Final report

Unlocking the keys to ewe survival

Project code: L.LSM.0019

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Abstract

Ewe survival over the lambing period is important, with ewes representing the most productive unit in a flock. However, there is a lack of published data on the scale of ewe mortality during lambing and the causes contributing to this mortality. Hence the aims of this project were to:

1. Estimate non-Merino ewe mortality over lambing in Southern Australia
2. Determine the causes of ewe mortality over lambing and
3. Identify factors which contribute to ewe mortality over lambing

To achieve these aims, an observational study involving both producer records and veterinary assessment was conducted on 51 non-Merino, commercial farms across southern Australia over two lambing seasons. The project did not require animal ethics approval.

Mean cumulative ewe mortality over the lambing period was 2.0% in 2020 and 2.5% in 2019. The most common causes of mortality across both years were septicaemia, primary dystocia and trauma. Factors that influenced ewe survival included parity (number of times pregnant), litter size and age. Risk factors varied for different causes of death. The findings support using current best practice management and some additional steps to address ewe mortality, and potentially increased productivity and welfare outcomes. Project findings will be shared with industry via extension materials, including producer case studies and project infographic.

Executive summary

Background

Under commercial extensive grazing production systems in Australia, it is estimated that annual ewe mortality is between 2-10%. Overseas, the highest risk period for ewe mortality is the lambing (periparturient) period, but there is limited data in Australia regarding ewe mortality. Furthermore, the factors that cause ewe mortality are not routinely determined in sheep production systems due to labour and time constraints. Understanding the incidence of ewe mortality during lambing, and reducing it, is a high priority for the Australian sheep industry both in terms of animal welfare and improving productivity. The results from this research will be disseminated widely to industry (including sheep producers, vets and advisors). It will be used to improve the information included in existing sheep reproduction extension packages (e.g. Lifetime Ewe Management and Lifting Lamb Survival), providing sheep producers with an opportunity to adopt learnings from the research to further improve ewe survival during lambing.

Objectives

The core research objective for this project was:

What are the major causes of ewe mortality in the lead up to and at the time of lambing for commercial non-Merino flocks across a range of climatic zones?

The three research questions underpinning this objective were:

1. Estimate the prevalence of periparturient mortality in well managed, commercial non-Merino ewe flocks in southern Australia (from the time ewes are placed in their lambing paddocks until lamb marking).
2. Identify the causes of periparturient ewe mortality in commercial non-merino ewe flocks in southern Australia.
3. Identify the factors contributing to ewe mortality and the major causes of periparturient ewe mortality in commercial non-merino ewe flocks in southern Australia.

The project achieved the objective and addressed the research questions.

Methodology

- 39 non-Merino commercial sheep producers were engaged to participate during the 2019 and 41 during the 2020 lambing seasons. The producers engaged in this research project were using industry accepted best practice sheep management.

- Producers monitored ewes from when they were first placed in lambing paddocks until lamb marking, as per normal farm practice. During this period, all ewe deaths and the suspected cause of death were recorded in a farm diary.

- Other descriptors recorded in the farm diary for each lambing paddock included ewe age, litter size, ewe breed, sire breed, food on offer (FOO) at the start and end of lambing, and the number of ewes in the paddock at the start of recording and at lamb marking.

- Project veterinarians attended each farm at three time points and conducted post-mortem examinations on any ewes that died in the preceding 48 hours.

- Using a combination of farm and veterinary data, the prevalence and cause of non-Merino periparturient ewe mortality was estimated and risk factors for causes of death investigated.

Results/key findings

The mean cumulative mortality over the lambing period was 2.0% in 2020 and 2.5% in 2019 with no significant difference between years. The primary causes of ewe death across both years were septicaemia, primary dystocia and trauma. The biggest single factor was dystocia, interlinked with other causes of death including septicaemia, trauma and hypocalcaemia. Factors that influenced ewe survival included parity (number of times pregnant), litter size, and age. The risk factors identified varied for each cause of death examined.

Benefits to industry

The results from this project can be used to inform management recommendations for improved ewe survival. These build on and reinforce the existing best practice guidelines promoted through programs such as Lifetime Ewe Management, with some new or additional guidelines now able to be added. Some of the findings from this project potentially offer significant gains for industry in improving ewe (and hence lamb) survival through either more targeted management or new management recommendations.

Resources developed by the project team for use during the project have been adapted and made available to industry. Scientific papers, producer case studies, presentations by the project team to industry and a project infographic are all mechanisms that have and will be used to share project findings.

Future research and recommendations

- Formally incorporate findings from this research into existing sheep reproduction extension packages, to enable these products to have greater impact on ewe and lamb survival.

- Refine recommendations specific to older (>5 years) ewes to maintain productivity and welfare over lambing for this age group (especially if retention of older ewes is used as a strategy to re-build flock numbers).

- Investigate the role of hypocalcaemia in periparturient ewe mortality and refine current recommendations on mineral supplementation.

- This project has highlighted current gaps in the understanding of ewe mortality, where improved knowledge could inform management recommendations to improve animal welfare and ewe productivity. These include:
    - Condition score targets for different ewe genotypes
    - The role of genetics in reducing dystocia in Australian flocks.
    - Management options that reduce impact of metritis for lambing ewes.
    - Strategies for managing triplet bearing ewes to improve ewe (and lamb) survival.
    - Prevention and management of septicaemia, including association with dystocia.

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1. Background

The periparturient period is the time leading up to, during and after birth. It is a time of great change, during which a complex cascade of events must occur in a timely manner. Any disruption in the normal process is potentially fatal for the foetus and/or dam if time critical intervention is not provided. The nature of extensive livestock enterprises limits the monitoring of individuals over the periparturient period. Intervention is complicated by this and the potential detrimental consequences of it including disrupting other birthing livestock.

It is well documented that lamb losses from late pregnancy until marking are a significant contributor to reproductive wastage in the Australian sheep industry (Hinch & Brien, 2014). In contrast, the prevalence and causes of ewe mortality over this same period are relatively poorly defined (Jacobson et al., 2020). The ewe mortality described in much of the literature represents annual data (Harris & Nowara, 1995; Kelly et al., 2014; McGrath et al., 2013; Munoz et al., 2018; Trompf et al., 2011) and does not delineate what time of year in the farming calendar ewe deaths are most likely to occur. According to Mavrogianni and Brozos (2008) the highest risk of ewe mortality is during the periparturient period. This assertion is echoed by the unpublished results of the sentinel flock project which showed the causes of ewe mortality were largely centred around the periparturient period and included dystocia, metabolic disease and mastitis (Suter, 2013).

Annual ewe mortality in Australia has been estimated at 2-11% (Harris & Nowara, 1995; Kelly et al., 2014; McGrath et al., 2013; Munoz et al., 2018; Trompf et al., 2011; Watt et al., 2021) with a higher susceptibility to death in multiple bearing ewes has been suggested (Ferguson et al., 2014; McGrath et al., 2013; Trompf et al., 2011). Harris and Nowra (1995) found annual ewe mortality in non-merino flocks to be higher than that of merinos (11% and 6% respectively) based on survey results from randomly selected producers surveyed in the Mallee region of Victoria.

Watt et. al (2021) described ewe mortality on the Central Tablelands of New South Wales in 2010, a year of above average rainfall. The mean annual ewe mortality in this study was 5.4% (ranging from 0.1% to 28.6%) with producers reporting the most important causes of death as ‘died during lambing’ and ‘foot abscess’ (Watt et al., 2021). Adult ewes had a 5.61 times higher odds of dying compared to maidens and ewes lambing down on pasture heights >5 cm had a 3.96 times higher odds of dying compared to ewes lambing on pasture <5cm (Watt et al., 2021). The time of year of lambing was also significant. Winter and spring lambing ewes had 3 and 4.87 times higher odds of dying compared to autumn lambing ewes respectively (Watt et al., 2021).

Kelly et al. (2014) suggests the primary risk factors underpinning Merino ewe mortality on the Northern Tablelands of New South Whales are low body weight and fat score, as well as high intestinal parasite burdens. Kelly’s findings do not delineate whether these risk factors are pertinent during the periparturient period.

Much work has been done in the Australian sheep wool industry to improve understanding of the impacts of ewe nutrition on ewe performance, mainly through the lifetime wool project. The data from this work was used to develop guidelines for managing ewes (lifetime ewe management) (Curnow et al., 2011; Young et al., 2011). Producers who have participated in lifetime ewe management and have adopted the practices taught are considered to manage their flocks according to best practice principles. Anecdotally some of these producers still have issues with ewe mortality during the periparturient period.

Mavrogianni and Brozos (2008) classify the most common causes of periparturient ewe death into three categories: pre-partum, during lambing and immediately post-partum causes. These conditions range from obstetrical issues (during lambing) to metabolic disturbances, clostridial diseases and septicaemia-toxaemia (pre and post-partum) (Mavrogianni & Brozos, 2008). It has been noted that dystocia, uterine prolapse, retained placenta and postpartum metritis are the most common obstetrical issues that affect the subsequent fertility of ewes (Majeed & Taha, 1995). However, there is little evidence on the prevalence of these diseases and the incidence of ewe mortality subsequent to these diseases.

In 2015 Lane et al described twenty-three priority diseases in the sheep meat industry. Of these, four occur in periparturient ewes, including dystocia, mastitis, pregnancy toxaemia and hypocalcaemia. The combined cost of these diseases to the Australian sheep meat industry alone was estimated to be about AUD$300 million per year (Lane et al., 2015).

It is evident that there is a lack of published information when it comes to the causes and prevalence of periparturient ewe mortality in Australia. The primary aim of this research project was to address this knowledge gap. This will provide a better understanding of the causes of mortality in non-Merino ewes, enabling existing information to be updated to improve ewe survival during lambing. The results from this work will be relevant to sheep producers throughout Australia. The project will improve the sheep industry's capacity to provide personnel skilled in animal health, and provide industry with an evidence-based approach to improving productivity and animal welfare outcomes.

1.1 Dystocia

Dystocia is defined as a difficult birth, or birth process due to a long, unassisted parturition or prolonged delivery requiring assistance (Arthur, 1975) . Dystocia can occur due to maternal factors or foetal factors (Jacobson et al., 2020) or both in the case of fetopelvic disproportion with inadequate ewe pelvis size being a maternal factor and an oversized foetus or foetuses being a foetal factor. For the purposes of this review and to keep consistency with other studies, foetopelvic disproportion will be considered a maternal factor (Cloete et al., 1998; Jacobson et al., 2020).

The foetal origin of dystocia relates to malpresentations, congenital deformities and foetal disease and death while maternal factors include uterine inertia, incomplete cervical dilation (ring womb), uterine torsion, foetal-pelvic disproportion (Arthur et al., 1982), vaginal prolapse and inguinal hernia (Jacobson et al., 2020). Uterine inertia has been described as a likely sequalae of pregnancy toxaemia (Barbagianni et al., 2015). If left unassisted dystocia will directly compromise ewe and lamb survival (Arnold & Morgan, 1985). Dystocia-related mortality may be attributed to haemorrhage, trauma and septicaemia (Mavrogianni & Brozos, 2008).

There is little published data on incidence of dystocia related death in Australian ewes (Jacobson et al., 2020). In Harris and Nowra's 1995 study, dystocia was recorded to have caused mortality in 18% of the recorded dead ewes which were 3 years and older and in 6% of ewes that were rising one year old's (Harris & Nowara, 1995). Lane et al., 2015 states that a 50% reduction in dystocia will gain the industry approximately AUD$77 million per annum (Lane et al., 2015).

1.2 Mastitis

Mastitis is the inflammation of the mammary gland regardless of cause (Constable et al., 2016). The condition may be divided into further categories based on the time period (acute or chronic) or clinical presentation (clinical or subclinical) (Barber et al., 2011; Mavrogianni & Brozos, 2008; Omaleki et al., 2011).

Acute, clinical mastitis can affect and lead to the death of ewes in the immediate post parturient phase (Mavrogianni & Brozos, 2008) and for this reason is the only form of mastitis that will be discussed further in this report.

Clinical mastitis is characterised by visible changes in the udder and or milk (Omaleki et al., 2011). The udder may be swollen, red and painful when palpated while mammary secretions may be watery or blood tinged (Barber et al., 2011; Mavrogianni & Brozos, 2008). Systemic signs include toxaemia, pyrexia, anorexia, tachycardia, ruminal stasis, depression, lameness and recumbency, and in severe cases may lead to death (Constable et al., 2016). Gangrene of the udder can follow and is characterized by a bruised udder and necrosis, which is accompanied by a severe systemic reaction, which often leads to death due to toxaemia (Hirsh et al., 2004).

The inciting cause of clinical mastitis is most commonly bacteria, however mastitis may be caused by any infectious organism or can be due to trauma (Barber, 2015). *Mannheimia spp* are the most common inciting cause of clinical mastitis (Barber, 2015; Omaleki et al., 2010; Omaleki et al., 2011). This differs from European studies whereby *Staphylococcal spp* are the most common inciting cause. Breed predisposition to mastitis has been suggested, with terminal sire breeds such as the Poll Dorset ewes and White Suffolk ewes being over represented compared to Merino ewes (Barber et al., 2011). It is worth noting, that in general merino flocks are less intensively supervised, meaning cases go unobserved during the periparturient period. On post-mortem examination, the swollen, haemorrhagic, and/or gangrenous nature of fatal acute ovine mastitis is obvious and a purulent exudate is sometimes present. Confirmation of diagnosis is through bacterial culture of chilled fresh mammary gland (Constable et al., 2016).

The average clinical infection rates in Australian flocks range from 1-4% with significant variation on a year by year basis (Barber et al 2011). Clinical infection rates of up to and exceeding 10% occur in terminal sire breeds with up to half of these ewes dying despite treatment and most of the others culled following that lactation (Barber et al., 2011). This is in agreeance with Constable and colleagues (2016) who suggest clinical mastitis in grazing ewes averages only about 2% per year, but mastitis can be responsible for up to 10% of all ewe deaths (Constable et al., 2016).

1.3 Hypocalcaemia

Hypocalcaemia (low blood calcium levels) in the peri-parturient period is sometimes termed milk fever or periparturient paresis (West et al., 2017). The condition occurs most commonly in late-pregnant ewes when calcium resorption from skeletal reserves is insufficient and/or there is insufficient intake and absorption of calcium from feed to meet demands for foetal skeletal mineralisation and udder development (West et al., 2017). In sheep this usually occurs after an interruption to feed intake, grazing cereal crops or prolonged feeding of grain without calcium supplementation and/or a stressor such as prolonged mustering, transport or sudden feed deprivation (Larsen et al., 1986; Masters & Thompson, 2016; Mavrogianni & Brozos, 2008; West et

al., 2017). The highest demand for calcium in sheep occurs 3 to 4 weeks prior to parturition, when foetal bones begin to mineralise (Scott, 2013).

Hypocalcaemia can be difficult to diagnose accurately (Cockcroft & Whiteley, 1999). The disease is suspected when pregnant ewes become acutely unco-ordinated or recumbent (West et al., 2017). However these signs were only seen in 57% of confirmed hypocalcaemic cases in one study (Cockcroft & Whiteley, 1999), with ruminal stasis and hyposensitivity been most frequently observed in the hypocalcaemic ewes in this study. Without treatment, the condition develops to coma and death following 1 to 2 days after the onset of recumbency (Scott, 2013). On post mortem examination, low aqueous humour calcium levels of <1 mmol/litre are suggestive of terminal hypocalcaemia (Edwards & Foster, 2009).

Whilst hypocalcaemia is anecdotally widespread, there are few detailed reports and surveys indicating the prevalence of hypocalcaemia in ewes (Friend et al., 2020). In 1986 it was estimated that between 100 000 and 300 000 ewes died each year due to hypocalcaemia in Victoria (Caple et al., 1988) representing between 0.6-1.8% of the Victorian breeding flock at the time. Larsen and colleagues (1986), found the incidence of hypocalcaemia on the 9 farms the authors studied varied from 1 to 8% of all ewes, with some mobs over 10% after a period of drought in the western districts of Victoria, of which the case mortality rate was about 20% (Larsen et al., 1986). This equates to up to 2% mortality in certain mobs studied by Larsen and colleagues, a slightly higher figure than that described by Caple et al, 1988.

1.4 Pregnancy toxaemia

Pregnancy toxaemia, colloquially termed “twin lamb disease” (Brozos et al., 2011) is a metabolic disease of late-pregnant ewes with a poor prognosis of clinically affected animals even with treatment (Crilly et al., 2021). It is caused by deficiency of glucose availability relative to need combined with altered metabolism in late pregnancy and individual variability in insulin insensitivity (Brozos et al., 2011). Lean or overly conditioned ewes are predisposed as well as ewes carrying two or more foetuses (Brozos et al., 2011). Furthermore, poor nutrition and concomitant disease such as foot or teeth issues, high parasitic infestations and ovine Johne’s disease can predispose to the disease (Crilly et al., 2021; Liamadis & Milis, 2007; Papadopoulos et al., 2013). Clinically, ewes isolate from the flock, become anorexic, depressed and show neurological signs including blindness (Crilly et al., 2021). Untreated the condition will lead to recumbency and subsequent death (Brozos et al., 2011; West et al., 2017).

On post mortem examination, ewes are generally found to have two or more foetuses in utero, have a pale, friable liver and have adrenal glands which are enlarged and sometimes haemorrhagic (West et al., 2017). Beta- Hydroxybutyrate (BHB) is a ketone body which accumulates in ewes in negative energy balance and can be used to diagnose pregnancy toxaemia.

Clinical pathology results from sampling the aqueous humour of the eye post-mortem will typically reveal a BHB above 2.5 mmol/L if ewes were affected by pregnancy toxaemia before death (Scott et al., 1995). However, there are reports of clinically normal ewes with high BHB levels and ewes with signs consistent with pregnancy toxaemia but normal BHB levels (Crilly et al., 2021). Although pregnancy toxaemia will occur in all climatic zones, scant prevalence data in Australia is available (Lane et al., 2015).

Harris et al. (1995) recorded pregnancy toxaemia related death in 3% of one year old ewes compared to 12% in flocks 3 years and older (Harris & Nowara, 1995). This is in keeping with the sentinel flock project where 13% of ewe deaths were caused by metabolic disease of which 80% were attributed to pregnancy toxaemia (Suter, 2013).

1.5 Other causes

Other known causes of ewe mortality in the peri-parturient period include but are not limited to vaginal and uterine prolapse, hypomagnesaemia (Friend et al., 2020), traumas and injuries to the genital tract (Friend et al., 2020; Mavrogianni & Brozos, 2008), foot abscess (McGrath et al., 2013), post parturient gangrene and metritis (Mavrogianni & Brozos, 2008).

2. Objectives

The key research question for this project, as stated in the research agreement was:

What are the causes of ewe mortality in the periparturient period for commercial non-merino ewes in southern Australia across a range of climatic zones?

The three research questions underpinning this objective were:

1. Estimate the incidence of periparturient mortality in commercial non-merino ewe flocks in southern Australia (from the time ewes are placed in their lambing paddocks until lamb marking)
2. Identify the causes of periparturient ewe mortality in commercial non-merino ewe flocks in southern Australia
3. Identify the factors contributing to ewe mortality and the major causes of periparturient ewe mortality in commercial non-merino ewe flocks in southern Australia

All project objectives have been successfully met.

2.1 Project outputs

Project outputs, as stated in the research agreement are:

1. Submission of a preliminary report on the key causes of ewe mortality during lambing based on data from a ewe mortality study of 40 non–Merino properties managed under commercial conditions across Victoria, NSW, SA and WA.
2. Submission of a final report on the key causes of ewe mortality during lambing based on data from a ewe mortality study of 40 non–Merino properties managed under commercial conditions across Victoria, NSW, SA and WA. The report must provide a clear picture of the magnitude and causes of ewe mortality to enable management and research priorities to be identified.
3. Submit at least one peer-reviewed scientific article and presentation of the findings at the Australian Sheep Vets Conference and International Sheep Vets conference in 2021.

3. Methodology

This research project was an observational, cohort study. The target population comprised non-Merino, commercial ewes in southern Australia during the periparturient period. For the purposes of this report, this period was defined as the time from when ewes were first placed in their lambing paddocks through to lamb marking. A total of 40 commercial host producers in southern Australia running non-Merino breeds were chosen to be included in the study in 2019. The number of host producers selected was sufficient to provide a cross section of well managed sheep enterprises across a range of geographies. The host producers chosen met the following criteria:

1. Located in either Victoria (VIC), New South Wales (NSW), South Australia (SA) or Western Australia (WA).
2. Joining more than 1000 non-Merino ewes.
3. Pregnancy scanning and separate management of single and twin/multiple bearing ewes.
4. Preferential management of multiple bearing ewes from scanning to lambing as per lifetime ewe management (LTEM) principles.
5. Willingness of host producers to record ewe deaths during the periparturient period.

The opportunity for sheep producers to be part of the project was promoted through industry networks (e.g. Friday Feedback, LTEM networks) and through the project teams' client networks.

Thirty-two of the host producers participating in 2019 also participated in 2020. Eight of the host producers were replaced in 2020 due to logistical issues or insufficient data collection in 2019. Deidentified locations of host producers are shown in Figure 1. The entire breeding flock of non-Merino ewes at each property were monitored by the producers during the lambing period in each year that the farm participated, according to routine management practices on that farm. No changes to management were made on any property for the purposes of this project.

Figure 1 Participating host producers in 2019 (year 1) and 2020 (year 2) (Google MyMaps 2020)

The core data collected across all properties was:

- Quantitative information on ewe deaths (i.e. ewe mortality across flocks).
- Qualitative information on ewe deaths (i.e. producer reported cause of death)
- Post mortem examination of a subset of dead ewes to determine cause of death
- History collection including documenting management practices associated with each flock.

Animal Ethics Committee (AEC) Approval was sought in all states involved in the project. It was concluded that as the project involved no intervention to normal management and ewes were not euthanised for research purposes, this project did not fit within the definition of "animal research" under the Animal Research Act 1985 and did not require AEC approval.

3.1 Basic data collected from all host producers

For each participating enterprise, the entire non-Merino breeding ewe flock was included in the project. This ensured that whole farm mortality was recorded as part of meeting objective 1, in addition to ensuring as many carcasses as possible were available for post-mortem examination during the project. This provided as true a representation as possible of the on-farm situation. The key tasks for each participating host producer were:

- During lambing (from the time ewes were placed in their lambing paddocks until marking) monitor ewes using their routine schedule and record the number of ewe deaths, as well as the suspected cause of death against the syndromes described in the Farm Diary (Appendix 8.1) provided by the project team (e.g. stuck lamb(s), uterine prolapse, cast). The farm diary ensured consistency in recording across all host properties.
- Collect ewes for post-mortem examination if they died within 48 hours of a scheduled vet visit. Dead ewes could be left where they were found. If in full sun or in difficult to reach areas they could be moved to a more suitable location.
- Record paddock history information where ewes were run during lambing:
    - Paddock name
    - Scanning details (single/twin/triple/multiple)
    - Age of ewes (tag colour if all one age or maidens/mixed/>5years old)
    - Ewe breed
    - Sire breed (that ewes were joined to)
    - Pasture dry matter when ewes put into paddock (kg green DM/ha)
    - Pasture dry matter at lamb marking (kg green DM/ha)
    - Number of ewes counted into the paddock
    - Number of ewes at marking
    - Number of lambs at marking

Paddock checks were performed as per routine management, so project findings reflect normal management practices on these properties.

