Chapter

Reproductive Rates of Merino Ewes and Offspring Quality under AI Program

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Abstract

Reproductive wastage is a major economic burden in sheep production globally, especially within Australia as livestock production systems face increased pressure from climatic variability (e.g. prolonged droughts or flooding). Sheep are sensitive to acute changes in their environment such as heat stress, which if not adequately monitored will result in significant production losses such as reproductive failure, increased parasite and worm burden, morbidity and mortality risks. Through basic and applied research in the areas of stress and reproductive physiology our team has made significant advancements in the understanding of sheep behaviour and physiological responses to acute and chronic stressors. Using minimally invasive hormone monitoring technology in combination with field based assessment of sheep health and productivity traits, our team has delivered new knowledge on how sheep react to acute environmental stress and how it impacts on sheep reproduction. In this chapter, we evaluated the fertility rates and embryo quality of Merino ewes under AI breeding program. We discuss factors such as heat stress that can impact on ewe and offspring quality.

Keywords: Reproductive Wastage, Merino Sheep, Heat Stress, Resilience, Embryo Quality

1. Introduction

Merino ewes account for 75% of all breeding ewes in Australia, comprising of those used for high quality fleece production, as well as for the production of first cross lambs for the meat market [1]. Despite Australia's high usage of this breed, the reproductive performance of merinos is often described as being substantially lower than those of other breeds [2–4]. Many studies have attempted to understand the sources of this poor performance, in the hope that by better understanding the causes of the loss, that they can better implement strategies to mitigate the losses.

Kilminster and Greeff [5] found that significantly lower rates of conception were found in Merino ewes who were joined at only 8 and 9 months of age, when compared to their same age Dorper and Damara counterparts. Ewes that were maiden, that is, having their first lambs, were also more likely to have lower success rates [3, 6]. In these studies, this conception rate drastically increased as the ewes matured and became experienced mothers. A study [7] into the reason for the increasing conception rate with age and amount of parturitions found that the rate of cervical passage, as is used for transcervical artificial insemination, increased with increasing parturitions due to cervical stretching. This study did not observe ewes beyond 3 parturitions so did not observe if this cervical stretching may cause problems into older age. A 2015 study [8] of 22,758 Churra ewes, a Spanish dairy sheep breed, reported that ewes are most fertile between 1.5 and 4.5 years of age. Ewes older than 4.5 years often would have had numerous parturitions, a factor that Anel determined was a contributing factor to the decline of fertility.

Ewes that conceive multiple foetuses experience a compounding risk of poor reproductive performance, as there is a high risk of losing one foetus between pregnancy scanning and parturition. Those that are able to keep both foetuses until parturition are still at risk of losing a lamb during the sensitive post-parturition period [3, 9].

Sheep are considered to be seasonal breeders. They experience marked changes in their behaviour, endocrine and ovulatory levels between their ovulatory and anovulatory seasons. Hormonally, luteinizing hormone (LH) remains at a relatively constant level, although the pulsation rate is lowered. Plasma progesterone is essentially undetectable during anoestrus [10]. Farmers are able to manipulate this seasonal variation through the use of light pulses and melatonin supplementation to create short days and long days [11]. Oestrus is stimulated after the longest day of the year, at which point the day-length begins to shorten. In Australia, this is late December. Fogarty (year) found that oestrus and fertility peaked during autumn (February) joining with the lowest fertility rate being seen in Spring (October and November) joining's.

The impact of the thermal environment on fertility and conception rate is not a new concept. In 1964, Dutt placed ewes in a temperature-controlled room prior to and/or after breeding and studied their responses [12]. The results showed a significantly lower rate of fertilisation in the heat-treated ewes. Placental research has similarly shown that high ambient temperatures reduce success rates. Bell et al. [13] and Early et al. [14] found that placental development is reduced by up to 54% in heat-treated ewes, which had a carry-on effect to the offspring: as the placenta was smaller, the foetus's growth was stunted. Studies by Kleeman et al. [3, 15] found that fertility was negatively influenced by the number of days ambient temperatures were above 32.0°C during mating, suggesting that high ambient temperatures may reduce embryo survival.

In spite of this large body of research into reproductive wastage from the perspective of gestational or pre-weaning loss, as well as genetic quality concerns, there is limited research into the impact of the ewe on the quality of her offspring, especially long-term studies that look beyond weaning and into adulthood. This study aims to fill this gap by determining factors in the ewe that will lower her reproductive success and the quality of offspring using lifetime production data from the MerinoLink Limited Sire Evaluation Program.

