Final report

Reducing Kid Loss – Select and Protect. Phase 1

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Executive summary

Background

The value of the Australian goatmeat exports peaked at $257M in 2017 but has continued to demonstrate growth since 2014 (MLA, 2020a), with substantial increases in value due to higher in carcase price and goat slaughter numbers. Goat meat production tripled since 2001 without increases in average carcase weight. Hence, surplus goats and price are the main drivers of the increased industry value and therefore, reproduction is an important underlying factor limiting sustainable supply. The review of endemic diseases of the red meat industries (Lane *et al*. 2015) shows that perinatal kid mortality was not an issue of importance to the industry, as determined via surveys of producers and veterinarians. This is in direct contrast to the findings for Australian sheep, for which the same report costed perinatal mortality, including losses of ewes to dystocia and mastitis, at $540.4M. At that time perinatal mortality cost more than 10% of the value of the $5.1B Australian sheep meat and wool industries (ABS, 2016).

Goats are produced in many of the same areas of Australia as are sheep, yet, while there is a comprehensive knowledge of the reproductive performance of sheep, there are few Australian-specific reports on goat reproduction, disabling any capacity to assess the extent and impact of reproductive wastage in the industry.

Objectives

This project aimed to establish a baseline understanding of reproductive wastage, causes and costs of reproductive wastage in the Australian goatmeat industry and make recommendations to effectively address of reproductive wastage, including outlined additional RD&A requirements.

Methodology

To achieve this, several levels of investigation were undertaken. These included a review of literature; an investigation of disease submissions made to State Laboratories; twenty goatmeat producer case studies; the collection of goat pregnancy scanning and kid marking rates from over 9,000 does; an estimate of the cost of kid loss to the Australian managed meat goat sector and; an examination of the impact of reproductive wastage at the farm level, using farm system modelling software, GrassGro. As the project progressed, messages and findings were made available to the industry via webinar, conference presentation, radio, print and social media as well as Goats On the Move circulation.

The collaboration between NSW DPI and Charles Sturt University (CSU) enabled a team to be assembled containing strengths in fields of goat production systems, ruminant reproduction and epidemiology. The collaboration provided the opportunity to build capacity in the goat industry via the development of an Honours-level research project.

Results/key findings

The initial review of literature examined causes of reproductive wastage in the goat, sheep and cattle industries. This review was refined after peer-review to be goat-specific and was expanded to include all components of reproduction with comparisons made against sheep knowledge, when appropriate. The components of goat reproduction include season of breeding, age of puberty, ovulation, fertilisation, embryo and foetal loss, perinatal and post-weaning mortality.

The State laboratory disease investigations commenced with requests made to State Laboratories in NSW, Victoria, South Australia, Western Australia and Queensland. Support from Western Australia and Queensland was not forthcoming due to the focus of those organisations on the risk of African Swine Fever. Data was therefore, only supplied by NSW, Victoria and South Australia.

Following media exposure of the project and direct approaches to goat meat producers, producers engaged with the research team, leading to 20 producers agreeing to participate in a case study of on-farm practices, animal health and reproductive wastage. This component of the project was the primary focus of the Honours student. A total of 40 questions were asked on topics relating to demographics, husbandry practices, animal health practices and concerns, reproductive management, and perceptions on reproductive wastage and kid loss.

The direct approaches and media exposure enabled producers to engaged with the on-farm component of the project. This component involved the pregnancy scanning of does and the collection of doe and kid survival to marking records. A target of 10,000 does from 10 farms was identified as a sufficiently large sample to represent the potential variability. The pregnancy scanning records were targeted to the managed and semi-managed meat goat sector and limited to NSW and QUEENSLAND. Producers were sought to represent several production zones, including the semi-managed rangeland zone, the northern high rainfall mixed-farming, small-scale zone and the southern high rainfall mixed-farming, small-scale zone.

Estimates of the cost of reproductive wastage to the managed meat goat sector were made using information sources that indicated the size of the managed meat goat population and assumptions for the levels of reproductive wastage, such as low fertility and high kid mortality. The size of the meat goat population was adjusted to account for non-female and non-reproductive classes of goats, such as bucks, wethers and weaners. The rates modelled for fertility and kid mortality were derived from the findings of the literature review and the on-farm pregnancy scanning to marking component. Using five-year average meat goat prices and published information about mean carcase weights, the average carcase value was calculated. Industry-scale cost estimates and sensitivities were modelled, with support from Fiona Scott, economist with the NSW DPI Business Strategy and Performance Unit.

Farm-level bio-economic modelling was also undertaken. The farm modelling used the CSIRO developed GrazPlan decision support software (DSS), GrassGro. This software has been developed for sheep and cattle but contains no goat production data. To model the goat, the assumption had to be made that goat production will behave similarly to a sheep genotype with limited wool production. However, since there is no goat, or shedding sheep genotype available in the GrazPlan DSS packages, the small frame Merino model was used with the fleece parameter set to the lowest possible production. The model was established for Trangie in Central Western NSW and was simulated for the time period 1970-2020. Sensitivities were developed to test several combinations of fertility and kid mortality rates. To increase kid mortality, the weather file was manipulated to cause high chill and target levels of mortality, but only in the days after birth.

The review of literature has revealed that the breeding season is typically between March and September, although NSW and QUEENSLAND producer perceptions of the breeding season suggest it can range between December and May. Out-of-season cycling can be manipulated using melatonin implants or with the presence of sexually active bucks. The age at puberty depends on liveweight, nutrition, season of birth and breed. The number of ova shed per ovulation is also influenced by breed and liveweight, but is also influenced by age, body condition, can be up to 40%

higher at the peak of the natural breeding season than outside the breeding season, and is improved by pre-ovulatory nutrition. Mating success is also affected by season, nutrition, age and breed.

Reproductive wastage post-ovulation can be affected by embryonic mortality, which is a common source of reproductive wastage and the levels in goats are similar to sheep. In contrast, fetal losses appear to be higher in goats than in sheep, with susceptibility to abortion storms from around Days 90–120 of gestation. High levels of foetal loss can be due to nutritional stress and has the potential to be a significant cause of reproductive wastage in Australian goats, but little data is available on this as a cause of wastage. Perinatal loss is a major source of reproductive wastage in goats, although there are limited data for Australian commercial herds, KIDPLAN data suggesting mortality to weaning averaged 20%, with notable variation, and is affected by environment, litter size, nutrition and breed effects. Very little literature exists that considers causes of perinatal kid mortality. Dystocia or stillbirth and the starvation–mismothering– exposure (SME) complex appear to be the pre-dominant causes of death. In Australia, producers report predation as a key cause of perinatal mortality. The review has been published with the CSIRO journal, Animal Production Science, and is freely available for industry to access.

Examination of State Laboratory disease submissions reveals a low number of goat submissions compared to cattle and sheep. The reason for low submissions may reflect the extensive nature of the industry. Nutritional disorders were the most commonly identified disease among goat submissions, however, there was generally a low rate of positive diagnoses. There may also be some degree of bias in the submissions process, where producers may not submit samples when they feel they know the cause or may be seeking information about a specific cause.

The producer case studies suggested to the authors, a sense among the participants that sources of information for goat management are either not accessed generally, or not adhered to. Questions relating to animal health found some producers had no regular vaccination regime, deferring sensibly to a needs-based administration, and not all producers were using worm egg counting to guide decision-making for drenching. The participants identified predation, doe nutrition and mismothering were the largest contributors to kid loss.

The on-farm reproduction study revealed fertility rates averaged 71%, with 1.65 foetuses per pregnant doe, and 65% kid survival. Doe survival was reasonable, averaging over 95%. When compared to adults, maiden doe performance was lacking, with lower fertility and higher doe and kid mortality. These performance figures compare within the range reported in the literature. The number of kids marked ranged from 37.5% to 130%. The effect of the intense drought of 2019 was apparent in the study, with the uncertainty about carrying capacity being a barrier to engagement for many producers. Some producers expressed concerns that their nannies were not breeding due to the difficult conditions. The drought impacted on the herds with the lowest reproduction rates observed, where undernutrition impacted on some herds during kidding.

Benefits to industry

Estimates for the cost of reproductive wastage to the managed meat goat sector commenced with assumptions for the size of the population, at 158,761 head, and a mean sale value of surplus progeny calculated using a five-year average price ($5.41) and carcase weight (14.9 kg). At the industry scale, decreasing kid loss from 30% to 20%, at a fertility rate of 95% would increase the value of the managed meat goat sector by approximately $786,710.

Farm-scale modelling was undertaken, and for the first-time, attempts have been made to model the goat using the GrassGro DSS. At the farm scale, the lowest modelled gross margin was 2.7 times lower than the higher estimates. The lowest reproduction rates observed in this 2019 study were insufficient to maintain a self-replacing herd without retaining does to an older age. However, four in ten of the herds observed had high marking rates per doe scanned, indicating a substantial opportunity for improvement in the goatmeat sector.

Future research and recommendations

This project has highlighted numerous areas for further detailed research. Of note include the development of management packages that establish weight and condition score targets for maidens and adult does. Further RD&A needs to closely examine sources of reproductive wastage, such as the factors affecting fertility, foetal losses and the stages at which the losses are occurring and why. Management solutions to need to be developed improve kid survival, including quantifying the role of, and solutions to, predation. The case studies have re-emphasised the need to understand the efficacy of a wide range of drench products, and what solutions may be found via co-inhabiting ruminant species on worm burdens, as well as the role for browse and other forages. Future RD&A opportunities should consider the need to validate the GrazPlan sheep model for use with goats.

The key recommendation for the industry is to implement a number of well selected sentinel herds, where all animals are identified and their lifetime performance is monitored, which will enable a greater record-keeping and improve the understanding of the factors affecting meat goat reproduction and performance. The sentinel farms should be supported by participatory research PDS sites that undertake detailed and specific research studies. The PDS pathway will enable the sentinel farm to operate unencumbered by research designs, adding the value of relevance to the findings from those farms, and demonstrating the rate and value of adoption.

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1. Background

The value of the Australian goatmeat exports was $257M in 2017 (MLA 2020a) and had grown substantially in value since 2014, due to substantial increases in price and higher goat slaughter. Goat production (tonnes, carcase weight) has tripled since 2001 without increases in average carcase weight. Hence, goat numbers and price are the main drivers of the increased industry value. Therefore, reproduction is an important underlying factor limiting supply.

A recent review into the endemic diseases of the red meat industries (Lane *et al*. 2015) shows that perinatal kid mortality was not an issue of importance to the industry. This is in direct contrast to the findings for Australian sheep, for which the cost of perinatal mortality, including losses of ewes to dystocia and mastitis, was $540.4M; at the time more than 10% of the value of the $5.1B Australian sheep meat and wool industries (ABS 2016).

The review by Lane *et al*. (2015) included a survey of 30 goat producers, and while representing all states where goat production occurs, 9 of the producers were in states contributing little to the Australian national production. Most respondents had relatively small goat herds, less than 500 head. The question must be asked whether the sampling process has captured all the available information or, if the matter of perinatal kid mortality and reproduction rates are not important sources of loss in goat herds. Examples of high levels of kid loss are published, for example Mellor and Stafford (2004) cite examples ranging typically between 7% to 51% for countries including Africa, New Zealand, India and Mexico, but can be as high as 85%. Causes of death are generally in line with those understood for neonatal lambs, although a lower tolerance to cold thermal conditions is an important difference. A lack of data is a constraint to understanding the cost of kid loss. Given around 10% of producers adopt pregnancy scanning services, it is not surprising that so little is known about reproduction performances in commercial herds. Nevertheless, the surveys by Nogueira *et al*. (2016) revealed pregnancy rates around 60% for pastoral region herds and 94% for high rainfall zones, with similar litter size prolificacy as, for example, the South Australian Merino sheep (Kleeman & Walker 2005).

Primary issues facing goat producers appear to depend on regional factors. For example, harvest systems are more focused on climate, breed and legislation as major issues affecting production and business, while managed herds focus more on climate, nutrition and predation as issues (Baker *et al*. 2012). Interestingly, both breed and predation are likely factors affecting the number of kids weaned.

Several investigations have been reported into the opportunities available to the goat industry, such as nutrition (Jolly, 2013), where opportunities to induce a dynamic ovulation response may be possible, but largely un-investigated for its applicability to extensive production systems and between genotypes. However, most recent surveys of producer priorities, issues and opportunities, generally have not focused specifically on reproduction rates.

Research and technical specialist officers at NSW Department of Primary Industries led the investigation, partnering with researchers at Charles Sturt University and the Graham Centre. The project was conducted to examine each of the following four components:

1.1 Review of literature

A literature review was conducted, including reviewing all available scientific, government and industry publications. The review includes previous and current research projects on newborn survival and reproductive performance in sheep and goats to assess likely commonality for both species that could inform drivers of kid loss.

1.2 State laboratory disease submissions

The assessment of submissions related to kid loss and goat abortion to state animal health laboratories. State animal health laboratories were contacted to gather information on the level and cause of submissions relating to kid loss/goat abortions in the past 15 years. In addition, data on cattle and sheep submissions in relation to abortions and neonatal loss was gathered for the same period. Data for the three species was assessed, summarised and compared to identify potential commonalities and differences in relation to incidence and diagnosis.

1.3 On-farm reproduction records

Aimed to assess the reproductive performance in goat meat enterprises keeping reproductive records. Using the government and industry contacts of the research team, a list of goat meat producers with managed herds was created and provided to MLA. The estimated cost of kid loss to the industry will be assessed on the basis on the conclusions drawn from components 1 and 2.

a) Case studies to assess reproductive performance was undertaken, via contacting producers to identify those keeping reproductive records and who were willing to be part of a case study to estimate the cost of kid loss. Producers were interviewed to gather information about on-farm reproductive performance and their perceptions on the significance of kid loss to their enterprises. Where available, longitudinal reproductive data was to be collected and analysed to assess reproductive performance. A total of six case studies will be published.
b) Ultrasound pregnancy diagnosis was aimed to be conducted on at least 10,000 does on a minimum of 10 different properties to assess the scanning to kidding losses. The impact of practice change will be collected/estimated through this project for inclusion in reporting and producer communication.

1.4 Analysis of data and recommendations

Information gathered to date was used to estimate the cost of kid loss at a farm and industry level, to make practical recommendations at a farm level in relation to data collection for assessing kid loss and to identify gaps in knowledge and needs for future research and/ or extension in relation to kid loss in the goat meat industry.

Producer engagement and data collection was sought from the production zones identified in Figure 1.1 below, except for Zone 5 because nearly all enterprises in that region are harvest operations.

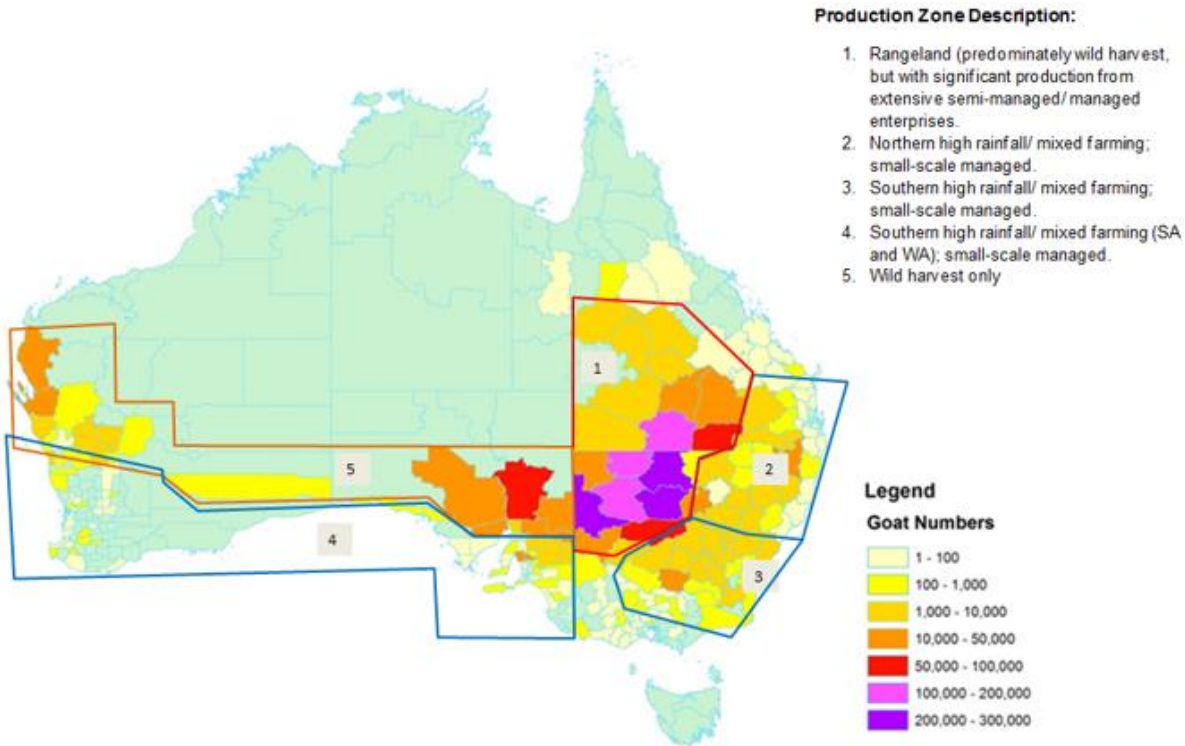

Figure 1.1. The number of goats supplied from each NLIS regionof Australia during the 2016-17 financial year, overlayed with the geographic production zones (reprinted with permission from T.A. Atkinson and W. Smith. Unpublished data. Source NLIS Ltd.)

Communication with the managed and semi-managed goat meat sector was tailored to suit different geographic regions production systems and enterprises. The value proposition to producers for adoption will be clearly articulated. Target audiences include:

- Australian producers with managed and semi-managed rangeland goatmeat enterprises.
- Australian producers with commercial goatmeat enterprises (non-rangeland environments).
- Australian producers who breed stud animals for commercial goatmeat enterprises.

The following awareness raising, engagement and capacity building activities were to be delivered as a part of the:

- Support and guidelines on-farm data collection for producers
- Development and publication of six case-studies
- Four articles published in the Goats on the Move e-newsletter.
- The delivery of 2 webinars
- Presentations at one key industry meeting

A network of producers who want to trial on-farm management practices to address the causes of kid loss identified in the project will also be established.

2. Methodology

Details relating to the methodologies incorporated in the project are fully described in detail in Section 3.

3. Results

3.1 Review of literature

The review of literature examined causes of reproductive wastage in the goat, sheep and cattle industries. This review was produced (Milestone 3) and refined to be more goat focused with elements relating to sheep. The review was expanded to include all components of reproduction, and is reported, as follows. The literature review was submitted to Animal Production Science and the final manuscript has been published.

3.1.1 Introduction

In 2018 the goat industry in Australia was worth $A182 million in meat exports and a further $A7.7 million in live exports (MLA, 2019). While the industry has historically been based on harvesting of wild populations, there is increasing interest in semi or intensively managing goats. The industry aims to increase managed goat numbers to improve the stability of meat supply, and therefore markets and meat prices (Anon., 2015).

Reproductive rate is one of the limitations to production in farmed animals and for goat meat enterprises, weaning percentage is a key determinant of profitability (Norton, 2004). Goats are produced in many of the same areas of Australia as sheep and/or cattle, yet while there is a comprehensive knowledge of the reproductive performance of sheep and cattle, there are limited reports for goats under Australian conditions. The lack of industry benchmarks hampers identification of sub-optimal performance and so the ability to develop and apply management interventions to improve the reproductive rate. Of particular interest is the observation that perinatal mortality was not noted as a priority disease for goats in a recent industry survey (Lane *et al.*, 2015), while it was for sheep and cattle, despite mean kid losses of up to 33% in some regions (Nogueira *et al.*, 2016). Perinatal mortality is the largest source of reproductive wastage in sheep (Kleemann and Walker, 2005b) and improvements increase profitability (Young *et al.*, 2014). Only 10% of goat producers pregnancy scan (Nogueira *et al.*, 2016), and this, combined with the extensive nature of many operations, would limit knowledge of the extent and causes of reproductive wastage.

The aim of this review is to investigate the level of reproductive wastage in the Australian goat industry to provide benchmarks for performance. Since kid losses, particularly perinatal mortalities, are known to be significant, the probable major causes of kid losses will be identified with reference to lambs, where there is a larger quantity of literature and the causes are likely to be similar, and beef cattle, where similar environmental conditions apply.

3.1.2 Reproductive potential in sheep

Fertility, ovulation rate, fecundity, embryonic, fetal and postnatal losses all contribute to the reproductive rate. On average 95% of ewes are expected to mate during the joining period

(Kleemann and Walker, 2005b). If mated, fertilisation rates in ewes are typically high (Restall *et al.*, 1976). The mean fertility or conception rate for both Merino and crossbred ewes on commercial farms mainly in southern Australia has been reported as approximately 90% (Allworth *et al.*, 2016), as assessed at the time of pregnancy scanning. This is consistent with the mean for South Australian Merino flocks in the cereal and high-rainfall zones (Kleemann and Walker, 2005b). In that study, the conception rate varied from 53 to 99% between properties, and in south-west Queensland where the mean was 93%, properties ranged from 77-100% (Jordan *et al.*, 1989). The pregnancy rate particularly for maiden ewes can be markedly lower in some years, and lower rates are reported for a drought year (Fowler, 2007). Low ewe bodyweights at mating have historically been the cause of poor reproduction in many flocks (Plant *et al.*, 1976), and given seasonal variability, are likely to remain so. Regional differences can also be important, with heat-induced infertility of rams and seasonal sub-maintenance levels of nutrition restricting oestrus in ewes being identified as factors limiting fertility in semi-arid Queensland (Smith, 1960). Oestrogenic clover and *Brucellosis* infection were previously significant causes of low fertility rates in parts of NSW (Plant *et al.*, 1976) although their current importance nationally is unknown, given control programs. However, the more recent literature indicates that the conception rates in Australian flocks are generally not the major cause of reproductive loss.

Embryonic mortality is a source of loss of fertilised embryos in sheep with numerous causes, with typical levels 20-30% (Diskin and Morris, 2008). Ewes may have the opportunity to re-mate, depending on the time of loss and the length of the joining period, since most embryonic losses occur prior to day 30 after mating, with fetal losses from day 60 (approximate earliest time of commercial pregnancy scanning) to term ranging between 0 and 5.3% (Viñoles *et al.*, 2012; Quinlivan *et al.*, 1966; Jordan *et al.*, 1989). Higher losses can occur with severe malnutrition, disease, and with multiple ovulations (Kelly *et al.*, 1989).

Ovulation rate limits the potential number of lambs produced. While the mean for Merino ewes in commercial flocks has been reported as 1.4 ova/ ewe, flocks ranged between 1.0 and 2.0 (Kleemann and Walker, 2005b). Ovulation rate and fecundity (number of lambs per pregnant ewe) are increased with autumn versus summer mating, higher liveweight or ewe body condition, higher nutritional conditions and crossbred rather than Merino breed of ewe (Cumming, 1977). In addition to the impact of management, the large variation in seasonal conditions which influence the grazing environment in Australia means there is a wide range in ewe fecundity. Commercial flocks of Merino ewes have been reported to produce approximately 150 fetuses/100 pregnant ewes in southern Australia (Allworth *et al.*, 2016), although lower mean rates are reported (127%) and the variation between properties is large (100 to 172%) in Western and South Australia (Kleemann and Walker, 2005b; Croker *et al.*, 1985). The percentage of ewes bearing triplets is low in the Merino, with reports of 7.8% of pregnancies when the twinning rate was 56% (Holst *et al.*, 2002), but at lower levels of twinning, the percentage of triplets in the Merino is also lower, 1.8% of multiple-ovulating ewes being reported (King *et al.*, 2010). Fecundity is higher in Border Leicester x Merino ewes, and triplets have occurred at 23% of pregnancies when the twinning rate was 48% (Holst *et al.*, 2002).

The mean lamb marking percentage (lambs marked/ewe joined) in a survey of commercial Merino flocks of 78% (range 10 to 115%) in south west Queensland (Jordan *et al.*, 1989) is below the 83% (range 31-124%) in southern Australia (Kleemann and Walker, 2005b). Between year variation is large, with lower marking percentages reported in poor seasons (Jordan *et al.*, 1989).

The difference between high mating, conception and fecundity rates and relatively lower percentages of lambs present per ewe at marking (after the end of the lambing period), is largely due to perinatal mortality of lambs. Perinatal lamb mortality is generally the largest source of reproductive wastage in sheep in extensive Australian conditions (Kelly *et al.*, 1989; Jordan *et al.*, 1989; Kleemann and Walker, 2005b; Croker *et al.*, 1985). Perinatal survival has been reviewed recently by Hinch and Brien (2014). The levels vary widely between flocks, are typically 2 to 3 times higher in twins than singles, and an average Australian level is 20% of lambs born. Approximately 87% of deaths occur during or within three days of birth (Dennis, 1974; Robertson *et al.*, 2011; Hall *et al.*, 1995). Anteparturient deaths (dead before parturition begins) are uncommon in sheep (0.9% (Croker, 1968) to 5% of dead lambs (Dennis, 1974); 0.2 to 4.8% of dead lambs (Hughes *et al.*, 1971). Merino lambs have higher mortality rates than crossbreds (Donnelly, 1984), and Merino ewes have higher levels of loss than other breeds (Allworth *et al.*, 2016). Even in experimental flocks throughout southern Australia, typical levels of mortality were 10% for singles, 20% for twins, and 40% for triplets, but with large variation in levels between years and locations (Geenty *et al.*, 2014). The range in commercial flocks appears to be larger, with reports of between 15 and 85% mortality to marking in South Australian flocks (Kleemann and Walker, 2005b), although these estimates include fetal loss since pregnancy scanning. Lamb losses between marking and weaning are typically small (< 2% (Kleemann and Walker, 2005b)) but mean post-weaning losses vary widely, for example 5.9% (Hatcher *et al.*, 2008) and 14% (Campbell *et al.*, 2009), reflecting variation in the key contributing factors of nutrition pre and post-weaning, and parasite and flystrike risk.

3.1.3 Reproductive potential in goats

3.1.3.1 Fertility

The fertility or conception rate of goats is influenced by the time of year when mated. Goats are seasonal breeders, with bucks as well as does influenced by photoperiod and becoming sexually inactive when day length is increased (Delgadillo *et al.*, 2015), although the degree of seasonality varies between breeds (Fatet *et al.*, 2011). Similar to sheep, introduction of bucks can induce does to ovulate (Chemineau, 1987). However, sexually active bucks are required to induce oestrus behaviour and ovulation in seasonally anoestrus does (Delgadillo *et al.*, 2002; Martínez-Alfaro *et al.*, 2014). Delgadillo *et al*. (2015) showed that an artificial reduction in day length induces sexual activity in bucks at low latitudes, and stimulation of oestrus activity in does by active bucks is also effective at temperate latitudes (Chasles *et al.*, 2016). While photoperiod is the key determinant of buck activity, exposure of Australian cashmere bucks to improved nutrition or oestrus does can lengthen the period when bucks are active (Walkden-Brown *et al.*, 1994). Does do not need to be isolated from bucks in order for buck introduction to stimulate ovulation (Véliz *et al.*, 2006a). The continual presence of active bucks can prevent does entering seasonal anoestrus, but anoestrus will occur if bucks are not active (Delgadillo *et al.*, 2015). Buck activity is therefore a limitation if out-of-season joining is required.

Similarly, while in Australia feral does in north east New South Wales (NSW) only ovulated between April and August if no bucks were present, with either continual or part-time exposure to bucks, ovulations were recorded between March and September (Restall, 1992). This contrasts with NSW and Queensland producer perceptions of the breeding season as being between December and May (Nogueira *et al.*, 2016), which may reflect differences in climate, nutrition or management practices. Good pasture conditions can allow feral does to enter oestrus year round (SCA, 1982). Other environmental factors may also be involved in the timing of doe breeding activity, since oestrus seems to be triggered by monsoon rain (cited by Fatet *et al*. (2011)), and Australian producers report does to exhibit oestrus following late spring rainfall which promotes pasture growth (Nogueira *et al.*, 2016). There is some support for this possibility since the percentage of Creole goats in oestrus was shown to be negatively correlated with minimum temperatures and maximum humidity (Chemineau, 1986). That author suggested thermal comfort improved doe reproductive activity. Ovulation is also less likely to be induced by the presence of active bucks in does with lower weights (Véliz *et al.*, 2006b), and presumably body condition. It is possible, therefore, that an improvement in pasture so nutrition of does following rainfall may increase doe weights and induce oestrus, particularly in pastoral areas where nutrition is more likely to be limiting. A similar effect has been observed in sheep (Smith, 1960). An increase in nutrition is also likely to increase buck activity, which will also stimulate the does (Walkden-Brown *et al.*, 1994).

Fertilisation rates in goats, as with sheep, are expected to be close to 100%. However, there is some evidence that for the out of season August to February period in Australia, although mating after buck introduction, the fertility at that mating may be low (< 50% kidding) (Restall, 1992; Norton, 2004). Pseudopregnancy is a condition which will reduce fertility, and in international studies is reported to occur particularly in older dairy goats in the non-breeding season at levels of between 3 and 20% (Fatet *et al.*, 2011), although there do not appear to be any reports of this in Australian flocks.

In Mexico, body condition at mating as low as 1.5 (1-5 scale) did not reduce the proportion of ewes becoming pregnant (Mellado *et al.*, 2004b), although this may be because the goats were not below a critical threshold, as apparent in sheep (Coop, 1962). Conception rates were higher in does with plasma glucose levels >60 mg/ml, and with higher magnesium (>4 mg/ml) and calcium (>10 mg/ml) levels, (Mellado *et al.*, 2004b), indicating that low levels of nutrition at mating will reduce pregnancy rates. This is consistent with improved nutrition at mating increasing the pregnancy rates of does in the semi-arid rangelands of Mexico (Urrutia-Morales *et al.*, 2012), and does with low bodyweight not responding to bucks (Véliz *et al.*, 2006b).

Producers also report weight loss due to bucks harassing does if left together (Jones, 2012), which could limit fertility. Removal of males, or excess males, outside of the joining period therefore has some potential to improve fertility. Australian producers in western NSW also indicate that breed of buck may be limiting fertility in rangeland flocks (Jones, 2012). Boer bucks are thought to result in reduced pregnancy rates compared with rangeland bucks, in part due to poorer survival of pure Boer bucks. The current recommendation to prevent Boer buck mortality and reduced fertility is to acclimatise bucks after purchase, preferably at a young age, in addition to providing more care to manage the greater susceptibility of Boer goats to nutritional stress and internal parasites (Plumbe *et al.*, 2019). Boer does in Tennessee (southern United States) have also been found to have higher intestinal parasite burdens and higher death rates than Kiko or Spanish does (Browning *et al.*, 2011), so while performing well under more intensive management, may also be less fit for the challenging pastoral conditions of Australia than adapted feral goats.

3.1.3.2 Embryonic and fetal losses

Embryonic mortality is a source of loss in goats and the levels appear to be similar to that in sheep (Diskin and Morris, 2008). There are few reports of fetal loss in goats under Australian conditions. However, high rates of fetal loss are frequently recorded in other countries, and inadequate nutrition is a factor implicated in these losses. A liveweight loss of 25 g/day has been shown to increase the risk of fetal loss (cited by Urrutia-Morales (2012)). In Australian fibre-producing Angora goats, allowing 2 kg (6%) weight loss during mid-pregnancy rather than feeding to maintenance requirement, has resulted in 17% fetal losses, rather than 2% (McGregor, 2016), in contrast to earlier reports that fetal loss in Angoras has not been considered to be significant in Australia (SCA, 1982).

Fetal loss in Angora goats is also reported to occur due to stress, with Shelton and Groff (1984) suggesting that factors which reduce feed intake, such as handling and weather events, can lead to stress abortions between days 90 and 120 of gestation. Fetal losses occurred in 53% of does under nutritional stress during late pregnancy in the semi-arid region of Mexico (Urrutia-Morales *et al.*, 2012), and the nutritional stress may be induced by both limited pasture and negative effects of social status on food intake. However, the incidence of fetal loss due to nutritional stress can be 70% (cited by Mellado *et al*. (2004b)).

Extensively grazed crossbred native does in Mexico with a condition score at mating of 1.5 showed a 9 times greater risk of aborting than fatter does, such that it is recommended does should be above condition score 2 at mating to avoid high levels of fetal loss (Mellado *et al.*, 2004b). Their estimates indicate a fetal loss of <7% for does in condition score 3, increasing to 20% for does in condition score 2 at mating. Polled goats were also more likely to abort than those with horns, although this was not observed previously in a study using dairy breeds (Engeland *et al.*, 1997). Does mated during summer are reported as less likely to abort than those mated in autumn (Mellado *et al.*, 2006), although this does not appear to be consistent with a higher level of fetal loss reported for winter mating elsewhere (Rattner *et al.*, 1994) and may reflect differences in temperature and/or nutritional patterns in different countries. Also of interest is that does with a growth rate <136 g/day between birth and 25 days of age were more likely to abort as mature animals (Mellado *et al.*, 2006). The literature therefore indicates that management of nutrition is a key factor in preventing fetal losses in does.

