Te Kunenga
ki Pūrehuroa

Epidemiological Study of Removals in New Zealand Dairy Goats

A thesis presented
in partial fulfilment of the requirements
for the degree of Master of Veterinary Studies
at Massey University

Milan Gautam
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— Abstract —

This thesis provides a description of the demography, production and reproductive characteristics of dairy goats on commercial dairy goat farms in New Zealand. In addition, it quantifies the influence of individual animal-level characteristics on the length of productive life (LPL).

A secondary set of data provided by the New Zealand Dairy Goat Co-operative formed the basis of the analyses presented in this thesis. Details were available for 23,771 does from 38 herds which were born between 1 January 2000 and 31 December 2009. Survival analyses were used to describe the pattern of removal of does as a function of age and within a lactation cycle, as a function of days in milk and days dry. A piece-wise Cox model was used to quantify the effect of individual doe level characteristics on LPL.

The median age of does at first kidding was 394 days (Q1 369 days, Q3 722 days). The median age at the time of removal was 3.7 years (Q1 2.5 years, Q3 4.9 years). On average does completed less than three lactation cycles at the time they were removed from the herd. Within a lactation cycle the majority of removals took place soon after dry off date. We found that the majority of does were removed as culls as opposed to those removed by sale or death. Compared to dairy cows, does were removed for a wide range of reasons, the majority of which comprised various infectious and non-infectious health disorders. This indicates that those managing animal health on dairy goat farms require detailed knowledge on the control and prevention of a wide range of caprine health disorders.

The effect of first lactation milksolids yield (MSL1) on LPL varied over time. During the first two years following the date of second kidding, high MSL1 yields had a protective effect on removal whereas beyond two years from the date of second kidding, does with high MSL1 yields were at a greater risk of removal compared to average producers. These findings indicate that high MSL1 producers should be preferentially managed beyond two years from the date of second kidding, in order to avoid preventable losses. In turn this should ensure longer LPLs among a more profitable sub-group of the herd.

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Nomenclature

CI	Confidence interval
DP	Dynamic programming
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
KM	Kaplan-Meier
LIC	Livestock Improvement Corporation (New Zealand)
LPL	Length of productive life
MNR	Marginal net revenue
MSL1	Milksolids yield in the first lactation (kg)
NZDGC	New Zealand Dairy Goat Co-operative
Q1	First quartile
Q3	Third quartile
RPO	Retention pay-off
SD	Standard deviation
US	United States
USD	United States dollars

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CHAPTER 1

Introduction

Goats were introduced into New Zealand more than two centuries ago. Despite having such a long history, they currently hold a modest status, compared to other species of farm animals such as cattle, sheep, deer and horses. A clear dearth of relevant scientific information exists with respect to goats and their production and management systems in New Zealand. Although goats are, in general, multi-purpose animals, this thesis is limited to investigations into dairy goats and the dairy goat industry in New Zealand.

In 2010, the dairy sector directly contributed approximately four billion US dollars (USD) to the New Zealand economy. This figure represents approximately 2.8% of the country's total gross domestic product (GDP) (Schilling et al. 2010). The contribution made by the dairy goat industry to this figure was negligible. Milk and milk products derived from cows are cheaper and more plentiful, compared to dairy goats in temperate countries. For instance, in 2009 the total cost of producing one tonne of whole fresh goat milk in Spain was USD 746, compared to USD 405 for a similar quantity of cow milk. Similarly, costs in Greece in 2009 were USD 840 and USD 599, respectively (Food and Agriculture Organization of the United Nations 2011a). Under these circumstances it is not always easy to justify expenditure on growth of the dairy goat industry.

While limitations of goat milk production are mainly related to economics, goat milk *per se* offers a number of distinct medical benefits over cow milk (Park 1994, Alferez et al. 2001, Haenlein 2004). For example, goat milk is highly digestible and alkaline with a better buffering capacity, compared to cow milk (Park 1994). In addition, it is a suitable alternative for people with allergies to cow milk (Park 1994, Haenlein 2004). Finally, goat milk is free of A1 beta-casein, a milk protein which has been hypothesised to be associated with several health disorders including cardiovascular diseases, autism, type-1 diabetes, lactose intolerance and autoimmune diseases (Woodford 2007). An additional advantage of goat milk and value-added products produced from goat milk is the prospect of being able to sell these products at prices that are higher than those produced from cow milk or its derivatives. With the help of effective and imaginative marketing, goat milk products can be traded profitably in order to meet the demands of niche markets (Haenlein 2004).

Within the New Zealand context, a few issues related to the dairy goat industry are noteworthy. Firstly, commercial dairy goat farming is practiced by a relatively small number of farmers. Although the number of milking does per herd has increased over the last 10 years, the total population of goats has decreased, at an average of 9,000 goats per annum (Solis-Ramirez et al. 2011). Competition from the dairy cow and sheep industries may be one of the reasons for this trend. Secondly, the sustainability of the dairy goat industry is almost entirely dependent on international markets due to a small domestic market. An opportunity exists in New Zealand because expertise and infrastructure developed for the dairy cow industry can be, for the most part, extended to the dairy goat industry.

Expansion of the production system (i.e. the overall number of goats and number of goat farms in the country) and market areas is essential to widen the dimensions of the dairy goat industry (Sheppard & O'Donnell 1979). This expansion, in turn, requires scientific research and extension. Based on scientific studies that focus on addressing problems faced by goat farmers, it is possible to identify factors that influence the overall efficiency of the goat farm production system. The extension of the findings from these studies could eventually help producers and managers to make better management decisions, based on scientific rather than subjective opinions.

Decisions relating to which animals are to be removed from a herd and when to remove them, for example, are tasks that have to be frequently undertaken by herd managers. Due to the relative high cost of rearing replacements, a knowledge of factors that would increase the likelihood of premature removal means that interventions can be applied to minimise their impact. If successful, this would allow herd managers to exercise greater discretion to remove animals voluntarily. Over time, this strategy stands to increase the overall genetic merit of a herd.

Unfortunately, the number of studies conducted on dairy goats within a New Zealand context is sparse and the number published in peer-reviewed journals or books is even less.

To the best of our knowledge, the only studies conducted on goats and the goat industry in New Zealand include Sheppard & O'Donnell (1979), Kettle et al. (1983), Kettle and Wright (1985), Morris et al. (1997), Singireddy et al. (1997) and Solis-Ramirez et al. (2011).

This thesis provides a description of the demography, production and reproductive characteristics of dairy goats on commercial dairy goat farms in New Zealand. It also quantifies the influence of individual animal-level characteristics on the length of productive life. The data used were provided by the New Zealand Dairy Goat Co-operative (NZDGC). The body of the thesis is divided into four main chapters. Chapter 2 is a review of the literature, including a brief description of the history of the New Zealand goat industry, definitions of terms, and a review of factors influencing the risk of removal in dairy cows and goats. Given the substantial body of research describing longevity in dairy cattle and the paucity of information within the same subject area for dairy goats, it was felt that reviewing factors associated with removal in dairy cows would provide a useful background for understanding the research methods used in this subject area.

In Chapter 3, demographic and production characteristics, in addition to pattern of removal in New Zealand dairy goats, are described. Chapter 4 investigates individual animal-level characteristics associated with the length of productive life using a piecewise Cox proportional hazards regression model. Finally, in Chapter 5, the major findings of the descriptive (Chapter 3) and analytical (Chapter 4) studies are summarised and some recommendations are made in relation to improving existing systems of data recording on those farms registered with the NZDGC. The relevance of research focused on goats in developing countries is discussed in a separate section within this chapter.

CHAPTER 2

Literature review

2.1 Introduction

The domestic goat (*Capra hircus*) has served mankind since the early days of human civilisation (Zeder & Hesse 2000, Joshi et al. 2004). Goats were an important animal in ancient societies due to their religious, cultural, economical and nutritional significance (Boyazoglu et al. 2005). Their diversified role as providers of milk, meat and fibre is prominent even today.

Worldwide, the goat is the third most common livestock species after cattle and sheep (Boyazoglu et al. 2005). Regardless of its current rank, the period towards the end of the 19th century until the first half of the 20th century, was very difficult for goat farming. Various factors, such as changes in the social structure and production methods in the 19th century, the two World Wars causing intense food shortages, and the perception of goats as a threat to the environment in the middle of the 20th century, led to the promotion of intensive farming systems for cows, at the cost of goat stocks in developed countries (Boyazoglu et al. 2005). In addition, these factors restricted the remaining goat population to more marginal and poorer rural areas (Morand-Fehr et al. 2004). As a consequence, the potential economic and commercial value of goats was never fully appreciated. Even today, the goat is the least publicly and academically supported livestock species in developed countries, compared to other animal industries such as dairy and beef cattle, poultry, pigs, sheep and horses (Dubeuf et al. 2004). The goat industry also lags in terms of breeding and market development.

Despite this predicament, renewed consumer interest in goats and goat products during the early 1960s provided much needed support for the revival of a global goat industry

(Boyazoglu et al. 2005). This reversed the trend towards a declining goat population and during the past two decades the global goat population has increased from 591 million in 1990 to 880 million in 2009 (Food and Agriculture Organization of the United Nations 2011b). While most of this increase can be explained by a higher uptake in low income countries, the increase in goat numbers in some countries with intermediate and high incomes has also been significant (Haenlein 1996). As a result of increasing awareness and demand for products derived from goats, many developed countries have now started to perceive goat farming more positively (Haenlein 1996, Boyazoglu et al. 2005). Examples of European countries such as France, Greece, Italy and Spain show that goats can contribute to the national revenue defying their long-tagged 'poor man's cow' status (Haenlein 2001).

Dairying is one of the most prominent industries in New Zealand. In 2010 the dairy sector directly contributed approximately 2.8% (approximately four billion US dollars) to the country's national GDP figure (Schilling et al. 2010). Although New Zealand produces only two percent of the world's total milk production (Ministry for Primary Industries, New Zealand 2012), it sells 95% on the international market and holds one quarter of all global trade for dairy products. This makes New Zealand a key international player in the dairy sector trade.

Regardless of this achievement, the range of dairy animals in New Zealand is not diverse and its dairy industry consists almost entirely of cow's milk. The country's goat population has decreased by an average of 9,000 animals per annum for the last 10 years. During the same period of time the approximate number of milking does per herd has increased (Solis-Ramirez et al. 2011). In this context, it is useful to mention that the average number of milking does on farms registered with the New Zealand Dairy Goat Co-operative (NZDGC), the largest dairy goat co-operative in the country, is 550. The majority of dairy goats in New Zealand are managed intensively (Morris et al. 1997).

Captain James Cook is accredited for introducing goats into New Zealand in 1773 (Kettle et al. 1983). A brief history of the goat industry in New Zealand can be found in the discussion paper titled 'A Review of the New Zealand Goat Industry' (Sheppard & O'Donnell 1979). According to Sheppard & O'Donnell the goats that Captain Cook brought with him were killed by the Māori, but in 1814 immigrants brought in more goats and successfully established this animal in the country. The introduction of the Angora goat for mohair production in 1910 was the first government effort to stimulate the goat industry. Later, in 1921, the Milch goat was introduced to encourage commercial milk production (Sheppard & O'Donnell 1979). Unfortunately, this endeavour failed due to a lack of market opportunities for goat milk. The government has not made any further formal attempts to fortify the goat industry since that time.

Despite government indifference, the production of goat milk began to take the shape of an industry during the 1980s (Orr 2009, Solis-Ramirez et al. 2011). Over a short period of time the dairy goat industry became well established and there has been a steady increase in interest in dairy goats (Kettle et al. 1983, Solis-Ramirez et al. 2011). The contribution of the industry to the national economy, however, has been limited (Kettle et al. 1983). New Zealand can use its privileged position, as one of the leading producers of dairy products in the world to extend the limited dimensions of its goat industry and reap additional economic benefits. In order to achieve this further research and promotional activities, together with professional development focused on the industry, will be required.

Livestock farm management encompasses several important procedures. An example is the making of culling decisions, a concept that will be elaborated upon later in this chapter. In simple terms culling refers to the removal of animals from the herd. The majority of studies which have investigated the risk factors related to culling in production animals have focused on dairy cattle (see, for example Cobo-Abreu et al. 1979, Dohoo & Martin 1984, Bascom & Young 1998, Stevenson & Lean 1998b, Vries et al. 2010, and Bell et al. 2010). Several studies conducted on pigs (Stein et al. 1990, Brandt et al. 1999, Engblom et al. 2008) and beef cattle (Rogers et al. 2003, Waldner et al. 2009) are also available. Compared to dairy cows, studies that have examined factors associated with culling in goats are sparse and to the best of our knowledge none have been carried out in New Zealand. Differences exist, in terms of anatomical, physiological, nutritional, metabolic and pathological characteristics, between small and large ruminants (Haenlein 2001). Nevertheless, the findings from cow-based studies can serve as a guideline for understanding the general nature of culling in dairy animals. In this thesis, cow-based studies are cited in order to understand the general concept of culling in food producing animals.

This chapter begins with a review of the different types of culling used in dairy cow management systems, followed by a brief discussion on two major mathematical models that can be used in making culling decisions. Finally, studies investigating risk factors for removal in dairy cows and goats are reviewed.

2.2 Culling: definitions, classifications and significance

The term ‘culling’, in the context of domestic animal production systems, refers to the removal of stock from the herd. Fetrow et al. (2006) suggested that it is the most general term that can be used to describe the ‘separating off’ of animals, irrespective of their destination and condition at removal. In this chapter, we use the terms ‘culling’ and ‘removal’ synonymously. Fetrow et al. (2006) further explained that culled animals can be sub-grouped according to their destination, in order to remove any ambiguity caused by nomenclature. Such groups are mutually exclusive and include animals removed for (1) sale, (2) slaughter-salvage and (3) death. Although a rare occurrence, animals in pasture-based herds may sometimes break through fences and become lost. Such forms of removal may be separately categorised as ‘losses’. However, since the number of animals that actually get lost in a well-managed farm is negligible, further discussion throughout this thesis, on ways by which animals get removed, will not include losses as a separate category.

While ‘sale’ comprises live animals that are sold to other farms where they are to be used for productive purposes the category ‘salvage-slaughter’ includes live animals that are removed from the herd to be killed, either for human consumption (slaughter) or other purposes (salvage). ‘Death’ comprises animals that are no longer alive as a result of diseases or any other reasons, such as trauma or accidents.

‘Longevity’, in contrast to culling, is a term used to refer to the capability of an animal to remain in a herd over time. In the literature two different terms for longevity are found: true and functional. While true longevity refers to an animal’s ability to delay any form of culling, regardless of the reason for the removal, functional longevity implies its ability to defer only involuntary disposals, i.e. removal for health and reproductive disorders (Durcrocq et al. 1988, Essl 1998).

The idea of true and functional longevity can be explained with the help of an example from Durcrocq et al. (1988). It is assumed that a farmer has removed two cows from his herd: the first cow was profitable in terms of milk production, but infertile and the second was healthy and fertile, but not profitable due to low milk production. In the first case, the farmer's decision to remove the cow was involuntary because it was unfit for further production. In the second case, his decision was voluntary. Coming back to the notion of true and functional longevity, either of the cited removals would be deferred if the true longevity of the cows were improved, while only the first would be delayed if there was an improvement in functional longevity. Although both types of longevity are important it is more profitable to improve the functional longevity since this allows high milk-producing animals to live longer (Essl 1998). Under farm conditions functional longevity cannot be directly measured because, to some degree, voluntary culling always exists (Essl 1998).