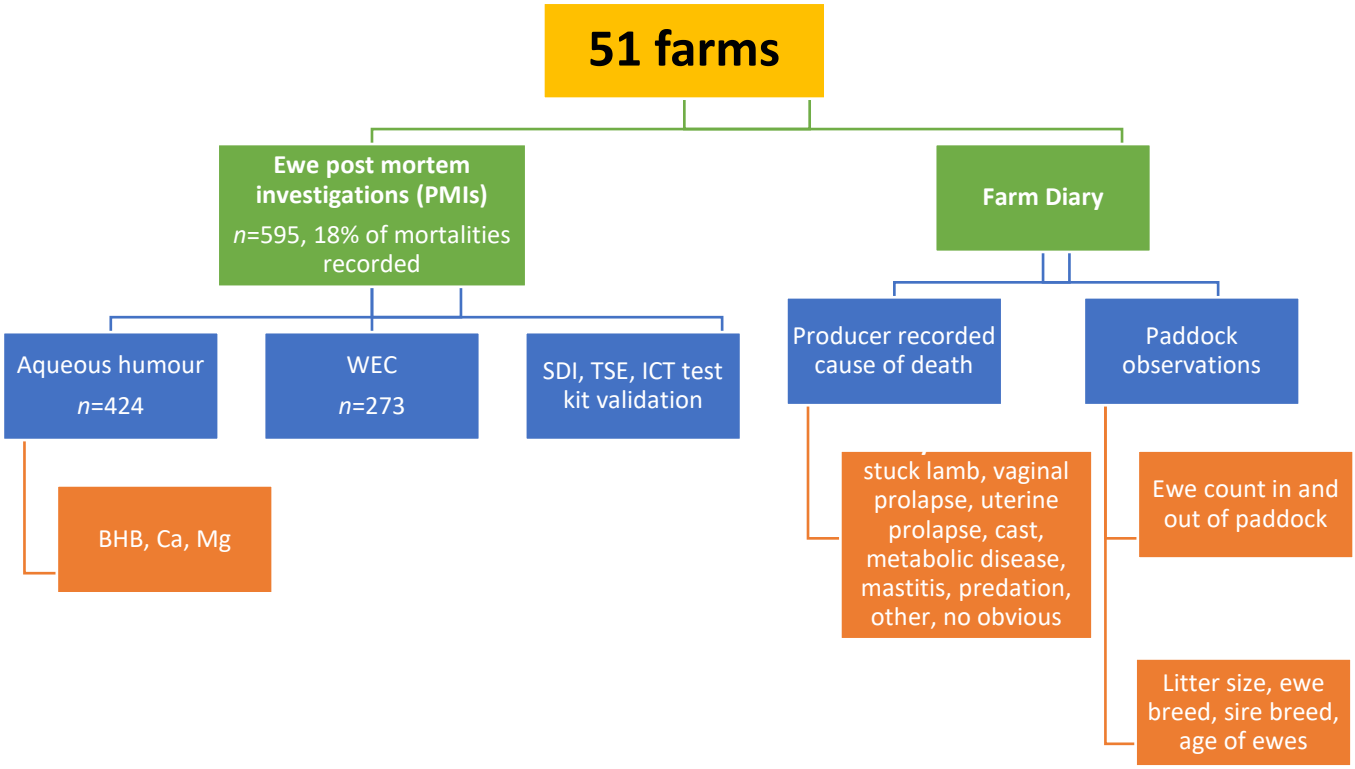

Figure 2 Summary of project methodology (*SDI = significant disease investigation, TSE = Transmissible Spongiform Encephalitis surveillance program, ICT = Anthrax Immunchromatographic antigen detection assay, BHB = beta hydroxy-butyrate, Ca = calcium, Mg = magnesium*)

3.2 Data collection process

Protocols and templates were developed to ensure consistency in data collection and collation including:

- Information sheet for host producers: detailed project overview for host producers to assist them in understanding their role in the project.
- Consent form for host producers: document outlining roles and responsibilities to be signed by host producers, to ensure they fully understood their commitment and the project objectives and protocols.
- Farm diary (Appendix 8.1): recording management data and ewe deaths during lambing.

Three farm visits per year were scheduled during the lambing period by the site coordinators. Livestock Logic, co-ordinated thirty-nine host producers in NSW, Victoria and South Australia, Murdoch University co-ordinated six host producers in Western Australia and the Mackinnon Project University of Melbourne co-ordinated four host producers in Victoria. During each visit a vet conducted post-mortem (PM) examinations on all ewes that died in the preceding 48 hours. If no suitable carcasses were present on the day of the scheduled visit, the visit was either re-scheduled or cancelled.

In 2019 these visits were scheduled to coincide with peak lambing as it was assumed that this coincided with a higher mortality rate per day. In 2020 if two or more deaths occurred prepartum,

host producers would contact the project team to arrange a PM visit. This change to the methodology in 2020 was initiated to better capture metabolic disease, which is more likely to occur prior to parturition.

Post-mortem examination protocols were developed to ensure consistency in the PM process and to smooth data collection and facilitate retrospective examination of the PM findings:

- A PM examination protocol (Appendix 8.2) developed by the team to ensure that all veterinary examinations were performed in a consistent, repeatable manner.
- Electronic capturing of PM results through a secure online application developed in CommCare (CommCare, Dimagi, 2021) by the Mackinnon Project (University of Melbourne).
- Aqueous humour (calcium, magnesium and beta hydroxybutyrate (BHB) levels; submitted to external laboratory) and faeces (worm egg counts) were taken from each ewe examined, where possible.
- Laboratory test results were interpreted in light of the clinical history and post mortem examination findings in consultation with veterinary team members.
- If a notifiable disease was suspected or carcasses were eligible for significant disease investigation (SDI), samples were submitted to relevant state department animal health laboratories.
- Post-mortem findings were not reported to host producers during data collection (i.e. during the lambing period) unless the results were deemed by the consulting veterinarian to be unusual or concerning (e.g. high barbers pole worm burdens in one flock). This only occurred in a small number of situations. A personalised summary of results was provided to each producer at the conclusion of the lambing season (example provided in Appendix 8.3).

The Farm Diary and post-mortem protocol have been adapted for use by industry (producers and vets, respectively). These are useful resources to enable others to explore periparturient ewe mortality for their own flock or clients and will be made available on the MLA website.

3.3 Data analysis

At the conclusion of the lambing period, three separate but linked datasets were collated:

1. Ewe mortality over the periparturient period, drawn from host producer reporting of head counts of live ewes into lambing paddocks and live ewes at lamb marking, and from deaths recorded in farm diaries
2. Host producer reported causes of death for each ewe found dead during routine lambing rounds
3. Detailed post-mortem results from the subset of ewes submitted for post-mortem (identification of cause of death by veterinarian)

The main outputs of this research project are the estimated mortality of non-Merino ewes over the periparturient period, a quantification of the causes of death as recorded by each producer and cause of death as determined by veterinary PM examinations.

Both descriptive data and statistical analyses are presented in the results. A brief overview of the analytical approach to the three datasets is outlined below as is a description of the risk factor analysis performed on the veterinary PM results.

3.3.1 Cumulative mortality rate

Mortality over the periparturient period was calculated as cumulative mortality by dividing the number of ewe deaths by the total number of ewes present at the start of lambing. Where possible, this was calculated for ewes of different parity (i.e. first lambers or second or more lambers), age and litter size. Farm was included as the variable in this analysis, with the mean and 95% upper and lower confidence intervals (CI) reported. The whole of project ewe mortality numbers are also provided by litter size and age.

The source of the mortality data used to calculate cumulative mortality varied between participating farms. In 2020, the farm diary mortality records were used as the source of mortality data for 30 of the host producer records. For seven host producers the difference in head counts between allocation to lamb paddock and lamb marking were used in the analysis. The diary and head count figures matched for nine host producers. In 2019, the farm diary mortality records were used as the source of mortality data for eight of the host producers and for 15 host producers the difference in head counts were used in analyses. The diary and head count figures matched on three farms, and on one farm a combination of host producer records and head count records were used. The decision on which source of data to use was made in consultation with each participating producer on what they believed to be most accurate.

Data collected in 2019 and 2020 included some host producers with records in both years. This allowed for comparisons of cumulative mortality across year, litter size and parity using a linear mixed model with farm considered as a random factor.

3.3.2 Host producer reported cause of death

Host producer reported causes of death are presented as the proportion of all dead ewes on each farm with each cause of death. The mean proportion of deaths due to each cause was calculated across all farms and is presented as the mean (95% CI) proportion of ewes on farm that were suspected to have died of that disease for each year of the project (2019, 2020). Where possible comparisons were made between cause of death from ewes of different age, parity and litter size.

3.3.3 Veterinary post-mortems

Veterinarian diagnosed causes of death are presented as the proportion of all ewes submitted for PM on each farm with each diagnosis. As multiple diagnoses were possible per case, the total of the proportion exceeds 1.0 per farm. Each cause of death is presented as the mean (95% confidence interval, CI) proportion of ewes on farm that were diagnosed with that condition across the two years of submissions (2019, 2020). Descriptive results for litter size, age and BCS in the ewes submitted for PM are also presented.

3.3.3.1 Risk factor analysis on veterinary post-mortem results

Risk factors affecting the likelihood of diagnosing a cause of death were analysed for the most commonly diagnosed causes of death in the subset of ewes submitted for PM (n = 595). For this purpose, each submitted ewe was considered an individual case rather than analysing at a farm level. This decision was justified by the convenience sampling technique, the range in submission numbers between properties (mean: 13.2, range: 1-32; Appendix 8.4) and consequently the small *n* and frequent zeros for individual diseases and potential risk factors on each farm.

Common causes of death diagnosed by veterinary PM were dystocia, trauma, septicaemia, hypocalcaemia, uterine prolapse, dorsal vaginal wall rupture and vaginal prolapse. A derived diagnosis, 'periparturient trauma and/or septicaemia', was created for the risk factor analysis. Cases of major trauma and septicaemia related directly to the periparturient period e.g. uterine rupture and metritis were included in this diagnosis, allowing separation from secondary or 'other' causes of either trauma or septicaemia including intestinal torsion and enteritis. These other conditions were either not or only indirectly related to parturition. Additionally, individual cause of death diagnoses that also caused physical trauma, including dorsal vaginal wall rupture and prolapse, were not included in this diagnosis unless there was also evidence of other major trauma for example uterine rupture, bladder rupture or uterine artery rupture. This facilitated further analysis of risk regarding potential sequelae to dystocia and avoided duplication.

Risk factors potentially affecting the likelihood of diagnosing the most commonly reported causes of death were analysed by calculating the proportions and 95% CI of each cause of death by the factor of interest. The risk ratios were calculated using EpiTools in R version 4.0.3 (R Core Team, 2020). They are presented as risk ratio, p-value (RR, P) where a risk ratio >1 signifies an increased risk associated with exposure to that factor and a risk ratio <1 is protective. The factors explored and the sample size for each are presented in Table 1. Note that where a risk ratio was found to be significant, the interpretation is that there is either an increased or decreased risk of diagnosis of that cause of death associated with that factor compared with diagnosis of the cause in the comparator group.

Risk ratios were calculated relative to target body condition score (BCS 3), three-year old ewes (age) or for the most common level (pasture type, litter size, rainfall zone). Where there were no cases for a category within a factor, the proportions, risk ratios and p-values are not presented.

Rainfall zone was derived from the mean annual rainfall (mm) recorded at the nearest Bureau of Meteorology station (http://www.bom.gov.au/climate/data). Each ewe was allocated to either the to the low (<575 mm annual), medium (575-700 mm) or high (>700 mm) rainfall zone based on the rainfall zone on her farm of origin. Within some factors, categories were formed to reduce the number of groups with low numbers (less than 5). Age was analysed for 1-5 year-olds (by year) and >5 years old (5+). Age was also split into two categories, with all ewes <5 classified as 'younger' and ≥5 as 'older'. Body condition score values were rounded to the nearest quarter. All ewes less than 2 were grouped into the 2 BCS category, and all >3.75 were grouped into the 3.75 category. A categorization of low (≤2.25), mid (2.5-3.5) and high (≥3.75) BCS was also used to examine factors. Estimated feed on offer (FOO, kg DM/Ha) in the paddock the ewe was found dead in was rounded to the nearest 500 and reduced to four groups, ≤1000, 1500, 2000 and ≥2500 kg DM/Ha. Pasture type was categorized into seven groups, improved (including phalaris, ryegrass, cocksfoot and clover base pastures), annual, native, Lucerne, Lucerne-mix, improved-mixed and crop (including wheat, red wheat, oats, barley, brassica and mixes thereof). Total litter weight was split into ≤5 kg, 5-10 kg, 10-15 kg and >15 kg.

Table 1 Animal and environmental factors and the sample size for each (*n*) included in the analysis of risk for the common causes of death diagnosed in periparturient ewes submitted for veterinary post-mortem

Animal factors	Categories	*n*
Ewe BCS (no record 30)	≤2	52
	2.5	94
	3	215
	3.5	152
	≥3.75	52
Litter size	1	89
	2	246
	3+	69
	No record	*191*
Ewe Age	1	17
	2	80
	3	87
	4	85
	5	116
	5+	200
	No record	*10*
Total litter weight kg	≤ 5	47
	5-10	137
	10-15	127
	≥15	30
	No record	*254*

Environmental factors	Categories	*n*
Rainfall Zone (mm annual)	Low (<575)	27
	Med (575-700)	431
	High (>700)	137
State	VIC	443
	NSW	93
	SA	37
	WA	22
Feed on offer (kg DM/ha)	Low (≤1000)	148
	Med (1500)	225
	Med (2000)	110
	High (≥2500)	27
	No record	*85*
Pasture type	Improved	400
	Annual	31
	Fodder crop	23
	Lucerne	14
	Lucerne mixed	14
	Improved mixed	14
	Native	26
	No record	*73*

For this report, results are presented as the mean and upper and lower 95% CIs, and significance reported where $P < 0.05$. Analysis was conducted using Microsoft Excel® and R version 4.0.3. The level of risk analysis presented in this report considers the presence of the diagnosis in question alone in relation to the risk factors being examined. It does not incorporate interactions with other diagnoses or other potential risk factors, unless explicitly discussed.

The analyses presented in this report were conducted by Dr David McGill and Elsa Glanville (Mackinnon Project) following on from the 2019 analyses guided by A/Prof Angus Campbell (Nossal Institute of Global Health, The University of Melbourne).

4. Results

4.1 Summary of the data set

In 2019 (year one), 39 properties were recruited from four states, and in 2020 (year two) 41 properties, as outlined in Table 2.

Table 2 Summary of number and location of participating sheep enterprises

State	**Number of properties** (n) **year 1**	**Number of properties** (n) **year 2**	**Lead organisation/site coordinator**
Victoria	22	23	Livestock Logic
Victoria	4	4	University of Melbourne
New South Wales	4	5	Livestock Logic
South Australia	2	3	Livestock Logic
Western Australia	7	6	Murdoch University
TOTAL	39	41	

Of the 51 farms enrolled over the course of the study, five farms either did not scan ewes or did not separately manage scanned ewes. All these farms were based in Western Australia.

4.2 Periparturient mortality for commercial non-Merino flocks

4.2.1 Overall periparturient ewe mortality

Mean cumulative mortality over the periparturient period (mortality expressed as a percentage of total ewes that entered the lambing paddocks, regardless of duration of observation, including all ages and litter sizes) was 2.0% in 2020 (*n*=37, 95% CI 1.9%, 2.5%) and 2.5% in 2019 (*n*=26, 95% CI 1.9%, 3.1%) (Table 3). There was no significant difference in cumulative mortality between 2019 and 2020 (P = 0.89).

Table 3 Cumulative ewe mortality over the periparturient period in 2019 and 2020.

2020							2019						
FarmID	**State**	**Ewes at start of lambing period** (n)	**Ewes at marking (n)**	**Total deaths (n)**	**Observation period (weeks (n))**	**Cumulative mortality (%)**	**FarmID**	**State**	**Ewes at start of lambing period (n)**	**Ewes at marking (n)**	**Total deaths** (n)	**Observation period** (weeks (n))	**Cumulative mortality (%)**
1	NSW	7060	6868	142	6	2.01%	**1**	NSW	12753	12342	411	12	3.22%
2	NSW	3669	3585	81	4	2.21%	**2**	NSW	3545	3463	82	6	2.31%
3	NSW	2946	3317	100	4	3.39%							
4	NSW	4076	3845	116	4	2.85%	**4**	NSW	4790	4622	162	3	3.38%
5	SA	2292	2271	21	3	0.92%	**5**	SA	n.a	n.a	18	6	n.a
6	SA	4424	4357	90	6	2.03%	**6**	SA	6521	6389	132	7	2.02%
7	VIC	2362	2309	53	6	2.24%	**7**	VIC	4508	4572	36	5	0.80%
8	VIC	949	954	18	10	1.90%	**8**	VIC	1082	n.a	9	6	0.83%
10	VIC	8388	8245	134	6	1.60%	**10**	VIC	n.a	n.a	74	6	n.a
11	VIC	3111	3061	50	3	1.61%	**11**	VIC	3740	3711	43	12	1.15%
13	VIC	6154	5646	122	8	1.98%	**13**	VIC	5381	5145	236	7	4.39%
							15	VIC	8304	8134	170	2	2.05%
16	VIC	1055	1034	17	4	1.61%	**16**	VIC	10184	10038	146	4	1.43%
17	VIC	1768	1749	18	6	1.02%	**17**	VIC	4167	4104	71	4	1.70%
19	VIC	8331	n.a	102	6	1.22%	**19**	VIC	9081	8731	350	3	3.85%
20	VIC	4436	4390	48	6	1.08%	**20**	VIC	n.a	n.a	30	6	n.a

2020							2019						
FarmID	**State**	**Ewes at start of lambing period** (n)	**Ewes at marking (n)**	**Total deaths (n)**	**Observation period (weeks (n))**	**Cumulative mortality (%)**	**FarmID**	**State**	**Ewes at start of lambing period (n)**	**Ewes at marking (n)**	**Total deaths** (n)	**Observation period** (weeks (n))	**Cumulative mortality (%)**
21	VIC	7154	6907	89	6	1.24%	**21**	VIC	5755	5673	82	6	1.42%
24	VIC	5455	4467	186	6	3.41%	**24**	VIC	4727	4562	162	7	3.43%
25	VIC	4283	4227	56	4.8	1.31%	**25**	VIC	3048	3008	45	12	1.48%
26	VIC	3250	n.a	60	8	1.85%	**26**	VIC	9747	n.a	138	4	1.42%
27	VIC	886	n.a	16	8	1.81%	**27**	VIC	1565	1529	36	16	2.30%
29	WA	782	759	23	6.3	2.94%	**29**	WA	1194	660	20	6	1.68%
30	WA	1009	987	22	n.a.	2.18%	**30**	WA	1045	1028	17	10	1.63%
31	WA	2432	2351	28	8.9	1.15%	**31**	WA	1480	1414	66	12	4.46%
32	WA	2158	2097	61	n.a.	2.83%	**32**	WA	1910	1798	112	12.4	5.86%
							33	WA	856	852	4	8.5	0.47%
35	VIC	1422	1394	29	4	2.04%	**35**	VIC	2495	n.a	31	9	1.24%
37	VIC	2153	2075	84	6	3.90%	**37**	VIC	2512	n.a	62	9	2.47%
38	VIC	1510	1439	71	8	4.70%	**38**	VIC	1848	1772	66	11	3.57%
40	VIC	2293	1628	82	n.a.	3.58%	**40**	VIC	1891	1837	54	9	2.86%
							41	WA	698	660	38	5	5.44%
42	VIC	1738	1722	16	4	0.92%							
43	VIC	1611	1571	37	8	2.30%							
44	SA	3557	3499	62	4	1.74%							
45	VIC	2674	2619	36	6	1.35%							
46	VIC	3297	3238	61	6	1.85%							
47	VIC	2085	2057	28	8	1.34%							
48	VIC	2761	2417	22	3	0.80%							
51	WA	2325	2298	27	n.a.	1.16%							
52	VIC	4428	4369	59	10	1.33%							

2020							2019						
FarmID	**State**	**Ewes at start of lambing period** (n)	**Ewes at marking (n)**	**Total deaths (n)**	**Observation period (weeks (n))**	**Cumulative mortality (%)**	**FarmID**	**State**	**Ewes at start of lambing period (n)**	**Ewes at marking (n)**	**Total deaths** (n)	**Observation period** (weeks (n))	**Cumulative mortality (%)**
Mean		3250.919	3051.529	61.27027	6.75541	1.98%	**Mean**		4253	4176	97	8	2.48%
Minimum		782	954	16	3	0.80%	**Minimum**		698	660	4	2	0.47%
Maximum		8388	8245	186	10	4.70%	**Maximum**		12753	12342	411	16	5.86%
n		37	34	37	33	37	***n***		27	23	30	30	27
Total		120284	103752	2267			**Total**		114827	960544	2903		

n.a. data not available

In 2020, the periparturient cumulative ewe mortality for the lowest 25th percentile of host producers was ≤1.28% compared to ≤1.42% in 2019. Mortality in the highest 25th percentile of host producers was ≥2.27% in 2020 and ≥3.43% in 2019 (Table 4).

Table 4 Percentile for mean cumulative ewe mortality over periparturient period

Percentile Ranges	Cumulative mortality 2020	Cumulative mortality 2019
0 to 25th	0.8%-1.28%	0.47%-1.42%
Median	1.85%	2.05%
75th to 100th	2.27%-4.7%	3.43%-5.86%

Twenty-three farms contributed mortality data in both years of the project. Table 5 highlights the farms that had the lowest (blue) and highest (yellow) cumulative mortality percentages in 2019 and 2020. Only one farm had ewes in the 0 to 25th percentile in both years (farm 21) while three farms had ewes in the 75-100th percentile in both years.

Table 5 Cumulative ewe mortality results for ewes on farms present in both years of study. Blue highlighted cells represent cumulative mortality (%) results in the 25th (lowest) percentile. Yellow highlighted cells represent cumulative mortality (%) results in the 75th (highest) percentile in each year of the study.