Does in their first pregnancy have higher fetal loss compared with mature goats (Mellado *et al.*, 2004b). This is in agreement with another Mexican study using housed dairy goats (Mellado *et al.*, 2006) which showed that does in parity 2 to 5 had a much lower (half) risk of aborting compared with does in their first or greater than 5th pregnancy, although the overall level of fetal loss was only 3.5%. Similarly, goat and crossbred goat/Ibex in Israel had 11% fetal loss in first parity does, compared with 5% in adults (Rattner *et al.*, 1994). In contrast, a survey of 8356 does in 126 herds in Jordan (Aldomy *et al.*, 2009) 3.3% of does aborted, mainly during the last month of gestation, but the highest level of loss occurred in 3-5 year old does. The authors suggested this may have been due to disease, although the causes of loss were not monitored. Infectious disease including brucellosis and bluetongue are endemic in some regions, but where not, non-infectious causes of fetal loss are more important causes (Kouri *et al.*, 2018; Givens and Marley, 2008). Indeed, in housed Norwegian dairy herds with a history of high fetal loss (>15%) (Engeland *et al.*, 1997), infectious causes were not implicated. Rather, factors including previous foetal loss, more than 2 foetuses, low social status and pregnancy from the third or later oestrus opportunity all indicated at least twice the risk of loss. The higher rate of fetal loss for does bearing triplets is also reported for Israeli breeds and crosses (Rattner *et al.*, 1994). While abattoir surveys of Australian feral goats have indicated that Q fever (*Coxiella burneti*) is common in goats in some regions, brucellosis was not found (SCA, 1982).

The Boer breed is being widely used in Australia so investigation of fetal loss in that breed is of interest. A 3 year study in Croatia observed a 93% pregnancy rate in intensively managed Boer goats over 3 years, with fetal loss not reported but presumably low (Đuričić *et al.*, 2012). This is above the 80% kidding rate (kids born/doe joined) reported for a 2003 to 2009 study in Tennessee (South Eastern USA) for semi-intensively managed Boer does, but Kiko and Spanish does in that study had a higher kidding rate (94 to 96%) (Browning *et al.*, 2011). The pregnancy rates of stud Boer flocks in high-rainfall areas of NSW and Queensland have been reported as 94% (Nogueira *et al.*, 2016), but there appears to be limited data for Boer or feral does in less favourable environments in Australia.

The kidding rate of does joined (pregnant – fetal losses) for Boer goats in an experiment at Gatton (Queensland) suggested that breed of buck did not alter doe fertility, but crossbred Boer x Feral does had an 18% lower kidding rate than feral does (62.5% vs. 80.4%), although not statistically different (Norton, 2004). In Australian feral goats in experimental conditions, a kidding rate of 88% was observed from an April mating (Restall, 1992), which is consistent with the 89% for does of feral cashmere heritage when intensively managed for an April mating (Eady and Rose, 1988).

The literature indicates that high levels of fetal loss due to nutritional stress have the potential to be a significant cause of reproductive wastage in Australian goats. While this does not appear to be a major loss in closely managed flocks, further investigation is needed from commercial flocks particularly in the lower-rainfall and pastoral regions where nutritional stress is more likely.

3.1.3.3 Fecundity

Goats are prolific breeders and high rates have been reported in numerous countries and breeds. However, in some locations, either due to breed or other factors, fecundity can be low with reports of 95% of does producing single kids (Aldomy *et al.*, 2009). The Kalahari Red had a fecundity of 1.65 in a Nigerian study (Oderinwale *et al.*, 2017). The fecundity of the Boer goat is reported as about 2 kids/doe (Erasmus, 2000), although reports of the ovulation rate are lower (1.72) (Greyling, 2000), likely as a consequence of differing environments. High litter sizes are common in Boer goats with litter sizes of 1 (22.5% of does), 2 (49.2%), 3 (18.6%), 4 (7.4%) and 5 (2.3%) reported (Đuričić *et al.*, 2012). In Australian flocks, stud Boer flocks are reported as having a fecundity of 1.6 kids/doe, with 14% singles, 65% twins and 13% triplet births (Nogueira *et al.*, 2016). This is consistent with an experimental flock in Queensland which recorded similar fecundity in Boer cross, Saanen cross and feral does of approximately 1.6 kids born/doe, although few triplet or higher births, while Angora and Angora cross does had lower fecundity and produced only 1.3 to 1.4 kids/doe (Norton, 2004).

Feral Australian goats have high fecundity if mated under adequate nutritional conditions. Feral goats mated in autumn at Condobolin had a litter size of 2.17 kids/pregnant doe (Allan *et al.*, 1991). Cashmere goats mated in an experiment in southeast Queensland produced up to 1.96 kids/doe (Goodwin and Norton, 2004). A 2004-2007 survey of NSW, VIC and SA Angora producers (McGregor and English, 2010) found kids born per doe joined of 35 to 130%, but while the actual fecundity and sources of reproductive failure are not clear from this data, it is clear that there was a wide range in the reproductive rate on commercial properties.

3.1.4 General patterns of kid survival from birth and post-weaning

Perinatal survival is a major source of reproductive wastage in goats, although there is limited data for Australian commercial flocks. However, the mean mortality rate of kids to weaning for Boer stud flocks in high rainfall areas has been reported as 11.6%, which was much lower than the 33.3% reported for 3 commercial flocks of varying breed in pastoral regions (Nogueira *et al.*, 2016). The mortality rates from 4 to 12 months were also usually lower in the high-rainfall regions (6%) than the pastoral regions (15.7%). Data from 16050 records on KidPlan, the Australian performance recording scheme representing data from Boer stud flocks, indicates mortality to weaning of singles, twins and ≥ triplets was 17, 18 and 29% respectively (Aldridge *et al.*, 2015). The survival to weaning of Boer and Boer cross kids is similar to that of feral goats (approximately 90%) under mild experimental conditions in Queensland (Norton, 2004). Under experimental grazing conditions, a 21% mortality to ≤ 16 days has been reported for cashmere goats at Temora (Allan *et al.*, 1991), which was higher than the 2.9 to 17.8% mortality to 16 days reported for a grazing experiment in southeast Queensland (Goodwin and Norton, 2004). Mortality rates may be lower when goats are kidding in pens (6.4% to 14 days) (Eady and Rose, 1988), although even with intensive pen management a mortality of 21% within 1 day of birth has been reported for Angora goats at Werribee (McGregor, 2016). However, Angora kids have lower levels of survival than feral or Boer goats (Norton, 2004).

The levels of mortality reported in experiments where adequate nutritional levels were used, and from stud flocks where the high value of stock is expected to be associated with improved management, means this data may not well reflect kid losses particularly in marginal regions where nutritional conditions are less controlled. The impact of nutritional level on mortality levels is clear from grazing studies at Condobolin, where feral goats had 5.5 or 33.3% mortality to weaning under high or low nutrition, respectively (Bajhau and Kennedy, 1990).

The timing of kid loss is also not well documented in the limited Australian literature or elsewhere, but it is clear that large losses occur in the perinatal period, with most losses occurring within days of birth (Bajhau and Kennedy, 1990; Allan *et al.*, 1991). However, post weaning losses can be high in some situations (Rattner *et al.*, 1994; Nogueira *et al.*, 2016), and therefore it is critical to understand the timing of kid loss for a particular flock if effective intervention strategies are to be devised.

As for sheep, perinatal kid survival is associated with litter size, but the litter size at which survival is reduced varies, probably due to a combination of both breed and environmental influences. In stud Boer goats, the mortality to weaning of singles and twins in Australia was similar (18%) with ≥ triplets higher (29%) (Aldridge *et al.*, 2015). In contrast, single and twin-born goats in Israel showed a 2 to 4 fold lower mortality than triplets (Rattner *et al.*, 1994). In Boer and Nguni goats, the impact of litter size differed from earlier studies in that twins had higher mortality than singles; mortality for litter sizes of 1, 2, 3 and 4, was 0, 18.0, 18.2 and 83.3%, respectively (Lehloenya *et al.*, 2005). In Angora stud goats, kid mortality increased across all litter sizes (1, 2, 3; 10, 13, and 22%) (Snyman, 2010). Increasing litter size up to the 5th parity at least partially explains the reduction in kid survival of older does in barn-housed Matou goats in China (Moaeen-ud-Din *et al.*, 2008), although not all studies show a reduction in kid survival up to the 6th parity (Awemu *et al.*, 1999). The reasons for the impacts of litter size will be discussed under causes of mortality.

Boer cross does have a higher reproductive rate than Angora does when mated with Angora bucks (98 vs 78% kids weaned/doe, respectively) (Huston *et al.*, 2000). However, the results of this study also indicate that the survival of Boer cross kids may be higher than that of Angora kids since when joined to a meat buck, Boer cross does weaned 140% kids, while Angora does weaned 69% kids. The cause of the difference is unclear since neither pregnancy rate not kid survival rate were reported, but is consistent with the observations of poor Angora survival rates elsewhere (Norton, 2004). Genetic differences in maternal traits including mothering behaviour, physiology and kid behaviour are likely to contribute to breed differences in kid survival. In sheep, breed of ram may have a limited influence on lamb survival (Fogarty *et al.*, 2000), while breed of ewe has a large impact (Donnelly, 1984). The Boer goat has clearly been shown to have lower kid survival than some other breeds in South Africa (Lehloenya *et al.*, 2005) and the United States (Browning *et al.*, 2011). Australian producers suggest rangeland goats produce more kids than the Boer goat (Anon., 2006; Nogueira *et al.*, 2016), although it was unclear whether this was due to kidding rate or kid survival. Experimental studies support this observation with Boer cross does having a lower pregnancy rate than feral does, with the conclusion that introduction of Boer genetics would not increase weaning percentages in feral flocks (Norton, 2004).

There is also relatively little information on the kid marking or weaning rates in commercial flocks in Australia. Weaning rates for a survey of 15 Victorian goat producers using Boer bucks with Boer cross or feral cross does averaged 99%, but there was a large variation between properties (51 to 165%) (Ferrier and McGregor, 2002). More detailed data is needed to determine the time of loss and cause of lower performance on some properties, but the between-property variation is consistent with that seen for sheep flocks.

3.1.5 Causes of perinatal mortality

3.1.5.1 Cattle

Beef cows are managed across many regions in which goats are also produced, so there may be some similarity in the factors involved. In a review of reproductive rates, Burns *et al*. (2010) notes that it may be difficult to reduce perinatal mortality below 4% in northern Australian herds. However, seasonal variation is large. In one study, fetal and calf losses from pregnancy diagnosis to weaning averaged 13.5 (range 9.4 to 19%) with perinatal losses averaging 4.4%, and 44% of postnatal losses occurring within 14 days of birth (Holroyd, 1987). In a larger study, calf survival was recorded for 9296 animals born in several extensively managed Brahman and tropically adapted breed herds in Queensland between 2003 and 2011 (Bunter *et al.*, 2013). Calf mortality to 3 months of age averaged 9.6% but was highly variable between herds and seasons, ranging from 1.5% to 41%. Most of the losses (67%) occurred within 7 days of birth, and while the cause of death was frequently unknown due to lack of observations/post-mortems, low birthweight and being born a twin increased the risk of mortality, as did high birthweight and assisted delivery, although the latter was uncommon. The importance of both low and high birthweights, and large seasonal variation, indicate that climatic factors and nutritional conditions are likely an important factor in mortality. An earlier study (Rowan, 1992) identified dystocia and 'weak calf syndrome' as the major causes of perinatal loss, although the latter may have been strongly influenced by the genetics used. Brahman genetics have previously been noted for poor vigour in calves resulting in higher rates of pre-weaning mortality, with poor vigour being associated with higher rates of dystocia (Riley *et al.*, 2004). Holroyd (1987) also found genetic differences in calf losses between breeds, but while dystocia was important in 2 year old cows, bottle teats and maternal factors were the main identified cause in older cows, although the cause of perinatal loss was not identified in many cases. While predation by wild dogs is a common reason given by producers as a cause of calf loss (McGowan *et al.*, 2014), recent studies suggest that predation of calves accounts for few losses, although it does occur, particularly during poor seasons (Allen, 2014; Campbell *et al.*, 2019).

In contrast, in southern Australia with temperate breeds, where nutrition is often higher and European breeds dominate, dystocia is a major cause of perinatal loss, and the majority of losses are perinatal rather than postnatal (Morris, 1980). Mortality in Angus calves to 7 days of age was reported at 2.7%, but varied from 1.8 to 5.4% with different genetic lines (Copping *et al.*, 2018). Dystocia has been shown to be a major cause of perinatal calf loss in heifers (Sawyer *et al.*, 1991), with feto-pelvic disproportion a key cause (Hickson *et al.*, 2011). However, a range of other factors also cause perinatal calf loss, including disease, nutritional deficiencies and mismothering (Holroyd and McGowan, 2014).

3.1.5.2 Sheep and goats

The causes of perinatal lamb mortality in Australia and elsewhere have been reviewed previously (Hinch and Brien, 2014; Dwyer, 2008; Dwyer *et al.*, 2015). The key causes known in sheep will be discussed with reference to goats, where possible, due to a lack of definitive information for goats.

The relative importance of various causes of perinatal lamb mortality are shown in Table 3.1.1. A larger list of references is given by Hinch and Brien (2014), and the same causes have been identified in other countries (Scales *et al.*, 1986). There appear to be no reliable quantitative studies defining the relative importance of the various causes in goats. The literature indicates that dystocia (including birth injury and stillbirth) and the starvation/mismothering/exposure (SME) complex are the pre-dominant causes of death in Australian lambs, responsible for around 80% of perinatal deaths. However, any of the causes may increase in importance on particular properties or years. The importance of dystocia relative to SME varies between studies, partly due to differences in the post-mortem technique used. Although use of central nervous system injury to define cause of death as dystocia or birth injury (Haughey, 1973b; Haughey, 1973a) is controversial, difficult birth does increase the risk of lambs dying from SME (Darwish and Ashmawy, 2011). As such, there is some relationship between the two causes at least in a proportion of lambs.

Table 3.1.1. The relative importance of various causes of perinatal lamb mortality in Australia

Cause of death[A]	Percentage of deaths (%)			
	WA	Temperate	Queensland	Queensland
	Dennis (1974)	Refshauge *et al*. (2016)	Smith (1960)	Jordan & Le Feuvre (1989)
Death in utero/premature	0	10	0	0
Dystocia, birth injury and stillbirth	19	48	15	19
Starvation/mismothering/exposure	48	30	69	65
Primary predation	3	7	16	17
Infection	14	1	-	0
Congenital abnormalities	9 (1-2)[B]	0	-	-
Other	7	5	-	-
Number of lambs	4417	3198	981	171

[A]Data adapted from source where necessary to conform with the categories presented.

[B]In two years of the survey malformed lambs were requested, biasing the average. In other years the incidence was 1-2% (Dennis, 1975).

3.1.5.3 Dystocia

Dystocia includes newborns where the mother requires assistance to deliver the term fetus, as well as those born naturally but either born dead or compromised due to a prolonged or difficult delivery. The incidence varies between breeds, and has a variety of causes including feto-pelvic disproportion, malpresentation, prolonged delivery due to exhaustion of the ewe and weak uterine contractions (uterine inertia) (Cloete *et al.*, 1998). The proportion of lambs born dead (of all born) varies, with reports of 6.7% (SA Mutton Merinos) (Cloete *et al.*, 1998), or of 30.6% of dead lambs (Dennis, 1974). Even in young which survive the birth process, significant injury is possible, such as liver rupture. Young which survive the birth process may also have been deprived of oxygen and hypoxia results, with 33% of lambs reportedly affected (Dutra and Banchero, 2011). Lambs which survive prolonged deliveries are slower to stand and suck (Dwyer *et al.*, 1996) and have a reduced ability to thermoregulate, which may persist for 3 days after birth (Darwish and Ashmawy, 2011). Mild hypoxia results in a much shorter period (30 minutes) of reduced thermoregulatory ability (Eales and Small, 1985). Impaired thermoregulation predisposes lambs to hypothermia in cold conditions. Ewes which have difficult births also have impaired maternal behaviour (Dwyer *et al.*, 1996) and are more likely to abandon their lambs (Shelley, 1970).

In sheep, dystocia is common (Table 3.1.1), although in extensive flocks is usually unassisted. There are few reports on the incidence of dystocia in goats. Bajhau and Kennedy (1990) reported dystocia as an important source of loss in goats at Condobolin when well fed. Although assistance at delivery was not required, dystocia was involved in a portion of deaths - slow to stand, or no activity observed, in the Temora study of feral goats of Allan *et al*. (1991). McGregor (2016) in a pen study reported dystocia as the main cause of death in Angora goats, but did not quantify separately from other causes. For dairy breed goats Mellado *et al*. (2006) recorded 4.2% stillbirths, which is similar to that reported elsewhere for sheep, but kids were artificially reared and other later causes of death were not reported. The rate of kid stillbirths is higher in triplets compared with singles or twins (Rattner *et al.*, 1994), and is more than double the incidence in does of more than 5 parities compared with younger does (Mellado *et al.*, 2006).

In contrast, Shelton and Groff (1984) do not note dystocia or stillbirth as a cause of Angora kid loss, nor is it listed in various countries for meat goats when listing key causes (Lehloenya *et al.*, 2005; Aldomy *et al.*, 2009; Kouri *et al.*, 2018). A high level of supervision at kidding may be the reason why dystocia was not mentioned in the latter studies. In Australian extensive studies (Nogueira *et al.*, 2016), dystocia was also not noted, but this may be because in the stud flocks reported a high level of husbandry minimised deaths, while on large rangeland properties, kidding is not observed in order to determine cause of death.

A high birth weight is a large risk factor for death from dystocia in sheep, where the relationship between birth weight and survival is quadratic (Geenty *et al.*, 2014). The limited information available for goats suggests a curvilinear relationship, without a reduction in survival at higher weights (Snyman, 2010; Rattner *et al.*, 1994; Lehloenya *et al.*, 2005), including for Boer goats on the Australian KidPlan database (Aldridge *et al.*, 2015). However, high birthweights did result in dystocia of feral and crossbred does extensively grazed at Condobolin (Bajhau and Kennedy, 1990). It seems probable that dystocia can be an important cause of perinatal kid loss in some situations. However, further investigation under commercial management conditions is warranted.

Management to reduce the incidence of deaths from dystocia focuses on producing progeny within the optimum birthweight range for each breed, and on ensuring the mother is adequately fed to be in healthy condition. High birthweight lambs can result from overfeeding during late pregnancy. The propensity for multiple foetuses in goats perhaps makes the likelihood of excessive birth weights less than in sheep, particularly under Australian rangeland conditions. However, undernutrition and loss of ewe condition at any stage during pregnancy is common in Australian commercial ewe flocks (Kelly, 1992), and can also lead to dystocia. The level of ewe mortality can be reduced from 4.9% to 2.8% when managed to higher nutritional targets (Trompf *et al.*, 2011) or when seasonal conditions at the time of lambing are good to average (4-5%) rather than poor (16%) (Jordan *et al.*, 1989). Increased rates of dystocia are expected to be a component of these increased losses, and it is expected that a similar response may be obtainable in goats. However, given the strong relationship between litter size, birthweight and survival (Lehloenya *et al.*, 2005; Awemu *et al.*, 1999), management to limit the number of triplet pregnancies in goats may also be an effective means of reducing kid loss due to prolonged parturitions resulting in stillbirths.

Genetic selection is another potential method to reduce deaths from dystocia. The heritability of birth weight in Boer goats is 0.32, and is genetically positively correlated with kid survival (0.54) (Aldridge *et al.*, 2015). Selecting bucks with appropriate birthweights for the does used is expected to minimise dystocia.

3.1.5.4 Starvation, mismothering and exposure

Starvation, mismothering and exposure are often inter-related, and the exact cause is often difficult to diagnose without direct observation during the peri-natal period. SME, with dystocia, is the other predominant cause of perinatal death in Australian lambs (Table 3.1.1). It has also been stated as the major cause of death in some studies of Australian goats (Eady and Rose, 1988; Bajhau and Kennedy, 1990; Allan *et al.*, 1991). Pen studies indicate that nearly all lambs would survive if given assistance at birth where needed, and adequate food and warmth (Alexander and Peterson, 1961).

Hyperthermia does cause the death of kids (Kouri *et al.*, 2018) and lambs (Rose, 1972) born during hot weather, although the importance of this cause will depend on location and month of birthing. Distance to water is likely to be a contributing factor, since young would be affected when attempting to follow their mothers. Dehydration has been reported by producers as a key cause of death in goat flocks in pastoral Australia (Nogueira *et al.*, 2016), so it seems likely that hot weather may be involved in the perinatal death of kids born during hot weather in Australia.

Hypothermia is common in lambs due to the common months of lambing. Primary exposure occurs when bodily heat loss exceeds heat generation. Maximum heat production in lambs is approximately 1100 $kJ/m^2.hr$ (Alexander, 1962b), and the ability of lambs to survive adverse weather is least before 24 hours after birth (Obst and Ellis, 1977). Heat loss increases in cold, wet, windy weather (Alexander, 1984) and the probability of weather of high chill index differs between locations and with time of year (Broster *et al.*, 2012). Susceptibility to high chill is greater in Merino than crossbred and in twins rather than single-born lambs (Donnelly, 1984). Twins are more susceptible due to their lower birthweights, so larger surface area to weight, with hypothermia probable in some lambs at temperatures of 23^oC under windy conditions (Alexander, 1962c). Under extreme conditions up to 90% of lambs born may die from exposure (Obst and Day, 1968), although much lower levels of loss are more common (Refshauge *et al.*, 2016), in part due to the sporadic occurrence of high chill weather during the lambing period.

Secondary hypothermia occurs where the levels of chill alone are insufficient to cause death. Any factor which reduces the ability of the lamb to consume sufficient milk can result in a failure to generate sufficient heat, such that hypothermia develops. Such factors include insufficient milk supply or damaged teats, competition from littermates and mismothering. Sucking drive is reduced in hypothermic lambs, such that even if milk is available, they become increasingly incapable of consuming it. Lambs which have suffered a difficult birth are slow to stand and suck (Darwish and Ashmawy, 2011), so dystocia predisposes lambs to hypothermia in cool environments.

Kids are susceptible to low temperatures (Shelton and Groff, 1984; Mellado *et al.*, 2000; Aldomy *et al.*, 2009) and are reportedly more susceptible than lambs to hypothermia due to low levels of subcutaneous fat (Anon., 2006). The evidence to support this last claim is unclear, because lambs at birth have negligible levels of subcutaneous fat (Alexander, 1962a). As with lambs, kids with lower birthweights have an increased risk of mortality, and in cold weather, the major cause of death for low birthweight kids is due to an increased susceptibility to hypothermia. At Condobolin, in Australian feral and crossbred goats, 62% of all perinatal kid losses occurred when the chill index was above 950 $kJm^{-2}\ hr^{-1}$ (Bajhau and Kennedy, 1990).

Mismothering causes death due to starvation, as both lambs and kids are reliant on milk for the first few weeks of life. Mismothering can be an important cause of lamb mortality, with the Merino being less capable than other breeds of mothering twins (Alexander *et al.*, 1983). Mismothering is less likely under nutritional conditions which promote desirable maternal behaviour (Dwyer, 2014). Mismothering is recognised as a cause of some kid mortality in both extensive and intensive conditions (Eady and Rose, 1988; McGregor, 2016; Shelton and Groff, 1984).

Starvation does occur in the absence of mismothering. Teat problems have been implicated in perinatal deaths of both lambs (Jordan and Le Feuvre, 1989; Griffiths *et al.*, 2019) and kids (Snyman, 2010). Teat/udder problems are more common in older does, and shearing cuts may cause a higher rate of faults in Angora does compared with dairy/meat breeds (Shelton and Groff, 1984). In addition, inadequate milk production or a delay in lactogenesis result from low levels of nutrition (McCance and Alexander, 1959).

Several management strategies can potentially reduce deaths from SME. Lambing in milder months will reduce the risk of mortality associated with exposure (Broster *et al.*, 2012). Provision of shelter to reduce windspeed is not effective in mild conditions (Glover *et al.*, 2008), but has reduced mortality by 50% in adverse weather (Lynch and Alexander, 1976).

Optimising birthweight within a breed reduces the risk of SME as well as dystocic deaths. Lighter than average lambs (Geenty *et al.*, 2014) and kids (Rattner *et al.*, 1994) have a lower survival rate. Very high levels of kid mortality are reported for the lowest category of birthweights of ≤ 1.5 kg (44%) (Awemu *et al.*, 1999), ≤1.5 kg (20%) (Rattner *et al.*, 1994); < 2kg (50%) (Lehloenya *et al.*, 2005); <4kg (80%) (Shelton and Groff, 1984) in varying breeds, and low birthweight kids are reported to have low vigour. Boer stud kids in Australia show a similar trend although lower mortality, with birthweights < 2 kg having more than 30% mortality, compared with 15% for 2 to 2.4 kg, and approximately 5% for birthweights 3 to 6.4 kg (Aldridge *et al.*, 2015). Young of low birthweight are more susceptible to hypothermia, but also are more likely to be from multiple births (Bajhau and Kennedy, 1990). Behaviour of the young, competition from littermates or deficiencies in maternal ability to mother multiples contribute to the lower survival rate of multiples, since even at the same birthweight the survival of multiple-born lambs is less than for singles (Holst *et al.*, 2002; Oldham *et al.*, 2011; Schreurs *et al.*, 2010). The approximate birthweight of Australian feral kids in the pastoral zone is 2.5 to 3 kg (SCA, 1982).

Provision of adequate nutrition is key to achieving optimum birthweight (Oldham *et al.*, 2011), adequate milk production (McCance and Alexander, 1959), optimal maternal behaviour (Dwyer, 2014) and ensuring that lambs have high energy reserves at birth (Alexander, 1962a). Similar patterns occur in goats (Idamokoro *et al.*, 2017). However, overfeeding ewes in an attempt to increase the average birthweight is likely to reduce survival due to an increased risk of dystocia (Hatcher *et al.*, 2009). Despite the higher risk of mortality of low and high birthweight lambs, the majority of lambs which die in a flock are within the optimum range, due to the majority of lambs being born closer to average weight.

Differences in the nutritional level of the ewe, as assessed from mid-pregnancy liveweight (Kelly, 1992) or pre-lambing condition score (Kleemann and Walker, 2005a), have some association with perinatal lamb survival. Other studies have shown that a mid-pregnancy condition of 2.0 does not reduce lamb survival if ewes are adequately fed during late pregnancy (Kenyon *et al.*, 2011). This appears to be similar in goats, where a 6% mid-pregnancy weight loss has not reduced perinatal survival in pen-fed goats (McGregor, 2016). Poor nutrition of the ewe during late pregnancy has increased lamb mortality from 15% to 33% (Putu *et al.*, 1988). Similarly, a higher level of nutrition during the last month of pregnancy reduced kid mortality from 36% to 14% at Condobolin. Pre-weaning kid mortality differed between seasons and years by up to 60% (10% to 50%) in a Nigerian study (Awemu *et al.*, 1999), and it is expected that differences in nutritional level and weather would have contributed to this variation. Goat producers in the pastoral regions of Australia cite poor nutrition as a key cause of mortality (Nogueira *et al.*, 2016), so it is probable that it contributes to the high between flock and between year variation in weaning rates reported at least partially through impacts on perinatal kid survival. Poor nutrition appears to be a key factor in poor survival of lambs in Queensland (Rose, 1972).

In sheep, short-term feeding prior to lambing can increase colostrum production (Banchero *et al.*, 2007) and lamb survival (Nottle *et al.*, 1998), although it may not increase lamb survival under conditions of ample quality pasture (Kopp *et al.*, 2016; Kenyon *et al.*, 2010). Similarly, supplementation with 360 g/day grain/meal for 2 weeks prior to kidding reduced mortality from 17.8% to 2.9% in cashmere does in Queensland (Goodwin and Norton, 2004). Protein supplementation at sub-maintenance levels has resulted in 19% of kids dying overnight, compared with 10% at above maintenance levels, in addition to a higher rate of mismothering (Allan *et al.*, 1991). These results suggest the lower nutritional level impaired kid energy reserves or milk supply, with the colder overnight temperatures contributing to death by starvation/exposure. Therefore, even short-term changes in nutrition around the period of parturition can alter perinatal survival.

A range of nutritional supplements, if given to ewes, have the potential to improve lamb survival through improving lamb birth weight, vigour and/or thermoregulation, and these are reviewed elsewhere (Liu *et al.*, 2014; McCoard *et al.*, 2017).

Several other management factors have the potential to alter maternal behaviour and the mother-young bonding process, thereby impacting on the level of mortality due to SME. The literature on the effect of mob size at lambing is contradictory. A survey of South Australian commercial flocks (Kleemann *et al.*, 2006) indicated that a quadratic relationship exists, with an optimum mob size of approximately 400 ewes. In contrast, a Victorian survey showed a 3.5% reduction in survival of twin lambs per 100 ewes in the mob (Lockwood *et al.*, 2019c). The trends in both of these studies may have been influenced by other property or environmental factors which are associated with mob size. Further replicated studies indicated a 6.2% higher survival rate for a mob size of 210 compared with 55 ewes when trail fed (Lockwood *et al.*, 2019a), but mob size did not alter survival when abundant pasture was present (Lockwood *et al.*, 2019b). Higher stocking rates have also reduced survival by 24% in some studies (Robertson *et al.*, 2012) but not others (Winfield, 1970). Further studies are clearly required to determine the conditions under which increased mob size or stocking rate may impact on lamb survival. Lamb survival is also reduced by 8% by exposing maiden ewes to mature lambing ewes either during (Robertson *et al.*, 2017b) or immediately prior to lambing (Robertson *et al.*, 2017a), likely through an unmeasured change in maternal behaviour. It is unclear whether the same responses would be obtained in goats due to their differing care behaviours (hiders, not followers) and aggressive defence response to interference (Allan *et al.*, 1991). However, mismothering is well recognised as a cause of kid mortality (Allan *et al.*, 1991; Snyman, 2010; Eady and Rose, 1988; Shelton and Groff, 1984), so any factor which influences the mother-young bond has the potential to alter kid survival.

3.1.5.5 Primary predation

Primary predation is the killing of a viable lamb, whereas secondary predation is the killing of lambs which would have died due to some other compromising factor, or scavenging of dead animals (Rowley, 1970). Predation is frequently cited by Australian producers as a key cause of perinatal mortality presumably due to the presence of predators, but quantitative data indicate that primary predation typically causes less than 10% of all deaths (Rowley, 1970; Greentree *et al.*, 2000; Dennis, 1974). There are, however, instances where predation is significant (Table 3.1.1) (Smith, 1960; Jordan and Le Feuvre, 1989; Rowley, 1970), and pig exclusion has resulted in a 37% increase in lamb marking percentages (Plant *et al.*, 1978). High levels of predation are more likely in regions where predators are more common (Fleming *et al.*, 2006), and where the type of predator is known to cause significant losses. In the Australian rangelands, predation by wild dogs, foxes and pigs have been implicated in kid losses, with producers reporting reproduction rates being reduced from 150% at kidding to 30% at weaning (Anon., 2006). Kids may be particularly vulnerable, in part due to the 'hider' nature of maternal care, where the doe leaves young kids to graze. However, due to the need to differentiate primary from secondary predation and the low contribution of predation to losses in many studies in southern Australia, caution should be exercised in attributing high levels of loss to predation without appropriate evidence for the specific location.

3.1.5.6 Infection

Historically, infection has not been a significant cause of the perinatal death of Australian lambs. Post-mortem surveys of 4408 perinatal lamb deaths in NSW flocks found infection present in 1.6% of dead lambs, or an estimated 0.3% of all lambs born (Hughes *et al.*, 1971). The rate of infection was higher in a WA survey of 4650 lambs, < 14% of dead lambs or < 3% of lambs born (Dennis, 1974). More recent studies across states indicated that infection remains a minor cause of death in lambs (Refshauge *et al.*, 2016), although it may increase in importance on particular properties.

There do not appear to have been any post-mortem surveys of perinatal kid mortality conducted in Australia, but infection has not been noted as a cause in the limited studies where cause of death was reported. *Toxoplasma gondii* has been found in Queensland goats (SCA, 1982) although it is unclear whether this disease is significantly impacting on kid survival rates.

The importance of infection as a cause of death internationally is likely to be higher than in Australia, with intensive or semi-intensive management systems likely to be a contributing factor (Aldomy *et al.*, 2009; Snyman, 2010).

3.1.5.7 Other

Congenital abnormalities in lambs typically occur at a low level (<2%) (Table 3.1.1). The limited Australian studies do not report malformations as a cause of perinatal loss, but they are recorded for goats in Jordan, although the level was not recorded (Aldomy *et al.*, 2009), and in South African Angora goats at ≤ 4% of deaths (Snyman, 2010). Perinatal deaths as a result of congenital abnormalities are therefore not likely to be a large factor in Australian kids.

There is potential for mineral deficiencies in some areas to contribute to perinatal mortality and preventive strategies are recommended in regions where deficiencies are known to occur (Caple and McDonald, 1983). Goats have higher requirements for some minerals than sheep, including iodine and copper (SCA, 1982). Iodine may be of high relevance to goats due to its role in thermoregulation (SCA, 1990) and the importance of cold exposure as a cause of death.

Other causes such as misadventure do not generally cause many losses.

3.1.6 Causes of post-weaning mortality

The Australian average post-weaning mortality of lambs from a producer survey was 4.6% (Campbell *et al.*, 2014). Higher levels of loss were evident in Queensland and Western Australia than in other states. However, the mortality rates can be much higher on individual farms with up to 18% recorded in southern Australia (Hatcher *et al.*, 2008), and 24% in Queensland (Rose, 1972). Inadequate nutrition is a key factor in deaths, with low (< 22 kg) weaning weights the most important risk factor (Hatcher *et al.*, 2008; Campbell *et al.*, 2009) although a post-weaning growth rate of at least 1 kg/month is also important (Campbell *et al.*, 2009). Inadequate worm control and time of shearing also contribute to deaths (Hatcher *et al.*, 2008). Time of shearing may be related to post-shearing exposure, but also to the risk of flystrike. A more detailed review of factors involved in post-weaning mortality is available elsewhere (Campbell, 2010).