2.2.1 Types of culling

Culling has traditionally been classified into two types: voluntary and involuntary. In the case of voluntary culling, the herd or flock manager chooses to remove either low milk-producing, but otherwise healthy and fertile animals, or those surplus to requirements (Fetrow et al. 2006). With involuntary culling there is no such choice available. An excess of animals removed from the herd for involuntary reasons reduces herd profitability by limiting the opportunity to make voluntary replacements (Beaudeau et al. 1993).

The voluntary-involuntary method for classifying culling can be useful to identify problems in herd management and preventive health programmes, but it has limited use in developing a strategy for making profitable culling decisions in the future (Lehenbauer & Oltjen 1998, Monti et al. 1999). This limitation can be addressed by classifying the reasons for removal into biological and economic categories (Radke & Shook 2001, Fetrow et al. 2006). The biological category includes all animals that are unfit for further production (e.g. severe injuries, permanent sterility or death). On the other hand the economic category comprises the remaining removal reasons, the decisions for which are based on the most suitable economic option, be it the sale of surplus animals or removal of those with reduced production capabilities.

Fetrow et al. (2006) argued that the non-traditional approach to classifying culls would offer management a more useful guide for making prospective decisions on the removal of cows. The rationality of such an argument is augmented by the fact that not all factors classified as causes of involuntary removal are truly ‘involuntary’. For instance, diseases are the most commonly reported causes of involuntary culling in cows, but not all diseases (except those requiring emergency disposal or those leading to permanent sterility) render animals biologically unproductive. Lameness in cattle, for example, can lead to a significant loss of milk production (Enting et al. 1997, Warnick et al. 2001) and impair reproductive performance (Enting et al. 1997, Kiliç et al. 2007), but the deaths that occur as a result of lameness alone are rarely reported. However, as a result of this health disorder, the reproductive and productive capacity of animals is reduced to such an extent that the cost to replace them is less than retaining them in the herd. This situation underscores the reality that culling is basically an economic decision-making process (Lehenbaurer & Oltjen 1998). Table 2.1 summarises the key features of different culling systems used in dairy herd management.

2.2.2 Significance of culling decisions

The situations that require decisions to be made regarding the disposal of animals from herds or flocks occur recurrently. Despite being an indispensible part of management, the decision to retain or dispose of an animal is complex, involving a wide spectrum of elements. Dairying is an economic activity and intrinsically profit is its ultimate focus. It is, therefore, important that producers acknowledge culling as an economically orientated process rather than adhering to the traditional approach of retrospectively analysing voluntary and involuntary reasons for culling in isolation (Lehenbaurer & Oltjen 1998). This change in mind set would be a first step in the formulation of a profitable culling policy which could guide prospective (i.e. planned) culling decisions.

Culling decisions based on economic principles, rather than biological considerations, can be expected to improve farm profitability (Groenendaal et al. 2004). Advanced producers can use computer software to record detailed biographical information about their animals. These records can then be used to improve culling decisions. However, the best culling decisions cannot be made from the collected data *per se* but the way in which they are analysed. Such analyses can be enhanced by incorporating economic models into managerial decision making (Lehenbaurer & Oltjen 1998).

In the literature, there is a clear paucity of studies that document the use of economic variables as aids for the development of replacement policies in dairy goats. However, there have been several attempts to determine optimal replacement policies for dairy cows, through economic variables and assessing the long-term consequences of culling decisions. Examples of such studies include McArthur (1973), Stewart et al. (1976), DeLorenzo et al. (1992), Kennedy and Stott (1993), Groenendaal et al. (2004), Heikkilä et al. (2008) and Kalantari et al. (2010).

The majority of such studies have underscored the application of dynamic programming (DP) as a tool to aid in making culling decisions. Marginal net revenue (MNR) techniques have also been used (Groenendaal et al. 2004). Although it is beyond the scope of this thesis to discuss these techniques in detail, a brief discussion, as follows, will help the reader to understand their fundamental differences.

2.2.3 Dynamic programming

Dynamic programming, also known as Bellman's Principle of Optimality, is a mathematical technique that is useful when a sequence of decisions have to be made (Huirne et al. 1997). Using this technique large and multi-stage sequential decision processes can be broken down into a series of single-stage problems that can be independently solved (Smith 1973, Stewart et al. 1976).

Consider a multi-stage problem in which a dairy herd manager needs to develop a replacement policy for the next five years. This time period is termed the 'finite planning horizon' and can be divided into five stages, each lasting one year. These stages refer to intervals into which the decision-making process has been divided for the planning horizon (Burt & Allison 1963). Each stage, in turn, is associated with a number of states which refer to the condition in which the system (a cow in our example) might be (Huirne et al. 1997). Once these stages and states are defined, the computation of the optimal replacement policy for each state of the final stage begins and then the process is repeated for all remaining stages by proceeding backwards in time, stage by stage, until it reaches the present stage. This establishes a backward recursive relationship among various stages for the entire planning horizon (Smith 1973).

In its simplest form, the DP technique makes a reasonable assumption that future replacement animals may not be identical to present animals, due to continuous genetic improvement (Arendonk 1984, DeLorenzo et al. 1992). In addition, it can take into account seasonal variations in revenues and costs and the repeatability of traits (Arendonk 1988, DeLorenzo et al. 1992). These features are considered advantages compared with the MNR technique. The major limiting factor of the DP technique is that it is prone to becoming easily complicated and may be time consuming to develop due to the intensive resource requirements in terms of skills and the amount of information required to manage the programme (Arendonk 1984, Groenendaal et al. 2004).

2.2.4 Marginal net revenue

Assume that a herd manager has to make a decision on how long a cow has to be kept in the herd. Using the MNR technique, the optimum time for the replacement of the cow depends upon the shape of the MNR curve, the characteristics of replacement heifers as well as the presence or absence of discounting and involuntary replacements (Arendonk 1984, Huirne et al. 1997). Assuming the simplest scenario, where discounting and involuntary replacement are absent and replacement heifers(s) are identical to the cow of interest, the most profitable time for replacement is when the cow's marginal net revenue is equal to the expected maximum average net revenue anticipated from a replacement heifer (Huirne et al. 1997). In case the replacement heifers are not identical to the present cow, the optimum time for replacement may not necessarily coincide with the time when the expected net revenue from a replacement heifer is maximum.

There are two major limitations of the MNR technique (Huirne et al. 1997). Firstly, it does not directly take into account the continuous genetic improvement in animals and seasonal variation in revenues and costs. Secondly, it does not consider the variation in expected performances of the present and replacement animals. Regardless of these limitations, Groenendaal et al. (2004) presented a model that was based on the MNR approach to determine optimal culling and breeding decisions for dairy cows. The authors calculated the retention pay-off (RPO) value of each individual cow and then used it as an economic index to decide whether to retain or replace her. After the opportunity cost is calculated it can be used to determine the optimal life span of an individual cow. This optimal lifespan, in turn, is used in the calculation of RPO value of the cow. The RPO is equal to the extra profit that can be expected by retaining a cow until her optimal age as compared to immediate culling after the chances of involuntary premature disposal are taken into account (Huirne et al. 1997). Groenendaal et al. (2004) argued that the use of the MNR technique is less complicated compared to the DP technique and therefore, can be expected to be more useful as a decision-making tool at the farm level.

2.2.5 Risk factors for culling in dairy cows

The literature is replete with studies on risk factors for culling in dairy cows. Examples include Cobo-Abreu et al. (1979), Dohoo & Martin (1984), Milian-Suazo et al. (1988), Esslemont & Kossaibati (1997), Bascom & Young (1998), Stevenson & Lean (1998b), Gröhn et al. (1998), Hadley et al. (2006), Vries et al. (2010) and Bell et al. (2010). The majority of these studies have highlighted the role of heath disorders as risk factors for culling. Besides diseases, production and environmental factors associated with culling have also been documented. The following sections briefly review these risk factors.

Health factors

It has been estimated that health-related events contribute to more than 50% of all culls in cows (Dijkhuizen et al. 1985, Beaudeau et al. 1993, Seegers et al. 1998). While the role of health disorders in culling is well documented, the literature shows a variation in numbers and types of reported disorders. In addition, the use of inconsistent case definitions makes comparison between studies difficult (Beaudeau et al. 1993). In the same way, a variation in terms of statistical analyses, model variables and provisions for effect modifiers means that caution is required when making comparisons between studies (Gröhn et al. 1998). Finally, it is important to take into account the interrelations between diseases, when analysing a disease as a risk factor for culling (Beaudeau et al. 1993).

The effect of diseases on culling are not always direct (Rajala-Schultz & Gröhn 1999). Indirect effects may manifest through reduced milk production and reproductive performance, which ultimately lead to the disposal of the affected animal (Cobo-Abreu et al. 1979). Meanwhile, a herd manager may decide to retain high-producing animal regardless of their health status (Gröhn et al. 1998). The most commonly reported health reasons for culling in dairy cattle can be categorised as follows:

1. Reproductive disorders and infertility;
2. Udder disorders;
3. Locomotor disorders;
4. Metabolic disorders;
5. Miscellaneous health disorders.

Reproductive disorders and infertility

The most frequently reported causes for culling in the literature are infertility and reproductive disorders (Milian-Suazo et al. 1988, Esslemont & Kossaibati 1997, Bascom & Young 1998, Stevenson & Lean 1998a, Seegers et al. 1998). Some studies have identified specific types of reproductive disorders and investigated their role in culling, as discussed in the following paragraphs.

Studies into the association between the occurrence of cystic ovaries and their effect on culling have produced contradictory results. Erb et al. (1985), Milian-Suazo et al. (1988) and Oltenacu et al. (1990) reported a positive association between cystic ovarian disease and the risk of culling. In contrast, Rajala-Schultz & Gröhn (1999) and Martin et al. (1982) found that cystic ovarian disease was protective against culling. While an increase in the risk of culling may be an indirect consequence of a longer calving interval resulting from cystic ovarian disease (Hogeveen et al. 1994) a decreased risk may be explained by a higher milk yield from affected cows (Johnson et al. 1966, Bigras-Poulin et al. 1990, Fleischer et al. 2001). This example highlights the need to consider both production and economic aspects of a farm operation when making comparisons of risk factors for culling.

Metritis often leads to poor reproductive performance and milk production in cows and, as a result, it has an indirect effect on culling (Lewis 1997). Studies on the effect of metritis on culling have reported varying results. Bartlett et al. (1986), for example, found that cows with metritis were 1.3 times more likely to be culled compared to unaffected cows. A positive association between metritis and culling was also reported by Cobo-Abreu et al. (1979), Milian-Suazo et al. (1988) and Oltenacu et al. (1990). However, Gröhn et al. (1998) found that metritis did not affect culling in cows and Dohoo and

Martin (1984) reported that reproductive tract infections including metritis detected after 60 days from calving, were negatively associated with culling. A lack of homogenous case-definition for metritis makes comparisons between studies difficult and this partly explains variations in the effect of the disorder on culling (Monti et al. 1999).

The effect of abortion and dystocia on culling has been more consistent. Milian-Suazo et al. (1988) found that cows that aborted were twice as likely to be culled compared to unaffected cows. Peter (2000) reported a three times increase in the risk of culling in cows that aborted compared with cows that carried their calves to full term. Likewise, Bascom & Young (1998) found high yielding cows were more likely to be culled than low producers, in relation to abortion. Similar to the case of abortion, several authors have reported positive associations between calving difficulty and culling, regardless of differences in case definition (Oltenacu et al. 1990, Dematawewa & Berger 1997, Rajala-Schultz & Gröhn 1999, Tenhagen et al. 2007, Bicalho et al. 2007, Bell et al. 2010, Vries et al. 2010).

Studies on the effect of retained placenta in culling have reported conflicting results. Some authors, such as Cobo-Abreu et al. (1979), Milian-Suazo et al. (1988) and Oltenacu et al. (1990) reported a positive association between retained placenta and the risk of culling. In the study by Gröhn et al. (1998) the positive relationship between retained placenta and culling was eliminated after adjustment for milk yield and conception status. In contrast, Beaudeau et al. (1995) reported that there was a positive association between the presence of retained placenta in the first lactation and the risk of culling.

Udder disorders

Mastitis is the most extensively studied udder disorder of dairy cows. Its role in culling has been frequently investigated and a positive association found by many authors (Cobo-Abreu et al. 1979, Dohoo & Martin 1984, Erb et al. 1985, Milian-Suazo et al. 1988, Oltenacu et al. 1990, Beaudeau et al. 1995, Bascom & Young 1998, Rajala-Schultz & Gröhn 1999, Bell et al. 2010). In their review of the literature, Seegers et al. (2003) reported that the relative risk of culling, following clinical and sub-clinical mastitis, ranged from 1.5 to 5.0. Herd managers may choose to cull animals with mastitis either because affected animals fail to recover, or the infection results in reduced milk production (Bascom & Young 1998). Some authors (Dohoo & Martin 1984, Sewalem et al. 2006) have identfied a positive association between somatic cell count and the risk of culling.

The presence of teat injuries has frequently been identified as a risk factor for culling (Milian-Suazo et al. 1988, Beaudeau et al. 1994, Rajala-Schultz & Gröhn 1999).

Locomotor disorders

The proportion of dairy cows culled for lameness and foot-health disorders is generally less compared to those removed for reproductive and udder disorders. Esslemont & Kossaibati (1997) reported that around 6% of all animals culled from herds were for lameness; Stevenson & Lean (1998a) reported 4%. Lower proportions (3% and 1%) of the total cull were attributable to feet and leg disorders in studies by Seegers et al. (1998) and Milian-Suazo et al. (1988), respectively. A positive association between lameness and culling was reported by Rajala-Schultz & Gröhn (1999) and Booth et al. (2004). However, Beaudeau et al. (1995) found no such association, arguing that the role of locomotor disorders in culling is not always prominent, since many of these disorders only occur at a sub-clinical level.

Metabolic disorders

The impact of post parturient hypocalcaemia (milk fever) on culling has been contradictory. In a study by Rajala-Schultz & Gröhn (1999) milk fever was a significant risk factor in the early culling of cows within a lactation cycle. Similarly, Gröhn et al. (1998), Dohoo & Martin (1984) and Milian-Suazo et al. (1988) found that the disorder and risk of culling were positively associated. In another study by Esslemont & Kossaibati (1997) milk fever was cited as the main non-infectious cause of death. However, Erb et al. (1985) indicated that milk fever had only an indirect effect on culling, which was mediated through poor fertility and the occurrence of other reproductive disorders. Finally, Cobo-Abreu et al. (1979) and Martin et al. (1982) found no association between milk fever and culling risk.