2. Methods

2.1 MerinoLink limited sire evaluation program

The MerinoLink Limited Sire Evaluation Program is designed as a standard sire evaluation trial that follows progeny of selected Merino Superior Sires (MSS), assessing their characteristics at 10 months and 22 months of age, in line with the Australian Merino Sire Evaluation Association. The selected traits are those deemed to be of value to breeders and commercial producers. For the purpose of our study, we do not know which progeny belong to which sire, as this was deemed a potentially confounding variable if sire identification was known.

2.2 Study group

The 2016 breeding season was conducted at a commercial farming property in Jugiong, NSW (−34.770150, 148.304470). Ewes were managed as one contemporary flock until 10 days before lambing, when they were separated into their respective sire groups. This was to ensure that there was no external influence by environment or pasture type and quality. The ewes were also given equal opportunity and access to a supplementary feeding program. The feeding program was designed to sure that nutritional requirements were met throughout all stages of gestation. The researchers were supplied with the following data from the research data providers; it is thus mixed aged ages spread evenly across all sire groups. The exact age grouping for each sire is unknown. The foundation ewes that were used to generate the 2016 and 2017 drops were sourced from five flocks and allocated evenly across all sire groups, the foundation ewe base consisted of:

- Bluechip ewes – approximately half of the ewe base came from two drops of ewes that were the result of a previous sire evaluation program. All ewes have full pedigree and ASBVs.

- Pooginook - 155 2, 3 and 4-year-old ewes were selected from 1,050 stud ewes. They consist of single mated ewes (104) and syndicate mated ewes (51). All ewes have ASBV's and are structurally sound. The average MP+ index is 143.

- Commercial Pooginook - 200 commercial Pooginook blood ewes were selected out of 750. The ewes had been measured for micron and greasy fleece weight and reared a lamb.

- Bundilla - 150 ewes were selected from an ewe base of 800 stud ewes. All ewes had reared a lamb and consisted of 3 and 4 year old ewes with an average MP+ 140.

- Centre Plus - 150 ewes were selected from a ewe base of 350 stud ewes. The ewes have an average MP+ of 158.

Insemination occurred in a shed environment on the 23rd February 2016 with a total of 107 ewes each being inseminated *via* artificial insemination to one of twelve randomly selected sires. The insemination day ran for a total of 5 hours and 22 minutes, from 10:48:19 to 16:10:23. Breaks were had at 11:48 for 41 minutes, 13:11 for 16 minutes and 14:01 for 1 hour and 8 minutes. All sires were previously evaluated for semen quality. Each ram was given 50 mixed aged ewes as noted above. In the 2016 trial the age breakdown of the sires used were 2011 – 1, 2012 – 3, 2013 – 3, 2014 – 3, 2015 – 5; 2017 trial 2011 -1, 2013 – 3, 2014 – 4, 2015 – 5. This was from a sire evaluation trial and various sires semen was used from various studs.

At time of the research being conducted the standard AI protocol in Australia based on AllStock Artificial Breeding Services (www.allstock.com.au) was implemented. All laparoscopic AI procedures conducted on the ewes were performed by the same qualified AI technician. On the day of AI, ewes were sedated with 0.05 mg/kg of Zylazil injection 20 minutes prior to the AI procedure. Ewes were then artificially inseminated via laparoscopy, with frozen semen. Semen quality was assessed post thawing by a qualified veterinary surgeon. Rectal temperature was recorded twice (immediately before sedation and 30 min post AI). All laparoscopic AI procedures conducted on ewes in this study were performed by a qualified veterinary surgeon.

Pregnancy scanning occurred on the 26th May 2016, where ewes were scanned as being dry (not pregnant), pregnant with a single lamb or pregnant with twins. Ewes gave birth between the 22nd and 30th July, lambs were marked on the 2nd September 2016, and weaning occurred on the 29th October 2016. The data supplied to the researchers was from an Australian Industry trial that the researchers had no influence on the methodology or overall design. Authors of this paper understand that pregnancy can be detected post 45 days in sheep and would recommend this to be of best practice. However, it is believed that 92 days would have allowed back up rams to inseminate ewes that had lost a lamb early after insemination and be drafted off from the trial mob with small embryos. All ewes are commercial ewes were being used in the trial.

The 2017 breeding season was conducted at a property south of Yass NSW (−34.977260, 148.855810). A total of 800 ewes were managed in the same manner as the 2016 flock, until 10 days before parturition, when they were divided into 5 mobs. Data sets for 531 individuals were made available for our study, of which 136 were randomly selected to be used for further data collection and analysis.

Insemination occurred in a shed environment on the 28th February and 1st March 2017, where the 800 ewes underwent artificial insemination to one of sixteen sires, selected at random. The first day began at 7:51:30 and ran to 14:32:51 with breaks at 9:08 (37 minutes) and 11:38 (66 minutes). The second day began at 7:18:03 and finished at 13:06:40, with breaks at 9:06 (47 minutes) and 11:38 (65 minutes).