Estimates of post-weaning kid mortality in Australia are limited, but similar to those for sheep. For Boer studs in high rainfall areas, 4-15% is reported, but higher (15%) levels in pastoral regions for varying breeds (Nogueira *et al.*, 2016). A rate of 3.2% is estimated for the study by Eady and Rose (1988). In Israel, post-weaning mortalities are also significant, were higher for kids of low birthweight, and varied with kidding season (Rattner *et al.*, 1994). These studies indicate that nutrition is likely to be a key factor in post-weaning survival of kids, as with lambs. Intestinal parasites (worms) are common in feral goats and have the potential to cause high post-weaning mortality, but their importance varies between locations (SCA, 1982; Nogueira *et al.*, 2016).

3.1.7 Conclusions

Goats have the potential for high weaning percentages, and some commercial Australian flocks are weaning in excess of 160%/doe joined. However, there is a large variation between properties, indicating potential for gains. There is clear data to indicate that pregnancy rate and kidding rates are at expected levels (> 90%) in intensively managed flocks and that in these flocks perinatal loss is typically the largest source of kid loss. The known impact of low nutrition on fetal loss indicates this as a potentially important source of kid loss in goats under seasonally variable pasture conditions, which may be important in the pastoral regions. However, there is little data for flocks in pastoral regions, nor detailed information from commercial non-stud flocks, to explain the causes of the wide variation in weaning rates between properties, nor to identify the timing and cause of poor performance. However, this variation is similar to that reported for commercial sheep flocks, where perinatal mortality is widely recognised as the most important cause of loss. The main causes of perinatal kid loss appear similar to those in sheep, and are starvation/mismothering/exposure, dystocia/stillbirth, and in some regions, predation. Further studies are warranted to more clearly define the time of reproductive failure on commercial farms in different regions, and to quantify the relative importance of the different causes of perinatal and post-weaning losses, to allow regionally relevant recommendations to be provided to reduce potential kid loss.

3.2 State Laboratory disease submissions

3.2.1 Introduction

This report provides a summary of state laboratory data on abortion, stillbirth and perinatal death in cattle, sheep and goats from New South Wales (NSW), South Australia and Victoria.

3.2.2 Materials and methods

Data was collected from New South Wales, South Australian and Victorian State laboratories in relation to abortion, stillbirth and perinatal death in cattle, sheep and goats. State Laboratories were contacted in Western Australia and Queensland, but these agencies did not supply any data.

Data from NSW was provided to the research team in a Microsoft Excel document. In total 3,720 cases were submitted between 2006 and October 2019. Cases relating to abortion and stillbirths were analysed together and cases related to perinatal death were analysed separately. In total, 2,602 cases were submitted between 2009 and October 2019 to Victorian laboratories. Similar to NSW data, cases relating to perinatal deaths were analysed separately to cases relating to abortion and stillbirth. Data from South Australia included 781 cases from 2006 to October 2019, these cases related to abortion and stillbirths only.

Each of the cases submitted to NSW was classified as either **'No diagnosis'**, which included cases that had no information or the original conclusion was identified as no diagnosis; **'No positive'**, which included cases that more than one disease was suspected to be the cause, however no clear conclusion was provided; or **'Positive'**, where a clear conclusion was evident and the causative agent was identified. Due to the presentation of the data from Victoria and South Australia, data was only classified as **'Positive'** and **'No diagnosis'** for this report.

Microsoft Excel was used for the analysis of all three datasets. Descriptive statistical analysis was used to summarise the data. Due to the differences in the type of data available from each of the states, the definitions used and the presentation of this data, comparisons between the three datasets could not be made. Further analysis of the data is currently underway to identify if comparisons can be made for subsets of the databases.

3.2.3 Results

3.2.3.1 Perinatal death submissions from NSW

In total 703 cases were submitted to the NSW state laboratories, related to the perinatal death in lambs, calves and kids from 2006 to 2019. Of these cases, 611 related to calf deaths, 20 related to kid deaths and 72 related to lamb deaths.

The frequency of submitted cases according to the year of submission is shown in Figure 3.2.1. The number of goat and sheep cases submitted remained consistent throughout the years with sheep submissions showing a slight increase. However, submissions for cattle cases were highly varied with a downward trend.

It was found that the maximum number of submissions for cattle cases was 59 in 2016, and the minimum 24 in 2019, the average number of submissions per year was 43.6 submissions. The maximum number of submissions for goat cases was 3 (2009, 2011) and minimum was 0 (2013, 2019). The average number of cases submitted was 1.4. The maximum number of submissions relating to perinatal loss in lambs was 10 cases (2018) and the minimum was 0 (2013). The average number of cases submitted was 5.1 submissions.

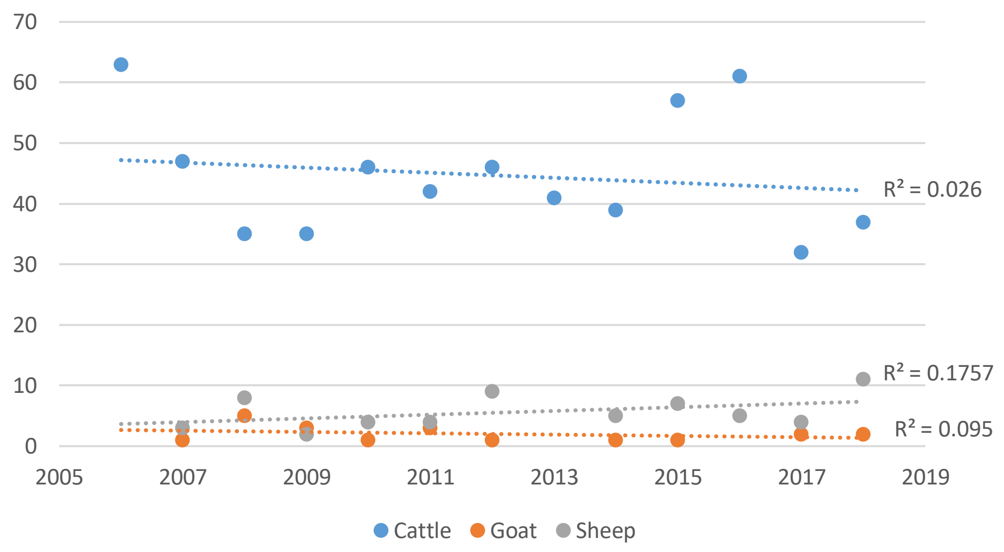

Figure 3.2.1: Scatter plot of the number of perinatal death cases submitted between 2006 and 2019 to NSW sate laboratories

Table 3.2.1 presents the outcomes recorded for submitted cases. Across all species, 43.5% of cases had a confirmed diagnosis (cattle 43%, goat 40% and sheep 48.6%), with 21% being identified as 'No diagnosis' and 35% as 'No positive'. In cattle, there was a higher proportion of 'No positive' (38%) than 'No diagnosis' (19%). In comparison, goats and sheep had a higher proportion of 'No diagnosis' (goat 40%, sheep 38%) compared to 'No positive' (goat 20%, sheep 14%).

Table 3.2.1. Case outcome for perinatal death submissions in cattle, sheep and goats from New South Wales veterinary laboratory from 2006 to 2019.

Species	No diagnosis	No positive	Positive	Total
Cattle	114	234	263	611
Goat	8	4	8	20
Sheep	27	10	35	72
Total	149	248	306	703

For each case, the property Rural Lands Protection Board (RLPB) was provided and information is presented in Table 3.2.2. The use of the term RLPB appears to be retained by the NSW State Veterinary Laboratory, notwithstanding that RLPBs became the Local Health and Pest Authority (LHPA) and more recently the Local Lands Services (LLS). For 177 cases the property RLPB was unavailable. The RLPBs with the most cases submitted were Moss Vale (n = 48) and Central Tablelands (n = 41). The average number of total cases submitted was 13.5 per board, with a median of 11.5, which is represented in the boxplot for each species in Figure 3.2.2. Cases from cattle were submitted from 40 different RLPBs. Most cattle submissions were from Moss Vale RLPB, with 46 cases submitted. Goat cases were submitted from 12 RLPBs, with the most submissions originating from the South Coast RLPB (n = 4). Sheep cases were submitted from 22 RLPBs and of these, the most submissions were from the Central Tablelands RLPB (n = 7).

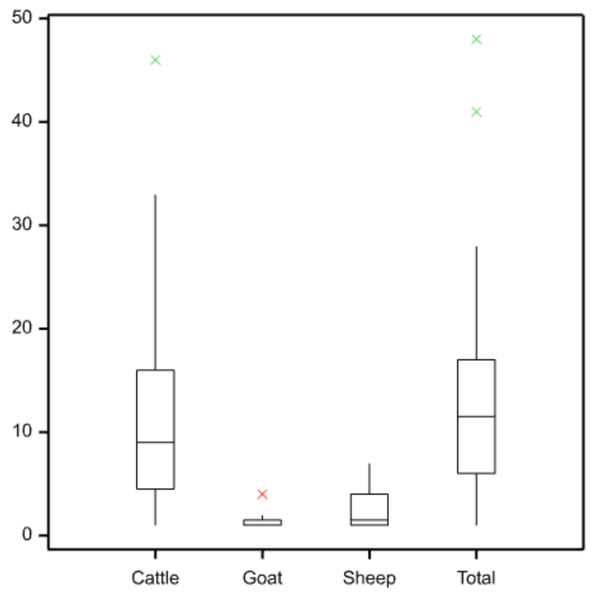

Figure 3.2.2. A box plot for the number of perinatal death cases submitted per Rural Lands Protection Board (RLPB) from 2006 to 2019.

Table 3.2.2 Number of cases perinatal death cases submitted per Rural Lands Protection Board (RLPB) from 2006 to 2019.

RLPB	Cattle	Goat	Sheep	Total
Armidale	22	1	2	25
Bathurst	1		1	2
Bombala	2			2
Braidwood	7	1		8
Canonba	2			2
Casino	15			15
Central Tablelands	33	1	7	41
Condobolin	2		1	3
Cooma	5			5
Coonabarabran	6	2		8
Coonamble	3		4	7
Dubbo	10	1	4	15
Forbes	16			16
Gloucester	16		1	17
Goulburn	4		1	5
Grafton	8	1		9
Gundagai	5		3	8
Hay	1	1		2

Hillston	1			1
Hume	19		1	20
Hunter	21			21
Kempsey	12			12
Maitland	7		1	8
Molong	14	1	1	16
Moree	5		1	6
Moss Vale	46	2		48
Mudgee-Merriwa	11	1	4	16
Murray	16			16
Narrabri	13			13
Narrandera	4		2	6
Northern New England	17	1	1	19
Northern Slopes	16		1	17
Nyngan	4			4
Riverina	6			6
South Coast	22	4	1	27
Tamworth	24		4	28
Tweed-Lismore	12			12
Wagga Wagga	15		4	19
Yass	6		5	11
Young	7		3	10
N/A	155	3	19	177

Between the three species, there were 60 different diagnoses given as causes of perinatal death. Seventeen cases had more than two causes listed as the cause of death, all 17 of these cases related to cattle deaths. Table 3.2.3 presents a condensed list of causes. Those cases with more than one cause identified are counted more than once, i.e. a case with two different casual organisms identified will appear twice. A full list with cases with more than one diagnosis listed as a single cause is included separately (Appendix A). The number of cases classified as ‘No positive’ and ‘No diagnosis’ are also included in the table. Table 3.2.4, 3.2.5 and 3.2.6 present the number of cases for each diagnosis and for each RLPB, for cattle, goat and sheep, respectively.

There were 48 different causes of perinatal death listed for cattle (when condensed). The three top causes of death were Cryptosporidia (57 cases), Rotavirus (48 cases) and Pestivirus (36 cases). Goat cases only had six different causes of death diagnosed and of these, *Escherichia coli* and nutritional deficiency were each diagnosed twice. Twenty-four different causes were diagnosed in relation to perinatal lamb death. Of these, the most diagnosed causes were Dystocia (5) and nutritional deficiency (3).

Dystocia, *Escherichia coli*, encephalomalacia and nutritional deficiencies were the only causes diagnosed in all three livestock species. Sheep and cattle together shared another nine diagnoses (coccidiosis, congenital defect, foetal distress, *Histophilus* spp., *Mannheimia haemolytica*, meningitis, meningoencephalitis, *Pasteurella* spp., *Salmonella* spp., starvation/mismothering, *Streptococcus* spp. and *Trueperella pyrogenes*). One disease was identified in submissions from cattle and goats (pneumonia), while sheep and goats did not share any further diagnoses.

Table 3.2.3. List of diagnoses for cases relating to perinatal death submitted to NSW state laboratories from 2006 to 2019.

Diagnosis	Cattle	Goat	Sheep	Total
Akabane	8			8
Arthrogryposis	1			1
Ataxia	1			1
Bibersteinia trehalosi		1		1
Cardiomyopathy	1			1
Cerebellar hypoplasia	1			1
Chondrodystrophy	2			2
Coccidiosis	2		1	3
Congenital defect	7		1	8
Contagious Pustular Dermatitis / ORF			1	1
Contractual Arachnodactyly (fawn calf syndrome)	1			1
Coronavirus	3			3
Cryptosporidia	57			57
Dermatophilus congolensis			1	1
Diarrhoea	1			1
Dummy Syndrome	1			1
Dwarf calf	1			1
Dyspnoea	1			1
Dystocia	12	1	5	18
Escherichia coli	34	2	1	37
Encephalomalacia	1	1	2	4
Enterotoxigenic colibacillosis	1			1
Epidermolysis bullosa	1			1
Failure of lung aeration	1			1
Foetal distress	3		2	5
Fusobacterium necrophorum			1	1
Hepatitis	1			1
Histophilus spp.	1		1	2

Hydranencephaly	2			2
Hypotrichosis			1	1
IBR/IPV/BHV-1	1			1
Internal parasites			1	1
Ixodid tick	1			1
Leptospora spp.	3			3
Malpresentation	1			1
Mannheimia haemolytica	3		1	4
Maple Syrup Urine Disease	1			1
Meningitis	3		1	4
Meningoencephalitis	2		1	3
Microencephaly	1			1
Neuropathy-diplomyelia and diastematomyelia	1			1
Nutritional deficiency*	2	2	3	7
Omphalitis			1	1
Pasteurella	4		1	3
Pestivirus	36			36
Pneumonia	10	1		9
Rotavirus	48			48
Salmonella spp.	34		1	34
Scabby mouth			1	1
Simbu Virus	3			3
Squamous metaplasia			1	1
Staphylococcus spp.	1			1
Starvation/Mismothering	1		2	3
Streptococcus spp.	1		2	3
Sudden death	1			1
Trauma	1			1
Trueperella pyogenes	4		2	5
No Diagnosis	114	8	27	149
No Positive	234	4	10	248
Total	656	20	72	748

* Nutritional deficiencies included cases of hypocalcaemia, vitamin deficiencies (A and E), polioencephalomalacia (PEM), urea toxicity and goitre.

The reported age at death was also examined (Table 3.2.4). Calf deaths occurred between one and ten days of birth, averaging 4 days with a mode of 7 days (142/656 submissions). Kid deaths occurred between one and seven days after birth, with an average of 3 days, with 4 out of 14 cases being from 1-d old kids. Lamb deaths also occurred between one and seven days after birth, with an average age of 3 days and the majority of samples with an age reported coming from 1 and 2 day old lambs.

Table 3.2.4. Reported age (days) of the perinate that death occurred in cases submitted to NSW state laboratories from 2006 to 2019.

Age (days)	Cattle	Goat	Sheep	Total
1	54	4	6	64
2	69	2	10	81
3	50	2	-	52
4	32	2	1	35
5	35	2	3	40
6	15	-	-	15
7	142	2	5	149
8	1	-	-	1
10	2	-	-	2
NA*	211	6	47	264
Total	611	20	72	703

*NA = Age information not available

Table 3.2.5. Cattle perinatal death diagnoses for each Rural Lands Protection Board (RLPB) of cases submitted to NSW state laboratory from 2006 to 2019 (Diagnoses with less than 5 cases were removed, and a full table with all cases is extremely large and can be provided on request).

RLPB	Akabane	Congenital defect	Cryptosporidia	Dystocia	E. coli	Pestivirus	Pneumonia	Rotavirus	Salmonella spp.	No Diagnosis	No Positive	Total
Armidale	1				3	3	1	2		3	9	22
Bathurst											1	1
Bombala											2	2
Braidwood						1				3	3	7
Canonba											1	1
Casino			1	1	4			2		2	5	15
Central Tablelands		1	4	2	1	1		6		5	14	34
Condobolin							1				1	2
Cooma		1					1			1		3
Coonabarabran										2	4	6
Coonamble										1		1
Dubbo										3	5	8
Forbes			3		2	3		1	3	2	4	18
Gloucester	1		5			2		1	1	1	5	16
Goulburn		1							1	1	1	4
Grafton	1									1	6	8
Gundagai					1					2	2	5
Hay								1	1			2

Hillston				1								1
Hume			2			1		1			9	13
Hunter		1	3				1	6	2	3	8	24
Kempsey					1	1			3	2	4	11
Maitland			1				1	1		3	2	8
Molong		1	1							5	3	10
Moree	1					1				2	2	6
Moss Vale	1		5	1	6	1		8	5	5	19	51
Mudgee – Merriwa			1							2	6	9
Murray			1		2	1		2	3	4	4	17
Narrabri		1		2						4	5	12
Narrandera										2	2	4
Northern New England			1				1			7	7	16
Northern Slopes	2				1	4				2	8	17
Nyngan				1						1	2	4
Riverina					1	1			2		1	5
South Coast			4		1	1		4	2	2	8	22
Tamworth	1		1			2			1	8	9	22
Tweed - Lismore								1	2	2	7	12
Wagga Wagga			6		2			1	3	1	2	15
Yass				1		1					4	6

Young				1		2					1	4
N/A		1	18	2	9	10	4	11	5	32	58	150
Total	8	7	57	12	34	36	10	48	34	114	234	594

Table 3.2.6. Goat perinatal death diagnoses for each Rural Lands Protection Board (RLPB) of cases submitted to NSW state laboratory from 2006 to 2019.

RLPB	Bibersteinia trehalosi	Dystocia	Escherichia coli	Encephalomalacia	Nutritional deficiency	Pneumonia	No Diagnosis	No positive	Total
Armidale								1	1
Braidwood							1		1
Central Tablelands		1							1
Coonabarabran			1				1		2
Dubbo								1	1
Grafton							1		1
Hay					1				1
Molong	1								1
Moss Vale				1			1		2
Mudgee-Merriwa							1		1
Northern New England			1						1
South Coast						1	2	1	4
N/A					1		1	1	3
Total	1	1	2	1	2	1	8	4	20

Table 3.2.7. Sheep perinatal death diagnoses for each Rural Lands Protection Board (RLPB) of cases submitted to NSW state laboratory from 2006 to 2019.

Diagnosis	Armidale	Bathurst	Central Tablelands	Condobolin	Coonamble	Dubbo	Gloucester	Goulburn	Gundagai	Hume	Maitland	Molong	Moree	Mudgee-Merriwa	Narrandera	Northern New England	Northern Slopes	South Coast	Tamworth	Wagga Wagga	Yass	Young	N/A	Total
Coccidiosis			1																					1
Congenital defect																	1							1
Contagious Pustular Dermatitis / ORF																						1		1
Dermatophilus congolensis																							1	1
Dystocia						2				1												1	1	5
Escherichia coli																							1	1
Encephalomalacia																							2	2
Foetal distress															1						1			2
Fusobacterium necrophorum														1										1

Histophilus spp.																							1	1
Hypotrichosis																1								1
Internal parasites			1																					1
Mannheimia haemolytica	1																							1
Meningitis																							1	1
Meningoencephalitis									1															1
Nutritional deficiency					1															1		1		3
Omphalitis									1															1
Pasteurella		1																						1
Salmonella spp.																			1					1
Scabby mouth					1																			1
Squamous metaplasia						1																		1
Starvation/ Mismothering							1																1	2
Streptococcus spp.	1																				1			2
Trueperella pyogenes			1																				1	2
No Diagnosis			3		1	1		1	1			1	1	3	1			1	3	2	3		5	27

No Positive			1	1	1						1									1			5	10
Total	2	1	7	1	4	4	1	1	3	1	1	1	1	4	2	1	1	1	4	4	5	3	19	72

3.2.3.2 Abortion and stillbirth submissions from NSW

In total, 3,017 cases related to abortions and stillbirths in sheep, cattle and goats, were submitted to the NSW state veterinary laboratory from 2006 to 2019. Of these cases, 2,609 related to calf deaths, 83 related to kid deaths and 325 related to lamb deaths.

The number of submissions received each year is reported in Figure 3.2.3. It should be noted that the data from 2019 is not complete. Goat and sheep submissions remained consistent throughout the years with a steady increase in submissions. The number of cattle submissions varied more throughout the years, with no clear pattern.

The maximum number of submissions for cattle cases was 253 in 2011, and the minimum 160 in 2014 (without considering 2019), with an average number of submissions per year of 186.4 submissions. For goats, an average of 5.9 cases were submitted per year, with a maximum number of submissions of 21 in 2018, and a minimum of 1 submission in 2014 and 2016. The maximum number of submissions relating to perinatal loss in lambs was 47 cases in 2018 and the minimum was 5 in 2006, with an average number of cases submitted per year of 23.2.

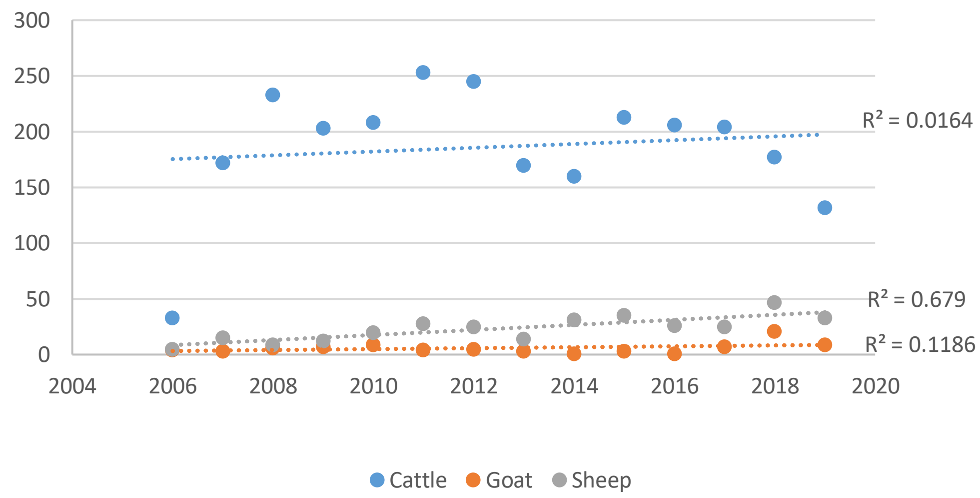

Figure 3.2.3. Scatterplot of the number of cases submitted to NSW state laboratories per year relating to abortion and stillbirths in cattle, goats and sheep from 2006 to 2019.

Overall and across all species, 39.9% of all cases had a 'Positive' conclusion, this being the largest proportion of cases. Goat submissions had the lowest 'Positive' diagnosis rate (19.3%), with sheep (36.3%) and cattle (41%) having a higher proportion of cases with a 'Positive' diagnosis. 'No positive' was the second largest proportion of outcomes, accounting for 38.3% of all cases and 'No diagnosis' accounted for 21.8% of submitted cases.

Table 3.2.8: Case outcome for abortion and stillbirth cases submitted to NSW state laboratories from 2006 to 2019.

	No diagnosis	No positive	Positive	Total
Cattle	557	982	1070	2609
Goat	27	40	16	83
Sheep	70	136	119	325

Total	654	1158	1205	3017

The number of abortion and stillbirth cases submitted from each property RLPB was investigated and presented in Table 3.2.9 and Figure 3.2.4. For 730 cases the property RLPB was unavailable and not included in Figure 3.2.4. Overall, the average number of total cases submitted was 46.7 per RLPB, with a median of 35. Similarly to perinatal loss related submissions, the RLPBs with the most cases submitted labelled as abortion and stillbirth, was Moss Vale (n = 226) and Central Tablelands (n = 130).

Cases relating to cattle were submitted from 47 locations. Most submissions were from the Moss Vale RLPB with 218 cases submitted. Goat cases were submitted from 27 RLPBs, with most submissions being from the Grafton (n = 8). Sheep cases were submitted from 39 RLPBs, with the majority of submissions being from the Central Tablelands (n = 23).

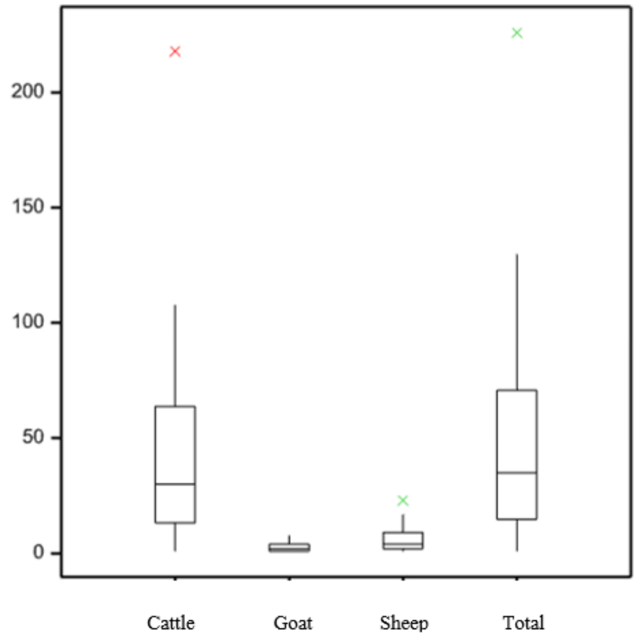

Figure 3.2.4. A box plots of the number of abortion and stillbirth cases submitted per Rural Lands Protection Board (RLPB) from 2006 to 2019.

Table 3.2.9. Number of cases relating to abortion and stillbirths per Rural Lands Protection Board (RLPB) submitted to NSW state laboratory from 2006 to 2019.

RLPB	Cattle	Goat	Sheep	Total
Armidale	99	3	7	109
Balranald-Wentworth	3			3
Bathurst	3			3
Bombala	12		6	18
Bourke			1	1
Braidwood	16	1		17

Broken Hill	1		2	3
Carcoar	6			6
Casino	91		3	94
Central Tablelands	101	6	23	130
Condobolin	18	1	8	27
Cooma	33	4	6	43
Coonabarabran	26	1	8	35
Coonamble	16		2	18
Denman/Singleton	1			1
Dubbo	33	5	15	53
Forbes	47	3	12	62
Glenn Innes	5			5
Gloucester	100	2	1	103
Goulbourn	29	2	4	35
Grafton	68	8	1	77
Gundagai	54		13	67
Hay	10		1	11
Hillston	2		2	4
Hume	65		17	82
Hunter	35			35
Kempsey	84	4	1	89
Maitland	49	2		51
Molong	43	2	12	57
Moree	16	2	3	21
Moss Vale	218	6	2	226
Mudgee-Merriwa	60	2	7	69
Murray	46		1	47
Narrabri	20	2	9	31
Narrandera	15	1	3	19
Northern New England	89	4	7	100
Northern Slopes	44	2	5	51
Nyngan	13		9	22
Riverina	21	1	4	26
South Coast	83	4	1	88
Tamworth	108	1	11	120

Tenterfield	1			1
Tweed-Lismore	72	1	3	76
Wagga Wagga	30	1	9	40
Walgett	14		2	16
Warialda			1	1
Wyuna	1			1
Yass	25		2	27
Young	49	4	13	66
N/A	634	8	88	730
Total	2609	83	325	3017

Between the three species, there were 98 different diagnoses given as causes of abortions. Forty-six cases had more than two causes listed as the cause of death, 37 of these cases related to cattle abortions and nine related to sheep abortions. Table 3.2.10 presents a condensed list of diagnoses, with cases with more than one cause being counted more than once, i.e. a case with two different casual organisms identified will appear twice. A full list with cases with more than one diagnosis listed as a single cause is included separately (Appendix B). The number of cases classified as 'No positive' and 'No diagnosis' are also included in the table. Tables 3.2.11, 3.2.12 and 3.2.13 present the number of cases for each diagnosis and RLPB, for cattle, goat and sheep, respectively.

Forty-four different causes of abortion/stillbirth were listed for cattle. The three top causes of abortion were *Pestivirus* (618 cases), *Neospora* (261 cases) and *Leptospira* spp. (101 cases). Goats had seven different causes of abortion diagnosed. The top three causes for abortion were nutritional deficiency (8 cases), *Chlamydia* (2 cases) and *Yersinia enterocolitica* (2 cases). Twenty-two different causes were diagnosed in relation to abortions in sheep. Of these, the most diagnosed causes were *Campylobacter* spp. (34 cases), nutritional deficiency (22 cases) and *Listeria* (22 cases).

Toxoplasma, *Listeria*, *Chlamydia* and nutritional deficiencies were causes listed for all three species. In addition to this, cattle and sheep shared eight causes of abortion/stillbirth (*Campylobacter* spp., Congenital defects, *Escherichia coli*, *Enterobacter*, *Pasteurella*, Pestivirus, *Salmonella* spp. and *Trueperella pyogenes*), cattle and goats shared one common diagnosis (*Streptococcus* spp.) and sheep and goats also shared one common diagnosis (*Yersinia enterocolitica*).

Table 3.2.10. List of diagnoses for cases relating to abortions and stillbirth cases submitted to NSW state laboratories from 2006 to 2019.

Diagnosis	Cattle	Goat	Sheep	Total
Actinobacillus seminis			1	1
Akabane	42			42
Anaemia	2			2
Arbovirus	1			1
Babesia bigemina	1			1
Bovine Ephemeral Fever (BEF)	10			10
Brucella ovis			2	2
Calcium oxalate crystals	1			1
Campylobacter spp.	55		34	89
Cardiomyopathy	1			1
Chlamydia	6	2	10	18
Cholestasis	1			1
Clostridium spp.		1		1
Congenital defect	8		2	10
Coxiella burnetii	1			1
Escherichia coli	10		2	12
Endometritis			2	2
Endotoxemia	1			1
Enterobacter spp.	1		1	2
Enterococcus faecalis	1			1
Foetal hydrops	1			1
Freemartinism	1			1
Hepatitis	1			1
IBR	7			7
Internal parasites^	16			16
Intrauterine infection	1			1
Leptospira spp.	101			101
Listeria	3	1	22	26
Neospora	261			261
Nutritional deficiency*	25	8	23	56
Pasteurella	1		1	2
Pestivirus	620		3	622

Placental calcification			1	1
Placentitis	1			1
Pneumonia	1			1
Premature birth	2			2
Prerenal azotaemia			1	1
Pseudomonas	1			1
Q fever	1		1	2
Rhinotracheitis virus	1			1
Salmonella spp.	10		5	15
Septicaemia			1	1
Simbu viruses	6			6
Squamous cell carcinoma			2	2
Staphylococcus spp.	2			2
Streptococcus spp.	3	1		4
Theileria	19			19
Toxoplasma	1	1	14	16
Trichomonas foetus	1			1
Trueperella pyogenes	9		2	11
Ureaplasma diversum	1			1
Yersinia enterocolitica		2	1	3
No diagnosis	559	27	71	657
No positive	982	40	136	1158
Total	2780	83	338	3190

^ Internal parasites that were identified included, Ostertagia spp., *Fasciola hepatica,* paramphistomes and nematodes.

* Nutritional deficiencies included cases of hypocalcaemia, hypomagnesaemia, ketosis, pregnancy toxaemia, mineral deficiencies (manganese, selenium, iodine), vitamin deficiencies (A and E), PEM, White muscle disease, goitre and nitrate and urea poisoning.

Table 3.2.11. Cattle abortion and stillbirth diagnoses within for each Rural Lands Protection Board (RLPB) of cases submitted to NSW state laboratory from 2006 to 2019 (Diagnoses with less than 5 cases were removed, and a full table with all cases can be provided on request).

	Armidale	Balranald-Wentworth	Bathurst	Bombala	Braidwood	Broken Hill	Carcoar	Casino	Central Tablelands	Condobolin	Cooma	Coonabarabran	Coonamble	Denman/Singleton	Dubbo	Forbes	Glen Innes	Gloucester	Goulburn	Grafton	Gundagai	Hay	Hillston	Hume	Hunter	Kempsey	Maitland	Molong	Moree	Moss Vale	Mudgee-Merriwa	Murray	Narrabri	Narrandera	Northern New England	Northern Slopes	Nyngan	Riverina	South Coast	Tamworth	Tweed-Lismore	Wagga Wagga	Walgett	Wyuna	Yass	Young	N/A	Total
Akabane	1								1									2		1					1	2	2		1	5			2		8	2				6	2						6	42
BEF								1																1				1	1							5				1								10
Campylobacter				1				7	1				1			1		6	1	1		1			1	2	1			3	2					2	1			4	2		1				16	55
Chlamydia																					1		1														1			1							2	6
Congenital	1												1							2										1			1		1												1	8

E. coli					1				1									1						1						2		1								2							1	10
IBR															1																					2				1		1				1	1	7
Internal					1			1	4																		1			1											1	1					6	16
Leptospira	9							4	3				1	1	4	1		2	1		3	1		3	2	1	3	1	1	5	6	3	2	1	5	2	2	1	4	5		1	1		1	3	18	101
Neospora	3							10	3		1				2			27	1	12				7	4	11	10			57	2	4			10			1	19	2	14				1		60	261
Nutritional	2				1			1	4											1				1			1			1	1					1	1	1	1	4							4	25
Pestivirus	32			5	4	1		15	36	9	4	12	6		12	7	1	8	10	10	15	7	1	15	11	8	10	17	7	26	12	10	5	3	24	11	4	6	23	24	10	5	3		6	17	168	620
Salmonella																								1			1			1	2		1							3		1						10
Simbu	1																												1	1					1												2	6

Theileria	3																	1		1					1	1	1	1		2					2				2	2							2	19
Trueperella													1					2												1		1							1							1	2	9
No	22	1	2		5		3	17	12	2	9	7	2		3	13	4	26	7	11	8			15	8	25	11	7	2	46	8	11	4	7	19	10	3	3	12	26	18	8	3	1	5	6	146	559
No	36	1	1	7	5		2	40	44	6	19	7	6		15	24		28	10	32	29	3		21	11	36	16	17	5	70	32	17	6	4	29	14	3	9	25	41	29	13	7		14	20	228	982
Total	110	2	3	13	17	1	5	96	109	17	33	26	18	1	37	46	5	103	30	71	56	12	2	65	39	86	57	44	18	222	65	47	21	15	99	49	15	21	87	122	76	30	15	1	27	48	663	2745

Table 3.2.12. Goat abortion and stillbirth diagnoses for each Rural Lands Protection Board (RLPB) of cases submitted to NSW state laboratory from 2006 to 2019.

