.3%

Herd Number	Calving Pattern	Number of Animals	Number of First Lactation Heifers	Herd Mean AFC (months)	Herd Calving Interval (days)	Herd 305 day yield (kg)	Herd Culling Rate (%)
167	SC	42	21	34.3	467	4146	23.8%
168	SC	7	5	34.6	390	4831	0.0%
169	AYR	119	50	28.7	405	4222	26.1%
170	AYR	94	25	29.0	410	7603	22.3%
171	AYR	72	16	35.7	404	4220	23.6%
172	AYR	58	13	28.5	460	5003	13.8%
173	AYR	212	75	28.7	399	7107	17.9%
174	AYR	219	43	35.7	411	3837	16.0%
175	AYR	153	28	28.4	409	6077	22.9%
176	AYR	130	17	30.4	403	7610	27.7%
178	AYR	208	63	33.0	407	5040	38.0%
179	AYR	118	51	28.3	407	6639	27.1%
180	AYR	87	24	31.7	402	4756	19.5%
181	AYR	98	14	35.8	413	5821	23.5%
182	SC	144	30	31.9	384	5819	23.6%
183	AYR	93	16	36.7	445	4859	21.5%
184	AYR	161	48	29.4	421	7875	37.9%
185	AYR	245	79	28.6	415	7358	36.7%
186	AYR	265	38	37.3	392	7771	25.7%
187	SC	165	56	36.0	375	5050	27.9%
188	AYR	59	22	32.5	443	7627	27.1%
189	AYR	507	48	32.0	417	6046	27.6%
190	SC	33	1	39.0	401	6351	27.3%
191	AYR	84	11	30.9	405	8876	10.7%
192	AYR	45	6	26.3	416	6714	17.8%
193	AYR	162	25	35.2	400	8769	20.4%
194	AYR	142	80	30.8	458	7037	5.6%
195	AYR	102	28	29.5	416	7293	26.5%
196	AYR	38	9	33.9	417	7331	28.9%
197	AYR	48	8	38.3	461	6111	14.6%
198	AYR	175	43	30.5	415	9306	13.1%
199	AYR	326	69	26.1	403	7308	26.7%
200	AYR	81	7	35.9	426	6675	24.7%
201	AYR	169	22	28.6	420	5762	12.4%
202	AYR	184	37	31.3	409	2175	17.9%
203	AYR	83	27	35.2	420	6336	25.3%
204	AYR	57	13	24.9	403	7838	8.8%
205	AYR	119	20	31.4	432	7789	15.1%
206	AYR	195	38	31.7	408	7303	1.0%
207	AYR	267	98	29.6	384	6667	33.7%

Herd Number	Calving Pattern	Number of Animals	Number of First Lactation Heifers	Herd Mean AFC (months)	Herd Calving Interval (days)	Herd 305 day yield (kg)	Herd Culling Rate (%)
208	AYR	98	13	34.3	435	6538	22.4%
209	AYR	127	27	32.5	394	8728	21.3%
210	AYR	43	10	31.7	404	6218	4.7%
211	SC	153	54	23.3	395	8593	33.3%
212	SC	142	30	34.5	411	7153	19.7%
213	AYR	106	19	25.7	387	8681	17.0%
214	AYR	159	29	26.5	381	7100	26.4%
215	AYR	96	12	29.3	395	7460	26.0%
216	AYR	181	57	32.0	441	8232	14.4%
217	AYR	215	60	29.9	400	8567	16.3%
218	AYR	200	49	27.3	393	7844	14.5%
219	AYR	142	17	29.2	447	7477	32.4%
221	AYR	181	26	33.0	380	8216	17.7%
222	AYR	211	61	28.5	415	7519	22.7%
223	SC	210	73	23.4	406	8377	19.0%
224	AYR	88	28	34.2	460	6031	28.4%
225	AYR	101	19	27.5	458	6433	28.7%
226	AYR	88	25	27.0	416	9229	19.3%
227	AYR	110	34	29.0	410	6679	37.3%
228	SC	501	112	31.4	402	7358	24.2%
229	AYR	93	42	26.4	426	9150	35.5%
232	AYR	75	7	33.1	451	6810	30.7%
233	AYR	109	28	29.1	418	7305	18.3%
236	AYR	150	33	30.8	391	5953	26.0%
237	AYR	106	23	34.3	439	7628	24.5%
238	AYR	374	125	25.8	390	8474	31.6%
239	AYR	121	20	32.7	414	6995	28.1%
240	AYR	176	63	31.3	420	7933	34.1%
241	AYR	66	19	27.3	404	7141	28.8%
242	AYR	150	33	31.6	456	8642	17.3%
244	AYR	400	126	27.6	405	9398	23.0%
245	AYR	207	34	27.9	397	9120	21.3%
247	AYR	85	7	96.3	417	8156	31.8%
248	AYR	151	19	27.2	462	7950	18.5%
249	AYR	88	14	31.4	366	5134	25.0%
251	AYR	174	67	28.3	401	7254	33.9%
252	SC	124	26	35.9	422	7898	21.8%
253	AYR	87	34	26.7	412	8637	47.1%
255	AYR	113	25	38.2	413	7732	17.7%

Herd Number	Calving Pattern	Number of Animals	Number of First Lactation Heifers	Herd Mean AFC (months)	Herd Calving Interval (days)	Herd 305 day yield (kg)	Herd Culling Rate (%)
256	AYR	123	30	35.3	392	6576	35.0%
257	AYR	310	70	27.0	451	8599	32.9%
258	AYR	103	1	27.4	449	2240	17.5%
259	AYR	61	17	31.5	441	6591	21.3%
261	AYR	195	102	28.0	424	7446	31.8%
262	AYR	248	73	27.4	436	9824	22.6%
263	AYR	175	28	26.8	394	8767	21.7%
264	AYR	190	42	26.7	408	7536	26.8%
265	AYR	55	10	28.1	439	7899	27.3%
266	SC	145	50	23.5	387	7414	31.0%
267	AYR	180	46	27.1	393	7821	27.2%
269	AYR	125	41	27.6	411	9434	16.8%
270	AYR	65	12	28.7	355	8090	10.8%
271	AYR	148	55	33.8	420	6173	31.1%
272	AYR	284	92	25.6	388	9262	25.0%
275	AYR	356	111	31.6	412	7845	22.5%
276	AYR	206	54	32.7	421	7130	33.5%
277	AYR	86	13	28.8	385	8092	23.3%
278	AYR	127	10	32.8	449	7152	29.1%
279	AYR	65	12	28.5	388	8399	21.5%
280	AYR	400	126	27.6	408	9337	23.5%
281	AYR	60	10	27.3	393	5046	13.3%
282	AYR	163	39	27.1	395	9424	15.3%
283	AYR	744	162	24.6	391	8403	22.2%
284	SC	349	104	24.4	427	8117	35.5%
285	AYR	143	51	29.5	443	8888	28.7%
286	AYR	102	17	32.8	408	6548	9.8%
287	AYR	82	21	32.8	403	6462	22.0%
288	AYR	303	70	29.8	407	7950	17.2%
289	AYR	546	180	29.6	420	7780	21.1%
290	AYR	107	22	34.1	403	7248	29.9%
291	AYR	207	48	35.1	399	7051	19.8%
292	AYR	572	159	32.9	384	4724	21.2%
293	AYR	89	27	35.2	419	4920	15.7%
294	AYR	172	46	33.6	423	7005	18.6%
295	AYR	167	49	25.7	394	7482	29.3%
296	AYR	271	52	27.9	439	7500	26.6%
297	AYR	96	25	29.0	447	6122	12.5%
298	AYR	171	57	25.3	388	7975	26.9%
299	SC	74	26	30.7	437	6308	39.2%

Herd Number	Calving Pattern	Number of Animals	Number of First Lactation Heifers	Herd Mean AFC (months)	Herd Calving Interval (days)	Herd 305 day yield (kg)	Herd Culling Rate (%)
300	SC	205	57	23.9	390	3152	24.4%
301	AYR	34	8	39.8	472	4484	11.8%
302	AYR	146	7	42.7	384	5038	20.5%
303	AYR	126	43	60.6	415	5059	19.0%
304	AYR	172	37	30.1	401	6335	20.9%
305	AYR	224	44	31.7	416	6169	18.3%
306	AYR	90	65	57.7	421	5315	4.4%
307	SC	113	19	27.4	393	1253	9.7%
308	AYR	246	69	28.2	444	7825	34.6%
309	AYR	107	18	32.1	437	5487	18.7%
310	AYR	240	73	32.2	399	6560	29.6%
312	AYR	67	10	33.4	431	3008	13.4%
313	AYR	175	33	26.5	389	7677	19.4%
314	AYR	75	16	57.9	400	950	9.3%
315	SC	117	27	23.4	415	9646	17.1%
316	AYR	318	107	33.6	408	7847	19.5%
317	AYR	208	52	28.7	419	7100	19.2%
319	AYR	241	57	26.5	399	9878	22.4%
320	AYR	58	14	34.6	421	4692	19.0%
321	AYR	192	48	34.2	399	6183	21.9%
322	AYR	201	21	32.6	440	6918	16.4%
324	AYR	50	9	34.0	390	5289	20.0%
325	AYR	81	14	35.9	417	7468	23.5%
326	AYR	493	161	27.4	411	10112	22.1%
327	AYR	99	13	29.8	453	9522	29.3%
328	AYR	88	1	28.0	488	6570	37.5%
330	AYR	326	94	28.7	409	7237	18.1%
331	AYR	178	33	36.6	401	8369	23.6%
332	AYR	153	53	31.8	400	7553	24.8%
333	AYR	278	48	28.0	403	7645	17.6%
334	AYR	126	8	41.0	457	8132	21.4%
335	AYR	96	38	30.7	480	8154	26.0%
336	AYR	102	27	25.7	412	6658	19.6%
337	AYR	118	36	28.3	398	9356	26.3%
338	AYR	123	30	29.8	422	7521	17.9%
339	SC	57	10	35.7	407	8243	10.5%
340	AYR	153	25	32.2	383	7666	25.5%
341	AYR	369	107	27.1	406	6296	43.9%
342	AYR	361	96	24.6	422	9239	23.3%
343	AYR	67	16	36.1	440	5795	14.9%