The 2017 flock were scanned for pregnancy confirmation on the 24th May 2017. All ewes gave birth between 28th July and 8th August 2017. Marking occurred on the 1st September 2017, where their sex was recorded and lambs were weaned from the ewes on the 9th November 2017. At the time of weaning, the data for the category "weaning weights" was collected. Post-weaning weights were collected when the lambs were 6.5 months old (14th February 2018), and yearling weights were taken when the lambs were 12.5 months old (27th June 2018). Finally, fleece data, including fibre diameter, staple length, staple strength and wool weight (greasy and clean) were obtained at 10 months of age, on the 21st May 2018.

For the 136 selected for further analysis (study group), we obtained data on the year of birth of mother, diagnosis as twin or singleton at the time of pregnancy ultrasound and the body temperature (rectal) of mother at insemination.

2.3 Types of data collected

For the purpose of this data set, lambs considered to be of the "weaning" age category were between 6 weeks and 4 months of age (42 to 120 days). Those in the "post-weaning" category were between 4 and 10 months of age (120 to 300 days). Finally, those in the "yearling" category were between 10 and 13 months of age (300 to 400 days).

Fibre diameter refers to the measurement in micrometres (microns) of the wool fibres from an individual sheep. Merino sheep are a breed specifically designed for their fine wool diameter, aiming for 20 microns or lower; a lower micron size denotes a finer wool, and thus a higher quality wool. Staple length is the length in millimetres of a piece (staple) of wool. The length of a staple determines its end use – whether it will be used for weaving or knitting. Staple strength refers to the amount of force required to break a wool staple, recorded as Newtons per kilotex

(Nkt). A kilotex refers to a staple of a given thickness. This informs us of the efficiency of wool processing; how likely the fleece is to break during processing.

All fleece, as shorn straight from the sheep, including skirtings is called greasy fleece weight. As this weight occurs before cleaning, it includes all fibre, vegetable matter, dirt, wax and other environmental contaminants. Clean fleece weight is the weight after these contaminants have been removed, and the fleece has been washed. It is calculated using the formula:

$$\text{Clean fleece weight}\,(\text{kg}) = \text{greasy fleece weight}\,(\text{kg})\ \text{x washing yield}\,(\%)$$

2.4 Statistical analysis

All data was analysed using IBM SPSS Modeller (SPSS Inc. 1994). A covariate analysis and chi square analysis were performed for both the 2016 and 2017 flocks to analyse the fertility rates for time of day of insemination. The 2017 flock underwent further analysis, including regression analysis of bodyweight, greasy and clean fleece weights, yearling fibre diameter and temperature at insemination. One sided T-tests were used to assess yearling staple strength, staple length, ewe body temperature at insemination vs. progeny sex and body weight at weaning. Year of birth of mother was analysed using a Fishers one-sided exact test. Differences were considered significant at $P < 0.05$.

Conception rate (also referred to as "artificial insemination rate" or "fertility rate") is calculated using the formula: conception rate = (successful conceptions)/(total ewes inseminated)

3. Results

3.1 Fertility in 2016 flock

The 2016 flock (n = 107) had an artificial insemination success rate of 55% (n = 59), with a further 40 ewes conceiving via a backup ram after artificial insemination. This combined total lead to a total fertility rate of 93% (n = 99).

The earliest period of the day (period 1) had the most conceptions, with 40.67% (n = 24) of all successful inseminations occurring in this period. This was a rate of 73% of the period 1 ewes that conceived. The lowest period in the day was period 2 with 11.86% of all conceptions occurring in this period. This was a rate of 29% of the period 2 ewes that conceived; this different is statistically significant

	Period 1	Period 2	Period 3	Period 4	Total
Successful conception from AI	24	7	9	19	59
Failed conception from AI	9	17	10	12	48
Fertility rate for period	73%	29%	47%	61%	55%
Singletons	11 (46%)	1 (14%)	5 (56%)	10 (53%)	27 (46%)
Twins	13 (54%)	6 (86%)	4 (44%)	9 (47%)	32 (54%)

Table 1.
Fertility rates of merino study ewes (n = 107) via artificial insemination in 2016 by period of day inseminated. Singleton vs. twin rates provided based on scanning data for those that conceived.

(Fishers one-sided; P = 0.001). However, as the day progressed, the conception rate improved, with 32% (n = 19) of all conceptions, 61% of the period's conceptions, occurring in period 4 (**Table 1**). The difference in conception rate between period's 2 and 4 was statistically significant (Fishers one-sided; p = 0.018). The difference between period 1 and 4, 2 and 3, and 4 and 3 were not statistically significant (Fishers one-sided; p = 0.252).