FarmID	State	Ewes at start of lambing period (n)	Ewes at marking (n)	Total deaths (n)	Observation period (weeks (n))	Cumulative mortality (%) 2019	Ewes at start of lambing period (n)	Ewes at marking (n)	Total deaths (n)	Observation period (weeks (n))	Cumulative mortality (%) 2020
1	NSW	12753	12342	411	12	**3.22**	7060	6868	142	6	**2.01**
2	NSW	3545	3463	82	6	**2.31**	3669	3585	81	4	**2.21**
4	NSW	4790	4628	162	3	**3.38**	4076	3845	116	4	**2.85**
6	SA	6521	6389	132	7	**2.02**	4424	4357	90	6	**2.03**
7	VIC	4608	4572	36	5	**0.78**	2362	2309	53	6	**2.24**
8	VIC	1082	n.a	9	6	**0.83**	949	954	18	10	**1.9**
11	VIC	3740	3711	43	12	**1.15**	3111	3061	50	3	**1.61**
13	VIC	5381	5145	236	7	**4.39**	6154	5646	122	8	**1.98**
16	VIC	10184	10038	146	n.a	**1.43**	1055	1034	17	4	**1.61**
17	VIC	4167	4104	71	4	**1.7**	1768	1749	18	6	**1.02**
19	VIC	9081	8731	350	3	**3.85**	8331	n.a	102	6	**1.22**
21[a]	**VIC**	**5755**	**5673**	**82**	**6**	**1.42**	**7154**	**6907**	**89**	**6**	**1.24**
24[b]	**VIC**	**4724**	**4562**	**162**	**7**	**3.43**	**5455**	**4467**	**186**	**6**	**3.41**
25	VIC	3048	3008	45	12	**1.48**	4283	4227	56	4.8	**1.31**
27	VIC	1565	1529	36	16	**2.3**	886	n.a	16	8	**1.81**
29	WA	1194	660	20	n.a	**1.68**	782	759	23	6.3	**2.94**
30	WA	1045	1028	17	10	**1.63**	1009	987	22	n.a.	**2.18**
31	WA	1480	1414	66	12	**4.46**	2432	2351	28	8.9	**1.15**
32[b]	**WA**	**1910**	**1798**	**112**	**12.4**	**5.86**	**2158**	**2097**	**61**	**n.a.**	**2.83**
35	VIC	2495	n.a	31	9	**1.24**	1422	1394	29	4	**2.04**
37	VIC	2512	n.a	62	9	**2.47**	2153	2075	84	6	**3.9**
38[b]	**VIC**	**1838**	**1772**	**66**	**11**	**3.59**	**1510**	**1439**	**71**	**8**	**4.7**
40	VIC	1891	1837	54	9	**2.86**	2293	1628	82	n.a.	**3.58**

a=Farm in lowest 25th percentile in both years, b=farms in highest 75th percentile in both years. n.a. = no data available

4.2.2 Cumulative ewe mortality by litter size and age

Total ewe mortality across both years of the study by litter size and age are presented below. Again, the cumulative ewe mortality (%) was calculated by dividing the total number of deaths in each litter or age category by the number of ewes on entry into their lambing paddocks. This is not an average of mortality across the participating farms, but is overall data.

Across all farms, the overall cumulative mortality of single-bearing ewes was 1.4%. Twin-bearing ewes had an overall mortality of 2.2% while ewes that were scanned as multiple bearing (i.e. twin and triplet bearing ewes were not scanned separately) had a mortality of 2.7%. The cumulative mortality of triplet bearing ewes was 5.1% (Table 6).

Table 6 Ewe mortality for ewes in different litter sizes in both years of the study (whole of project figures from allocation to lambing paddock to lamb marking)

Litter Size	Number of deaths	Number of ewes in to lambing paddocks	Cumulative ewe Mortality (%)
Single	938	66,658	1.41%
Twin	1,256	56,417	2.23%
Multiple	1,778	65,734	2.70%
Triplet	232	4,593	5.05%
Undifferentiated	723	29,895	2.4%
OVERALL	4,927	223,297	2.2%

By age group, across all farms the overall cumulative mortality of ewes under two years old was 2% (Table 7). Ewes between 2 and 5 had an overall mortality of 2.4%. Where information was submitted separately on older ewes (>5 years old), overall mortality was 3.3%. Ewes that were not separated into different age categories had a mortality of 1.9%.

Table 7 Ewe mortality (%) for ewes in different age categories in both years of the study (whole of project figures from allocation to lambing paddock to lamb marking)

Age (years)	Number of deaths	Number of ewes in to lambing paddocks	Cumulative ewe mortality (%)
<2	607	31,000	1.96%
2-5	2,788	117,858	2.37%
>5	321	9,785	3.28%
Mixed*	1,211	64,654	1.87%

* Mob includes more than one age category (*e.g.* ewes 2-5 years old plus ewes older than 5 or less than 2)

4.3 Host producer recorded cause of death

Of the 41 host producers enrolled in 2020, 37 supplied data allocating causes of death to dead ewes (including 'stuck lamb', 'cast', 'unknown'). A total of 2,168 deaths were reported across these 37 host properties with the average proportion of deaths due to each cause shown in Figure 3. In 2019, 27 host producers supplied cause of death data for 1,324 ewes.

Obvious dystocia (recorded as 'stuck lamb/s) was the most commonly recorded cause of death in both 2020 (28%) and 2019 (33%) followed by 'no obvious cause of death' (2020 24%; 2019 28%). (Figure 3).

In 12.8% of cases in 2020 an 'other' cause of death was recorded. Twenty-three of the 'other' causes recorded included suspicion of complications associated with dystocia including 'ewe with dead rotten lamb, closed up so had to euthanise ewe', 'pulled lamb couple days ago, suspect infection', 'retained fetal membranes and nerve damage after lambing'. The 'other' category in 2019 included ewes being in poor condition, phalaris staggers, euthanasia and trauma cases such as abdominal muscle rupture. Additionally, in 2019, 'other' causes of death included suspect metabolic disease (both hypocalcaemia and pregnancy toxaemia). To isolate metabolic disease as a distinct syndrome, a 'metabolic disease' column was included in the descriptive analysis of the results from the farm diaries. Those cases were removed from the 'other' causes of death category into the metabolic disease category. On average, metabolic disease was reported as the suspected cause of death in 4.3% of deaths reported in 2019. Metabolic disease was included as a syndrome in the 2020 Farm Diaries to streamline the process and it was recorded as the suspected cause of death in on average 6.3% of deaths reported in 2020.

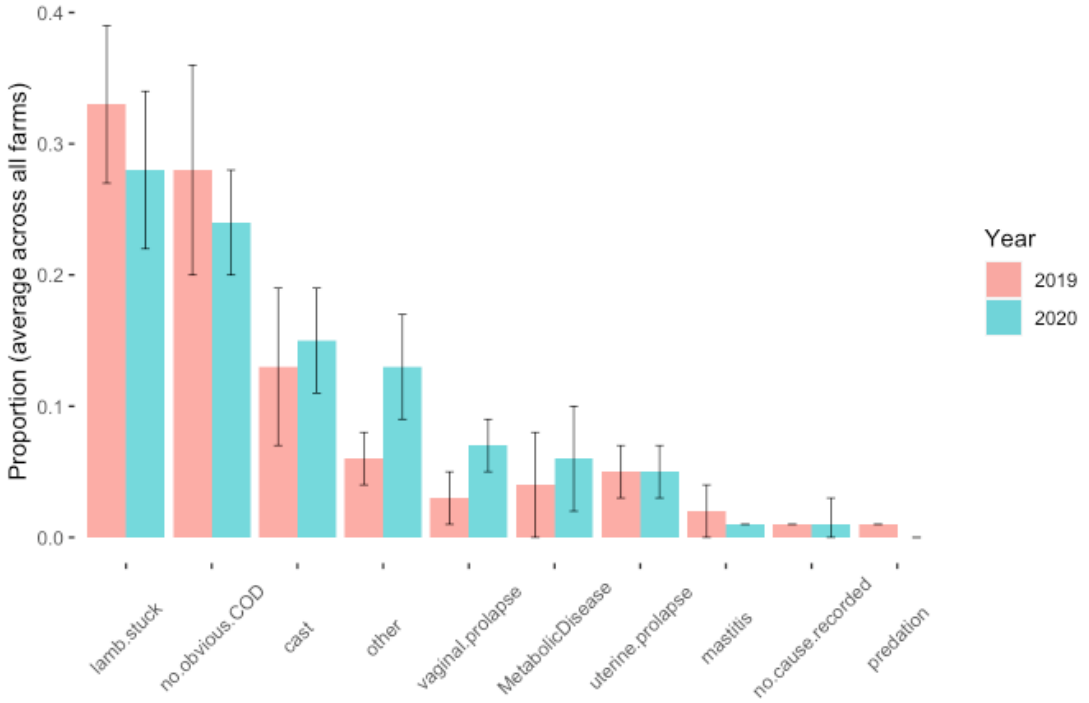

Figure 3 Host producer reported cause of death for 2020 (n = 2168) and 2019 (n = 1324) as the mean proportion of deaths due to each syndrome across participating farms. Error bars represent the upper and lower 95% CI for each cause of death.

4.3.1 Age and litter size as risk factors for dystocia deaths reported by producers

The risk of host producer reported cause of death being dystocia ('lamb stuck') was associated with age at maiden lambing (Figure 4). In 2019, ewes that first gave birth as ewe lambs were 2.55 times more likely to have an obvious dystocia recorded as cause of death compared to ewes that first gave birth as two-year old maidens (95% CI: 1.68, 3.86; P < 0.001). For the host producer records in 2020, ewe lambs were 1.62 times more likely to have obvious dystocia recorded as a cause of death compared with two-year old maidens.

For ewe lambs recorded as dystocia, there was no association with litter size. Similarly, there was no association with litter size for two-year old maiden ewes. In 2020, there was also no trend in mortality observed with an increased litter size with either ewe lambs, or 2-year old (see results in Appendix 8.5 for Parity 1 ewes in 2020). Hence there was no evidence to suggest that increased risk of 'stuck lamb' for ewe lambs compared to two-year old maidens was driven by a higher proportion of large single lambs from ewe lambs.

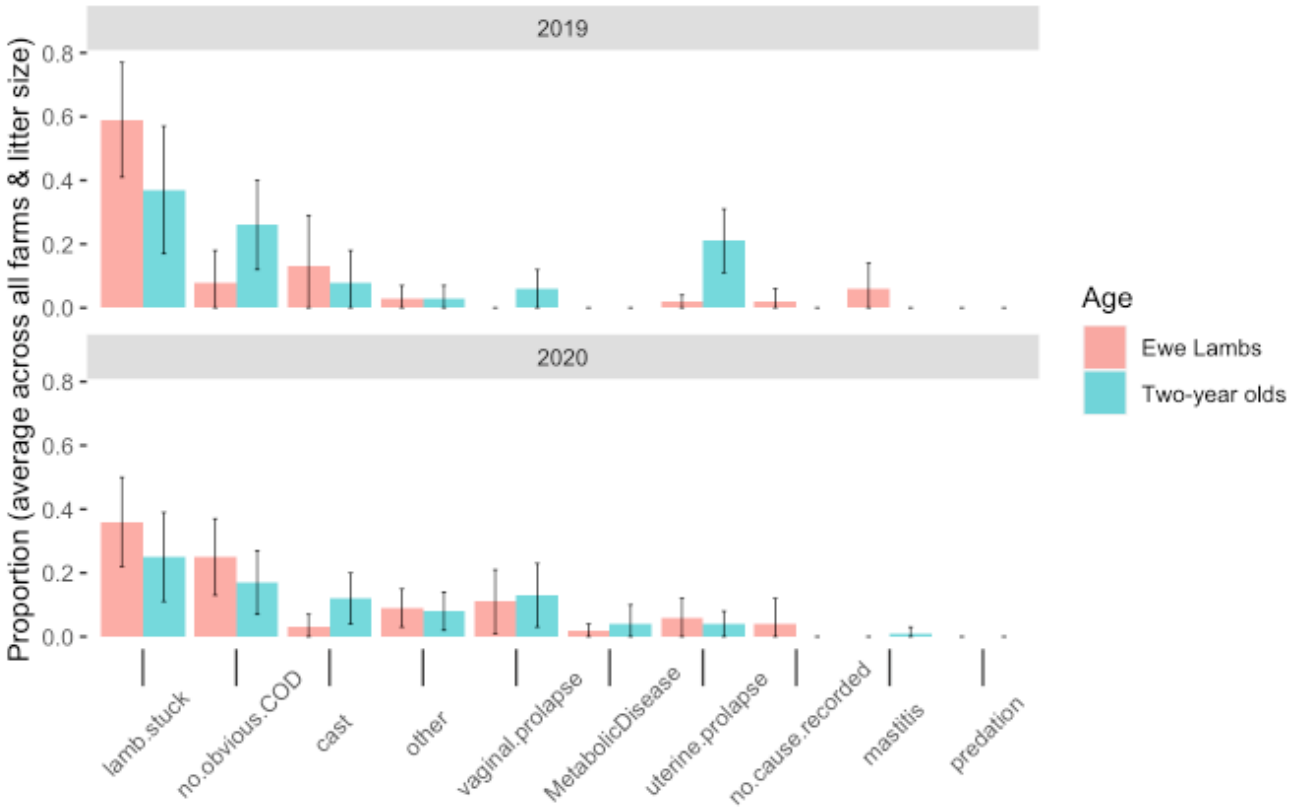

Figure 4 Host producer reported causes of death for parity one (maiden) ewes lambing first as ewe lambs (pink columns) or as two-year-old (green columns) expressed as a proportion of total deaths recorded across all ewes within that age category. This is split according to the year of recording (2019 – top graph, 2020 – bottom graph). Error bars represent the upper and lower 95% CI for each proportion.

4.4 Cause of death determined by veterinary post mortem examination

A total of 595 PM examinations were performed over both years of this project. An average of eight PM examinations (range 1-32) were conducted per farm on 38 farms in 2020 and 35 farms in 2019 (Appendix 8.4). Ewes submitted for PM represented 18% of recorded mortalities in 2020 and 17% in 2019. Ocular fluid samples were available for β-hydroxybutyrate (mmol/L), calcium (mmol/L) and magnesium (mmol/L) testing from 432 (73%) cases over both years. These results were incorporated into the overall diagnosis for each case where appropriate.

For both the 2020 and 2019 PM data, the most commonly diagnosed causes of death are shown in Figure 5 (more details in Appendix 8.4). These include:

- Septicaemia – in 2020 41% cases (95% CI: 31%, 51%) and 2019 43% cases (95% CI: 33%, 53%), with metritis and peritonitis most commonly recorded as the likely origin.
- Dystocia – in 2020 29% cases (95% CI: 20%, 36%) and in 2019 41% cases (95% CI: 29%, 49%), including malpresentation and foeto-pelvic disproportion.
- Trauma - in 2020 39% cases (95% CI: 31%, 47%) and in 2019 19% cases (95% CI: 13%, 25%), including uterine rupture, bladder rupture, uterine torsion, intestinal torsion, uterine artery rupture, abdominal muscle avulsion and nerve compression.
- Hypocalcaemia – 2020 15% cases (95% CI: 9%, 21%) and 2019 10% cases (95% CI: 6%, 14%).
- Dorsal vaginal wall rupture – 2020 11% cases (95% CI: 5%, 17%) and 2019 3% cases (95% CI: 1%, 5%).
- Uterine prolapse – 2020 5% cases (95% CI: 0%, 11%) and 2019 10% cases (95% CI: 4%, 16%).
- Vaginal prolapse – 2020 7% cases (95% CI: 3%, 11%) and 2019 1% cases (95% CI: 0%, 3%).
- Gastrointestinal worm burdens – 3% cases (95% CI: 1%, 5%) in 2019 and 2020.
- Septicaemia, trauma and hypocalcaemia frequently co-occurred with primary dystocia. This is discussed later in the report.

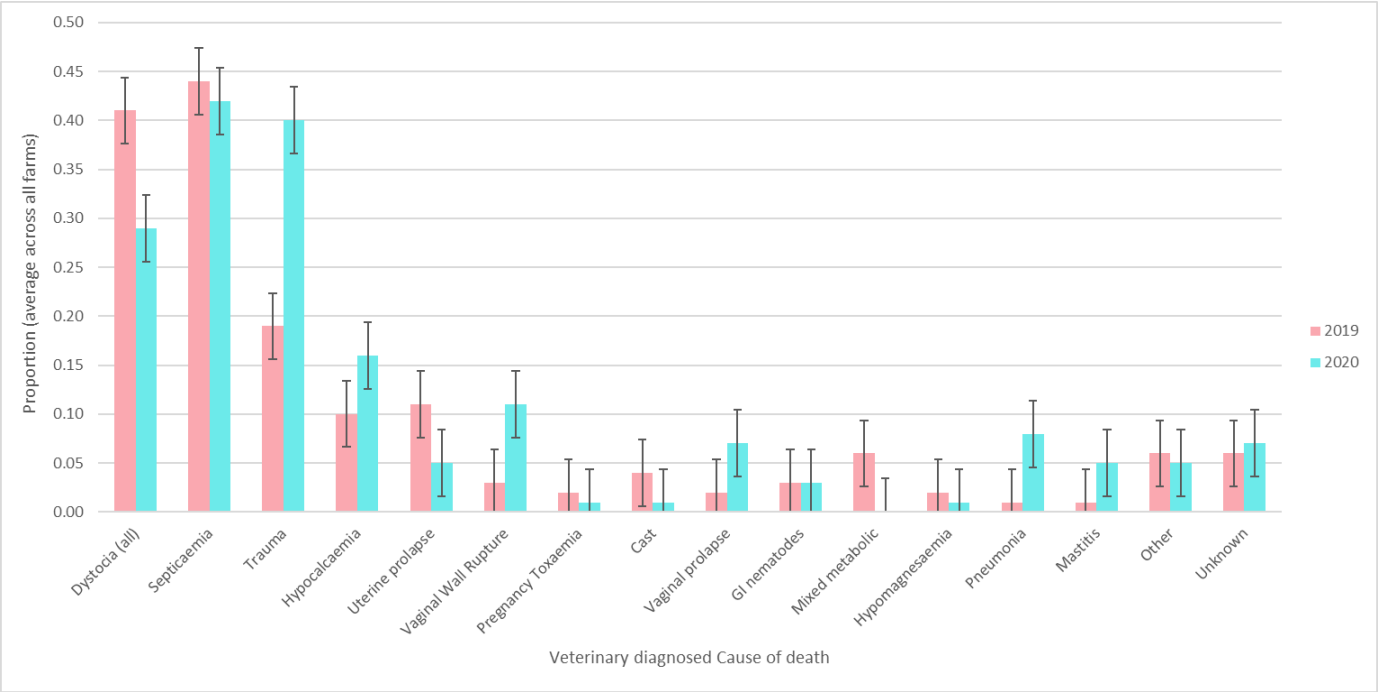

Figure 5 Proportion of cases with each diagnosis for 2019 (294 PM examinations from 35 host producers) and 2020 (301 PM examinations from 38 host producers). Multiple diagnoses were possible per ewe. Error bars represent the upper and lower 95% CI for each proportion. The diagnosis 'mixed metabolic' includes both hypocalcaemia and pregnancy toxaemia.

4.4.1 Dystocia

Of the 91 cases of primary dystocia in 2020, 57% (95% CI: 46%, 67%) were reported as 'obvious dystocia' based on external evidence of dystocia (e.g. protruding head/s or limb/s). In 2019, 66% of primary dystocia cases had obvious dystocia (95% CI: 56%, 75%). Of secondary dystocia cases in 2020, 14.3% (95% CI: 0%, 49%) were obvious on external examination. In 2019, 12.5% (95% CI: 0%, 31%) of the secondary dystocia cases had obvious external signs. The remaining cases were identified by internal examination during the PM process. These findings suggest that dystocia is likely to be under-reported if internal examination, or PM examination of deceased animals, is not conducted.

There was a difference in primary dystocia (PD) cases in 2019 and 2020 (Figure 6) whereby primary dystocia alone was only diagnosed in 9% of cases (95% CI: 4%, 16%) in 2020 whereas in 2019 primary dystocia alone was reported in 37% of cases (95% CI: 28%, 47%).

Over both years, 48% of all ewes submitted for post-mortem had evidence of considerable trauma and/or septicaemia directly related to late pregnancy or birth (described as 'periparturient trauma and septicaemia' in Section 4.4.5.2 below). A significantly higher proportion of all dystocia cases had evidence of periparturient trauma and/or septicaemia (62%, 95% CI: 55%, 69%) than non-dystocia cases (41%, 95% CI: 36%, 46%; P<0.01).

Trauma was frequently diagnosed in conjunction with primary dystocia. It was more likely to be diagnosed with primary dystocia in 2020 compared to 2019 (72% and 40% of cases respectively, Figure 6. Across both years, the most common causes of trauma in cases of primary dystocia was

uterine rupture followed by haemorrhage after uterine artery rupture, and bladder rupture. Septicaemia was also frequently diagnosed in conjunction with primary dystocia (Figure 6). The most likely origins of septicaemia was recorded as 'metritis' and 'peritonitis' following to rupture of the uterus and/or bladder.

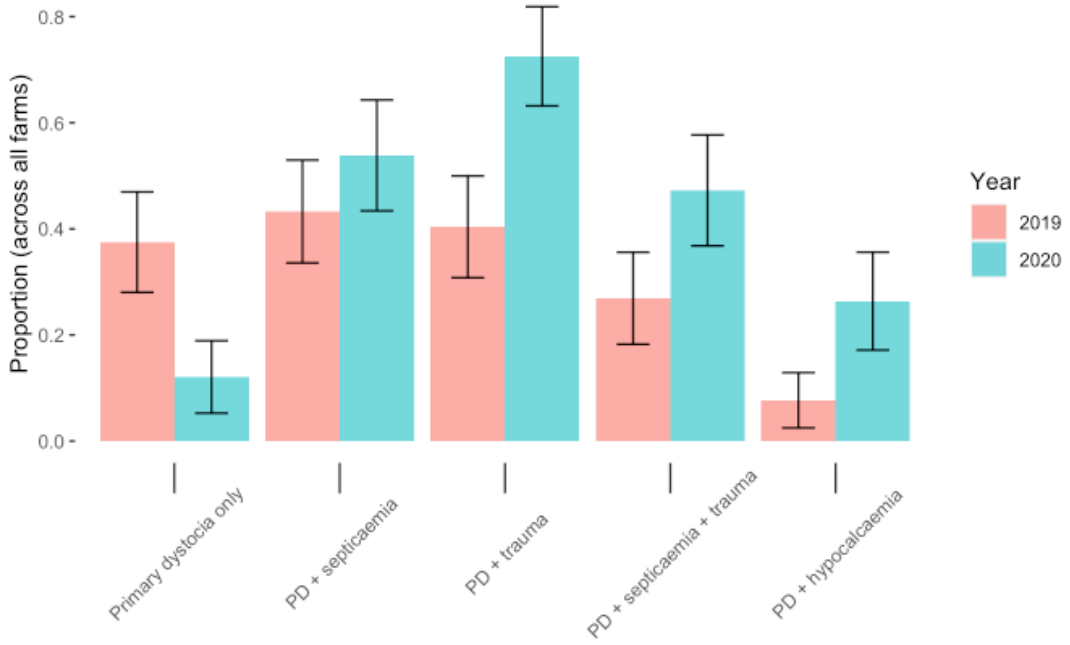

Figure 6 Proportion primary dystocia (PD) cases (n=104 in 2019, and n=91 in 2020) with or without sequelae. Error bars show upper and lower 95% CI.