Herd Number	Calving Pattern	Number of Animals	Number of First Lactation Heifers	Herd Mean AFC (months)	Herd Calving Interval (days)	Herd 305 day yield (kg)	Herd Culling Rate (%)
344	AYR	195	37	29.2	397	7739	21.0%
345	AYR	266	42	27.3	399	7204	23.3%
346	AYR	89	15	32.7	405	7176	14.6%
347	AYR	104	34	34.0	410	5794	21.2%
348	AYR	847	226	23.0	384	9199	29.5%
349	SC	127	35	35.2	396	9426	33.1%
350	AYR	462	112	29.0	393	6538	30.1%
351	AYR	253	172	28.4	391	6149	14.6%
353	AYR	194	52	30.7	404	8742	1.5%
354	AYR	176	46	24.4	388	7905	18.2%
355	AYR	293	90	36.3	425	6888	28.7%
356	AYR	54	17	23.9	416	9828	14.8%
357	AYR	134	32	28.4	414	6441	23.9%
358	AYR	269	19	34.2	406	7777	24.9%
359	AYR	98	19	40.9	488	5683	29.6%
360	AYR	232	86	29.3	415	8003	29.7%
361	AYR	164	43	27.5	416	8053	15.9%
362	SC	67	12	52.6	428	7659	11.9%
363	AYR	132	31	29.0	407	7081	16.7%
364	SC	174	58	24.4	394	8854	19.5%
365	AYR	262	66	29.0	436	7463	33.2%
366	AYR	277	56	30.7	404	5588	36.8%
367	AYR	80	15	33.9	436	6602	27.5%
368	AYR	232	51	24.8	408	7128	24.6%
369	AYR	178	28	24.5	403	8403	19.7%
370	SC	106	28	28.4	384	7965	19.8%
371	SC	129	35	25.0	401	7441	24.0%
372	AYR	194	58	31.9	454	8783	20.6%
373	AYR	154	43	32.6	402	7282	20.8%
374	SC	33	4	51.3	418	6141	21.2%
375	AYR	141	26	27.9	419	7530	27.0%
376	AYR	70	14	33.9	517	6948	22.9%
377	AYR	73	9	28.1	422	7456	13.7%
378	AYR	135	21	40.6	352	6195	12.6%
380	AYR	237	64	27.8	441	6949	26.2%
381	AYR	64	5	28.8	450	8624	21.9%
382	AYR	141	22	39.0	413	7519	11.3%
383	SC	314	59	28.4	415	4888	17.2%
384	AYR	98	25	30.2	431	8851	30.6%
385	AYR	217	52	31.6	407	7354	16.1%

Herd Number	Calving Pattern	Number of Animals	Number of First Lactation Heifers	Herd Mean AFC (months)	Herd Calving Interval (days)	Herd 305 day yield (kg)	Herd Culling Rate (%)
386	SC	72	1	71.0	393	6697	8.3%
387	AYR	352	157	32.2	454	7515	27.3%
388	AYR	222	45	26.4	381	6148	22.5%
389	AYR	398	123	27.3	380	7373	30.4%
390	AYR	144	47	31.8	409	8397	30.6%
391	SC	145	27	26.5	422	8054	24.8%
392	AYR	233	68	43.1	400	7521	33.5%
393	AYR	232	63	28.9	400	6105	23.3%
394	SC	146	38	26.6	407	10144	31.5%
395	AYR	513	134	36.0	406	6829	22.6%
396	SC	134	28	22.7	406	7564	12.7%
397	AYR	384	137	25.1	387	6747	35.2%
398	SC	227	49	25.4	425	7814	18.9%
399	AYR	210	39	24.1	413	8058	25.2%
400	AYR	203	43	25.4	406	7676	25.1%
401	AYR	654	181	25.4	384	10149	23.7%
402	SC	166	30	25.4	416	4809	22.9%
403	AYR	97	30	26.3	392	8526	36.1%
404	AYR	195	37	29.2	388	7737	21.0%
405	AYR	128	29	22.8	385	8044	27.3%
406	SC	177	35	27.7	391	9232	28.2%
407	AYR	213	36	28.2	423	8968	19.2%
408	SC	92	86	25.7	399	3704	37.0%
409	AYR	128	32	25.6	410	8115	13.3%
410	SC	151	51	34.8	421	6528	23.2%
411	SC	148	31	34.1	431	7222	15.5%
412	SC	279	47	26.1	421	6923	16.8%
413	AYR	163	21	28.5	428	8405	19.6%
414	SC	84	6	24.5	462	9068	20.2%
415	SC	159	43	27.0	449	7743	26.4%
416	AYR	241	9	25.0	383	6003	24.5%
417	SC	255	56	23.9	365	6890	24.3%
418	SC	25	1	25.0	386	6473	8.0%
419	AYR	140	36	27.4	392	9103	22.9%
420	AYR	133	20	28.9	384	6656	24.1%
423	SC	83	14	31.3	422	7055	28.9%
424	AYR	161	42	31.0	424	6103	26.1%
426	SC	85	19	37.6	389	5233	30.6%
427	AYR	62	4	29.5	417	6330	35.5%
428	AYR	53	10	42.3	448	6374	30.2%

Herd Number	Calving Pattern	Number of Animals	Number of First Lactation Heifers	Herd Mean AFC (months)	Herd Calving Interval (days)	Herd 305 day yield (kg)	Herd Culling Rate (%)
429	AYR	194	59	28.6	419	7629	24.7%
430	AYR	74	23	30.9	406	5001	25.7%
431	AYR	109	24	30.5	467	4792	16.5%
432	AYR	202	55	28.5	400	8413	31.7%
433	AYR	72	6	28.5	435	2486	12.5%
434	AYR	58	17	34.2	415	6537	8.6%
435	AYR	59	10	26.4	378	6203	15.3%
436	AYR	183	62	30.8	439	7180	30.1%
437	SC	106	30	29.1	369	5037	37.7%
438	AYR	40	4	37.0	411	7376	15.0%
439	AYR	172	60	29.4	397	7081	25.6%
440	SC	58	5	34.0	432	5221	15.5%
441	AYR	66	9	27.3	383	8397	18.2%
442	AYR	112	31	32.7	406	6884	27.7%
443	SC	104	22	34.0	435	7702	35.6%
444	AYR	306	69	31.2	409	7701	24.2%
445	AYR	141	31	26.3	424	7912	27.7%
446	AYR	146	44	29.3	381	8022	58.2%
447	AYR	222	65	27.1	464	8143	31.5%
448	AYR	143	56	27.0	435	8355	17.5%
449	AYR	88	29	36.6	458	7442	28.4%
450	AYR	130	35	27.4	407	6615	21.5%
451	SC	115	23	33.8	381	4966	28.7%
452	AYR	115	32	28.1	431	7007	24.3%
453	AYR	127	29	28.1	453	6873	30.7%
454	SC	6	2	24.0	502	8744	16.7%
455	AYR	177	41	28.6	398	7847	28.8%
456	AYR	237	92	30.5	419	5563	33.3%
457	AYR	114	23	30.7	422	7469	18.4%
458	AYR	134	43	25.7	422	8786	32.8%
459	AYR	173	46	26.5	413	8112	15.6%
460	SC	139	35	25.1	411	8261	20.1%
461	AYR	146	48	29.8	414	5746	26.0%
462	SC	70	23	53.4	378	2470	8.6%
463	AYR	60	8	35.9	387	3291	35.0%
464	AYR	188	58	34.4	432	7455	17.6%
465	AYR	179	44	26.5	391	6987	28.5%
466	AYR	122	32	26.1	411	8340	20.5%
467	AYR	63	23	32.9	368	6499	36.5%
468	SC	101	5	26.6	405	6014	24.8%

8. APPENDIX: Sherwin et al. 2016

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9. Appendix: Clinical Portfolio

The purpose of this chapter is to describe and demonstrate the clinical and professional achievements and development during the clinical training scholarship. The clinical training scholarship has been focused upon dairy herd health management, as well as allowing the development of clinical skills and knowledge required for the credentials and examination for the European Diploma of Bovine Health Management.

9.1 Clinical Work

9.1.1 CLINICAL CASE LOGS

The clinical caseloads for both individual animal medicine and surgery and herd health are shown below in Table 17 and Table 18. These are the clinical case logs which are submitted on an annual basis to the ECBHM committee for the credentials. The level of supervision was recorded for each case, for the purposes of the ECBHM, and the different levels of supervision are shown in Table 16.

The individual animal cases were seen through a mixture of teaching the final year undergraduate veterinary students at the University Of Nottingham dairy farm for a morning once per week, externships and locum work for local practices. During the clinical scholarships, two externships were undertaken; one at the University of California Davies with their extension team in Tulare for one week (January 2016) and a second at the University College Dublin, based at their hospital for two weeks (March 2016). Both of these externships offered the opportunity to work alongside herds with different management systems to those usually seen within the residency.