Despite this lower rate of conception in period 2, this period produced a higher rate of lambs, with six of the seven period 2 ewes having twins. The proportions of twins and singles in the other three periods (periods 1, 3 and 4) were all similar and there was a borderline statistically significant difference between period 2 and all other periods (Fishers one-sided; p = 0.082).

3.2 Fertility in 2017 flock

The 2017 flock had a total conception rate of 87% (n = 180 lambs at scanning). 66% (n = 138) of these conceptions occurred via artificial insemination, with the remainder of lambs being conceived via the use of a back up ram (n = 42 lambs at scanning). Only 28 ewes failed to conceive during this period via either artificial insemination or after spending two cycles with a back-up ram.

In 2017, the artificial insemination was performed over three periods. 36.9% (n = 51 lambs at scanning) of all lambs conceived, were from ewes inseminated in the first period. The within-period conception rate was 70.8%. The middle period (period 2) contributed the highest conception rate of the day, with 45.6% (n = 63 lambs at scanning) of all lambs conceived on the day, with a within-period success rate of 77.7%. The final period (period 3) had the lowest conception rate, with 17.3% (n = 24%) of lambs being conceived in this period. The ewes that were inseminated in the afternoon period (period 3), including those that failed to conceive *via* artificial insemination, but that went on to conceive via the use of a back-up ram had the highest twinning rate, with 55% of lambs in this period scanning as twins. This was followed closely by the middle period (period 2) which had a twinning rate of 39%, followed by period 1 which had a twinning rate of 49%. The difference between the periods of insemination performed before the major break of the day (periods 1 and 2) and the afternoon period (period 3) was statistically significant (Chi2; p = 0.0005) (**Table 2**).

3.3 Year of birth of mother

In 2017, both the eldest ewes (born in 2011) and the youngest ewes (born in 2014) each contributed 13% (n = 24 each) of lambs in the 2017 conceptions. Both

	Period 1	Period 2	Period 3	Total
Successful conception from AI	51	63	24	138
Failed conception from AI	21	18	31	70
Successful conception from use of back-up ram	—	—	—	42
Singletons	32 (51%)	34 (47%)	20 (45%)	86 (48%)
Twins	31 (49%)	39 (53%)	24 (55%)	94 (52%)

Table 2.
Fertility rates of merino study ewes (n = 136) via artificial insemination and back-up ram in 2017 including the rate of singleton and twins from both the artificial insemination and ram back up usage.

	2011	2012	2013	2014	Total
Singletons	13 (54%)	21 (37%)	39 (52%)	13 (54%)	86 (48%)
Twins	11 (46%)	36 (63%)	36 (48%)	11 (46%)	94 (52%)
Total	24	57	36	24	180

Table 3.
The effect of year of birth of mother on the conception of single or twin pregnancies.

of these also had a twinning rate of 46% (n = 11 each). The most fertile ewes were those born in 2012, with 31.7% (n = 57) of lambs conceived by these ewes, of which 63% (n = 36) were twins. The 2013 born ewes contributed 20% (n = 36) of lambs in 2017, with 48% (n = 36) being twins. The difference in fertility between 2012 ewes and all other ewes was statistically significant (Fishers one-sided; p = 0.033), however 2011, 2013 and 2014 ewes were not significantly different from each other (**Table 3**).

3.4 Temperature at conception (2017)

The distribution of maternal body temperature at time of conception was slightly skewed from normal (**Figure 1**). The ewes body temperatures (rectal) ranged from 39.0°C to 40.9°C, with a mean of 39.78°C, and a similar median of 39.7°C. We considered temperatures over 40.2°C to be abnormal, as only 11% (n = 15) had temperatures at or over this point. The variation in body temperatures did not produce different rates of male or female progeny (t-test; p = 0.021).

Regression analysis showed no statistical significance for temperature*all_weaning_weight (p = 0.506), temperature*postweaning_weight (p = 0.215), temperature*male_weaning_weight (p = 0.783), and temperature*male_postweaning_weight (p = 0.532). Temperature*female_weaning_weight was not significant, but had a lower p-value than the other weaning samples (p = 0.281) and

