

New South Wales sheep producers' perceptions regarding lamb mortality and the adoption of pregnancy scanning

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ABSTRACT

Context. Proven strategies to address lamb mortality include pregnancy scanning and the differential management of single- and twin-bearing ewes. However, current adoption rates of this best-practice management by Australian producers remain low at ~20%. **Aims.** We explored producer perceptions about lamb mortality and the adoption of pregnancy scanning, and analysed whether producer characteristics, demographics, beliefs or management practices have an influence on perceptions towards pregnancy scanning or lamb survival. **Methods.** Data were collected through an on-line self-administered survey of lamb producers in New South Wales, Australia. Descriptive and inferential statistics were used to summarise the data and test for interdependence of variables. **Key results.** The survey results revealed that New South Wales sheep producers have low participation rates in extension programs and low engagement in record-keeping practices. Only 4% of respondents considered current lamb mortality rates acceptable and the majority agreed that lamb mortality poses a threat to Australia's sheep industry. Findings identified numerous significant relationships between producer characteristics, demographics, beliefs, management practices, non-participation in extension programs, and perceptions towards pregnancy scanning, lamb mortality and sheep welfare. Survey participants were more likely to have adopted pregnancy scanning if they had participated in extension programs. **Conclusions.** Further extension efforts should be focused on producers who have not adopted any record-keeping practices or previously participated in extension programs. Extension should be tailored to different enterprises, owing to the influence of enterprise focus on beliefs, while also considering producer demographics. **Implications.** A strong case exists for continued investment in future marketing, education, and research, development and extension to increase the capacity of Australia's sheep industry and, in particular, to increase the adoption of pregnancy scanning.

Keywords: adoption, extension, lamb mortality, perceptions, pregnancy scanning, research and development, sheep producers, sheep welfare.

Introduction

Lamb mortality continues to be an issue of concern for the Australian sheep industry. In addition to the economic costs of lost production, high lamb mortality rates are associated with negative consumer perceptions about industry animal welfare standards (Doughty *et al.* 2017). Perinatal lamb mortality rates in Australia of 10% for singletons and 30% for twins are typical but can range between 5% and 70% (Hinch and Brien 2014; Allworth *et al.* 2017). Lamb mortality typically occurs within the first week of life and is attributed to numerous factors, the most prevalent being low birthweight, dystocia, starvation, mismothering, exposure and predation (Dwyer *et al.* 2003; Hinch and Brien 2014). Strategies to increase lamb survival include reducing mob size and stocking density, managing nutrition, providing shelter and exploiting genetic selection (Hinch and Brien 2014; Allworth *et al.* 2017; Behrendt *et al.* 2019; Lockwood *et al.* 2019, 2020). The effectiveness of these strategies has potential to be increased through the use of pregnancy scanning.

Preferential management of dry, single- and twin-bearing ewes allows producers to allocate feed and resources efficiently (Allworth *et al.* 2017). Additionally, survival of twin lambs can be improved by allocating sheltered paddocks and reducing mob size (Young *et al.* 2011), which maximises production and profit. Howard and Beattie (2018) reported that just 31% of producers surveyed were pregnancy-scanning for litter size. Hence, the potential to increase lamb survival is substantial and would seem vital in maintaining the social licence of the Australian sheep industry.

The low pregnancy scanning rates across Australia are attributed to the inability of some producers to assess accurately the true levels of lamb losses and recognise the control they have over lamb survival, doubts about the benefits of scanning, mixed messages from consultants, incompatibility with current production systems, and lack of evidence on the profitability of scanning (Elliott *et al.* 2011; Kubeil 2017; Howard and Beattie 2018). However, little is known about whether producer characteristics, demographics, beliefs or management circumstances have an influence on different perceptions towards pregnancy scanning or lamb survival.

The present study delves into producers' principal beliefs regarding lamb survival and connects these beliefs with on-farm practices. Of particular interest is the nexus between producers' participation in extension programs and their beliefs regarding lamb mortality. Extension is the critical link in building sustained industry capacity and resilience (Vanclay 2004; Sheng *et al.* 2011; Hunt *et al.* 2014). However, as noted by Curnow *et al.* (2011), it tends to target the most progressive producers and relies on voluntary recruitment. As such, it is unlikely to transfer knowledge to the wider farming population, which renders low rates of adoption.

The focus in this study is on sheep producers in New South Wales (NSW), which has the highest rates of pregnancy scanning of all Australian states. For this reason, the perceptions gained from NSW sheep producers should provide more valuable insights into barriers restricting adoption than similar research in other states (Kubeil 2017; Howard and Beattie 2018).

Methods

Data were collected through an anonymous online survey created using Qualtrics XM (Qualtrics, Provo, Utah). The survey link was distributed by NSW Local Land Services, The Farm Table and Sheep Connect NSW via e-newsletters and Facebook pages. The survey questionnaire was approved by the University of New England Human Research Ethics Committee (Approval Number HE19-176). Data collection began on 26 August 2019 and ceased on 30 December 2019, with 57 responses in total recorded. The survey was structured in three main sections and consisted of both closed and open-ended questions. Likert-scale responses

were used for questions regarding producer beliefs and attitudes (Likert 1932). A brief description of each survey section is provided below.