Similarly, the relationship between ketosis and culling is inconsistent. Milian-Suazo et al. (1988) and Gröhn et al. (1998) found that ketosis and the risk of culling were negatively associated. This negative association was restricted only to the first and second parity cows in a study by Beaudeau et al. (1995). In contrast, Dohoo & Martin (1984) found that ketosis was protective against culling, at less than 150 days after calving. Although the positive association between survival and ketosis was attributed to milk yield (Dohoo & Martin 1984), Cobo-Abreu et al. (1979) observed that cows with ketosis produced less milk than non-ketotic cows.

Miscellaneous health disorders

In addition to the health disorders discussed above, the effect of other diseases on culling have been reported. Displacement of the abomasum, for instance, was negatively associated with survival in a study by Gröhn et al. (1998) and Milian-Suazo et al. (1988). However, Cobo-Abreu et al. (1979) and Dohoo & Martin (1984) did not find any such association. Furthermore, pneumonia increased the risk of culling in a study by Cobo-Abreu et al. (1979) and Dohoo & Martin (1984).

Animal factors

The risk of culling increases with age (Dohoo & Martin 1984, Milian-Suazo et al. 1988, Beaudeau et al. 1995, Gröhn et al. 1998, Bell et al. 2010). In an Irish study more than 50% of total culls occurred in cows older than seven years of age (Maher et al. 2008). However, the effect of age on culling risk should not always be considered in isolation. Particularly in commercial farms, very few animals are actually removed from the herd because of old age (Durcrocq et al. 1988, Esslemont & Kossaibati 1997, Essl 1998). Young et al. (1983) and Esslemont & Kossaibati (1997)) found that, with increases in age, the risk of culling for multiple reasons increases. A higher disposal rate among older animals was primarily mediated through conditions such as udder disorders (Milian-Suazo et al. 1988, Seegers et al. 2003) and reduced milk yields (Milian-Suazo et al. 1988). However, animals culled for infertility included a higher proportion of younger cows (parities one and two) in studies by Esslemont & Kossaibati (1997) and Seegers et al. (2003).

Culling, due to different health disorders within a lactation cycle in cows may be described in relation to the stage of lactation. Early lactation, for example, was a risk period for culling due to udder disorders (Dohoo & Martin 1984, Milian-Suazo et al. 1988, Seegers et al. 2003), but Beaudeau et al. (1994) found that mastitis occurring early in lactation was positively associated with late lactation culling. This was explained by the herd manager's choice to treat animals suffering from mastitis before they reached their peak production and provide an opportunity for them to recover. Furthermore, animals removed for infertility and poor reproductive performance were removed late in the lactation (Beaudeau et al. 1994, Rajala-Schultz & Gröhn 1999, Seegers et al. 2003) probably because it was more profitable to replace high milk-producing, non-pregnant cows, only after they were dried off.

Additional animal factors that are associated mainly with voluntary culling include temperament and conformational faults (Esslemont & Kossaibati 1997).

Environmental factors

In their review of the literature, Monti et al. (1999) mentioned that culling rates may vary by season. In many cases the effect of environment on culling, however, is indirect as shown by the following examples. A study in Kenya by Ojango et al. (2005) found that animals were at a higher risk of removal during the rainy season. This season corresponded with an increase in the frequency of livestock diseases. Likewise, cows calving in the autumn season were at a significantly lower risk of culling in Finland (Rajala-Schultz & Gröhn 1999). A higher risk of culling in cows calving in the autumn and the summer was also observed by Hadley et al. (2006). However, the calving season was not a risk factor for culling in the study by Gröhn et al. (1998) and Burnside et al. (1971) did not observe any effect of calving season on the risk of involuntary culling. It is difficult to draw conclusions on the effect of the calving season on culling, based on the results of these studies only. Another indirect way of describing the relationship between season and culling is to look at the role of season as a risk factor for disease, the incidence of which can be influenced by season. Mastitis is a classic example of such a disease and its role in the culling of dairy cows is well documented (Oltenacu & Ekesbo 1994, Fadlelmoula et al. 2007).

2.2.6 Risk factors for culling in dairy goats

A number of epidemiological studies on dairy and non-dairy goats have focused on factors influencing reproductive performance (Engeland et al. 1997, 1998, 1999, Mellado et al. 2006, Užeda et al. 2007, Nordstoga et al. 2010), parasitism (Morris et al. 1997, Qamar et al. 2009) and resistance of nematode parasites to anthelminthics (Kettle et al. 1983, Maingi et al. 1996, Requejo-Fernández et al. 1997). In contrast, studies examining aspects of herd demographics such as the frequency, timing and risk factors for culling are limited. Following a literature search of peer-reviewed papers published in the English language, only two were found that investigated risk factors for culling in dairy goats. The first was a prospective longitudinal study of 43 intensively managed dairy goat herds in France

(Malher et al. 2001). These authors found that mortality was more common in younger age groups and in those with higher milk yields. In the second paper risk factors for stayability were investigated for different breeds of dairy goats in Mexico (Pérez-Razo et al. 2004). These authors defined ‘stayability’ as the probability of survival up to the fourth, fifth and sixth kidding. In this study Alpines had better stayability compared to Saanens and increases in age at first kidding and litter weight at first kidding were positively associated with stayability.

2.3 Conclusions

A large body of work has been undertaken to identify and quantify the effect of various risk factors for culling in dairy cattle. Although findings from the dairy cow literature provide a useful starting point, it is not always appropriate to extrapolate results from dairy cow-based studies to dairy goats. Independent studies conducted on dairy goats will not only help us to understand the pattern of culling in dairy goats but will also identify factors influencing the risk of being culled such as characteristics of the animal itself (for example age, breed, milk production), or time (for example stage of lactation). Better knowledge of these factors will allow herd managers to make the necessary interventions to minimise their impact at the herd level. This approach will ultimately help to improve herd profitability by minimising numbers of preventable losses.

Table 2.1: A summary of the different types of culling systems used in dairy cattle.

Classification system	**Comments**
'Traditional'	
Strengths	Commonly used classification system. See Esslemont & Kossaibati (1997), Weigel et al. (2003), and Bell et al. (2010) for examples.
Weaknesses	Definitions of involuntary and voluntary culling can be ambiguous. In the majority of animals that are removed for involuntary reasons, decisions are actually 'voluntarily' made. For example, a cow with a poor reproductive performance may be removed because the herd manager believed it would be more economic to replace her with a younger heifer, instead of including her in the breeding programme.
Categories	*Voluntary*: Animals are removed because they are surplus to the requirements of herds, or they produce low levels of milk, but are otherwise healthy. *Involuntary*: Animals are removed because of disease or death.
'Alternative'	
Strengths	Less ambiguous definitions of different types of culling compared to the traditional approach.
Weaknesses	A relatively recent concept, but less commonly used (Radke & Shook 2001, Fetrow et al. 2006).
Categories	*Biological*: Animals are removed because they are totally unfit for future production. Examples include permanent sterility, infection with brucellosis. *Economic*: Animals are removed because it is more desirable to replace them for economic reasons.

CHAPTER 3

Descriptive epidemiology of removals in New Zealand dairy goats

Abstract – We describe the demographic characteristics and pattern of removal of goats in commercial dairy goat herds in New Zealand. The population of interest was comprised of dairy goats from herds registered with the New Zealand Dairy Goat Co-operative. The study population comprised 23,771 does from 38 herds. Starting from 1 January 2000, does were followed until 31 December 2009. Survival analyses were used to describe the pattern of removal of does as a function of age and within a lactation cycle, as a function of days in milk and days dry.

Herds were comprised predominantly of Saanens or Saanen hybrids. The median age of does at first kidding was 394 days (Q1 369 days, Q3 722 days). The median age at the time of removal was 3.7 years (Q1 2.5 years, Q3 4.9 years). On average, does completed less than three lactation cycles at the time of removal. Approximately two thirds of all removals were involuntary and more than half of all removals occurred as a result of culls, compared with those removed by sale or death. The maximum instantaneous hazard of removal increased from 0.025 per 100 animals per day during the first year of life to approximately 0.050 per 100 animals per day during the fourth year. Within a lactation cycle, the hazard of removal in does was highest during the early days of the dry period.

Non-infectious disorders comprised the major source of loss in this study. Further research is required to more precisely define the disorders within this category so that appropriate preventive measures can be applied to offset their impact. Regardless, the range of disorders within the non-infectious category identified in this study implies that those managing or advising on the productivity of dairy goat farms need to have detailed knowledge on the control and prevention of a wide range of individual health disorders.

3.1 Introduction

Milk from farm animals has long been an important part of the human diet, particularly for infants. Although bovines (in particular, dairy cows) play a prominent role as a source of milk for human consumption, milk from goats makes an important contribution, particularly among the poor in developing countries (Haenlein 2004, Aziz 2010). Worldwide, the number of people who consume goat milk is greater than that of people who consume milk from any other mammalian farm species (Park 1994). Despite having a significant role in human nutrition, the number of technical studies focusing on the nutritional and medical benefits of goat milk is low (Park 1994, Jandal 1996, Haenlein 2004). Compared to cow milk, goat milk has some distinct advantages. These relate to its beneficial effects on human health such as higher digestibility and suitability for people with allergies (Park 1994, Haenlein 2004).

In the majority of developed countries, dairy goat industries typically contribute small amounts to the national economy. Countries such as France have shown, however, that a milking goat industry, if supported with the necessary infrastructure for processing, marketing, promotion and research can make significant contributions (Haenlein 2004).

Inadequate resources and expertise together with a comparatively small industry size have long been identified as some of the limiting factors affecting dairy goat production in New Zealand (Kettle & Wright 1985). The overall trend of a decreasing goat population in New Zealand is partly attributable to the reduction in the number of meat and fibre goats, due to competition from the cattle and sheep industries (Solis-Ramirez et al. 2011). Conversely, increases in animal efficiency and the average number of milking does per herd over the past two decades (Singireddy et al. 1997, Morris et al. 2006, Solis-Ramirez et al. 2011) indirectly indicate that profit can be made out of dairy goat farming.

It is easy to assume that research findings based on dairy cattle can be directly applied to dairy goats. However, such extrapolations are not always appropriate since dairy goats differ from cows in terms of anatomy, physiology, nutrition and metabolism (Haenlein 2001). Unfortunately, in many developed countries, dairy goats are often overlooked when it comes to research and promotional support, probably due to a general belief that research findings from the dairy cattle industry can be applied to dairy goats. An additional challenge also remains in making future scientific information more relevant to the exact needs of goat sector development (Boyazoglu et al. 2005). Finally, as pointed out by Haenlein (2001), languages other than English are often used to publish proceedings of many conferences focused on goats, thus leaving wider audiences deprived of updated information.

A number of epidemiological studies on dairy and non-dairy goats have focused on factors related to reproductive performance (Engeland et al. 1997, 1998, 1999, Mellado et al. 2006, Uẑeda et al. 2007, Nordstoga et al. 2010), gastrointestinal parasitism (Morris et al.

1997, Qamar et al. 2009) and resistance of nematode parasites to anthelminthics (Kettle et al. 1983, Maingi et al. 1996, Requejo-Fernández et al. 1997). In contrast, studies examining aspects of herd demographics and other aspects of production management such as the frequency, timing and risk factors for removal are limited (Malher et al. 2001, Pérez-Razo et al. 2004). To the best of our knowledge, there have been no studies undertaken to investigate the patterns of removal of dairy goats in New Zealand. In order to address this knowledge gap the objectives of this study were to describe the demographics and production characteristics of dairy goats on commercial dairy goat farms in New Zealand. A secondary objective was to describe the pattern of removal from herds as a function of age and stage of lactation. The results of this study provide a starting point towards the development of planned (as opposed to reactionary) culling strategies in New Zealand dairy goat herds.

3.2 Materials and methods

3.2.1 Data collection

The data used for this study were provided by the New Zealand Dairy Goat Co-operative (NZDGC) a farmer-owned organisation based in Hamilton, located in the upper North Island of New Zealand. The NZDGC was established in 1994 and its key activity is the manufacture of infant formula and other value-added commodity products based on goat milk. These products are exported to several countries including South Korea, Taiwan and China. In early 2012 the NZDGC was comprised of 45 farmer shareholders, the majority of which were located in the Waikato region, with smaller numbers in Northland and Taranaki.

The data used for this study were recorded by farmers using various methods, such as hand-written entries into record books or direct entries into a personal computer. Some herd managers used the MINDA system, developed and run by Livestock Improvement Corporation (LIC) for managers of dairy herds. In brief, MINDA provides the facilities to record and manage information at the individual animal level including dates and details of births, treatments, vaccinations, kiddings, matings and dry-off events. In the past, these details were recorded on paper and sent to LIC be entered into a central database. In recent times, herd managers have been able to record data electronically using purpose-built software. This information can then be sent to the central database via the Internet. Further information about MINDA is available from the LIC website.[1]

The current practice for herd testing in dairy goats registered with the NZDGC involves the measurement of milk volume and milk constituents every two months throughout the lactation. Data recorded in the central database of LIC are transferred to the NZDGC in digital format and this information is used to calculate breeding indices for individual animals. In order to provide NZDGC members with technical support and advise in the areas of animal health and herd improvement the co-operative employs one full-time veterinarian.

The following individual goat-level details were used for the analyses described in this paper: the unique animal identifier, sex, breed percentage, date of birth, date of removal from the herd (if applicable), removal fate (sold, culled or died), and reason for removal (if applicable). In addition, the easting and northing coordinates of the centroids of the territorial land authority in which each herd was located were provided. Finally, individual lactation details such as dates of parturition, dates of dry-off events and total lactation milk, fat and protein yields were also used.

Although the complete dataset was comprised of records for a total of 48,699 animals (including those with birth dates as early as August 1983) only those animals born on or after 1 January 2000 were used in the analyses presented in this paper. This restriction was applied because the majority of animals born before this date had missing observations, particularly those related to lactation length, milk, fat and protein yields. Bucks were also excluded. Records were screened and limited to does that had a lactation length of less than or equal to 305 days or a total lactation milk yield of less than or equal to 1800 kg. Unlike dairy cows, a standard lactation length for dairy goats has not yet been defined. Majid et al. (1993) have suggested that, in the absence of specific standards being defined for goats, metrics originally developed for dairy cattle can be used with minimal loss of accuracy.

Since the majority of does in the study group had a portion of Saanen genes, does were classified into two main categories: Saanen and non-Saanen. These categories were then

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[1] `www.lic.co.nz`

sub-categorised depending on the percentage of Saanen and non-Saanen genes for individual does.

Culling is a general term used to refer to the departure of animals from their herd regardless of condition and destination at the time of removal (Fetrow et al. 2006). For the purpose of this paper, we use the term ‘removal’ to include those animals that left a herd because they had either died, were culled or were sold (Fetrow et al. 2006). While the term ‘sale’ refers to live animals sold for continued dairy use, ‘culls’ refers to those live animals that were removed for all other reasons.

Removal reasons were classified into one of two categories: voluntary and involuntary. Voluntary removals comprised reasons associated with production or sale of surplus animals. Involuntary removals included elimination as a result of disease or injury. A third ‘unknown’ category was created for animals that no reason listed as their cause of removal.