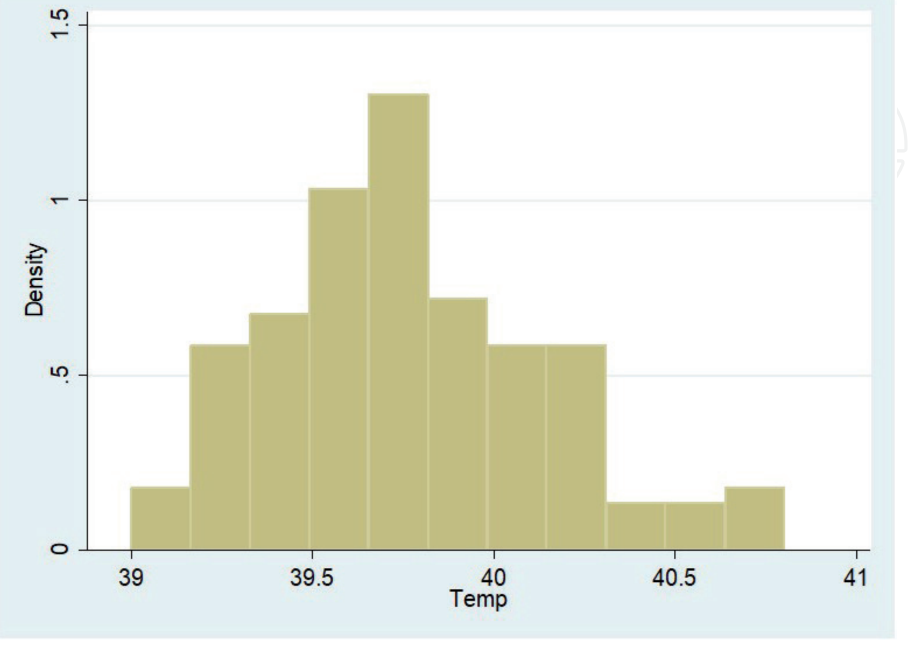

Figure 1.
Histogram of temperature of 2017 ewes at conception. Mean = 39.78°C. temperatures over 40.2°C were considered abnormal.

temperature*female_postweaning_weight was significant (p = 0.021). No regression was performed for yearling weights.

Conception temperatures above and below 39.5°C had a borderline significance for female progeny (t-test; p = 0.13), with a difference in post-weaning weight of +0.46 kg. Conception temperatures above and below 40.2°C likewise showed statistical significance (t-test; p = 0.033) with a difference in post-weaning weights of +1.09 kg.

Weaning weights for female progeny likewise showed non-significance (t-test one-sided; p = 0.281), with a difference in average weaning weight for both low (<40.2°C) and high (>40.2°C) maternal conception temperature of +0.41 kg (low = +0.06 kg; high = −0.36 kg). Finally, yearling weights showed significance, for conception temperatures above and below 39.5°C (±1.9°C) (t-test; p = 0.0300) and above and below 40.2°C (t-test; p = 0.0073).

3.5 Pregnancy scans (2017)

At the time of scanning, there was a 1:1 ratio of singleton and twin lambs, with 54 ewes scanned as being pregnant with singletons and a further 54 scanning as having twins. Of these 54 twin-scanned ewes, 48% (n = 26) lost one of their lambs, having only a single survive to birth.

3.6 Progeny sex (2017)

In the study group, the ratio of males to females was 0.84:1, with 62 males and 74 females being born.

3.7 Progeny weight (2017)

Regression analysis found no significant difference in each age category (weaning, post-weaning and yearling) between the study and non-study groups. As yearlings, however, there were proportionately more progeny in the study group that were under the mean weight than those in the non-study group, who showed a higher range of weights (**Figure 2**).

The change in weight between age categories was not statistically significant through regression analysis, however the range of weight changes is notable – some sheep gained weight between age groups, whilst others lost weight between ages. The widest range of weight changes, including loss of weight, occurred from weaning to yearling age (**Figure 3**).

3.8 Fibre diameter, length and strength (2017)

There was no statistically significant difference (t-test; p = 0.12) in yearling fibre diameter (YFD) between the study and non-study groups. The study group averaged +0.073, whilst the non-study group averaged −0.006. A regression analysis showed no relationship between yearling fibre diameter with the mother's temperature, year of birth, or the sex of the progeny tested. There was, however, a highly significant relationship with whether the progeny was scanned as a twin or singleton, and its yearling fibre diameter. Those scanned as twins had an average YFD of −0.084, and those scanned as single lambs averaged at +0.398.

The final yearling fibre diameter analysis was a regression of yearling fibre diameter versus scan fecundity (single or twins) and sex. This found that the sex*fecundity interaction was not significant, nor the sex*twinning interaction, but