Production characteristics and demographics

The questions in the first section of the survey were aimed at collecting demographic and economic information about the respondents and the types of sheep production enterprises managed. General demographic questions included gender, age and education level. Production characteristic questions gathered information on the type of sheep production enterprise, main enterprise type, number and breed of sheep managed, property size, and gross value of annual production. Also included in this section were questions about average lamb marking percentages, average twinning percentages, the extent of record keeping, use of Australian Sheep Breeding Values (ASBVs) to select breeding stock, recent participation in extension programs, and beliefs regarding acceptable lamb marking rates for Merino and non-Merino sheep. The information provided in this section provides a platform to analyse how key demographic and economic information may influence decisions or beliefs regarding lamb mortality, welfare or pregnancy scanning, covered in later sections of the survey.

Lamb mortality

The second section of the survey comprised a series of questions regarding respondents' beliefs about the costs and benefits of pregnancy scanning, views on current rates of lamb mortality in Australia, and whether increasing lamb survival was a production goal. Furthermore, respondents' perceptions of their control over lamb mortality were considered through a series of questions regarding the inevitability of lamb mortality, confidence in providing adequate nutrition, and whether nutrition was considered to affect lamb mortality. Welfare considerations were also addressed in this section, with respondents asked whether high levels of lamb mortality and insufficient nutrition are breaches of animal welfare legislation. Similarly, the impact of lamb mortality at the industry level was investigated with respondents questioned about whether they considered lamb mortality to be a threat to Australia's sheep and wool industry, and in particular whether they considered activism on lamb mortality a threat if there was no improvement in current Australian lamb mortality rates.

Adoption/non-adoption of pregnancy scanning

The third section of the survey split respondents into two categories depending on their use of pregnancy scanning. Respondents who utilise pregnancy scanning were asked a series of questions focused on why they undertake scanning and what they do with the flock information gathered from

scanning. Respondents who did not use pregnancy scanning were asked a series of questions regarding the reasons for not implementing the management practice and what would entice them to consider adopting the practice.

Statistical analyses

Any outliers in the survey data were removed prior to analysis. Descriptive statistics were used to summarise the data, and chi-square tests for interdependence were used to identify statistically significant relationships between variables.

Results

Production characteristics and demographics

The total number of participants in the survey was 57, with the gender breakdown of respondents being approximately equal. This gender split is not representative of farm ownership in Australia. Australian Bureau of Statistics (2018–19) data indicate that 77% of Australian farmers are male. Hence, it is likely that a degree of bias exists in the survey responses, which is consistent with the conclusion of

Smith (2008) that women are more likely to self-select in online survey participation. Almost three-quarters of respondents were aged 45 years and older. Nearly 80% of respondents identified themselves as the property owner and 11% as occupying a manager's role. Only 45% of producers indicated that they have participated in extension programs within the past 5 years. Of the extension programs listed, Lifetime Ewe Management was the most popular, with 75% of participating respondents having completed the course, followed by the Making More from Sheep program (50%). Fewer than 30% of producers had completed other extension programs (Bred Well Fed Well, Lambs Alive, Winning with Weaners, Grazing for Profit, Business Edge).

The locations of sheep producers participating in the survey were widespread, with 41 postcodes identified across New South Wales (Fig. 1).

The majority of sheep production was conducted on properties 400–4999 ha in size, with 96% occurring on privately owned land. Livestock was selected as the business focus for 91% of respondents, with sheep (wool production) selected as the main enterprise for the majority of those respondents. Within the sample, 25% of respondents indicated they do not run any Merino sheep and 36% indicated that they run only Merino sheep, with the remainder of respondents

