Taylor & Francis
Taylor & Francis Group

New Zealand Veterinary Journal

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/tnzv20

Where do all the ewes go? Ewe culling and mortality in 34 sheep flocks in New Zealand

AL Ridler, RA Corner-Thomas, S Mote, S Morgan, PR Kenyon & KJ Flay

To cite this article: AL Ridler, RA Corner-Thomas, S Mote, S Morgan, PR Kenyon & KJ Flay (17 Oct 2024): Where do all the ewes go? Ewe culling and mortality in 34 sheep flocks in New Zealand, New Zealand Veterinary Journal, DOI: 10.1080/00480169.2024.2409216

To link to this article: https://doi.org/10.1080/00480169.2024.2409216

NEW ZEALAND VETERINARY JOURNAL
https://doi.org/10.1080/00480169.2024.2409216

Taylor & Francis
Taylor & Francis Group

RESEARCH ARTICLE

OPEN ACCESS Check for updates

Where do all the ewes go? Ewe culling and mortality in 34 sheep flocks in New Zealand

AL Ridler [a], RA Corner-Thomas [b], S Mote[a], S Morgan[c], PR Kenyon [b] and KJ Flay [d]

[a]Tāwharau Ora – School of Veterinary Science, Massey University, Palmerston North, New Zealand; [b]School of Agriculture and Environment, Massey University, Palmerston North, New Zealand; [c]Department of Agricultural Sciences, Lincoln University, Lincoln, New Zealand; [d]Department of Veterinary Clinical Sciences, City University of Hong Kong, Kowloon, Hong Kong

ABSTRACT

Aims: To describe rates of and reasons for culling and mortality of ewes between breeding and mid-lactation on New Zealand sheep farms; to investigate associations of these variables with farm demographic variables; and to describe rates of and reasons for culling of ewes at weaning.

Methods: Participants were a convenience sample of 34 farms from across New Zealand. Demographic data were initially collected for each farm via a questionnaire administered in-person to the flock owner or manager. During approximately 8 months from breeding to mid-lactation, ewe tally, culling and mortality data were collected and used to calculate various parameters related to flock performance and to investigate associations. During the main ewe-culling event at weaning, ewe-culling data were collected from 29/34 flocks participating in the study.

Results: There was considerable variation between flocks, but the between-flock mean replacement percentage was 29.2 (SD 5.0)%. Overall, a between-flock mean of 10.5 (SD 4.6)% of ewes presented for breeding were culled or dead/missing by mid-lactation and thus did not rear any lambs. Additionally, from 27 flocks that reported data on ewes' success at rearing lambs, a between-flock mean of 3.9 (SD 2.5)% of ewes that remained alive at mid-lactation failed to rear any lambs, resulting in an overall between-flock mean loss of 23.1 (SD 6.3) potential lambs per 100 ewes. Two-thirds of ewe mortalities between breeding and mid-lactation occurred during the lambing period. Model results showed flocks with higher pregnancy scanning percentages had lower rates of culling and mortality between breeding and mid-lactation. However, apart from farm contour, from breeding to mid-lactation there were no associations for culling and mortality with farm size, flock size, number of ewes per labour unit, whether ewe hoggets (7–9 months of age) were presented for breeding, or duration of the breeding period. A between-flock mean of 16.5 (SD 8.3)% of ewes present at weaning were culled, and among mixed-age ewes, the most common reasons for culling at this time were age, incisor teeth defects and udder defects.

Conclusions: To reduce unnecessary ewe culling and mortality, attention should be focused on maximising conception rates, ensuring judicious culling decisions, optimising body condition score, and identifying farm-specific causes of death over the lambing period to facilitate targeted intervention strategies.

Clinical relevance: Identifying why and when ewes exit flocks, and comparing it with the data presented here, will facilitate the development of flock-specific interventions to reduce ewe culling and mortality.

Abbreviations: BCS: Body condition score; NI: North Island; SI: South Island

ARTICLE HISTORY
Received 12 April 2024
Accepted 2 September 2024

KEYWORDS
Sheep; culling; mortality; death; wastage; longevity; reproduction; replacement

Introduction

Within sheep flocks, ewes can be removed from a flock either due to culling or mortality. Culling refers to the deliberate removal of ewes by selling them to slaughter or to other properties, or by slaughtering them on-farm for pet food or personal consumption. Mortality comprises inadvertent deaths due to disease, injury or accident. In extensive farming systems where it is difficult to physically find all dead ewes, mortality also includes ewes that are missing from the flock based on discrepancies in flock numbers at different time points (Flay *et al*. 2022) and these are sometimes referred to as "dead/missing" ewes (Capdevila-Ospina *et al.* 2021). In seasonally-based pastoral sheep-farming countries such as New Zealand, Australia and the United Kingdom, it is probable that many farmers routinely cull ewes at the end of their expected productive lifespan, with a mean culling age of 5–7

CONTACT AL Ridler a.l.ridler@massey.ac.nz
Supplemental data for this article can be accessed online at https://doi.org/10.1080/00480169.2024.2409216

years (Wishart *et al.* 2016; McLaren *et al.* 2020; Ridler *et al.* 2023). However, ewes exiting a flock before the end of their potential productive lifespan results in a higher proportion of maiden ewes in the flock, which are less productive than mature ewes (Annett *et al.* 2011a; Edwards *et al.* 2015; Flay *et al.* 2022) and reduces cash profit (Farrell *et al.* 2019). Furthermore, ewe mortality results in a complete financial loss for that ewe, as the cull value of the ewe for meat production or sale to another flock cannot be realised.

Culling of non-dairy breed ewes is primarily due to failure to become pregnant, being pregnant but failing to rear a lamb ("wet-dry"), having a vaginal prolapse or perceived defects of the teeth, feet, udder, form, type or conformation (Mekkawy *et al.* 2009; Flay *et al.* 2022; Ridler *et al.* 2023). Annual ewe mortality rates in New Zealand, Australia and the UK range from around 3–16% (reviewed by Flay *et al.* 2022) but in most cases the causes of mortality were not identified. Around two-thirds of ewe deaths in New Zealand are reported to occur over the lambing period (Flay *et al.* 2021; Capdevila-Ospina *et al.* 2021) which means their potential lambs are also lost.

There are limited data on the extent of culling and ewe mortality in New Zealand sheep flocks. Flay et al. (2021) evaluated culling and mortality over the lifetime of >13,000 ewes but these ewes were on only three North Island farms, and most were on two, limiting the ability to extrapolate the data more generally. Furthermore, the percentage of ewes culled for particular reasons is largely unknown. Therefore, the aims of this study were to investigate ewe culling and mortality in 34 sheep flocks located throughout New Zealand.