Over both years, 64% of ewes submitted for PM died whilst pregnant. Of the ewes that died whilst pregnant, 47% had lamb/s at least partially engaged within the birth canal. The majority of ewes that were presented for PM that had died in active labour were diagnosed with dystocia (89%). In cases that were not recorded as dystocia, hypocalcaemia and significant trauma were recorded as other causes of death during parturition. For some of these cases, the diagnosis did not rule out difficulties during parturition consistent with dystocia, but the attending veterinarian did not deem dystocia to be the primary cause of death.

Of the dead ewes that were diagnosed with dystocia, the most common type of dystocia was malpresentation (58%), followed by foetal size (15%) and uterine inertia with failure to progress labour for unknown reason (13%; Figure 7). The most common malpresentations were leg/s back (35%), breech (tail or hindlimbs first, 26%), two lambs simultaneously (19%) and head back (13%).

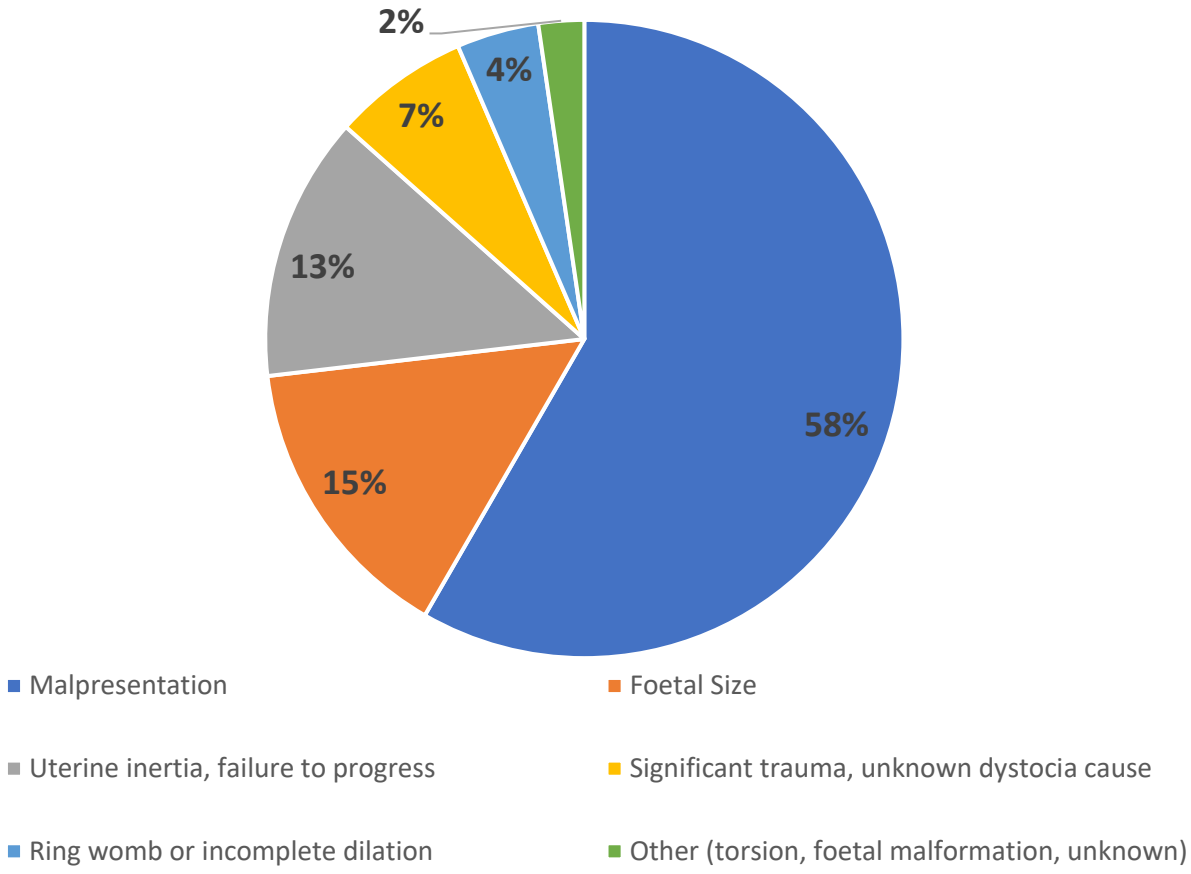

Figure 7 Proportion of ewes submitted for post-mortem with dystocia of each type (over all ewes submitted for PM diagnosed with dystocia)

When dystocia type was examined for each ewe age group submitted for PM, foetal size appeared to contribute to proportionately more dystocia diagnoses in one-year-old ewes (43%) compared to other age groups (10-19%, Appendix 8.7). However, the number of ewes submitted for PM within the youngest age cohort was very small (*n* = 17) with only seven cases diagnosed as dystocia, limiting the conclusions able to be drawn from this observation.

4.4.2 Litter size and causes of death

Litter size as determined at pregnancy scanning or by lambs present at necropsy was recorded for 196 of the ewes submitted for PM in 2019 and 208 in 2020. Across both years, the majority (61%) of ewes submitted for PM with litter size recorded were twin-bearing (Figure 8). There are two likely explanations for this observation:

- Higher number of twin (or higher) compared to single pregnancies on host producer properties.
    - In 2019, 57,521 ewes were reported as carrying two or more foetuses, compared to 33,902 carrying singles (13,744 were undifferentiated)
    - In 2020, 72,965 ewes were reported as carrying two or more foetuses compared to 36,555 carrying singles (10,764 were undifferentiated)
- The trend toward a higher mortality in ewes carrying two or more foetuses compared to single-bearing ewes (section 4.4.5).

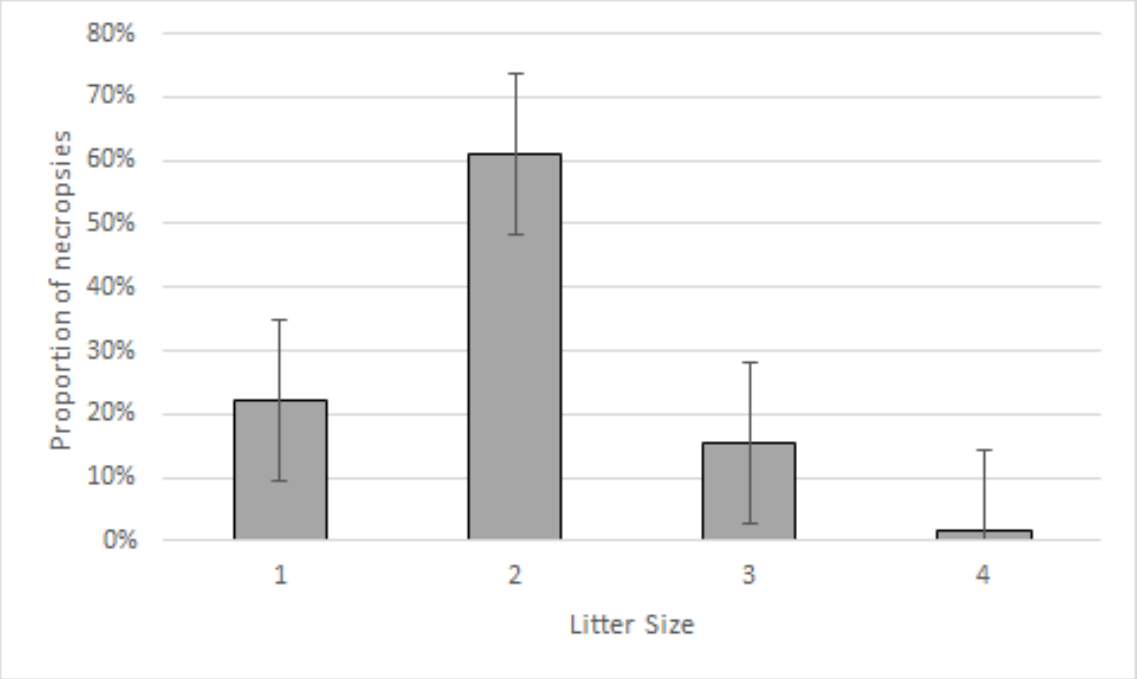

Figure 8 Proportion of post mortem examinations conducted on ewes with a litter size of one to four across both years. Error bars represent the 95% upper and lower CI for each proportion

For all ewe PM examinations with litter size recorded, primary dystocia was the most common cause of death in 2019, but in 2020 trauma was the most common.

The rank of other causes of death varied with litter size:

- Diagnoses increasing in rank with increasing litter size included
  - Dorsal vaginal wall rupture (DVWR) in both years
  - Hypocalcaemia in 2019 and
  - Primary dystocia in 2020.
- Diagnoses decreasing with increasing litter size in both years included
  - Septicaemia, and
  - Pneumonia

4.4.3 Condition score and cause of death

The body condition score (CS) of 269 (in 2019) and 295 (in 2020) PM examined ewes was recorded. Results are presented in five CS brackets ranging from less than 2.5 to greater than 3.75 (Table 8). Most ewes submitted for PM were CS 2.75 to 3.25 (52% in 2019 and 55% in 2020). However, 25% of 2019 and 11% of 2020 cases were less than 2.5 at the time of death. In contrast, 14% cases in 2019 and 27% in 2020 had CS 3.5 or greater.

Table 8 Proportion of post mortem examined ewes by condition score (CS) brackets.

	<2.5 (%)	2.5 (%)	2.75 – 3.25 (%)	3.5 (%)	>3.5 (%)	Total records
2019	24.9	9.3	52.4	6.7	6.7	269
2020	10.5	7.5	55.3	15.3	11.5	295

There were 40 cases of dorsal vaginal wall rupture in 2020. On average the CS of these ewes was 3.4. All dorsal vaginal wall rupture cases were in BCS 2.75 or greater and 55% were in CS 3.5 or more.

Across both years of the project, ewes submitted for PM from NSW were in higher BCS (3.43, SEM 0.03) compared to those submitted from VIC (2.95, SEM 0.02), SA (2.99, SEM 0.10) and WA (2.82, SEM 0.11; $P < 0.01$).

4.4.4 Age and cause of death

Over both years, 54% of the ewes submitted for PM were five years or older. By age bracket, most ewes submitted fell into the 5-6 year old group, followed by those in the 3-4 year old age group. The greater proportion of ewes submitted that fall in the older age cohorts likely reflects the increased risk of mortality within these cohorts.

Table 9 Proportion of mortality in each age cohort for ewes examined by PM

	Ewe lamb (1 year old)	2 year old	3-4 year old	5-6 year old	7 year old	Total records
2019	3.5	15.5	27.1	37.7	16.2	284
2020	2.3	12	31.6	39.5	14.6	301

4.4.5 Risk factor analysis – post mortem results

4.4.5.1 Dystocia

Single bearing ewes submitted for PM were 1.3 times more likely to be diagnosed with dystocia as a cause of death than twin bearing ewes across all age groups (P < 0.05), with 62.9% (95% CI: 52.0-72.9%) of single bearing ewes diagnosed with dystocia compared to 48.4% of twin bearing ewes (95% CI: 42.0-54.8%) (Appendix 8.8). Triplet-bearing ewes were no more likely to be diagnosed with dystocia compared to twin-bearing ewes (RR 1.11, P = 0.50).

Compared to a three-year-old ewe, there was no difference in the risk of a dystocia diagnosis in any other age group of ewe submitted for PM. Similarly, there was no difference in the proportions of dystocia diagnosed in 'older' versus 'younger' ewes at PM (P = 0.73).

Ewes with a BCS of 2.5 at necropsy had a significantly lower risk of a dystocia diagnosis compared to ewes submitted for PM with a BCS of 3 (RR 0.7, P < 0.05, Appendix 8.8). The raw data and mean values suggest a decrease in the risk of dystocia diagnosis in ewes in BCS 2 or less compared to those in BCS 3 at PM but the confidence intervals were wide, and it was not statistically different.

Neither higher (10-15 kg, >15 kg) or lower (<=5kg) total litter weight changed the likelihood of dystocia being diagnosed as a cause of death compared to a total litter weight of 5-10 kg for those ewes where litter weight was recorded at PM (Appendix 8.8).

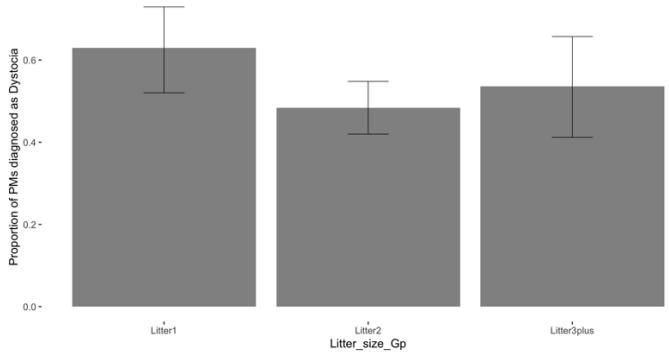

Figure 9 Dystocia diagnoses by litter size across all ewes submitted for PM with litter size recorded. Error bars represent the 95% upper and lower CI for each proportion.

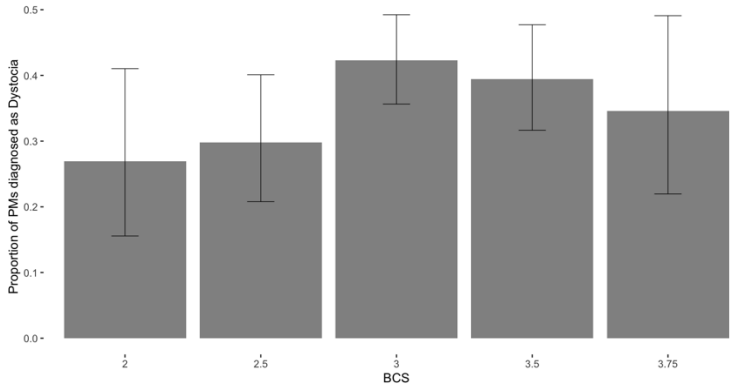

Figure 10 Dystocia diagnoses by body condition score (BCS) across all ewes submitted for PM. Error bars represent the 95% upper and lower CI for each proportion.

Ewes submitted for PM that were grazing crop at the time of death were 1.7 times more likely to be diagnosed with dystocia as a cause of death compared to those grazing improved pastures ($P < 0.05$). The likelihood of dystocia being diagnosed as a cause of death did not differ significantly between improved pasture and any other pasture type recorded (Figure 12, Appendix 8.8). Compared to ewes submitted for PM with a history of grazing pasture with 1500 kg DM/ha estimated feed-on-offer, there was no significant difference in the risk of dystocia being diagnosed in ewes that died on pasture with 'low' (≤1000 kg DM/ha) or 'high' (≥2500 kg DM/ha) feed-on-offer (Figure 13).

The risk of dystocia being diagnosed as a cause of death (COD) was significantly higher in ewes submitted from the Victorian (VIC) low rainfall zone, where 67% of cases had a dystocia diagnosis, compared to the VIC medium rainfall zone, where 38% of cases had a dystocia diagnosis (RR 1.78, $P < 0.05$). There were no other rainfall-by-state regions that differed in the risk of dystocia being diagnosed as a cause of death from the risk in the VIC medium rainfall zone (Figure 11).

There were no differences in proportions of dystocia diagnoses in ewes submitted from either the low or high rainfall zone compared to the medium rainfall zone or from NSW, SA or WA compared to VIC (Appendix 8.8).

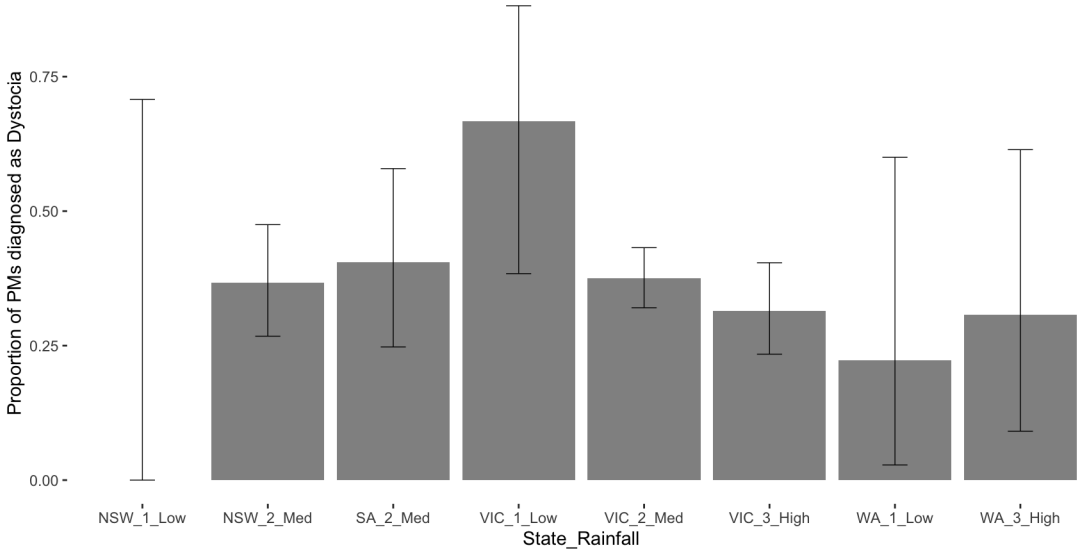

Figure 11 Dystocia diagnoses in ewes submitted for PM across three rainfall zones by state (low <575 mm, medium 575-700 mm, high >700 mm mean annual rainfall). Error bars represent the 95% upper and lower CI for each proportion.

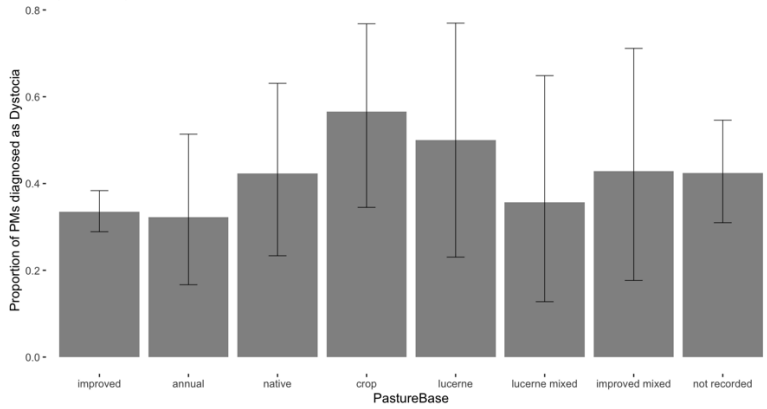

Figure 12 Dystocia diagnoses by pasture type across all ewes submitted for PM. Error bars represent the 95% upper and lower CI for each proportion.

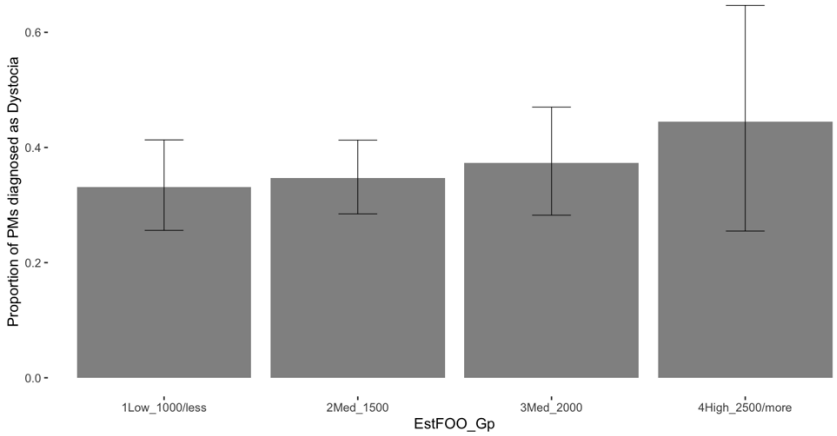

Figure 13 Dystocia diagnosis by estimated feed-on-offer across all ewes submitted for PM. Error bars represent the 95% upper and lower CI for each proportion.

4.4.5.2 Periparturient trauma and/or septicaemia

The risk of a periparturient trauma and/or septicaemia (PTS)diagnosis was decreased in ewes submitted for PM from the low rainfall zone, where 30% received a PTS diagnosis, compared to those from the medium rainfall zone, where 50% received a PTS diagnosis (RR 0.59, $P < 0.05$, Appendix 8.9). There was no difference in the risk of PTS diagnosis as a cause of death in ewes submitted from the high compared to medium rainfall zone (Appendix 8.9).

Ewes submitted for PM from Western Australia had a lower risk of PTS being diagnosed compared to ewes submitted from Victoria (RR 0.55, $P = 0.05$). No other states differed in risk from Victoria (Appendix 8.9).

Of the ewes submitted where litter size was recorded, litter size did not affect the risk of PTS being diagnosed as a cause of death (Appendix 8.9). Additionally, there was no difference in the risk of PTS being diagnosed as a cause of death in any age group compared to three-year-old ewes or in any BCS group compared to ewes in BCS 3 at PM (Appendix 8.9). Compared to ewes with a total litter weight of 5-10 kg, the risk of PTS being diagnosed as a cause of death was decreased in ewes with a total litter weight ≥15 kg (RR 0.48, P < 0.05). No other category of total litter weight differed in risk from the 5-10 kg category (Appendix 8.9).

In cases where pasture type was recorded, there was no difference in the risk of PTS being diagnosed on ewes that died grazing any pasture type compared to improved pasture (Appendix 8.9). Ewes grazing an estimated 2000 or ≥2500 kg DM/ha FOO had a decreased risk of being diagnosed with PTS at PM compared to ewes grazing 1500 kg DM/ha FOO (RR 0.77, P < 0.05; RR 0.57, P < 0.05; Appendix 8.9).

4.4.5.3 Hypocalcaemia

The risk of a diagnosis of hypocalcaemia at PM was 1.77 times greater in ewes from the VIC high rainfall zone, where 27% of cases were diagnosed with hypocalcaemia, than in those from the VIC medium rainfall zone, where only 16% were diagnosed with hypocalcaemia (P < 0.01). Importantly, this finding may be explained by age differences in the ewes submitted from these rainfall zones. Ewes submitted for PM from the VIC high rainfall zone were significantly older (mean age of PM ewe: 4.88) than the ewes submitted for PM from the VIC medium rainfall zone (mean age of PM ewe: 4.36, P < 0.01). As described below, there was an increased risk of hypocalcaemia diagnosis in ewes >5 years of age at PM.

The risk of a hypocalcaemia diagnosis at PM was decreased in ewes submitted from the NSW medium zone, where only 4% of cases were diagnosed with hypocalcaemia, compared to those from the VIC medium zone (RR 0.29, P < 0.01; Figure 14). No cases of hypocalcaemia were diagnosed in ewes submitted from WA or from the NSW low rainfall zone.

By rainfall zone alone, ewes submitted from the high rainfall zone were 1.88 times more likely to have a diagnosis of hypocalcaemia than those submitted from the medium zone (P < 0.01). There was no difference in the risk of hypocalcaemia being diagnosed as a cause of death in ewes from the low and medium rainfall zones (RR 0.56, P = 0.56).