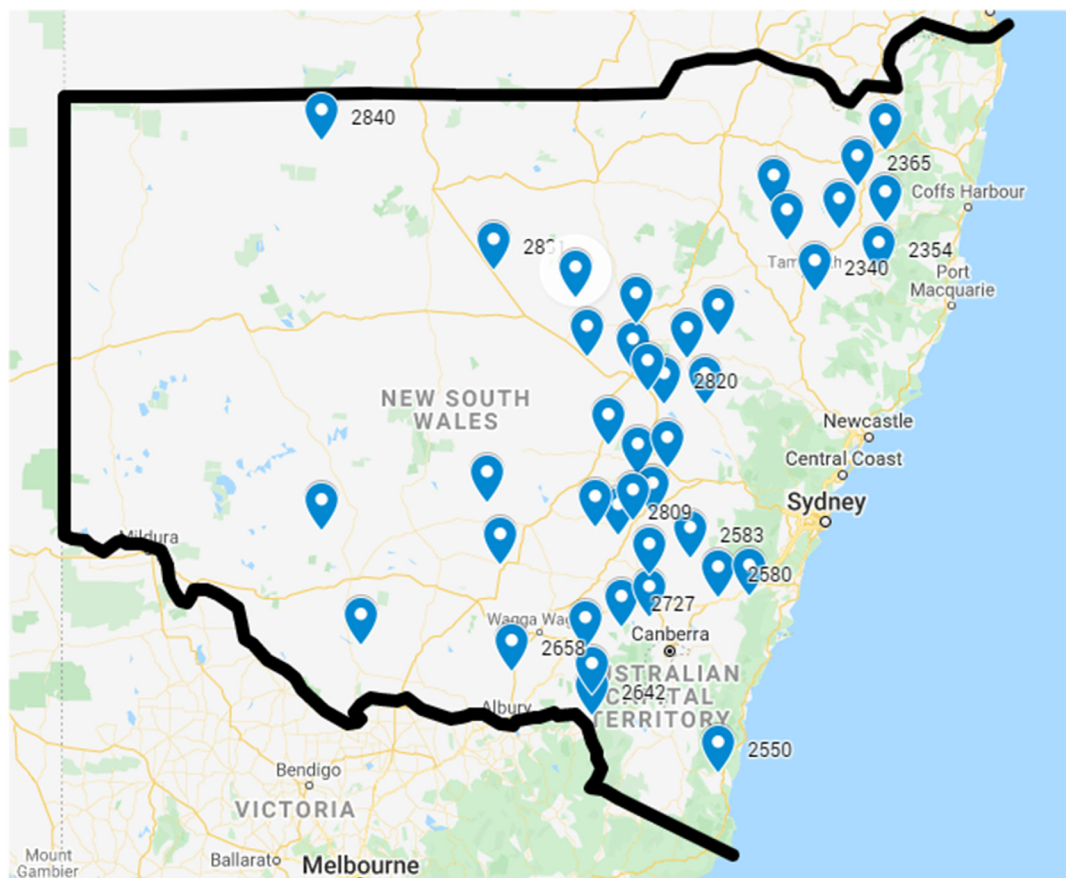


Fig. 1. Geographical distribution of survey participants ($n = 57$).

running a mixed flock of Merinos and non-Merinos including first-cross ewes, White Suffolk and Australian Whites.

One-third of respondents indicated they do not record ewe mortality or wet/dry ewes at lamb marking, which can potentially prevent the identification of issues such as reproductive inefficiency. Approximately 20% of producers reported average lamb marking percentages of 91–100%, whereas 50% reported average lamb marking percentages of 101–150%. National lamb marking rates reported by Meat and Livestock Australia (2019) were 82% for Merinos and 108% for non-Merinos. The somewhat higher percentages reported by respondents in this study suggests that some producers may be overestimating lamb marking and lamb survival rates, which corresponds with conclusions found in other studies (Kubeil 2017; Munoz *et al.* 2019; Kopp *et al.* 2020). Lamb marking percentages reported by respondents are presented in Table 1.

Approximately 45% of respondents specified that they do not utilise ASBVs when selecting breeding stock. This low percentage suggests substantial opportunity to increase national productivity through additional adoption, as noted by Hatcher *et al.* (2010). Of the producers that do use ASBVs, the five most important traits were considered to be eye muscle depth, fibre diameter, weaning weight, clean fleece weight and fat depth. Approximately 30% of these producers considered fat to be an important trait for breeding stock, a result that supports the principle that selection for fat has the potential to increase ewe body condition and lamb survival (Walkom *et al.* 2016).

Lamb mortality

The three most significant benefits of pregnancy scanning identified by respondents were management to increase

lamb survival, targeted feed management and increased fertility through culling of dry ewes (Fig. 2). The most significant costs of pregnancy scanning identified by respondents were grazing management conflicts, scanning costs per ewe, infrastructure investment, and the planning and implementation of differential management (Fig. 3). This is not surprising and highlights the investment in infrastructure and time to which producers must be willing to commit (Howard and Beattie 2018). Furthermore, producers may not see the benefit of adoption of scanning in the short-term, and this can alter their perception of the net benefit (Pannell *et al.* 2006; Elliott *et al.* 2011). Per-ewe scanning cost was the second most recorded cost of scanning, which was also recognised by Munoz *et al.* (2019). However, the per-ewe cost of scanning has been shown to have little impact on the profitability of scanning and is considered unlikely to impede adoption (Young 2008; Young *et al.* 2016). The results of the survey challenge that assumption, and highlight that producers do tend to focus on the upfront costs, which signifies that an opportunity exists for further education on the long-term cost-benefit analysis of scanning and differential management.

Although respondents estimated their lamb marking percentages to be above the Australian average, the majority of producers are still actively seeking to improve their lamb survival rates. For Merino enterprises, only 51% of respondents believed the acceptable lamb marking percentage to be >100%. This contrasts with prime lamb enterprises, where 94% of respondents considered the acceptable lamb marking percentage to be >100%. Almost 90% agreed that some lamb losses are inevitable despite unconstrained management, highlighting the lack of control producers perceive that they have over lamb mortality. These results support existing literature showing that producers have a

Table 1. Reported lamb marking percentages by scanning status for Merino and non-Merino enterprises.