	Armidale	Braidwood	Central Tablelands	Condobolin	Cooma	Coonabarabran	Dubbo	Forbes	Gloucester	Goulburn	Grafton	Kempsey	Maitland	Molong	Molong	Moss Vale	Mudgee-Merriwa	Narrabri	Narrandera	Northern New England	Northern Slopes	Riverina	South Coast	Tamworth	Tweed-Lismore	Wagga Wagga	Young	N/A	Total
Chlamydia							1										1												2
Clostridium spp.																												1	1
Listeria												1																	1
Nutritional deficiency			1				1				1					1			1	1		1						1	8
Streptococcus spp.					1																								1
Toxoplasma										1																			1
Yersinia enterocolitica												1		1															2
No diagnosis	1		1		2	1	1		1		4	2	1		1	2	1	2					2	1		1	1	2	27
No positive	2	1	4	1	1		2	3	1	1	3		1	1	1	3				3	3		2		1		3	4	40
Total	3	1	6	1	4	1	5	3	2	2	8	4	2	2	2	6	2	2	1	4	3	1	4	1	1	1	4	8	83

Table 3.2.13. Sheep abortion and stillbirth diagnoses for each Rural Lands Protection Board (RLPB) of cases submitted to NSW state laboratory from 2006 to 2019 (Diagnoses with less than 5 cases were removed and a full table with all cases can be provided on request).

	Armidale	Bombala	Bourke	Broken Hill	Casino	Central Tablelands	Condobolin	Cooma	Coonabarabran	Coonamble	Dubbo	Forbes	Gloucester	Goulbourn	Grafton	Gundagai	Hay	Hillston	Hume	Molong	Moree	Moss Vale	Mudgee-Merriwa	Murray	Narrabri	Narrandera	Northern New England	Northern Slopes	Nyngan	Riverina	South Coast	Tamworth	Tweed-Lismore	Wagga Wagga	Walgett	Warialda	Yass	Young	N/A	Total
Campylobacter spp.	2	1				6			1		1	2						1	4	1			1				1		1	2									10	34
Chlamydia						3			1											1			1		3														1	10
Listeria	1	1									1	2		1		2				2			2					1		1								3	5	22
Nutritional deficiency						1	3	1			1	3							1	1			1	1	1	1			1	1	1	1			1	1			2	22
Toxoplasma		1			1	1	1	1												1			1		1		2					1		2					1	14
No diagnosis	1	1		1	1	3	1	1	2		3	3		1		6			2	1	2	1	1		2		2	2	2			3	1	1				3	24	71
No positive	3	2	1	1	1	11	3	2	4	1	7	1	1	2	1	5	1	1	10	5	1		2		2	2	1	2	5			5	2	5	1		1	5	39	136
Total	7	6	1	2	3	25	8	5	8	1	14	13	1	4	1	13	1	2	17	12	3	1	9	1	9	3	6	5	9	4	1	10	3	9	2	1	1	11	82	314

3.2.3.3 Perinatal submissions from Victoria

A total of 1,625 cases relating to perinatal death in cattle, goats and sheep, were submitted to Victorian state laboratories between 2009 and 2019. Of these, 1,237 cases related to perinatal calf deaths, 57 cases related to perinatal kid deaths and 331 related to perinatal lamb deaths. As with the NSW data, it should be noted that the data for 2019 is incomplete.

The number of submissions received each year is reported in Figure 3.2.5. The number of submissions relating to cattle was highly varied, however, there was a steady increase in cases overtime. Similarly, sheep submissions were varied from year to year, however there was a downward trend. Goat submissions remained consistent with a very slight decrease.

The maximum number of submissions for cattle cases was 161 in 2014, and the minimum 40 in 2009, with an average of 112.5 submissions per year. The maximum number of submissions for goat cases was 13 in 2010 and the minimum was 1 submission in 2011 and 2015. On average 5.9 cases were submitted per year. For perinatal loss in lambs, the maximum number of submissions was 75 cases in 2010, the minimum was 11 in 2013 and the average was 30.1 submissions per year.

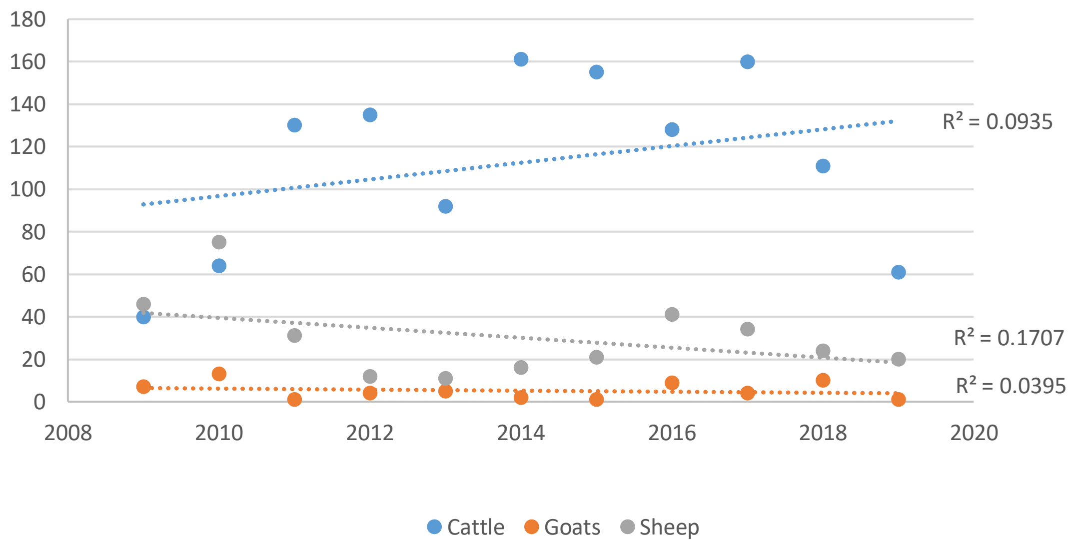

Figure 3.2.5. Scatterplot of the number of perinatal cases submitted to Victorian state laboratories per year from 2009 to 2019.

As seen in Table 3.2.14, overall across all species, the majority of cases (77.4%) resulted in a 'Positive' conclusion. Table 3.2.15 lists the different diagnoses that were made from the perinatal death submissions. A total of 50 different diagnoses were made between the three species. Among all cases submitted, 42 diagnoses related to cattle, 31 diagnoses related to sheep and 18 diagnoses related to goats.

Table 3.2.14. Case outcome of perinatal submissions from Victorian state laboratories from 2009 to 2019.

	Positive	No diagnosis	Total
Cattle	958	279	1237
Goat	44	13	57
Sheep	256	75	331
Total	1258	367	1625

The most diagnosed causes of perinatal death in calves was *Salmonella* spp. (315 cases), internal parasites (150 cases) and Rotavirus (138 cases). The most diagnosed cause of perinatal death for goats were *Salmonella* spp. (7 cases), nutritional disease (6 cases) and mismothering/starvation (7 cases). In regard to perinatal death of lambs the most diagnosed causes were starvation/mismothering (60 cases), nutritional disease (36 cases) and dystocia (28 cases).

Fourteen diagnoses were shared by all three species, this included *Campylobacter* spp., congenital malformation, dystocia, enterotoxaemia, *Escherichia coli*, internal parasites, management induced, mismothering/starvation, navel ill, nutritional disease, *Pasteurella* spp., *Salmonella* spp. *Streptococcus* spp. and trauma.

Table 3.2.15. List of diagnosis for cases relating to perinatal cases submitted to Victorian state laboratories from 2009 to 2019.

Diagnosis	Cattle	Goat	Sheep	Total
Actinobacillus infection	1			1
Acute bovine pulmonary oedema and emphysema	1			1
Aino virus	1			1
Aspiration pneumonia	3	1		2
Border Disease (Ovine Pestivirus)			1	1
Bovine respiratory syncytial virus (BRSV)	1			1
Campylobacter spp.	4	2	14	20
Chlamydia		1	3	4
Clostridial disease	5		1	6
Congenital chondrodysplasia	13		1	14
Congenital malformation	22	1	10	33
Contagious ecthyma (scabby mouth)			1	1
Coronavirus	20			20
Cryptosporidiosis	28			28
Dystocia	5	3	28	36
Escherichia coli	107	3	3	113
Enterotoxaemia	1	1	3	5
Erysipelothrix rhusiopathiae		1	1	2
Fusobacterium necrophorum	1		6	7
Gastrointestinal torsions			1	1
Hereditary disease	1		5	6
Hypothermia	1		8	9
Infectious bovine rhinotracheitis (IBR/IPV/BHV-1)	5			5
Internal parasites^	150	2	4	156
Leptospira spp.	8			8
Listeriosis	2		12	14
Mannheimia haemolytica	1		7	8
Mismothering/starvation	1	7	60	68
Mycoplasma spp.	2			2
Mycotic/fungal infection (organism identified)	2			2
Navel ill (Omphalitis)	1	1	8	10

Neoplasia (not notifiable)	2			2
Neospora	15			15
Nutritional deficiency*	7	6	36	48
Parainfluenza-3 (PI3)	1			1
Pasteurella spp.	3	1	3	7
Pestivirus	36			36
Predation			7	7
Rotavirus	138		1	139
Salmonella spp.	315	7	1	323
Staphylococcal spp.	1			1
Streptococcus spp.	3	1	2	6
Terminal dehydration	1			1
Theileriosis	1			1
Toxoplasmosis			5	8
Trauma	5	1	2	8
Trueperella pyogenes	2		2	4
Yersiniosis	4			4
N/A	35	3	19	57
No diagnosis	281	15	76	372
Total	1237	57	331	1625

3.2.3.4 Abortion and stillbirth submissions from Victoria

A total of 997 cases relating to abortion and stillbirth in cattle, goats and sheep, were submitted to Victorian state laboratories between 2009 and 2019. Of these, 707 cases related to cattle, 33 cases related to goats and 262 related to sheep. As with the NSW data, it should be noted that the data for 2019 is incomplete as the data was collected in October 2019.

The number of submissions received each year is reported in Figure 3.2.6. The number of submissions relating to cattle was highly varied, however there was a steady increase in cases overtime. Similarly, sheep submissions were varied from year to year with an upward trend. Goat submissions remained consistent.

On average, there were 63.8 cattle submissions per year with a maximum of submissions for 102 submissions in 2014, and a minimum of 13 in 2009. The maximum number of submissions for goat cases was 8 in 2013 and the minimum was 0 submissions in 2009, with an average of 3 cases per year. In relation to perinatal loss in lambs, the average number of submissions per year was 23.8, with a maximum of 39 cases in 2014 and a minimum of 8 in 2009.

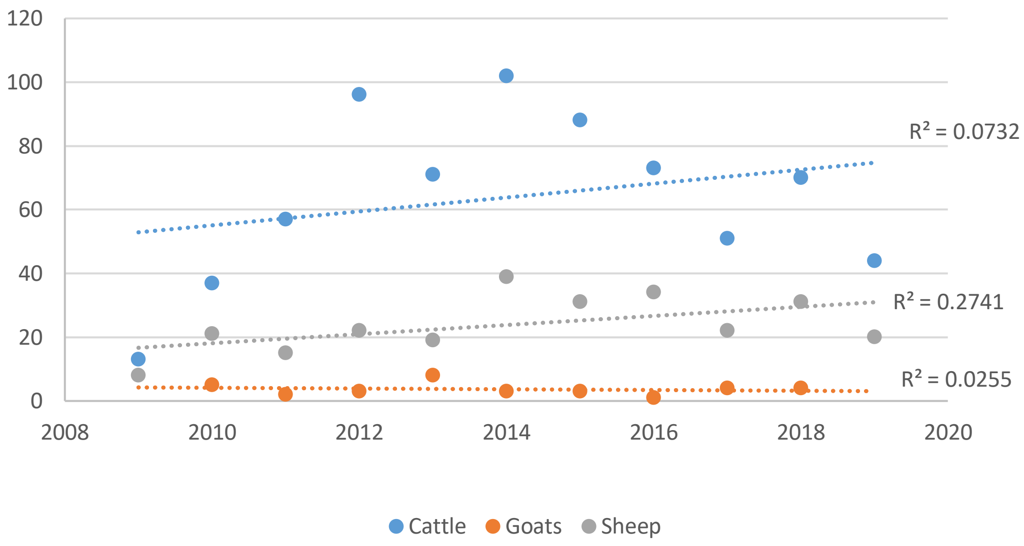

Figure 3.2.6. Scatterplot of the number of abortion and stillbirth cases submitted to Victorian state laboratories per year from 2008 to 2019.

Table 3.2.16 shows the case outcomes for abortion and stillbirth submissions in Vitoria. Overall and across all species, 61.1% of cases were identified with a positive outcome, with sheep having the highest proportion of positive cases (71.8%), followed by cattle (57.4%) and goats (54.5%).

Table 3.2.16. Case outcome of abortion and stillbirth submissions from Victorian state laboratories from 2009 to 2019.

	Positive	No diagnosis	Total
Cattle	403	299	702
Goat	18	15	33
Sheep	188	74	262
Total	609	388	977

In total, 44 different diagnosis were made for abortion and stillbirths, with 38 being related to cattle submission, eight diagnoses related to goat abortion and stillbirths and 21 diagnosis related to sheep cases.

The most diagnosed causes of abortions and stillbirth in cattle were Pestivirus (101 cases), Neospora (59 cases) and Leptospirosis (54 cases). Among goat cases, the most common diagnoses were internal parasites (6 cases), nutritional disease (5 cases) and chlamydia (2 cases). Listeriosis (57 cases), *Campylobacter* spp. (50 cases) and nutritional disease (20 cases) were the most diagnosed causes of abortion and stillbirth in sheep.

Nutritional disease, internal parasites and paratuberculosis were diagnoses shared by all three species. Yersinia and *Mannheimia haemolytica* were diagnoses shared by goats and sheep. Chlamydia was diagnosed in both goats and cattle. Cattle and sheep shared 12 diagnoses in common.

Table 3.2.17. List of diagnosis for cases relating to abortion and stillbirth cases submitted to Victorian state laboratories.

Diagnosis	Cattle	Goat	Sheep	Total
Actinobacillus spp.	1			1
Actinomyces spp.	1		1	2
Acute Bovine Liver Disease	1			1
Acute bovine pulmonary oedema and emphysema	1			1
Adenovirus	1			1
Aino virus	1			1
Aspergillus infection	9			9
Aspiration pneumonia			1	1
Border Disease (Ovine Pestivirus)			2	2
Bovine ephemeral fever	2			2
Bovine malignant tumour (eye, >2cm)	1			1
Bovine respiratory syncytial virus (BRSV)	1			1
Campylobacter spp.	9		50	59
Chlamydia	2	2		4
Congenital malformation	1		4	5
Cryptosporidiosis	1			1
Dystocia	2		2	4
Escherichia coli	10		4	14
Erysipelothrix rhusiopathiae	1			1
Histophilus somni	2			2
Infectious bovine rhinotracheitis (IBR/IPV/BHV-1)	7			7
Internal parasites^	3	6	5	14
Leptospirosis	54		1	55
Listeriosis	2		57	59
Mannheimia haemolytica		1	3	4
Mismothering/Starvation	1		1	2
Mycotic/fungal infection (organism identified)	2			2
Neospora	59			59
Nutritional deficiency*	18	5	20	43
Parainfluenza-3 (PI3)	2			2
Paratuberculosis (Johnes disease)	3	1	1	5
Pasteurella spp.	1			1
Pestivirus	101			101
Q fever		1		1
Rotavirus	1			1
Salmonella spp.	32		5	37
Streptococcus spp.	6		2	8
Theileriosis	23			23
Toxoplasmosis			10	10
Trauma	1		1	2
Trueperella pyogenes	4		1	5
Yersiniosis spp.		1	4	5

N/A	35	1	10	46
No diagnosis	300	15	74	389
Total	702	33	259	977

3.2.3.5 Abortion and stillbirth submissions from South Australia

In total, 781 cases related to abortions and stillbirths in sheep, cattle and goats, were submitted to the South Australian state laboratories between 2006 and 2019. Of these cases, 643 related to cattle, 23 related to goat and 115 related to sheep.

The number of submissions received each year is reported in Figure 3.2.7. The number of cases submitted per year varied greatly for all three species. Goat submissions were the most consistent and showed a slight decrease across the years. Sheep submissions showed an increase, and cattle a slight decrease.

The maximum number of submissions for cattle cases was 73 in 2011, and the minimum 1 in 2006, the average number of submissions per year was 45.9 submissions. The maximum number of submissions for goat cases was 11 (2008) and the minimum was 0 submissions in (2006, 2007, 2010, 2011, 2014, 2015, 2018 and 2019). On average 1.6 cases were submitted per year. The maximum number of submissions relating to perinatal loss in lambs was 23 cases (2016) and the minimum was 0 (2013). The average number of cases submitted was 8.2 submissions per year.

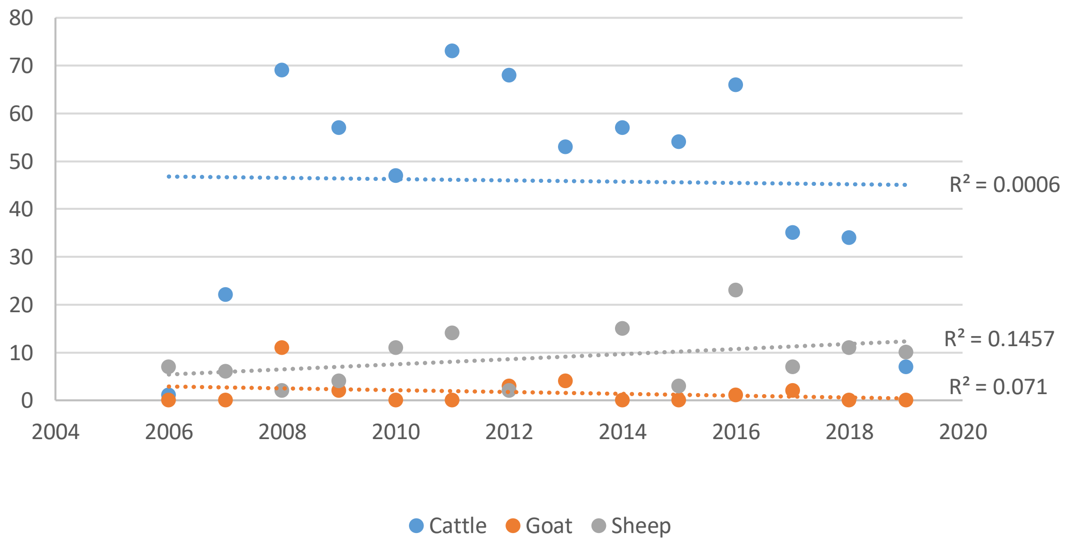

Figure 3.2.7. Scatterplot of the number of cases submitted to South Australian state laboratories per year from 2006 to 2019.

The outcome of submitted cases in shown in Table 3.2.18. Overall, only 16.6% of cases had a positive outcome. Sheep had the highest proportion of positive outcomes (31.3%) followed by cattle (14.3%) and goats (8.7%) positives.

Table 3.2.18. Case outcome of abortion and stillbirth submissions from South Australian state laboratories from 2006 to 2019.

	Positive	No diagnosis	Total
Cattle	92	551	643
Goat	2	21	23
Sheep	36	79	115
Total	130	651	781

Between the three species, there was 29 different causes of abortion and stillbirth listed. Cattle had 22 different cause of abortion and stillbirth, with the top diagnoses listed as Pestivirus (21 cases), placentitis (12 cases) and *Campylobacter* spp. (11 cases). Goats had two cases diagnosed, these being Myopathy and Necrobacillus. Sheep had 12 diagnoses listed, with the most common causes being Listeriosis (13 cases), *Campylobacter* spp. (6 cases) and placentitis (5 cases).

None of the causes listed were shared by all three species, with only sheep and cattle sharing the same diagnoses. The shared diagnoses included *Campylobacter* spp., dystocia, *Escherichia coli*, *Leptospira* spp., listeriosis, placentitis, and *Trueperella pyogenes*.

Table 3.2.19. List of diagnosis for cases relating to abortion and stillbirth cases submitted to South Australian state laboratories from 2006 to 2019.

Diagnosis	Cattle	Goat	Sheep	Total
Trueperella pyogenes	3		3	6
Bacteraemia	1			1
Campylobacter spp.	11		6	17
Clostridia	1			1
Congenital Defect	1			1
Congenital Myoclonus	1			1
Dystocia	3		1	4
Escherichia coli	3		1	4
Erysipelas			1	1
Hypocalcaemia	1			1
Inf Abortion	5			5
Leptospira spp.	3		1	4
Listeriosis	1		13	14
Meningitis	1			1
Myopathy		1		1
Necrobacillus		1		1
Neospora caninum	7			7
Nephritis			1	1
Internal parasites (*Strongylosis* spp.)			1	1
Peritonitis	1			1
Pestivirus	21			21
Placentitis	12		5	17
Pneumonia	3			3
Poisoning			2	2
Salmonella spp.	9			9

Septicaemia	1			1
Staphylococcus spp.			1	1
Streptococcus spp.	2			2
Trauma	1			1
No diagnosis	551	21	79	651
Total	643	23	115	781

3.2.4 Summary findings and conclusions

Data on cattle, sheep and goat submissions related to perinatal death and abortions and stillbirths was obtained from NSW, Victoria and South Australia (SA). The time period included in the study was from 2006 to 2019; however, data from Victoria was only available from 2009 to 2019. In addition, data was obtained in October 2019, therefore 2019 data is incomplete. For South Australia, information was only available for cases identified as abortion and stillbirth, with no specific information for perinatal deaths. Differences between the type of data collected in each state, the recording system and the definitions used made the comparison between the three states not possible and further information is required to be able to conduct a more comprehensive analysis of the data. Despite the limitations on the data obtained this report provides an overview of submissions and the diagnosis outcomes reported.

In relation to submissions identified as perinatal death, there were 703 and 1,625 submissions in NSW and Victoria, respectively. Among these, the majority of cases were from cattle (NSW, 87%; Victoria, 76%), followed by sheep (NSW, 10%; Victoria, 20%) and with only a small proportion of cases being from goats (approximately 3% in each state). In NSW, between 40 and 48% of the submitted cases across all species had a specific diagnosis, with the rest being identified a no positive or no diagnosis. The three most common diagnosis for cattle submissions were cryptosporidia, rotavirus and pestivirus and for sheep submissions, dystocia and nutritional deficiencies. For goats, only six causes of death were identified with nutritional deficiencies and *E. coli* being diagnosed twice. In Victoria, a higher proportion of submitted samples had a specific diagnosis (just over 75%), when compared to NSW, however, this should be interpreted with caution given the differences on data recording. The three most common diagnosis for cattle submissions were *Salmonella* spp., internal parasites and rotavirus. For sheep submissions, the most common causes identified were similar to those identified in NSW, these being starvation/mismothering, nutritional diseases and dystocia. For goats, the most common causes identified were similar to those for sheep, these being starvation/mismothering and nutritional diseases, in addition to *Salmonella* spp. This data suggest that nutritional deficiencies are identified as a common cause of perinatal death across NSW and Victoria for sheep and goats.

In relation to submissions identified as abortions and stillbirth, there were 3,017, 997 and 781 in NSW, Victoria and South Australia, respectively. The distribution of cases across species for these submissions is very similar than for submissions related to perinatal death. Among these the majority of cases were from cattle (NSW, 87%; Victoria, 71%; SA, 82%), followed by sheep (NSW, 11%; Victoria, 26%; SA, 15%) and with only a small proportion of cases being from goats (approximately 3% in each state). In NSW, an average of approximately 40% of cases submitted had a positive diagnosis; however, this proportion was higher among cattle and sheep cases (41 and 36.3%, respectively) than for goats (19.3%). In Victoria, similarly than for perinatal deaths, the proportion of submissions with a specific diagnosis was higher than that of NSW (approximately 60%), with cattle submissions being those with the highest proportion of diagnosed cases (almost

72%). In South Australia, the proportion of samples with a positive outcome was the lowest among the three states, with an average of 16.6%. Less than 10% of goat samples had a conclusive diagnosis. The most common diagnosis for cattle submissions were the same for NSW and Victorian samples, these being pestivirus, neospora and leptospirosis. In South Australia, pestivirus was also identified a frequent cause of abortion and stillbirth. The most common causes of abortion and stillbirth identified for sheep samples across the three states were very similar, these being *Campylobacter* spp., nutritional deficiency and *Listeria*. For goat samples, the most common causes of abortion and stillbirth identified in NSW and Victoria were nutritional deficiencies and chlamydia, with *Yersinia enterocolitica* identified in NSW and internal parasites identified in Victoria. Similar to perinatal death, data suggest a common cause identified in abortion and stillbirth related submissions, in NSW and Victoria, for sheep and goats is nutritional deficiencies.

The descriptive analysis of the data identified that the number of submissions related to goat perinatal deaths, abortions and stillbirth is low across NSW, Victoria and South Australia, with a very significant proportion of these submissions not having a specific diagnosis. Given the low number of submissions from goats, the interpretation of the identified diagnoses should be done with caution. This study identified the need to further investigate goat perinatal deaths and abortions and stillbirth, to increase understanding of the potential causes of these animal health events.

3.3 Producer case studies

An exploratory study was undertaken to investigate animal health and reproductive wastage among Australian meat goat producers. Twenty goat producers were interviewed to produce this report.

3.3.1 Introduction

In Australia, the value of goat meat exports doubled between 2011 and 2017 and production has tripled since 2001 (MLA, 2020a). In 2018, due to several factors, including drought conditions, production fell by 26% from 2017 O'Connor (2016). However, carcase weight has remained at an average of 15 kg, suggesting that the main drivers for growth are price and number of goats produced (O'Connor, 2016). Therefore, the longer-term sustainability of supply for the meat goat industry relies heavily on reproduction. However, little is known about reproduction rates across the sectors of the industry, which vary on their level of management intensity.

Animal health management across the meat industries has clear and important impacts on growth, welfare, reproduction and survival of animals, as well as carcase weight and meat quality (Alexandre *et al.*, 2010). As with information on reproduction rates, information on current animal health management practices and disease within the Australian meat goat herd is minimal. Producers and veterinarians have previously identified the lack of useful and specific information which in turn impacts their ability to care for their animals (Lane *et al.*, 2015; Hernández-Jover *et al.*, 2019).

Australian studies that have listed the most important diseases according to producers have aimed to estimate costs of priority diseases (Lane *et al.*, 2015) or were conducted over five years ago on a specific area of Australia (Nogueira *et al.*, 2016). Thus, up to date information on animal health management in the Australian goat meat industry is needed given the significant increase in production in the recent years.

A Victorian benchmarking survey, conducted in 2002 among commercial goat meat enterprises, found weaning rates varied from 51% to 165%, with producers noting doe fertility, kid predation and poor kid growth rates as important husbandry issues, suggesting pre-weaning losses are a significant issue (Ferrier and McGregor, 2002) . However, there is little reproductive data detailing fecundity, fertility and kid survival within the goat industry. This could be due to the low number of producers who keep reproductive records, as revealed by Nogueira *et al.* (2016), who found only 48% of surveyed producers keeping reproduction records, and only 10% undertaking pregnancy scanning. Although there is limited data detailing the extent of kid loss, rates are thought to be similar to lamb losses, with estimates varying between 11% and 33% (Hinch and Brien 2014). A report by Lane *et al.* (2015), ranked neonatal loss in sheep as the top ranking disease; however, neonatal mortality in goats was not identified to be of importance among the surveyed goat producers or goat veterinarians. The lack of benchmarks within the goat industry, in addition to the apparent lack of awareness of the issue by producers and veterinarians means potential for improvement may not be being addressed.

Insufficient knowledge of herd management practices in the goat meat industry has been identified as a limitation by the Australian Goat Industry Council, which must be addressed in order to increase productivity (Goat Industry Council of Australia GICA, 2015). Previous studies have not focused primarily on the managed sector of the goat meat industry and have not represented all major goat meat production zones within Australia; with these studies having been conducted more than five years ago and prior to the significant increase in goat meat production. Therefore, the aim of the current exploratory study is to gather up to date information from a diverse group of Australian goat meat producers operating managed, semi-managed and stud production systems to gain insight into their practices and perceptions on animal health management, with a focus on reproduction and perceptions of kid loss, to better understand any potential for intervention.

3.3.2 Methodology

An exploratory study gathering information using interviews with goat producers was conducted. The study was approved by the Human Research Ethics Committee at Charles Sturt University (H19077).

Interview development

The interview contained a total of 40 questions related to general demographics, husbandry practices, animal health practices and concerns, reproductive management, and perceptions on reproductive wastage and kid loss. The interview contained 31 closed questions and nine open-ended questions. The questionnaire was piloted with two producers (one was not included in the results), in order to identify areas for improvement, and was revised before use across the wider population.

Producer identification and interview process

Due to the exploratory nature of this study and the qualitative approach of the methods used, the study did not aim to obtain a representative sample of meat goat producers in Australia, but rather include a number of producers to ensure adequate diversity across different meat goat enterprises and geographical locations. Therefore, a small cohort of producers who operate managed and semi-managed meat goat enterprises and kept more than 20 animals were targeted, ensuring different geographical locations / production zones were represented. Managed meat herds include stud, commercial and hobby operations keeping domestic breeds, whilst semi-managed herds typically consist of rangeland goats that have been capture and are maintained with minimal animal husbandry input (Goat Industry Council of Australia GICA, 2015). Production zones one, two, three and four were included in the study (Figure 1.1). Producers from production zone five were not targeted, as this area consists of wild harvest production only.

The study was promoted through online and radio media communications, from which interested producers were invited to contact the research team. Producers were also recruited through direct approach and personal contacts. A 45-minute interview was conducted with engaged producers either via phone or face-to-face on farm. A further snowballing approach was undertaken to increase the number of producers.

Definitions and calculations

As part of the interview, producers were asked to provide estimates of fertility, kidding rate and weaning rate. These terms were defined as follows:

Fertility rate (%) = (number of does pregnant/number of does joined) × 100

Kidding rate (%) = (number of kids born/number of does joined) × 100

Weaning rate (%) = (number of kids weaned/ number of does joined) × 100

Given the actual number of kids born and perinatal kid losses were rarely available, estimates for the proportions were provided by producers for weaning and kidding rates. Estimated kid loss per cent was calculated as follows:

Estimated kid loss (%) = 100 – [(weaning rate / kidding rate) *100]

Data Analysis

All data collected from the interviews were entered into Microsoft® Excel (Windows XP, 2006). Descriptive statistical analysis was used for the quantitative data gathered during the interviews, using proportions and summary statistics for continuous data. Questions in relation to opinions and perceptions, which produced qualitative data, were analysed to identify common descriptors and a thematic analysis was conducted to derive key themes from across the data (Green and Thorogood, 2018).

3.3.3 Results

A total of 20 producers agreed to participate in the study, with interviews being conducted between June and August 2019. Five interviews were conducted in person and 15 were conducted via a telephone interview.

3.3.3.1 Producer demographics

Table 3.3.1 presents a summary of the demographic and enterprise characteristics of the 20 meat goat producers participating in this study. The median number of years of producer involvement with meat goat production was 20 years, and most producers were over 50 years of age. In relation to production system, 12 producers identified themselves as operating managed herds, with four producers operating stud enterprises, two operating semi-managed enterprises and two producers running mixed operations. Of the two mixed operations, one identified as operating a stud plus a managed commercial herd; the second a stud and a rangeland herd. Most producers (n = 15) predominantly kept Boer goats or their crosses.

Due to widespread drought conditions, 11 producers reported having partially destocked their herds. Stock numbers were highly varied with the number of breeding females kept in an average season ranging between 20 and 6,000 and the number of bucks ranging between 1 and 1,800.

Table 3.3.1. A description of the demographic and enterprise characteristics of 20 meat goat producers.

Characteristic		Number of respondents
Production zone*		
	1	11
	2	5
	3	2
	4	2
Age		
	Mean	55.4
	Median	53
	Min - Max	33 – 74
Education level		
	≤ Year 10	6
	Year 12	3
	Tertiary	8
	Post graduate	3
Years involved in meat goat production		
	Mean	16.9
	Median	20
	Min - Max	2.5 – 30
Production system		
	Managed	13
	Semi-managed	2
	Stud	5
Property size (ha)		
	Mean	6,382
	Median	1,550
	Min-Max	8 – 26,300

*Production zone: 1= Rangeland (predominantly wild harvest, but with significant production from extensive managed and semi-managed enterprises); 2= Northern high-rainfall (mixed farming, small-scale managed); 3= Southern high-rainfall (mixed farming, small scale managed); 4= Southern high-rainfall SA and WA (mixed farming, small scale managed) (refer to Figure 1.1 for geographical location).

3.3.3.2 Nutrition

Producers were questioned about their feed base and provision of supplements and supplementary feed to their stock. Native pastures were frequently grazed (15/20), with the remaining producers using improved pastures (3/20), handfeeding (1/20) or browse (1/20) as their main feed bases. Fourteen producers used supplementary feeding (commonly hay and/or grain) to provide extra feed to their stock. Most producers supplementary fed all stock during the dry periods. Additionally, seven producers would provide supplementary feed to does during late pregnancy and lactation.