Materials and methods

Sheep flocks

Farmer participants for this study were required to collect and share data on ewe numbers, culling and mortality, be visited by researchers on two occasions, and commit to the study for 10 months. Therefore, flocks were convenience-sampled by contacting a nationwide network of personal contacts, farm advisors and veterinarians previously known to the researchers to identify potentially suitable participants. Members of the network made the initial contact with the farmers to assess their interest in potential participation, and, if interested, gain their consent to pass on their contact details to the researchers. Farmers were then contacted by the researchers via email or a phone call and were emailed an information sheet. The study was judged to be low risk through peer evaluation and an online assessment by the Research Ethics Office (Massey University, Palmerston North, NZ), and therefore did not require review by a human ethics committee.

Data collection

Ewe culling and mortality between breeding and mid-lactation

Farms were visited in autumn (April and May) 2021 and a questionnaire (Supplementary Information 1) was completed via an in-person interview with the farm owner or manager to collect demographic information including: farm size, contour (based on the percentage of flat land), livestock numbers, ewe breed/s, farmer-reported average mature ewe liveweight at breeding, number of permanent labour units whose role was primarily working with livestock, duration of the breeding period (in days), and whether replacement ewe hoggets were joined with the ram at 7–9 months of age. Farmers were asked how ewes were grouped over the year and were briefed on supplying ewe data for the upcoming 2021 year through until mid-lactation, stratified by these groups. Farmers were requested to provide data on the number of ewes at key management events, which in chronological order, were pregnancy diagnosis (mid-gestation), set stocking (1–2 weeks prior to the planned start of lambing) and docking/tailing (when lambs are approximately 3–6 weeks of age). They were also asked for pregnancy diagnosis data (number of ewes non-pregnant, single-bearing and twin- or triplet-bearing) and the number of ewes that were pregnant and survived up to docking/tailing but did not rear any lambs ("wet-dry"). Finally, the dates, number and reason/s for any ewes culled, and mortality data, including where possible, the date and farmer-reported cause of death were collected.

At this time farmers were also interviewed about their general ewe-culling policies; this data is presented elsewhere (Ridler *et al.* 2023) but was used to categorise farmers' culling policies based on age as: no culling for age, culling at < 6 years, at 6 years, or at > 6 years of age.

Throughout 2021, farmers were contacted at the time of key management events and prompted to supply the requested data. Contact was made by email, phone call, text or messaging app, based on each farmer's stated preference. Non-response was followed up using a different contact method. Farmers supplied data via a range of methods including downloads from software packages, photographs of relevant pages of notebooks or other written records, verbal communication, or completing and returning requests sent via email. All data were entered into an Excel spreadsheet (Microsoft, Redmond, WA, USA).

Calculated flock productivity, culling and mortality parameters between breeding and mid-lactation

At breeding, all farmers kept ewes in two or more different management groups generally based on ewe age or on whether the ewes were to be mated to maternal-breed rams (to generate replacement ewe lambs) and or to terminal-breed rams (ram breeds whose progeny are all sent to slaughter). However, after pregnancy diagnosis or set stocking, management groups were often mixed or re-allocated based on litter size and thereafter were difficult to differentiate until weaning. Therefore, all culling and mortality parameters between breeding and mid-lactation are presented for two-tooth and mixed-age ewes combined. For each flock, the parameters listed below were determined and then used to calculate between-flock means and SD.

Replacement percentage: number of two-tooth ewes at the start of breeding as a percentage of the total number of two-tooth and mixed-age ewes at the start of breeding.

Percentage non-pregnant: number of non-pregnant ewes at pregnancy diagnosis as a percentage of the number of ewes presented for breeding.

Percentage culled for non-reproductive reasons: number of ewes culled between the start of breeding and mid-lactation for reasons other than non-pregnant or failure to rear a lamb, as a percentage of the number of ewes presented for breeding.

Number of missing ewes: number of ewes missing between the start of breeding and mid-lactation that were not accounted for by culling or recorded deaths.

Percentage dead/missing: number of ewes recorded dead or calculated to be missing between the start of breeding and mid-lactation, as a percentage of the number of ewes present at breeding. Four farms did not provide ewe tally data for mid-lactation and on these farms, the number of ewes present at weaning (approximately 6 weeks after mid-lactation) was used as a proxy for the number present in mid-lactation.

Percentage of ewes exiting the flock: number of ewes that were non-pregnant, culled for non-reproductive reasons and dead/missing between breeding and mid-lactation, as a percentage of the number of ewes presented for breeding.

Percentage pregnant but failed to rear a lamb: number of ewes that were diagnosed as pregnant and survived to mid-lactation, at which time they were determined by the farmer to not be lactating based on udder palpation (Griffiths *et al*. 2016), as a percentage of the number of ewes present prior to lambing.

Percentage of ewes presented for breeding that did not rear any live lambs: number of ewes that exited the flock between breeding and mid-lactation plus those that were pregnant but failed to rear a lamb, as a percentage of the number of ewes presented for breeding.

Scanning percentage: number of fetuses identified at pregnancy diagnosis as a percentage of the number of ewes presented for breeding (note: calculated scanning percentages are likely to be an underestimate as most flocks did not identify triplet fetuses and therefore ewes with more than one fetus were recorded as carrying two fetuses only).

Potential lambs lost per 100 ewes: ewes presented for breeding that did not rear any live lambs, multiplied by the scanning percentage, divided by 100 ewes.

Statistical analysis

Descriptive statistics (mean and 95% CI for continuous variables, proportions for categorical variables) were calculated for each of the parameters measured.

SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) was used to further analyse the data and fit general linear models for the following outcome variables: "percentage dead/missing", "percentage of ewes exiting the flock" and "percentage of ewes presented for breeding that did not rear any live lambs". The normality of continuous variables was assessed using graphical displays in combination with the Shapiro–Wilk test of normality, and correlations were assessed using Pearson's r. Then, for each of the three outcome variables, the relationship between each predictor and the outcome was modelled separately. Predictor variables considered for each of these models were: region (Eastern North Island (NI), Northern NI, Western NI, Northern and Central South Island (SI), Southern SI), farm contour (< 25% flat land, 25–75% flat land, > 75% flat land), farm size (effective ha), flock size (number of ewes), labour units (number), ewes per labour unit, farmer-reported average ewe weight (kg), scanning percentage, replacement percentage, length of breeding period (≤ 42 days, > 42 days), hogget mating (yes, no) and age at which ewes were culled for age (< 6 years old, 6 years old, > 6 years old, do not cull for age).

A model was also specifically created to assess the relationship between scanning percentage and the outcome percentage of dead/missing ewes that only occurred over the lambing period (calculated based on the timing of the dead/missing ewes, thus only considering those that went missing or died during the lambing period as a percentage of all ewes that were dead/missing between breeding and mid-lactation).

After each model was fitted, the model assumptions were checked visually using diagnostic plots. Results of all models are presented as predicted mean and 95% CI for categorical variables and beta coefficient (estimate) and 95% CI for continuous variables. To further facilitate visualisation, a graphical representation has been included for some of the continuous variables.