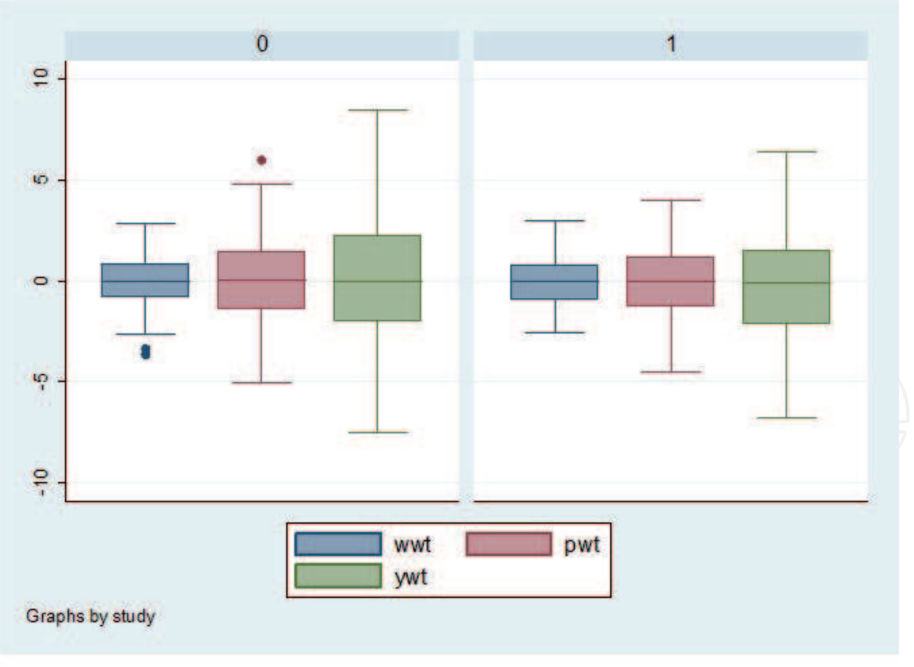

Figure 2.
Boxplots of bodyweights at weaning (wwt = blue), post-weaning (pwt = red) and yearling (ywt = green) for study and non-study groups (study group = 0; non-study group = 1).

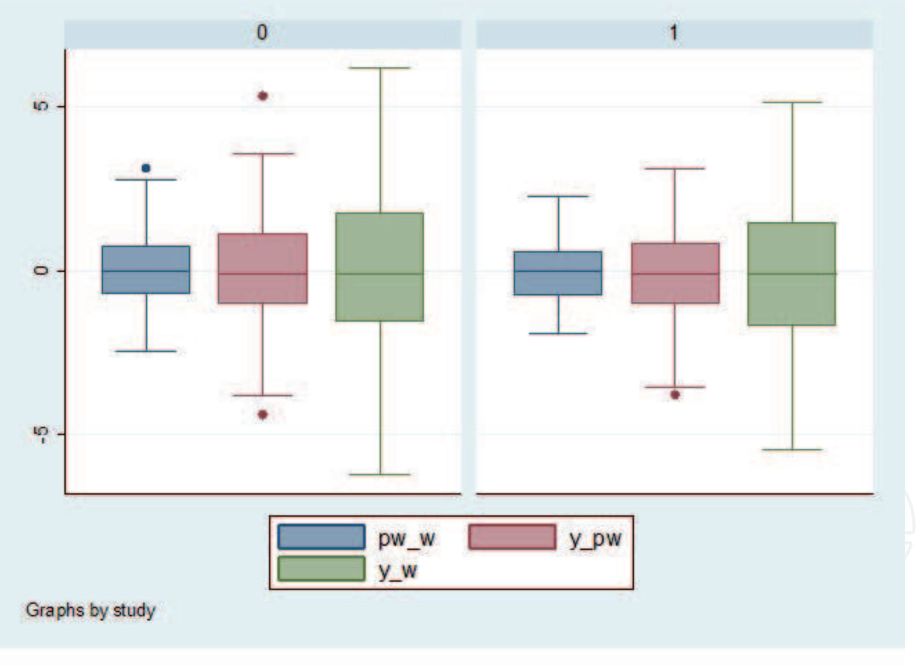

Figure 3.
Boxplots of change in bodyweights in study (0) and non-study (1) progeny. Pw_w (blue) = weaning to post-weaning; y_pw (red) = post-weaning to yearling; y_w (green) = weaning to yearling.

was the for sex*singletons. Females had a mean yearling fibre diameter of +0.057, and males had a mean diameter of +0.524. The singles showed a marked bimodal distribution, but not those born as twins (**Figure 4**).