Fifteen producers reported providing dietary vitamin and/or mineral supplements to their goat herds. All producers identified using mixes of different vitamins and/or minerals, however iodine, magnesium, copper, selenium, calcium, potassium and sulphate. Producers identified several reasons for providing vitamins and minerals, the main reason provided was soil deficiency ("*we know there are not enough minerals in the soil…*[after adding supplements] *reduced foot problems;* Producer 4". Additional reasons that were provided were natural deficiency of minerals in goats, lack of green feed, pre-kidding management and as an anticoccidial.

3.3.3.3 Animal health perceptions and management

Vaccination was practiced by over half of producers (12/20). Producers used 6-in-1 (7/12) or 5-in-1 (5/12) for protection against the five main clostridial diseases (black leg, black disease, malignant oedema, enterotoxaemia and tetanus) and caseous lymphadenitis (CLA; 6-in-1 only). One producer vaccinated against leptospirosis in addition to clostridial diseases. Eight producers vaccinated all stock, two producers only vaccinated does and kids, and two producers vaccinated kids only. Vaccination occurred once or twice per year depending on the type of animal. Most producers reported vaccinating bucks (7/8) and does (8/10) once per year, with half of producers (6/12) vaccinating kids once per year with the other half vaccinating twice per year.

Drenching was a common practice by producers (15/20). Producers who operated semi-managed production systems did not vaccinate or drench their stock. Most producers (9/15) did not have a regular drenching regime, instead they drenched according to need, which was based mainly on faecal egg counts and after heavy rain events. Those with a drenching regime drenched either once per year (4/6) or twice per year (2/6). Additionally, four producers drenched all classes of stock and the remaining two producers only drenched does and kids. Six producers were able to recall what type of drench they were currently using: these were moxidectin (3/6), avermectin (1/6), abamectin (1/6) and ivermectin (1/6). One of these was a product registered for use in sheep. In addition, one producer stated that they were currently using a sheep drench (although they were unable to recall what type) because they felt the drenches available for use in goats were not effective. Four producers noted that they would rotate drenches to minimise drench resistance.

The interview also investigated the occurrence of disease in the herd. Seventeen producers reported to have experienced disease and/or animal health issues on their properties, with internal parasites being the most common issue identified (10/17). Issues had occurred within 12 months of the interview in 8/17 cases. Furthermore, four of these producers specifically identified the nematode Barber's pole worm (*Haemonchus contortus*) as a problem. Further diseases that producers identified included, pulpy kidney (enterotoxaemia caused by *Clostridium perfringens*) (5/17), benign footrot (3/17), acidosis (3/17), foot problems (3/17), plant poisoning (3/17), scabby mouth (2/17), mastitis (1/17), campylobacterosis (1/17), salmonellosis (2/17), dermatitis (1/17) and chlamydiosis (*Chlamydia pecorum*) (1/17). Six producers reported that the diseases they had experienced were of a concern to them, most notably internal parasites.

Seventeen producers had contacted a veterinarian in relation to the health of their goats, which included contacting government veterinarians (5), private veterinarians (12) and both government and private veterinarians (2). However, the time of last contact varied greatly, from the day that the interview was conducted to almost 20 years, the median was eight months. The main reasons for contacting a veterinarian were treatment for specific health issues (6/18), general health information (including nutritional and product recommendations) (5/18), kidding problems (5/18) and drug dosages (including for "off-label" product use) (3/18). The lack of need and the limited knowledge of veterinarians about goats were the two reasons identified by the two producers who have not had contact with a veterinarian in the past. Furthermore, one producer who had not contacted a vet in over 10 years, stated "*we haven't found a vet who knows enough* [about goats]" (Producer 4).

All but one producer actively sought information about the health and management of their goat herd. The most common source of information was veterinarians (9/19), followed by the internet (8/19), industry bodies (7/12), such as Meat and Livestock Australia, Goat Industry Council of Australia and Boer Goats Australia, government departments (7/12), other producers (4/19), animal health retailers (3/12) and goat related books (1/19). However, one producer who operated a semi-managed enterprise in production zone one, noted that "*it was hard* [to find information] *because there was not a lot out there… a lot doesn't relate to what is going on out here*" (Producer 20).

The majority of producers stated that they kept animal health records (18/20). Producers kept records of treatments (dosages, chemicals used, batch numbers) (16/18), animal movements (3/18), feeding regimes (3/18), births and deaths (6/18) and animal behaviour (1/18). Records were predominantly kept in written form (10/18), three producers kept only electronic files and five producers kept both written and electronic records.

3.3.3.4 Reproductive management

A summary of the reproductive management practices of participant producers by production type is shown in Table 3.3.2. In relation to joining management, most producers (n =17) introduced bucks to the does at a specific time during the year, most commonly between January and April. Of these, 15 producers had a controlled joining period ranging from five to nine weeks, with the other two producers not removing their bucks until kidding. Three producers (including both semi-managed producers) reported continuously running their bucks and does together, with kidding being reported at varied times: July and December; August and March; and the third during autumn and spring.

Six producers monitored condition score of their does prior to joining, while three producers monitored live weight. The range of condition score that producers aimed to have their does in was between two to four out of five for joining. Those that monitored live weight reported having a minimum weight for joining, two producers reported a minimum weight of 40 to 45kg, one producer reported a minimum weight of 18kg.

Nine producers engaged in pregnancy scanning. The time that pregnancy scanning occurred varied between 80 to 110 days after the bucks were introduced. Eight producers scanned for non-pregnant, single and multiple foetuses, with one producer scanning only for pregnant and non-pregnant. All producers using pregnancy scanning reported making management decisions based on the scanning outcome, with all producers reporting pregnant and non-pregnant being separated and four producers separating does with single and multiple pregnancies, in order to provide increased nutrition for does carrying multiple foetuses. One had engaged in this practice in the past, however, they reported to have stopped due to "*cost, too hard to organise and increased fertility rates*"

(Producer 17). Producers who did not engage in pregnancy scanning identified the small herd size, the related cost and not finding it necessary as the main reasons for not conducting this practice.

Producers were asked if they had observed a natural stop in breeding of their herd. Eight producers reported that they had, and identified drought conditions, heat and mating out-of-season as reasons why breeding had stopped, with increased feed and rain as factors contributing to the commencement of breeding. The producers who did not identify an unusual stop in breeding in their herds considered goats to be seasonal animals and as such their breeding would naturally stop at certain times of the year.

Table 3.3.2. Reproductive management practices reported by producers, based on an average year.

	Managed (n = 13)	Semi-managed (n = 2)	Stud (n = 5)	Total (n = 20)
Joining percentage				
Average	3.18	-	2.17	3.19
Median	3	-	2	3
Min – Max	1.5 – 5	-	1.5 – 5	1.5 – 5
Bucks continuously running with does				
Yes	1	2	0	3
No	12	0	5	17
Age of maiden does (months)				
Average	12.17	-	15.8	12.8
Median	12.5	-	15.9	14
Min – Max	6 – 18	-	12 – 18	6 – 18
Age of oldest does (years)				
Average	7.77	-	9.6	8.1
Median	8	-	9.8	8
Min – Max	4 – 12	-	8 – 12	4 – 12
Monitor condition score or live weight				
Yes	7	0	2	9
No	6	2	3	11
Use pregnancy scanning				
Yes	8	1	2	11
No	5	1	3	9
Herd has stopped breeding in some years				
Yes	4	2	2	8
No	9	0	3	12

Use artificial insemination				
Yes	1	0	3	4
No	12	2	2	16
Use oestrus synchronisation				
Yes	1	0	3	4
No	12	2	2	16

3.3.3.5 Records and perceptions on reproductive loss

Table 3.3.3 presents a summary of the reproductive records reported by participant goat producers. The number and detail of reproductive records kept by producers varied greatly. Fertility rates ranged between 53 to 100%, with producers who did not use pregnancy scanning assessing pregnancy status visually. Of those that used pregnancy scanning, one producer reported that the youngest does, born in 2018, had the lowest fertility rate (17%) compared to older does (95 to 99% for does born in 2015 to 2017). Furthermore, one producer reported a very significant difference in fertility rate depending on joining time (12% fertility rate in does joined in December; 95% in does joined in April).

Table 3.3.3. Reproductive records of 20 meat goat producers participating in a study investigating animal health and reproduction in 2019*.

Reproductive record	Managed	Stud	Total
Fertility rate (%)	(n = 11)	(n = 5)	(n = 17)
Average	89	87	88
Median	91	92	92
Min – Max	75 – 100	53 - 100	53 - 100
Kidding rate (%)	(n = 5)	(n = 3)	(n = 8)
Average	154	198	188
Median	150	195	195
Min – Max	90 – 225	160 – 238	90 - 238
Number of kids weaned per year (%)	(n = 10)	(n = 5)	(n = 15)
Average	125	161	137
Median	120	150	135
Min – Max	80 – 200	120 - 196	80 - 200
Estimated kid loss from birth to weaning (%)	(n = 4)	(n = 3)	(n = 7)
Average	33.5	20.75	28
Median	36.5	17.6	27.3

Min – Max	20 – 46.7	6.25 – 38.4	6.25 – 46.7

*Only managed and stud operations kept reproductive records

The level of kid loss (6.25 - 46.7%) could only be estimated for those producers who provided fertility, kidding and weaning rates. Among these, one producer reported that the levels of kid loss they had experienced had been increasing each year from 18% in 1995 to 40% in 2018. Producers were asked at what level kid loss was concerning, the median was 10% with a range from 1 to 40%. The most frequently reported reason for kid loss among producers was predation (15/20; Table 3.3.4), according to producers, predation was caused by foxes (*Vulpes vulpes*), wedge-tailed eagles (*Aquila audax*), feral pigs (*Sus scrofa*) and wild dogs (*Canis lupus familiaris*). Following predation, the most frequently mentioned causes of kid loss were poor nutrition of the doe (13/20) and mismothering (9/20). Most producers (14/20) reported most kid losses occurring within the first week of birth, with birth and the first three days after birth being identified as the most likely time of kid loss. The majority of producers (13/20) identified maiden does and multiple bearing does experiencing the most kid loss, with the rest of producers reporting all classes of does experiencing similar levels of kid loss.

All producers agreed that kid loss could be minimised through improved herd and animal management, with predator control (13/20), management of doe nutrition (9/20), and addition of kidding paddocks and/or shelter (7/20) being the practices commonly identified.

Table 3.3.4. Perceptions on causes of reproductive and kid loss of 20 meat goat producers participating in a study investigating animal health and reproduction in 2019.

Causes of reproductive loss	Managed (n = 13)	Semi-managed (n = 2)	Stud (n = 5)	Total (n = 20)
Poor doe nutrition	9	-	4	13
Drought conditions	3	2	1	6
Young doe	2	-	-	2
Buck issues	1	1	-	2
Low birth weight	2	-	2	4
Abortion	1	-	-	1
Birthing difficulties	1	-	1	2
Predation	11	2	2	15
Mismothering	6	-	3	9
Cold weather	1	-	4	5
Large litter sizes	1	-	-	1
Kid did not drink	1	-	2	3

3.3.4 Discussion

This study provides an insight into current practices and perceptions on animal health and reproduction among goat meat producers in Australia and identifies potential improvements for the industry. This study was designed to provide exploratory data to be used as a guide for further research and as such results should be interpreted with caution as the small sample size prevents a fully representative picture of the meat goat industry. Among participating producers, there was a higher representation of those operating managed systems, and of those located in production zone one, likely due to the recruitment strategy and the topic of the study. It is likely that only those more engaged with the industry and with an increased interest in management and reproduction volunteered to participate. A further limitation with using interviews for gathering data is the potential for recall bias, as some questions referred to past events.

Although the number of producers interviewed in the current study does not allow a comparison between production systems, participating producers operating semi-managed systems reported minimal animal husbandry practices and did not keep specific animal health and reproductive records, which is consistent with what is known about semi-managed production systems (Maher, 2018). Animal health practices were similar between stud and managed production systems; however, perceptions and reproductive management differed, with stud producers undertaking more intensive practices in comparison to managed producers.

Nutrition appeared to be a high priority for most producers, especially in relation to reproduction, with over half of producers identifying poor doe nutrition as contributing to reproductive losses. Most producers used supplementary feed to manage nutrition either during dry periods feeding to all stock, or for pregnancy and early lactation management. Increased nutrition during late pregnancy and early lactation is important for pregnant does, especially those carrying twins, as they have increased energy demands (Jolly, 2013). A common practice among producers was supplementation with vitamins and/or minerals to support reproductive performance, due to the perception of either plants/soil being deficient or the goats themselves being naturally deficient. Calcium, iodine, selenium, copper and sulphate deficiencies have been linked to the birth of weak kids and decreased reproductive performance (Jolly, 2013). However, soil deficiencies can vary between locations, therefore in order to determine whether the soil is deficient and the need for supplementing minerals, producers should test their soils and animals (MLA, 2018), a practice not conducted among participant goat producers.

Body condition scoring is a useful tool for determining the nutritional needs of animals (Browning R and Leite-Browning, 2011); however, monitoring of BCS of does was conducted by less than half of the producers interviewed. Some producers only scored at joining and the target BCS varied greatly. Condition score is an important tool for reproductive success, with studies showing that joining does too low in condition is associated with lower fertility (Mellado *et al.*, 2004a) and during late pregnancy, too low or too high condition scores can cause metabolic diseases, such as pregnancy toxaemia (Jolly, 2013).

Producers identified a wide range of diseases that had occurred on their properties, with intestinal parasites being the most commonly reported. This finding is consistent with Lane *et al.* (2015) which listed internal parasites as the most economically important disease to the goat industry. Enterotoxaemia, lice and footrot were also listed as economically important diseases in the study by Lane *et al.* [3], and in the present study, but were identified to be of less concern. In the present study, many of the diseases listed were non-infectious and due to nutritional issues, which suggest that there is a need to further investigate nutritional management strategies. The failure by some producers to report disease concerns may be associated with lower prevalence of disease or the extensive nature of some systems. Gunther *et al.* (2019) interviewed dairy goat producers, and reported producers perceiving an 'apathy' within the industry towards biosecurity and disease. Despite a low level of disease concern identified in the current study, producers reported concern of the specific diseases that occurred within their herd and were not asked about the extent and impact caused by the disease.

In relation to animal health management, vaccination regimes varied between systems, with many producers not providing booster doses to bucks and does as recommended by the MLA Husbandry guide (MLA, 2020b). Only three types of vaccines were used by producers, with most only using 6-in-1 or 5-in-1. Although scabby mouth was reported to be an issue for some producers, none reported vaccinating against this disease.

Drenching for internal parasites was practiced by all the producers who reported intestinal parasites as an issue. However, not all producers who drenched on need, used faecal egg testing to determine this need. This is particularly interesting considering the concern that many producers had with drench resistance, which has been seen in other farmed animals due to inappropriate and excessive administration (Playford *et al.*, 2014). This issue may be even more important in goats, due to the limited number of products that are registered for use in this species. The reported use of unregistered products can result in residues in products from the treated goats, as was seen with the use of antibiotics in dairy goats in Spain (Quintanilla *et al.*, 2018). Maher (2018), who surveyed meat goat producers and interviewed stakeholders within the industry, found that producers recognised the need for more approved products for goats.

Nearly all producers had contacted a veterinarian, and most producers had done so in the past 18 months, with similar levels of contact being reported among producers in the dairy goat industry (Gunther *et al.*, 2019; Hernández-Jover *et al.*, 2019). There was a variety of reasons reported for contacting veterinarians, with one of the main reasons being for use of "off-label" products, which reaffirms that products registered for use in goats are limited. A common reason for the lack of veterinary contact was the perceived limited knowledge about goats among veterinarians. This is supported by the study by Maher (2018), who reported the same reason among goat industry stakeholders. This study also identified that there are limited resources for veterinarians to treat goats.

Most producers kept animal health records of some description. Those operating stud production systems tended to keep more specific individual records for their goats, while those operating managed and semi-managed production systems kept less detailed records. These findings are similar to what has been found by Nogueira *et al.* (2016) and Maher (2018).

Most producers reported seeking information in regard to the health and management of their goats. However, producers noted the lack of information available specific for their enterprises. Similarly, Maher (2018) in a study among goat producers in Australia, found that 44% of participants thought that available information was inadequate, and that more specific information and research on animal health management was needed.

Most producers had controlled breeding seasons, with the introduction of the bucks usually occurring in March to May. This aligns with the natural mating season (autumn) and with what has been found in similar studies (Fatet *et al.*, 2011; Nogueira *et al.*, 2016). However, kidding time differed among producers who reported running their bucks continuously, even though these producers were in the same production zone. Additional research in this area is warranted to understand the reasons for these differences as this could have an impact on reproductive performance, including kid loss.

Pregnancy ultrasonography is an important tool to understand where reproductive loss is occurring, management of does and overall productivity (Fridlund *et al.*, 2013). Pregnancy ultrasonography was only used by approximately half of producers, with these being managed herds or studs. The number of producers using pregnancy ultrasonography is similar to numbers in the sheep industry, where a recent study by Howard and Beattie (2018) found that 50% of sheep producers undertook this practice. Furthermore, similar reasons for not utilising ultrasound pregnancy diagnosis were reported by sheep producers to those reported by meat goat producers in the current study.

Another aspect investigated in this study was the occurrence of discontinuation of breeding in some specific years, with almost half of participant producers reporting this event. Heat and drought were identified by producers as the main reasons for discontinuation of breeding. In an Australian study of reproductive performance in Merino ewes, heat was identified as a cause of decreased fertility and embryo survival (Kleemann and Walker, 2005a). Additionally, drought has been identified as severely impacting reproductive performance in sheep (Fowler, 2007). Furthermore, producers reported that increased feed through supplementation or rainfall, caused breeding to recommence, suggesting that poor BCS was limiting reproduction, or that the reproductive physiology of the goat is particularly sensitive to environmental cues. There have been studies showing the relationship between BCS and reproductive performance, as discussed above (Mellado *et al.*, 2004a), however further studies are required to better understand factors contributing to the reported mating patterns and of conditions where breeding stops.

Fertility rates were at expected high levels [4] for both stud and managed production systems, although there were some herds with suboptimal fertility. It should also be noted that estimation of fertility by producers who did not pregnancy scan were included in this number and it is unclear how accurate their estimations were. However, the high mean fertility rates suggest that there is not a large issue with fertility, although it is low on some properties.

Although there was limited data available from participating producers, it is apparent that kid loss is often high. Previous studies have reported kid losses in Australia ranging from 11-40% (Nogueira *et al.*, 2016; Jolly, 2013). Similar values were obtained in the current study, with estimations ranging from 6% to 47%. Despite the limited data, given the scale and range of losses, there is a clear need for further research into kid loss. Nearly all producers reported kid losses occurring within the first week of birth, which aligns with what has been reported in sheep, where 55.6% of total losses occurred in the perinatal period (Hinch and Brien, 2014). Producers considered predation, doe nutrition, mismothering and weather conditions, including cold weather and drought, to be the biggest contributors to kid losses. These causes are similar to those found by Snyman (2010), who investigated losses in live born kids in Angora goats in South Africa, and found that predation was the biggest cause of kid loss, accounting for 39.1% of losses, with mismothering and weather events contributing to 6.8% and 5.3% of losses, respectively. A clearer understanding of losses due to predation is needed to distinguish between the levels of primary and secondary predation. A study on neonatal lamb losses showed that 7% of dead lambs had been affected by predation, however, it was concluded that primary predation was the cause of death for only 0.12% lambs born (Refshauge *et al.*, 2016). Further study into the causes of kid loss is needed, so that informed decisions can be made by producers to reduce the levels of kid loss.

This exploratory study provides an insight into animal health and reproduction practices and the perceptions of Australian meat goat producers. This study highlights the need for more reliable and specific information on husbandry, animal health and reproduction management practices. Kid loss remains a significant source of reproductive loss and effective preventative measures need to be developed.

3.4 On-farm pregnancy scanning and kid marking

3.4.1 Methodology

Several forms of media communication were used to attract interest from producers to engage with the pregnancy scanning component of the study. The industry communication occurred in print media via Goats on The Move and via newspaper and magazine formats. Radio interviews were also undertaken, resulting in widespread awareness of the study. More details on the degree of industry engagement are reported in Section 3.7.

Professional networks and personal contacts snowballed the number of producers engaging with the study. The widespread and intense drought made it difficult for producers to feel sufficiently confident they could retain their pregnant does throughout the period from scanning to marking or weaning, reducing the number of properties.

The producers were encouraged to arrange the details of the date and location of pregnancy scanning with their regular pregnancy scanner or were directed to a local scanning contractor where necessary.

The researchers requested management of the does was to reflect normal decision-making, with the exception to enable the counting of does and kids post-kidding to occur.

In some locations it was clear that the age of the doe herd was mixed, with some young kids included in the mated herd. Some herds had completely controlled mating programs, while other sites kept the bucks in until pregnancy scanning. On the occasions when that happened, the dry does were scanned a second time and separate counts were made.

Attracting interest from the goat industry was moderately successful in 2019. The target number of does to be scanned was 10,000 and we were able to achieve 92% of that target, with 9,187 does scanned.

3.4.2 Results

It is not possible to tell if the level of engagement was normal or whether barriers for engagement were operating during 2019. Possible barriers for engagement will include the long-term and intense drought conditions of NSW and QUEENSLAND; the requirement to pregnancy scan meat goats in a semi-managed or managed production system, and the request of at least 200 does to pregnancy scan.

The producers engaging in the project were from production zones one, two and three, as depicted in Figure 1.1, and two states (NSW and QUEENSLAND). The production zones included Rangeland, Northern high rainfall and Southern high rainfall. Does were joined and kidded across the seasons, including autumn, winter, spring and summer. The spread of seasons provides helpful data for industry.

The weighted mean fertility was 71.5% (Table 3.4.1) and the weighted mean kid survival was 65.0%, resulting in a mean marking rate (kids marked per doe scanned) of 76.5% (Table 3.4.2). The producers were asked to manage the does according to their normal management practice for the circumstances facing the operation. On some farms it was possible to identify maiden does from adult does. These maiden class includes doe-kids, which are similar to ewe lambs in the sheep industry that are mated to lamb at about 12-14 months of age. These very young does might also be described as yearling kids. Their exposure to the bucks did contribute to the lowest pregnancy rates observed, but do not explain all low fertility rates observed (Table 3.4.3). The mean pregnancy rate for the maidens was 47.7% and the mean litter size was typical for all pregnant does around 1.61. Mean doe and kid survival rates respectively, were 87.2% and 37.8%. On the properties where the pregnant maiden does were kidded separately to the adult pregnant nannies Table 3.4.4 reports for herds where adult and maiden does were kidded separately and shows the kid survival rate for adult does was 60.5% and for maidens was 35.8%, resulting in 88.8% and 45.9% kids marked per doe scanned, respectively.

The average herd fertility was low in 2019 at 71.5% and the widespread and long-term, intense drought will have had a depressing effect on body condition of does at joining, leading to lower fertility and conception rates and possibly lower ovulation rates. An important driver of the low mean conception rates is due to the maiden doe, for which the mean conception rate was 47.7%. These herds include the mating of doe kids (< 12-month-old females). However, the conception rate was much improved (75.5%) in herds that separated their maidens from their adult does for kidding. The conception rate of the adult does was 81% overall, but in operations where adult does were kidded separately, the conception rate was higher at 86.2%. Taken together these differences imply that differential management according to age has reproduction benefits, presumably due to the ability of managers to allocate feed resources to the younger stock. Continuous variation was observed in the number of kids marked per doe scanned (Figure 3.4.1).

Among the participating properties, Farm A (Table 3.4.1) was an agreeable manager of a goat depot in far western NSW. At this location, rangeland, wild harvest does were pregnancy scanned and those with an identifiable litter size were retained for kidding. The drought conditions were severe throughout gestation and lactation. Farm J was located in central QUEENSLAND and is new to goat production and operating a semi-managed operation, also experienced difficult and severe drought conditions. All other operations were managed enterprises. Some maiden does on Farm F experienced spontaneous nutritional abortions. The does on Farm G experienced challenging nutritional shortages as the drought was very difficult in their location, leading to abnormally high kid losses.

From these highlighted examples, the results of the 2019 on-farm survey can be contextualised to some degree. The circumstances these producers were bound to manage were very difficult. How well the 2019 reproduction rates reflect long-term performance is difficult to ascertain. The most valuable observation this study has made is the potential for high marking rates coupled with high doe survival.

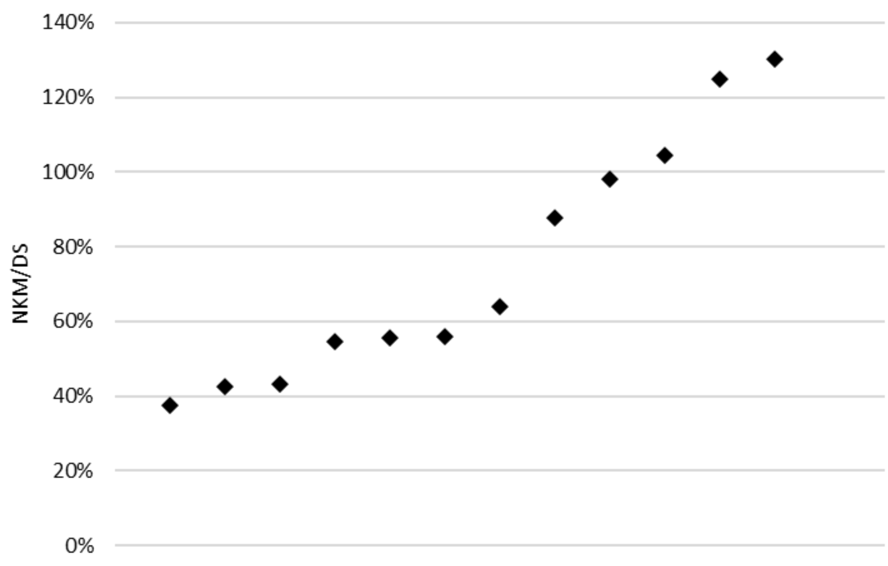

Figure 3.4.1. The number of kids marked per doe scanned (NKM/DS), sorted from the lowest to the highest outcomes.

Table 3.4.1. Pregnancy scanning results for meat goat producers from goat production zones 1, 2 and 3. The season of mating (In, Out, or on the shoulder of In), the number of does scanned, the number of non-pregnant (Dry) does, the number of pregnant does bearing a single, twin or triplet litter and the reproduction rates (%) for fertility, the scanning rate (number of fetuses/number of does scanned). Among pregnant does, the proportion of which are bearing one (Single %) or more than one foetus (Multiples %) and the total number of fetuses per pregnant doe (Fetuses per wet doe %).

Producer	Scan date	Season	Production zone	Does scanned (*n*)	Dry (*n*)	Single (*n*)	Twin (*n*)	Triplet (*n*)	Fertility (%)	Scanning (%)	Single (%)	Multiples (%)	Fetuses per wet doe
A (NSW)	5/04/2019	Out	1	605	212	252	141		65 %	88 %	64 %	36 %	136 %
B (NSW).1	24/04/2019	Out	1	1178	178	364	636		85 %	139 %	36 %	64 %	164 %
C (NSW)	24/05/2019	Shoulder	2	1040	432	235	369	4	58 %	95 %	39 %	61 %	162 %
D (NSW)	13/06/2019	Shoulder	3	183	9	25	130	19	95 %	187 %	14 %	86 %	197 %
E (NSW)	19/06/2019	In	1	924	375	329	218	2	59 %	83 %	60 %	40 %	140 %
F (NSW).1	25/06/2019	In	2	387	51	153	178	5	87 %	135 %	46 %	54 %	156 %
G (NSW)	28/06/2019	In	3	95	4	41	50		96 %	148 %	45 %	55 %	155 %
F (NSW).2	2/07/2019	In	2	283	46	82	151	4	84 %	140 %	35 %	65 %	167 %
H (NSW)	18/07/2019	In	3	2038	782	418	786	52	62 %	105 %	33 %	67 %	171 %
I (QUEENSLAND)	25/08/2019	In	1	284	22	58	204		92 %	164 %	22 %	78 %	178 %

J (QUEENSLAND)	24/09/2019	In	1	845	464	145	236		45 %	73 %	38 %	62 %	162 %
B (NSW).2	15/10/2019	In	1	1325	43	310	972		97 %	170 %	24 %	76 %	176 %
Total				9187	2618	2412	4071	86					
Mean				*765*	*218*	*201*	*339*	*14*	*71.5 %*	*118 %*	*26.3 %*	*46.1 %*	*165 %*
s.d.				*575*	*246*	*136*	*296*	*19*					

Note: Where indicated under Producer, the .1 or .2 denotes the first or second herd scanned, with separate mating periods and different date of scanning.

Table 3.4.2. Kid marking results for meat goat producers from Goat production zones 1, 2 and 3. The season of mating (In, Out, or on the shoulder of In), the number of pregnant does, the number of fetuses scanned, the number of does and kids present at marking. Where available, the number of does rearing kids[1] and the number of does not rearing kids[1] (KL, Kids born and Lost) and rates (%) for doe and kid survival and the reproduction measures for the number of kids marked per doe scanned (KM/DS) and the number of kids marked per doe at marking (KM/DM).

Producer	Season	Production zone	No. pregnant does (*n*)	Scanned fetuses (*n*)	Does at marking (*n*)	Kids marked (*n*)	Rearing does[1] (*n*)	KL & dry does[1] (*n*)	Doe survival (%)	Kid survival (%)	KM/DS (%)	KM/DM (%)
A (NSW)	Out	1	393	534	316	257			80.4 %	48%	42 %	81 %
B (NSW)-1	Out	1	1000	1636	998	1469			99.8 %	90%	125 %	147 %
C (NSW)	Shoulder	2	608	985	601	913	547	54	98.8 %	93%	88 %	152 %
D (NSW)	Shoulder	3	174	342	174	191	160	26	100 %	56%	104 %	110 %
E (NSW)	In	1	549	771	535	514	444	91	97 %	67%	56 %	96 %
F (NSW)-1	In	2	336	524	328	217	205	123	98 %	41%	56 %	66 %
G (NSW)	In	3	91	141	91	41	43	48	100 %	29%	43 %	45 %

F (NSW)-2	In	2	237	396	228	106	101	127	96 %	27%	37 %	46 %
H (NSW)	In	3	1256	2146	1167	1111			93 %	52%	55 %	95 %
I (QUEENSLAND)	In	1	262	466	284	370	265	21	108 %[2]	79% [2]	130 %[2]	130 %
J (QUEENSLAND)	In	1	381	617	347	540			91 %	88%	64 %	156 %
B (NSW)-2	In	1	1282	2254	1201	1299			94 %	57.6%	98 %	108 %
Total			6569	10812	6270	7028	1765	490				
Mean			*901*	*547*	*523*	*586*			*95.4 %*	*65.0 %*	*76.5 %*	
s.d.			*716*	*413*	*390*	*491*						

Note: Where indicated under Producer, -1 or -2 denotes the first or second herd scanned, with separate mating periods and different date of scanning.

[1] Counts of does not rearing kids was based on udder inspection and provided for where research staff were in attendance. When non-pregnant does were retained with the kidding does, adjustments to the tally of dry does was made.

[2] At this property, more does were counted than were scanned and that data is not included in the reported mean for all farms.

Table 3.4.3. List of producers with maidens identified at pregnancy scanning, and where available, kidded separately and counted at marking. Fertility (%) is the number of pregnant does per doe scanned. The number of does rearing kids and the number of does not rearing kids (KL, Kids born and Lost) and rates (%) for doe and kid survival and the number of kids marked per doe scanned (KM/DS).

Producer	Season	Production zone	No. does scanned (*n*)	Fertility (%)	Scanned fetuses (*n*)	Does marked (*n*)	Kids marked (*n*)	Rearing does (*n*)	KL & dry does (*n*)	Doe survival (%)	Kid survival (%)	KM/DS (%)
C (NSW)	Shoulder	2	516	19.4 %	128							
D (NSW)	Shoulder	3	91	95.6 %	168	87	91			100 %	54 %	100 %

E (NSW)	In	1	364	18.4 %	71							
F (NSW)	In	2	283	83.7 %	396	228	106	101	127	96 %	27 %	37 %
G (NSW)	In	3	34	100 %	50	34	11	9	25	100 %	22 %	32 %
H (NSW).S	In	3	440	64.1 %	472	209	181			74 %	38 %	
H (NSW).B	In	3	184	66.3%	217							
I (NSW).a	In	1	48	47.9 %	30							
I (NSW).b	In	1	52	17.3 %	14							
Total			2012		1546	558	389	110	152			
Mean				*47.7 %*						*87.2 %*	*35.8 %*	*45.9 %*

[S] denotes does were kidded separately to adults

[B] denotes does were kidded with adults

[.a] denotes maiden does mated and not rearing kids at the time of pregnancy scanning

[.b] indicates maiden does that were rearing kids at the time of pregnancy scanning.

Table 3.4.4. Comparison of adult doe reproduction performance against maiden reproduction performance, where does were kidded separately. Fertility (%) is the number of pregnant does per doe scanned, rate (%) for kid survival and the number of kids marked per doe scanned (KM/DS).