The majority of herd health clinical cases were from assisting the final year herd health clinical rotation. This rotation involved an in depth look at the production and health data of one farm per fortnight, alongside a visit to that farm to investigate any potential variables which could affect the outcomes of interest. The findings within the data and from observations on farm were collated by the final year students and presented to the farmer in one presentation. A summary of these findings were presented to a subset of other final year students at rounds, postgraduate students and members of staff. The role of the resident within this rotation was to facilitate the discussion amongst the students and aid them with their analysis and recommendations, as well as undertaking more complex separate projects.

Level of Supervision	Information regarding that level of supervision
1	No supervision, the resident dealt with the case by him/herself
2	Resident dealt with the case by him/herself, supervised by an ECBHM diplomate
3	Resident dealt with the case by him/herself, supervised by an non-ECBHM diplomate
4	Resident assisted, supervision of a ECBHM diplomate
5	Resident assisted, without the supervision of a ECBHM diplomate
6	Resident just observed, supervision of a ECBHM diplomate
7	Resident just observed, without supervision of a ECBHM diplomate

Table 16 Description of the levels of supervision for the clinical case logs

Table 17 Individual Animal Clinical Case Load

Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
29/05/2014	University of Nottingham Dairy	Female, adult, Holstein cow	Ocular Ulcer	Ocular examination and treatment	1
23/06/2014	University of Nottingham Dairy	Female, adult, Holstein cow	Abomasal displacement with an abomasal ulcer	Clinical examination and surgery	5
26/06/2014	University of Nottingham Dairy	Female, adult, Holstein cow	Retained fetal membranes	Clinical examination and treatment including fluid therapy	1
26/06/2014	University of Nottingham Dairy	Female, adult, Holstein cow	Chronic lameness in left hind leg due to cellulitis	Clinical examination. Previously had long term NSAIDs (1 month) - so opted euthanise	1
07/07/2014	University Smallholding (Val)	Female adult Holstein cow	Hindlimb lameness due to hock effusion	Orthopaedic examination (joint fluid aspiration, ultrasonography) and treatment	
07/07/2014	University Smallholding	Female, 11 year old Holstein-Friesian cow	Vegetative endocarditis lesion with DIC	Clinical examination and haematology with serum chemistry	3
10/07/2014	University of Nottingham Dairy	Female, adult, Holstein cow	Ketotic Cow	Clinical examination and treatment including fluid therapy	1
10/07/2014	University of Nottingham Dairy	Female, adult, Holstein cow	Traumatic lesion above the metacarpophalangeal joint	Clinical examination and treatment with wound flushing and dressing. NSAIDs given	1
14/07/2014, 17/07/2014, 21/07/14	University of Nottingham Dairy	Female, adult, Holstein cow	Re-examination of a traumatic lesion above the metacarpophalangeal joint	Repeated wound flushing and dressing	1
21/07/2014	University of Nottingham Dairy	Female, adult, Holstein cow	RDA	Clinical examination and surgical correction	1
21/07/2014	University of Nottingham Dairy	Female, adult, Holstein cow	Traumatic injury - upper hindlimb	Clinical examination including orthopaedic examination. Treatment consisting of box rest and NSAID	1
18/07/2014	University of Nottingham Dairy	Female, 1 day old, Holstein calf	Septicaemia	Clinical examination and treatment including fluid therapy	1

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
18/07/2014	University of Nottingham Dairy	Female, 2 month old, Holstein calf	Ruminal Bloat	Clinical examination including tube placement. Treatment with a ruminal trocar	3
25/07/2014	University of Nottingham Dairy	Female, H-F adult cow	Uterine abnormality	Reproductive examination: one uterine horn on palpation with thickened uterine wall. Poor prognosis for reproduction	3
30/07/2014	Gleadthrope Farm (Bacons)	Female, adult, Holstein cow	Traumatic foot lesion	Clinical examination and treatment including pain management and claw amputation.	3
31/07/2014	University of Nottingham Dairy	Female, adult, Holstein cow	Bilateral sole ulcers	Foot examination and corrective trimming. Blocked medial claws of both hind limbs. Treated with NSAIDs	1
31/07/2014	University of Nottingham Dairy	Female, adult, Holstein cow	Surgical incision infection after a LDA	Clinical examination, ultrasonography of incision, flushing of wound and treatment with antibiotics and NSAIDs	1
07/08/2014	University of Nottingham Dairy	6 week old calf	Pneumonia	Clinical examination and treatment	1
07/08/2014	University of Nottingham Dairy	Female, adult, Holstein cow	Mastitis	Clinical examination and treatment	1
07/08/2014	University of Nottingham Dairy	Female, adult, Holstein cow	LDA:	Clinical examination and treatment. As had already had previous DA surgery, opted for left sided surgery.	3
08/08/2014	University of Nottingham Dairy	Female, adult, Holstein cow	LDA	Clinical examination and surgical correction	1
14/08/2014	University of Nottingham Dairy	Female, adult, Holstein cow	Peritonitis post op	Clinical examination. Farmer opted to euthanise	1
21/08/2014	University of Nottingham Dairy	Female, adult, Holstein cow	Tibial Nerve Paralysis	Clinical examination including neurological examination. Treatment with NSAIDs and box rest	3
21/08/2014	University of Nottingham Dairy	Neonatal calves x 12	Assessment of passive transfer	Blood samples taken for serology	3

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
21/08/2014	University of Nottingham Dairy	pre-weaned calves x 30	Pneumonia	Clinical examination x 30 using the Wisconsin Health Scoring method. Treatment of clinical cases	3
28/08/2014	University of Nottingham Dairy	Female, H-F adult cow	Peritonitis originating from the liver	Clinical examination and diagnostic exploratory laparotomy	1
01/09/2014	Pollard	Female, H-F adult cow	Depressed rumination	Clinical examination and treatment	1
03/09/2014	Willcocks	Female, H-F adult cow	Pericarditis	Clinical examination and treatment including fluid therapy	1
03/09/2014	Willcocks	Female, H-F adult cow	Hindlimb lameness due to bilateral hock effusions	Clinical examination and orthopaedic examination. Treatment with steroid.	1
04/09/2014	Heller	Female, adult, Holstein cow	LDA	Clinical examination and surgical correction	1
04/09/2014	Heller	Female, adult, Holstein cow	Sole Ulcer	Foot examination and corrective trimming. Blocked medial. Treated with NSAIDs	1
04/09/2014	Wellington	5 month old steer	Free gas bloat	Clinical examination and placement of trocar	1
04/09/2014	Wills Brothers	Female, adult, Holstein cow	LDA	Clinical examination and surgical correction	1
04/09/2014	Wills Brothers	Female, adult, Holstein cow	LDA	Clinical examination and surgical correction	1
04/09/2014	Wills Brothers	Female, adult, Holstein cow	Toxaemia	Clinical examination and treatment including fluid therapy	1
04/09/2014	Wills Brothers	Female, adult, Holstein cow	Endometritis	Clinical examination and treatment	1
05/09/2014	Parkhouse	Female, H-F adult cow	LDA	Clinical examination and surgical correction	1
05/09/2014	Parkhouse	Female, H-F adult cow	LDA	Clinical examination and surgical correction	1

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
05/09/2014	Parkhouse	Female, H-F adult cow	Hip dislocation	Clinical examination including orthopaedic examination. Treatment consisting of box rest and NSAID	1
05/09/2014	Wills Brothers	Female, adult, Holstein cow	LDA	Clinical examination and surgical correction	1
05/09/2014	Wills Brothers	Female, adult, Holstein cow	2 x post-operative checks from LDA	Clinical examination	1
06/09/2014	Bailey	Female, H-F adult cow	Calving	Obstetrics	1
08/09/2014	Button	Female, H-F adult cow	LDA	Clinical examination and surgical correction	1
08/09/2014	Willcocks	Female, H-F adult cow	Calving	Obstetrics	1
08/09/2014	Cobbley	Female, H-F adult cow	Peritonitis and caecal dilation	Clinical examination and right sided exploratory laparotomy.	1
11/09/2014	George	Female, H-F adult cow	Ketosis	Clinical examination and treatment	1
12/09/2014	Parkhouse	Female, H-F adult cow	LDA	Clinical examination. Previously had surgery so bilateral approach	1
12/09/2014	Parkhouse	Female, H-F adult cow	Uterine Torsion	Obstetrics	1
25/09/2014	University of Nottingham Dairy	5 week old heifer	chronic pneumonia	Clinical examination	1
25/09/2014	University of Nottingham Dairy	Female, H-F adult cow	Mastitis	Clinical examination and treatment	1
02/10/2014	University of Nottingham Dairy	Female, H-F adult cow	RFM	Clinical examination and treatment	1
02/10/2014	University of Nottingham Dairy	Female, H-F adult cow	Metritis	Clinical examination and treatment	1