As there were biologically plausible relationships between some predictor variables, these relationships were also examined both descriptively and using univariable linear models; for example, the relationship between scanning percentage and percentage of ewes that were non-pregnant; between scanning percentage and average ewe weight; and between age at which ewes were culled for age and replacement percentage.

Finally, the outcome parameter “percentage of ewes exiting the flock” was selected for further analysis where multiple predictors were considered for inclusion in one model. This outcome was selected as it was accompanied by the most complete dataset and is an outcome measure that encompasses overall culling and mortality from breeding to mid-lactation. The following predictor variables, with $p < 0.3$ in the above univariable analysis, were considered for inclusion: region, farm contour, average ewe weight, scanning percentage, hogget mating, duration of breeding period, and age at which ewes were culled for age. The most significant (smallest p-values) were considered first, namely average ewe weight and scanning percentage, then the other variables were added one at a time and their impact on overall model fit was assessed.

Reasons for ewe culling at weaning

Lambs were weaned at approximately 10–16 weeks of age. Subsequently, 0–6 weeks after weaning, farmers assessed their whole ewe flock for culling purposes. At this time, data were collected regarding the total number of ewes examined in each flock, the number of ewes culled, and the reasons for culling them. This was done by either the researchers or the farmers using a recording sheet (Supplementary Information 2). Data were entered into a spreadsheet and the percentage culled for each reason for each flock was calculated. These data were then used to calculate between-flock means and SD.

Results

Summary statistics for enrolled sheep flocks

Thirty-eight sheep flocks were recruited from throughout New Zealand, of which 34 provided sufficient data for analysis, with 18 in the North Island and 16 in the South Island. Based on the Beef + Lamb New Zealand regions (Anonymous 2023a), farms were in the Northern (n = 7), Eastern (n = 9) and Western (n = 2) regions of the NI and the Northern and Central (n = 11) and Southern (n = 5) regions of the SI.

All farms kept beef cattle as well as sheep, and two also farmed deer. One farm kept Merino breed ewes while the remainder farmed Romney or Romney-derivative ewe breeds. Throughout the study all ewes were managed entirely outdoors (no housing) under commercial conditions, primarily grazing pasture.

Farm size, ewe flock size, farmer-reported average mature ewe weight and number of two-tooth and mixed-age ewes per permanent labour unit are summarised in Table 1.

Table 1. Range, mean and SD of farm size, ewe flock size (two-tooth and mixed-age ewes combined), farmer-reported average mature ewe weight, and number of two-tooth and mixed-age ewes per permanent labour unit for 34 New Zealand sheep farms enrolled in a survey to investigate the extent and drivers of ewe culling and mortality in 2021.

Parameter	Range	Mean	SD
Farm size (effective ha)	204–4,000	1,205	874
Ewe flock size	920–17,461	4,702	3,919
Farmer-reported average mature ewe weight (kg)	54–77	66.4	4.8
Ewes per labour unit	511–2,910	1,502	584

Ewe hoggets were bred on 21/34 farms. Details on farm contour were obtained from 28 farms and were categorised as < 25% flat land (n = 9), 25–75% flat land (n = 9) and > 75% flat land (n = 10). Farm culling policies based on ewe age were available for 32 farms and were categorised based on the routine ewe age for culling as: < 6 years old (n = 7), 6 years old (n = 15), > 6 years old (n = 4), did not cull for age (n = 6). The between-flock mean replacement percentage was 29.2 (min 19.2, max 44.9, SD 5.0)%.

Summary statistics for ewe culling and mortality between breeding and mid-lactation

Overall, of the 155,164 ewes that were present at the start of breeding, 16,725 (10.8%) had exited their flock by mid-lactation. The between-flock mean percentage that exited during this time was 10.5 (SD 4.6)% (Table 2) due to either being non-pregnant and therefore culled (between-flock mean 3.3 (SD 2.4)%), culled for non-reproductive reasons (between-flock mean 1.7 (SD 2.5)%), or dead/missing (between-flock mean 5.5 (SD 2.9)%) (Table 2). Farmers reported that most of the ewes that were culled for non-reproductive reasons were due to low body condition score (BCS).

Summary statistics for wet-dry ewes and potential lambs lost per 100 ewes presented for breeding

Twenty-seven of the 34 farms reported data on ewes that survived to mid-lactation but did not rear any live lambs (wet-dry ewes). In addition to ewes exiting

Table 2. Range, mean and SD of ewe culling, mortality and selected reproductive parameters between breeding and mid-lactation for two-tooth and mixed-age ewes in 34 New Zealand sheep flocks enrolled in a survey to investigate the extent and drivers of ewe culling and mortality in 2021.

Parameter	Range	Mean	SD
Non-pregnant ewes (culled) (%)	0.6–12.2	3.3	2.4
Ewes culled for non-reproductive reasons (%)	0–9.5	1.7	2.5
Dead/missing ewes (%)	1.1–15.5	5.5	2.9
Total ewes exiting flock (culled or dead/missing)	2.4–21.7	10.5	4.6
Scanning percentage	115–216	171.4	17.8

these flocks due to culling and mortality between breeding and mid-lactation, a between-flock mean of 3.9 (min 0.4, max 9.1; SD 2.5)% of ewes that were diagnosed pregnant failed to rear any lambs (wet-dry). Considering these losses and their flock scanning percentages, for these 27 flocks this resulted in a between-flock mean of 23.1 (min 12.8, max 37.7; SD 6.3) potential lambs lost per 100 ewes presented for breeding.

Flocks varied in whether, and when, some or all wet-dry ewes were culled (Ridler *et al.* 2023) and most of this culling occurred in mid-lactation at docking/tailing. Eleven of the 27 flocks reported the number of ewes that were specifically culled for wet-dry with a between-flock mean of 4.0 (SD 2.3)% of ewes culled for this reason.

Summary statistics for the timing of ewe mortality and recording of dead ewes

Twenty-one flocks reported the number of dead ewes that were found. Of all ewes that died or went missing during the study period from these flocks, a between-flock mean of 65.2 (SD 28.7)% were recorded dead. Of the ewes that died or went missing between breeding and mid-lactation, a between-flock mean of 66.9 (SD 24.0)% occurred between set stocking and mid-lactation (i.e. during the lambing period).

Only four farms reported the suspected causes of death for ewes found dead, and this was only recorded during the period between pregnancy diagnosis and mid-to-late lactation. During this time the suspected cause of death was recorded for 192 ewes of which 55 (29%) were attributed to dystocia, 46 (24%) to unknown causes, 33 (17%) to poor body condition and the remainder to other causes such as vaginal prolapse, metabolic disorders and mastitis.

Univariable associations

Associations with the percentage of dead/missing ewes (mortality) between breeding and mid-lactation

There was an association with farm policy on culling at a fixed age and mortality between breeding and mid-lactation. Flocks that routinely culled ewes at > 6 years of age had higher dead/missing predicted mean percentages compared to those that did not cull for age, culled at 6 years of age, or culled at < 6 years of age (Table 3). There were no associations, however, between any of the other predictor variables and ewe mortality between breeding and mid-lactation.