3.2.2 Statistical analyses

Survival analyses were used to describe the timing of removal from the herd, expressed in two ways: relative to the date of birth and relative to the date of last kidding. Each doe born on 1 January 2000, or later, was observed until it was removed from the herd or until 31 December 2009, whichever occurred first. Those does that were still present in their respective herd at the termination of the study on 31 December 2009 were treated as censored observations.[2] For does that were removed age at the time of removal, days milked at the time of removal, days dry at the time of removal, lifetime milk production and length of productive life was calculated. Length of productive life was defined as the number of days between the date of first kidding and the date of removal.

The Kaplan-Meier method (Kaplan & Meier 1958) is a commonly used technique in survival analysis used to describe time to event (in the context of this study, time to removal). Denoted by $S(t)$, the Kaplan-Meier survival function defines the probability that an individual’s survival time (a random variable denoted by T) is greater than a specified time, t. The Kaplan-Meier estimate of survival can be plotted graphically with survival time on

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[2] The reader is referred to Clark et al. (2003) for a description of the basic concepts and terms used in survival analysis.

the horizontal axis and the corresponding proportion of surviving individuals at each time point on the vertical axis. Such a graph is typically presented as a series of horizontal steps, which is ever-declining in magnitude. While the Kaplan-Meier estimate of survival is relatively easy to calculate and plot, it is often difficult to compare and interpret the slopes of different survival curves by eye (Efron 1988). Comparison of the survival of different sub-groups of a population is easier when the instantaneous hazard of failure is plotted as a function of time. Here, instantaneous hazard, $h(t)$, represents the instantaneous risk of the event of interest (in this case, removal) occurring at time, t given that it has not occurred already.

3.3 Results

Figure 3.1 shows locations in New Zealand that represent the presence of at least one dairy goat herd used in this study. The maximum number of herds per location was six.

In total 24,323 goats born after 1 January 2000 provided data for this study. Further screening of the data to remove bucks (n = 398) and those with implausible production records (n = 154) reduced the study group to 23,771 does. Of these 23,771 does, 9648 were recorded as having been removed during the 10-year follow-up period. Removal reasons stratified by type (involuntary, voluntary, or unknown) are shown in Table 3.1.

A breakdown of the total number of does based on breed percentage (Table 3.2), shows that 42% of does were comprised of 100% Saanen genes. The median age of the study group was 3.8 years (Q1 2.5 years, Q3 5.5 years). Approximately 59%, 25% and 16% of all removals occurred as a result of culls, deaths and sales, respectively (Table 3.3). A total of 62% of all removals were involuntary. Miscellaneous disorders (infectious diseases, non-infectious diseases and trauma or injury) was the cited removal reason for 44% of all removed does. Non-infectious causes comprised more than one third proportion of all removals. Finally, 19% of all does were removed voluntarily and 19% were removed for unknown reasons.

Table 3.4 provides descriptive statistics of each of the production outcomes. The median age at first kidding was 394 days. The median age at the time of removal was 3.7 years (Q1 2.5 years, Q3 4.9 years). The median parity commenced at the time of removal was

2 (Q1 1, Q3 3). The characteristics of the productive life of does that were removed are shown in Table 3.5.

Figure 3.2 shows instantaneous removal hazard (expressed as a probability of removal per day) as a function of age. The maximum instantaneous removal hazard observed during the first year of life was 0.00025 (i.e. 0.025 per 100 animals per day), which later increased to 0.050 per 100 animals per day during year four. After the fourth year, the maximum instantaneous hazard remained constant approximately at 0.040 per 100 animals per day, up to eight years.

Similarly, Figures 3.3, 3.4 and 3.5 present separate curves of instantaneous removal hazard for culls, death and sale, respectively. Age-wise, the maximum instantaneous removal hazard for culls was observed at year four, after which it remained unchanged up to six years. The graphs of instantaneous removal hazard, due to all reasons (Figure 3.2) and those for culls and deaths (Figures 3.3 and 3.4 respectively) show regularly fluctuating pattern, with the crests representing the dry period within a lactation cycle. A relatively flat curve, in which the maximum instantaneous hazard never exceeded 0.01 per 100 animals per day was observed for removal as a result of sale (Figure 3.5.)

Since very few animals were actually removed when they were still in milk the instantaneous hazard of removal during lactation was virtually constant at zero (Figure 3.6). In contrast, the hazard of removal was relatively high immediately after going dry at 0.15 per 100 animals per days (Figure 3.7). Beyond 100 days dry the hazard of removal was less than 0.05 per 100 animals per day.

Table 3.1: Classification of removal reasons in dairy goats.

Removal category	**Details**
Involuntary:	
Kidding disorders	Kidding trouble (including septicaemia).
Metabolic disorders	Ketosis, hypocalcaemia, hypomagnesaemia.
Locomotive discorders	Leg problems, lameness.
Miscellaneous disorders	
Infectious	Brucellosis, caprine arthritis encephalitis, Johne's diseases, listeriosis, pneumonia, scours, tuberculosis, other diseases.
Non-infectious	Bloat, cast, gastrointestinal disorders, cancer, other causes.
Trauma	Drowned, injury, accident.
Reproductive disorders	Abortion, late kidder, empty.
Udder disorders	Mastitis, high cell count, udder breakdown, slow milker, blind quarter, one titter, unsuitable udder or teats.
Voluntary:	Low production, traits other than production, unsuitable type, old age, surplus to requirements.
Unreported:	Unknown or unreported causes of removal.

Table 3.2: Breed composition for Saanen and non-Saanen does in this study.

Breed	**Proportion of genes**	**Number of animals (*n*)**	**%**
Saanen	<0 Saanen ≤ 0.25	2257	9.5
	>0.25 Saanen ≤ 0.5	5489	23.0
	>0.50 Saanen ≤ 0.75	2940	12.4
	>0.75 Saanen ≤ 1.0	1994	8.4
	Saanen = 1.0	9936	41.8
Non-Saanen	Toggenburg = 1.0	572	2.4
	Alpine = 1.0	43	0.2
	Nubian = 1.0	38	0.2
	Unreported	502	2.1
Total		23,771	100

Table 3.3: Count of does removed during the study period by destination and disorder.

Removal category	**Number of animals (n)**			
	Culled	**Died**	**Sold**	**Total (%)**
Involuntary:				
Kidding disorders	61	238	0	299 (3)
Metabolic disorders	39	30	0	69 (1)
Lameness disorders	142	11	0	153 (2)
Miscellaneous infectious	143	327	0	470 (5)
Miscellaneous non-infectious	2008	1166	503	3677 (36)
Miscellaneous trauma	52	44	0	96 (1)
Reproductive disorders	630	3	2	635 (7)
Udder disorders	560	74	16	650 (7)
Voluntary:	1087	36	688	1811 (19)
Unreported:	976	479	333	1788 (19)
Total	5698	2408	1542	9648 (100)

Table 3.4: Production and reproductive outcomes of 23,771 does that were present in goat herds throughout the study period.

Outcome	n	**Mean**	**SD**	**Median**	**Q1, Q3**
L1 milk yield (litres)	19,017	435	236	409	257, 580
L1 fat yield (kg)	18,943	15	8	14	9, 20
L1 protein yield (kg)	18,943	13	7	12	8, 17
Ln - 1 milk yield (litres)	14,628	547	322	532	327, 760
Age at first kidding (days)	23,338	603	434	394	369, 722
Lifetime milk yield (litres) [a]	8078	1425	1365	975	414, 1984

SD: Standard deviation.
Q1, Q3: First and third quartiles.
L1: First lactation.
Ln - 1: The lactation before the lactation of removal.
[a] Includes only removed does.

Table 3.5: Descriptive statistics of productive life outcomes for 9,648 does removed during the study period.

Outcome	n	**Mean**	**SD**	**Median**	**Q1, Q3**
Age (days)	9648	1415	656	1362	943, 1814
Number of lactations commenced	9648	2.5	1.6	2	1, 3
Days since last kidding	9647	263	212	256	104, 341
Days in milk	5882	167	73	172	104, 232
Days dry	9428	166	185	102	35, 242
Length of productive life (days)	9648	809	606	678	319, 1130

SD: Standard deviation.
Q1, Q3: First and third quartiles.

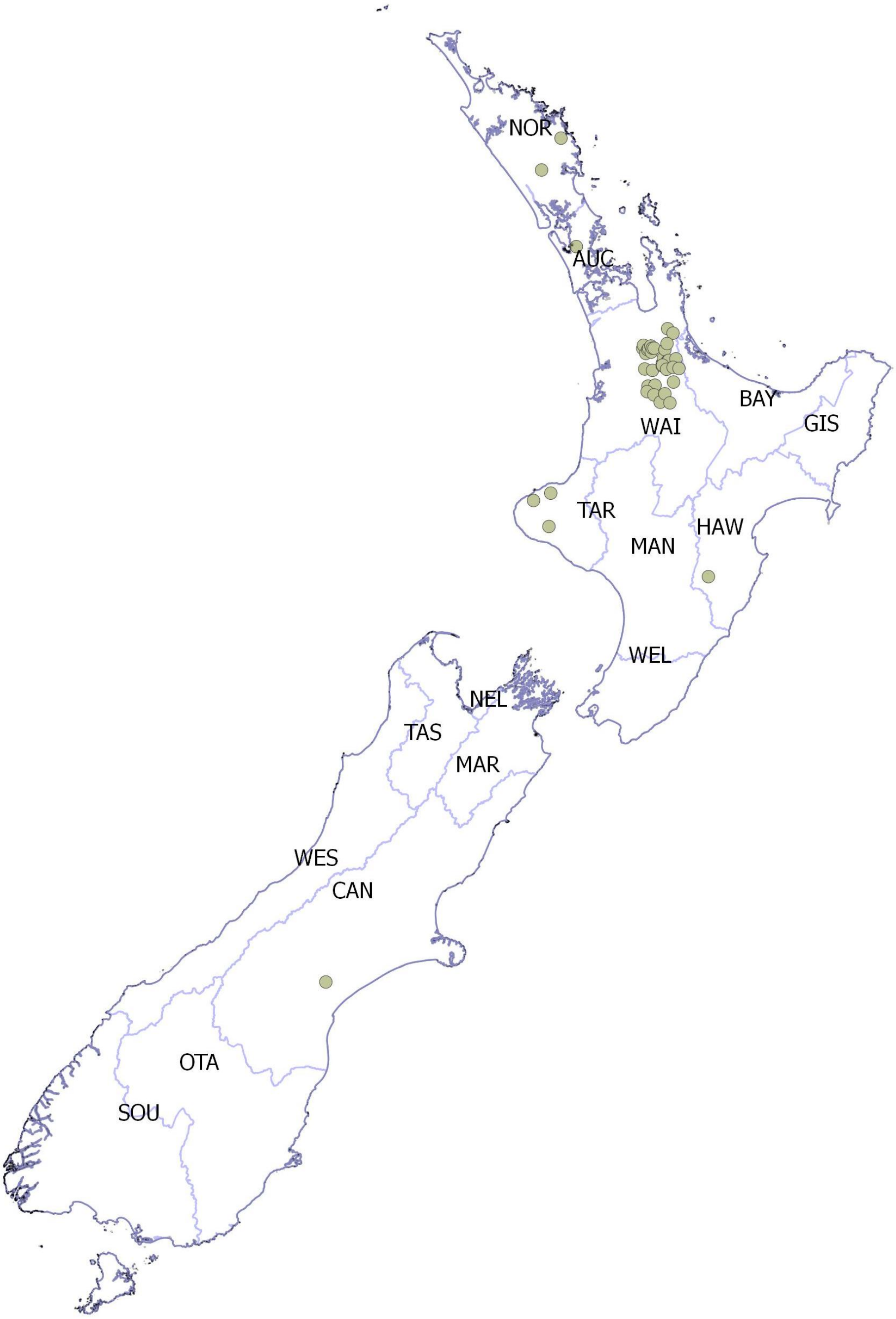

Figure 3.1: Map of New Zealand showing the centroids of the territorial land authorities where the herds used in this study were located. Each point on the map identifies the presence of between one and six goat herds at that location. Key: NOR Northland, AUC Auckland, WAI Waikato, BAY Bay of Plenty, GIS Gisborne, TAR Taranaki, MAN Manawatu-Wangauni, HAW Hawke's Bay, WEL Wellington, NEL Nelson, TAS Tasman, MAR Marlborough, WES West Coast, CAN Canterbury, OTA Otago, and SOU Southland.

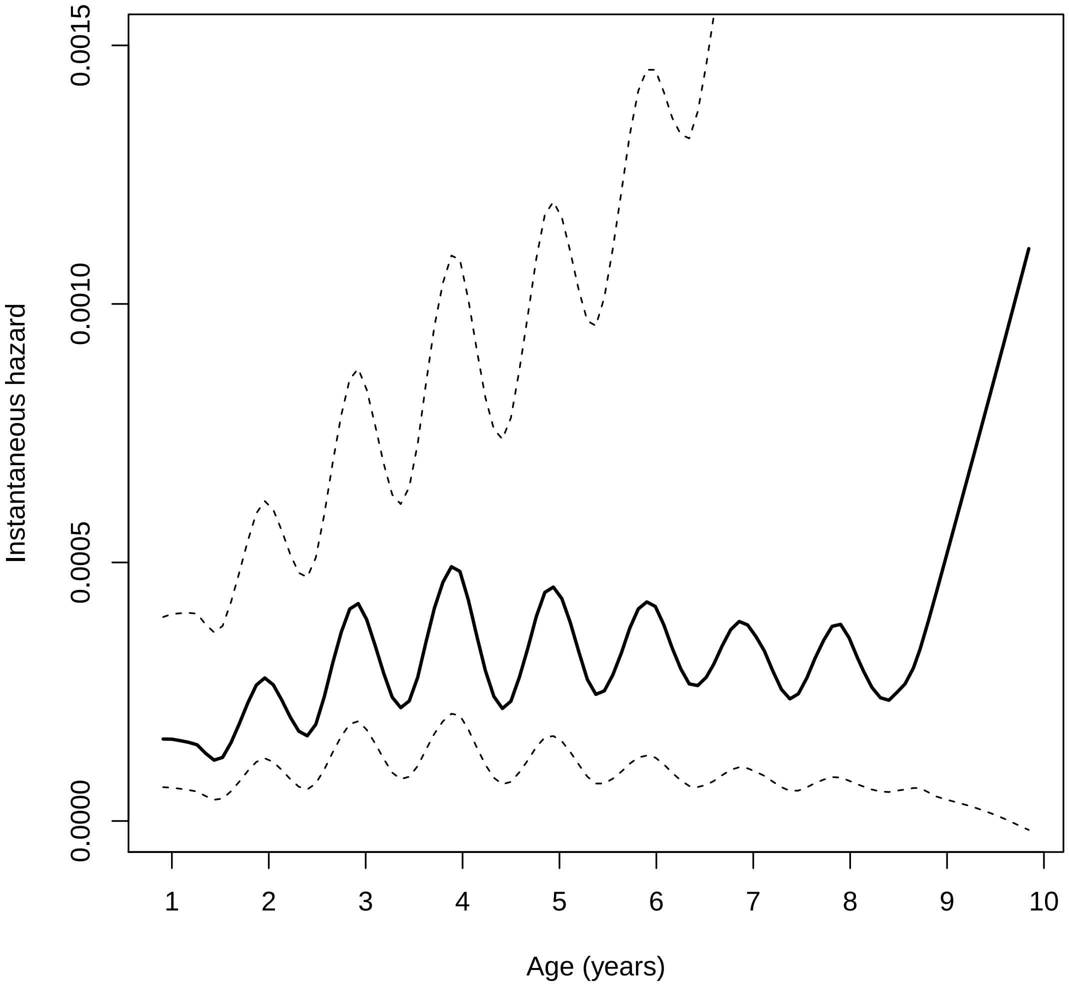

Figure 3.2: Line plot showing the instantaneous hazard of removal for all reasons as a function of age. Instantaneous hazard is expressed as the probability of removal per day. The dashed lines represent 95% confidence intervals around the point estimates of the instantaneous hazard estimates.