	Lamb marking percentage					
	≤60%	61–70%	71–80%	81–90%	91–100%	101–150%
No scanning						
Merino enterprise (<i>n</i> = 6)	50%	–	–	50%	–	–
Non-Merino enterprise (<i>n</i> = 6)	–	–	–	33%	33%	33%
Scan only in bad years						
Merino enterprise (–)	–	–	–	–	–	–
Non-Merino enterprise (<i>n</i> = 2)	–	–	–	–	100%	–
Scan for pregnancy status only						
Merino enterprise (<i>n</i> = 3)	–	–	100%	–	–	–
Non-Merino enterprise (<i>n</i> = 4)	–	–	–	–	50%	50%
Scan for singles/twins						
Merino enterprise (<i>n</i> = 29)	–	–	14%	31%	55%	–
Non-Merino enterprise (<i>n</i> = 22)	–	–	–	9%	68%	23%

Data presented as the number of lambs marked per 100 ewes joined (maiden and adult ewes).

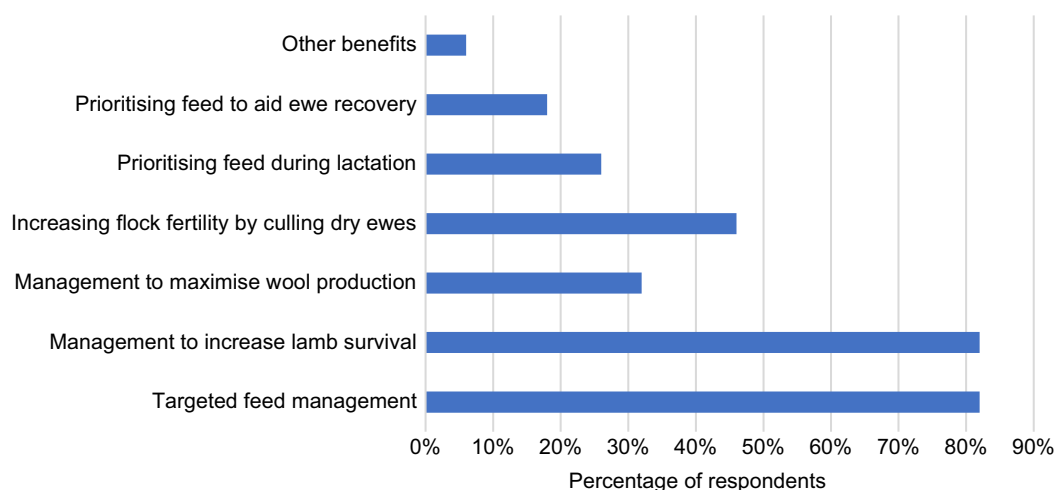


Fig. 2. Benefits of pregnancy scanning as selected by respondents.

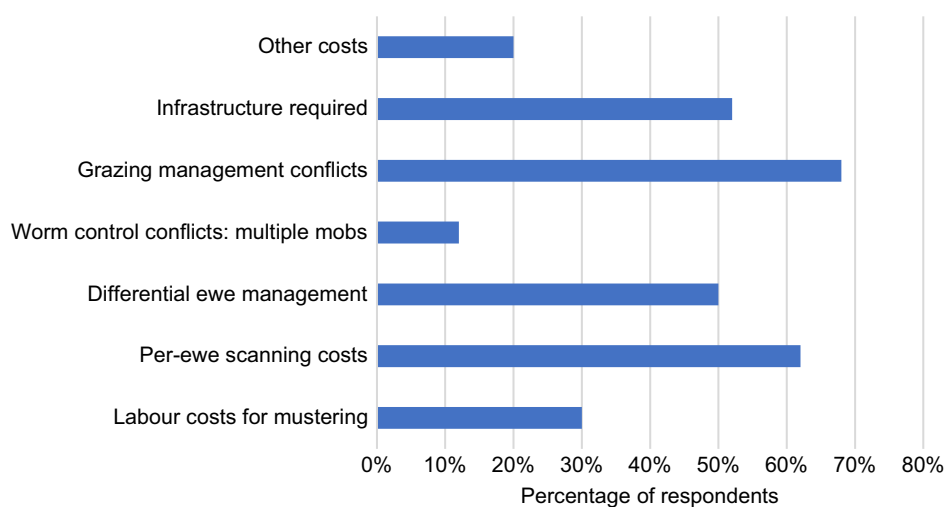


Fig. 3. Costs of pregnancy scanning as selected by respondents.

positive attitude towards increasing lamb survival but their management behaviours are influenced by perceptions of control (Elliott *et al.* 2011; Munoz *et al.* 2019). The majority of producers also indicated that they are wanting to increase their twinning percentage. Given that 75% of respondents run Merino sheep, these results contradict previous research findings suggesting that Merino producers generally perceive twins to be a nuisance (Elliott *et al.* 2011; Kubeil 2017).

All respondents agreed that nutrition is important for both ewe and lamb survival during pregnancy, and the majority indicated an understanding of nutritional effects on maternal behaviour and the nutritional requirements of single- and twin-bearing ewes. Furthermore, 82% of respondents identified that they were confident in providing adequate nutrition to pregnant and lactating ewes.