Associations with the percentage of ewes exiting the flock between breeding and mid-lactation

Flocks in the Northern and Central SI region had a higher percentage of ewes exiting the flock compared with the Eastern NI region, but there were otherwise no differences between regions (Table 4). Farms with

Table 3. Unadjusted analyses showing the predicted mean (categorical variables) or beta coefficient (continuous variables) and associated 95% CI when the outcome variable was the percentage of ewes dead/missing between breeding and mid-lactation, from a study of 34 New Zealand sheep flocks to investigate the extent and drivers of ewe culling and mortality in 2021.

Variable	Predicted mean or beta coefficient[a]	95% CI	P-value[b]
Region			0.288
Eastern North Island	4.3	2.4–6.2	Reference
Northern North Island	5.7	3.5–7.9	0.339
Western North Island	4.2	0.1–8.2	0.943
Northern and Central South Island	5.5	3.6–7.2	0.389
Southern South Island	7.8	5.2–10.4	0.037
Farm size (ha)	−0.0001	−0.001 to 0.001	0.836
Flock size	−0.00002	−0.0003 to 0.0003	0.876
Ewes per labour unit	0.0003	−0.002 to 0.002	0.759
Mating period			
≤42 days	5.6	4.4–6.8	Reference
>42 days	5.1	3.0–7.2	0.679
Ewe weight	−0.087	−0.301 to 0.128	0.418
Scanning %	−0.032	−0.089 to 0.026	0.269
Replacement rate	−0.171	−0.387 to 0.044	0.115
Hogget breeding			
Yes	5.6	4.3–6.9	Reference
No	5.2	3.4–6.9	0.662
Contour			0.355
<25%	5.9	4.3–7.5	Reference
25–75%	4.3	2.7–5.9	0.166
>75%	4.8	3.2–6.3	0.311
Cull age			0.023
<6 years old	3.7	1.6–5.7	0.003
6 years old	5.5	4.0–6.9	0.024
>6 years old	9.0	6.3–11.7	Reference
Do not cull for age	4.7	2.5–6.9	0.016

[a]Continuous variables are presented as the beta coefficient (the increase in the dependent variable for one unit increase in the predictor), 95% CI and p-values. Categorical variables are presented as the predicted mean for each level of the respective categorical variable, 95% CI and p-values.
[b]Significance of the variable as a whole and for categorical variables with > 2 levels, the significance of each level of the variable within the model compared to the referent

Table 4. Unadjusted analyses showing the predicted mean (categorical variables) or beta coefficient (continuous variables) and associated 95% CI when the outcome variable was the percentage of ewes exiting the flock between breeding and mid-lactation, from a study of 34 New Zealand sheep flocks to investigate the extent and drivers of ewe culling and mortality in 2021.

Variable	Predicted mean or beta coefficient[a]	95% CI	P-value[b]
Region			0.144
Eastern North Island	8.0	5.0–11.0	Reference
Northern North Island	11.3	7.9–14.7	0.146
Western North Island	6.7	0.3–13.0	0.695
Northern and Central South Island	12.7	9.8–15.5	0.027
Southern South Island	11.5	7.5–15.5	0.161
Farm size (ha)	−0.0004	−0.002 to 0.001	0.655
Flock size	−0.0001	−0.0005 to 0.0003	0.664
Ewes per labour unit	0.0007	−0.002 to 0.004	0.632
Mating period			
≤42 days	11.3	9.4–13.1	Reference
>42 days	8.4	5.2–11.6	0.126
Ewe weight			
Scanning %	−0.145	−0.221 to −0.068	< 0.001
Replacement rate	−0.066	−0.417 to 0.285	0.702
Hogget breeding			
Yes	9.7	7.7–11.7	Reference
No	12.1	9.5–14.8	0.142
Contour			0.043
<25%	12.5	9.9–15.2	Reference
25–75%	7.8	5.2–10.5	0.015
>75%	9.2	6.7–11.7	0.070
Cull age			0.170
<6 years old	8.8	5.3–12.2	Reference
6 years old	10.7	8.3–13.2	0.346
>6 years old	14.7	10.1–19.2	0.043
Do not cull for age	8.7	5.1–12.6	0.965

[a]Continuous variables are presented as the beta coefficient (the increase in the dependent variable for one unit increase in the predictor), 95% CI. Categorical variables are presented as the predicted mean for each level of the respective categorical variable, 95% CI.
[b]Significance of the variable as a whole and for categorical variables with > 2 levels, the significance of each level of the variable within the model compared to the referent.

< 25% flat land had higher percentages of ewes exiting the flock compared with farms that had 25–75% flat land (Table 4). The higher the average ewe weight or flock scanning percentage the fewer ewes that exited the flock (Table 4). For every 10-kg increase in average ewe weight, there was a 3.7% decrease in the percentage of ewes exiting the flock. Similarly, for every 10% increase in scanning percentage, there was a 1.5% decrease in the percentage of ewes exiting the flock. Flocks that routinely culled ewes at > 6 years of age had higher percentages of ewes exiting the flock between breeding and mid-lactation compared to those that culled at < 6 years of age (Table 4).

Associations with the percentage of ewes at breeding that did not rear any live lambs

Farms with < 25% flat land had a higher percentage of ewes at breeding that did not rear a live lamb compared with farms with > 75% flat land and farms with 25–75% flat land (Table 5). Farmer-reported average mature ewe weight and scanning percentage were both significant (Table 5). For every 10-kg increase in average ewe weight, there was a 4.4% decrease in the percentage of ewes at breeding that did not rear a live lamb. Similarly, for every 10% increase in scanning percentage, there was a 1.8% decrease in the percentage of ewes at breeding that did not rear a lamb.

Association between percentage of dead/missing ewes over lambing and scanning percentage

There was a significant relationship between the scanning percentage and the percentage of dead/missing ewes that occurred over the lambing period (estimate 0.542; 95% CI = 0.062–1.022; p = 0.029). Flocks with higher scanning percentages had a greater percentage of ewe mortality (dead/missing) during the lambing period than at other times of the year. For every 10% increase in scanning percentage, there was a 5.4% increase in ewe mortality percentage occurring during the lambing period.

Relationship between potential predictor variables

Ewe age at culling and ewe replacement percentages

Flocks with a culling policy to routinely cull ewes at < 6 years of age had a higher mean replacement rate (32.4%; 95% CI = 28.6–36.3%) than those that routinely culled ewes at 6 years of age (27.4%; 95% CI = 24.5–30.3%; p = 0.041) but there were no differences with those that did not cull for age (30.0%; 95% CI = 25.4–34.6%; p = 0.419) or those who routinely culled at > 6 years of age (27.4%; 95% CI = 22.3–32.5%; p = 0.120).