3.9 Staple length and staple strength

Yearling staple strength was significantly greater in the study group (t-test; one sided p = 0.032) with the study group's mean staple strength at +0.0621, and

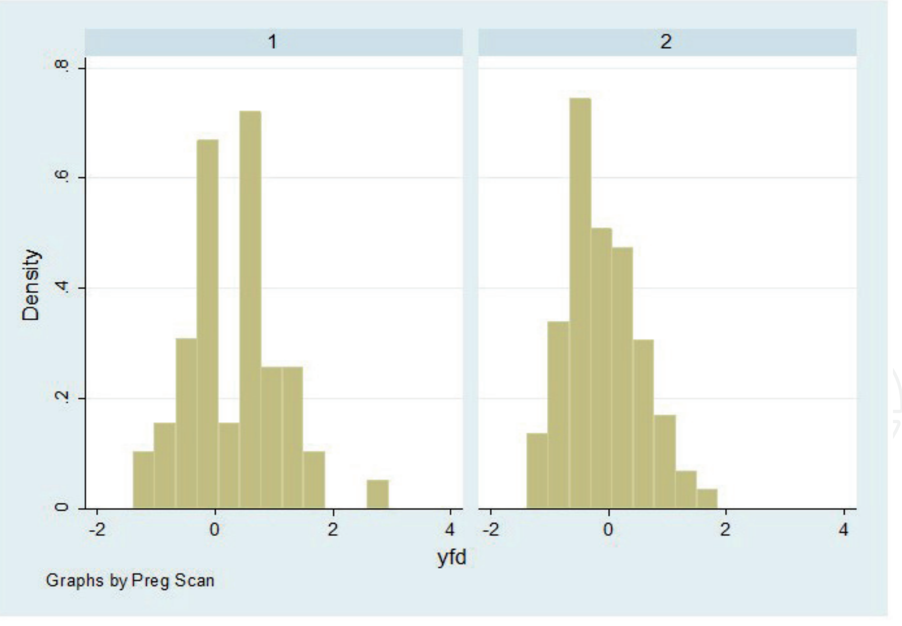

Figure 4.
Histogram of yearling fibre diameter by scan fecundity (1 = singletons, 2 = twins).

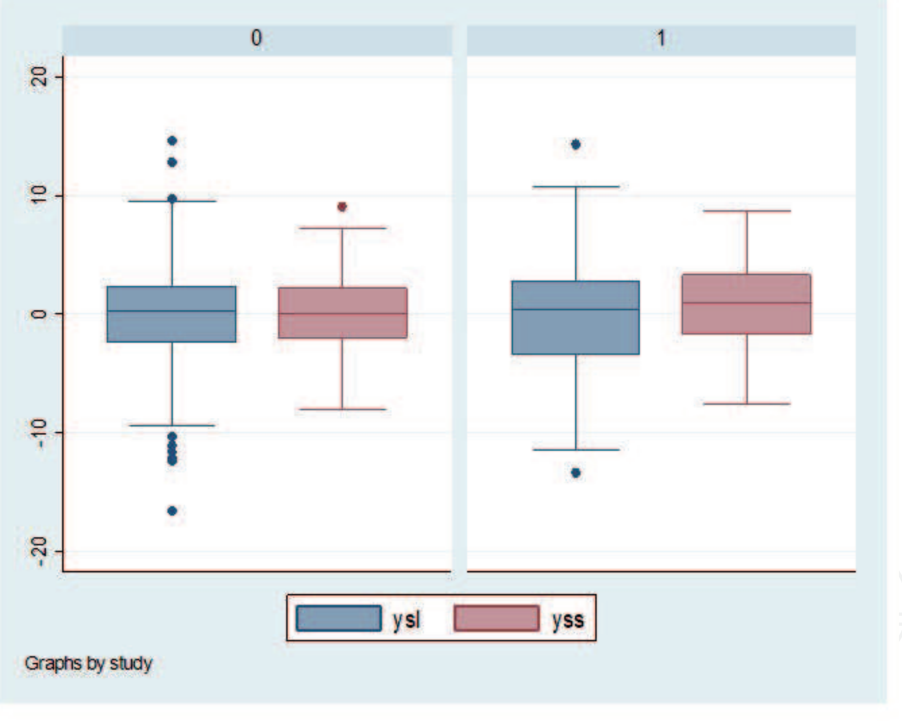

Figure 5.
Boxplots of yearling staple length (ysl = blue) and yearling staple strength (yss = red).

the non-study group's mean at +0.033 (**Figure 5**). Yearling staple length was not significantly different between study and non-study groups (**Figure 5**).

4. Discussion

The MerinoLink program with its comprehensive range of collected data has been a powerful tool for understanding the relationship the ewe has with her progeny. In the present study, we found that the youngest ewes (born in 2014) and the eldest ewes (born in 2011) had the lowest conception rates (13% each). The low rate of conception from young ewes is consistent with data presented by Kleeman and Walker [3, 15] who found that maiden Merino ewes had a fecundity rate up to 11% lower than the mature ewes of their study. Additionally, an Egyptian study by Abdel-Mageed et al. [6] found that maiden ewes (of the Rahmani and Barki breeds) had a reproductive wastage rate as high as 70% in maiden ewes (vs. 42% for mature ewes). Mature ewes in both of these studies had higher successful conceptions and lower reproductive wastage, as was seen in our study with the 2012 and 2013 ewes (31.7% and 20% respectively). The ewes born in 2012 also had a significantly higher twinning rate with 63% of lambs born as twins. Kleeman and Walker [3, 15] reported a similar result and found that this was due to a higher ovulation rate with more multiple ovulations, as is often required for twins to be conceived.