Only 4% of respondents agreed that Australia's lamb mortality rates are acceptable, with 62% considering lamb

mortality to be a threat to the future of the Australian sheep industry. Similarly, 68% considered that activism from animal welfare groups regarding lamb mortality could become evident into the future. Hence, most respondents recognised the potential threat to the industry's social licence and are actively seeking to improve their survival rates. However, beliefs about lamb welfare were ambiguous, with only 46% of respondents considering lamb mortality from birth to weaning to be an animal welfare issue (22% had a neutral response and 32% disagreed). By contrast, 66% of respondents agreed that not providing pregnant ewes with adequate nutrition is a breach of the Australian animal welfare guidelines. This difference in beliefs regarding ewe and lamb welfare could be due to perceived lack of control of lamb mortality compared with providing ewes with adequate nutrition (Elliott *et al.* 2011). Producer beliefs regarding the welfare of ewes and lambs are of considerable importance

owing to increasing public awareness and the influence of social licence. Yang and Renwick (2019) found that consumers are willing to pay more for livestock products with high-quality credence attributes (e.g. animal welfare). A surprising finding was that despite their beliefs towards the level of lamb mortality in Australia, only 28% of respondents felt pressured to increase their lamb survival rates. Of these, 79% perceived the pressure to stem from increasing profitability and only 29% from the threat of welfare implications, indicating that profit is the main motivating factor.

Adoption/non-adoption of pregnancy scanning

The survey results regarding the use of pregnancy scanning are presented in Fig. 4, which shows that 70% of respondents indicated that they scan for pregnancy status and litter size. The 10% who scan for pregnancy status alone and the 4% who only scan in bad years represent partial adopters. Previous research indicates that the adoption rate of scanning for pregnancy status and litter size across Australia is low, at 26% (Kubeil 2017; Howard and Beattie 2018); therefore, the survey sample may not be an accurate representation of the true NSW sheep producer population. However, the results still allow for useful insights into producer beliefs regarding sheep management.

Of the respondents who do implement pregnancy scanning, 78% indicated that they managed ewes separately according to energy requirements. The remaining 22% of producers who do not implement differential management may choose not to do so because the characteristics of their production systems render the costs of adoption greater than the benefits. For example, producers with systems lacking infrastructure such as sufficient paddocks to manage twin/single-bearing ewes differentially may perceive the costs of additional fencing to outweigh the benefits from differential management. Scanning but not differentially managing ewes may be seen as a way to break down full

adoption of recommended practices, allowing producers to manage their adoption and not be overwhelmed by significant change. However, the issue here is that unless completely adopted, the benefits of scanning and differential management cannot be attained. Without attaining benefits through partial adoption, it is also unlikely further investment in adoption will occur (Vancley 2004). Therefore, the reasoning behind partial adoption warrants additional investigation.

Approximately 93% of respondents indicated that they implement scanning to maximise lamb survival, allocate resources such as feed, and identify dry ewes. However, 41% of respondents recorded a neutral response when asked if they pregnancy-scan to aid post-weaning ewe recovery. This lower usage may indicate that another husbandry practice such as condition scoring is used at weaning to allocate resources rather than the initial scanning and subsequent allocation of lambing mobs. However, this result could also indicate that producers do not fully understand that twin-bearing ewes lose a greater amount of condition during lactation and thus require differential management to recover condition prior to re-joining. A neutral response was recorded by the majority of producers when asked whether they utilise pregnancy scanning to maximise wool production. Given that the majority of producers indicated that their main enterprise was wool production, this result is surprising. The high neutral response rate suggests a lack of thorough understanding of nutritional effects on ewe and progeny wool-production potential (Kelly *et al.* 2006; Behrendt *et al.* 2011; Edwards *et al.* 2011). Other key reasons nominated for implementing scanning included: identification of early and late lambs, benchmarking survival rates, and improving sales options by knowing the pregnancy status of sale ewes.

Most respondents (90%) agreed that scanning was profitable; 77% agreed that all producers should utilise the practice; and, despite the costs and commitment required in the differential management of ewes, 66% of producers disagreed that differential management was complicated. Only eight producers indicated they did not pregnancy-scan their flock and, of these, just five completed the survey. Nonetheless, some interesting findings emerged. Non-scanners seemed to be satisfied with their lamb survival rates, a finding that Kubeil (2017) suggested could be due to lack of data recording and recognition of the true levels of lamb mortality. Non-scanners also did not consider required management infrastructure to be an impediment to adoption, nor was the social impact of other local successful producers who do not scan an influence on their decisions. Conflicting responses were given by non-scanners regarding the profitability of scanning, suggesting that scope exists for increased awareness and education about the benefits of scanning for increased lamb survival percentages and increased profitability. Additional reasons given for non-adoption included having a low percentage of dry ewes, having a small mob size, the

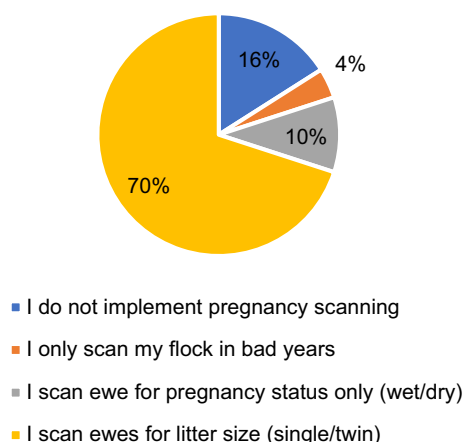


Fig. 4. Use of pregnancy scanning.