Table 5. Unadjusted analyses showing the predicted mean (categorical variables) or beta coefficient (continuous variables) and associated 95% CI when the outcome variable was percentage of ewes presented for breeding that did not rear any live lambs, from a study of 34 New Zealand sheep flocks to investigate the extent and drivers of ewe culling and mortality in 2021.

Variable	Predicted mean or beta coefficient[a]	95% CI	P-value[b]
Region			0.550
Eastern North Island	12.4	9.0–15.7	Reference
Northern North Island	13.8	10.0–17.7	0.567
Western North Island	10.8	3.6–18.0	0.684
Northern and Central South Island	16.2	12.3–20.0	0.140
Southern South Island	13.9	6.7–21.0	0.704
Farm size (ha)	0.002	−0.0006 to 0.004	0.143
Flock size	0.0002	−0.0002 to 0.0007	0.327
Ewes per labour unit	0.001	−0.002 to 0.005	0.357
Mating period			
≤ 42 days	14.2	12.0–16.2	Reference
> 42 days	12.1	8.1–16.2	0.365
Ewe weight	−0.442	−0.819 to −0.065	0.023
Scanning %	−0.179	−0.255 to −0.104	< 0.0001
Replacement rate	0.061	−0.349 to 0.470	0.762
Hogget breeding			
Yes	12.4	10.1–14.7	Reference
No	15.9	12.9–18.9	0.071
Contour			0.004
<25%	17.7	14.7–20.8	Reference
25–75%	10.2	7.5–12.9	0.001
>75%	12.9	10.0–15.8	0.027
Cull age			0.590
<6 years old	12.6	7.9–17.3	Reference
6 years old	13.7	10.8–16.6	0.683
>6 years old	17.9	10.5–25.3	0.223
Do not cull for age	12.4	7.7–17.0	0.941

[a]Continuous variables are presented as the beta coefficient (the increase in the dependent variable for one unit increase in the predictor), 95% CI. Categorical variables are presented as the predicted mean for each level of the respective categorical variable, 95% CI.

[b]Significance of the variable as a whole and for categorical variables with > 2 levels, the significance of each level of the variable within the model compared to the referent.

Ewe live weight and scanning percentage

There was an association between scanning percentage and farmer-reported average ewe live weight such that flocks with heavier ewes had higher scanning percentages; for every 10% increase in scanning percentage, there was a 1.5-kg increase in average ewe weight (estimate 0.151 (95% CI = 0.070–0.231); $p < 0.001$).

Scanning percentage and percentage of ewes not pregnant

There was also an association between scanning percentage and percentage of ewes non-pregnant (estimate −0.070 (95% CI = −0.111 to −0.029); $p = 0.002$); for every 10% increase in scanning percentage, there was a 0.7% decrease in the percentage of ewes non-pregnant. There was no association between farmer-reported average ewe liveweight and the percentage of ewes non-pregnant ($p = 0.201$).

Multivariable model for percentage of ewes exiting the flock between breeding and mid-lactation

Due to the relationship between scanning percentage and farmer-reported average ewe weight, only one of these variables was included in the final multivariable model. Scanning percentage was offered into the model rather than ewe liveweight, as a scanning percentage was an accurate flock-level measure, whereas ewe weight was an estimated average ewe weight reported by the farmers that did not account for the distribution of ewe weights within the flock. When assessing variables for inclusion in a multivariable model predicting the percentage of ewes (of all ages) leaving the flock, only scanning percentage and farm contour were retained. The higher the flock scanning percentage, the lower the percentage of ewes that exited the flock early (beta coefficient for scanning percentage = −0.123 (95% CI −0.201 to −0.045); $p < 0.001$)). Farm contour (Figure 1) improved the fit of the model in terms of the R^2 value and visual assessment of residual diagnostic plots.

Summary statistics for reasons for ewe culling at or after weaning

Reasons for ewe culling at or after weaning

Culling data were collected during the main culling event, shortly after weaning, on 29/34 farms included in the study. Twenty of the 29 farms were visited by researchers during these ewe examinations and tallies were recorded by them; of these, seven were large farms on which ewes were examined for culling over multiple days and it was not possible for researchers to be present on-farm for the entirety of this time, so culling data of representative mixed-

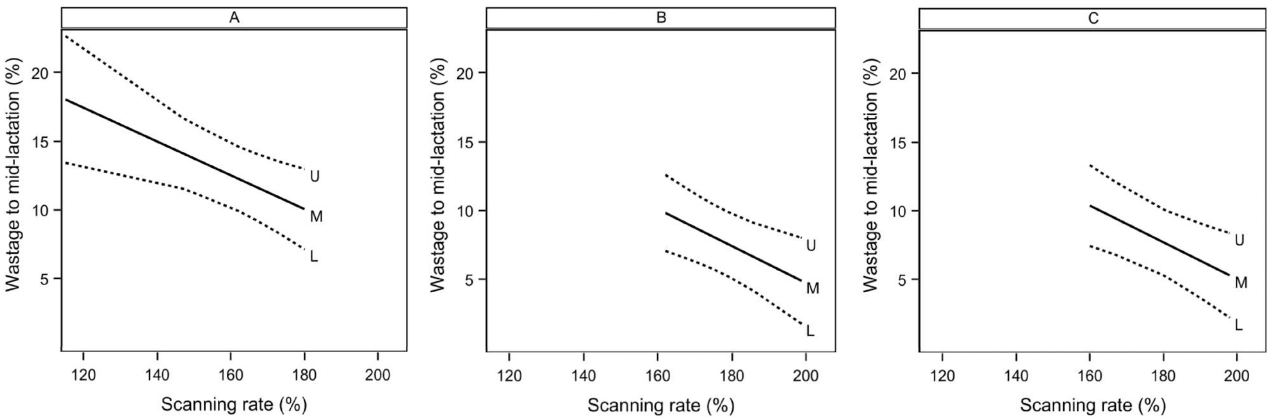

Figure 1. Predicted mean (M (solid black lines) and upper (U) and lower (L) CI (dashed lines)) percentage of ewes exiting their flocks between breeding and mid-lactation due to culling or dead/missing vs. scanning percentage from 34 New Zealand sheep flocks enrolled in a study of the extent and drivers of ewe culling and mortality in 2021. A) Farm contour comprising < 25% flat land; B) farm contour comprising 25–75% flat land; and C) farm contour comprising > 75% flat land.

age mobs were collected. On the remaining nine farms, the farmers recorded the information themselves using recording sheets provided by the researchers.

A total of 71,416 two-tooth and mixed-age ewes were examined at the main culling events and 10,983 (15.4%) ewes were selected for removal from the flocks and slaughtered or sold. The between-flock mean was 16.5 (min 4, max 38.7; SD 8.3)%.

For mixed-age ewes only, a total of 50,490 ewes from 22 flocks were examined. Age was the most common reason for their removal from the flock and a total of 2,849 (5.6%) ewes were culled for this reason. A between-flock mean of 6.3 (SD 6.6)% (Figure 2) of ewes were culled for age; however, six flocks did not cull any ewes for age and if these flocks were excluded then a between-flock mean of 8.6 (SD 6.2)% mixed-age ewes were culled for age in the remaining 16 flocks (37,913 ewes).