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
02/10/2014	University of Nottingham Dairy	Female, H-F adult cow	Endometritis	Clinical examination and treatment	1
02/10/2014	University of Nottingham Dairy	Female, H-F adult cow	Sole Ulcer	Foot examination and corrective trimming. Blocked medial. Treated with NSAIDs	1
06/10/2014	University of Nottingham Dairy	7 week old calf	Traumatic injury - lower pinna	Clinical examination, regional anaesthetic and sutured back together	3
13/10/2014	University of Nottingham Dairy	Female, H-F adult cow	Peritonitis	Clinical examination and right sided exploratory laparotomy.	1
15/10/2014	University of Nottingham Dairy	Female, H-F adult cow	Depressed rumination	Clinical examination	1
20/10/2014	Watchorn, Scalford Lodge	Female, H-F adult cow	BALs taken for respiratory pathogen assessment	Bronchioalveolar lavage of three cows	3
20/10/2014	Watchorn, Scalford Lodge	Female, H-F adult cow	Serology samples taken for mycoplasma assessment	Blood samples taken for serology	1
13/11/2014	University of Nottingham Dairy	3 month old calf	chronic pneumonia	Clinical examination	1
13/11/2014	University of Nottingham Dairy	12 month old H-F heifer	chronic lameness due to stifle injury	Clinical examination including orthopaedic examination. Treatment consisting of box rest and NSAID	1
20/11/2014	University of Nottingham Dairy	Female, H-F adult cow	LDA	Clinical examination and surgical correction	1
20/11/2014	University of Nottingham Dairy	Female, H-F adult cow	Metritis	Clinical examination and treatment including fluid therapy	1
22/11/2014	Bray	Female, H-F adult cow	Poor rumen turnover due to lameness	Clinical examination and treatment including fluid therapy	1
24/11/2014	Redman	Female, Simmental adult cow	Underrun heel with abscess underneath	Foot trim and block on medial claw. Treated with NSAIDs.	1

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
24/11/2014	Redman	Female, Simmental adult cow	White line disease	Foot trim, ensuring no weight bearing on affected surface. Treated with NSAIDs.	1
25/11/2014	Buttons	Female, H-F adult cow	LDA	Clinical examination and surgical correction	1
02/12/2014	University of Nottingham Dairy	Female, H-F adult cow	Abdominal catastrophe	Clinical examination and euthanasia	3
18/12/2014	University of Nottingham Dairy	8 week old calf	Castration	Surgery	1
22/01/2015	University of Nottingham Dairy	15 month old heifer	Free-Martin	Reproductive tract examination	1
22/01/2015	University of Nottingham Dairy	Female, H-F adult cow	Ketosis and Metritis	Clinical examination and treatment	1
22/01/2015	University of Nottingham Dairy	Female, H-F adult cow	Grade I Metritis	Clinical examination and treatment	1
22/01/2015	University of Nottingham Dairy	Female, H-F adult cow	Low grade chronic peritonitis	Clinical examination and treatment	1
29/01/2015	University of Nottingham Dairy	16 month heifer	Upper limb swelling and lameness	Clinical examination and treatment	1
29/01/2015	University of Nottingham Dairy	Female, H-F adult cow	Facial swelling from trauma	Clinical examination including an ocular and neurological examination	1
29/01/2015	University of Nottingham Dairy	4 month old heifer	End stage pneumonia with severe dyspnoea	Clinical examination and euthanasia	1
12/02/2015	University of Nottingham Dairy	Female, H-F adult cow	LDA	Clinical examination and surgical correction	1
12/02/2015	University of Nottingham Dairy	Female, H-F adult cow	Endometritis	Clinical examination and treatment	1
19/02/2015	University of Nottingham Dairy	Female, H-F adult cow	LDA	Clinical examination and surgical correction	1

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
19/02/2015	University of Nottingham Dairy	Female, H-F adult cow	Ketotic Cow	Clinical examination and treatment	1
02/03/2015	Morley	Pre-weaned calves	Castration	Surgical castration x 16	1
06/03/2015	Bowler	Pre-weaned calves	Castration	Surgical castration x 10	1
06/03/2015	Hill	Pre-weaned calves	Castration	Surgical castration x 8	1
09/03/2015	Parsons	Adult beef cross	Caesarean	Surgery	1
09/03/2015	Beake	Adult Red Devon	Calving	Assisted calving	1
10/03/2015	James	HF adult dairy cow	Uterine torsion	Rolled cow and assisted calving	1
11/03/2015	Hockridge	Beef cross	Vulval torsion	Sutured back together	1
11/03/2015	Hutchins	Adult beef cross	Caesarean	Surgery	1
12/03/2015	Gilbert	Jersey X	Uterine prolapse	Replacement and treatment of animal including calcium injection and oral fluids	1
16/03/2015	Shottle	Pre-weaned calves	Castration	Surgical castration x 20	1
26/03/2015	University of Nottingham Dairy	Female adult Holstein cow	Localised peritonitis	Clinical examination and treatment	1
26/03/2015	University of Nottingham Dairy	Female adult Holstein cow	Hock Abscess	Orthopaedic examination (joint fluid aspiration, ultrasonography) and treatment	1
26/03/2015	University of Nottingham Dairy	Female adult Holstein cow	Depressed rumination	Clinical examination and treatment	1
26/03/2015	University of Nottingham Dairy	Female adult Holstein cow	Ketotic Cow	Clinical examination and treatment	1
26/03/2015	University of Nottingham Dairy	Calves x 2	chronic pneumonia	Clinical examination and treatment	1

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
09/04/2015	University of Nottingham Dairy	Female adult Holstein cow	Mastitis	Clinical examination and treatment	1
09/04/2015	University of Nottingham Dairy	Female adult Holstein cow	Hock Abscess	Clinical examination and treatment with flushing of the abscess and systemic antibiotics	1
09/04/2015	University of Nottingham Dairy	Female adult Holstein cow	Vagal indigestion	Clinical examination and treatment	1
20/04/2015	Nealson, West Peake	Female adult crossbred	Peritonitis	Clinical examination and treatment	1
20/04/2015	Nealson, West Peake	Female adult crossbred	Vulval growth	Clinical Examination	1
20/04/2015	Nealson, West Peake	Female adult crossbred	Clinical milk fever	Clinical examination and treatment	1
21/04/2015	Vines	New-born welsh black calf	Ruminal bloat	Clinical examination, insertion of trocar and fluid therapy	1
22/04/2015	Leeson, Hele Barton	Female adult crossbred	Pre-partum milk fever and tibial nerve paralysis	Clinical examination, induction of labour, biochemistry diagnostics and treatment	1
22/04/2015	Leeson, Hele Barton	Female adult crossbred	Fractured rib 13 on the left hand side	Clinical examination and treatment	1
22/04/2015	Leeson, Hele Barton	Female adult crossbred	Upper respiratory infection	Clinical examination and treatment	1
22/04/2015	Wrights	Female adult Holstein cow	LDA	Surgery	1
23/04/2015	Cleave	12 month old male beef	Epidectomy	Surgery	1
23/04/2015	Cleave	Female adult beef	Forelimb lameness	Clinical examination and treatment	1
23/04/2015	Cleave	Female adult beef	Mastitis	Clinical examination and treatment	1

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
28/04/2015	University of Nottingham Small holding	Adult beef cross	Foot trim x 4 cows	5 step Dutch method foot trim	1
30/4/215	University of Nottingham Dairy	Female adult Holstein cow	Mammary gland abscess	Clinical examination and surgical drainage	1
07/05/2015	University of Nottingham Dairy Centre	6 day old Holstein Calf	Fly Strike	Treatment of wound including debridement. Treatment of scour including fluid therapy	1
27/05/2015	University of Nottingham Dairy Centre	Adult Holstein Cow	LDA	Diagnosis and Surgical Correction	1
10/06/2015	University of Nottingham Dairy Centre	Adult Holstein Cow	Metritis	Clinical examination and treatment	1
10/06/2015	University of Nottingham Dairy Centre	Calf	Pneumonia	Clinical examination and treatment	1
10/06/2015	University of Nottingham Smallholding	Adult Holstein Cow x 2	Overgrown hooves	5 step Dutch method foot trim	1
17/06/2015	University of Nottingham Dairy Centre	Adult Holstein Cow	RFM	Clinical examination and cleanse.	1
17/06/2015	University of Nottingham Dairy Centre	Adult Holstein Cow	Metritis	Clinical examination and treatment	1
17/06/2015	University of Nottingham Dairy Centre	Adult Holstein Cow	Lameness	Clinical examination and treatment of upper limb abscess by drainage and flushing.	1

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
17/06/2015	University of Nottingham Dairy Centre	Adult Holstein Cow	Abortion x 3	Clinical examination and blood sampled	1
26/06/2015	Adkins	Adult Holstein Cow x 5	Metritis	Clinical examination and treatment	1
26/06/2015	Adkins	Adult Holstein Cow	Ocular Lesion	Clinical examination and treatment	3
01/07/2015	University of Nottingham Dairy Centre	Adult Holstein Cow	Sole ulcer	Clinical examination and treatment	1
01/07/2015	University of Nottingham Dairy Centre	5 day old calf	Navel infection and umbilical herniation	Clinical examination, ultrasonography of umbilicus and therapy	1
10/07/2015	Adkins	Adult Holstein cow	LDA	Clinical examination and surgery	1
15/07/2015	University of Nottingham Dairy Centre	6 days old calf	Scours	Clinical examination, treatment and fluid therapy	1
22/07/2015	University of Nottingham Dairy Centre	Adult Holstein cow	LDA	Clinical examination and surgery	1
29/07/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Metritis	Clinical examination and treatment	1
05/08/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Post calving check	Clinical examination and supportive treatment	2
05/08/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Toxic Mastitis	Clinical examination, treatment and fluid therapy	2