Class	No. does scanned (*n*)	No. pregnant does (*n*)	Scanned fetuses (*n*)	Kids marked (*n*)	Fertility (%)	Kid survival (%)	KM/DS (%)
Adult	2952	2544	4331	2621	86.2%	60.5%	88.8%
Maiden	848	640	1086	389	75.5%	35.8%	45.9%
Total	3800	3184	5417	3010			

3.4.3 Discussion and conclusion

This component of the project attracted interest from 10 goat producers, enabling the pregnancy scanning of 9187 does. The does included kid does, adult does and does with kids at foot. The herds were mated across a range of seasons. Of all herds mated, eight of the dozen herds participating mated in the normal breeding season, while two mated outside the normal breeding season and two mated in the early stages of the breeding season.
The weighted mean fertility was 71.5% and the weighted mean kid survival was 65.0%, resulting in a mean marking rate (kids marked per doe scanned) of 76.5%. The producers were instructed to manage their herds as their normal practice dictates, leading to maidens kidding with adult does, leading to a reduction in the depth of data that was able to be collected. Nevertheless, the data maintains a high value because it represents normal management in a difficult season.
The results from this project component contributed significantly to the predictions of the cost of kid mortality to the Australian managed meat goat sector. The results from the on-farm scanning component also contributed significantly to the farm level bioeconomic modelling, enabling a wide range of real-world examples to be tested and compared.

A general observation that was made in many herds was the udder and teat shape varied considerably and the feeling was that too many does had dysfunctional teats and udders. This observation requires more specific data record keeping but efforts directed toward culling does with poor teat and udder structures would lead to long-term improvements in the herd.

The conclusions from this work demonstrate clearly that maiden doe management can be substantially improved. These results imply that separate management of does according to their age will have benefits for the industry and warrants further research. The attitude of exposing young does to bucks, “because a few extra weaners is a bonus” is a mindset the industry must challenge. The pregnant doe that successfully conceives but fails to rear kids are occupying precious feed resources (grain and grass), especially in difficult drought conditions. This impact is most clear in the bioeconomic model, where farms experiencing high conception rates with low kid survival suffer substantial proportional gross margin reductions. The reasons for the higher wastage of maidens will include the primiparity (first pregnancy) which is the breeder necessarily untested for reproduction. Further, until the primiparous female is tested, poor performers cannot be removed. Thus, primiparous breeders experience the highest rates of reproductive wastage in all production livestock. Further RD & A investment is warranted to explore the management requirements to lift the rearing success of maidens, as well as lifting the fertility and kid survival for all does. In particular, the role of spontaneous nutritional abortion requires much greater understanding; RD&A investment is required to benchmark and minimise the incidence and increase its predictability.

3.5 Estimates for the cost of reproductive wastage to the industry

3.5.1 Background

NSW DPI recognises the importance of the goat industry to the NSW economy (Extensive Livestock Unit Plan 2017-2022), and in line with the ‘Goatmeat and Livestock Industry Strategic Plan 2015-2020’, identifies on-farm productivity as the way to increase supply to meet export demand. On-farm productivity improvements are currently limited because the industry cannot quantify the kid loss in different production systems, causes of neonatal mortality or the economic impact of reproductive wastage on goat production enterprises.

The objective of the current project, "B.GOA.1905 Reducing kid loss - select & protect - phase 1", is to investigate the baseline level of reproductive wastage in Australian managed meat goat production systems and examine how management could minimise the losses.

This report reports a current estimate of the economic returns foregone due to low fertility rates and kid loss to the managed meat goat industry.

3.5.1.1 Industry significance

In 2011–12 the gross value of goat meat production was around $81 million. Australia slaughtered approximately 2.07 million goats in 2013, yielding around 31 700 tonnes of goat meat (MLA 2014b), around 95 per cent of which was exported (Deards *et al*, 2014). In 2018, Australia processed 1.65 million goats (Table 3.5.1). The industry sold over 23,000 tonnes of goat meat and 21,000 live goats to international markets. The total export value was $190 million.

The gross value of production figures includes both managed meat goats and unmanaged, wild-harvested-rangeland goats. This report only refers to the managed meat goat population.

Table 3.5.1. National and NSW slaughter numbers and carcass weight (cwt) production.

	Production, tonnes cwt		Number slaughtered	
Year	Australia	NSW	Australia	NSW
2015	32,746	1,485	2,140,406	110,606
2016	30,268	1,171	1,933,586	82,956
2017	31,413	1,887	2,070,653	123,839
2018	23,388	963	1,649,668	67,860

Source: MLA and ABS

Australia is one of the world's largest exporters of goat meat and live goats. The main export markets for Australian goat meat are the United States and Taiwan, followed by South Korean, Canada and Trinidad and Tobago.

In 2011, Australia's live goat exports accounted for only 1 per cent of global exports (Deards *et al*, 2014). Malaysia has been the largest market for Australian live goats for over a decade (AgriFutures Australia, 2017). Malaysia accounted for around 80 per cent of live goat exports in the 10 years to 2013, the majority of which were air freighted. In 2013, the majority of live goat exports come from New South Wales (34%), South Australia (34%) and Queensland (26%) (Deards *et al*, 2014).

3.5.2 Methodology

Information was sourced from Australian literature sources, coupled with data from on-farm investigations from this current project. On-farm data collection was used to benchmark industry reproduction rates.

3.5.2.1 Managed goat numbers

The 2016 Agricultural Census (Table 3.5.2) found that there were 424,913 goats in Australia in the "Livestock - All other livestock - Goats (excluding unmanaged feral goats)" category i.e. managed goats (ABS, 2017). The managed goat numbers for Western Australia, Tasmania and the Northern Territory were not reported individually, but were reported in the total for Australia. These numbers do not include the number of rangeland goats Australia, which were estimated to be between 4-6 million in 2017 (AgriFutures Australia, 2017).

Table 3.5.2. Managed goat numbers from the 2016 Agricultural Census.

Jurisdiction	Number of goats	Percentage of population	Number of businesses
New South Wales	231,061	54%	479
Queensland	109,516	26%	247
Victoria	35,735	8%	194
South Australia	22,976	5%	67
Western Australia, Tasmania & Northern Territory	25,626	6%	121
TOTAL	424,914		1,108

3.5.2.2 Estimation of managed doe numbers

In order to estimate the number of breeding does, we used the 2015-2016 Agricultural Census numbers. The ABS undertakes surveys in the years in between the Agricultural Census, and do not ask for goat numbers. The Agricultural Census is undertaken at five-yearly intervals.

The methodology applied, using fertility rates and kid loss rates, required an estimation of breeding doe numbers (Table 3.5.3).

Field pregnancy scanning during this project, at the time of the study, indicated a fertility rate of 71% and a scanning rate of 116%. The scanning percentage was used as a target rate to derive the estimated number of does. NSW DPI gross margin budgets for Dorper sheep indicate a ram percentage of 2%. This figure was used as a target for the number of bucks (Table 3.5.3).

Table 3.5.3. Inference of proportion of breeding does.

Category	As a proportion of the total	Scanning or bucks as % of does
Does	45.9%	116%
Bucks	0.9%	2%
Young stock	53%	

Additionally, the number of does used for milk production had to be subtracted from the total managed goats in NSW. The Agricultural Census statistics do not differentiate between meat goats, dairy goats and fibre goats. Zalcman (2018) attempted to estimate the number of dairy goats in Australia and estimated there were 30,550 milking goats in Australia in 2016. According to AgriFutures (2017b), dairy goat farms are located in almost every Australian state, with production in Victoria (35%), New South Wales (18%), Queensland (15%) and Western Australia (13%) with minor production in South Australia and Tasmania (each 9%). The total estimated by Zalcman (2018) and the state proportions by AgriFutures (2017b), were used to estimate the number of dairy goats in each state (**Table 3.5.4**).

Table 3.5.4. Estimated number of milking goats by jurisdiction, 2016.

Jurisdiction	Licensees	% licensees	Est milking does
New South Wales	12	18%	5,391
Queensland	10	15%	4,493
Victoria	25	37%	11,232
South Australia	6	9%	2,696
Western Australia	9	13%	4,043
Tasmania	6	9%	2,696
Totals	68		30,551

This total number of dairy goats and the state proportions were subtracted from the 2016 Agricultural Census data (**Table 3.5.7**). The numbers for WA, Tasmania and Northern Territory were combined because the ABS Agricultural Census data does not report them separately.

The mohair industry makes up the larger proportion of the Australia goat fibre industry, so contact was made with the Mohair Association with regard to current numbers. They do not keep records of numbers or conduct surveys but were able to provide some estimated numbers such as tonnes produced per year, average yield per goat, shearings/year, and doe proportion, to enable calculation of an estimate (**Table 3.5.5**).

Table 3.5.5. Estimation of mohair goat numbers.

Mohair Goats	
Tonnes mohair/year	100
Average kg per goat/shearing	3.00
Shearings/year	2
Approx. number of goats	16,667
Estimated proportion of does	50%
Est number of does in Australia	8,334

Source: Steve Roots, Executive Officer, Australian Mohair Association, Nov 2019

The state breakdown was not available, so the proportions of dairy goats in each jurisdiction listed in Table 3.5.6 were used as a proxy.

Table 3.5.6. Estimated mohair does in each jurisdiction.

Jurisdiction	Mohair does
NSW	1,471
QUEENSLAND	1,226
Vic	3,064
SA	735
WA, Tas & NT	1,838
Total	8,334

Table 3.5.7 shows the 2015-16 Agricultural Census figures for total managed goats, the total does inferred from the proportions in Table 3.5.3, the total estimated number of milking and mohair does, to derive the final number of meat does in the rightmost column. These calculations have resulted in an estimated 158,761 does in Australia.

Table 3.5.7. Estimated number of managed meat goat does by jurisdiction.

Jurisdiction	Managed Goats 2016 Ag Census	Estimated total does	Estimated milking and angora does	Estimated total meat does
NSW	231,061	106,011	6,862	99,149
Queensland	109,516	50,246	5,719	44,527
Victoria	35,735	16,395	14,296	2,099
South Australia	22,976	10,541	3,431	7,110
WA, Tas & NT	25,626	11,757	8,577	5,876
TOTALS	424,914	194,950	38,885	158,761

NSW DPI gross margin budgets for Dorper (meat) sheep indicate 21.7% of females are kept for breeding so in the absence of goat industry data, this was used as the base figure for number of females kept for breeding, plus a proportion of 2% of males kept for breeding (NSW DPI, 2018).

Data provided by the ABS and MLA for number of goats slaughtered, tonnes of goat meat by carcase weight (cwt) from September 2014 onwards and prices in c/kg cwt were used to derive the average carcase weight and price per kg (Table 3.5.8).

Table 3.5.8. Average carcase weight (kg) by state, 2014-2019 Source: ABS and MLA.

	Australia	Queensland	NSW	Victoria	SA	WA	Tasmania
Average cwt/hd	14.9	16.8	14.2	14.4	13.7	14.7	13.5

Figure 3.5.1 shows the prices for goat meat from 2014 to mid-2019 (not adjusted for inflation). The prices are the same across the different carcase weight categories. The long-term average price is 541 c/kg cwt, and this price was used in the valuation of sale stock in the calculations. Prices have risen above 900 c/kg during 2019, if these prices were to be sustained, the values estimated for kid loss in this report would be considerably higher.

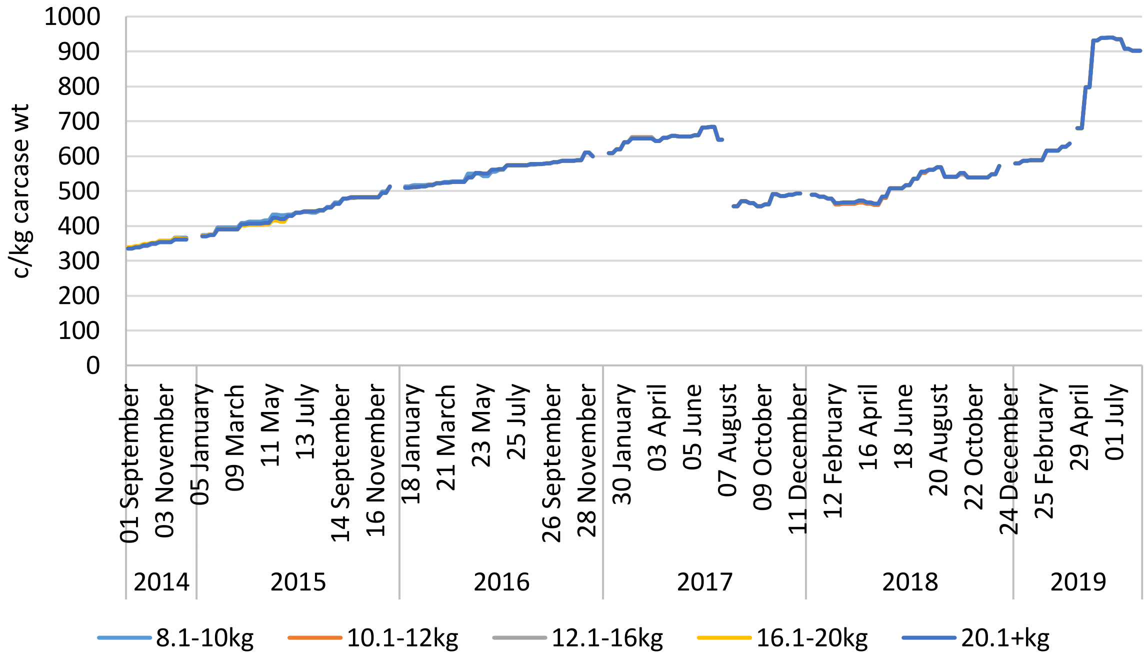

Figure 3.5.1. Goat meat prices 2014-2019, Source: MLA's NLRS.

3.5.2.3 Methodology – Annual

Table 3.5.9 shows the methodology used. The methodology compares current scenarios against a "Best-case" scenario. Both the fertility percentage and kid loss percentages may be varied in the calculator. The fertility and kids per pregnant doe percentages are derived from project field data to date. This methodology allows for comparing a number of scenarios for both fertility and kid loss, and therefore can be refined as further fertility and kid loss data comes to light during the course of this research project.

After applying the proportions found in **Table 3.5.3**, and subtracting the estimated number of milking does in NSW, the estimated number of managed meat goat does in NSW in 2016 was 99,149 (**Table 3.5.9**). Fertility rates obtained from current project field work have indicated an average fertility rate of 71% and a kids per wet doe figure of 160%. The latter figure was mainly due to a high rate of twins (and some triplets). The kid loss percentage was subtracted from the estimated kids at scanning, as well as the number kept for breeding (21.7% females and 2% males, based on typical figures in the NSW DPI meat sheep gross margin budgets for Dorper sheep), to return an estimated number of progeny to be sold for slaughter.

The initial scenario shown in **Table 3.5.9** shows a "Best-case" scenario of 10% kid loss, compared to an estimated 20% kid loss. The best-case scenario of 10% losses is an estimated rate, based on expert opinion, this may be refined as more industry information comes to light for the current on-ground case study work. Some losses were assumed to occur due to a range of factors including nutrition, weather conditions, mismothering, lower survival rates of multiples such as triplets, predation and disease.

This methodology was also applied to the State jurisdictions, using the long-term average carcase weights in **Table 3.5.8**.

Table 3.5.9. Kid loss methodology (NSW).

	Number of Managed does	Fertility %	Wet does	Kids per wet doe	Est kids at scanning	Kid loss %	As % of does - kids kept for breeding	Kids kept for breeding	Progeny sold for slaughter
Best-case scenario	99,149	71%	70,396	160%	112,634	10%	23.7%	23,498	77,873
Current kid loss/fertility scenario	99,149	71%	70,396	160%	112,634	20%	23.7%	23,498	66,609

3.5.2.4 Methodology – Net Present Value

The methodology was initially set up on an annual basis, but this fails to value the potential cumulative industry losses over time. In order to estimate cumulative losses, a standard cost-benefit approach was applied, calculating the Net Present Value of the annual kid loss over a period of twenty years, at a range of discount rates (3%, 7% and 10%) (NSW Treasury, 2017).

In this analysis, the estimated number of does in each jurisdiction was held constant (i.e. assumes no industry growth or decline).

Results

Table 3.5.10 shows the calculation for the kid loss values for NSW on an annual basis, based on value of production lost. At a rate of 20% kid loss, an extra 11,264 kids would not have survived between birth to saleable age. The estimated number of saleable progeny was then multiplied by the long-term average price (541 c/kg cwt) and long-term average carcase weights (14.2 kg for NSW).

Table 3.5.10. Value of kid loss (NSW 2015-16)

	Number kids sold for slaughter	kg/head cwt	Price per kg cwt	Value of production
Best case scenario	77,873	14.2	$ 5.41	$ 5,960,526
Current kid loss/fertility scenario	66,609	14.2	$ 5.41	$ 5,098,361
Estimated value of kid loss and/or fertility loss in NSW				$ 862,165

Table 3.5.11 shows the annual results for the jurisdictions using the 2015-16 Agricultural Census numbers, comparing 20% kid loss with a best-case 10% kid loss, with fertility at the current field-tested rate of 71% in both cases. The 2015-16 Agricultural Census figures did not have any goats in the ACT. Based on these estimates, the value of kid loss, assuming there are the same number of meat goats in Australia currently as in 2015-16, was $862,165 for NSW and $1.45m for Australia.

Table 3.5.11. Results using 2015-16 Ag Census numbers

Jurisdiction	Value of kid loss	
NSW	$	862,165
QUEENSLAND	$	458,489
VIC	$	18,493
SA	$	59,975
WA, Tas & NT	$	50,922
TOTAL - AUSTRALIA	$	1,450,044

Figure 3.5.2 shows the range of values of kid loss by jurisdiction for using the average fertility rate of 71% for NSW (observed by field results from this project to date).

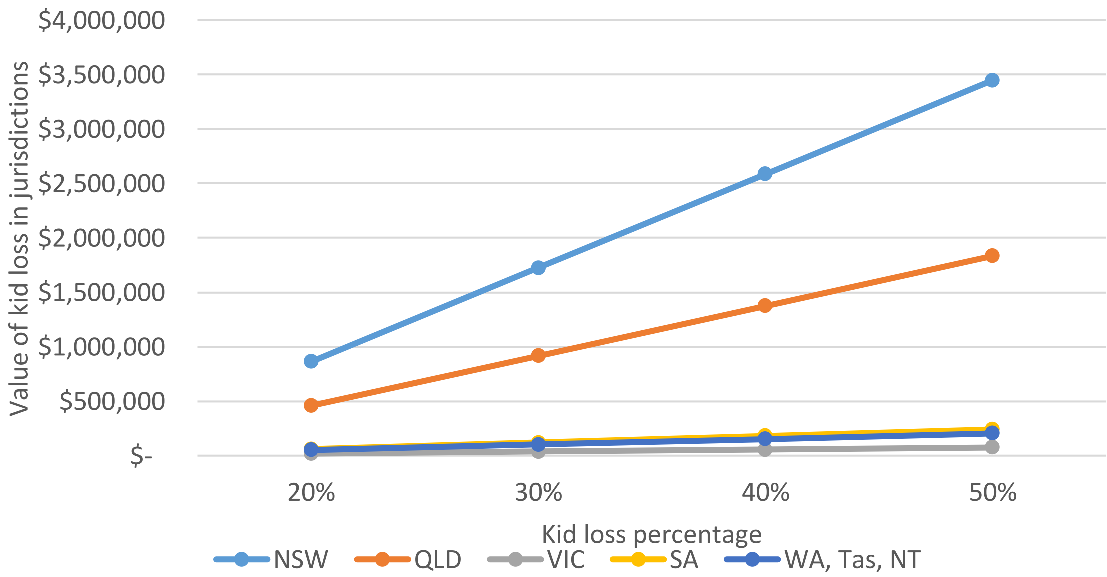

Figure 3.5.2. Estimated value of kid loss by jurisdiction (compared to best case of 10%, with fertility rate 71%)

Table 3.5.12 shows the net present value from the

Table 3.5.11, projected over a 20-year period and discounted back to today's (2019) terms.

Table 3.5.12. NPV Results for NSW based on 2015-2016 numbers

	NSW	Other States	Australia
NPV @ 3%	$12,826,836	$7,961,874	$20,788,711
NPV @ 7%	$9,133,787	$5,669,525	$14,803,312
NPV @ 10%	$7,340,096	$4,556,145	$11,896,240

3.5.3 Sensitivity testing

A range of 18 kid loss and fertility scenarios were tested using this methodology (**Table 3.5.13**). These included the base kid loss scenario of 20% compared to the best case of 10%, with kid loss rates of 30%, 40% and 50%. These kid loss rates were also run with 45% and 95% fertility rates. These fertility rates cover the full range of those observed in the field. These account for Scenarios 1 to 12.

Scenarios 13 to 18 are only concerned with the variation in fertility rates alone and assume a 20% kid loss rate.

Table 3.5.13. Kid loss and fertility scenarios

Scenario 1: Current kid loss 20%, Best kid loss 10%, Fertility 71%
Scenario 2: Current kid loss 30% Best kid loss 10%, Fertility 71%
Scenario 3: Current kid loss 40%, Best kid loss 10%, Fertility 71%
Scenario 4: Current kid loss 50%, Best kid loss 10%, Fertility 71%
Scenario 5: Current kid loss 20%, Best kid loss 10%, Fertility 45%
Scenario 6: Current kid loss 30%, Best kid loss 10%, Fertility 45%
Scenario 7: Current kid loss 40%, Best kid loss 10%, Fertility 45%
Scenario 8: Current kid loss 50%, Best kid loss 10%, Fertility 45%
Scenario 9: Current kid loss 20%, Best kid loss 10%, Fertility 95%
Scenario 10: Current kid loss 30%, Best kid loss 10%, Fertility 95%
Scenario 11: Current kid loss 40%, Best kid loss 10%, Fertility 95%
Scenario 12: Current kid loss 50%, Best kid loss 10%, Fertility 95%
Scenario 13: Current & Base kid loss 20%, current fertility 45%, improved fertility 53.7%
Scenario 14: Current & Base kid loss 20%, current fertility 45%, improved fertility 62.3%
Scenario 15: Current & Base kid loss 20%, current fertility 45%, improved fertility 71%
Scenario 16: Current & Base kid loss 20%, current fertility 71%, improved fertility 79%
Scenario 17: Current & Base kid loss 20%, current fertility 71%, improved fertility 87%
Scenario 18: Current & Base kid loss 20%, current fertility 71%, improved fertility 95%

Figure 3.5.3 shows the estimated annual value of kid loss at different kid loss rates and the full range of measured fertility rates to date for NSW. For example, if the current rate of kid loss is 30%, at the currently estimated rate of 71% fertility, the value of losses (i.e. income foregone) to the NSW industry is $1.72m per annum. If kid loss is 20%, the estimated income foregone per annum is NSW is $862,165. These figures indicate the range is quite large and that this project can add value by determining what the actual rate of loss is and the potential returns from industry RD&A investment in reducing the rate of loss.

These estimates are income only and do not include the costs associated with the extra production, such as extra cost of feed and husbandry. These costs are unclear since it is currently unclear what would be the best approach or approaches to improving kid loss in the industry.

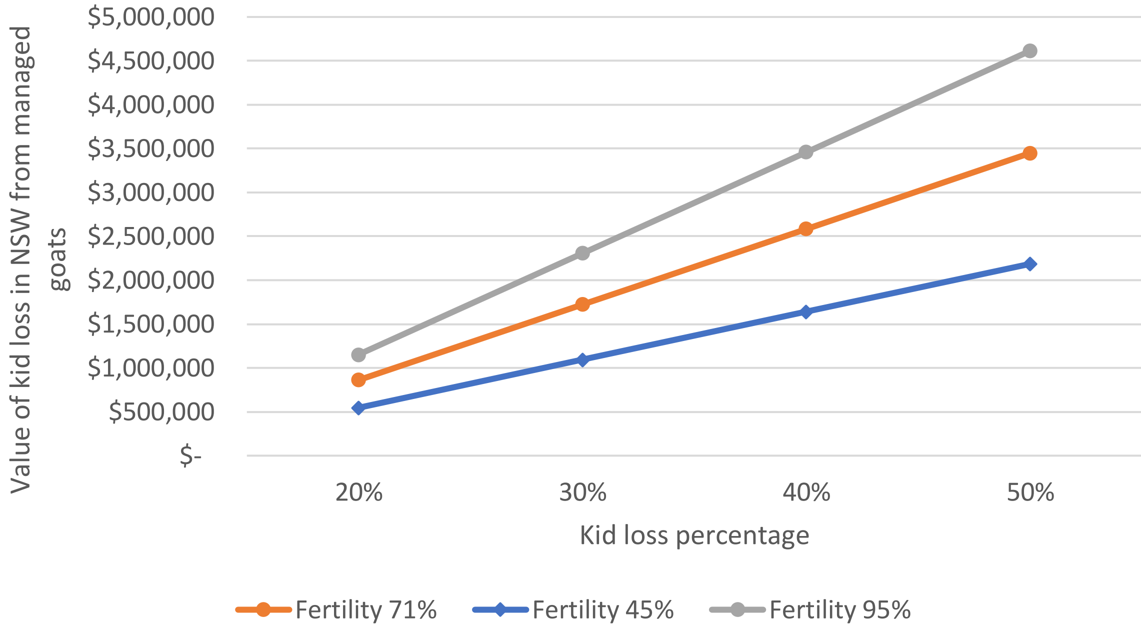

Figure 3.5.3. Estimated value of kid loss: NSW (compared to base case of 10% kid loss)

Figure 3.5.4 shows the estimated annual value of kid loss at different kid loss rates and fertility rates for other jurisdictions (QUEENSLAND, Victoria, SA, WA, Tasmania and NT).

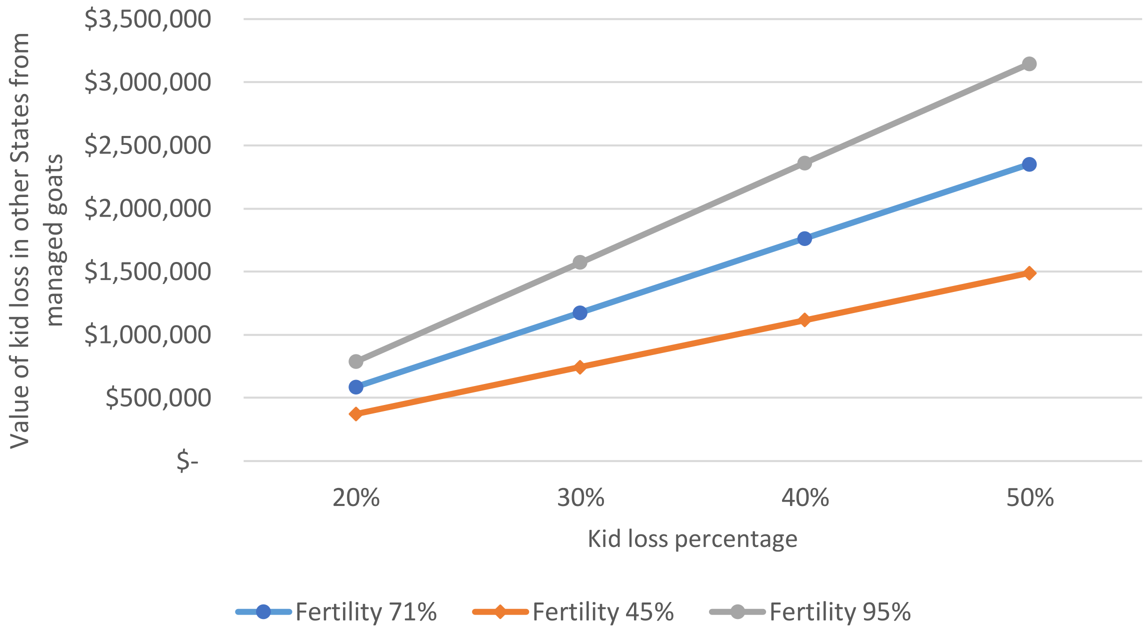

Figure 3.5.4. Estimated value of kid loss: Other jurisdictions than NSW (compared to base case of 10% kid loss)

Figure 3.5.5 shows the range of annual values for different rates of fertility compared to base rates of 45% and 71%. This assumes a 20% kid loss rate. For example, if fertility is 71%, improving average fertility in NSW to 79%, would gain the industry an extra $77,127 per annum. These estimates are income only and do not include the costs associated with that extra production, such as extra cost of feed and husbandry. These costs are unclear since it is currently unclear what would be the best approach or approaches to lifting fertility in the industry.

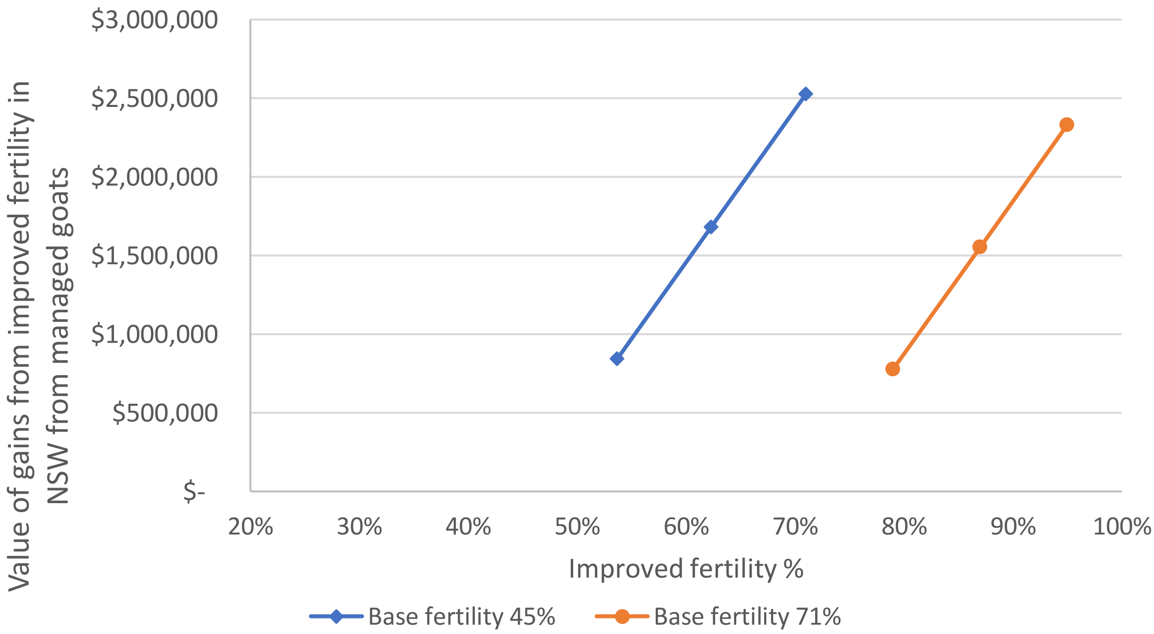

Figure 3.5.5. Estimated values of fertility changes: NSW

Figure 3.5.6 shows the shows the range of annual values for the other jurisdictions of different rates of fertility compared to base rates of 45% and 71%. This assumes a 20% kid loss rate**.**

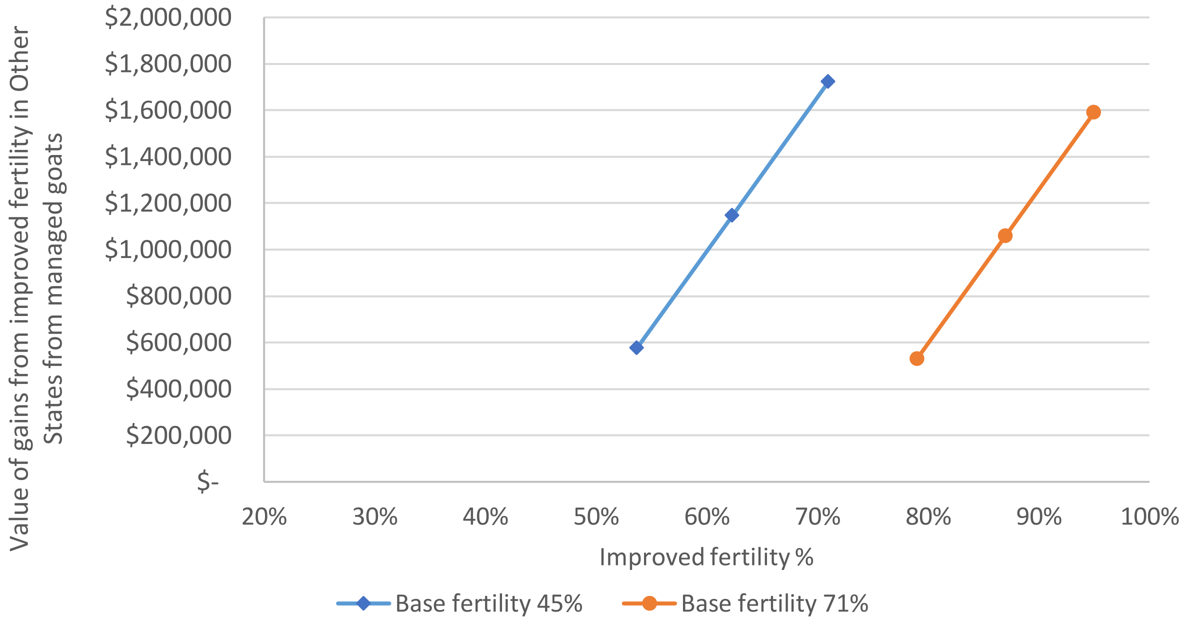

Figure 3.5.6. Estimated value of fertility changes for other jurisdictions than NSW (kid loss 20%)

This methodology indicates there are economic gains of a similar magnitude to be made in the industry by improving fertility rates as well as reducing kid loss. For instance, assuming an average fertility of 71%, and a kid loss rate of 20%, increasing average fertility to 79% in NSW would increase annual industry value by $777,127 in NSW and $529, 970 in other jurisdictions. If kid loss is 20% (and fertility 71%), the estimated income foregone per annum is NSW is $862,165, and $587,880 on the other jurisdictions.

The opportunity exists to re-evaluate the methodology to include industry expansion, as the rangeland production management systems change from harvest to semi-managed.