The next most common reason for culling mixed-age ewes was teeth defects, with a total of 1,867 (3.7%) ewes culled for this reason. A between-flock mean of 4.7 (SD 6.0)% were culled for teeth defects. A total of 1,248 (2.5%) ewes were culled for udder defects (between-flock mean 2.1 (SD 3.4)%), and 715 (1.4%) were culled for low BCS (between-flock mean 1.8 (SD 3.2)%). A between-flock mean of 1.1% or less was removed for each of feet defects, perceived

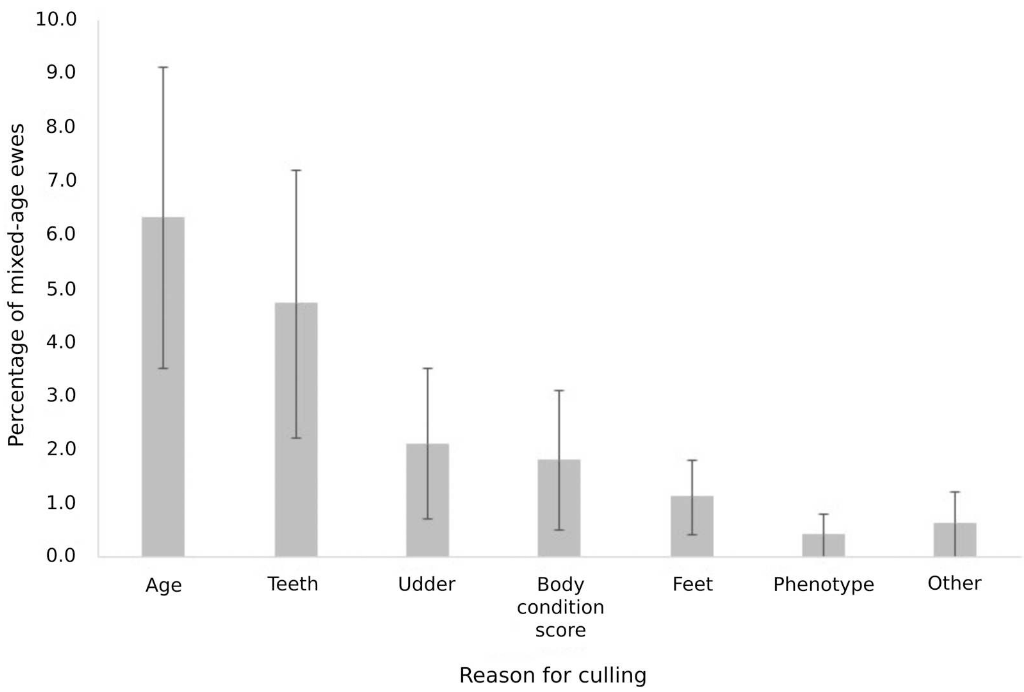

Figure 2. Unadjusted between-flock mean (and 95% CI) percentages of mixed-age ewes selected at weaning (summer) for culling and the associated reasons in 22 New Zealand sheep flocks (n = 50,490 ewes) enrolled in a survey to investigate the extent and drivers of ewe culling and mortality in 2021.

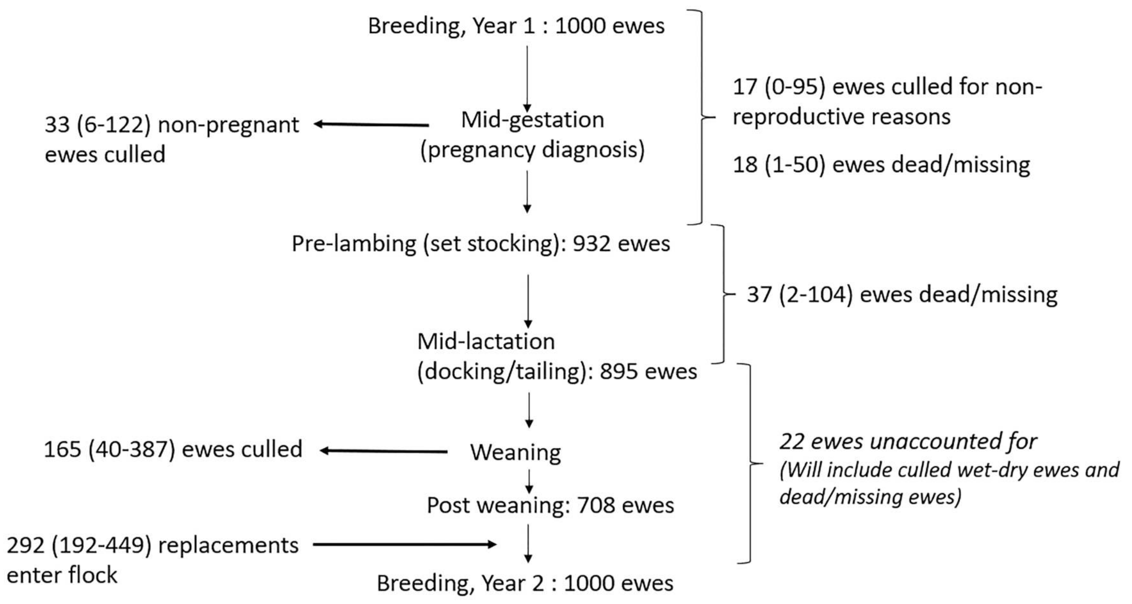

Figure 3. Flow diagram showing loss of ewes (two-tooth and mixed-age ewes combined) due to culling and dead/missing in a hypothetical New Zealand sheep flock based on 1,000 ewes and where flock numbers remain stable from year to year. Parameters are between-flock means (and ranges) and based on data obtained from 29 to 34 New Zealand sheep flocks enrolled in a survey to investigate the extent and drivers of ewe culling and mortality in 2021.

phenotype defects (type/looks/conformation), or other reasons (Figure 2).

Summary of ewe culling and mortality

Figure 3 depicts the loss of ewes from a flock over time, based on a flock of 1,000 two-tooth and mixed-age ewes. For the period between breeding and mid-lactation, this is based on the mean and range data for culling and mortality from the 34 flocks included in this study (Table 2). Additionally, the mean and range data for replacement rates and total ewes culled during the main culling event around weaning have been used to extrapolate the loss of ewes from mid-lactation to the next breeding period.