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
05/08/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Hindlimb lameness	Foot trimming and orthopaedic examination	4
05/08/2015	University of Nottingham Dairy Centre	14 month old Holstein heifer	Dislocation at P1 and P2	Digit amputation	2
26/08/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Retained fetal membranes	Clinical examination and treatment	1
26/08/2015	University of Nottingham Dairy Centre	Adult Holstein cow	LDA	Clinical examination, surgical correction and fluid therapy	1
26/08/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Calving	Assisted calving - manual without calving aid	1
09/09/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Metritis and mastitis	Clinical examination and treatment	1
09/09/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Ocular lesion	Clinical examination and treatment	1
09/09/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Poor milk yield	Clinical examination and nothing abnormal identified	1
09/09/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Swollen limb	Clinical examination, diagnostic sampling and treatment for mycoplasma	1
16/09/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Peri-orbital soft tissue swelling	Clinical examination and treatment	2

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
23/09/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Calving	Correction and calved	1
23/09/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Mastitis	Clinical examination and treatment	1
23/09/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Metritis	Clinical examination and treatment	1
23/09/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Low yielding cow	Clinical examination	1
22/10/2015	University of Nottingham Dairy Centre	Calf x 2	Scour	Clinical examination, fluid therapy and treatment	1
22/10/2015	University of Nottingham Dairy Centre	Adult Holstein cows x 6	High SCC	CMT all four quarters due to rise in overall bulk SCC and their total contribution to the bulk tank was >50%	2
28/10/2015	University of Nottingham Dairy Centre	5 x calves	Pneumonia	Clinical examination and treatment	1
28/10/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Infection of the tarsal joint	Clinical examination and treatment	2
08/11/2014	Home Farm, Church Langton	Adult Highland cow	Trauma after being stuck in a fence	Clinical examination, rehydration and treatment	1
25/11/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Sole ulcer with secondary infection	Clinical examination and treatment	1

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
01/12/2015	University of Nottingham Dairy Centre	Pre-weaned calves x 5	Pneumonia	Clinical examination and treatment	2
09/12/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Sole abscess from penetration injury	Clinical examination and treatment	2
09/12/2015	University of Nottingham Dairy Centre	Weaned Calf	Cruciate Ligament rupture	Clinical examination and euthanasia	1
16/12/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Endometritis	Clinical examination and treatment	1
16/12/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Sole Bruising	Clinical examination and treatment	1
16/12/2015	University of Nottingham Dairy Centre	Adult Holstein cow	Ketosis	Clinical examination and treatment	1
16/12/2015	University of Nottingham Dairy Centre	Calves x 5	Blood samples for Total Protein Assessment	Blood samples collection	1
19/12/2015	Lohn	Steer	Laceration to lower lip	Clinical examination and surgical treatment	1
19/12/2015	Adderson	Adult Crossbred Dairy cows	Pneumonia within the herd	Clinical examination x 5, treatment x 2 and blood samples x 6	1
06/01/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Subclinical Ketosis	Clinical examination, blood sample and treatment	1
06/01/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Hardware Disease	Clinical Examination	2

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
06/01/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Metritis	Clinical examination and treatment	1
06/01/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Lameness	Clinical examination and treatment	1
25/01/2016	Rancho Teresita, California	Adult Holstein cow	Metritis	Clinical examination and treatment	3
26/01/2016	The High School Dairy, Tulare, CA	Adult Jersey cow	Right Displaced Abomasum	Clinical examination, treatment and fluid therapy	3
29/01/2016	Rancho Teresita, California	Adult Holstein cow	Prolapsing 3rd eyelid	Clinical examination	3
10/02/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Clinical Mastitis	Clinical examination and treatment	1
10/02/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Metritis	Clinical examination, treatment and fluid therapy	1
10/02/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Bilateral hock swelling	Clinical examination, treatment with anti-inflammatories but poor prognosis so advised euthanasia	1
10/02/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Surgical site infection	Clinical examination and surgical debridement and flushing	2
12/02/2016	Greaves	Twin neonatal heifers	Dehydration	clinical examination and fluid therapy	1
11/02/2016	Wilder	Adult Holstein cow	Uterine tear post calving	Clinical examination and euthanasia	1
13/02/2016	Smith	Adult Charolais	Vaginal Prolapse	Replacement and placement of Buhner suture	1
13/02/2016	Schumacher	Calf	Fractured metacarpal	Clinical examination and treatment	1

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
17/02/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Surgical site infection	Clinical examination and surgical debridement and flushing	1
17/02/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Subclinical Ketosis	Clinical Examination and Treatment	1
24/02/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Clinical Mastitis	Clinical Examination and Treatment	2
07/03/2016	University College Dublin	Adult Holstein cow	Post-operative LDA check	Clinical Examination and Treatment	6
07/03/2016	University College Dublin	Adult Holstein cow	Replacement of abomasum after laceration to abdominal wall	Clinical examination and surgical debridement and replacement. General anaesthesia and fluid therapy given	6
07/03/2016	University College Dublin	Adult Holstein cow	RDA	Clinical examination, surgical correction and fluid therapy	4
08/03/2016	University College Dublin	Adult Holstein-Friesian cow	LDA	Clinical examination, surgical correction and fluid therapy	4
09/03/2016	University College Dublin	Holstein-Friesian Heifers x 2	Papilloma removal from teats	Clinical examination and surgical removal	2
09/03/2016	University College Dublin	Adult Jersey cross	RVA	Clinical examination, surgical correction and fluid therapy	2
09/03/2016	University College Dublin	Adult Holstein cow	LDA	Clinical examination, surgical correction and fluid therapy	2
10/03/2016	University College Dublin	Holstein Calf	Fractured femur	Clinical examination and euthanasia	4
11/03/2016	University College Dublin	Adult Holstein cows x 2	Swollen Metacarpus	Clinical examination, ultrasonography of joint, radiography and joint tap	4

Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
11/03/2016	University College Dublin	Holstein-Friesian Steer	Lumpy Jaw	Clinical examination and treatment	4
11/03/2016	University College Dublin	Holstein-Friesian Steer	Exophthalmus	Clinical examination and enucleation	4
11/03/2016	University College Dublin	Holstein Steer	Submandibular Abscess	Clinical examination, diagnosis and treatment including flushing	2
14/03/2016	University College Dublin	Holstein-Friesian Adult	Metritis	Clinical Examination and Treatment	2
14/03/2016	University College Dublin	Holstein-Friesian Adult	Anaemia	Clinical Examination, Diagnostic Sampling and Treatment	2
14/03/2016	University College Dublin	Holstein-Friesian Adult	Lameness	Clinical Examination and Treatment	2
14/03/2016	University College Dublin	Holstein Adult Cow	Cervical tear	Clinical examination and treatment	4
15/03/2016	University College Dublin	18 month old limousine	Epididymectomy	Clinical examination and surgery	3
15/03/2016	University College Dublin	Holstein Adult Cow	Transabdominal ultrasound	Observation	6
16/03/2016	University College Dublin	Jersey Adult cows x 2	Bronchioalveolar lavage for pneumonia	Clinical examination, diagnostic sample collection including BALs	2
17/03/2016	University College Dublin	Holstein-Friesian cow	Ketosis	Clinical examination	4
18/03/2016	University College Dublin	Charolais calf	Septicaemia	Clinical examination, blood sample, fluid therapy and treatment	4
22/03/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Hypocalcaemia	Clinical examination, diagnostics and therapy	5
22/03/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Caecal dilation post-operation check	Clinical examination	5

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
23/03/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Vagal Indigestion	Clinical examination and therapy	1
23/03/2016	University of Nottingham Dairy Centre	12 week old calf	Septic Arthritis	Clinical examination and therapy	1
23/03/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Haemorrhage from protruding granulation of sole ulcer	Clinical examination, removal of tissue and bandage	1
26/03/2016	Hodgkin	Adult Limousine	Dystocia	Attempted calving and then caesarean section due to feto-maternal disproportion	1
27/03/2016	Kingsley	Adult Beef Cross	Dystocia	Caesarean due to malpresentation	1
06/04/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Endometritis	Clinical examination and treatment	1
06/04/2016	University of Nottingham Dairy Centre	Holstein 18 month old heifer	Wound to right hind leg	Clinical examination and treatment	1
08/04/2016	Thornby Estate	Adult Hereford cow	Dystocia	Clinical examination and caesarean section	1
09/04/2016	Hart	Adult Charolais cross cow	Dystocia	Clinical examination and caesarean section	1
09/04/2016	Davies	Adult Angus cow	Vulva and vaginal tears from difficult calving	Clinical examination and suture of vulva	1
10/04/2016	Bolton	17 month old Angus Heifer	Dystocia	Clinical examination and caesarean section	1
13/04/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Infected sole ulcer	Clinical examination, foot trim and treatment	1

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
13/04/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Teat Laceration	Cynical Examination and Treatment	1
13/04/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Pericarditis	Clinical examination, ultrasonography of heart and treatment	2
27/04/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Metritis	Clinical Examination and Treatment	1
27/04/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Digital Dermatitis	Cynical Examination and Treatment	1
27/04/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Abscess on the Hindlimb	Cynical Examination and Treatment	1
28/04/2016	University of Nottingham Dairy Centre	Adult Holstein cow	Nervous Ketosis	Cynical Examination and Treatment	3
04/05/2016	University of Nottingham Dairy Centre	Adult Holstein Cow	Left displaced abomasum	Clinical examination, surgical correction and fluid therapy	1
06/05/2016	Davies	Neonatal Aberdeen Angus	Fractured Metacarpal	Clinical examination and cast	1
06/05/2016	Bounds	Adult Holstein Friesian cow	Hypocalcaemia	Clinical examination, diagnostic bloods and treatment	1
08/05/2016	Hodgkins	Adult Limousine Cow	Uterine Torsion	Attempted correction of torsion, followed by caesarean	1
08/05/2016	Hospital Farm	Adult Hereford cow	Post-calving obturator nerve paralysis	Clinical examination and treatment	1