Hypocalcaemia was diagnosed in a lower proportion of ewes submitted from NSW (0.04, 95% CI 0.01, 0.11) compared to Victoria (0.19, 95% CI 0.15, 0.23; Appendix 8.10). The risk of hypocalcaemia being diagnosed as a cause of death in ewes post mortemed from NSW was significantly lower than that in ewes from Victoria (RR 0.23, P < 0.00). Ewes submitted from NSW were in higher BCS at PM than those submitted from VIC (Section 4.4.3 above). The lower risk of diagnosing hypocalcaemia in ewes that were in higher CS at death (below) potentially explains this finding. No cases of hypocalcaemia were diagnosed in ewes submitted from Western Australia.

The risk of hypocalcaemia being diagnosed as a cause of death did not differ in single- or triplet-bearing ewes compared to twin-bearing ewes submitted for PM (Appendix 8.10).

Ewes that were over five years of age at the time of PM were 2.4 times more likely to be diagnosed with hypocalcaemia than three-year-old ewes submitted for PM (P < 0.01). The risk compared to

three-year-old ewes was no different in any other age group (Appendix 8.10). Overall, ewes in the younger age bracket at necropsy had a decreased risk of being diagnosed with hypocalcaemia as a cause of death than ewes in the older bracket (RR 0.39, P < 0.001, Figure 14).

Ewes that were in BCS 2 or less at death had 1.9 times the risk of a hypocalcaemia diagnosis compared to those that were in BCS 3.0 at necropsy (P < 0.05; Appendix 8.10). Additionally, when analysed by BCS category, the low BCS group had 2.0 times the risk of hypocalcaemia being diagnosed as a cause of death than ewes in the middle BCS group (P < 0.05). The risk of a hypocalcaemia diagnosis in necropsied ewes in the high BCS category did not differ from that of those in the middle BCS category (Appendix 8.10).

The raw data suggested an increased risk of hypocalcaemia as a cause of death if total foetal weight was ≤5 kg compared to ewes with a total litter weight of 5-10 kg, but this was not significant (RR 1.86, P = 0.05). Higher total litter weights did not change the risk of hypocalcaemia being the cause of death compared to ewes necropsied with a litter weight of 5-10 kg (Appendix 8.10).

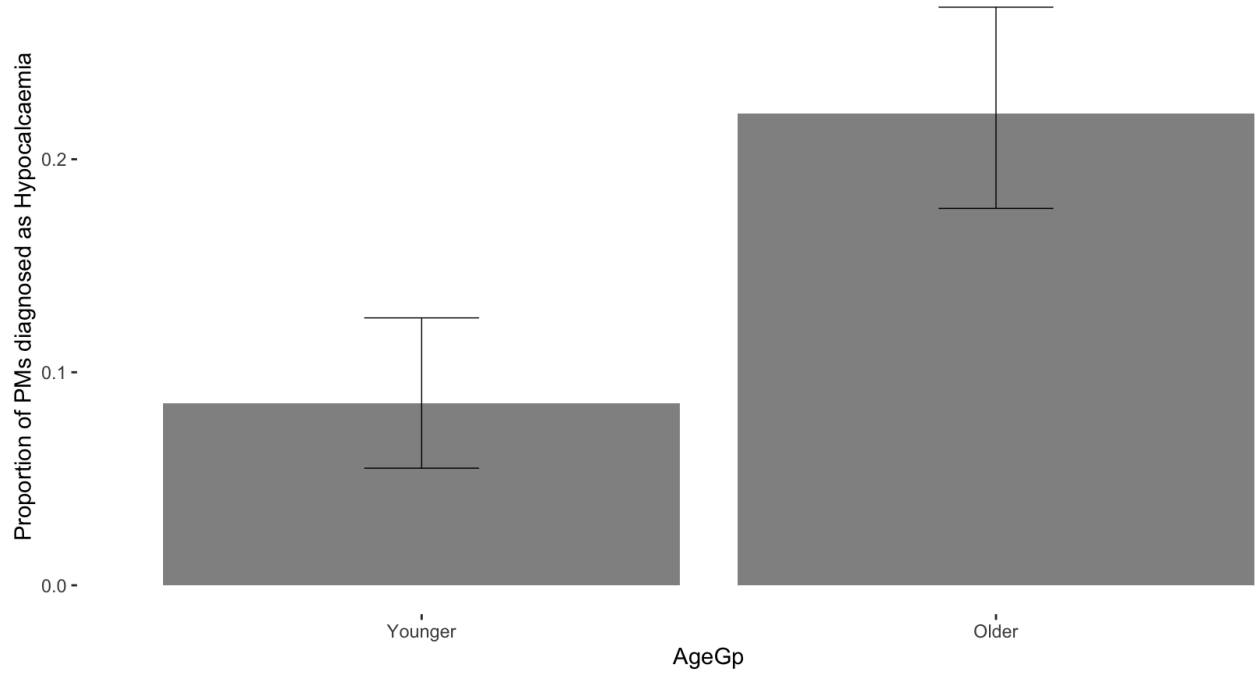

Figure 14 Proportion of post-mortems (PMs) diagnosed as hypocalcaemia in ewes submitted that were <5 years of age (younger) compared to those that were 5 years or older at post-mortem. Error bars represent the 95% upper and lower CI for each proportion.

There was no significant difference in the risk of a hypocalcaemia diagnosis in ewes grazing any other pasture sward compared to improved pasture at the time of death (Appendix 8.10). Similarly, there was no significant difference in the risk of a hypocalcaemia diagnosis in ewes necropsied from ≤1000 kg DM/ha or 2000 kg DM/ha estimated FOO pasture compared to ewes grazing 1500 kg DM/ha (Appendix 8.10). No cases of hypocalcaemia were submitted in ewes grazing high FOO (≥2500 kg DM/ha) pastures.

4.4.5.4 Uterine prolapse

The risk of a uterine prolapse diagnosis at PM was significantly increased in two-year old ewes compared to three year old ewes submitted for PM (RR 3.63, P < 0.05, Appendix 8.11).

The risk of a uterine prolapse diagnosis did not differ by rainfall zone or state in ewes submitted for PM (Appendix 8.11). No cases of uterine prolapse were diagnosed in the submissions from WA high, NSW low or VIC high rainfall zones. No ewes with uterine prolapse were submitted from the High rainfall zone. Litter size and total litter weight was poorly reported for cases of uterine prolapse, as this condition occurs post-partum and in many cases the ewes lambs were not presented with her at post-mortem.

4.4.5.5 Vaginal prolapse

The risk of a diagnosis of vaginal prolapse as cause of death was decreased in single-bearing ewes compared to twin-bearing ewes (RR 0.15, P < 0.05) but there was no difference in risk between triplet and twin-bearing ewes (RR 0.99, P = 1.00 Appendix 8.12) (Figure 15). The risk of a prolapse diagnosis did not differ between ewes of any age compared to three-year-old ewes Appendix 8.12). There was also no difference in the risk of a vaginal prolapse diagnosis in ewes of any other BCS compared to ewes submitted in BCS 3.0 at necropsy (Appendix 8.12). Interestingly, no cases of vaginal prolapse were diagnosed in the 52 ewes that were in BCS 2.0 or less at PM.

There were no cases of vaginal prolapse in the submissions from WA nor from the NSW low rainfall zone. The risk of a vaginal prolapse diagnosis did not differ in ewes submitted for PM from any rainfall-state region compared to the risk in the VIC medium rainfall zone Appendix 8.12. There was no difference in the risk of a prolapse diagnosis in ewes from a low or high rainfall zone compared to those submitted from the medium rainfall zone. The risk of vaginal prolapse diagnosis at PM did not differ in ewes submitted from any other state compared to the risk in Victorian submissions (Appendix 8.12).

The risk of a vaginal prolapse diagnosis did not differ in ewes carrying less or more total litter weight compared to ewes carrying 5-10 kg of litter weight at necropsy (Appendix 8.12). The wide confidence intervals, and relatively small number of submissions with this diagnosis in some categories decreases the ability to detect differences in this factor of interest.

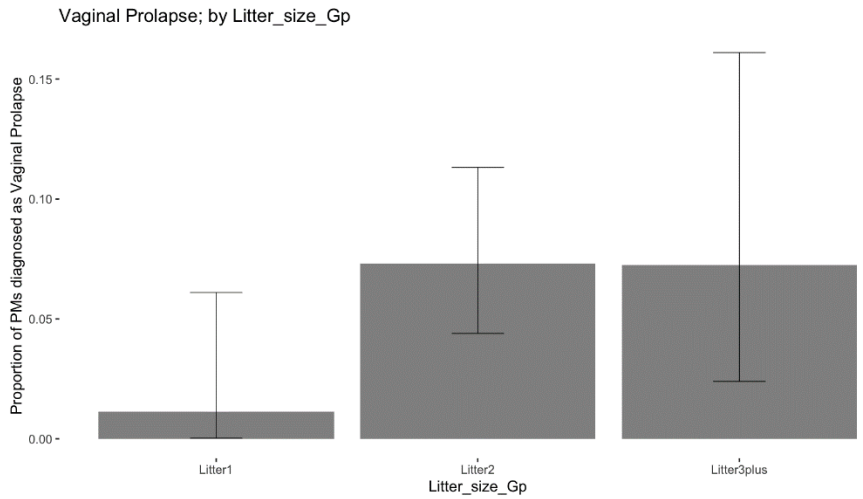

Figure 15 Vaginal prolapse in single bearing ewes (litter 1), twin-bearing ewes (litter 2) and triplet-bearing ewes (litter 3 plus) at necropsy. Error bars represent the 95% upper and lower CI for each proportion.

No cases of prolapse were diagnosed in ewes grazing lucerne or improved mixed swards prior to submission for PM. There was no difference in the risk of a vaginal prolapse diagnosis at PM in ewes submitted from any other pasture compared to improved pasture or in ewes grazing pasture with low, med-2000 or high compared to med-1500 estimated FOO prior to death (Appendix 8.12).

4.4.5.6 Dorsal Vaginal Wall Rupture (DVWR)

The risk of a DVWR diagnosis was decreased in ewes submitted from the high rainfall zone compared to the medium rainfall zone, (RR 0.34, $P < 0.05$; Appendix x). By state, the risk of a DVWR diagnosis was increased by a factor of 4.76 in ewes submitted from NSW compared to those submitted from Victoria ($P < 0.001$, Appendix 8.13). The significantly higher BCS of ewes submitted from NSW may explain this finding (section 4.4.3), due to the increased risk of DVWR diagnosis in ewes in higher BCS at necropsy.

The risk of DVWR being diagnosed as a cause of death was increased by a factor of 4.3 in ewes post mortemed from the NSW medium rainfall zone compared to ewes necropsied from the VIC medium rainfall zone ($P < 0.01$). The risk of a DVWR diagnosis did not differ in ewes submitted from any other zone compared to therisk in submissions from the VIC medium high rainfall zone (Figure 16). No cases of DVWR were diagnosed in submissions from the WA rainfall zones, VIC low rainfall zone or NSW low rainfall zone.

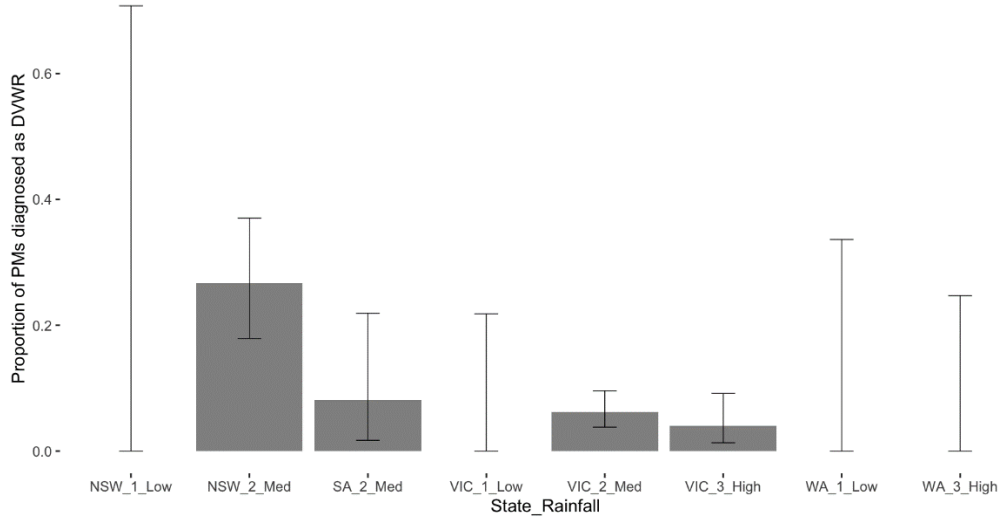

Figure 16 Proportion of cases diagnosed with dorsal vaginal wall rupture (DVWR) by rainfall zone and state. Error bars represent the 95% upper and lower CI for each proportion.

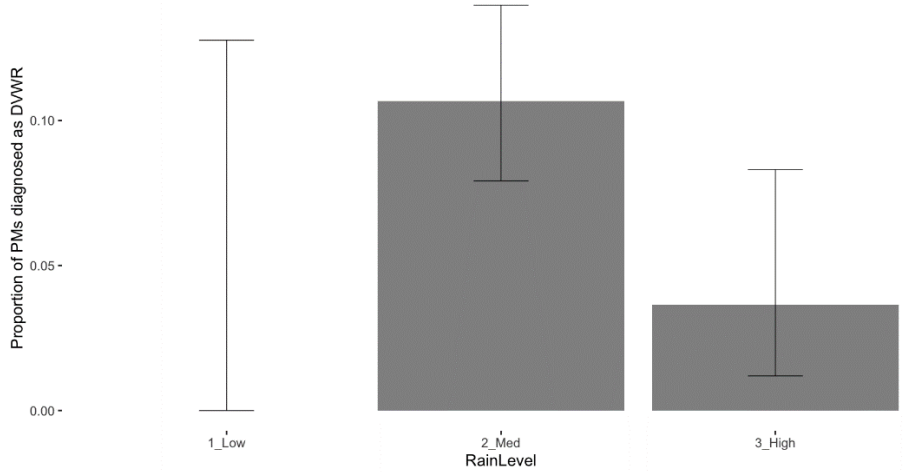

Figure 17 Proportion of ewes submitted for PM diagnosed with DVWR by rainfall zone. Error bars represent the 95% upper and lower CI for each proportion.

In ewes submitted for PM where litter size was recorded, single bearing ewes had a decreased risk of a DVWR diagnosis compared to twin-bearing ewes (RR 0.08, P < 0.001). Only one case of DVWR was diagnosed in the 89 single-bearing ewes submitted for necropsy. The risk of a DVWR diagnosis in triplet compared to twin bearing ewes was not significantly increased (RR 1.36, P = 0.34; Figure 18, and Appendix 8.13).

Compared to three-year-old ewes, the risk of a DVWR diagnosis in ewes of any other age was neither significantly increased nor decreased (Appendix 8.13). There was no change in the risk of a DVWR diagnosis in younger compared to older ewes. No cases of DVWR were diagnosed in 1-year-old ewes.

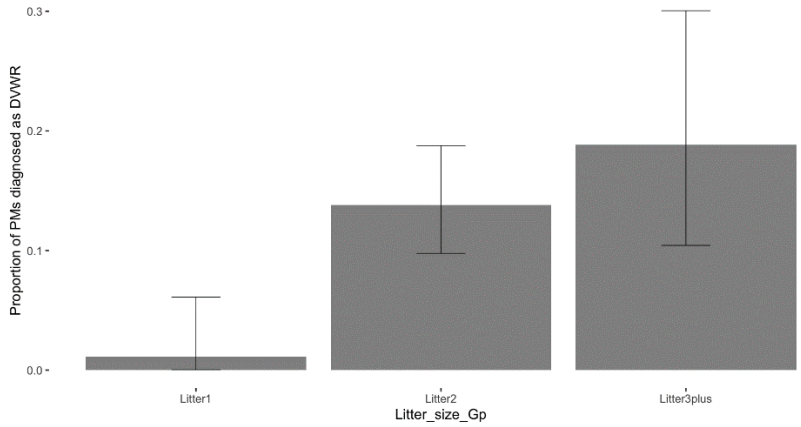

Figure 18 Proportion of PMs diagnosed with DVWR in ewes of different litter size. Error bars represent the 95% upper and lower CI for each proportion.

Ewes in BCS 3.5 and 3.75 or more were 2.5 times and 3.3 times more likely to be diagnosed with DVWR at necropsy compared to ewes in BCS 3 at necropsy ($P < 0.01$, Figure 19 and Appendix 8.13). There were no cases of DVWR in ewes in BCS ≤2.5 at necropsy. When analysed by BCS group, the high BCS group had a 2.5 times increased risk of DVWR diagnosis at necropsy compared to the mid-BCS group ($P < 0.05$, Figure 19 and Appendix 8.13).

The risk of DVWR being diagnosed as a cause of death in ewes with a total litter weight exceeding 10 kg was increased compared to ewes with a total litter weight of 5-10 kg (10-15 kg: RR 2.5, $P < 0.01$; >15 kg: RR 3.0, $P < 0.05$; Figure 20 and Appendix 8.13). There were no cases of DVWR in the 47 ewes with a total litter weight of ≤5 kg at necropsy.

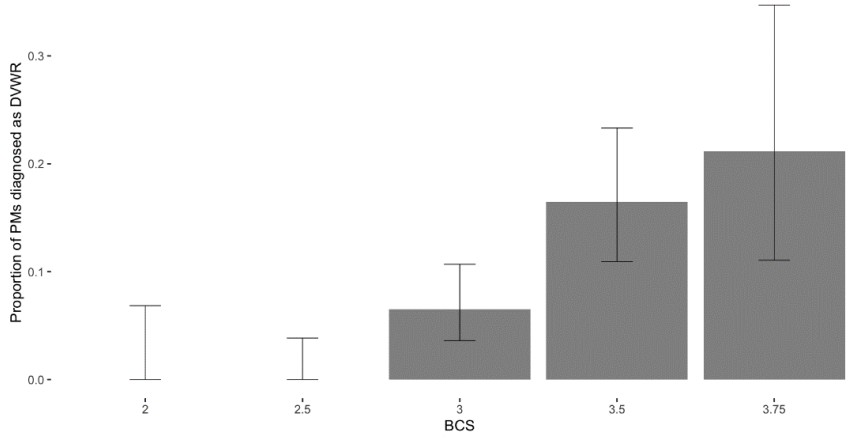

Figure 19 Dorsal vaginal wall rupture diagnoses in ewes according to body condition score (BCS) at PM. Error bars represent the 95% upper and lower CI for each proportion.

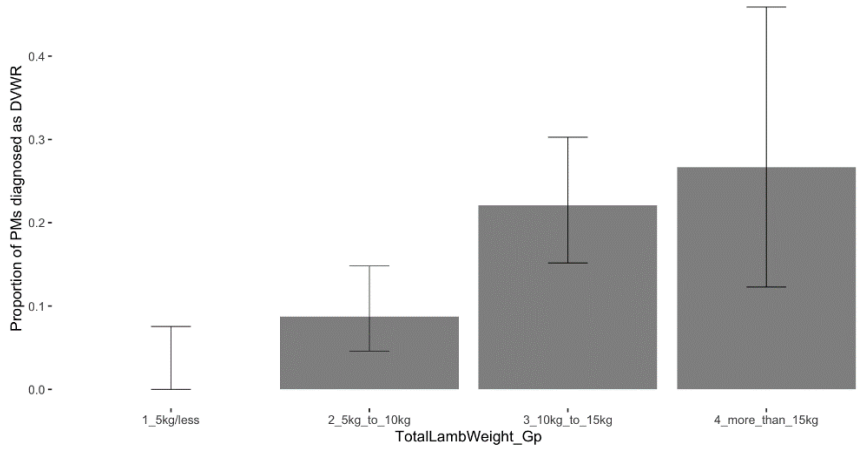

Figure 20 Proportion of ewes submitted for PM with DVWR diagnosis by total litter weight at PM. Error bars represent the 95% upper and lower CI for each proportion.

The DVWR diagnosis was no more or less likely to be diagnosed on ewes grazing any other pasture base compared to improved pasture prior to PM (Appendix 8.13). However, the small number of submissions from some pasture types limits this analysis.

Ewes grazing 'low' estimated FOO pasture with ≤1000 kg DM/ha had a decreased risk of being diagnosed with DVWR at PM compared to ewes submitted from 'medium' 1500 kg DM/ha FOO (RR 0.29, $P < 0.05$; Appendix 8.13). There were no other differences in risk associated with FOO level compared to medium level FOO.

5. Conclusion

Periparturient non-Merino ewe mortality on well-managed commercial properties ranged from 1.3% to 5.9% across farms over two consecutive years.

Appropriate benchmarks to determine potential for improvement in non-Merino ewe mortality over lambing for Australian farms based on this study are:

< 1%	Industry best target
1 to 2%	Good performance
2.1 to 4%	Opportunity for improvement
>4%	Action to identify and address issues is a priority

Dystocia and conditions related to dystocia (including septicaemia and trauma) were the biggest contributors to periparturient ewe mortality. Conditions such as hypocalcaemia and septicaemia frequently occurred concurrently with other conditions, reinforcing the complex process of disease that occurs in pregnant and lambing ewes.

Key risk factors for ewe mortality identified in this study included condition score, litter size, ewe age and nutritional management (including managing feed availability in variable seasons).

Findings from this study support current industry best practice management guidelines for pregnant and lambing ewes, specifically the importance of:

- Pregnancy scanning and differential management of twin, single and where possible triplet bearing ewes to relevant condition score targets (*i.e* Lifetime Maternal guidelines for maternal ewes).
- Managing variation in ewe condition scores to minimise the proportion of ewes above and below condition score thresholds, where there is increased mortality risk for ewes and lambs.

Strategies that should be added to current industry best practice management guidelines include:

- Recording ewe mortality during lambing to identify trends and opportunity to improve
- If concerned, seek veterinary assistance. Veterinary post mortem examination can assist in diagnosing metabolic disease and understanding dystocia.
- Separate older ewes (>5 years) and maiden ewes (especially ewe lambs) from other age groups for management during late pregnancy and lambing. This facilitates cost-effective management of the ewe mortality risk factors that are specific to each of these age groups
- Ram selection should include consideration of birthweight and lambing ease with the goal of avoiding outliers in the ram team.
- Mineral supplementation should be considered in consultation with an advisor during late pregnancy and lambing, particularly for older ewes, and/or when risk factors for hypocalcaemia are present (e.g. prolonged grain supplementation, grazing cereal crops, transitioning between low and high calcium forages).
- Time off-feed in late pregnancy should be minimised for groups at higher risk of hypocalcaemia.

For all lambing mobs, particularly those at increased risk of dystocia, recommendations for intervention include:

- Ensure ewes are familiar with personnel and vehicles at least 4 weeks before lambing starts. Disturbance of ewes during monitoring may interrupt labour and increase incidence of dystocia if not managed carefully.
- Use a different vehicle to check lambing ewes than is used to feed livestock.
- Check ewes regularly during lambing (at least once daily): especially high-risk groups (e.g. older ewes, maiden ewes). Don't allow a struggling ewe to labour for too long — stage two labour (when the ewe starts to strain) should take 40 – 60 minutes.
- Use gloves, lubricant and minimal force when helping ewes to lamb.
- Where possible, correct position before delivering malpresented lambs to reduce injury to ewe and lamb.
- Develop a treatment protocol with your veterinarian prior to the start of lambing. This could include antibiotics, non-steroidal anti-inflammatories, such as meloxicam, and 4-in-1 treatment for metabolic diseases if labour is extended, or lambs are dead or rotten.