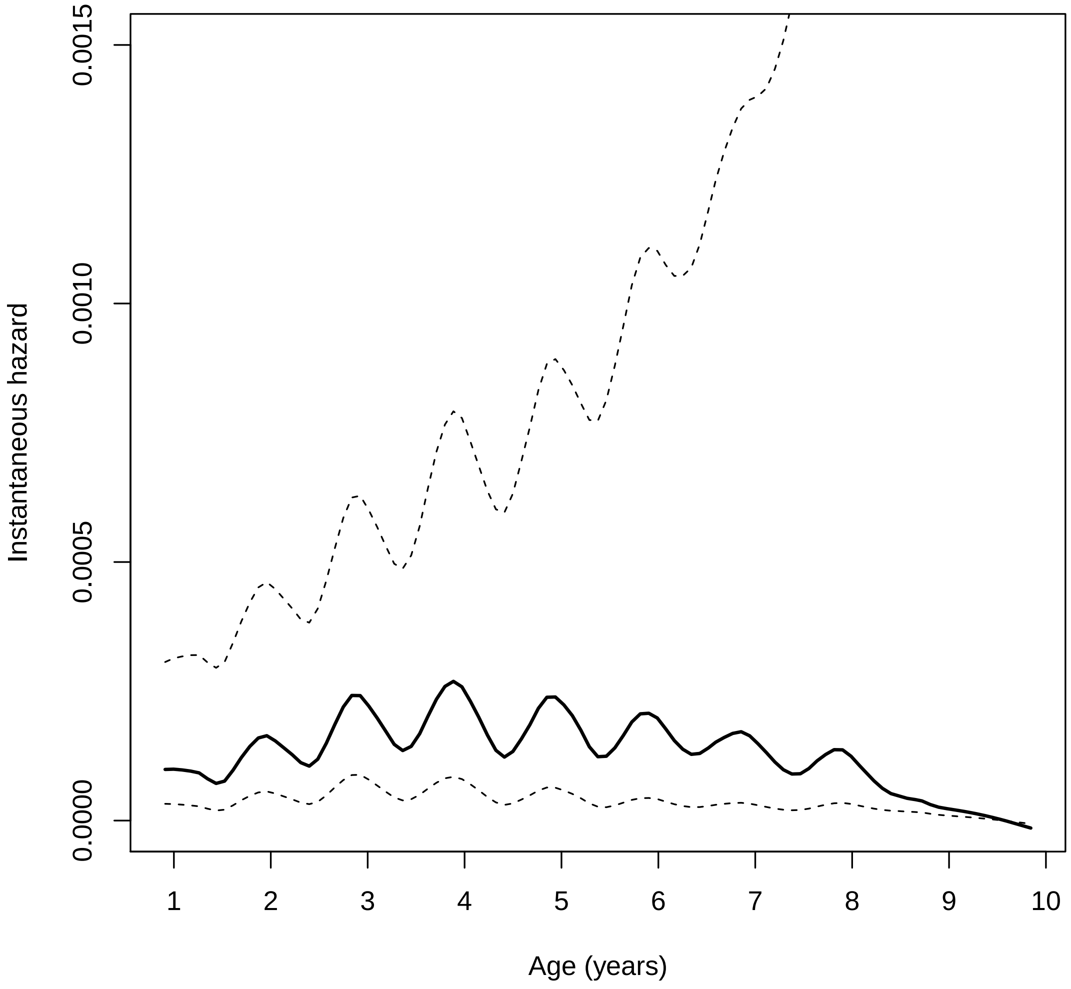

Figure 3.3: Line plot showing the instantaneous hazard of removal by culling as a function of age. Instantaneous hazard is expressed as the probability of removal per day. The dashed lines represent 95% confidence intervals around the point estimates of the instantaneous hazard estimates.

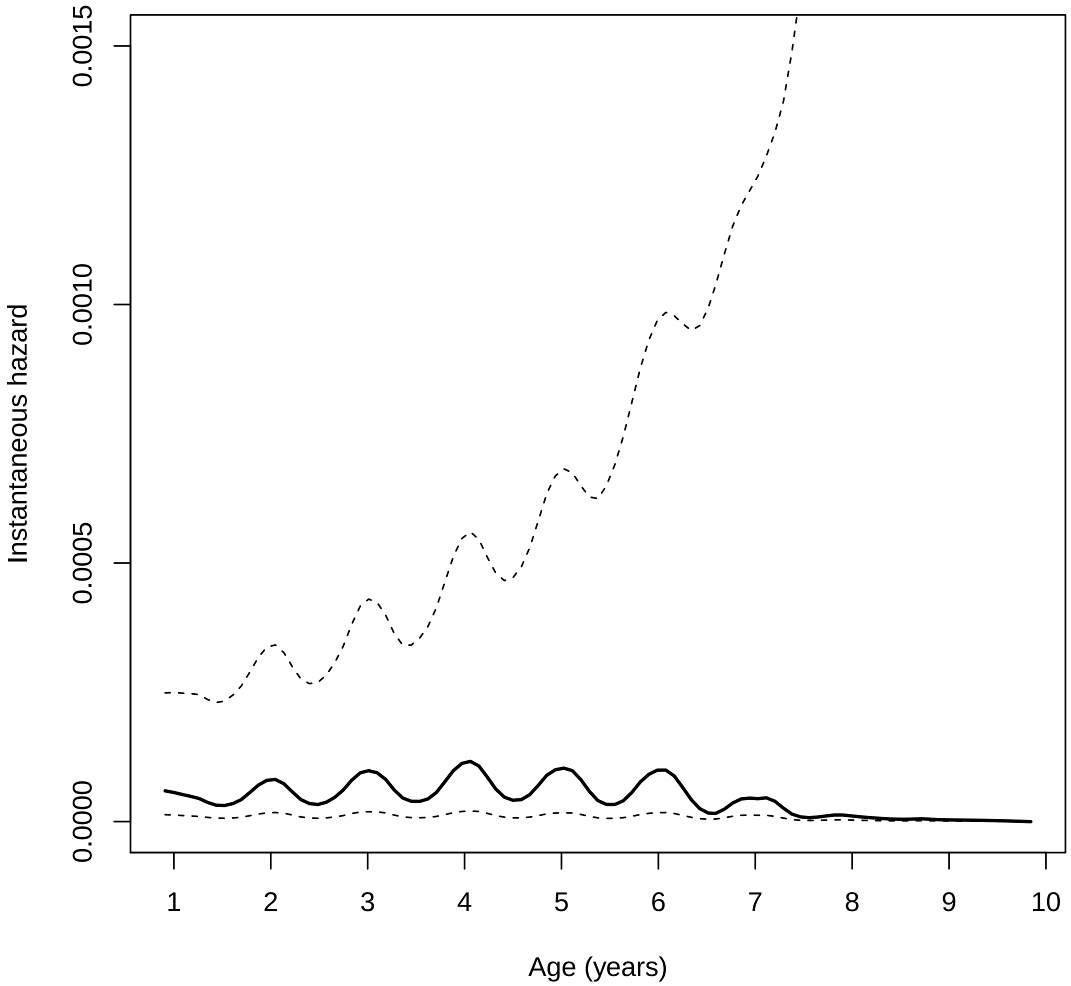

Figure 3.4: Line plot showing the instantaneous hazard of removal by death as a function of age. Instantaneous hazard is expressed as the probability of removal per day. The dashed lines represent 95% confidence intervals around the point estimates of the instantaneous hazard estimates.

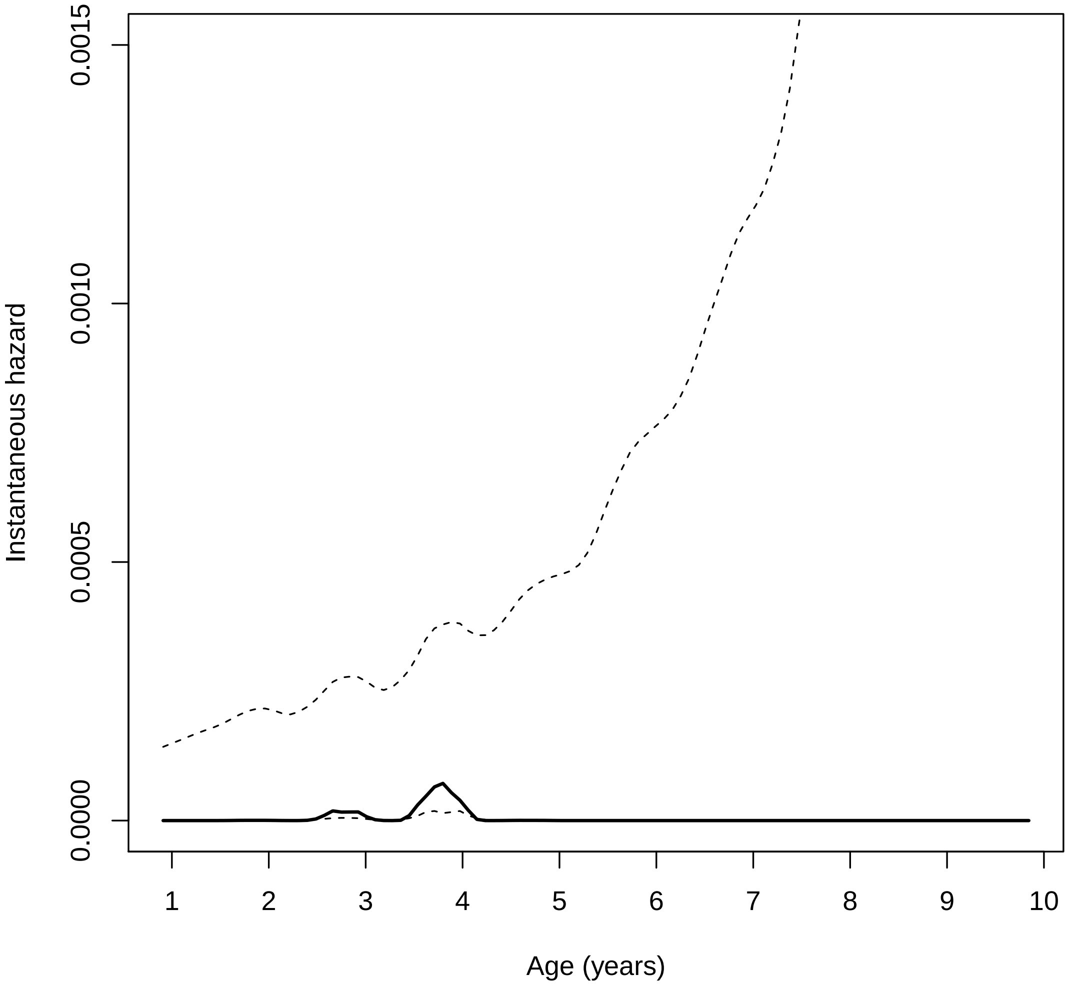

Figure 3.5: Line plot showing the instantaneous hazard of removal by sale as a function of age. Instantaneous hazard is expressed as the probability of removal per day. The dashed lines represent 95% confidence intervals around the point estimates of the instantaneous hazard estimates.

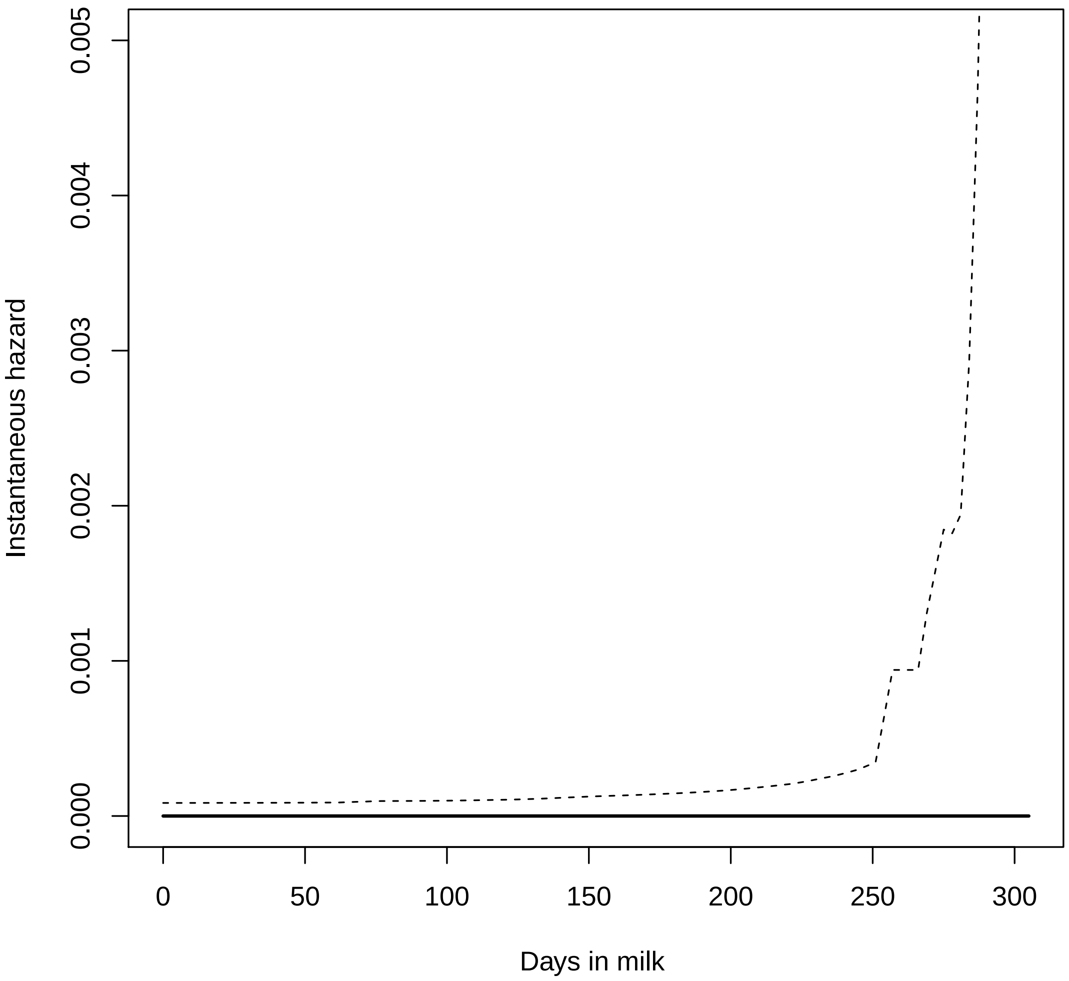

Figure 3.6: Line plot showing the instantaneous hazard of removal for all reasons as a function of days in milk. Instantaneous hazard is expressed as the probability of removal per day. The dashed lines represent 95% confidence intervals around the point estimates of the instantaneous hazard estimates.