3.6 Bioeconomic modelling of reproductive wastage at the farm level

The influences of conception and mortality rates on the gross margin of a goatmeat enterprise was examined. The economic impact of long-term average conception (72, 86, 93%) and mortality rate (15, 20, 30, 40%) was modelled for a goatmeat enterprise at Trangie, NSW. This is the first report produced for goat enterprises using GrassGro software.

3.6.1 Methodology

Farm-system modelling software (GrassGro, CSIRO) was used to simulate pasture growth and animal production over a range of seasonal conditions (1970-2020). The first three years of data were not included in the outputs or results (i.e. the output contained only the results from the years 1973-2020). A base farm system was constructed to represent a goatmeat production system at Trangie, NSW using the assumptions presented in Appendix 8.3.1. The optimal stocking rate in dry sheep equivalents per hectare (DSE/ha) was determined after conducting several simulations at varying stocking rates. This method identified the DSE/ha with the highest mean gross margin, where further DSE increases led to lower gross margins with greater between-year variability. The farm system's resource sustainability was also examined by checking the level of ground cover (>70% cover for 70% of the time) and pasture utilisation rates (<35%). Taken together, the model offering the highest gross margin that also met the resource sustainability requirements was deemed the acceptable baseline stocking rate.

The reproduction parameters were derived from on-farm data collected during 2019, where ten commercial meat goat properties pregnancy scanned 9,187 does and followed them to kid marking. The reproduction parameters tested in the present study used the wide range observed from the on-farm scanning and marking results. Four farm systems with long-term average mortality rates of 15, 20, 30 and 40% (Table 3.6.1) were developed by artificially manipulating the weather file (see Appendix 8.3.2) of the base farm-system. These adjustments caused minimal changes to pasture growth, which maintained comparable pasture conditions among the four farm systems. Annual mating commenced on April 20th with a birthdate of September 16th. In the model, most losses occur neonatally, while some foetal losses occur during gestation (2.6% of foetuses) and post-marking losses to weaning (1.1% kids).

Twelve farm systems were then developed by adjusting the conception rates (n=3) to 72%, 86% or 93% (at condition score 3) for each of the four examined mortality rates (Table 3.6.1). All farm systems had the same proportion of single (0.33), twin (0.65) and triplet (0.02) foetuses at condition score 3. In Grassgro, these values set the parameters of the model, which simulates the conception rates at each joining as a function of the relative size and body condition (Freer *et al.* 2012). Adjusting mortality and conception rates caused the farm systems to have different average DSE/ha. The DSE/ha of each farm system was matched to the DSE/ha of the base farm system (i.e. 4.7 DSE/ha) by adjusting the notional stocking rate. These adjustments accounted for the practical reality that production systems that produce more kids can carry fewer does, and vice versa. Output parameters of each farm system including pasture utilisation, sale weight of weaner kids, doe liveweight and condition score were compared.

The analysis assumed no changes in farm management or associated costs with improved or reduced reproduction rates, other than the variable costs of husbandry and sales, and income of increased or decreased kid production.

Table 3.6.1. The reproduction parameters set for the economic sensitivity test

Treatment model	Reproduction sensitivity parameters
1	72% doe conception, 40% kid mortality
2	72% doe conception, 30% kid mortality
3	72% doe conception, 20% kid mortality
4	72% doe conception, 15% kid mortality
5	86% doe conception, 40% kid mortality
6	86% doe conception, 30% kid mortality
7	86% doe conception, 20% kid mortality
8	86% doe conception, 15% kid mortality

9	93% doe conception, 40% kid mortality
10	93% doe conception, 30% kid mortality
11	93% doe conception, 20% kid mortality
12	93% doe conception, 15% kid mortality

3.6.2 Results and Discussion

Reproductive performance substantially influenced enterprise profitability. The average gross margin is 2.6 times greater when comparing the lowest sensitivity to the highest sensitivity. At conception rates of 72% and 93%, reducing kid mortality from 30% to 15% increases the gross margins by 32% and 18%, respectively (Table 3.6.2). Reducing kid mortality from 30% to 15%, at a conception rate of 86%, increases the gross margin by 20%. When conception and mortality rates are improved concurrently the between year variation in the gross margins is also reduced (Figure 3.6.1).

There were nominal differences in the livestock and pasture output parameters among the farm systems (see Appendices 8.3.3 to 8.3.7), which is expected when the reproduction parameters are varied. However, no farm system appeared to be overly advantaged or disadvantaged by these differences. Further work is required to test the sensitivity of these results using different production systems, assumptions and variables. This study demonstrates the capacity of bioeconomic modelling to inform the economic implication of management interventions that influence reproductive performance.

The Grazplan farm system models (Donnelly *et al.*, 1997) and decision support tools used in Australia don't include goat specific parameters for factors such as intake and growth rate. In this analysis, we have assumed that a 45 kg goat is equivalent to a 45 kg sheep, but which incurs no shearing costs nor produces more than 0.25 kg fleece per annum. Further interrogation of the model is required to review the estimates of intake against published intakes for goats at varying quantity and quality (energy and protein) levels. Our assumption is intake will be a function of liveweight and no great deviation from this relationship is anticipated.

The modelled growth rates of weaner kid appear low, however, possibly reflecting the feed base. Alternatives for manipulating growth rate need to be further investigated. Also, investigating the feasibility of developing goat specific intake and production models for use in whole farm system models, including Grassgro, and other decision support tools (e.g. NSW DPI's Drought and Supplementary Feed Calculator) is warranted.

Table 3.6.2. Average gross margin at three conception and four mortality rates (expressed as a percentage relative to the baseline. The baseline is 86% conception and 20% mortality.

		Mortality Rate (%)			
		15	20	30	40
Conception Rate (%)	72	84%	76%	64%	45%*
	86	110%	100%	92%	72%

	93	122%	115%	103%	84%

* This system was not self-replacing using the assumptions in Appendix 1. The cast for age rule was increased to 7-8 years to allow this system to achieve the self-replacement standard. The gross margin was calculated based on this assumption.

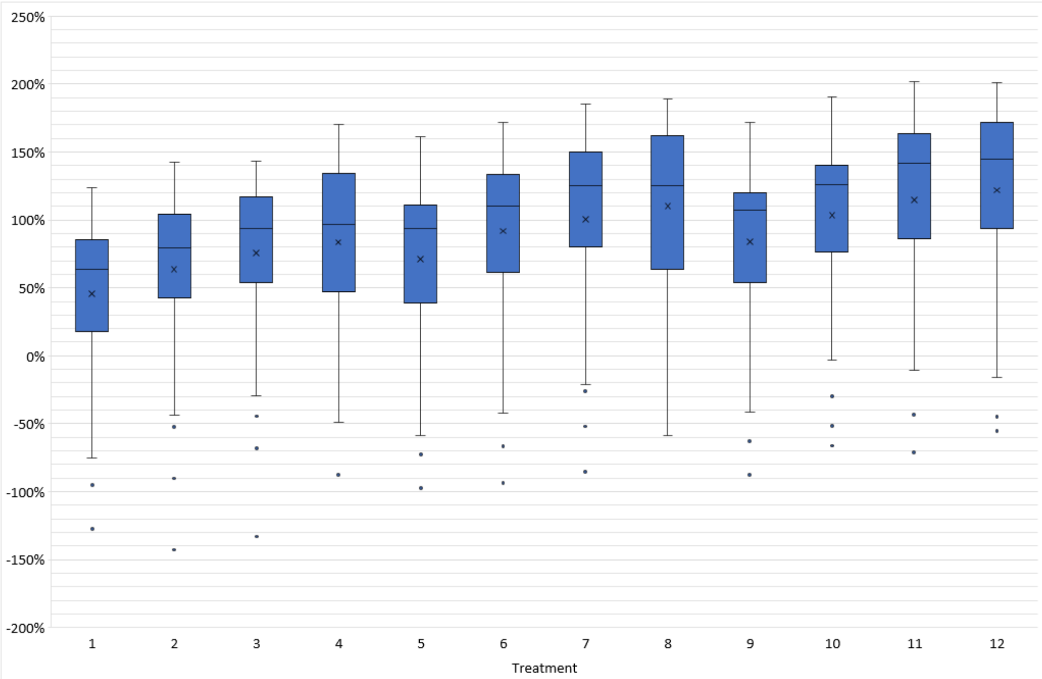

Figure 3.6.1. Boxplots for annual gross margins ($/ ha) for all treatments

The box shows the middle 50% of values (the interquartile range). The horizontal line inside the box is the median. The lines extending above and below the box (whiskers) show the upper and lower quartiles (25% of values). Beyond the whiskers, outlying values are shown by dots, lie more than 1.5 times the interquartile range beyond the upper and lower quartiles.

3.7 Project extension and industry engagement

This section reports on the communications undertaken to engage with the industry through direct contact with known goat meat producers, and via forms of media including radio, social media, print, television, conference, webinar and publications.

3.7.1 Radio interview

In early December 2018, radio interviews were held with ABC Central West, 2SEM Sydney and via the radio networks reaching AM1494 2AY Albury Wodonga, AM1522 3NE Wangaratta, Edge FM 102.1 Wangaratta and ACE Radio Network.

The interview was aired on 11 radio stations, including ABC and 2GB.

3.7.2 Social media

NSW DPI has over 9000 followers on Twitter and promoted the project on Twitter, December 5, 6 and 8th and was retweeted by industry representative with a further 1333 followers.

#Goat producers, what would more #kids mean to you? Find how @nswdpi is leading an #Australian research project to meet international demand for goatmeat kid numbers @meatlievstock @CSUMedia @GrahamCenter

3.7.3 Print media

Six print media outlets ran the media release in early December, via outlets including The Rural, Great Lakes Advocate, Wingham Chronicle, Manning River Times, Gloucester Advocate and Sheep Central.

3.7.4 Television

WIN TV News interviewed Dr Refshauge and a goat breeder in mid-January 2019 about the project. This article was aired throughout their network on outlets reaching Central West, Canberra, Riverina and Wide Bay on January 21st and on their networks reaching Illawarra, Hobart, Gippsland, Western Victoria, Albury, Central Victoria, Mildura, Shepparton, Lismore, Renmark, Mount gambier, Central Queensland, Sunshine Cost, Cairns, Bunbury, Townsville, Toowoomba, Mackay, Orange on the 22nd of January with a total of 116 items played.

3.7.5 Conference

Dr Refshauge delivered a presentation on the project primary findings and progress at the Goat Industry Development Conference, Ipswich, October 3rd, 2019.

3.7.6 Webinar

Dr Refshauge delivered a webinar for MLA on February 18 2020 on the primary project findings, including the summary findings from the review of literature, estimates of the cost of reproductive loss to the industry and the findings of the reproductive outcomes of the on-farm pregnancy scanning component and a summary of the key findings from the case studies. The conclusions included the research team's preliminary recommendations. Planning continues to host a final webinar for the producers that were directly involved in the on-farm scanning component of the study. Feedback about 2019 in review and their subsequent 2020 performance and any management changes undertaken as a result of being involved in the project will be discussed.

A second webinar was delivered to the Goat Forecasting Committee on September 18 2020. This detailed, hour-long webinar focussed on the on-farm scanning to marking results and how these informed the estimates of reproductive loss to the managed goat sector of the industry, as well as the farm level bio-economic modelling.

3.7.7 Publications

The review of literature has been published with the Animal Production Science. Open access has been paid for this publication, which means the article can be accessed free of charge, making it freely available for the industry. The citation is:

Robertson, S. M., Atkinson, T., Friend, M. A., Allworth, M. B. & Refshauge, G. (2020). Reproductive performance in goats and causes of perinatal mortality: a review. *Animal Production Science* 60(14): 1669-1680. https://doi.org/10.1071/AN20161

The case studies have also been accepted for publication with the Australian Veterinary Journal, which is the component undertaken by Charles Sturt University honours student, Ms Maddy Brady. It is a success to complete honours level study and return the research to a published format.

The title is: *An exploratory study to investigate animal health and reproductive wastage among Australian meat goat producers*.

An article was published in Goats On the Move and another submission was made in November 2019 (not published). Media available on the MLA website drawing some reference to the project includes:

https://www.mla.com.au/news-and-events/industry-news/goat-industry-development-day-a-success
https://www.mla.com.au/news-and-events/industry-news/goat-producers-help-lift-kid-numbers/

4. Summary findings and discussion

4.1 Review of literature

The key findings of the literature review reveal that while goats are seasonal breeders, but the degree of seasonality varies among breeds and with latitude. The breeding season is typically between March and September and can be manipulated by continual or part-time exposure to bucks. This contrasts with NSW and QUEENSLAND producer perceptions of the breeding season that suggest it is much longer and can range between December and May. Since good pasture conditions allows rangeland does to enter oestrus year-round, the perceptions of extended breeding seasons are understandable. Oestrus appears to be triggered by rain and subsequent pasture growth. Out-of-season cycling can be induced by use of melatonin implants or sexually active bucks. The age at puberty in does depends on liveweight, nutrition, season of birth and breed. Puberty typically occurs between 5 and 12 months of age, at around 15-kg liveweight in rangeland goats and 28 kg in Boer does.

Ovulation and fertilisation

Goats can be prolific breeders and have high rates of fecundity. Ovulation rate is influenced by age, breed, liveweight, body condition, can be 10–40% higher at the peak of the natural breeding season than outside the breeding season, and is improved by pre-ovulatory nutrition. Fertilisation rates are expected to be high but can range wildly. Mating success is also affected by season, nutrition, age and breed. Factors affecting conception rates that may be investigated experimentally include the following: the role of cryptorchids in stimulating oestrus without conception for does joined outside the breeding season; the effect of seasonality in central northern Australian goat herds; and the potential for melatonin implants to improve out-of-season breeding performance.

Embryo and foetal loss

Embryonic mortality is a common source of reproductive wastage and the levels appear to be similar in goats to that in sheep. In contrast, fetal losses appear to be higher than in sheep, with susceptibility to abortion storms from around Days 90–120 of gestation. Inadequate nutrition, low body condition, liveweight loss and age are key associated factors. High levels of foetal loss can be due to nutritional stress and have the potential to be a significant cause of reproductive wastage in Australian goats. It is spontaneous abortion from subtle variations in nutrition that would be most disconcerting for producers, especially at times of drought or delayed pasture growth. While this does not appear to be a major loss in closely managed herds, further investigation is needed from commercial herds, particularly in the lower-rainfall and pastoral regions. Walk-over-weighing systems may offer a low-cost method to examine variation in liveweight change and relationships with fetal loss.

Perinatal loss, cause of death and post-weaning mortality

Perinatal loss is a major source of reproductive wastage in goats, although there are limited data for Australian commercial herds, KIDPLAN data suggesting mortality to weaning averaged 20%, with notable variation. The key factors associated with perinatal kid mortality include location, litter size, nutrition and breed effects. Curiously, the gender does not appear to influence kid survival, unlike in sheep and cattle. Furthermore, the inconsistent relationships between birth weight and kid survival are intriguing. The timing of kid loss is not well documented in the available literature, but large losses occur perinatally, with most losses occurring within days of birth. While post-weaning losses can also be high in some situations, it is most important to understand the timing of kid loss for a particular herd if effective intervention strategies are to be devised.

The key causes of perinatal mortality for kids and goats appear to be similar. The lack of information for goats highlights a need to quantify the causes of death and their relative importance under the various management regimes. Very little literature is available to consider for causes of perinatal kid mortality. Dystocia or stillbirth and the starvation–mismothering– exposure (SME) complex appear to be the pre-dominant causes of death. There are few reports on the incidence of dystocia in goats. While high birthweight is a large risk factor for death from dystocia in sheep, in goats the relationship appears to be curvilinear, without a reduction in survival at higher weights. Further investigation under commercial management conditions is warranted, management strategies need to be devised to improve the survival of low-birthweight twins and higher-order births. Kids are susceptible to low temperatures; perinatal kid losses in Australian rangeland and crossbred goats significantly increase when the chill index exceeds 950 kJ/m2.h. There is a role for improved nutrition, as kid birthweight is a factor affecting the impact of SME on the probability of mortality.

However, the factors that result in poor mothering in does have not been fully investigated. Breed differences and the effects of nutrition on mothering ability is an area requiring further research. Teat problems have been implicated in perinatal deaths of kids. In Australia, predation by wild dogs, foxes, pigs and wedge-tailed eagles has been implicated in kid losses, with producers perceiving predation as a key cause of perinatal mortality.

Literature summary conclusion

Goats have the potential for high weaning percentages, and some commercial Australian herds are weaning in excess of 160%/doe joined. However, there is large variation among properties and the opportunity exists for substantial gain, although it is unclear at which stage of reproduction the majority of losses are occurring in Australian goat herds.

4.2 State Laboratory disease submissions

While all state laboratories were approached to supply recent historic data with disease submissions associated with abortion and perinatal mortalities for sheep, cattle and goats, not all states engaged in the study. Concerns for African Swine Fever was a major distraction for WA and QUEENSLAND authorities during 2019. Database results were shared by NSW, Victorian and South Australian state laboratories. The time period included in the study was from 2006 to 2019; however, data from Victoria was only available from 2009 to 2019. In addition, data was obtained in October 2019, therefore 2019 data is incomplete. This process has revealed each authority records submission results in different ways.

Most perinatal death submissions cases were from cattle (NSW, 87%; Victoria, 76%), followed by sheep (NSW, 10%; Victoria, 20%) and with only a small proportion of cases being from goats (approximately 3% in each state). In NSW, between 40 and 48% of the submitted cases across all species had a specific diagnosis, with the rest being identified a no positive or no diagnosis.

The distribution of abortion and stillbirth submissions was very similar than for submissions related to perinatal death. Again, the majority of cases were from cattle (NSW, 87%; Victoria, 71%; SA, 82%), followed by sheep (NSW, 11%; Victoria, 26%; SA, 15%) and with only a small proportion of cases being from goats (approximately 3% in each state). In NSW, an average of approximately 40% of cases submitted had a positive diagnosis; however, this proportion was higher among cattle and sheep cases (41 and 36.3%, respectively) than for goats (19.3%).

For goat samples, the most common causes of abortion and stillbirth identified in NSW and Victoria were nutritional deficiencies and chlamydia, with *Yersinia enterocolitica* identified in NSW and internal parasites identified in Victoria. Nutritional deficiencies were also a common cause of perinatal death, in NSW and Victoria.

The descriptive analysis of the data identified that the number of submissions related to goat perinatal deaths, abortions and stillbirth is low across NSW, Victoria and South Australia, with a very significant proportion of these submissions not having a specific diagnosis. Given the low number of submissions from goats, the interpretation of the identified diagnoses should be made cautiously. There may also be some degree of bias in the submissions process, where producers may not submit samples when they feel they know the cause or may be submitting samples seeking specific information.

4.3 Producer case studies – survey

This exploratory study has provided insights into the animal health and reproductive management practices and perceptions among meat goat producers in Australia. Twenty producers, located in New South Wales, Queensland, Western Australia and Victoria, and operating under different production systems were interviewed.

The results suggest that animal health management could be improved and that producers perceive a lack of relevant and species-specific information available to help them make informed decisions.

Reproductive management and records varied greatly across producers interviewed. Kid loss was identified as an issue, with losses from kidding to weaning estimated by the participants to range between 6% and 47%. Producers identified predation, doe nutrition and mismothering as the biggest contributors to kid loss, with the majority of losses occurring within a week of birth. All producers believed management could minimize kid loss.

The producer case studies highlighted the importance of improving reproductive rates among goat enterprises and provides new information on the current practices within the Australian meat goat industry. The sense among producers that information was limiting is concerning, notwithstanding the availability of materials via the MLA website, for example. The producer's sense for the range of kid loss and the causes aligns generally with the findings from the literature. The role of predators continues to remain a strong perception for losses within the industry.

4.4 On-farm pregnancy scanning and kid marking

The target of pregnancy scanning 10,000 does from at least 10 farms was nearly achieved, with 9187 does scanned from ten farms. In total, 33 mobs of does were scanned. The age of does varied across all farms, with some young doe kids exposed to bucks. In some instances, bucks were removed from the does one the day of scanning, and in another instance, kids were weaned the day before scanning, both examples reflecting the practice of continual exposure, a feature of rangelands systems. Continual exposure of bucks to does also reflects the great importance to the producer that every kid weaned offers a return, despite the complications such practice overlays onto the management of pregnant does.

The producers engaged in this component of the research were encouraged to manage their herds normally. The overall results demonstrate wide variation in the results from pregnancy scanning to marking. On the properties where maidens were identified and kidded separately, 22.3% of all does scanned were maiden. These maiden nannies reared 12.9% of all kids marked, with a kid mortality rate of 64.2%. On these farms, maidens occupied ¼ of the herd in number, yet rear 1/8th of the kids. For all does, however, the rate of kid loss was variable but averaged 65% in the year of the study.

Doe mortality varied between farms, and was generally as expected, with 95.4% of does surviving to marking. However, in herds where the maiden doe was held separately from the adult does for kidding and to marking, doe survival was 87.2%. Some caution is required when translating this finding to the entire meat goat sector, as this was a sub-sample of the herds and not all herds were able to capture such information.

The conclusions from this work demonstrate clearly that maiden doe management can be substantially improved. Our findings sit within the range of outcomes reported in the literature for conception rates (% of pregnant does per doe exposed to bucks) and for kid mortality and marking rates.

The results of the present study imply that separate management of does according to their age will have benefits for the industry, but this warrants further detailed research. In particular, the role of spontaneous nutritional abortion requires much greater understanding; RD&A investment is required to minimise the incidence and increase its predictability. Opportunities to incorporate melatonin implants into more intensive breeding systems also offers the industry the opportunity to maximise weaning potential, particularly given the apparent stability of ovulation rate that has resulted in the reasonably consistent litter sizes in pregnant does in maidens and adults. None of the herds in the present study were using melatonin implants. The observation was also made that too many does have poor udder and teat confirmation. Investing time to improve udder and teat structure is required. The size and extent of the problem of poor teat and udder structures needs to be quantified and extension messages, and possibly extension packages, need to be developed for producers to rapidly support udder quality checks after mating.

4.5 Estimates for the cost of reproductive wastage to the industry

With respect to the objective, which is to model the economic cost of kid loss to the industry, this modelling is new for the goat industry, and there was no available literature to benchmark our findings against.

This component predicted the cost of reproductive wastage by first estimating the number of does in the managed goat sector. After adjusting for the number of bucks and male weaners and yearlings, the proportion of known managed goats that are estimated to be breeding does was 45.9%, leading an estimate of 158,761 does. All subsequent estimates for the costs of reproductive wastage are made from this baseline. As the class of breeding does increases, the potential losses to reproductive wastage will also increase. The report by Lane *et al.* (2015) assumed a meat goat population of 250,000, which is smaller than our estimates.

This methodology indicated economic gains of a similar magnitude could be made in the industry by improving fertility rates as well as reducing kid loss. For instance, assuming an average fertility of 71%, and a kid loss rate of 20%, increasing average fertility to 79% in NSW would increase annual industry value by $777,127 in NSW and $529, 970 in other jurisdictions. If kid loss is 20% at a fertility of 71%, the estimated income foregone per annum is NSW is $862,165, and $587,880 in the other jurisdictions.

It is not appropriate to compare the costs of diseases to the goat industry, as indicated in the work by Lane *et al.* (2015) because the base assumptions are different in the two methods, so too the baseline prices and population estimates. Nevertheless, the scale of kid loss to the industry may be around $1.45 million p.a., assuming a kid loss rate of 20%, at 71% pregnancy rate, which leads the authors to suggest kid loss is a significant cost to the goat industry. If kid loss rates increased to 30% across the sector (at 71% fertility), the cost of the loss to industry would increase to $3.88 million p.a.

The value of this economic study is the model established to consider the cost of reproductive wastage, as well as the attempts to quantify the size of the losses for both fertility and kid loss. This model can be expanded if rangelands harvest systems change to include more semi-managed systems.

4.6 Bioeconomic modelling of reproductive wastage at the farm level

The approach to apply bio-economic models to a goat enterprise is novel. To our knowledge, such modelling has not been undertaken previously, and there was no published literature available to help guide the assumptions. We gratefully acknowledge the farm economics advice received from John Francis, Holmes & Sackett, Wagga Wagga, NSW.

The modelling software, GrassGro (Donnelly *et al*., 1997), was used. This software has animal production prediction algorithms for sheep and cattle, but not goats. Therefore, assumptions need to be made about the performance of goats on pasture and supplementary feed, and their interaction with the weather. The modelling cannot account for the browsing nature of the species. Our approach was to reduce fleece growth to the lowest possible setting (0.25 kg fleece weight grown p.a.) and to offset the shearing costs. Liveweights are set according to our experience (45 kg doe, 63 kg buck), see Appendix 8.3.1. To increase the susceptibility of neonatal kids to hyperthermia, the weather at kidding was modified to increase kid mortality without affecting pasture growth (Appendix 8.3.2).

The model clearly demonstrated that low reproduction rates (low fertility combined with high kid mortality) resulted in an unsustainable base population. Too few kids were entering the annual replacements to sustain the herd size. To allow for this effect, the model with the lowest reproduction rate was adjusted to retain older does.

This observation is an important reminder for the meat goat sector about the sheer importance of reproduction to the sustainability of the population and some consideration may need to be given to the sustainability of wild harvest under such scenarios. However, this comment may be considered over-reach as the scope of the present study is limited to managed and semi-managed herds and does not apply its findings to the wild harvest sector.

Some of the on-farm reproduction rates experienced much lower reproduction rates than were modelled for the present study, suggesting substantial pressures will be experienced from the 2019 reproduction outcomes and these will be felt in the herd structure for years to come. Furthermore, while 2019 was a difficult year for many, it is unclear what year to year variation exists and how frequently such low rates do occur on individual farm.

The key finding was expected; that the meat goat enterprise is highly sensitive to reproduction outcomes, but that these models need to be carefully interpreted for their novelty, their underlying assumptions that a goat can be a sheep in the production component of the model. Further work is recommended to interrogate the animal intake and liveweight growth relationships.

4.7 Project extension and engagement

The success of the project's engagement with industry is difficult to gauge. The print, radio and television media exposure for the project was widespread and far-reaching. The presentation of the results and progress of the project were well received at the Goat Industry Development Conference, in the Holms & Sackett hosted MLA webinar and in the webinar presentation for the Goat Forecasting Committee.

5. Conclusions and recommendations

5.1Review of literature

It is generally difficult to find information that is relevant to Australian conditions. There is scant literature reporting on the causes of reproductive loss in commercial herds. There is a wide range in reproductive performance, indicative of a large potential for improvement, however the timing and cause of losses are poorly defined. There is very little regional information to make comments about the effect of location on reproductive performance.

Further RD&A is required to understand the sources of reproductive wastage, such as the stages at which the losses are occurring and why. The factors requiring investigation include include out of season breeding, doe age, weight, body condition, periconceptional nutrition and buck performance.

It is unclear whether malnutrition, leading to foetal loss, is a primary cause for poor weaning rates in commercial Australian herds. This issue is not particularly prevalent in the research studies reported, but such studies may not reflect the commercial realities of the real world because of their design features and research objectives. The meat goat industry should undertake RD&A to investigate this issue further. Attempts to understand the risk factors will require larger scale studies to capture factors such as gestational age, doe parity, doe lifetime history, litter size, and underlying factors such as sub-clinical disease.

While kid survival can be high, there is limited data on the causes of mortality. The primary causes are similar to those affecting neonatal lambs. Evidence exists for higher twin and triplet survival rates in kids, when compared to lambs, but this requires further exploration. The contrasting findings surrounding the relationship between survival and birth weight also requires deeper investigation. Further RD&A is required understand more about the management solutions to improve kid survival. The sense that predation continues to play a large role in mortality also requires RD&A.

The present study did not examine the variation that exists between properties in the rates of post-weaning mortality. Efforts directed to increase weaning rates need to be supported with post-weaning management and the meat goat industry should monitor this metric.

It is recommended that a co-ordinated program of sentinel herds would provide useful longitudinal data into many aspects of farm performance, sources of reproductive wastage and post-weaning growth rates and mortality. The MLA PDS pathway should also be used to undertake participatory research activities in herds not engaged in the sentinel herd program, to explore in greater detail the causes for perinatal deaths. Such a study would require multiple locations and performed over several years to provide the most variable and useful data.

5.2 State Laboratory disease submissions

The number of goat submissions was low when compared to cattle and sheep. The reason for low submissions may reflect the extensive nature of the industry. Nutritional disorders were the most commonly identified disease among goat submissions, however very few submissions had been made and there was generally a low rate of positive diagnoses. The practical application of these findings requires cautious consideration when interpreting the key findings. Nutritional disorders were more common among the low number of submissions, but this finding will resonate with producers, as identified from the case studies.

This study identified the need to further investigate goat perinatal deaths and abortions and stillbirth, to increase understanding of the potential causes of these animal health events. Further RD&A is required to understand in greater detail nutritional abortions, stillbirths and perinatal mortality.

It is recommended that a co-ordinated program of sentinel herds would provide useful longitudinal data for disease investigations and increase the possibility for positive diagnoses.

5.3 Producer case studies – survey

The present study undertook a small-scale survey. An important theme among the participants was the sense that sources of information for goat management are either not accessed generally, or not adhered to. Some producers sought advice only from veterinarians, while others felt those professionals did not have the knowledge during their education.

The management practices were quite diverse, such as differences in vaccination regimes, the animal class vaccinated, and the number of times animals are vaccinated. Gastro-intestinal nematode drenching practice also varied considerably. Some producers had no regular regime, deferring sensibly to a needs-based administration. However, not all producers were using worm egg counting to guide decision making, while others drenched if it rained. Of great concern is the practice of off-label anthelmintic drug use, leading to uncertainty about dose rates and drench effectiveness.

There is an urgent RD&A need to understand the efficacy of a wide range of drench products and practices, including examination of the effect of other co-inhabiting ruminant species, such as cattle. Other RD&A investigations should consider the role browsing may have for managing worm burden. Consideration should be given to the possibility to revegetate farms with browse shrubs, or forage species high in condensed tannins, for example. However, the full biological impacts of such browse need consideration for production and health, including survival and mineral balance outcomes.

Producers identified predation, doe nutrition and mismothering were the largest contributors to kid loss, and most losses occurred within a week of birth. These observations align with the findings from the literature review.

The culling policies in the goat herd around self-replacement, breeding strategies and trait selection appear to be unknown, suggesting great improvements are also available in current generation gain and genetic improvement.

It is recommended that a co-ordinated program of sentinel herds would provide useful longitudinal data on predation and management practices, including WEC monitoring and drench effectiveness.

The MLA PDS pathway should also be used to undertake participatory research activities in herds not engaged in the sentinel herd program. Drench effectiveness, the effects of species co-habitation and the role of browse on managing worm burden should be examined.

5.4 On-farm pregnancy scanning to kid marking

Maiden reproduction performance requires continued RD&A investment to define management recommendations. Target mating weights and ages need to be established, as well as the requirement for continued liveweight growth during pregnancy and kidding. The degree of improvement to net reproduction and lifetime reproduction needs to be quantified via separation of maidens from adults during gestation and kidding.

Further RD&A is required to examine the timing of foetal loss. Serial pregnancy scanning operations could be undertaken cost-effectively to examine the time of foetal loss and potential factors associated with such loss, in adults and maidens. Scanning does at D50, D70, D90, D110 and D120 of gestation may reveal uterine quality indicators, as well as foetal disappearance. Such a study requires continued monitoring of does through to kidding, including collecting neonatal kid data.

A general observation that was made in many herds that nannies have dysfunctional teats and poor udder structures. This observation requires more specific record keeping but efforts directed toward culling does with poor teat and udder structures would lead to immediate short-term current generation gains in weaning rates, as well as long-term improvements in the herd.

An out-of-scope finding was that goat handling systems need evaluation. By and large, most systems observed were functional sheep handling facilities, but considerable additional handling pressure was required to keep the does moving through the facilities, particularly in races and the pregnancy scanning crate. Pregnancy scanners had to operate with great care for their own safety. Flighty does and those with long horns present a physical risk to the pregnancy scanner. This may be a significant impediment to the wider adoption of pregnancy scanning and requires urgent industry attention. The availability and willingness of commercial operators to pregnancy scan goats may underpin any potential improvements the industry seeks via improved management strategies. Solutions are required to enable faster throughput, reduced labour units, doe and labourer stress, and more accurate and safer pregnancy scanning outcomes.

It is recommended that a co-ordinated program of sentinel herds would provide useful longitudinal data on reproduction rates, baseline udder quality and improvements over time due to classing and selection. It is important to establish baseline relationships between liveweight and body condition scores for various age classes and at key stages of the reproduction cycle, as well as identifying causes of death and general mortality risks for breeders and neonates.

The MLA PDS pathway should also be used to undertake participatory research activities in herds not engaged in the sentinel herd program. Accelerated breeding programs, which are controlled system of breeding for three kiddings in two years, should be examined via the PDS funding stream. The MLA PDS pathway could also be used to develop goat-specific variations of small ruminant handling facilities.

5.5 Estimates for the cost of reproductive wastage to the industry

The population of managed meat does was estimated at 158,761 head, and the mean sale value of surplus progeny used a five-year average price ($5.41) and carcase weight (14.9 kg), leading to mean sale value of $80.61/hd.

Average reproduction rates for fertility were taken from the on-farm scanning survey. Sensitivities were developed to examine a range of outcomes. Our model can be easily updated for future RD&A industry cost estimates. This economic approach is robust, and the assumptions made are logical, clear and easy to replicate and modify for future evaluations. This study focuses on the managed sector, and the cost in the rangelands herds will have a larger economic impact to the industry.

The total value of the industry may be substantially constrained by the rangeland doe reproductive performance, but this is unknown. Understanding reproductive rates in these herds may be very valuable for the industry and may stimulate a move to managed production systems.