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Date	Patient ID	Patient Category	Diagnosis	Clinical activity of the student	Supervision
01/06/2016	University of Nottingham Dairy Centre	Adult Holstein Cow	Left displaced abomasum	Clinical examination, surgical correction and fluid therapy	1
05/06/2016	Brickyard Farm	Simmental Cow	Feto-maternal disproportion	Caesarean section	1
06/06/2016	Banbury Farm	Hereford Cow	Uterine Prolapse	Replacement and treatment for hypocalcaemia	1
22/06/2016	University of Nottingham Dairy Centre	Adult Holstein Cow	Mastitis	Clinical examination and treatment	2
22/06/2016	University of Nottingham Dairy Centre	Adult Holstein Cow	Ketosis	Clinical examination and treatment	1
22/06/2026	Greaves	4 month Holstein-Friesian calf	Bilateral ocular infection with Moraxella bovis	Clinical examination and treatment	1

Table 18 Clinical Case of Herd Health Cases

Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
29/05/2014	University of Nottingham Dairy	Dairy	Routine Fertility visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	3
17/06/2014	Bacons	Dairy	Herd Health Visit	Discussions regarding dry cow mastitis and housing as well as submission rate	5
26/06/2014	University of Nottingham Dairy	Dairy	Routine Fertility visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
31/6/2014	Arlingtons	Dairy	Herd Health Visit	Review of fertility within in the spring block of calvers as well as lameness	5
10/07/2014	University of Nottingham Dairy	Dairy	Routine Fertility visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
15/07/2014	Egglestons	Dairy	Herd Health Visit	Review of fertility within the spring block and nutrition as poor BCS and poor pregnancy rates seen within the spring calvers	5

Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
24/07/2014	University of Nottingham Dairy	Dairy	Routine Fertility visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	3
29/07/2014	Gleadthrope Farm (Bacons)	Dairy	Herd Health Visit	Discussion about new building design and mastitis especially lactation origin mastitis	5
07/08/2014	University of Nottingham Dairy	Dairy	Routine Fertility visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
12/08/2014	Arlingtons, Dean Hall Farm	Youngstock unit	Youngstock health review	Discussions regarding milk feeding protocol and energy requirements of calves and their DLWG to weaning; ventilation within the shed and management of pneumonia	1
21/08/2014	University of Nottingham Dairy	Dairy	Routine Fertility visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	3

Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
01/09/2014	Button	Dairy	Routine Fertility visit (PD + Fresh Cows)	Pregnancy diagnosis, management of periparturient disease (20xPD, 19xFC)	1
02/09/2014	Risdon	Dairy	End of breeding block PD	Pregnancy diagnosis x 600	1
02/09/2014	Disney	Beef	TB testing x 3	TB testing	1
03/09/2014	Heller	Dairy	Routine Fertility Visit	Pregnancy diagnosis (x28), management of not seen bullers (x20), management of periparturient disease (x2)	1
05/09/2014	Parkhouse	Dairy	Routine Fertility Visit	Pregnancy diagnosis (x9), management of not seen bullers (x2)	1
05/09/2014	Disney	Beef	TB testing x 3	TB testing	1
08/09/2014	Button	Dairy	Routine Fertility visit (PD + Fresh Cows)	Pregnancy diagnosis, management of periparturient disease (16xPD, 13xFC)	1
09/09/2014	Button	Dairy	Routine Fertility visit (Not seen bullers)	Management of not seen bullers (x32)	1
10/09/2014	Heller	Dairy	Routine Fertility Visit	Pregnancy diagnosis (x28), management of not seen bullers (x20), management of periparturient disease (x2)	1

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
11/09/2014	George	Dairy	Routine Fertility Visit	Pregnancy diagnosis (x7), management of not seen bullers (x12), management of periparturient disease (x6)	1
12/09/2014	Parkhouse	Dairy	Routine Fertility Visit	Pregnancy diagnosis (x9), management of not seen bullers (x2)	1
23/09/2014	Brown, Odstone Farm	Dairy	Calf Management Discussion	Discussed heifer housing, feeding practices and colostrum management	3
02/10/2014	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	3
07/10/2014	University of Nottingham Dairy	Dairy	Calf Management Discussion	Discussion of new calf housing design, hygiene regime and treatment protocols as well as colostrum management	3
15/10/2014	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
20/10/2014	Watchorn, Scalford Lodge	Dairy	Outbreak of respiratory disease investigation	Discussion and sampling (see individual animal section). Positive for Mycoplasma and liver fluke	3
21/10/2014	Greaves, Lodge Farm	Dairy	Transition Cow Management Discussion	Discussion focused on changes to transition cow management, including housing, nutrition, lameness and Johne's disease	5
30/10/2014	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
03/11/2014	Greaves, Lodge Farm	Dairy	Whole herd body condition scoring	Body condition scoring	1
04/11/2014	Bacon, Gleadthrope Farm	Dairy	Lameness management discussion	Discussion of building design, groupings and standing times, feed space and trimming protocols	5
13/11/2014	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
27/11/2014	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
11/12/2014	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
16/12/2014	Watchorn, Scalford Lodge	Dairy	Discussion around transition cow management	Discussion regarding feeding and feed access; grouping; stocking densities; transitioning of cows	1
08/01/2015	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
12/01/2015	University of Nottingham Dairy	Dairy	Herd health monitoring visit	Discussions involving heat detection for return serves, calf housing, new cases of lactational origin mastitis and digital dermatitis	5
14/1//15	Greaves	Dairy	Body condition scoring	Body condition scoring 227 cows	1

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
22/01/2015	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
26/01/2015	Oulton	Dairy	Herd health monitoring visit	Discussions mainly regarding Johnes disease and lameness	5
03/02/2015	Hill	Dairy	Herd health initial visit	Discussions involving fertility and mastitis	5
05/02/2015	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
10/02/2015	Arlington	Dairy	Herd health monitoring visit	Heifer review from pre-weaning to first lactation	1
11/02/2015	Greaves	Dairy	Body condition scoring	Body condition scoring 220 cows	1
19/02/2015	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
05/03/2015	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
10/03/2015	Buttons	Dairy	Routine Fertility visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
13/03/2015	Buttons	Dairy	Herd Health Plan	Annual herd health plan	1
19/03/2015	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
23/03/2015	Shaw	Dairy	Herd health monitoring visit	Discussions regarding decreasing conception rates and nutrition	1
02/04/2015	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
08/04/2015	Greaves	Dairy	Herd health monitoring visit	Discussions regarding dry period mastitis and housing	1
09/04/2015	Egglestons	Dairy	Herd health monitoring visit	Discussions regarding fresh cow health and preparation for the breeding season	1
16/04/2015	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1

Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
20/04/2015	Nealson, West Peake	Seasonal Dairy	Fertility Visit	Management of not seen bullers, pregnancy diagnosis of late calvers	1
23/04/2015	Chamberlain	Dairy	Fertility Visit	PD session	1
23/04/2015	Wright	Dairy	Fertility Visit	PD Heifers	1
29/04/2015	Greaves	Dairy	Whole herd BCS	BCS x 218 cows	1
30/04/2015	University of Nottingham Dairy	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
06/05/2015	Watchorn	Dairy	Herd Health Visit: Focus on dry cow management	Discussion of dry cow ration and transition cow management. Review of udder health and fertility	3
20/05/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
02/06/2015	Oultons	Dairy	Herd Health Visit: Focus on management of early lactation high yielding cows	Discussion regarding shed design, feed access, ration analysis, ketosis and claw horn lameness	3
03/06/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
16/06/2015	Browns	Dairy	Herd Health Visit (seasonal calving): Pre-drying off visit and preparation for calving	Discussion around infectious disease control, dry cow therapy and length, dietary management of over-conditioned cows and calf management	3
17/06/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
29/06/2015	University of Nottingham Dairy Centre	Dairy	Herd Health Visit: Negative energy balance and transition cow management	Discussion regarding peri-parturient disease in transition cows and the methods of minimising NEB	3
01/07/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
14/07/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
29/07/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
11/08/2015	Egglestons	Dairy	Herd Health Visit (seasonal calving): Fertility and mastitis	Discussion around the block calving performance so far and the changes in mastitis incidence rates within the herd	3
12/08/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
25/08/2015	Whiteoaks	Dairy	Herd Health Visit: Johne's disease and calf management	Discussion around prevention of calf disease, especially scour. Calf shed ventilation improvements. Management of Johne's disease and a more effective diagnostic testing protocol	1
26/08/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
08/09/2015	Shaws	Dairy	Herd Health Visit: poor conception rate and implications of becoming a flying herd	Discussions regarding fertility performance, concentrating on poor conception rate (AI technique and nutrition). Discussions regarding the disease implication and economic implications of becoming a flying herd.	2
09/09/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
22/09/2015	Sludge Hall Farm	Dairy	Herd Health Visit: Transition cow health	Discussion regarding transition cow management, nutrition and fertility	3
23/09/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
06/10/2015	Browns	Dairy	Herd Health visit: calf health	Discussion regarding optimising the environment for calves and feeding	2
07/10/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
20/10/2015	Oultons	Dairy	Herd Health visit: calf health	Discussion regarding high incidence pneumonia and prevention of pneumonia	3
21/10/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
03/11/2015	Greaves	Dairy	Herd Health visit: discussion of udder health and lameness	Discussion regarding milking herd housing and prevent of claw horn lesion and environmental mastitis	3
04/11/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
17/11/2015	Arlingtons	Dairy	Herd Health: Fertility review of block calving	Discussion about fertility, concentrating on return serves	3
18/11/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
01/12/2015	Smith, Ashbourne	Calf Rearer	Herd Health: Infectious disease	Discussion about treatment of pneumonia, vaccination and environment	2
02/12/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
16/12/2015	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
25/01/2016	CalfTech, California	Calf Ranch	Health Check	Discussion of current environmental conditions in weaned calves and management during wet periods	3
26/01/2016	Tulare High School Dairy, Tulare, CA	Dairy	Whole Herd Milk Sample collection	Collection of individual animal milk samples, udder hygiene scoring and teat end lesion scoring. Reporting and analyse of results	3
27/01/2016	River Ranch, CA	Dairy	Blood sampling of calves for serum total proteins	Collection of individual blood samples from 50 calves. Discussion of the results with owner	3
28/01/2016	DeLong Dairy, CA	Dairy	Brucella vaccination of calves	Vaccination, ear tattooing, ear tagging of 68 calves for Brucella abortus	5
29/01/2016	Rancho Terresitia, Tulare, CA	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	5