5.1 Key findings

Average non-Merino ewe mortality was 2.5% (2019) and 2.0 % (2020) on project host farms that represented a group of producers following industry best practice. There was considerable variation between mobs on farms, as well as between farms indicating there is room for improvement even within a cohort of producers that had largely adopted 'best practice'.

Dystocia was the most common single cause of death identified by both farmers and veterinarians performing PM exams. Other important conditions including septicaemia, trauma and hypocalcemia have important interactions with dystocia, as shown in Figure 21.

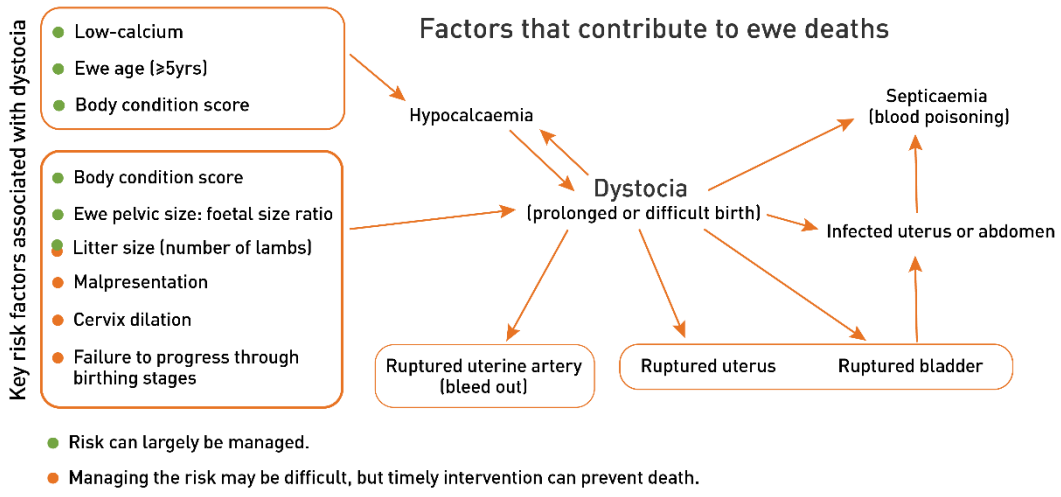

Figure 21 Flow diagram of contributing factors and proposed sequelae to dystocia

Dystocia is likely to be under-reported without necropsy. Just under half of the cases of dystocia identified using post-mortem examinations had no obvious external signs. Dystocia was a higher risk in ewe lambs and single-bearing ewes, as reported by host producers.

Hypocalcemia was most commonly identified concurrently with other conditions, making it challenging to differentiate if ewes die from or with hypocalcemia. Of the ewes that underwent PM exam, risk factors for hypocalcemia included older age (>5 years) and poorer body condition score (BCS 2 or less).

Other important causes of death included dorsal vaginal wall rupture, uterine prolapse and vaginal prolapse. Risk factors identified for a DVWR diagnosis in ewes that underwent post mortem exam included multiple bearing, ewe BCS ≥ 3.5 and high total litter weight (>10kg).

5.2 Benefits to industry

This project has provided:

- Industry data on non-Merino ewe mortality incidence to inform industry benchmarks.
- Insights into the important causes of ewe mortality during the periparturient period.
- Improved understanding of risk factors for periparturient ewe mortality to inform industry best-practice management recommendations for pregnant and lambing ewes.
- Improved understanding of how veterinarians can aid livestock producers with their sheep management through their diagnostic expertise.

Findings from this study have informed ewe management guidelines for improved ewe survival. This includes:

- Validation of existing best practice guidelines that were developed with a focus on lamb survival and promoted through programs such as Lifetime Ewe Management
- New or focussed recommendations to address risk factors for ewe mortality identified in this study (section 5.1).

The participatory research approach adopted during this study provided important insights into producer understanding of ewe health. Host producers gained valuable insight into conditions impacting ewes over lambing on their farm, and the project team identified opportunities for extension focussed on improving outcomes associated with common conditions for lambing ewes.

Resources developed during the project have been adapted and made available to industry. The data recording template (farm diary) will assist producers to capture data on ewe mortality specific to their enterprise and inform management decisions. The post-mortem protocol developed during this project provides a consistent and defined methodology that can be used for research or in-farm investigations. The project resulted in increased disease surveillance for state veterinary department and national surveillance (TSE).

Information from the project has been disseminated to industry through:

- a project designed infographic
- presentations at industry events including Livestock Advisor Updates (face to face Perth, online for southern event), MLA productivity and profitability webinar, April 2021, National conference for the Australian Sheep, Goat and Camelid Veterinarians, Wagga Wagga, June 2021.
- Livestock Logic Information night, Hamilton, July 2021
- Tasmanian health ewes field day March 2021Newsletter articles including Mackinnon Project Newsletter
- Three producer case studies developed that demonstrate positive impact.
- Results from this project will be included in at least one scientific journal article plus a DVStud thesis.

Further extension activities will target networks such as Lifetime Ewe Management (RIST), Sheep Connect, Best Wool Best Lamb to ensure that the resources and learnings are incorporated into existing programs and learning resources and shared as widely as possible.

The project has supported development of human skills, including:

- The project provided a stepping stone for one of the project team vets to embark on post-graduate study (DVStud).
- One of the key personnel was supported early in their career by a MLA veterinary residency and continued to develop their own experience and utilised their skills to support the project team, including developing skills of less experienced colleagues.
- Veterinary students and graduate veterinarians gained practical skills in disease investigation and greater understanding of commercial sheep management practices and challenges.
- Host producer skills were increased through direct contact with project team on their farm and a webinar summarising project results and implications for management.
- Collaborative relationships between commercial vets and advisors and University research teams.

6. Future research and recommendations

- Findings from this project should be formally incorporated into existing sheep reproduction extension packages (e.g. lifetime ewe management, lifting lamb survival) to enable improved ewe survival concurrent to practices designed to address lamb survival. Extension resources to increase the understanding by sheep producers of conditions causing periparturient ewe mortality could include:
    - Diagnosis of vaginal and uterine prolapse and DVWR, which can be confused but have different risk factors and management.
    - Dystocia and interactions with other diseases.
    - Recognition, diagnosis and management of metabolic diseases.
- The risk of mortality was increased for ewes >5 years old. Current recommendations for ewe management are based on data derived for mixed age ewes. Refinement of recommendations specific to older ewes to maintain productivity and welfare over lambing for this age group is warranted if retention of older ewes is used as a strategy to re-build flock numbers
- Further investigation of the importance of hypocalcaemia on periparturient ewe mortality and updating of current recommendations on mineral supplementation are warranted. This study identified high proportional mortality risk for hypocalcaemia in older ewes. It can be difficult to determine at PM whether a ewe has died from or with hypocalcaemia.
- This project has highlighted gaps in understanding of causes of ewe mortality. Improved knowledge could inform management recommendations to improve animal welfare and ewe productivity. These include:
    - Condition score targets for different ewe flocks (e.g. Merino, non-Merino, cross bred)
    - Investigate the role of management in reducing dystocia in Australian flocks (e.g. genetics, nutritional management, monitoring and intervention).
    - Improved understanding of management options that reduce metritis, trauma and septicaemia.
    - Effective strategies for managing triplet bearing ewes to improve ewe survival.
- Determine the differences (if any) in ewe mortality and causes of death for Merino ewes during the periparturient period to inform targeted management strategies specific to ewe breed.

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8. Appendix

8.1 Farm diary template

Unlocking the

Key to Ewe Survival

Farm Diary 2020

FARM NAME: _____

RECORD START DATE: _____

RECORD END DATE: _____

From four weeks before lambing until lamb marking, please fill out this farm diary every time you check your paddocks as per the following instructions:

1. Fill out the front cover including your farm name and the dates you start and finish recording ewe deaths.
2. Each entry page represents a paddock. Allocate a page to each paddock with lambing ewes and record the paddock name.
3. Tick the appropriate box to identify the pregnancy status (scanning result) of the ewes in the paddock.
4. Provide information on the age of the ewes in the paddock. If the ewes in the paddock are all one age write their NLIS tag colour and if they are different ages tick the appropriate box.
5. Record the ewe breed as well as the breed of the rams used over the ewes.
6. Record the number of ewes counted into the paddock.
7. Record the quantity of green feed on offer using the MLA pasture ruler provided when the ewes are first placed in a paddock.
8. For each dead ewe found in the paddock fill out:
   - The date the paddock inspection is completed
   - Whether you believe the ewe is pregnant (Y) or not (N)
9. Provide a description of each dead ewe found using the following coding system:

Possible contributor to death (death code):
A= lamb stuck
B= vaginal prolapse
C= uterine prolapse
D=cast (ewes found dead lying on their backs)
E=metabolic disease (includes low calcium, pregnancy toxaemia, grass tetany, mixed)
F= mastitis
G=predation
H=other (explain in comment section of table)
I=no obvious cause of death

   This coding system is shown at the bottom of each recording page for reference. Only record ONE cause of death for each ewe. When two or more causes of death are suspected, please make a note of this in the comments section.

10. If your inspection rounds coincide with an intended farm visit from the veterinary team (scheduled within 36 hours of ewe death), write Y in the "for post-mortem" column and spray a number on the ewe's body, starting with one from the first carcass identified for post-mortem and continuing for all ewes intended for post-mortem (not all ewes found dead, just those for post-mortem). Continue this numbering system throughout the lambing period (i.e. do not restart numbering each time the paddocks are checked).
11. Ewes intended for post-mortem ideally should be moved out of their paddocks to a central, preferably shaded location in order to minimise disturbances to the rest of the mob and to streamline post-mortems. If this is not possible, the research team can post-mortem the ewes in their paddocks.
12. Record any other relevant information in the "comments" column.
13. If more than 20 ewes die in a paddock, start a new page for the same paddock and write the paddock name/ID at the top of the page.
14. If two or more ewes die in a 24 hour period and a veterinary visit has not been scheduled; please contact your site co-ordinator to try and have a visit scheduled ASAP.
15. At marking record the quantity of green feed on offer using the MLA pasture ruler provided, the number of ewes counted at marking and the number of lambs in each paddock.
16. Accurate recording of information at the time of checking is critical to ensure that the project team can use the data for analysis. If you're not sure of something please contact your site coordinator to discuss.
17. Once lamb marking is finished, please return this completed farm diary to your site co-ordinator within 7 days.
18. Please see the example on the next page as a guide on how to fill out this diary.

Paddock Name/ID: Homestead

Scanned as: ☐ Singles ☒ Twins ☐ Triplets ☐ Multiples

Age of ewes: Tag colour (if all one age) Orange If not one age: ☐ Maidens ☐ Mixed ☐ >5

Ewe breed: Composite Sire of lambs breed: White Suffolk

Complete when ewes placed in paddock:	
Pasture dry matter when ewes put in paddock (kg green/DM/ha)	900
Number of ewes counted into paddock	120

Complete at marking:	
Pasture dry matter at marking (kg green/DM/ha)	1200
Number of ewes at marking	110
Number of lambs at marking	190

Date	Ewe pregnant (Y/N)?	Death Code	For Post Mortem (Y/N)?	If Y, ID of dead	Comments
29/5/20	Y	A	Y	1	
29/5/20	Y	E	Y	2	
1/6/20	Y	C	Y	3	
1/6/20	Y	D	Y	4	
1/6/20	Y	G	Y	5	caught in fence
3/6/20	Y	A	N		
5/6/20	Y	A*	Y	6	*also had mastitis (F)
5/6/20	N	F	Y	7	

Ewe Death Code Key		
A=lamb stuck	D=cast	G=predation
B=vaginal prolapse	E=metabolic disease	H=other (explain in comments section)
C=uterine prolapse	F=mastitis	I=no obvious cause of death

8.2 PM protocol

Note: this PM protocol has been made available as a stand-alone resource on the MLA website

General information

- Date
- Property name
- Manager name
- Manager contact details
- Paddock name/mob ID
- Ewe ID VID if present on tag
- Ewe ID NLIS tag colour
- If 'other' selected above, record other NLIS tag colour here
- Ewe litter size
    - 1
    - 2
    - 2+ (if triplets not differentiated through scanning)
    - 3
    - Unknown
- Attending vet name

External examination

- Condition of carcass
    - Fresh
    - Moderate autolysis
    - Advanced autolysis
- Estimated date and time of death (if known)

External pathology exam- general

- Photograph external carcass with visible ewe ID for reference
- Ewe body condition score (1 to 5, 0.25 intervals)
- Describe any external predation (location on carcass, predator species, before or after death)
- Describe any signs of struggle or prolonged recumbancy (e.g paddle marks on ground where found, unilateral periorbital swelling on down side)
- Discoloured mucosa
    - Yes, describe (e.g.jaundice, pallor, injected, etc)
    - No
- Dentition
    - No adult teeth
    - 2 tooth
    - 4 tooth
    - 6 tooth
    - Full mouth
    - Broken mouth
- Lesion on skin/subcutis
    - Yes
    - No
    - Evidence of advanced decomposition
- If 'yes', describe the skin lesions (e.g. petechial haemorrhage, echymotic haemorrhage, trauma)
- Joints
    - Normal

- Abnormal (describe joint abnormality, including joints affected)
- Unable to assess

- Feet
  - Normal
  - Abnormal
- If 'abnormal', what is the most likely foot abnormality (check all applicable)
  - Toe abscess
  - Heel abscess
  - Foot rot
  - Other, describe
- Any other general external observations including pelvic or spinal trauma
  - Yes, describe (e.g. spinal trauma or pelvic trauma. If either of these are present, describe location and extent of issue)
  - No
- Any other comments

Environment- brief

- Ewe moved from position found
  - Yes
  - No
- Brief description of where ewe was found (e.g. middle of paddock, under tree, stuck in fence, in a ditch)
- Pasture type in paddock where found (e.g. phalaris + clover, perennial rye grass (PRG), native, fodder crop-detail)
- Describe any important paddock observations (e.g. potentially toxic plant species, weeds, blue green algae etc).
- Estimate of feed on offer (kg DM/ha) in paddock where ewe was found
- Is supplementary feed on offer
  - Yes
  - No
- If 'yes' to above question, describe supplementary feed ration (kg/hd/week and feed type e.g. 3.5kg/ewe/wk barley)

External pathology exam-repro

- Signs of mastitis
  - Yes, describe
  - No
- Obvious dystocia (e.g. part of lamb protruding)
  - Yes, describe (e.g. head swollen, tail, 2x feet)
  - No
- Perineal trauma, including vulva and vestibule
  - Yes, describe extent and location of trauma
  - No
-
- Discharge from vulva *(NB lochia (dark odourless, persists up to 3 weeks post-partum))*
  - Yes, describe nature of discharge (e.g.bloody, mucopurulent, odourless or , malodorous, serous etc)
  - No
- Prolapse *(NB rectal or vaginal prolapse may occur post-mortem with normal gas distension of abdominal viscera)*

- Yes, describe (e.g. vaginal, uterine, rectal, etc)
- No

- Other external reproductive observations

Rule out anthrax

- Is carcass in rigor mortis? *(NB absence of rigor can be a sign of severe septicaemia (e.g. anthrax or clostridia). However, it can be variable in onset, duration and severity and can be missed. Thus absence of rigor may not be significant)*
  - Yes
  - No
- Bloody discharge from any orifice *(NB bloody nasal discharge may be due to nasal congestion at death and rupture of vessels as a normal part of autolysis)*
  - Yes
  - No
- History of anthrax on property
  - Yes
  - No
  - Unsure
- Suspicion of anthrax (i.e. sudden death with no other explanation +- no rigor, bloody discharge, history of anthrax on property)
  - Yes
  - No
- If 'yes' to above question PERFORM ICT TEST KIT AND RECORD RESULTS BEFORE GOING FURTHER
  - 1. Notify district veterinary officer (DVO) of suspect case
  - 2. Perform ICT (blood in EDTA tube needed)
  - 3. Photograph negative test result and send to DVO
  - 4. Report summary findings to local DVO using RODE form
- **IF POSITIVE ICT TEST KIT= STOP PM AND CONTACT DVO, OR RING EAD HOTLINE 1800 675 888**
- IF NEGATIVE CAN PROCEED WITH PM
- If ICT test kit performed take photo of result here

There may be subsidies to analyse samples where there is suspected significant disease, the conditions associated with these will vary on a state by state basis- contact your District Veterinary Officer (DVO) for more information if you think this may be relevant

TSE exclusion (Australia-wide)

Criteria: 18 month to 5 years old with at least 2 signs consistent with scrapie (e.g neural signs such as altered mental state, sensation and postural movements before death)

- Yes- collect brain in formalin + fresh/frozen 2-3cm of spinal cord and dorsal 1/3rd of cerebellum.
- No

Proceed- anthrax test negative or no suspicion of anthrax

Open carcass to display stage

- Take photograph

Carcass at display stage

- Discoloured connective tissue/fascia
  - Yes, describe (e. jaundice, pallor, etc)
  - No

Thoracic cavity

- Photograph thoracic cavity
- Pleural fluid

- Abnormal, describe fluid including quantity estimate, consistency and colour (e.g. 100ml thin, clear fluid)
- Normal

- Pericardial fluid
  - Abnormal, describe fluid quantity, consistency and colour, +/- presence of fibrin
  - Normal
- Pericardial fat deposits
  - None
  - Minimal
  - Moderate (standard amount on a healthy ewe)
- Lung texture
  - Normal- sponge like
  - Abnormal – rubbery (oedema or some viral pneumonias)
  - Abnormal- liver like (consolidation)
  - Other, describe any other lung texture change
  - Unable to assess
- Lung colour *(NB red/congestion doesn't necessarily mean pneumonia. If unilateral on dependent side likely liver mortis or if bilateral congestion this can occur when blood forced into lungs during rigor or due to post-mortem bloating. A normal lung is still be spongy compared to a pneumonic lung)*
  - Normal-some livor mortis of down side or congestion in absence of textural changes is normal post mortem
  - Abnormal, describe colour and distribution
- Lung pleural surface *(NB pleural fibrosis- areas of pale connective tissue may appear on dorsal surface of normal lung. Pulmonary emphysema may be present due to agonal gasps and are generally of no significance unless there is a history of respiratory distress)*.
  - Abnormal, describe (e.g. fibrinosuppurative pleurisy, fibrin, other lung surface observations including colour, size and distribution of any lesions (e.g. 3 x 50c coin sized abscesses cranioventral lobes, lung worm nodules dorsal, etc etc)
  - Normal
- Pulmonary consolidation- indicative of pneumonia
  - Yes- lung sinks in water, describe distribution of consolidation (e.g cranioventral lung fields)
  - No
  - Unable to assess
- Heart- epicardial abnormality *(NB epicardial and endocardial petechiae and ecchymosis are common and a normal finding especially in euthanased ruminants. If concerned about septicaemia or a clotting disorder there will also be haemorrhage elsewhere in the body)*
  - Yes, describe lesions on epicardium
  - No
  - Unable to accurately assess due to autolysis
- Heart- endocardial abnormalities (NB small foci of fat are normal)
  - Yes, describe endocardial abnormality
  - No
  - Unable to accurately assess due to autolysis
- Any other remarkable observations in thoracic cavity including tracheal contents, tracheal trauma, cut lung surface lesions, heart valve lesions and abnormalities of the bronchial tree (including foam, blood, worms, digesta, pus)
  - Yes, describe

- ☐ No

Peritoneal cavity

- ☐ Photograph peritoneal cavity
- ☐ Organ displacement
  - ☐ Yes, describe
  - ☐ No
- ☐ Peritoneal fluid *(NB action of stomach acid after death may result in abomasal wall breakdown and subsequent rupture. Antemortem rupture of abomasal ulcer will be associated with acute peritonitis signs, e.g. fibrin, pus, fluid and septic smell)*
  - ☐ Abnormal, describe (peritoneal fluid quantity, colour and consistency)
  - ☐ Normal
  - ☐ Unable to assess due to autolysis
- ☐ Omentum *(NB grey to black disclolouration or pseudomelanosis of anything in contact with intestine can occur normally with advanced autolysis when bacterial breakdown of Hb releases hydrogen sulphide. Common on liver, spleen, kidney and intestine)*.
  - ☐ Abnormal, describe
  - ☐ Normal
- ☐ Other peritoneal cavity observations including vena cava abscessation or thrombi.

Gastro-intestinal (GI) & hepatic system

- ☐ Take photograph
- ☐ Liver surface

Notes:

1. *Liver congestion may be normal post-mortem (due to rigor forcing blood central into viscera-lungs should be similar).*
2. *Large fibrous plaques extending no deeper than the capsule may be results of resolved adhesions from past local peritonitis.*
3. *Telangiectasis or 'plum pudding' liver are dark red, irregular but circumscribed area (pin point to 1-3 centimeter diameter) throughout liver. Dilated, blood filled hepatic sinusoids with no functional significance*
   - ☐ Generalised abnormality, describe size, consistency, colour and margins of liver (e.g. pale fatty and friable, rounded edges)
   - ☐ Localised abnormality, describe lesion and location (includes abscesses, fibrin, scarring including fluke exhaust)
   - ☐ Normal
   - ☐ Unable to accurately assess due to autolysis

- ☐ Cut surface of liver
  - ☐ Abnormal, describe
  - ☐ Normal
  - ☐ Unable to accurately assess due to autolysis
- ☐ Distended or thickened gall bladder *(NB gall bladder distension may occur following anorexia. Bile becomes more watery with time off feed)*
  - ☐ Yes, describe
  - ☐ No
- ☐ Spleen *(NB: splenic enlargement may occur with barbiturate euthanasia and can occur with anthrax (along with other changes). Enlarged spleen are soft and bleed freely when cut).*
  - ☐ Abnormal, describe
  - ☐ Normal

- Other observations of hepatic system.

Gastrointestinal

- Rumen-serosal surface
  - Abnormal, describe (e.g. haemorrhages, fibrin, adhesions, etc)
  - Normal
- Rumen-mucosal surface *(NB check ventral mucosa -more likely location for lesions. Rumen mucosa sloughs normally within an hour of death. Exposed submucosa may be pale if animal exsanguinated, otherwise intensely red. Not evidence of rumenitis unless also oedema, exudate or haemorrhage (mucosa less likely to slough).*
  - Abnormal, describe (e.g. inflammation, fibrin, scarring, short papillae, sloughing mucosa)
  - Normal
  - Unable to accurately assess due to autolysis

- Rumen contents: briefly describe fill and nature of contents. Include pH if carcass fresh enough.

NB rapid distension of rumen resulting in tympany is common post-mortem. Only diagnostic of frothy bloat if rumen is full of frothy foam.