Discussion

The present study is the first to describe ewe culling and mortality in an appreciable number of New Zealand sheep flocks and, to our knowledge, is the only study to have gathered specific data on the percentages of ewes culled for particular reasons in New Zealand flocks. While it only focused on one production season, it did so with 34 flocks with diversity of farm and flock size, location, and contour. Overall, almost 11% of ewes that were retained for breeding, exited the flock by mid-lactation approximately 8 months later due to culling or mortality and therefore did not rear any lambs. In the 27 flocks that also reported data on ewes that remained in the flock to mid-lactation but failed to rear any lambs, this represented a between-flock mean loss of over 23 potential lambs per 100 ewes presented for breeding. There do not appear to be comparable overseas studies with which to compare these data, but the main saleable product for non-dairy sheep breeds is lamb sold for meat, and this loss of potential lambs therefore represents a substantial financial loss. There was, however, considerable variation between farms in the numbers and reasons for ewes exiting their flocks; identifying why and when ewes exit their flocks will thus facilitate the development of flock-specific interventions to reduce ewe culling and mortality.

Scanning percentage was associated with the percentage of ewes exiting the flock between breeding and mid-lactation, primarily because flocks with higher scanning percentages culled fewer ewes due to a failure to conceive. Strategies to maximise ewe conception rates are therefore recommended; for example, managing ewes to achieve a satisfactory pre-breeding BCS (reviewed by Kenyon *et al*. 2014), pre-breeding ram soundness examinations, and ensuring adequate ram-to-ewe ratios and mating-period lengths (reviewed by Ridler *et al*. 2012). Ewe BCS was not measured during this study but there are known associations between optimal BCS and increased scanning percentages (reviewed by Kenyon *et al.* 2014), while poor BCS is associated with increased culling and mortality (Flay *et al.* 2021, 2022, 2023). Additionally, in this study, most of the ewes contributing to the between-flock mean of 1.8% of ewes culled between breeding and mid-lactation (and therefore included in the model analysis) were culled due to poor BCS, and a further between-flock mean of 1.8% of ewes were culled shortly after weaning due to poor BCS. Therefore, flock management practices to optimise BCS are likely to reduce ewe culling and mortality.

Two-thirds of ewe mortality occurred during the lambing period, and ewes that died in flocks with high scanning percentages were more likely to do so during this time compared to flocks with lower scanning percentages; these findings are consistent with those of Flay *et al.* (2021, 2023). Limited farmer-reported data were obtained on suspected causes of ewe death over the lambing period, but dystocia was the most frequently reported followed by unknown causes. Similarly, dystocia and septicaemia were the most common causes of ewe death diagnosed by veterinarians during the lambing period on Australian sheep farms (McQuillan *et al.* 2021). In contrast, Capdevila-Ospina *et al.* (2021) reported becoming cast as the most important cause of death. To reduce ewe mortality, focusing on the lambing period is likely to be the most efficient approach and farm-specific causes of ewe death during this time should be identified to facilitate the development of targeted intervention strategies.

Farms with < 25% flat land (i.e. which were primarily comprised of hill country) had higher percentages of ewes exiting the flock, and ewes at breeding that failed to rear a lamb, compared with flatter farms. It has been reported that perinatal lamb mortality is greater for lambs born on slopes compared with those born on flatter land (Knight *et al.* 1989) and it is likely that there are other factors that accompany sloping land that may also influence ewe and lamb losses. It was perhaps surprising that, apart from farm contour, there were no associations between mortality percentages or the percentage of ewes exiting the flock between breeding and mid-lactation and the other selected broad-based demographic and management practices investigated (such as flock size, farm size, ewes per labour unit and hogget breeding policy). This suggests these parameters were primarily impacted by specific farm management practices that are likely to be variable and complex, and it was beyond the scope of this study to investigate these.

Dead/missing ewes accounted for more than half of the ewes that exited the flock between breeding and mid-lactation. Despite committing to reporting the number of dead ewes in their flocks, less than two-thirds of farmers in this study did so, and in those flocks, only 65% of ewes that were dead/missing were reported dead. Discrepancies in the number reported dead compared with those calculated as missing might be because some dead ewes were not found, they were found but farmers did not always record them, and/or there were inaccuracies in the tally data used to calculate the number of missing ewes. Previous authors have reported the difficulty in physically identifying all dead ewes on extensive commercial farms (Flay *et al.* 2022), even with intensive researcher monitoring (Capdevila-Ospina *et al.* 2021). Consequently, it is probable that many sheep farmers in New Zealand underestimate their ewe mortality rates, as has been demonstrated in Australia (Doyle 2023).

The replacement rates for the farms in this study were variable but averaged > 29%, which means a considerable number of young ewes must be kept to maintain flock numbers and results in a relatively young age structure of the flock. Younger ewes are known to be less productive than older ewes (Annett *et al.* 2011b; Edwards *et al.* 2015), although they are likely to have lower mortality rates (Flay *et al.* 2023), which could potentially offset some of the negative impacts of having a higher number of young ewes. The financial impacts of high replacement rates will vary depending on the sale price for cull ewes and lambs, or the cost of purchasing replacements, but a high proportion of young sheep in a flock has been shown to result in reduced cash profit (Farrell *et al.* 2019). In the present study, approximately half of these replacements were likely required to replace ewes culled during the main culling event after weaning. It is probable that many of these culling decisions were justified, but culling ewes for perceived faults that may not impact production, such as phenotype or treatable feet defects, may be wasteful (Ridler *et al.* 2023). Culling for age was the most common reason for mixed-age ewes to be removed at that time although not all flocks culled at a fixed age. It might be expected that flocks that did not have a policy of culling ewes at a fixed age, or that culled ewes at > 6 years old, would have a lower replacement rate than those that routinely culled ewes at ≤ 6 years of age. However, that was not found to be the case. This suggests that farmers who were not culling ewes based on age, or who kept older ewes, were still culling a similar number of ewes for various other reasons and that replacement rate cannot therefore be predicted by culling-for-age policies.

Perceived defects of the incisor teeth were also a common reason for culling at weaning, including in many flocks that routinely culled ewes at a fixed age, which represents a substantial loss of potentially otherwise productive ewes. There is a relative dearth of research into the causes, risk factors and impacts of incisor teeth defects in sheep (reviewed by McGregor 2011), and further research is warranted. The percentage of ewes culled for udder defects was similar to that described by Ridler *et al.* (2022) at weaning. In that study, it was identified that additional ewes developed defects in the 4–8 weeks after weaning and it is likely that if the farmers in the present study examined their ewes a second time, they would identify more ewes with udder defects.

This study only included data from 34 farms, and the method of enrolling participating farms via networks means that it was likely biased towards farmers who engage with rural professionals, have an interest in research and are proactive in keeping records. Additionally, the mean size of sheep and beef farms in New Zealand is 700 ha (Anonymous 2023b), considerably smaller than the mean of 1,205 effective ha in the present study. It is difficult to secure highly accurate data from farm-based studies such as the one reported here, and it is probable that there were many farm-specific factors that influenced ewe losses on individual farms that were not measured in this study. Therefore, caution must be applied if extrapolating these data to New Zealand sheep flocks more broadly.