5.6 Bio-economic modelling of the cost of reproductive wastage at the farm level

The limitations of Grassgro include one joining date, where goat producers would likely use more than one mating opportunity annually. Future modelling should be undertaken with Ausfarm to enable multiple mating opportunities. It must be noted that neither Grassgro nor Ausfarm are goat-based modelling systems and future RD&A opportunities should consider the need to validate the GrazPlan sheep model for use with goats. Future RD&A needs to continue to provide evidence for weaner liveweight growth rates and mortality rates for industry comparisons.

It is recommended that a co-ordinated program of sentinel herds would provide useful longitudinal estimates for weaner growth rates and an avenue to improve the specificity of the Grazplan farm system models for goats.

6. Key Messages

The goat is a hardy and robust animal that needs more care than an inexperienced handler might expect, but the productivity of meat goat herds relies on successful breeding. The pregnancy scanning of does in the field study has revealed a relatively consistent foetal load per pregnant doe (fecundity), averaging 1.65 ± 0.16 (s.d.) per doe, reflecting the findings of the review of literature. However, the two primary factors affecting the number of kids marked were pregnancy rate (fertility) and kid survival. The on-farm data suggests that maiden does were less fertile, reared fewer kids per foetus scanned and had higher rates of doe mortality. Maiden does most likely require separate management to adult does to maximise their reproductive potential and survival.

Estimates have been in the present study for the cost of reproductive wastage at the levels of the farm and the managed goatmeat sector. At the industry scale, decreasing kid loss from 30% to 20%, at a fertility rate of 95% would increase the value of the managed meat goat sector by approximately $786,710. The reproduction rate on some farms in 2019 were insufficient to sustain self-replacement without retaining does to an older age. At the farm scale, the lowest modelled gross margin was 2.7 times lower than the higher estimates. The results of the field study indicate several herds had reproduction rates higher and lower than the modelled outcomes, indicating enormous potential to lift the returns of managed goat herds.

This research project, Reducing Kid Loss – Select and Protect – Phase 1, has established baseline reproduction levels on a sample of meat goat farms. The findings from each component of this study indicate opportunities to improve reproduction rates exist for the industry, both in future RD&A and at the commercial farm level. This study has revealed numerous research gaps and made recommendations for consideration.

Our primary recommendation for the industry is to establish a network of sentinel herds. These must be located across several different regions, must reflect normal commercial management, must be operated as a sentinel recording operation for several years (6 to 10 years). In this way, the sentinel farm will provide longitudinal information about doe lifetime performance. All animals born and raised in the system must be RFID tagged to support an accurate account of productivity and performance over time. Such a proposal requires careful selection of location and producers to make the best representation for the industry segments. Co-benefits include improved desk-top modelling, lifetime performance, health and performance, disease investigation and herd mortality and the opportunity to engage regional networks of producers in research and development to fast-track on-farm adoption.

The sentinel herds must also be supported by goat producer demonstration herds. Such herds can provide experimentation opportunities to improve production and welfare-focussed management options. Such demonstration herds will enable industry to witness best practice management. For validity, there will need to be numerous sentinel herds and associated PDS sites, and the adoption of practices can be observed through the sentinel herds, as those owners will continue to operate as normal and unencumbered.

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9. Appendix

9.1 Appendix A. Complete list of diagnosis of perinatal deaths from NSW state laboratories

Diagnosis	Cattle	Goat	Sheep	Total
Akabane	5			5
Arthrogryposis	1			1
Ataxia	1			1
Bibersteinia trehalosi		1		1
Cardiomyopathy	1			1
Cerebellar hypoplasia	1			1
Chondrodystrophy	2			2
Coccidiosis	2		1	3
Congenital defect	7		1	8
Contagious Pustular Dermatitis / ORF			1	1
Contractural Arachnodactyly (fawn calf syndrome)	1			1
Coronavirus/ Rotavirus	1			1
Coronavirus/ Salmonella spp.	1			1
Cryptosporidia	31			31
Cryptosporidia/ E. coli	2			2
Cryptosporidia/ Rotavirus	17			17
Cryptosporidia/ Rotavirus/ Coronavirus	1			1
Cryptosporidia/ Rotavirus/ Salmonella spp.	1			1
Cryptosporidia/ Salmonella spp.	4			4
Cryptosporidia/Salmonella spp. / E. coli	1			1
Dermatophilus congolensis			1	1
Diarrhoea	1			1
Dummy Syndrome	1			1
Dwarf calf	1			1
Dyspnoea	1			1
Dystocia	16	1	7	24
E. coli	27	2	1	30
E. coli/ Rotavirus	4			4
Encephalomalacia	1	1	2	4
Enterotoxigenic colibacillosis	1			1
Epidermolysis bullosa	1			1
Failure of lung aeration	1			1
Fusobacterium necrophorum			1	1
Hepatitis	1			1
Histophilus somnus			1	1
Hydranencephaly	2			2
Hypotrichosis			1	1
Internal parasites			1	1

Ixodid tick	1			1
Leptospora spp.	2			2
Mannheimia haemolytica	3		1	4
Maple Syrup Urine Disease	1			1
Meningitis	3		1	4
Meningoencephalitis	2		1	3
Microencephaly	1			1
Neuropathy-diplomyelia and diastematomyelia	1			1
Nutritional deficiency	2	2	3	4
Omphalitis			1	1
Pasteurella	2		1	3
Pasteurella/ Histophilus somni	1			1
Pasteurella/ Staphylococcus	1			1
Pestivirus	31			31
Pestivirus/ Akabane	3			3
Pestivirus/ IBR/IPV/BHV-1	1			1
Pestivirus/ Leptospira spp.	1			1
Pneumonia	10	1		11
Rotavirus	23			23
Rotavirus/ Salmonella	1			1
Salmonella spp.	25		1	26
Scabby mouth			1	1
Simbu Virus	3			3
Squamous metaplasia			1	1
Starvation/Mismothering	1		2	3
Streptococcus spp.			2	2
Sudden death	1			1
Trauma	1			1
Trueperella pyogenes	2		2	4
Trueperella pyogenes/ Streptococcus spp.	1			1
Trueperella pyogenes/ Salmonella spp.	1			1
No Diagnosis	114	8	27	149
No Positive	234	4	10	248
Total	611	20	72	703

9.2 Appendix B. Complete list of diagnosis of abortion and stillbirth cases from NSW state laboratories

Diagnosis	Cattle	Goat	Sheep	Total
Actinobacillus seminis			1	1
Akabane	26			26
Akabane / BEF / Pestivirus	1			1
Akabane / Leptospira spp. / Pestivirus	1			1
Akabane / Neospora	2			2
Akabane / Pestivirus	9			9
Akabane / Leptospira spp. / Neospora	1			1
Akabane/ Nutritional deficiency / Pestivirus	2			2
Anaemia	1			1
Anaemia / Neospora	1			1
Arbovirus	1			1
Babesia bigemina	1			1
BEF / Pestivirus	1			1
Bovine Ephermeral Fever (BEF)	8			8
Brucella ovis			1	1
Brucella ovis / Campylobacter spp.			1	1
Calcium oxolate crystals / Pestivirus	1			1
Campylobacter spp.	36		26	62
Campylobacter spp. / Chlamydia			2	2
Campylobacter spp. / Chlamydia/ Salmonella spp.			1	1
Campylobacter spp. / Chlamydia/ Toxoplasma			1	1
Campylobacter spp. / IBR / Nutritional deficiency / Pestivirus	1			1
Campylobacter spp. / Internal parasites	1			1
Campylobacter spp. / Leptospira spp.	1			1
Campylobacter spp. / Neospora	3			3
Campylobacter spp. / Neospora / Pestivirus	4			4
Campylobacter spp. / Nutritional deficiency / Toxoplamsa			1	1
Campylobacter spp. / Pestivirus	9			9
Campylobacter spp. / Salmonella spp.			1	1
Campylobacter spp. / Toxoplasma			1	1
Cardiomyopathy	1			1
Chlamydia	5	2	6	13

Chlamydia/ Leptospira spp. / Nutritional deficiency	1			1
Cholestasis	1			1
Clostridium spp.		1		1
Congenital defect	8		2	10
Coxiella burnetii	1			1
E. coli	9		2	11
E. coli / Streptococcus spp.	1			1
Endometritis			1	1
Endometritis / Septicaemia			1	1
Endotoxemia	1			1
Enterobacter spp.	2		1	3
Foetal hydrops	1			1
Freemartinism	1			1
Hepatitis	1			1
IBR	2			2
IBR / Neospora/ Pestivirus	1			1
IBR / Pestivirus	2			2
IBR / Salmonella spp.	1			1
Internal parasites	10			10
Internal parasites / Pestivirus	4			4
Internal parasites / Nutritional deficiency / Pestivirus	1			1
Intrauterine infection	1			1
Leptospira spp.	54			54
Leptospira spp. / Neospora	2			2
Leptospira spp. / Neospora / Pestivirus	3			3
Leptospira spp. / Nutritional deficiency / Pestivirus	1			1
Leptospira spp. / Pestivirus	33			33
Leptospira spp. / Pestivirus / Salmonella spp.	1			1
Leptospira spp. / Pestivirus / Simbu virus / Theileria	1			1
Leptospira spp. / Theileria	1			1
Leptospira spp. / Nutritional deficiency / Salmonella spp.	1			1
Listeria	3	1	22	26
Neospora	195			195
Neospora / Pestivirus	48			48
Neospora / Simbu viruses	1			1

Neospora / Theileria	1			1
Nutritional deficiency	13	8	22	43
Nutritional deficiency / Pestivirus	4			4
Nutritional deficiency / Pneumonia	1			1
Pasteurella spp.	1		1	2
Pestivirus	489		3	492
Pestivirus / Salmonella spp.	1			1
Pestivirus / Simbu Virus	2			2
Placental calcification			1	1
Placentitis	1			1
Premature birth	2			2
Prerenal azotaemia			1	1
Pseudomonas	1			1
Q Fever	1			1
Q Fever / Salmonella spp.			1	1
rhinotracheitis virus	1			1
Salmonella spp.	6		2	8
Simbu viruses	2			2
Squamous cell carcinoma			2	2
Staphylococcus spp.	4	1		5
Theileria	16			16
Toxoplasma	1	1	11	13
Trichomonas foetus	1			1
Trueperella pyogenes	9		2	11
Ureaplasma diversum	1			1
Yersinia enterocolitica		2	1	3
No diagnosis	559	27	71	657
No positive	982	40	136	1158
Total	**2609**	**83**	**325**	**3017**

9.3 Appendix C. GrassGro model assumptions and outputs

9.3.1 Grassgro model summary

Parameters	**Assumptions**
Location	Trangie NSW
Rainfall	487 mm (January 1st 1970 - February 2020) note: output included data from 1973 -2020.
Wind speed	2 m/s (constant)
Pasture	Pasture includes annual grass; *Stipa* and *Bothriochloa* (C4) grasses, subterranean clover; 0.8 Fertility.
Livestock	Self-replacing; 45 kg does; 63 kg bucks (1 buck per 40 does – bucks kept for 3 years); Mortality rate – adult: 5%; weaner 6%; Cull for age @ 6-7 years.
Stocking rate (Notional)	3.4 head/ ha
DSE/ ha (Long-term average)	4.4 DSE/ ha
Reproduction rule	Join: April 20th; Age at first joining: 1-2 years; Conception rate at CS3 single = 28%, twin = 56%, Trip. = 2%; Castrate (assumed husbandry practice in the GM, but not modelled to improve growth rates; Wean: December 8th (12 weeks).
Selling options	Sell at target weight: 30 kg (LWT) or by September 1st @ 50 weeks of age
Maintenance feeding	Feed in paddock, applying the rules Mature Females: If animal condition falls to 2.0 during 1 Jan to 31 Dec feed to maintain condition of average animals Other stock: If animal condition falls to 1.0 during 1 Jan to 31 Dec feed to maintain condition of the thinnest animals
Financial Year	January 1st- December 31st
Price	600 c/kg (Dressed CWT); Dressing % = 45% (all classes)
Costs	5-year average; Husbandry: doe: $4.70; kids: $2.95; Bucks: $400; Fixed sale costs $5.25; Maintenance feed: $290 $/tonne (Barley).

9.3.2 Tactical weather file adjustments

The weather files were adjusted in the experimental models to results in greater kid loss rates. To do this, the approach was to significantly shift the wind chill index risks around the two days that birth occurs in the model. Extensive trial and error adjustments were undertaken to achieve the different mean kid mortality rates.

The following table shows that tactical minimum and maximum temperatures on the days of birth were altered higher (+) or lower (-), as well as significant increases in wind speed, to achieve the desired mean mortality outcome. Adjusting the weather on the two days of birth resulted in no detectable impact on pasture growth.

For example, if the minimum temperature in the historic data was 15°C, the weather file in the 40% kid mortality model had to be changed for that day to -3.5°C, and the wind speed increased by a further 37 m/s (gale force).

Mortality Rate	**Conception Rate**	**Change to Weather file - ^{0}C added to the actual daily record (14 - 15 September)**		**Wind Speed (m/s) (14-15 September)**
		T. Max (°C)	**T. Min (°C)**	
15%	72-93%	+16	+35	0 (12-15 Sept)
20%	72-93%	+9.7	+9.7	
30%	72-93%	-5.1	-5.1	18
40%	72, 86%	-18.5	-6	37
40%	93%	-18.5	-7.5	37

9.3.3 Summary of average differences between farm systems

Average DSE, Stocking rate, Utilisation rate and Sale weight for all farm systems

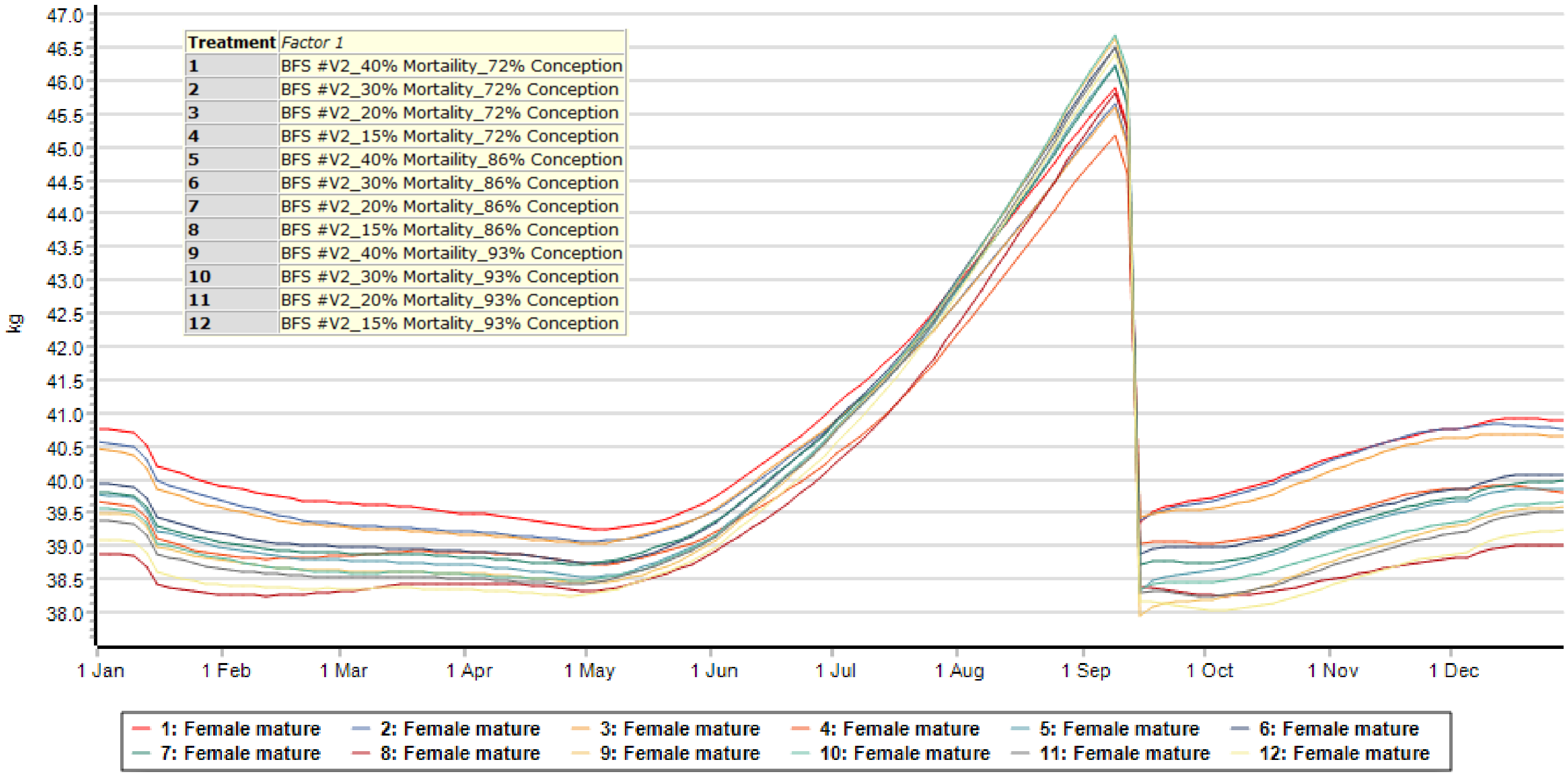
Mortality (%)	**40**	**30**	**20**	**15**	**40**	**30**	**20**	**15**	**40**	**30**	**20**	**15**
Conception (%)	**72**	**72**	**72**	**72**	**86**	**86**	**86**	**86**	**93**	**93**	**93**	**93**
Dry sheep equivalents (dse/ha)	4.6	4.7	4.7	4.7	4.7	4.7	4.7	4.6	4.7	4.7	4.7	4.7
Stocking Rate (head/ha)^	3.8	3.8	3.6	3.6	3.7	3.5	3.3	3.2	3.5	3.3	3.2	3.1
Pasture Utilisation (%)*	32	33	32	33	33	33	32	32	32	32	33	32
Kid per doe at conception	0.98	0.96	0.96	0.96	1.22	1.23	1.23	1.22	1.37	1.37	1.37	1.37
Sale weight of male weaners kg#	29.8	29.7	29.7	29.7	29.8	29.8	29.7	29.7	29.8	29.7	29.7	29.6
Meat sold- young stock (sum) (kg LW/ha)	32	35	40	43	39	46	51	54	44	51	58	60
Meat sold- total flock (sum) (kg LW/ha)	49	56	60	63	59	66	69	71	63	69	75	77

*The long-term average amount of pasture consumed by all stock as a proportion of the amount of pasture grown over the period analysed.

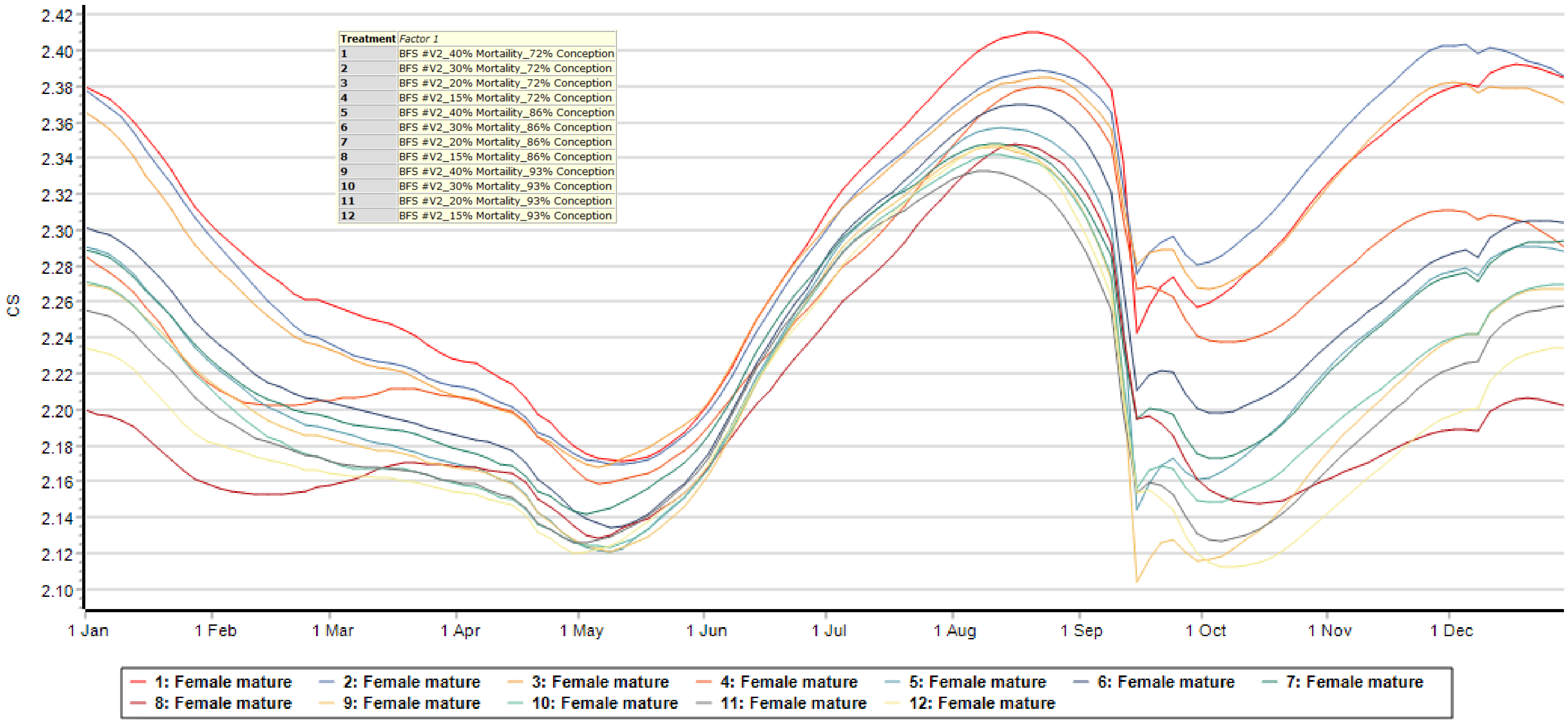
Long-term average live weight at sale of male weaners.

^The stocking rate (in animals per hectare) immediately after replacement animals are acquired. The stocking rate applies to the main herd only. Unweaned kid and weaned kids (other than those used as replacements are not counted as part of the notional stocking rate.

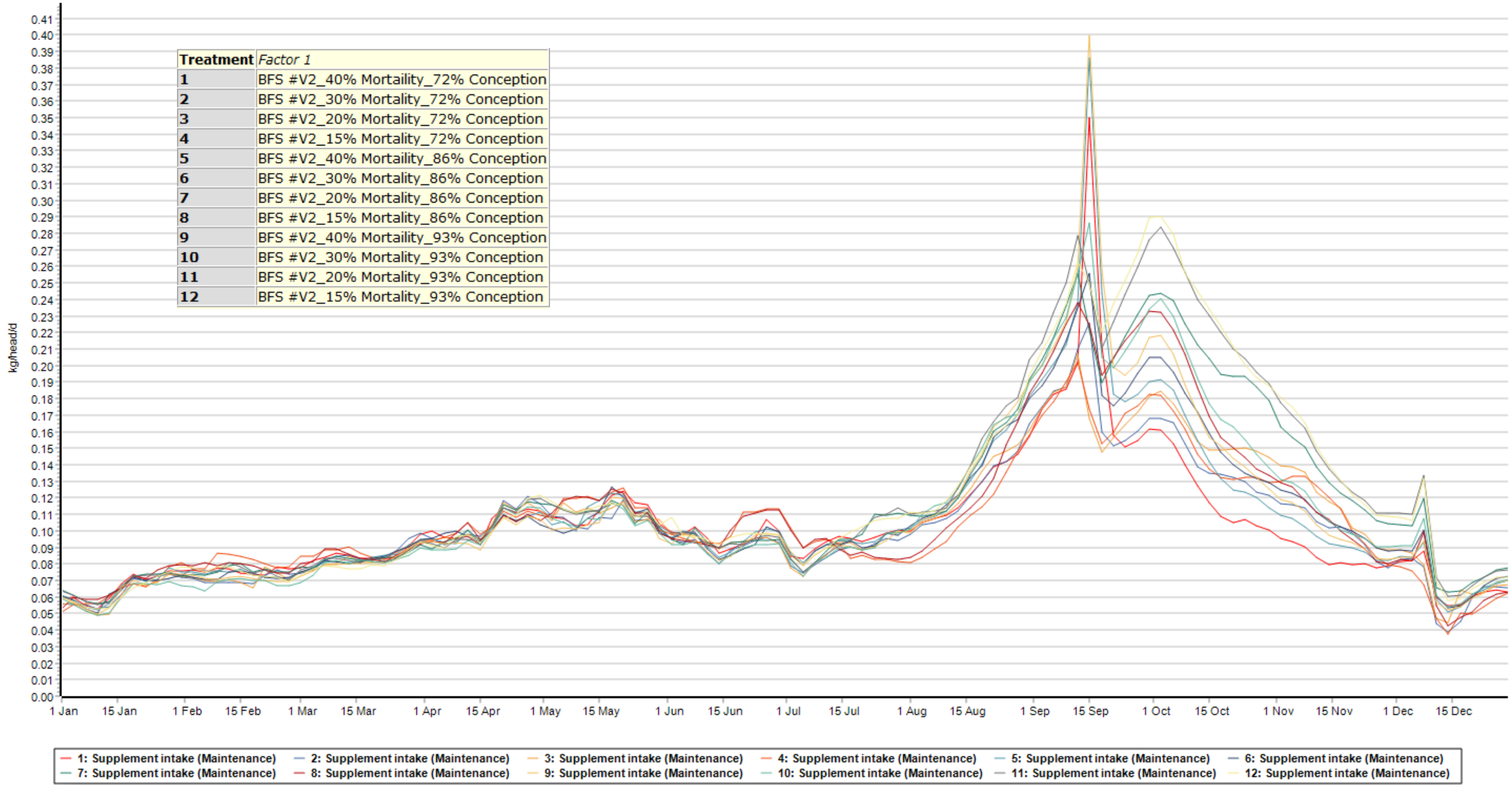
9.3.4 Long term average live weight of mature does for all farm systems



9.3.5 Body Condition of mature females for all farm systems

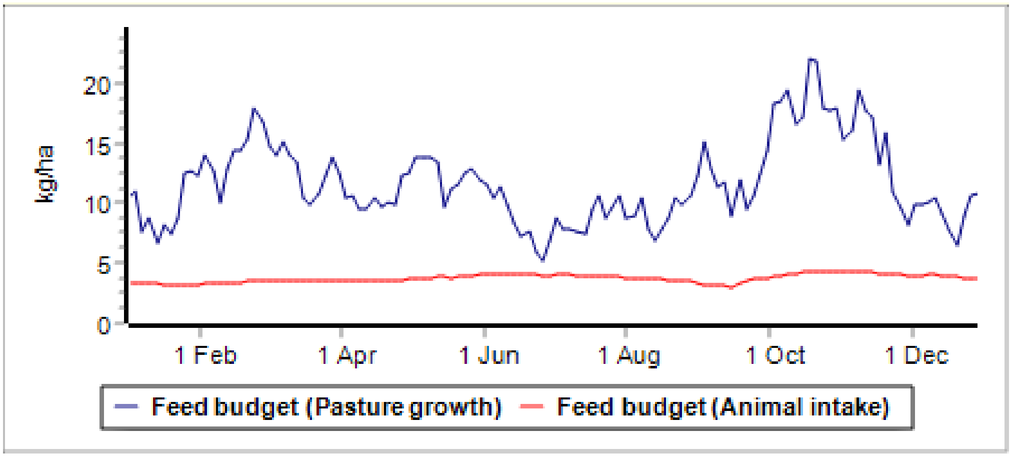


9.3.6 Supplement intake of the main herd for all farm systems

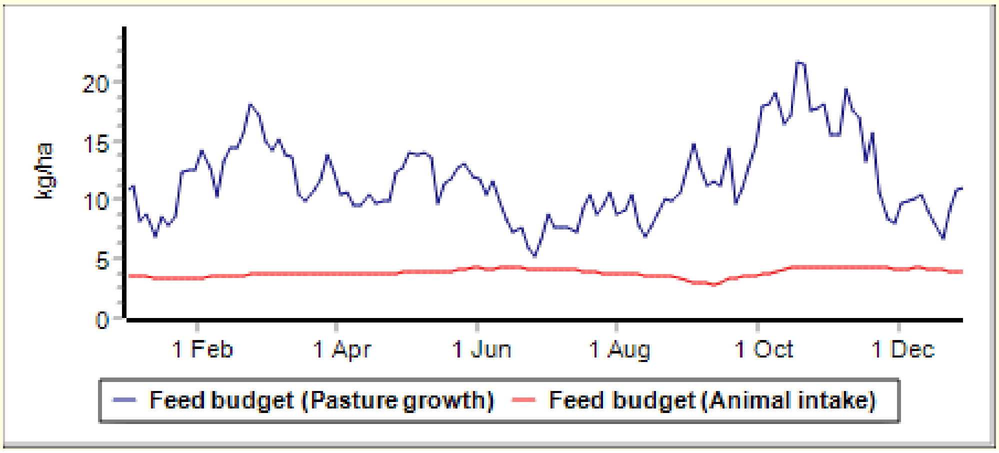


9.3.7 Feed budget for the whole enterprise (i.e. long-term average pasture growth and pasture intake (kg DM/ha/d) for farm system.

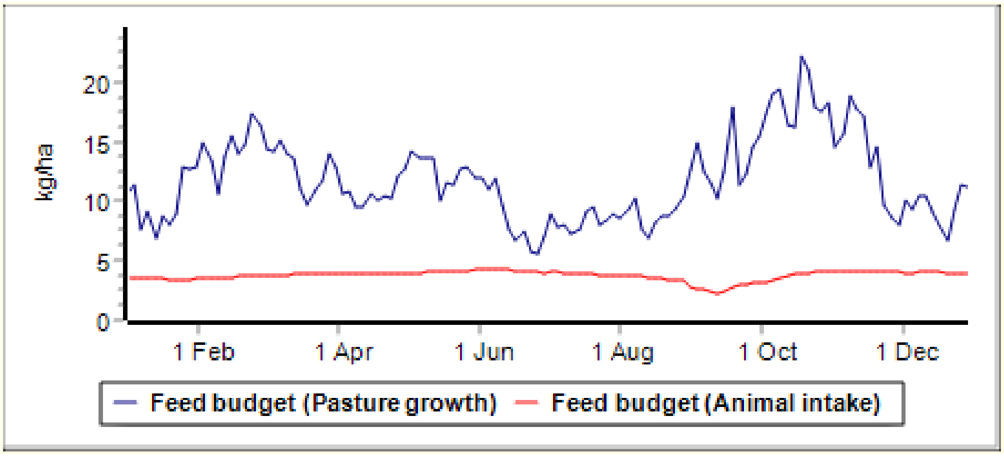
A. 40% Mortality & 72% conception



B. 30% Mortality & 86% conception



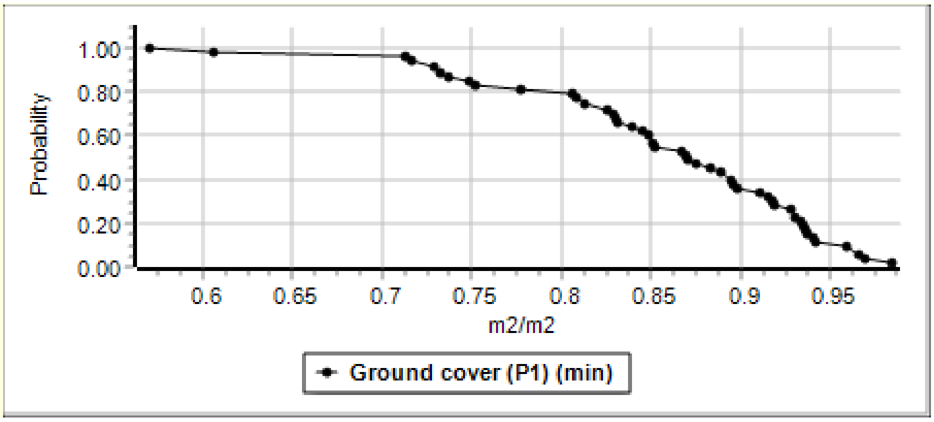
C. 15% Mortality & 93% conception



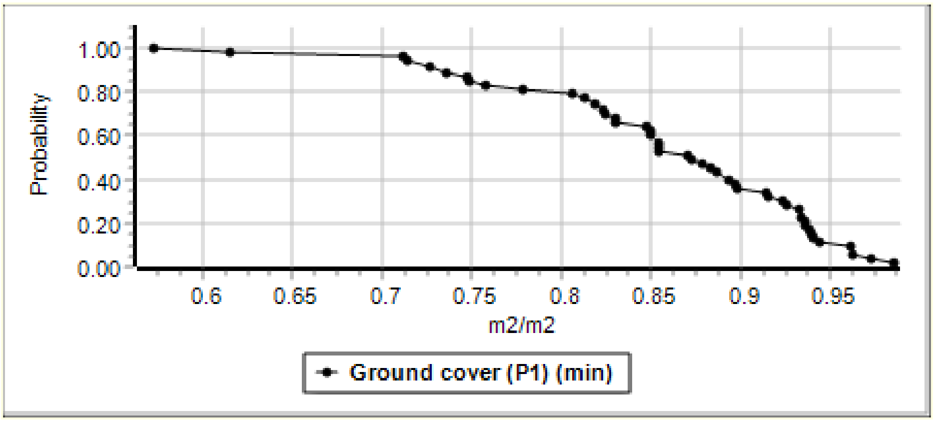
9.3.8 Cumulative distribution function for minimum ground cover for farm system

The probability (shown on the vertical axis) of the minimum cover in a year exceeding the value shown on the horizontal axis.

A. 40% Mortality & 72% conception



B. 30% Mortality & 86% conception



C. 15% Mortality & 93% conception