ease of low input for single mob management, unknown benefits of scanning implementation, and the belief that the 'wet and dry' technique is of greater benefit. The low percentage of dry ewes reasoning is economically sound; Young (2008) concluded that there was negligible net financial benefit from implementing scanning if the proportion of dry ewes in a flock was <5%. However, given that not all producers are motivated by financial incentives, the other benefits of implementing pregnancy scanning for multiples, including increased ewe and lamb welfare and wool production, are also likely to be of significance to producers whose flocks have a low percentage of dry ewes (Vanclay 2004; Edwards *et al.* 2011; Elliott *et al.* 2011; Trompf 2019).

Further open-ended questions revealed that respondents would consider implementing scanning if they purchased ewes with unknown mothering ability, if they had to downsize their flock, or if their lamb marking percentage dropped considerably. Furthermore, one respondent stressed that family pressure prevented the adoption of pregnancy scanning and that finding the right advice was difficult without willing participation in extension events.

Chi-square tests for independence

Responses from the survey were analysed using chi-square tests for independence to determine whether statistically significant relationships exist among producer demographics, their beliefs regarding lamb mortality, sheep management, their participation in extension programs, and their beliefs regarding pregnancy scanning. The majority of survey questions had five Likert-scale category answers: strongly agree, agree, neutral, disagree, strongly disagree. In view of the moderate completion rate of the survey ($n = 57$), some response categories were combined or removed to strengthen the statistical power of the tests. Combined categories

included strongly agree with agree, and strongly disagree with disagree. Where categories could not be combined, the statistical power of the chi-square tests is likely to be low because of the low expected frequencies. These results with violation of the frequency assumption are indicated in the tabulated data. In the interest of brevity statistically insignificant relationships are not presented in the following tables; however, unexpected results are discussed.

The producer demographic variables used in the tests were age, gender, education level, gross annual income, participation in an extension program in the past 5 years, main enterprise, and average number of Merino sheep. The results of the chi-square tests presented in Table 2 indicate the relationship between the belief of an acceptable lamb marking percentage for a Merino enterprise in an average year and the main enterprise was significant, suggesting that a focus on different enterprises (wool, meat or dual purpose) influences a producer's belief of the acceptable lamb marking rate. Knowledge of this relationship is important for future consultation with producers from different enterprise focuses, to ensure that information is effectively targeted in a way that matches their beliefs.

The relationship between the belief that Australia's lamb mortality rates are acceptable and participation in extension in the past 5 years (Table 2) indicates that producers participating in extension are more aware of the extent of the lamb mortality issue. Furthermore, the chi-square test results support previous findings that higher levels of skill and education increase innovative capacity in the agricultural sector (Sheng *et al.* 2011).

Dependent relationships were found between respondent age and gender and the belief that differential ewe management is complicated. These relationships support previous studies showing that background factors such as age influence producer attitudes towards management practices

Table 2. Relationships between producer demographic variables and producers' beliefs regarding lamb mortality, sheep management and pregnancy scanning.

Belief variable	Demographic variable	P-value
Acceptable Merino lamb marking percentage in an average year	Main enterprise	0.098fv
Belief that Australia's lamb mortality rates are acceptable	Participation in an extension program in the past 5 years	0.066fv
Belief that differential ewe management is complicated	Age	0.067fv
	Gender	0.072fv
	Gross annual income	0.047fv
Belief that providing insufficient nutrition to ewes is/is not a welfare breach	Education level	0.074fv
	Main enterprise	0.020fv
	Gross annual income	0.059fv
Belief about whether lamb mortality is an animal welfare issue	Gender	0.055
Belief that all sheep producers should utilise pregnancy scanning	Gross annual income	0.055fv
	Participation in an extension program in the past 5 years	0.029fv

fv denotes violation of the frequency assumption, suggesting that the statistical power of the test is low.

(Pignatti *et al.* 2015; Munoz *et al.* 2019). A dependent relationship was also found between gross annual income and the belief that differential ewe management is complicated, which suggests that as gross income levels rise, producers perceive differential ewe management to be less complex. A plausible explanation is that producers with large numbers of sheep are able to manage multiple mobs effectively because they readily perceive the monetary benefit associated with the management practice.

The test results also indicate that the main type of enterprise has an influence on beliefs regarding ewe welfare, with a lower percentage of wool-focused producers agreeing that failing to provide pregnant ewes with adequate nutrition was a breach of Australian animal welfare guidelines than producers with a prime-lamb or dual-purpose focus. This reinforces the view that enterprise focus influences producer beliefs, with wool producers less concerned about mortality and welfare than producers of other enterprise focus. This finding also emphasises that targeting of enterprise-specific information is likely to be more successful. Furthermore, dependent relationships were identified between education level and annual gross production income and beliefs regarding ewe welfare. Munoz *et al.* (2019) also found that ewe welfare was not compromised with increased farm size and that producer education level was correlated with animal welfare outcomes.