In summary, this study has identified the magnitude, timing and causes of ewe culling and mortality in 34 New Zealand sheep flocks. These were variable between flocks, but the culling and mortality rates were often high, highlighting the scope for improvement. To reduce unnecessary culling and mortality, attention should be placed on maximising ewe conception rates, ensuring judicious culling decisions, optimising ewe BCS, and identifying farm-specific causes of ewe deaths over the lambing period to facilitate targeted intervention strategies.

Acknowledgements

The authors would like to express their thanks to the farmers for their participation in this study, and to Andy Greer, Chris Logan and the veterinarians and advisors who assisted with identifying participating farmers. This study was funded by the Massey-Lincoln and Agricultural Industry Trust, grant number 38030.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

AL Ridler http://orcid.org/0000-0002-5210-0578
RA Corner-Thomas http://orcid.org/0000-0002-7398-2653
PR Kenyon http://orcid.org/0000-0003-1131-0736
KJ Flay http://orcid.org/0000-0003-3770-3765

References

*__Anonymous__. *B + LNZ Regional Team*. https://beeflambnz.com/sites/default/files/2023-06/BLNZ-Regional-Map.pdf (accessed 21 November 2023). Beef + Lamb New Zealand, Wellington, NZ, 2023a

*__Anonymous__. *Sheep & Beef Farm Survey*. https://beeflambnz.com/industry-data/farm-data-and-industry-production/sheep-beef-farm-survey (accessed 12 September 2023). Beef + Lamb New Zealand, Wellington, NZ, 2023b

Annett RW, Carson AF, Dawson LER, Irwin D, Kilpatrick DJ. Effects of breed and age on the performance of crossbred hill ewes sourced from Scottish Blackface dams. *Animal* 5, 356–66, 2011a. https://doi.org/10.1017/S1751731110002090

Annett RW, Carson AF, Dawson LER, Irwin D, Gordon AW, Kilpatrick DJ. Comparison of the longevity and lifetime performance of Scottish Blackface ewes and their crosses within hill sheep flocks. *Animal* 5, 347–55, 2011b. https://doi.org/10.1017/S1751731110002107

Capdevila-Ospina K, Corner-Thomas RA, Flay KJ, Kenyon PR, Ridler AL. Factors associated with ewe death and casting in an extensively farmed sheep flock in New Zealand. *Ruminants* 1, 87–99, 2021. https://doi.org/10.3390/ruminants1020007

*__Doyle R.__ *Assessing and Addressing On-Farm Sheep Welfare*. https://www.mla.com.au/contentassets/561bfedc68b64acfae2b4314760133bd/b.aww.0237_final_report.pdf (accessed 20 November 2023). Meat and Livestock Australia, Sydney, Australia, 2023

Edwards SJ, Juengel JL, O'Connell AR, Johnstone PD, Farquhar PA, Davis GH. Attainment of puberty by ewes in the first year of life is associated with improved reproductive performance at 2 years of age. *Small Ruminant Research* 123, 118–23, 2015. https://doi.org/10.1016/j.smallrumres.2014.11.006

Farrell LJ, Tozer PR, Kenyon PR, Ramilan T, Cranston LM. The effect of ewe wastage in New Zealand sheep and beef farms on flock productivity and farm profitability. *Agricultural Systems* 174, 125–32, 2019. https://doi.org/10.1016/j.agsy.2019.04.013

Flay KJ, Ridler AL, Compton CWR, Kenyon PR. Ewe wastage in New Zealand commercial flocks: extent, timing, association with hogget reproductive outcomes and BCS. *Animals* 11, 779, 2021. https://doi.org/10.3390/ani11030779

Flay KJ, Ridler AL, Corner-Thomas RA, Kenyon PR. Ewe wastage in commercial sheep flocks: a review of current knowledge. *New Zealand Veterinary Journal* 70, 187–97, 2022. https://doi.org/10.1080/00480169.2022.2032446

Flay KJ, Chen AS, Yang DA, Kenyon PR, Ridler AL. Identification of risk factors for ewe mortality during the pregnancy and lambing period in extensively managed flocks. *BMC Veterinary Research* 19, 257, 2023. https://doi.org/10.1186/s12917-023-03822-x

Griffiths KJ, Ridler AL, Heuer C, Corner-Thomas RA, Kenyon PR. The effect of liveweight and body condition score on the ability of ewe lambs to successfully rear their offspring. *Small Ruminant Research* 145, 130–5, 2016. https://doi.org/10.1016/j.smallrumres.2016.11.001

Kenyon PR, Maloney SK, Blache D. Review of sheep body condition score in relation to production characteristics. *New Zealand Journal of Agricultural Research* 57, 38–64, 2014. https://doi.org/10.1080/00288233.2013.857698

Knight TW, McMillan WH, Kilgour R, Hockey H-UP, Hall DRH. Effect of slope of lambing site on lambs slipping and lamb mortality. *New Zealand Journal of Agricultural Research* 32, 199–206, 1989. https://doi.org/10.1080/00288233.1989.10423454

McGregor BA. Incisor development, wear and loss in sheep and their impact on ewe production, longevity and economics: a review. *Small Ruminant Research* 95, 79–87, 2011. https://doi.org/10.1016/j.smallrumres.2010.11.012

McLaren A, McHugh N, Lambe NR, Pabiou T, Wall E, Boman IA. Factors affecting ewe longevity on sheep farms in three European countries. *Small Ruminant*

Research 189, 106145, 2020. https://doi.org/10.1016/j.smallrumres.2020.106145

***McQuillan M, Glanville E, Jacobsen C, Sherriff L, Whale A.** Unlocking the keys to ewe survival. *Proceedings of the 2021 Sheep, Camelid and Goat Veterinarians Conference*. Pp 48–50, 2021

Mekkawy W, Roehe R, Lewise RM, Davies MH, Bunger L, Simm G, Haresign W. Genetic relationship between longevity and objectively or subjectively assessed performance traits in sheep using linear censored models. *Journal of Animal Science* 87, 3482–9, 2009. https://doi.org/10.2527/jas.2008-1398

Ridler AL, Smith SL, West DM. Ram and buck management. *Animal Reproduction Science* 130, 180–3, 2012. https://doi.org/10.1016/j.anireprosci.2012.01.012

Ridler AL, Rout-Brown G, Flay KJ, Velathanthiri N, Grinberg A. Defects and bacterial pathogens in udders of non-dairy breed ewes from New Zealand. *New Zealand Journal of Agricultural Research* 65, 163–71, 2022. https://doi.org/10.1080/00288233.2021.1905005

Ridler AL, Kenyon PR, Greer A, Logan C, Morgan S, Corner-Thomas RA. Ewe culling in New Zealand: an interview study of 38 sheep farmers. *New Zealand Journal of Agricultural Research* 67, 361–71, 2023. https://doi.org/10.1080/00288233.2023.2280624

Wishart HM, Lambe NR, Morgan-Davies C, Waterhouse A. Which traits best predict ewe performance and survival the following year on a UK hill farm? *Proceedings of the New Zealand Society of Animal Production* 76, 159–62, 2016

*Non-peer-reviewed