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
29/01/2016	Rancho Terresitia, Tulare, CA	Dairy	Blood sampling of calves for serum total proteins	Collection of individual blood samples from 20 calves. Reporting of the results with owner	3
08/02/2016	Greaves	Dairy	Body Condition Score herd	Body condition scoring	1
09/02/2016	Whiteoaks	Dairy	Herd Health Visit: Performance monitoring	Discussion of increasing SCC, calf health including pneumonia and vaccination protocol and improvements for heat detection	2
10/02/2016	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
24/02/2016	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	2
23/03/2016	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
05/04/2016	Hill	Dairy	Herd Health Visit: Dry Cow Performance	Discussion regarding ketosis risks with current dry cow management; fertility performance and improving submission rate; decreasing digital dermatitis	5
06/04/2016	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
21/04/2016	Greaves	Dairy	Herd Health: Mastitis Monitoring	Discussion of bacteriology results and increase in clinical mastitis rate during the housing period	1
04/05/2016	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
18/05/2016	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1
31/05/2016	Whiteoaks	Dairy	Udder health, fertility and infectious disease	Discussion of high SCC in heifers, decreasing conception rate and Johne's control	1

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Date	Farm ID	Farm type	Area or problem dealt with on farm	Activity of resident	Supervision
01/06/2016	University of Nottingham Dairy Centre	Dairy	Routine Fertility Visit	Pregnancy diagnosis, management of not seen bullers, management of periparturient disease	1

9.2 ANCILLARY TOPICS

Ancillary topics for the ECBHM diploma included the requirement for post mortems, both supervised by specialist pathologists, other bovine veterinarians and to be undertaken by the resident alone. The same levels of supervision apply to the post mortems as to the clinical cases and are described in Table 16. During the externship to University of California Davies, there was an opportunity to spend some time alongside the pathologists at their Veterinary Investigation Centre and perform necropsies. The supervision of necropsies is to be continued in 2017, with a placement to a post mortem facility planned for the Spring in the UK. A list of the post mortems undertaken to date is shown in Table 19.

9.1 CLINICAL CASE REPORTS

As part of the credentials for the ECBHM diploma, candidates are required to write clinical case reports. Examples of these case reports are included as appendices at the end of this chapter.

Table 19 A list of the post mortems carried out during the scholarship

Date	Animal ID	Animal category	Diagnosis	Activity of the resident	Supervision
23/05/2014	University of Nottingham Dairy Centre (2040)	Calf	Fractured right hind metatarsus just proximal to the metatarsophalangeal joint	Post mortem of the lower limb to look at the configuration of the fracture	3
23/06/2014	University of Nottingham Dairy Centre (610)	Adult Dairy cow	Existing type III abomasal ulcer	Post mortem of the cow	3
26/06/2014	University of Nottingham Dairy Centre (223)	Adult Dairy cow	No abnormality found in the tarsal joint, however area of cellulitis in soft tissue found.	Post mortem of the cow	1
05/09/2014	Wills Brothers Limited 1	Calf	Calf pneumonia	Post mortem of the calf	1
05/09/2014	Wills Brothers Limited 2	Calf	Calf pneumonia	Post mortem of the calf	1
06/09/2014	Kendall	7 month old heifer	Abomasitis	Post mortem of the calf	1
25/11/2014	Button	10 day old calf	Septicaemia	Post mortem of the calf	1
04/12/2014	University of Nottingham Dairy Centre	Adult Dairy cow	Uterine torsion with twins leading to septicaemia and peritonitis	Post mortem of the cow	1
29/01/2015	University of Nottingham Dairy Centre	4 month old heifer	Calf pneumonia with pleural adhesions and pericardial adhesions	Post mortem of the calf	1
13/03/2015	Wills Brothers	Adult Dairy cow	Septicaemia	Post mortem of the cow	1
13/03/2015	Wills Brothers	4 week old calf	Abomasal ulcer	Post mortem of the calf	1

9.2 CONTINUING PROFESSIONAL DEVELOPMENT

9.3 CONFERENCES ATTENDED

A list of the conferences attended during the scholarship is given in

Date	Name of Meeting / Location	Duration
07/05/2014	DMCP Research Update (Pride Veterinary Centre)	1 day
12/06/2014	DMCP Day 2: Farm Presentation Day (NAC, Stoneleigh)	1 day
18-19/6/2014	BCVA Advanced Practitioner Mastitis Course (University of Nottingham)	1.5 days
23/06/2014	National Fertility Conference (University of Nottingham)	1 day
24/06/2014	National Feed Conference (University of Nottingham)	1 day
09/07/2014	Herd Health Group Meeting (University of Nottingham)	1 day
23-24/7/2014	BCVA Advanced Practitioner Lameness Course (University of Nottingham)	1.5 days
17-18/9/2014	BCVA Advanced Practitioner Youngstock Course (University of Edinburgh)	1.5 days
16-18/10/2014	BCVA National Congress (Hinckley Island Hotel)	3 days
13-15/4/2015	ECBHM Residents Workshop (University of Nottingham)	2.5 days
22/06/2015	National Fertility Conference (University of Nottingham)	1 day
23/06/2015	National Feed Conference (University of Nottingham)	1 day
16/07/2015	Herd Health Group Meeting (University of Nottingham)	1 day
15-17/10/15	British Cattle Veterinary Association Conference (Southport)	3 days
10-11/11/2015	British Mastitis Conference including research day (Worcestershire)	2 days
31/1/16-2/2/16	National Mastitis Conference (Phoenix)	2.5 days
18/4/16-20/4/16	ECBHM Residents' Workshop: Economics (Toulouse)	2.5 days

Table 20 A list of conferences attended during the scholarship

9.4 PRESENTATIONS GIVEN

The following research presentations have been given during the course of the scholarship:

- 15th October 2015: British Cattle Veterinary Association Conference

  "The survival of first lactation heifers within UK Dairy Herds"

- 11th November 2015: British Mastitis Conference

  "Isolation of *Streptococcus uberis* from faeces of dairy cows"

9.5 SEMINARS ATTENDED

Date	Speaker	Duration	Topic	Type of event/Location	Participants
23/05/2014-Fortnightly	various	3hrs	Herd Health, Case Presentation, Analysis of a paper and VPH	Undergraduate farm animal rounds, University of Nottingham	Final year students, Postgrads and clinical staff
23/05/2014	Andrew Henderson and Jon Huxley	3hrs	Body condition scoring	Postgraduate Farm animal rounds, University of Nottingham	Postgraduate students and clinical staff
06/06/2014	Andrew Henderson	0.5hrs	Selective dry cow therapy, individual animal cases	Postgraduate Farm animal rounds, University of Nottingham	Postgraduate students and clinical staff
20/06/2014	Andrew Henderson	0.5hrs	Protected choline, individual animal case	Postgraduate Farm animal rounds, University of Nottingham	Postgraduate students and clinical staff
04/07/2014	Oli Maxwell	0.5hrs	Lameness in Heifers	Postgraduate Farm animal rounds, University of Nottingham	Postgraduate students and clinical staff
09/07/2014	Martin Green and Jonathon Statham	1 day	Green Bedding and BVD	University of Nottingham	Nottingham Dairy Herd Health Group