- Reticulum- serosal
  - Abnormal, describe (e.g. haemorrhages, fibrin, adhesions, etc)
  - Normal
- Reticulum- mucosal
  - Abnormal, describe (e.g. haemorrhages, fibrin, inflammation, fibrin, scarring, sloughing mucosa (this can be a normal after death change, etc)
  - Normal
  - Unable to accurately assess due to autolysis

- Omasum- serosal surface
  - Abnormal, describe (e.g haemorrhages, fibrin, adhesions, etc)
  - Normal
- Omasum- mucosal surface
  - Abnormal, describe (e.g. haemorrhages, fibrin, inflammation, scarring, sloughing mucosa (this can be a normal after death change, etc)
  - Normal
  - Unable to accurately assess due to autolysis
- Abomasum- serosal surface

NB: action of stomach acid PM may result in abomasal wall breakdown and subsequent rupture. Antemortem rupture of abomasal ulcer will be associated with acute peritonitis signs (e.g. fibrin, pus, fluid and septic smell).

  - Abnormal, describe (e.g haemorrhages, fibrin, adhesions, etc)
  - Normal
- Abomasal- mucosal surface

NB: mucosal reddening seen in sheep that have recently eaten. Gastritis always accompanied by oedema, ulceration, fibrin or haemorrhage.

  - Abnormal, describe (e.g. haemorrhages, fibrin, inflammation, scarring, sloughing mucosa (this can be a normal after death change, evidence of parasitism (inhibited larvae), etc)
  - Normal
  - Unable to accurately assess due to autolysis
- Abomasal contents- select
  - Digesta
  - Visible GI nematodes

- Haemorrhage
- Relatively empty
- Other, describe

- Small intestine-serosal surface

NB:

1. *Post-mortem bile leakage into duodenum can cause duodenum and proximal jejunum to dilate, become thin wall and dark green. Bile also stains surfaces of organs in close contact (bile imbibition).*
2. *Large oval or linear, white raised plaques on ileum and jejunum are normal- Peyer's patches. They may extend around circumference of intestine.*
3. *Small intestine intussusception may occur post-mortem. May see congestion, but no oedema, haemorrhage or fibrin (present if it occurred antemortem).*
    - Normal
    - Abnormal

- If 'abnormal', select abnormal SI serosal surface observations and select location:
    - Haemorrhages
    - Fibrin
    - Adhesions
    - Other
    - Duodenum
    - Jejunum
    - Ileum
    - Small intestine- mucosal surface examined at several points
- Small intestine-mucosal surface

NB segmental intestinal congestion and diapedesis should not be confused with haemorrhagic enteritis. Variable settling of blood as peristalsis subsides results in areas of blue-black congestion giving a segmental appearance. Congested segments may fill with bloody fluid as vessels break down (diapedesis). Haemorrhage enteritis will have discolouration plus oedema, ulceration, fibrin (and necrosis) and oedematous mesenteric lymph nodes.

- Normal
- Abnormal, describe lesion and location. Location abbreviation; Jejunum 'J', duodenum 'D' and ileum 'I'.
- Unable to accurately assess due to autolysis

- Ileocaecal thickening
    - Yes
    - No
    - Unable to accurately assess due to autolysis
- Large intestine- serosal surface
    - Normal
    - Abnormal, describe lesion and location
- Large intestine- mucosal surface examined if suspicious of abnormality.

NB linear reddening or tiger striping on colonic and rectal mucosa due to clotting of trapped blood in contracted organ. Not diagnostically significant.

- Normal
- Abnormal
- Unable to accurately assess due to autolysis

- Faecal sample taken
- Faecal consistency (http://www.wormboss.com.au/sheep-goats/tests-tools/tests/assessing-faecal-consistency-score.php)

- 1
- 1.5
- 2
- 2.5
- 3
- Unable to accurately assess due to autolysis

- Other GI observation including oesophageal observations (e.g. capsule trauma).

Urinary System

- If any abnormalities photograph urinary system
- Kidney capsular surface
  - Abnormal, describe lesion and whether bi or unilateral
  - Normal
  - Unable to accurately assess due to autolysis
- Kidney cut surface
  - Abnormal, describe lesion and whether bi or unilateral
  - Normal
  - Unable to accurately assess due to autolysis
- Perineal fat deposits
  - None
  - Minimal
  - Moderate
  - Large
- Adrenal glands

NB: haemorrhage and congestion of adrenals can be normal agonal change. Can also occur in septicaemia-pair with other lesions

  - Enlarged
  - Normal
  - Other, describe
  - Unable to accurately assess due to autolysis
- Ureters
  - Abnormal, describe lesion and whether bi or unilateral
  - Normal
  - Unable to accurately assess due to autolysis
- Bladder wall

NB: linear reddening or tiger striping on bladder mucosa may occur due to clotting of trapped blood in contracted organ. Not diagnostically significant.

  - Abnormal
  - Normal
- Urine dipstick results
  - Protein, record level (number of +)
  - Blood, record level (number of +)
  - Glucose, record level (number of +)
  - Ketones, record level (number of +)
  - Unable to accurately assess due to autolysis
- Any other urinary tract observations?

Reproductive tract

- Photograph reproductive system

- External surface of uterus
  - Normal
  - Abnormal
- Is ewe currently pregnant
  - Yes, record information for pregnant ewes, as outlined below
  - No, record information for non-pregnant ewes, as outlined below

Pregnant ewes

Complete this section if ewe was pregnant at time of death

- Foetus(es) in utero
  - 1
  - 2
  - 3
  - 4
- Record all lamb weights (format: lamb number, kg)
- Record all crown rump lengths (format: lamb number, cm) for pre-term foetuses
- Is foetus in birth canal?
  - Yes, is the presentation normal (forelimbs and head first)?
  - No, describe abnormal presentation
- Lambs all the same state of preservation and developmental age
  - Yes
  - No, describe any differences between lambs in developmental stage or preservation state
- Describe wool distribution, other developmental markers
- Photograph foetuses
- Congenital foetal abnormalities
  - Yes, describe abnormality
  - No
- Foetus starting to decompose
  - Yes
  - No
- Amniotic fluid
  - Normal- clear
  - Abnormal, describe(e.g.meconium, etc)
  - Unable to assess due to autolysis
- Placenta
  - Abnormal, describe (comment on placentomes and intercotyledonary membrane)
  - Normal

- Cervix
  - Normal
  - Abnormal, describe (e.g.ring womb (failure to dilate), trauma/tear
- Is an abortogenic agent suspected

NB signs consistent with abortogenic agent vary with stage of gestation of foetus and the agent but for infectious abortogenic agents include congenital malformation, mummification, foetal lesions, distended abdomen of foetus, increased serosanguinous plural and peritoneal fluid, subcutaneous oedema, hepatomegly and liver lesions. Placental lesions consistent with this diagnosis include necrotic cotyledons (strawberries), placentitis.

- Yes (ENSURE GOOD PPE AND SUBMIT FOETUS & PLACENTA THROUGH STATE VET DEPARTMENT FOR TESTING), what is the suspected abortogenic agent?
- No

- Any other comments on reproductive tract of pregnant ewe

Non-pregnant ewes

Complete this section if ewe was not pregnant at time of death (i.e. already given birth, lost a pregnancy, never pregnant)

- If not currently pregnant, is there evidence that the ewe has given birth
  - Yes (e.g. perineal trauma, lochia, incomplete uterine involution, well developed udder, lamb found dead near by, etc)
  - No- uterus shows no signs of pregnancy
- Fluid within uterus
  - Mucopurulent
  - Frank blood
  - Lochia
  - Other, describe
  - Unable to accurately assess due to autolysis
- Endometrium
  - Normal
  - Abnormal, describe
  - Unable to accurately assess due to autolysis
- Cervix of non-pregnant ewes
  - Normal
  - Abnormal (describe, trauma/tear, etc)
- Any other observations of reproductive tract of non-pregnant ewes?

Musculoskeletal system

- Photograph femur
- Femur-bone marrow
  - Normal
  - Gelatinous
  - Other, describe
- Femur-cortical bone
  - Appears thin
  - Normal thickness

- Femur-trabecular bone
  - Deficient
  - Appears sufficient
- Other observations of femur
- Other skeletal abnormalities
  - Yes, describe
  - No
- Any visible muscular abnormalities
  - Yes, describe
  - No

Neurological system

Only open skull, spine and/or sample peripheral nerves if;

1. Suspicion of neuro disease (e.g. phalaris staggers)
2. Evidence of neuro disease antemortem (e.g. neuro signs observed)

3. TSE exclusion or
4. SDI

- ☐ Neurological post-mortem required
  - ☐ Yes
  - ☐ No
- ☐ If 'yes' then check box for samples required
  - ☐ Brain
  - ☐ Cervical spinal cord
  - ☐ Other spinal cord segments
  - ☐ Peripheral nerves
  - ☐ CSF fluid
  - ☐ Other
- ☐ Any other neurological observations?

Diagnosis

Record the most likely diagnosis and any alternative diagnoses, based on the gross PM findings. This will be able to be adjusted later following further consideration of case, discussion with colleagues and the additional information obtained from results of samples submitted for diagnostic testing.

- ☐ Primary diagnosis, including any contributing disorder linked to the primary diagnosis
  - ☐ Dystocia
  - ☐ Septicaemia (specify - metritis, peritonitis, pneumonia, etc)
  - ☐ Trauma (specify which of the following (and may be more than one) - ruptured bladder (antemortem), ruptured uterus (antemortem), ruptured uterine artery, etc)
  - ☐ Metabolic disease- hypocalcaemia
  - ☐ Metabolic disease-pregnancy toxaemia
  - ☐ Metabolic disease- mixed
  - ☐ Metabolic disease-hypomagnesemia
  - ☐ Mastitis
  - ☐ Vaginal prolapse
  - ☐ Uterine prolapse
  - ☐ Dorsal-vaginal wall rupture
  - ☐ Flystrike
  - ☐ Gastrointestinal parasitism
  - ☐ Other GI disorders, describe (e.g. Yersinia, salmonella)
  - ☐ Accident, (describe)
  - ☐ Toxicity (describe)
  - ☐ Foot disease (e.g. resulting in recumbency)
  - ☐ Other, describe

Alternative diagnosis

- ☐ Select all other differentials separate to the primary diagnosis
  - ☐ Dystocia
  - ☐ Septicaemia (specify - metritis, peritonitis, pneumonia, etc)
  - ☐ Trauma (specify which of the following (and may be more than one) - ruptured bladder (antemortem), ruptured uterus (antemortem), ruptured uterine artery, etc)
  - ☐ Metabolic disease- hypocalcaemia
  - ☐ Metabolic disease-pregnancy toxaemia
  - ☐ Metabolic disease- mixed
  - ☐ Metabolic disease-hypomagnesemia
  - ☐ Mastitis

- Vaginal prolapse
- Uterine prolapse
- Flystrike
- Gastrointestinal parasitism
- Other GI disorders, describe (e.g. Yersinia, salmonella)
- Accident, (describe)
- Toxicity (describe)
- Foot disease (e.g. resulting in recumbency)
- Other, describe

Samples taken

- Confirm that the minimum samples required have been taken
  - Aqueous humour-labelled
  - Faecal sample- labelled
  - Samples unable to be taken due to predation, insufficient faecal matter etc.
- Check box for samples taken for any other investigations
  - SDI
  - SDI-abortion investigation
  - TSE exclusion
  - Other
- If 'other' above, record investigation type requested

8.3 Example host producer summary report (2020)

MEAT & LIVESTOCK AUSTRALIA

Unlocking the key to ewe survival

Results from 2020 lambing

Project objective:
To identify the major causes of ewe mortality in the lead up to and at the time of lambing for commercial non-Merino flocks across a range of climatic zones.

Summary of 2020 results:

- Average mortality over the 2020 lambing period was 1.98% across all ages and litter sizes
  - Whole farm mortality ranged from 0.8% to 4.7%
- Dystocia (difficult birth) or 'stuck lamb' was the most commonly reported cause of death by producers (28%) followed by ewes that were cast or had vaginal prolapse
- Septicaemia (blood poisoning, 42%), trauma (40%) and dystocia (29%) were the most common causes of death diagnosed by veterinary post-mortem
  - Dystocia may be under-reported with no external signs of dystocia in some cases
  - A dystocia diagnosis was more likely in single- compared to twin-bearing ewes submitted for PM
- Multiple diagnoses were often recorded in dystocia cases, likely reflecting complications associated with the prolonged or obstructed birth. These other diagnoses included
  - Septicaemia, or blood poisoning, associated with infection of the uterus or abdominal infection after the uterus or bladder has ruptured
  - Trauma, including uterine and bladder rupture and catastrophic blood loss
  - Marked hypocalcaemia (milk fever)
- Hypocalcaemia was diagnosed in 16% of ewes submitted. This diagnosis was more likely in
  - Older ewes (5+ years old) compared to younger ewes (<5 years old)
  - Less than condition score 2.0 at time of death compared to ewes in CS 3.0 at death

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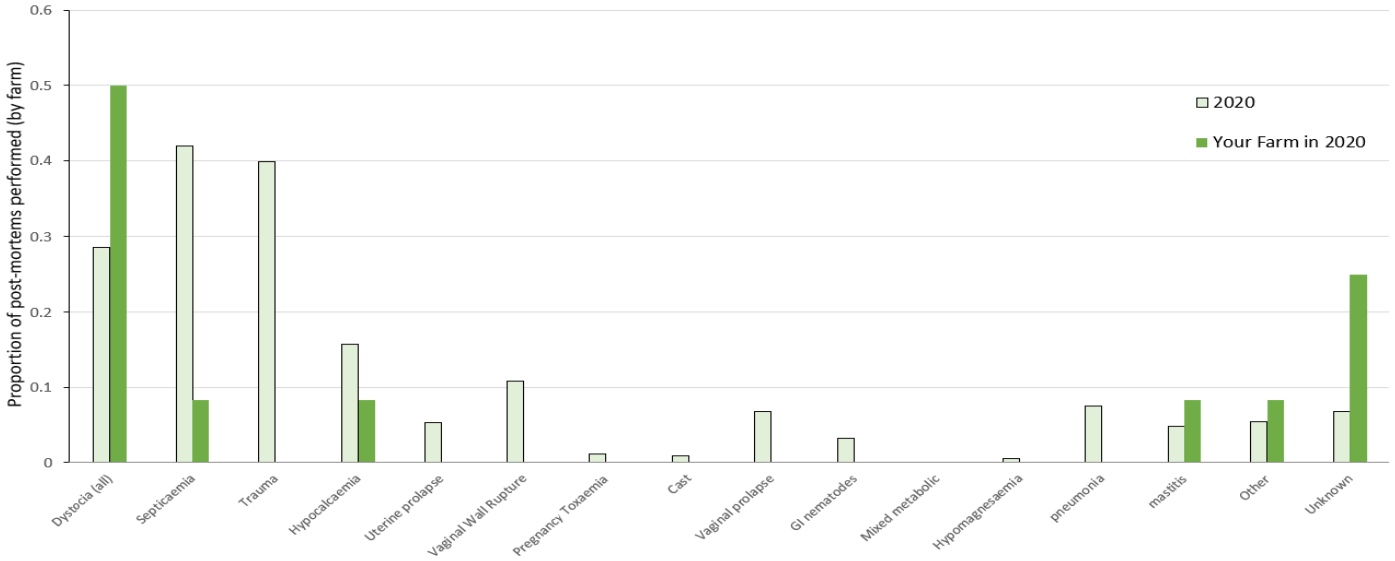

Figure 1: Percent of ewes post-mortemed with different diagnoses of cause of death. Average across all farms (light green) compared to the results for your farm (dark green bars).

- The cumulative mortality (number of ewes that died over lambing divided by the number of ewes at the start of lambing) across all mobs on your farm was **3.9%**
  - A post-mortem was performed on 14% of ewes recorded to have died over lambing

- The most common diagnoses in the 12 ewes post-mortemed on your property was:
  - Dystocia
    - 4 of 6 cases diagnosed as dystocia were cases of a failure to progress through birth not associated with malpresentation of a lamb or foetal oversize

  NB: septicaemia, hypocalcaemia, mastitis were all diagnosed once; three cases had an open diagnosis

For the purposes of this report both 'primary' and 'secondary' dystocia are grouped as 'dystocia'.

MEAT & LIVESTOCK AUSTRALIA

Brief explanations of the reported causes of death

- **Primary dystocia***: difficult lambing often due to either a mismatch between the size of the birth canal and the lamb(s), poor presentation of the lamb during birth or a foetal deformity.
- **Secondary dystocia:** difficult lambing due to the ewe's uterus failing to contract sufficiently and/or the cervix not dilating - subsequent to abortion, metabolic disease or management disturbances.
- **Septicaemia*:** blood poisoning as a consequence of bacterial infection. This was often associated with uterine or abdominal infections following primary dystocia or pneumonia.
- **Trauma***: including bladder, uterine and blood vessel ruptures and abdominal muscle tears.
- **Hypocalcaemia*** (milk fever): a metabolic disease due to low blood calcium.
- **Pregnancy toxaemia** (twin lambing disease): a metabolic disease that occurs in late-pregnant ewes due to a mismatch between energy availability (low) and demand (high). Risk factors include restricted feed intake (e.g. low rumen space due to large litter size and/or large foetal size), low feed quality, high (e.g. >3.7) or very low condition score and concurrent disease e.g. foot abscess).
- **Mixed metabolic disease:** co-occurrence of two or more metabolic diseases, often pregnancy toxaemia and hypocalcaemia
- **Uterine prolapse**: occurs when the uterus is pushed through the birth canal to hang outside the ewe.
- **Vaginal prolapse**: occurs when the vagina is pushed out of its normal position, to sit outside the ewe. Possible risk factors include straining, hormonally induced loosening of pelvic tissues and tail length.
- **Dorsal vaginal wall rupture**: spontaneous tearing of the wall of the vagina with subsequent prolapse of the intestines through the tear to hang outside the body of the ewe.
- **Cast:** ewes lying down and unable to right themselves are considered cast. Potential risk factors include high condition score, high litter size, hilly terrain, breed (e.g. short necked breeds).
- **Gastrointestinal parasitism**: heavy worm burdens leading to death.
- **Pneumonia**: lung inflammation and infection, often multifactorial involving bacteria and viruses.
- **Mastitis:** inflammation and/or infection of the udder due to bacteria. May result in septicaemia.
- **Hypomagnesemia** (grass tetany): metabolic disease due to low blood magnesium, often complicated by hypocalcaemia. Rare in ewes, but possible if lactating and on lush pasture.

If you would like more information about the project results, please contact your site coordinator:

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** these conditions often occurred concurrently, and are possibly related to dystocia*

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8.4 PM summary

Total post mortem examinations performed, total deaths per farm and the proportion of post mortem examinations performed compared to total deaths recorded on each farm. Farms where no post mortem examinations were performed and/or where mortality data was missing are recorded with a dash.

2019					2020				
Farm ID	**State**	**post mortem examinations (n)**	**Total deaths per farm (n)**	**Proportion of total deaths with necropsy (%)**	**Farm ID**	**State**	**post mortem examinations (n)**	**Total deaths per farm (n)**	**Proportion of total deaths with necropsy (%)**
1	NSW	18	411	4%	**1**	NSW	10	142	7.04
2	NSW	9	82	11%	**2**	NSW	10	81	12.35
3	NSW	9	-	-	**3**	NSW	14	100	14
4	NSW	8	162	5%	**4**	NSW	12	116	10.34
					49	NSW	3	-	-
	TOTAL	**44**			**TOTAL**		**49**		
5	SA	11	18	61%	**5**	SA	10	21	47.62
6	SA	7	132	5%	**6**	SA	5	90	5.56
					44	SA	4	62	6.45
	TOTAL	**18**				**TOTAL**	**19**		
7	VIC	7	36	19%	**7**	VIC	2	53	3.77
8	VIC	3	9	33%	**8**	VIC	1	18	5.56
9	VIC	2	-	-	**10**	VIC	11	134	8.21
10	VIC	15	74	20%	**11**	VIC	14	50	28
11	VIC	13	43	30%	**13**	VIC	19	122	15.57
12	VIC	1	-	-	**14**	VIC	6	-	-
13	VIC	32	236	14%	**15**	VIC	16	-	-
14	VIC	11	29	38%	**16**	VIC	4	17	23.53
15	VIC	13	170	8%	**17**	VIC	4	18	22.22
16	VIC	3	146	2%	**19**	VIC	6	102	5.88
17	VIC	6	71	8%	**20**	VIC	5	48	10.42
18	VIC	3	-	-	**21**	VIC	12	89	13.48
19	VIC	13	350	4%	**24**	VIC	7	186	3.76
20	VIC	4	27	15%	**25**	VIC	9	56	16.07
21	VIC	9	82	11%	**26**	VIC	21	60	35
22	VIC	-	-	-	**27**	VIC	5	16	31.25
23	VIC	1	-	-	**42**	VIC	11	16	68.75
24	VIC	10	162	6%	**45**	VIC	13	36	36.11
25	VIC	2	45	4%	**46**	VIC	8	61	13.11
26	VIC	6	34	18%	**47**	VIC	10	28	35.71
27	VIC	8	36	22%	**48**	VIC	4	22	18.18
28	VIC	7	-	-	**52**	VIC	6	59	10.17
	TOTAL	**169**				**TOTAL**	**194**		
29	WA	1	20	5%	**30**	WA	3	22	13.64
30	WA	3	17	18%	**31**	WA	2	28	7.14
31	WA	-	66	-	**32**	WA	3	61	4.92
32	WA	5	112	4%	**50**	WA	1	NA	NA
33	WA	-	4	-					
34	WA	4	-	-					
41	WA	-	38	-					
	TOTAL	**13**				**TOTAL**	**9**		

35	VIC	9	31	29%	**35**	VIC	5	29	17.24
37	VIC	8	62	13%	**37**	VIC	12	84	14.29
38	VIC	19	66	29%	**38**	VIC	6	71	8.45
40	VIC	14	54	26%	**40**	VIC	7	82	8.54
	TOTAL	**50**				**TOTAL**	**30**		
Mean (per farm)		**8.4**		**17%**	**Mean (per farm)**		**8.1**		**18**
Minimum		1		2%	**Minimum**		1		4
Maximum		32		61%	**Maximum**		21		69
Standard error		1.1		3%	**Standard error (%)**		0		2
n		35		28	***n***		38		33

8.5 Model means of cumulative mortality according to parity x litter size

Mixed model fitted values: Cumulative_mortality~Year+Parity*LitterSize

Year	Parity	LitterSize	lsmean	SE	df	lower.CL	upper.CL	.group
2019	Parity 1 (maiden)	1	1.80	0.34	166.26	1.13	2.47	123
2019	Parity 2+	1	1.94	0.29	157.83	1.36	2.51	123
2019	All mix	1	1.73	0.40	164.15	0.94	2.52	123
2019	Parity 1 (maiden)	2	3.07	0.53	177.44	2.01	4.12	12345
2019	Parity 2+	2	2.69	0.32	161.61	2.06	3.32	234
2019	All mix	2	3.10	0.44	161.90	2.24	3.97	345
2019	Parity 1 (maiden)	2+	2.50	0.35	166.59	1.80	3.19	1234
2019	Parity 2+	2+	3.17	0.42	177.77	2.34	4.01	345
2019	All mix	2+	3.50	0.63	177.23	2.26	4.74	123456
2019	Parity 1 (maiden)	3	NA	NA	NA	NA	NA	
2019	Parity 2+	3	5.12	0.44	176.48	4.25	5.99	56
2019	All mix	3	5.90	0.50	166.36	4.92	6.87	6
2020	Parity 1 (maiden)	1	0.96	0.32	164.40	0.34	1.59	1
2020	Parity 2+	1	1.10	0.27	150.57	0.58	1.63	1
2020	All mix	1	0.90	0.37	168.99	0.18	1.62	12
2020	Parity 1 (maiden)	2	2.23	0.48	177.80	1.28	3.18	1234
2020	Parity 2+	2	1.86	0.32	169.14	1.22	2.50	123
2020	All mix	2	2.27	0.43	169.91	1.43	3.11	1234
2020	Parity 1 (maiden)	2+	1.66	0.34	169.29	0.99	2.34	123
2020	Parity 2+	2+	2.34	0.36	175.89	1.62	3.06	1234
2020	All mix	2+	2.67	0.59	177.88	1.50	3.83	12345
2020	Parity 1 (maiden)	3	NA	NA	NA	NA	NA	
2020	Parity 2+	3	4.29	0.42	173.00	3.46	5.11	456
2020	All mix	3	5.06	0.48	171.94	4.12	6.01	56