The relationship between gender and beliefs regarding lamb welfare reinforces the conclusions of Doughty *et al.* (2017) that gender plays an important role in perceptions of animal welfare and that women tend to express greater concern over sheep welfare. However, in the present study, a greater proportion of male respondents compared to female respondents agreed that lamb mortality is an animal welfare issue, and this result is likely due to the fact that the majority of Australian farmers are male (Australian Bureau of Agricultural and Resource Economics and Sciences 2018).

Gross annual income and participation in an extension program in the past 5 years were both found to influence the belief that all producers should utilise pregnancy scanning. These outcomes indicate that a certain scale of enterprise is required for effective and efficient utilisation of the management practice (Young 2008; Edwards *et al.* 2011; Young *et al.* 2016; Allworth *et al.* 2017), and that producers who have recently participated in extension programs are likely to have a higher degree of knowledge and are better able to understand the universal benefits of pregnancy scanning. Bagheri *et al.* (2019) reached a similar conclusion that knowledge impacts perceived behavioural control over management outcomes and, therefore, implementation of management practices. Both of these results lend support to the success of recent extension activities in promoting the universal applicability of pregnancy scanning across enterprises, production situations and income levels, which is a positive result for the industry.

In terms of lamb mortality, there was no evidence of relationships between any of the demographic variables and the beliefs that activism arising from lamb mortality could be evident in the future, that lamb mortality poses a threat to the sheep industry, or that producers felt pressure to increase lamb survival. These findings are a little surprising given that other authors (e.g. Munoz *et al.* 2019) have indicated the existence of relationships between demographic or background factors and farmer attitudes.

Producers were found not to be influenced by the practices of other producers in their use of pregnancy scanning. This conclusion diverges from existing literature that suggests an important role of social influence in on-farm adoption (Lockie *et al.* 2002; Vanclay 2004; Llewellyn 2007; Lima *et al.* 2018). However, it does support the view that producers prefer to be advised on practices directly relevant to their situation (Wood *et al.* 2014). Existing literature on the direction of extension highlights the uniqueness of producers and emphasises that extension should focus on one-on-one consultation to maximise adoption and productivity (Vanclay 2004; Turner *et al.* 2017; Liu *et al.* 2018; Hall *et al.* 2019).

The results of chi-square tests undertaken to explore relationships of producer demographics, practices and producer beliefs with their use of pregnancy scanning are presented in Table 3. Producers with an on-farm main income source were found more likely to implement pregnancy scanning, giving credence to the suggestion that differences in decision making are likely to stem from producers' income sources and the reliability and dependability of those sources (Scott 2005). Producers who keep records of ewe mortality rates are also more likely to pregnancy-scan for multiples. Similarly, a statistically significant relationship between 'wet and dry' testing of ewes and pregnancy scanning was identified, with producers who practise the 'wet and dry' technique being more likely to pregnancy-scan for multiples. These results are consistent with conclusions reached by

Table 3. Relationships between producer demographics, practices and beliefs and the use of pregnancy scanning.

Variable 1	Variable 2	P-value
Use of pregnancy scanning	Main income (on or off farm)	0.053fv
	Recording of ewe mortality	0.011
	Undertaking the 'wet and dry' technique on ewes	0.006
	Participation in extension program in the past 5 years	0.000
	Belief that they are actively aiming to improve lamb survival	0.000fv
	Belief that Australia's lamb mortality rates are/are not acceptable	0.000fv

fv denotes violation of the frequency assumption, suggesting that the statistical power of the test is low.

Turner *et al.* (2017) that producers engaged in targeted record keeping practices are more open to change, with the results of these record keeping practices, along with pregnancy scanning data, providing a data-driven rather than reactive basis for making management decisions.

Another statistically significant relationship was found between producer participation in extension in the past 5 years and their use of pregnancy scanning, suggesting the success of extension programs in educating producers about management practices. Furthermore, a relationship was discovered between producers' beliefs regarding the acceptability of Australia's rates of lamb mortality and the use of pregnancy scanning, which underlines producer intention to improve mortality rates and recognition of the magnitude of the lamb mortality issue.

The notable relationships between producer demographics, practices and beliefs towards their participation in extension programs in the past 5 years are listed in Table 4. Not surprisingly, age, education level, gender and main income of producers were all found to have significant relationships with recent participation in extension programs. Similar conclusions have been reached in other studies (Llewellyn 2007; Elliott *et al.* 2011; Pignatti *et al.* 2015; Turner *et al.* 2017). Belief that Australia's lamb mortality rates are unacceptable and actively aiming to improve lamb survival were also related to recent participation in extension programs, as were the use of ASBVs and record keeping of ewe mortality. Australian sheep producers who engage in targeted record keeping are more open to change and it is likely that once behaviour is modified, producers become more flexible regarding additional changes (Turner *et al.* 2017; Bagheri *et al.* 2019; Munoz *et al.* 2019). Hence, producers that are already modifying their behaviour through adoption of ASBVs and implementation of record keeping are more likely to participate in additional extension services and respond positively to other innovations.