Date	Speaker	Duration	Topic	Type of event/Location	Participants
18/07/2014	Andrew Henderson	0.5hrs	Reproductive performance in seasonal calving herds in New Zealand	Postgraduate Farm animal rounds, University of Nottingham	Postgraduate students and clinical staff
01/08/2014	Oli Maxwell	0.5hrs	Bovine TB Journal article review	Postgraduate Farm animal rounds, University of Nottingham	Postgraduate students and clinical staff
24/10/2014	Andrew Henderson	0.5hrs	Approach to a blind steer	Postgraduate Farm animal rounds, University of Nottingham	Postgraduate students and clinical staff
07/11/2014	Oli Maxwell	0.5hrs	Review of a paper on mobility scoring	Postgraduate Farm animal rounds, University of Nottingham	Postgraduate students and clinical staff
18/11/2014	Shelia McGuirk	1.5hrs	Calf Health Scoring	ECBHM Webinar	ECBHM Residents
14/01/2015	various	1 day	Recent research update - lameness, MAP, mastitis, bTB and fertility	University of Nottingham	Nottingham Dairy Herd Health Group
24/01/2015	Jon Huxley	1hr	Dairy cow- cash cow or sacred cow	University of Nottingham	Postgraduate students and clinical staff
16/02/2015	Richard Emes	1hr	Multi-level modelling	Farm animal maths club - University of Nottingham	Postgraduate students and clinical staff
18/02/2015	Chris Hudson	1hr	Multi-level modelling	Farm animal maths club - University of Nottingham	Postgraduate students and clinical staff
02/03/2015	various	3hrs	various	Postgraduate Farm animal rounds, University of Nottingham	Postgraduate students and clinical staff
01/04/2015	Rachel Dean	2hrs	Odds Ratios	Stats club - University of Nottingham	Postgraduate students and clinical staff
27/04/2015	Richard Emes	1hr	Introduction to genomics	Population Health and Welfare meeting - University of Nottingham	Postgraduate students and clinical staff

Date	Speaker	Duration	Topic	Type of event/Location	Participants
20/08/2015	Alan Murphy	2hrs	Post Mortems	Resident's Club	Postgraduates
30/07/2015		1 day	Long document course (Microsoft Word)	University of Nottingham; Short Courses	Postgraduates
29/09/2015	Duncan Williams	3hrs	The use of selective dry cow therapy on Arla Farms in the UK	Kegworth Conference Centre - Seminar	Local Veterinary Practitioners
18/11/2015	Dr Sheila McGuirk	1hr	Timely diagnosis of dairy calf respiratory disease using a standardized scoring system	Webinar - ECBHM	ECBHM Residents
28/01/2016	Dr Rimadoli	1hr30	Gross Pathology	Rounds	Final year students and postgrads
28/01/2016	Dr.J.Champagne (UCD, CA)	1hr30	RMS bedding	Journal Club	Final year students, Postgrads and clinical staff
29/01/2016	final year students	2hrs	Epidemiology of disease outbreaks	Undergraduate project presentations	Final year students, Postgrads and clinical staff
10/03/2016	Eoin Ryan	1hr30	Clinical Examination of the Bovine	Seminar	Undergraduates
15/03/2016	Kathyrn Carty	1hrs30	Milk Fat Depression in Irish Herds	Resident's Presentations	Postgraduates and clinical staff
11/04/2016	Ingrid Lorenz	1hr	Acid-base disturbances and dehydration in calves	Webinar - ECBHM	ECBHM Residents
12/04/2016	Sebastien Buczinski	1hr30	Ultrasonographic examination of the thorax	Webinar - ECBHM	ECBHM Residents
06/05/2016	G.Gnemmi	1hr15	Follicular dynamic and hormonal control in cyclic cows	ECBHM Webinar	ECBHM residents
8-9/6/2016		1.5 days	Microsoft Access Introduction	University of Nottingham	Postgraduates and staff members

9.6 SEMINARS GIVEN

Date	Type of event	Topic	Location	Participants
06/06/2014	Undergrad and postgrad clinical and research discussion	Subcutaneous melanoma in a 12 month old steer: case work up	University of Nottingham	Clinical staff and Postgraduate students
20/06/2014	Undergrad and postgrad clinical and research discussion	Use of L-Lactate as a prognostic indicator in RDAs	University of Nottingham	Clinical staff and Postgraduate students
04/07/2014	Undergrad and postgrad clinical and research discussion	Case work up and discussion of an left abomasal displacement with localised peritonitis from an existing type III abomasal ulcer	University of Nottingham	Clinical staff and Postgraduate students
01/08/2014	Undergrad and postgrad clinical and research discussion	Individual case: vegetative endocarditis causing DIC and arterial thromboembolism in a cow with a VSD	University of Nottingham	Clinical staff and Postgraduate students
15/08/2014	Undergrad and postgrad clinical and research discussion	Review of meta-analysis on the use of prostaglandin treatment for endometritis.	University of Nottingham	Clinical staff and Postgraduate students
29/08/2014	Undergrad and postgrad clinical and research discussion	Presentation on the University Farm's Dairy Calves: progress on colostrum management and disease incidences	University of Nottingham	Clinical staff and Postgraduate students
26/09/2014	Undergrad and postgrad clinical and research discussion	Use of NSAIDs in surgery: the evidence behind their use	University of Nottingham	Clinical staff and Postgraduate students
10/10/2014	Undergrad and postgrad clinical and research discussion	Meta-analysis of endometritis treatment	University of Nottingham	Clinical staff and Postgraduate students
24/10/2014	Undergrad and postgrad clinical and research discussion	Case presentation of an outbreak of respiratory disease in a dairy farm, with diagnostic work up	University of Nottingham	Clinical staff and Postgraduate students
07/11/2014	Undergrad and postgrad clinical and research discussion	Meta-analysis of Johne's disease across 6 endemic countries: Review of paper	University of Nottingham	Clinical staff and Postgraduate students

Date	Type of event	Topic	Location	Participants
21/11/2014	Undergrad and postgrad clinical and research discussion	Quantifying the changes in mobility scores between different score dates	University of Nottingham	Clinical staff and Postgraduate students
05/12/2014	Undergrad and postgrad clinical and research discussion	Abomasal Ulceration	University of Nottingham	Clinical staff and Postgraduate students
16/01/2015	Undergrad and postgrad clinical and research discussion	Watchorn Dairy: The impact of Mycoplasma	University of Nottingham	Clinical staff and Postgraduate students
30/01/2015	Undergrad and postgrad clinical and research discussion	Evaluation of on-farm tools for colostrum quality measurements	University of Nottingham	Clinical staff and Postgraduate students
13/02/2015	Undergrad and postgrad clinical and research discussion	Research update: the prevalence of *Streptococcus uberis* in a UK dairy herd	University of Nottingham	Clinical staff and Postgraduate students
03/07/2015	Postgraduate presentation	Prevalence of *S.uberis* in the faeces of a dairy herd in UK	University of Nottingham	Clinical staff and Postgraduate students
31/07/2015	Rounds presentation	Presentation of clinical pathology of a steer with bracken fern poisoning	University of Nottingham	Clinical staff and Postgraduate students
25/09/2015	Rounds presentation	Presentation of Herd Health Data	University of Nottingham	Clinical staff and Postgraduate students
12/11/2015	Seminar and Practical	Cow Handling and Management	University of Nottingham	Undergraduate 1st year veterinary medicine students
20/11/2015	Rounds presentation	Presentation of a Paper: effect of building design on hazard of first serve (Martin et al)	University of Nottingham	Clinical staff and Postgraduate students
04/12/2015	Rounds presentation	clinical pathology of a case of pyelonephritis	University of Nottingham	Clinical staff and Postgraduate students
18/12/2015	Rounds presentation	Case Report: A case of cutaneous leishmaniosis	University of Nottingham	Clinical staff and Postgraduate students
12/02/2016	Rounds Presentation	Discussion of cases seen at University of California Davies	University of Nottingham	Clinical staff and Postgraduate students
22/02/2016	Seminar	Calf Handling and Basic Management	University of Nottingham	Undergraduate Bioscience students

Date	Type of event	Topic	Location	Participants
28/02/2016	Rounds Presentation	Case Report: Syringomyelia in a bull calf	University of Nottingham	Clinical staff and Postgraduate students
15/03/2016	Research presentation	Presentation of preliminary results of research project	University College Dublin	Clinical staff and Postgraduate students
24/03/2016	Rounds Presentation	Case Presentation of Mycoplasma infected cow	University of Nottingham	Clinical staff and Postgraduate students
08/04/2016	Rounds Presentation	Presentation of a case report of idiopathic haemorrhagic pericarditis and discussion on pericardiocentesis	University of Nottingham	Clinical staff and Postgraduate students

9.7 PUBLICATIONS

Throughout the scholarship, there were opportunities to become involved in other areas of research, as well as writing peer-reviewed case reports and clinically relevant review articles. The following list of articles which I was involved in during the scholarship.

- Breen, J., Henderson, A., Maxwell, O., Sherwin, V., Green, M. Bovine Mastitis in the UK: past, present and future. Livestock Vol.20 No.1 2015
- Henderson, A,. Maxwell, O., Sherwin, V., Breen, J., Green, M. Prevention and control of mastitis in UK dairy herds. Livestock Vol.20 No.1 2015
- Maxwell, O., Sherwin, V., Henderson, A., Breen, J., Green, M. Treatment of mastitis during lactation to prevent infection. Livestock Vol.20 No.1, 2015
- Sherwin, V., Baiker, K., Wapenaar, W. 2015. Consequences of endocarditis in an adult cow with a ventricular septal defect. Veterinary Record Case Reports Vol 3, Issue 1, 2015.
- Sherwin, V., Hudson, C., Henderson, A., Breen, J. Measuring health and performance in preweaning dairy calves. In practice Vol 38 Issue 3, 2016.
- Sherwin, V., Hudson, C., Henderson, A., Green, M. The association between age at first calving and survival of first lactation heifers within dairy herds. Animal Issue 2, May 2016.
- Henderson, A., Hudson, C., Bradley, A., Sherwin, V., Green, M. Prediction of intramammary infection status across the dry period from lifetime cow records. Journal of Dairy Science Vol 99, Issue 7, 2016.

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