[a] NOTE: The last column highlights ﷽groups﷽ which are significantly different from eachother

8.6 Post mortem diagnosed cause of death proportions in both years

Cause_of_Death	mean_PropnCOD	StDev	StError	CI_lower	CI_upper	fac_order	Year
septicaemia	0.41	0.29	0.05	0.31	0.51	1	2020
trauma	0.39	0.25	0.04	0.31	0.47	2	2020
dystocia	0.28	0.23	0.04	0.20	0.36	3	2020
hypoca	0.15	0.18	0.03	0.09	0.21	4	2020
dvwr	0.11	0.17	0.03	0.05	0.17	5	2020
vaginal_prolapse	0.07	0.14	0.02	0.03	0.11	6	2020
pneumonia	0.07	0.18	0.03	0.01	0.13	7	2020
unknown	0.07	0.13	0.02	0.03	0.11	8	2020
other	0.05	0.11	0.02	0.01	0.09	9	2020
uterine_prolapse	0.05	0.17	0.03	0.00	0.11	10	2020
mastitis	0.04	0.12	0.02	0.00	0.08	11	2020
gi_nematodes	0.03	0.07	0.01	0.01	0.05	12	2020
cast	0.01	0.03	0.00	0.01	0.01	13	2020
hypomg	0.01	0.03	0.00	0.01	0.01	14	2020
preg_tox	0.01	0.04	0.01	0.00	0.03	15	2020
mixed_metabolic	0.00	0.00	0.00	0.00	0.00	16	2020
septicaemia	0.43	0.28	0.05	0.33	0.53	1	2019
dystocia	0.39	0.28	0.05	0.29	0.49	2	2019
trauma	0.19	0.20	0.03	0.13	0.25	3	2019
hypoca	0.10	0.12	0.02	0.06	0.14	4	2019
uterine_prolapse	0.10	0.20	0.03	0.04	0.16	5	2019
other	0.06	0.10	0.02	0.02	0.10	6	2019
mixed_metabolic	0.06	0.14	0.02	0.02	0.10	7	2019
unknown	0.06	0.10	0.02	0.02	0.10	8	2019
cast	0.04	0.09	0.01	0.02	0.06	9	2019
dvwr	0.03	0.08	0.01	0.01	0.05	10	2019
gi_nematodes	0.03	0.07	0.01	0.01	0.05	11	2019
hypomg	0.02	0.05	0.01	0.00	0.04	12	2019
preg_tox	0.02	0.05	0.01	0.00	0.04	13	2019
vaginal_prolapse	0.01	0.04	0.01	0.00	0.03	14	2019
pneumonia	0.01	0.05	0.01	0.00	0.03	15	2019
mastitis	0.01	0.03	0.00	0.01	0.01	16	2019

8.7 Figures for proportions of dystocia diagnoses

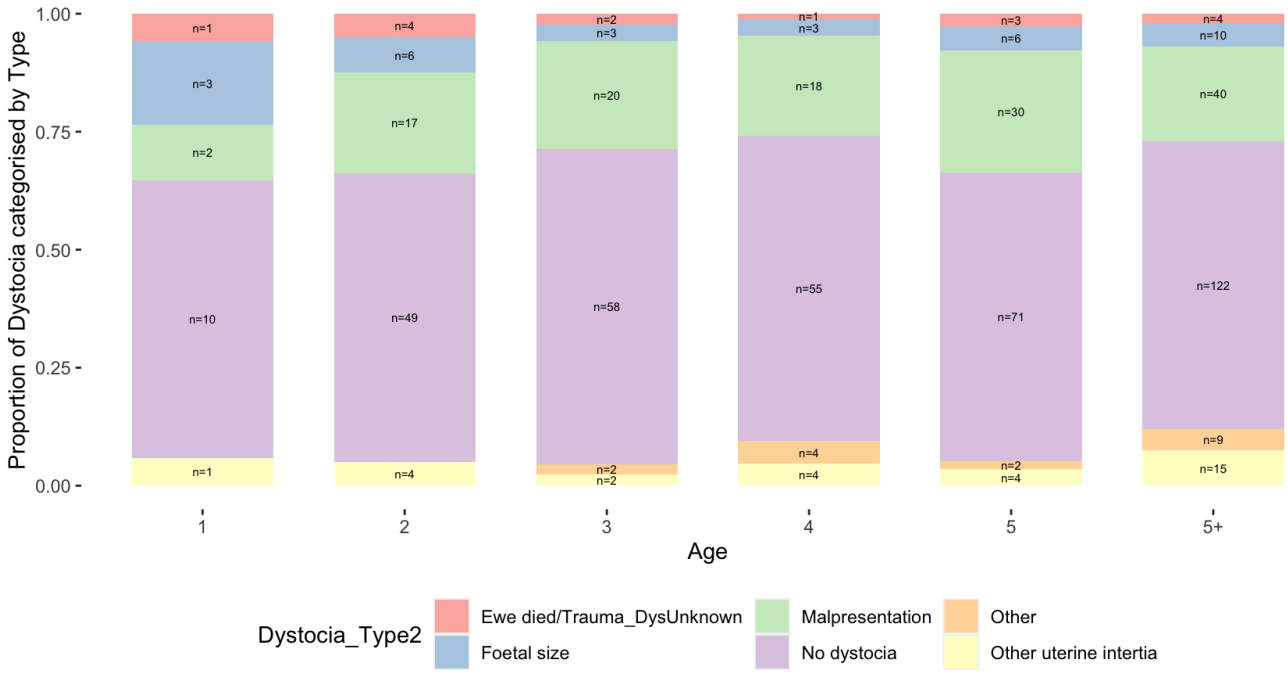

Figure 22 Proportions of dystocia diagnoses due to different dystocia 'types' by age of ewe at post-mortem.

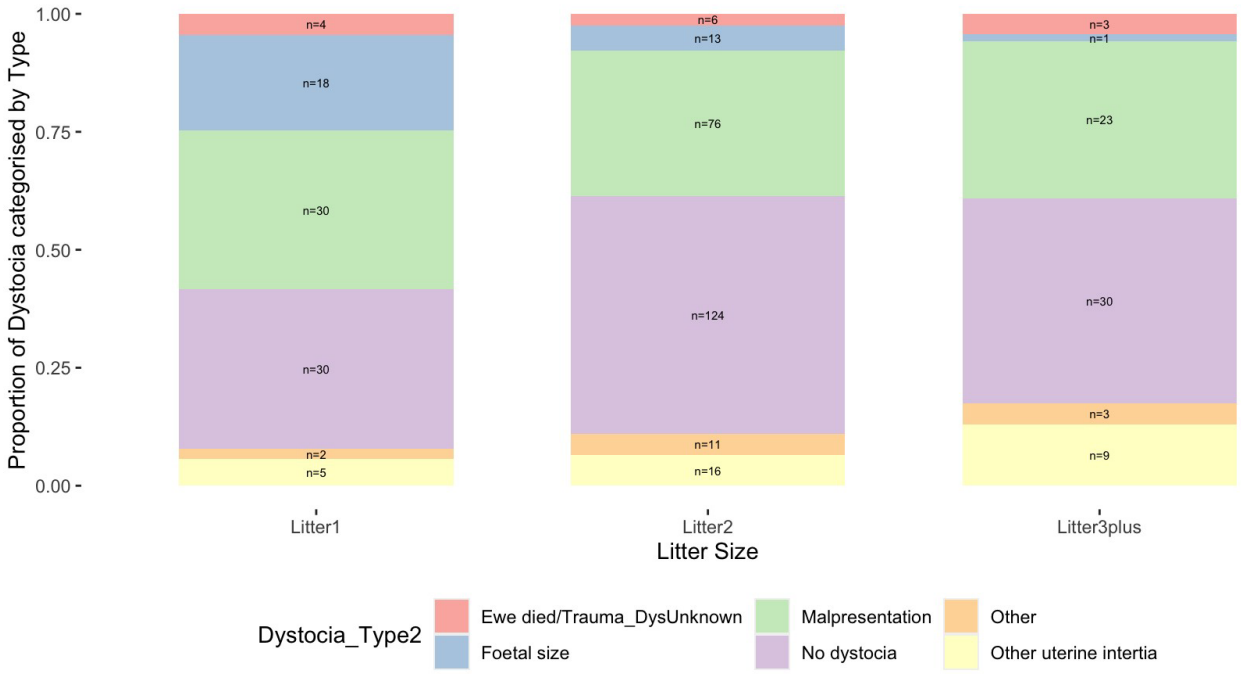

Figure 23 Proportions of dystocia diagnoses due to different dystocia 'types' by litter size of ewe at post-mortem.

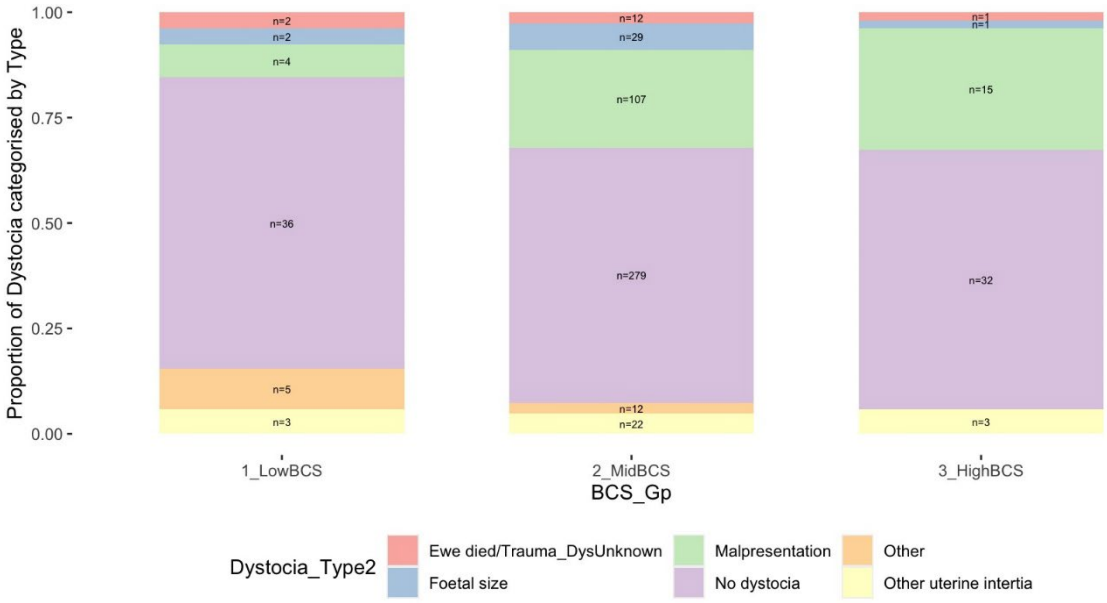

Figure 24 Proportions of dystocia diagnoses due to different dystocia 'types' by BCS of ewe at post-mortem

8.8 Dystocia risk factor diagnosis - results summary

Dystocia diagnoses in ewes submitted for post-mortem across both years, with proportion of dead ewes diagnosed with the condition in each level of each factor and the corresponding risk ratios (RR) and p-values compared to the comparator factor (the top row for each group, * for significance).

Factor	Level	Proportion	Risk Ratio	p-value RR
Litter size	Litter 2	0.48	1.00	
	Litter 1	0.63	1.30	0.02*
	Litter 3+	0.54	1.11	0.50
Age	3	0.32	1.00	
	1	0.41	1.28	0.58
	2	0.39	1.20	0.42
	4	0.34	1.06	0.87
	5	0.38	1.18	0.46
	5+	0.37	1.13	0.50
BCS	3	0.42	1.00	
	2	0.27	0.64	0.06
	2.5	0.30	0.70	0.04*
	3.5	0.40	0.93	0.59
	3.75	0.35	0.82	0.35
Total Litter Weight (kg)	5kg to 10kg	0.50	1.00	
	10kg to 15kg	0.50	0.99	1.00
	5kg/less	0.51	1.01	1.00
	>15kg	0.43	0.86	0.55
Pasture Base	improved	0.34	1.00	
	not recorded	0.43	1.27	0.14
	annual	0.32	0.96	1.00
	native	0.42	1.26	0.40
	crop	0.57	1.69	0.04*
	lucerne	0.50	1.49	0.25
	lucerne mixed	0.36	1.07	1.00
	improved mixed	0.43	1.28	0.57
Est. FOO	Med_1500	0.35	1.00	
	Low_1000/less	0.33	0.96	0.82
	Med_2000	0.37	1.08	0.72
	High_2500/more	0.44	1.28	0.40
State	VIC	0.37	1.00	
	NSW	0.36	0.96	0.91
	SA	0.41	1.10	0.72
	WA	0.27	0.74	0.50
Rainfall zone	Medium	0.38	1.00	
	High	0.31	0.84	0.22
	Low	0.44	1.18	0.54

8.9 Periparturient trauma and/or septicaemia risk factor diagnosis - results summary

Periparturient trauma and/or septicaemia diagnoses in ewes submitted for necropsy with proportion of dead ewes diagnosed with the condition in each level of each factor, corresponding risk ratios (RR) and p-values. Cases recorded as periparturient trauma and/or septiciaemia did not include DVWR, vaginal prolapse or uterine prolapse unless other trauma or septicaemia was present.

Factor	Level	Proportion	Risk Ratio	p-value RR
Litter size	Litter 2	0.48	1.00	
	Litter 1	0.60	1.23	0.08
	Litter 3+	0.36	0.75	0.08
Age	3	0.55	1.00	
	1	0.53	0.96	1.00
	2	0.40	0.73	0.06
	4	0.47	0.85	0.36
	5	0.53	0.95	0.78
	5+	0.47	0.85	0.25
BCS	3	0.50	1.00	
	2	0.37	0.73	0.09
	2.5	0.48	0.95	0.71
	3.5	0.53	1.06	0.60
	3.75	0.44	0.88	0.45
Total Litter Weight (kg)	5kg to 10kg	0.50	1.00	
	10kg to 15kg	0.47	0.94	0.62
	5kg/less	0.60	1.20	0.31
	>15kg	0.23	0.47	0.01*
Pasture Base	improved	0.51	1.00	
	not recorded	0.30	0.59	0.001
	annual	0.48	0.95	0.85
	native	0.50	0.99	1.00
	crop	0.57	1.11	0.67
	lucerne	0.57	1.13	0.79
	lucerne mixed	0.43	0.84	0.60
	improved mixed	0.64	1.27	0.42
Est. FOO	Med_1500	0.58	1.00	
	Low_1000/less	0.51	0.88	0.20
	Med_2000	0.45	0.77	0.02*
	High_2500/more	0.33	0.57	0.02*
State	VIC	0.49	1.00	
	NSW	0.47	0.96	0.73
	SA	0.54	1.10	0.61
	WA	0.27	0.55	0.05*
Rainfall Zone	Medium	0.50	1.00	
	High	0.48	0.97	0.77
	Low	0.30	0.59	0.048*

8.10 Hypocalcaemia risk factor diagnosis - results summary

Hypocalcaemia diagnoses in ewes submitted for post-mortem, with proportion of dead ewes diagnosed with the condition in each level of each factor and the corresponding risk ratios (RR) and p-values compared to the top row for each factor (* for significance)

Factor	Level	Proportion	Risk Ratio	p-value RR
Litter size	Litter 2	0.22	1.00	
	Litter 1	0.14	0.60	0.09
	Litter 3+	0.12	0.52	0.06
Age	3	0.10	1.00	
	1	0.06	0.57	1.00
	2	0.06	0.60	0.41
	4	0.09	0.91	1.00
	5	0.18	1.75	0.16
	5+	0.25	2.37	0.01*
BCS	3	0.15	1.00	
	2	0.29	1.88	0.03*
	2.5	0.14	0.90	0.86
	3.5	0.14	0.90	0.77
	3.75	0.14	0.88	0.83
BCS group	Middle	0.15	1.00	
	Low	0.29	1.99	0.02*
	High	0.14	0.93	1.00
Total Litter Weight (kg)	5kg to 10kg	0.16	1.00	
	10kg to 15kg	0.21	1.32	0.34
	5kg/less	0.30	1.86	0.05
	>15kg	0.13	0.83	1.00
Pasture Base	improved	0.17	1.00	
	not recorded	0.11	0.65	0.30
	annual	0.13	0.77	0.80
	native	0.12	0.69	0.78
	crop	0.09	0.52	0.40
	lucerne	0.21	1.28	0.71
	lucerne mixed	0.21	1.28	0.71
	Improved mixed	0.21	1.28	0.71
Est. FOO	Med_1500	0.19	1.00	
	Low_1000/less	0.17	0.88	0.68
	Med_2000	0.16	0.86	0.65
State	VIC	0.19	1.00	
	NSW	0.04	0.23	0.00*
	SA	0.16	0.87	0.83
Rainfall Zone	Medium	0.13	1.00	
	High	0.25	1.88	0.002*
	Low	0.07	0.56	0.56

8.11 Uterine prolapse risk factor diagnosis - results summary

Uterine prolapse diagnoses in ewes submitted for post-mortem, with proportion of dead ewes diagnosed with the condition within each level of each factor and the corresponding risk ratios (RR) and p-values compared to the top row for each factor (* for significance).

Factor	Level	Proportion	Risk Ratio	p-value RR
Litter size	Litter 2	0.01	1.00	
	Litter 1	0.01	1.38	1.00
Age	3	0.03	1.00	
	1	0.06	1.71	0.52
	2	0.13	3.63	0.04*
	4	0.06	1.71	0.49
	5	0.04	1.25	1.00
	5+	0.03	0.87	1.00
BCS	3	0.06	1.00	
	2	0.02	0.32	0.32
	2.5	0.04	0.70	0.60
	3.5	0.03	0.44	0.14
	3.75	0.08	1.27	0.75
Pasture base (no cases submitted from crop, Lucerne, Lucerne mixed or improved mixed)	improved	0.05	1.00	
	not recorded	0.07	1.37	0.57
	annual	0.10	1.94	0.22
	native	0.12	2.31	0.16
Est. FOO	Med_1500	0.04	1.00	
	Low_1000/less	0.07	2.09	0.15
	Med_2000	0.05	1.28	0.76
	High_2500/more	0.07	2.08	0.29
Rainfall Zone	Medium	0.07	1.00	
	Low	0.11	1.71	0.42
State	VIC	0.05	1.00	
	NSW	0.08	1.59	0.30
	SA	0.05	1.14	0.70
	WA	0.05	0.96	1.00

8.12 Vaginal prolapse risk factor diagnosis - results summary

Vaginal prolapse diagnoses in ewes submitted for post-mortem, with proportion of dead ewes diagnosed with the condition within each level of each factor and the corresponding risk ratios (RR) and p-values compared to the top row for each factor (* for significance).

Factor	Level	Proportion	Risk ration	p-value RR
Litter size	Litter 2	0.07	1.00	
	Litter 1	0.01	0.15	0.03*
	Litter 3+	0.07	0.99	1.00
Age	3	0.06	1.00	
	1	0.06	1.02	1.00
	2	0.05	0.87	1.00
	4	0.04	0.61	0.72
	5	0.05	0.90	1.00
	5+	0.03	0.52	0.32
BCS (no cases diagnosed in ewes submitted in CS 2 or less)	3	0.03	1.00	
	2.5	0.04	1.53	0.50
	3.5	0.07	2.59	0.08
	3.75	0.06	2.07	0.38
Total Litter Weight (kg)	5kg to 10kg	0.06	1.00	
	10kg to 15kg	0.09	1.48	0.48
	5kg/less	0.02	0.36	0.45
	>15kg	0.13	2.28	0.23
Pasture Base	improved	0.04	1.00	
	not recorded	0.01	0.37	0.49
	annual	0.10	2.58	0.13
	native	0.12	3.08	0.09
	crop	0.09	2.32	0.23
	lucerne mixed	0.07	1.91	0.43
Est. FOO	Med_1500	0.05	1.00	
	Low_1000/less	0.03	0.63	0.45
	Med_2000	0.04	0.68	0.59
	High_2500/more	0.11	2.08	0.21
State	VIC	0.04	1.00	
	NSW	0.04	1.06	1.00
	SA	0.08	2.00	0.21
Rainfall Zone	Medium	0.04	1.00	
	High	0.05	1.30	0.63
	Low	0.04	0.94	1.00

8.13 DVWR risk factor diagnosis - results summary

Dorsal Vaginal Wall Rupture diagnoses in ewes submitted for post-mortem, with proportion of dead ewes diagnosed with the condition in each level of each factor and the corresponding risk ratios and p-values compared to the comparator factor (the top row for each group; *for significance)

Factor	Level	Proportion	Risk Ratio	P-value RR
State of origin	VIC	0.05	1.00	
(no WA)	NSW	0.26	4.76	0.00*
	SA	0.08	1.50	0.45
Litter size	Litter 2	0.14	1.00	
	Litter 1	0.01	0.08	0.00*
	Litter 3+	0.19	1.36	0.34
Age	3	0.12	1.00	
(no cases in 1 yo)	2	0.06	0.54	0.29
	4	0.08	0.72	0.61
	5	0.07	0.60	0.32
	5+	0.10	0.87	0.68
BCS	3	0.07	1.00	
(no cases 2-2.5)	3.5	0.16	2.53	0.003*
	3.75	0.21	3.25	0.003*
Total Foetal Wt (kg)	5kg to 10kg	0.09	1.00	
(none in <=5kg)	10kg to 15kg	0.22	2.52	0.003*
	>15kg	0.27	3.04	0.012*
Pasture Base	improved	0.10	1.00	
	not recorded	0.03	0.27	0.04
	annual	0.03	0.32	0.34
	native	0.08	0.77	1.00
	crop	0.09	0.87	1.00
	lucerne	0.07	0.71	1.00
	lucerne mixed	0.14	1.43	0.64
	improved mixed	0.07	0.71	1.00
Est. FOO	Med_1500	0.09	1.00	
	Low_1000/less	0.03	0.29	0.01*
	Med_2000	0.16	1.75	0.07
	High_2500/more	0.19	1.98	0.17
Rainfall Zone (no cases from low	Medium	0.11	1.00	
zone)	High	0.04	0.34	0.01*