Table 4. Relationships between producer demographics, practices and beliefs and participation in extension programs in the past 5 years.

Variable 1	Variable 2	P-value
Participation in extension program in the past 5 years	Age	0.094
	Education level	0.029
	Gender	0.003
	Main income (on or off farm)	0.099fv
	Recording of ewe mortality	0.046
	Use of ASBVs	0.002
	Belief that they are actively aiming to improve lamb survival	0.094fv
	Belief that Australia's lamb mortality rates are/are not acceptable	0.066fv

fv denotes violation of the frequency assumption, suggesting that the statistical power of the test is low.

This supports the view of Hunecke *et al.* (2017) that adoption is the tip of the iceberg and after an initial adoption there will be further changes to management and acceptance of additional technologies.

General comments about the results

A few qualifications should be noted when interpreting the results. First, the approximately equal gender balance of survey respondents is not characteristic of the predominantly male ownership of farms in Australia as reported by Australian Bureau of Statistics (2018–19). Second, self-selection bias in the data may exist depending on producers' levels of conviction about lamb mortality rates. The propensity to complete the survey may have been higher among producers who consider lamb mortality to be an issue than those that do not (Kopp *et al.* 2020). Third, at the time of the survey, there were 10 206 agricultural businesses with breeding ewes in NSW (Australian Bureau of Statistics 2019–20). On that basis, the survey respondents represent 0.6% of the population. Hence, a degree of caution is warranted in any extrapolation of the results, because the relationships among producer demographics, practices and beliefs may not be characteristic of the general population. Finally, the number of scaled responses in some categories were low. Other non-parametric tests such as Fisher's exact test could be used to assess the statistical significance of the associations between variables.

Discussion and conclusions

Notwithstanding the qualifications about the results, several clear messages emerge from the outcomes of this research. The potential threat to the industry's social licence was clearly conveyed, with only 4% of respondents considering Australia's lamb mortality rates to be acceptable and the majority agreeing that lamb mortality poses a threat to the industry from animal activism. Ambiguous beliefs were discovered among producers regarding lamb welfare versus ewe welfare, with the discrepancy deemed to be the lack of perceived control over lamb mortality compared with ewe health. Nonetheless, most respondents indicated that they are actively seeking to improve their lamb survival rates despite only 28% feeling pressured to do so and the majority believing in the inevitability of some lamb losses.

The survey findings indicate that many producers do not have a thorough understanding of nutritional effects on ewe and progeny wool-production potential. This aligns with expectations that knowledge gaps exist concerning the benefits of pregnancy scanning and the impact of nutritional status on ewe and progeny lifetime performance.

The most significant barrier to the adoption of pregnancy scanning was identified as non-participation in extension programs. Producers who have participated in extension

programs within the past 5 years were found to be adopters of pregnancy scanning, and not only believe that scanning is profitable but that it should be utilised by all sheep producers. Generally, though, larger producers seem more likely to adopt scanning, perhaps indicating that a certain scale of enterprise is required for effective and efficient utilisation of the management practice. Producers implementing pregnancy scanning were found to be more likely to adopt record keeping practices and exhibited increased awareness of Australia's lamb mortality issue.

Producers not utilising pregnancy scanning indicated that their lamb survival rates were acceptable and that they were not considering adopting the practice given increased climatic variability or sustained high market prices. A lack of infrastructure, conflicting information regarding the costs and benefits of pregnancy scanning, and access to contractors or labour did not emerge as barriers to adoption. Overall, the responses from non-scanning respondents indicated a lower level of appreciation of lamb mortality as an issue and limited knowledge of the benefits of pregnancy scanning.

These findings highlight the critical role of extension programs in promoting awareness, shaping beliefs and generating change. Noting the important contribution that extension makes within industries and economy-wide, the results generated from this study are valuable for informing decisions on how maximum engagement can be achieved with scarce resources into the future. Furthermore, the results provide insight into how future extension efforts should be tailored, focusing on producers who have not adopted record keeping or previously participated in extension programs. The results also indicate that extension should be tailored to suit different enterprises because of the influence of enterprise focus on beliefs, but should also consider producer demographics and beliefs.

Extension programs ultimately rely on the willing participation of producers, which potentially limits widespread engagement and highlights the need for continuous improvement in extension content, delivery and administration (Kubeil 2017). Studies (e.g. Wood *et al.* 2014) have shown that producers prefer to learn about practices that can be directly applied to their individual circumstances rather than generalised best practices or extension that is based on institutional priorities. Recognising the individual needs of producers is paramount and the role of extension providers should be to work with individual producers on constraints that restrict the adoption of new technologies, and to ascertain the degree of change producers are willing to make in different areas (Turner *et al.* 2017). The most pressing issue relevant to this study is whether extension can alter producers' beliefs regarding lamb mortality. The results suggest the affirmative; however, if the answer is no, extension is necessarily limited to assisting producers to make the best possible decisions within the context of their existing beliefs and the limitations of the current research, development and extension system.

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