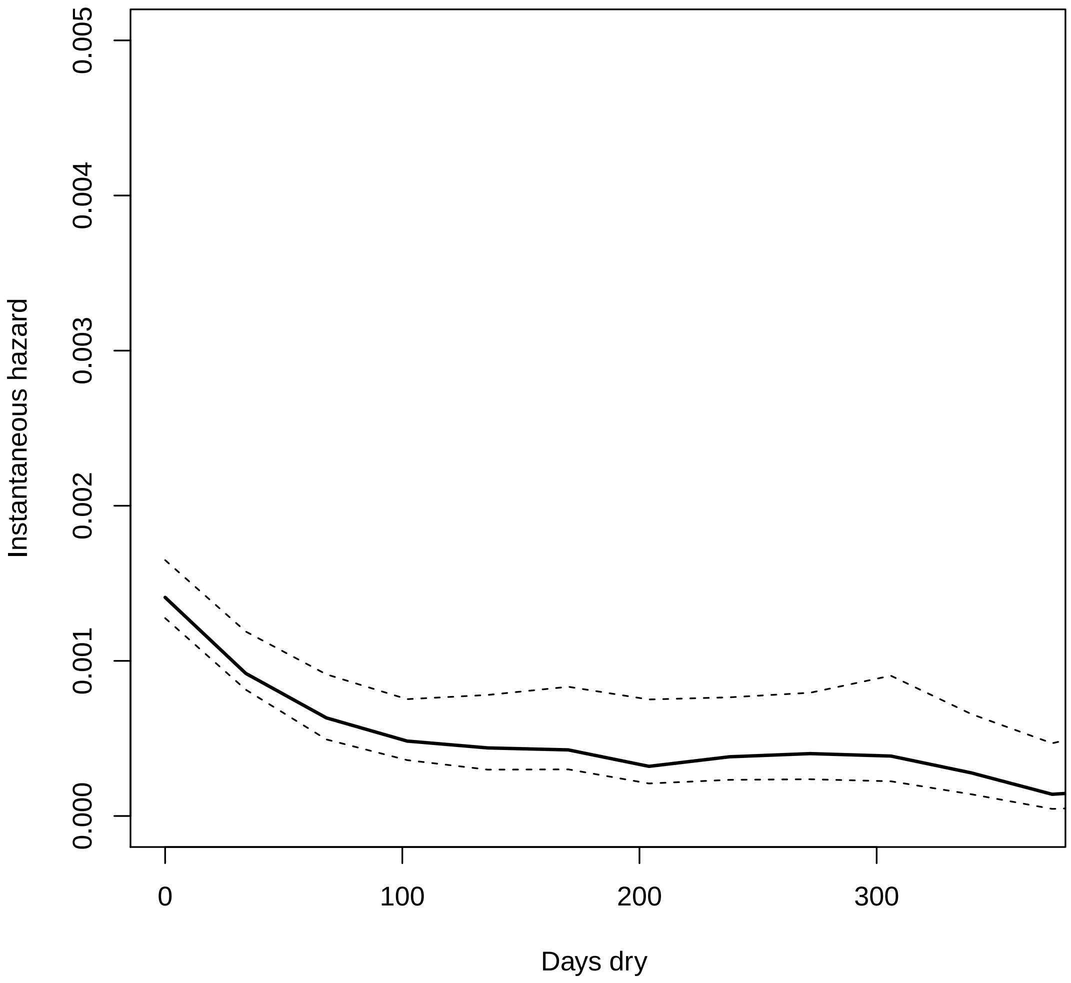

Figure 3.7: Line plot showing the instantaneous hazard of removal for all reasons as a function of days dry. Instantaneous hazard is expressed as the probability of removal per day. The dashed lines represent 95% confidence intervals around the point estimates of the instantaneous hazard estimates.

3.4 Discussion

This is a descriptive analysis of the production and survival characteristics of goats registered with the NZDGC for the period 1 January 2000 to 31 December 2009. The descriptive and analytical phases are two important components of an epidemiological investigation (Putt et al. 1988). While the former attempts to quantify the occurrence of an epidemiological event (for example disease, death, culling) the latter aims to determine the factors that influence such events. Since this study describes the findings of only the first of the above two steps, only the observed demographic and production characteristics and patterns of removal are presented and discussed.

A secondary dataset was used in this study which means that, because the data were not collected for the purpose of research, the researcher is not in a position to control the quality and methods of data collection (Sorensen et al. 1996). In spite of this disadvantage it is common to use secondary data in epidemiological research due to time and resource constraints. In addition, with secondary datasets a researcher is more likely to obtain a larger and more representative sample for analysis (Sorensen et al. 1996). An attractive feature of the data used in this study was that it had been collected over more than a decade, providing a unique opportunity to understand the current practices of data recording on commercial goat farms and to identify possible areas where data collection efforts by the NZDGC could be improved in the future.

Since the number of dairy goats and herds in New Zealand are relatively small we have assumed the farmers and herds affiliated with the NZDGC are representative of commercial dairy goat farming in the country. Based on recent estimates of the total number of goats in New Zealand (Food and Agriculture Organization of the United Nations 2011b) the number of goats in this study represented approximately 30% of the total New Zealand goat population. The Saanen is the most predominant breed of dairy goat in New Zealand (Orr 2009) and our results show that the NZDGC herds represented in this study were similar to other herds in the country in terms of breed composition. Originating from Switzerland, Saanens are popular for their milk producing capacity and they are the principle breed of dairy goat in other regions of the world (Haenlein 1996, Goat Industry Council of Australia 2011).

The median age of does at first kidding in this study was 394 days. This was slightly higher than the average age of 365 days reported in an American study by Majid et al. (1993), but lower than the 450 days and 840 days reported in an American and Cuban study by Alderson & Pollak (1980) and Ribas et al. (2003), respectively. Pérez-Razo et al. (2004) discussed the advantages and disadvantages of delayed reproduction in goats. The advantages of delayed age at first kidding include a higher stayability of does and increased milk yield during the first lactation. On the downside, the lifetime potential of does to produce kids and milk may be reduced. Aside from genetics, sub-standard husbandry, such as that related to feeding and reproduction (Mtenga et al. 1992) may be associated with delayed reproduction.

In this study the median parity at the time of removal was 2. These findings are similar to those reported by Olivier et al. (2005) in a study of Saanen, Alpine and Toggenburg does in South Africa and a study by Serradilla et al. (1997) based on Malaguena goats in Spain. Alderson & Pollak (1980) reported an average of 1.95 lactations per doe in a study of Alpine, LaMancha, Nubian, Saanen and Toggenberg goats in the USA.

In profitable dairy cow enterprises, the average number of completed lactations per cow is expected to be at least four (Knaus 2009). We were unable to find such a comparable figure for dairy goats in the literature, although it can be expected that an increase in the average number of completed lactations per doe will help to offset the cost of rearing, leading to increases in individual doe net profitability.

Miscellaneous disorders comprised the most common cause of removal of does in this study. This finding may, in part, be explained by the wide array of disorders classified as miscellaneous (Table 3.1). Stratification of this category showed that non-infectious causes of death and culls were the most important factors for removal (Table 3.3). The data that was available for analysis did not allow us to carry out an in-depth exploration of all removals classified as non-infectious. However, based on the evidence available in the literature (Morris et al. 1997, Orr 2009) we speculate that gastrointestinal parasitic infections are likely to comprise a substantial component of the non-infectious causes of removal. Further studies in this regard are therefore warranted.

Unlike in dairy cows, where a small number of categories of disorders such as reproductive failure, udder disorders and lameness comprise the bulk of involuntary removal reasons, we found no such clear trends in this population of dairy goats. Instead, the largest category of removals were those listed as miscellaneous, comprised of several diseases that were, by themselves, too trivial to be reported as a separate group. The range of disorders within the non-infectious category implies that those managing or advising on the productivity of dairy goat farms need to have detailed knowledge on the control and prevention of a wide range of individual health disorders.

Approximately equal proportions of does were removed for udder and reproductive disorders in this study. In contrast, many studies have reported reproductive disorders as the most common cause of culling in dairy cattle (Milian-Suazo et al. 1988, Esslemont & Kossaibati 1997, Bascom & Young 1998, Stevenson & Lean 1998a, Seegers et al. 1998). Comparisons between studies should be made with caution, because definitions of categories of disorders are likely to vary. Nevertheless, some of the differences between our study and the cow-based studies cited above might have been a consequence of the difference between species and management practices. A study of French goats found that infertility was the fourth most common reason for removal (Malher et al. 2001).

The maximum instantaneous removal hazard (expressed as a probability of removal per day) increased gradually from the first year of life through to four years of age. After that time the instantaneous hazard of removal remained fairly constant up to eight years. A sharp increase in the daily probability of removal beyond eight years is expected given the positive association between mortality hazard and age that exists in all mammalian species.

Within a given lactation cycle the instantaneous removal hazard for a doe in milk was relatively low (Figure 3.6), compared with the early dry period (Figure 3.7). This indicates that for most conditions necessitating removal, does were sufficiently healthy to complete the current lactation before being removed. A typical example would be those that failed to conceive. In this case herd managers would keep a doe until the end of lactation and then remove her when she became no longer productive at the time of dry off. In dairy herds is not unusual for infertile cows to be removed at the end of lactation (Beaudeau et al. 1994, Seegers et al. 1998).

In this study, the proportion of does that were removed voluntarily was lower than the proportion of does removed involuntarily. Although not the exclusive indicator, the proportion of animals removed for voluntary and involuntary reasons reflects the efficiency of herd management. If there is a reduction in the proportion of involuntary removals, it is possible to retain productive animals and replace the less productive ones. Over time, a reduction in the frequency of involuntary removals results in an increase in the number of high-yielding animals in the herd and a decrease in replacement costs because the cost of rearing replacements is amortised over a longer period of productive life (Stevenson & Lean 1998a).

3.5 Conclusions

Our findings show that non-infectious disorders are a major source of loss in New Zealand dairy goat herds. Further research is required to more precisely define the disorders that comprise this category so that appropriate preventive measures can be applied to offset their impact. Regardless, the range of disorders within the non-infectious category implies that those managing or advising on the productivity of dairy goat farms need to have detailed knowledge on the control and prevention of a wide range of individual health disorders.

CHAPTER 4

Risk factors for removal in New Zealand dairy goats

Abstract – A long length of productive life (LPL) is an economically important attribute in dairy animals. The aim of this study was to identify herd- and individual animal-level characteristics associated with LPL in dairy goats, within a New Zealand context.

A secondary dataset comprised of details of n = 13,197 does was used to analyse the effects of breed, first lactation milk yield and herd on LPL using a piece-wise Cox proportional hazards model. The yield of milksolids in the first lactation (MSL1) was significantly associated with LPL however its effect varied over time. LPL was therefore divided into two intervals: less than, or equal to, two years from the date of second kidding (T1) and greater than two years from the date of second kidding (T2). The effect of MSL1 on LPL was quantified separately for each interval.

In T1 does that had high MSL1 yields (>60 kg) had a lower hazard of removal compared with low MSL1 producing herd mates (those producing <31 kg). In T2 does that had high MSL1 yields had a higher hazard of removal compared with low MSL1 producing herd mates. The effect of herd, included in the model as a frailty term was highly significant (P <0.01) implying that some herd managers were better at managing LPL compared to others.

Our findings indicate that herd managers should take steps to reduce the likelihood of preventable losses among high MSL1 producers as they get older. This strategy will help to maximise the LPL of a profitable subgoup of the herd.

4.1 Introduction

In farmed animal production systems, (e.g. dairy, beef cattle, pig and dairy goat farms), a long length of productive life (LPL) for individual production units is an essential prerequisite for economic efficiency (Pérez-Razo et al. 2004). In dairy systems LPL is defined as the interval between delivery of the first offspring and the date of removal from the herd (Essl 1998). Longevity, on the other hand, refers to the age of an animal at the time of removal. Increasing the LPL of dairy animals means that the cost of rearing replacements is amortised over a longer period of income production (Stevenson & Lean 1998a).

A better understanding of factors that affect LPL can ultimately be used to enhance the productivity of dairy herds. With such knowledge, it would be possible to identify early indicators of removal and depending upon the strength of a particular factor, it may be possible to plan in advance the best time to remove an animal from a herd, when it is still profitable to do so — or at least incur the least amount of cost. Let us take an example from a dairy herd and assume that female calves with a low birth weight have a short LPL. A herd manager, who is aware of this information, may plan in advance the fate of the calves that are born with low birth weights. This approach not only saves the cost of raising calves that would end up having a short LPL, but also increases the frequency of calves with normal birth weight that would have a relatively longer LPL.

Survival analysis is a common technique used to quantify longevity (or LPL) in domestic animals (Radke & Shook 2001). Using survival analysis, the association between individual animal characteristics and removal can be examined, in terms of their effect on the time to the event instead of simply describing the relationship in terms of risk (Stevenson & Lean 1998a). In survival analysis a quantity termed 'hazard' is modelled instead of longevity itself (Forabosco 2005). Hazard represents the instantaneous probability that an animal is removed at a given time, given that it is still present up to that time. Since it is the hazard that is modelled and not the longevity, it is possible to use data from animals that have not yet been removed from the herd (as censored observations) in addition to those that have been removed (Forabosco 2005).

Although a number of studies have been carried out to identify risk factors for removals in dairy cows (see, for example, Seegers et al. 1998, Stevenson & Lean 1998b and Bell et al. 2010), the number of similar studies in dairy goats is limited (Malher et al. 2001, Pérez-Razo et al. 2004) and, to the best of our knowledge, none have been conducted within a New Zealand context. In order to address this information gap the objective of this study was to identify individual animal-level characteristics influencing LPL in dairy goats from commercial herds in New Zealand. Such knowledge will be helpful to goat farmers when setting their priorities for herd management and making rational decisions on disposal. This information assists herd managers to carry out the process of removing animals from a herd in a planned (as opposed to reactionary) way.

4.2 Materials and methods

The data for this study were obtained from the New Zealand Dairy Goat Co-operative (NZDGC), a farmer-owned organisation based in Hamilton, located in the upper North Island of New Zealand. Although the complete dataset was comprised of records for a total of 48,699 animals (including those with birth dates as early as August 1983) only those born on, or after, 1 January 2000 were used in the analyses presented in this study. This restriction was applied because the majority of animals born prior to January 2000 had missing observations, particularly those related to lactation length, milk, fat and protein yield.

Several other restriction criteria were also applied. For example, bucks were excluded and a doe had to complete her first lactation and then kid for the second time, in order to be included in the study dataset. Finally, the records were screened and limited to those does where lactation length(s) did not exceed 305 days and total lactation yield was less than, or equal to, 1800 kg. Goats were followed until 31 December 2009 or to the date of removal from the herd, whichever occurred first. Further description of the data used in the study is provided in Chapter 3.

Herds registered with the NZDGC record data for individual animals including the unique animal identifier, the date of birth, breed, sex, parity date(s) and the date and reasons for removal (if applicable). Production details such as lactation length, total lactation yields of milk, fat and protein are also recorded. Throughout the study period herd managers recorded details of individual animals into paper diaries or, more rarely, into dedicated herd health software. This information was then submitted to the national milk recording authority, Livestock Improvement Corporation (LIC). LIC merge this information with test-day milk yields measured at approximately 60-day intervals throughout the lactation. Animal biographical details and production data recorded in the central database of LIC are transferred to NZDGC in digital format. This information is used by NZDGC for genetic evaluation of individual animals (Singireddy et al. 1997). Estimated breeding values for milk, fat and protein yields obtained from genetic evaluations are then reported back to participating herd managers.

In the context of this study we define LPL as the difference in time (days) between the date of removal from the herd and the date of second kidding. Similarly, for animals that were still in a herd at the termination of the study (censored observations) LPL was quantified as the time between the date of second kidding and 31 December 2009. This approach was taken in order to ensure that a correct temporal relationship was maintained between exposure (production in the first lactation) and the outcome of interest, LPL.

The total yields of milk protein and milk fat during the first lactation were added together in order to create a single variable called first lactation milksolids yield (MSL1). Within the NZDGC database the different values under each category of breed ranged from 0 to 1. The breed value of an animal was determined by using recorded parental details. However, such recorded details on the parents were not available for all does and in these situations the genotype was specified by the herd manager. Breed was treated as a continuous variable in these analyses. For example, if a doe was 50% Saanen and 50% Toggenburg, the assigned value for each of the two breeds was 0.5.

Since all the covariates in our study were continuously distributed, they were first categorised into quartiles. The Kaplan-Meier technique (Kaplan & Meier 1958) was used to describe the removal of does within each quartile. The log rank statistic was used to test the homogeneity of the survival curves among the quartile groups. Those covariates that showed an association with LPL (that is, a difference in the Kaplan-Meier survival curves that was significant at P <0.20) were selected for inclusion in the multivariate analyses.

In the Cox proportional hazards model (Cox 1972) the hazard of failure at time *t* with a given set of predictor variables denoted *X* is expressed as follows:

$$h(t) = h_0(t)exp^{\sum \beta_i X_i} \tag{4.1}$$

Equation 4.1 shows that the hazard of an event at time t is the product of $h_0(t)$ and $exp^{\Sigma \beta_i X_i}$. The first of these quantities, $h_0(t)$, is called the baseline hazard function and holds a time component t, but no Xs. As a result, it represents how the hazard of removal changes as a function of survival time. The remaining quantity $exp^{\Sigma \beta_i X_i}$ is the exponential of the linear sum of a series of explanatory variables X_i. This quantity represents how the baseline hazard function changes in response to a given set of explanatory variables. In contrast to the baseline hazard function, the set of explanatory variables does not involve a time component t. An additional feature of the exponential expression is that it ensures the estimate of hazard ranges between zero and plus infinity. The estimates of hazard, by definition, are not allowed to have negative values (Kleinbaum 1996).

A key assumption of the Cox model is that of proportionality of hazards. According to this assumption, the effect of a covariate on the outcome of interest does not change over time. That is, the hazards for each level of an explanatory variable must be proportional at all times. If this assumption is violated then the estimated hazard ratios from the Cox model are invalid. In this situation, a stratified Cox model can be developed where separate baseline survival functions are estimated for each strata of the variable violating the proportional hazards assumption. Alternatively time-dependent covariates can be included in the model (Ata & Sözer 2007).

Model development was carried out using the contributed package 'survival' (Therneau 2012) implemented within R version 2.12.1 (R Development Core Team 2012). To start, a saturated Cox model was run including all of the explanatory covariates identified as influencing LPL at the bivariate level. A backward stepwise approach was then used for variable selection. Covariates were then removed from the Cox model one at a time, beginning with the covariate with the largest P value of $>$0.05.

The preliminary Cox model showed that MSL1, Nubian and Alpine were significantly associated with LPL. Nubian and Alpine were subsequently excluded from the model since the number of goats with non-zero values for these two covariates was very low (n = 186 and 167 for Nubian and Alpine, respectively).

The assumption behind including MSL1 in the model as a continuous variable was that the relationship between MSL1 and log hazard was linear. In order to test this assumption MSL1 was categorised into four quartiles and the regression coefficient for each quartile was plotted as a function of the midpoint of each quartile group. Since the line connecting the four midpoints was not linear, we concluded that the relationship between MSL1 and log hazard was non-linear. Consequently, a penalised spline term was used to account for the non-linear effect of MSL1 on LPL.

In order to verify the proportional hazards assumption, the scaled Schoenfeld residuals from the model were plotted as a function of LPL (Therneau & Grambsch 2001). In a model where the proportional hazards assumption holds the Schoenfeld residuals should be scattered around zero. We calculated the Pearson product-moment correlation between the scaled Schoenfeld residuals and LPL. The hypothesis of no correlation between the

Schoenfeld residuals and LPL was then assessed using a χ^2 test statistic. From these analyses, we concluded that MSL1 violated the proportional hazards assumption. To address this issue we divided LPL into two intervals: less than, or equal to, 730 days after the date of second kidding and greater than 730 days after the date of second kidding (referred to as T1 and T2, respectively, in the remainder of this paper). The decision to use 730 days was semi-arbitrary and was selected because, being equivalent to two years, it approximated the median length of productive life in does registered with the NZDGC (Chapter 3). This division allowed us to quantify the effect of MSL1 on the hazard of removal during each period separately. The technique of dividing the time component into intervals, in order to study the effect of a covariate that varies over time is referred to as a piece-wise Cox model.

In addition to the terms, which allowed for the interaction between LPL and penalised MSL1, our final model included the effect of herd as a frailty term. Commonly referred to as a random effect, a frailty term (within the context of this study) is a continuous variable centred at zero and quantifying the effect of unmeasured factors operating at the herd level (such as nutrition, housing and other aspects of management) on LPL. Frailty terms are important because they provide a means for taking into account the heterogeneity within a population arising from individuals within clusters (a herd, in this study) being more similar than those selected at random from the population. Since variations in management practices among herds can be expected, the inclusion of herd as a frailty term is standard practice in studies quantifying risk factors for given outcomes in farmed animal populations (Dohoo & Stryhn 2006).

4.3 Results

The dataset was comprised of lactation records from 23,771 does with a birth date greater than or equal to 1 January 2000. Only 14,248 of these animals completed their first lactation and kidded for the second time. Further screening of the production data and removal of implausible records reduced the final dataset to 13,197 individual does. Of this group 5386 were removed during the follow-up period and the remaining 7811 does recorded as being alive on 31 December 2009 were treated as censored observations. The mean MSL1 yield in the study population was 31 kg.

Table 4.1: Estimated regression coefficients for factors influencing LPL in New Zealand dairy goats from the piece-wise Cox proportional hazards model.

Variable	**Coefficient (SE)**	**Chi square**	***df***	**P**
MSL1 × T1				
Linear	-0.0033 (0.0014)	5.31	1.0	0.021
Non-linear		1.68	3.06	0.650
MSL1 × T2				
Linear	0.0014 (0.0016)	0.82	1.0	0.360
Non-linear		9.02	3.05	0.030
Herd-level random effect		2358.74	13.60	<0.01

As shown in Table 4.1, the interaction between MSL1 and LPL was statistically significant for T1 but not for T2. In T1, when the hazard ratio of removal was plotted as a function of MSL1 (Figure 4.1), the hazard of removal for does that produced more than 60 kg milksolids during the first lactation was less compared with low producers (does that produced <31 kg). In T2 (that is, 730 days after the date of second kidding) the protective effect of high MSL1 yield on the hazard of removal was no longer evident (Figure 4.2). In contrast, the hazard of removal for high MSL1 producers (>60 kg) was greater than that estimated for low MSL1 producers. These results show that relatively high levels of MSL1 production were protective for removal during the early phase of productive life. As does got older those with higher MSL1 yield were at a greater risk of removal compared with lower producing herd mates.

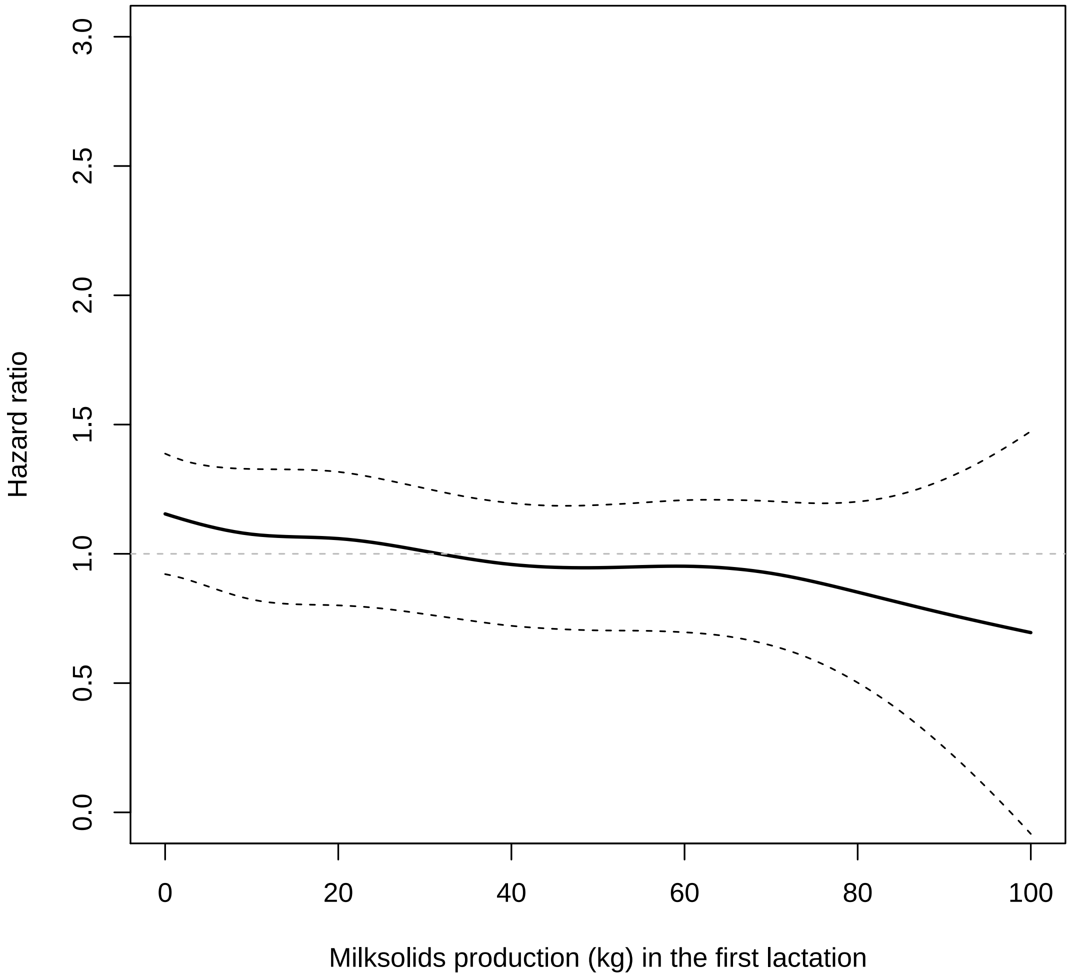

Figure 4.1: Line plot showing, for the interval 0 to 730 days from the date of second kidding, removal hazard ratio as a function of MSL1. This plot is based on the model presented in Table 4.1. The dashed lines represent 95% confidence intervals around the point estimates of the hazard ratio. In the above plot the reference category was a doe producing 31 kg milksolids in the first lactation. A doe producing 10 kg milksolids in the first lactation had 1.2 (95% CI 0.9 to 1.4) times the daily hazard of removal compared with a doe that produced 31 kg milksolids.

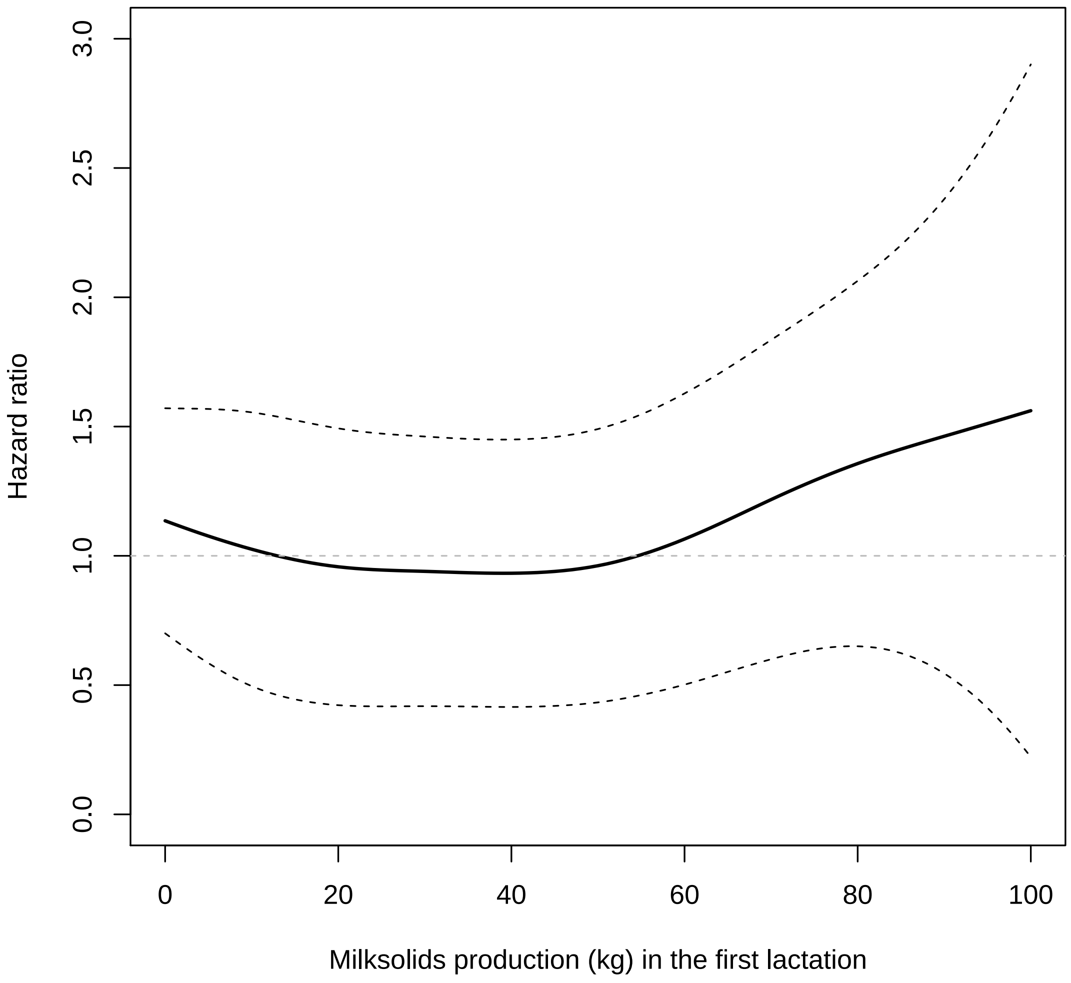

Figure 4.2: Line plot showing, for the interval beyond 730 days from the date of second kidding, removal hazard ratio as a function of MSL1. This plot is based on the model presented in Table 4.1. The dashed lines represent 95% confidence intervals around the point estimates of the hazard ratio. In the above plot the reference category was a doe producing 31 kg milksolids in the first lactation. A doe producing 80 kg milksolids in the first lactation had 1.4 (95% CI 0.7 to 2.0) times the daily hazard of removal compared with a doe that produced 31 kg milksolids.

4.4 Discussion

We used a piece-wise Cox model to study the effect of the yield of milksolids, during the first lactation on the length of productive life in New Zealand dairy goats. The Cox proportional hazards model is popular in biostatistics and is commonly used to study longevity in dairy cows (Beaudeau et al. 1995, Booth et al. 2004). To the best of our knowledge, this study is the first of its type to evaluate the effect of a time-varying covariate on the length of productive life in dairy goats.

One of the limitations of our study was that the data used for analysis came from only those herds that participated in the LIC herd testing programme, resulting in selection bias. As a result, our findings may have limited application to commercial herds that do not participate in herd testing. Furthermore, in studies investigating risk factors for removal in dairy animals it is desirable to study characteristics influencing removal for specific reasons (e.g. reproductive failure, udder health and lameness), as opposed to those influencing removal for all reasons considered as a single group. Failure to do so is likely to mask some of the more subtle influences on longevity. In this study, we could not evaluate risk factors for specific removal reasons for two reasons. Firstly, the data consisted of farmer-reported removal reasons and we could not ensure consistency of case definition over time and across herds. Ensuring the use of consistent case definition is a necessary prerequisite, if risks for specific removal reasons are to be examined in any detail in future studies. Secondly, in contrast to dairy cattle, the number of categories for removal reasons was relatively large and for this reason stratifying the data would have resulted in small group sizes leading to insufficient statistical power to detect effects of biological significance.

Longevity refers to the age of animals at the time of removal from a herd. Based on this definition it is not possible to obtain a direct measure of longevity for all animals, particularly those that are younger and still present in a herd (Szabó & Dákay 2009). An attractive feature of survival analysis is that the technique uses information from all animals within a study group, regardless of their removal status. We defined LPL as the number of days between the date of second kidding and the date of removal from the herd. Although this meant that data from does that kidded on one occasion only (n = 9523) were excluded from the analysis, the advantage of this approach was that the correct temporal sequence between exposure (MSL1) and the outcome of interest (LPL) was ensured.

Our results show that in the first two years after the date of second kidding does with a relatively high MSL1 yields were less likely to be removed compared with does with lower MSL1 yields. This trend reversed beyond two years after the date of second kidding such that does with high MSL1 yields were more likely to be removed compared with low producing herd mates. These results provide useful information for the management of dairy goat herds. As high producers get older, herd managers need to take steps to ensure that does are managed in such a way to minimise the impact of factors that influence the risk of removal. For example, a herd manager might elect to run his/her high MSL1 producers as a separate mob and to provide preferential feeding, housing and milking management for this group. Such efforts can be expected to increase the LPL of a potentially highly profitable subgroup of the herd.

Unlike the situation in dairy cattle, a search of the literature found no studies investigating the association between first lactation milksolids yield and LPL in dairy goats. Examples of such dairy cow-based studies include Robertson & Barker (1966), Pasman et al. (1995), Stevenson & Lean (1998b), Haworth et al. (2008) and Sawa & Krežel-Czopek (2009). While total lifetime yield can be expected to be high in dairy cows that produce more milk during their first lactation (Jairath et al. 1995, Haworth et al. 2008, Sawa & Krežel-Czopek 2009), overall reproductive performance in these animals is known to decrease (Sawa & Krežel-Czopek 2009). An explanation for this observation is that animals producing large volumes of milk during early lactations are subject to a higher level of metabolic stress as a result of negative energy balance (Pasman et al. 1995). In turn, this is believed to have a negative impact on fertility (Pryce et al. 2004). Since we investigated the effect of MSL1 (instead of first lactation milk yield on LPL) and our study involved goats, it is not possible to directly extrapolate the results of the above cow-based research to the findings reported in this study. Nevertheless, it would be biologically plausible that high yields during the first lactation would have a negative impact on energy balance (and therefore, reproductive performance) in dairy goats.

In this study the influence of MSL1 on LPL was investigated using a model that included herd as a frailty term. The significance of the herd-level frailty term indicates that, after controlling for the effect of MSL1, LPL varied across herds. This means that LPL varies across herds, implying that some herd managers are better at managing LPL than others.

Studies comparing those herds with upper quartile frailty terms with those herds with lower quartile frailty terms should be useful in terms of identifying herd-level factors that are influential determinants of LPL. For example, a cross-sectional survey could be designed to investigate various aspects of management such as nutrition, veterinary care, breeding practices and milking practices in upper quartile and lower quartile herds.

In general, where heterogeneity is an unavoidable feature of a population under investigation, researchers should take into account the existence of dissimilarities among groups in order to avoid errors during analysis. Typically, by failing to acknowledge such heterogeneity, one is more likely to make a Type I error, which means he/she is likely to report that an association between an explanatory and outcome variable exists when, in fact, there is none. Interestingly the protective effect of high MSL1 on the hazard ratio of removal in T1 was evident only after the herd-level random effect term was included in the model. When the effect of herd was not taken into account, high MSL1 yield in T1 was positively associated with an increase in the hazard of removal.

4.5 Conclusions

This study has demonstrated the time varying effect of MSL1 on the length of productive life in New Zealand dairy goats. Our results show that relatively high levels of MSL1 production were protective for removal during the early phase of productive life. As LPL progressed however, does with higher MSL1 yield were at a greater risk of removal. Our findings indicate that herd managers should take steps to reduce the likelihood of preventable losses among high MSL1 producers as they get older. This strategy will help to maximise the LPL of a profitable subgoup of the herd.

CHAPTER 5

General discussion

This thesis has documented the length of productive life (LPL) and reasons for removal in a cohort of New Zealand dairy goats. Our findings were that, compared with dairy cows, dairy goats were removed for a wide range of reasons. Furthermore, first lactation milksolids yield had a time-dependent effect on LPL. Due to differences in the findings reported here and the findings of similar, dairy cow studies, we conclude that longevity studies specifically involving goat populations need to be conducted, instead of extrapolating inferences from dairy cow-based studies. Nevertheless, dairy cow-based studies are helpful for understanding general concepts and the methodologies used in longevity research and such studies provide a useful starting point for informing the design of observational epidemiological research in dairy goat populations.

It has been established that a removal decision in dairy cattle is essentially an economic process. The same should also hold in the case of dairy goats. This being the case, the possibility of using mathematical models to assist in the removal decision process should be explored in dairy goat herds. For instance, dynamic programming and marginal net revenue techniques are used in making replacement decisions in dairy cattle and investigation of the application of these techniques in dairy goat production systems should be a potentially profitable area of future research.

Survival analysis was the main analytical technique used in this thesis (Chapters 3 and 4). In Chapter 4 a piece-wise Cox model was used to quantify the effect of first lactation milksolids yield on the hazard of removal. A key advantage of this approach was that analytical power was increased by using information from goats that experienced the outcome of interest (i.e. those that were removed from the herd) as well as those that were present at the end of the follow-up period (censored observations). Linear regression (or a variant of this technique) would have allowed us to model the length of productive life, but it would have only used details of those goats that had been removed. Logistic regression, on the other hand, would have used details of both removed and non-removed goats, but it would not have provided an estimate of the effect of covariates on the amount of time taken for the outcome of interest to occur.

A description of the reproductive and productive characteristics of goats, in Chapter 3, provided information on the current status of dairy goat production in New Zealand. Our findings were that the median number of lactations commenced at the time of removal was two. Compared with dairy cattle, goats were removed for a wide range of reasons, including both infectious and non-infectious disorders.

The analytical study presented in Chapter 4 identified a non-linear relationship between MSL1 and the daily hazard of removal. In addition, the effect of MSL1 on hazard varied over time. For the two years following the date of second kidding there was a negative relationship between MSL1 and daily removal hazard. After this time the protective effect of high MSL1 yield was no longer present and as MSL1 increased daily removal hazard also increased, although non-significantly. A plausible explanation for this trend is that herd managers were able to preferentially retain high producers when they were young (up to four years of age). As high producers aged their ability to resist removal decreased to the point where their removal hazard beyond four years of age (approximately two years after the date of second kidding) exceeded that of those that produced average amounts in the first lactation.

5.1 The New Zealand Dairy Goat Co-operative data

To the best of our knowledge the analyses presented in this thesis are the first studies of this type involving New Zealand dairy goats. We acknowledge that the data that was used were not originally collected for this purpose. The use of routinely collected data provided a number of distinct advantages in terms of saving time and other resources (both human and monetary), compared with situations where data are collected to address a specific research question. Moving forward, we recommend that the findings from this study are used to further improve the quality of data routinely collected by NZDGC. One example would be the recording of removal reasons. In Chapter 3 we found that 19% of does that were listed as being removed did not have a corresponding removal reason. Extension staff should encourage herd managers to record a removal reason for all animals that leave their herds and take steps to ensure that there is consistency in the use of cited removal reasons across herds. In this way greater value can be derived from future analyses of the NZDGC database.

We found that not all dairy goat farmers in New Zealand maintain biographical and production data on their goats at the individual animal level, but rather they do so only at the herd level. The reasons for this include: (1) the general inconvenience of observing, recording and maintaining individual animal records and (2) a lack of motivation among farmers probably due to the fact that historically, there has been relatively little financial and/or production incentive to do so. Detailed and accurate data recorded at the individual animal level can undoubtedly serve as a useful guide for better understanding and identifying herd-level production inefficiencies (Blood et al. 1978). Therefore, we propose some modifications in the existing systems of record keeping by dairy goat farmers, which will help to retain detailed and accurate individual animal data sets. Such efforts would support the development of the New Zealand dairy goat industry in the long term. Our recommendations are as follows:

1. Individual animal records should be routinely recorded on all dairy goat farms. Observations regarding production, disease status, vaccination and reproductive performance should be regularly updated. Wherever possible, dedicated software should be used for record keeping. Events such as birth date, kidding date(s), dry off date(s), service dates(s) and removal date (if applicable) must be recorded because with this information details such as age of the animal, lactation and dry off length and length of productive life can be calculated.

2. Specific effort should be made to accurately and consistently record removal types classified either as sales, slaughters, salvages, or death. Herd managers and their staff should be trained to ensure that they have a clear understanding of the difference between each of these removal types. Furthermore, pre-defined case definitions for removal reasons should be developed and steps taken to ensure that these are used consistently across farms.

3. Secondary and tertiary removal reasons should be recorded in addition to the pri-

mary reason. This will provide a better understanding of some of the more subtle factors influencing the risk of removal in dairy goats. For example, a herd manager would probably remove a doe with mastitis (as a primary reason) and bad temperament (as a secondary reason) earlier than a doe with mastitis or bad temperament alone.

4. Mathematical models based on retention pay-off or dynamic programming techniques have been successfully used to aid replacement decision-making in the dairy industry. The use of such methods ensures that a formal economic analysis has been performed prior to replacement decisions being made, rather than removing animals as a reactionary process. The possibility of using these models in the context of dairy goat farming should be explored. Regardless of which approach is used accurate information on biographical and production details of animals are prerequisites for a successful execution of this process. This reiterates the significance of proper and accurate data recording on farms at the individual animal level.

5.2 Goat research in developing countries

The overall position of the goat industry can be analysed more effectively if the scenario is presented separately for developing and developed countries. Developing countries maintain more than 95% of the world's goat population (Dhanda et al. 2003, Castel et al. 2010) but, unlike in developed countries, goats are managed in small flocks comprised of anywhere between three and 10 animals (Dhanda et al. 2003). Such goats are generally managed under tethering and extensive production systems. In addition, they have limited access to conserved forage and housing (Devendra 1980, Dhanda et al. 2003). Furthermore, goats in developing countries have a greater socio-economic significance, since they are used for a variety of purposes other than milk and meat production, such as the production of fibre, fertiliser and horn, or for transport, sport or prestige. Despite their significance, the current amount of research conducted on goats in developing countries is substantially less than that in developed countries (Sahlu & Goetsch 2005). This problem is partially attributable to limited financial and human resources in developing countries (Sahlu & Goetsch 2005). In addition, a smaller herd size means that a relatively larger number of farms and/or people have to be included in observational epidemiological studies in order to ensure sufficient sample sizes. Finally, as identified by Morand-Fehr & Lebbie (2004), there is an overall trend among researchers to choose other animals (such as cattle) over goats for their research. Regardless of the reasons for this paucity of goat-focused research, the predicament is unfavourable to the overall development of the goat industry in developing countries (Boyazoglu et al. 2005).

It has been estimated that the world's population will increase from less than 7 billion in 2012 to more than 9 billion by 2050 and the vast majority of this increase will occur in developing countries (Food and Agriculture Organization of the United Nations 2009). As a result of both population and economic growth coupled with rapid urbanisation in developing countries, the demand for food derived from livestock will increase. Under these circumstances, where on the one hand population growth has been so rapid and on the other hand the availability of land to support large ruminants is scarce (Sahlu & Goetsch 2005) the goat should be regarded as a promising source of animal protein, calcium and vitamins to meet human nutritional requirements.

The goat offers a number of advantages over large ruminants such as cattle or buffalo (Peacock 1996). For example, goats use fibrous feed more efficiently and they can be fed successfully on low quality forages. Similarly, they can adapt to a wider range of climatic conditions. Furthermore, goats have a relatively fast reproductive rate, which means that herds can be populated in a relatively short period of time and a return on investment can be achieved earlier. Finally, goat production requires fewer facilities and goats are easier for women and children to handle. However, issues such as their susceptibility to predators and internal parasites are seen as limiting factors.

These advantages, *per se*, would mean little, unless developing countries can exploit them by increasing productivity. This increase may be achieved by improving reproductive efficiency in addition to improving nutrition and management (Glimp 1995). Research carried out in developed countries may not be directly applicable to developing countries due to differences in production systems, genetics and environmental variations (Sahlu & Goetsch 2005). It is, therefore, imperative that developing countries encourage and promote local research that addresses the discriminating factors associated with their goat production systems (Boyazoglu et al. 2005).

5.3 Conclusions

In conclusion, this thesis has shown that dairy goats in commercial herds in New Zealand have a relatively short length of productive life and the majority of does are removed from herds due to a wide range of involuntary reasons. These results identify some key areas where herd management can be improved. This thesis has shown that, compared with average first lactation producers, goats with high yields of milksolids in the first lactation are at a greater risk of removal beyond two years from the date of second kidding. A logical response to this finding is for herd managers to take steps to reduce the likelihood of preventable losses among high MSL1 producers as they get older. This strategy will help to maximise the length of productive life of a profitable subgroup of the herd.

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