The time of day of conception was an important factor for the overall conception rate as well as the rate of singletons and twins being conceived. The 2016 flock had the highest conception rate in the first period of the day (73% success), followed by the last period of the day (61% success). The middle two periods experienced relatively low rates of conception (29% and 47% respectively). Despite this low rate of conception in the middle periods, period 2 experienced the highest rate of twins conceived, with 6 out of 7 (86%) of ewes conceiving twins. Unlike the 2016 flock, the 2017 flock saw the highest conception rate in the middle period (45.6% of all AI conceptions), followed by the first period (36.9% of AI conceptions). The final period of the day had only a 17.3% conception rate from AI. Overall, the 2017 flock had a conception rate 11% higher than 2016 (2017 = 66%, 2016 = 55%), and was 5.9°C cooler than the 2016 insemination day.

Previous studies suggest two potential lines of reasoning for this daily variation. The first potential line is that of daily melatonin variation. Melatonin, synthesised and secreted from the pineal gland is the hormone responsible for seasonal fertility in sheep, and is regulated by the day-night cycle. Seasonally, the study ewes were in prime fertility, however daily melatonin variations are rarely considered as a potential fertility factor. Melatonin implants [16–19] have been shown to not only prolong the breeding season, but also to improve the proportion of successful conceptions and the fecundity rate. Melatonin has been identified as a component required for in vivo oocyte maturation, as it has been quantified in the granulosa cells of healthy oocytes (Tamura et al., 2012, as cited in [20]). Tamura et al. and Peris-Frau et al. (2017, as cited in [20]) also suggested that melatonin may act as an antioxidant in the oocyte follicle, protecting it from reactive oxygen species (ROS), which are known to cause damage to oocyte and granulosa cells. Peris-Frau's studies added melatonin to the collecting media during ovary transport and found that the rate of degradation declined significantly. Whilst we did not measure melatonin levels in our study ewes, previous studies of daily melatonin changes indicate that melatonin is at its highest concentration early in the morning, declining until the evening when an animal returns to sleep, at which point the levels can be replenished.

The second line of reasoning involves the ambient and ewe temperatures. Decades of studies have shown that ewes have far higher conception rates when not exposed to high ambient temperatures and heat stress. Our present study did not have a heat treatment or comparison to cooler days, with all ewes being inseminated on the same day. We did, however, take rectal temperatures at the time of insemination, which allowed us to observe the temperature of ewes. There are many different numbers given for the "normal" rectal temperature of a sheep, with some suggesting as low as 38.3°C [21, 22]. The Australian Veterinary Association [23] suggests that a normal resting rectal temperature should be approximately 39°C, with mild heat stress beginning at 39.5°C. In the present study, the rectal temperature had a mean of 39.78°C, ranging from 39.0°C to 40.9°C. No ewes were reported as having low rectal temperatures and temperatures over 40.2°C were considered abnormal, with only 11% having temperatures over this range. The 11% of ewes with temperatures over 40.2°C are considered by the AVA to be in moderate to severe heat stress. Although the ewes were inseminated in a shed condition, the shed undergoes natural temperature variations throughout the day, potentially explaining this ewe temperature variation, and thus conception rate.

The biggest impact that abnormally high temperatures had on our study group was that female progeny were born significantly smaller and remained smaller even into yearling age. This has a definite potential impact for the merino industry, both in terms of available surface area for which to grow fleece, for capacity to carry lambs, and even fertility. There appears to be limited research about as to the potential reasons for this. One study considered the effect of heat on the placenta [13, 14]. This study found that high heat exposure caused placental stunting of up to 54%. They found that placental RNA and DNA content were reduced as were maternal plasma concentrations of progesterone, cortisol and placental lactogen. However, if this was the cause of smaller females, we would expect to see this in the male progeny as well.

Unfortunately our study had several confounding variables that we could not eliminate. Specific data relating to ram usage over each ewe was unavailable due to the sensitivity of that information, but this meant we were unable to consider the impact of the ram itself. A 2005 paper by Anel et al. studied the potential factors influencing the success or failure of artificial insemination. Overall, they found that the year, season and the technique of AI were the most important factors that would predict success or failure of insemination. Therefore, we suggest that future studies should consider minimising these confounding variables to ensure consistency and accuracy.

Based on our results, we conclude that the lifetime data program can be a highly effective tool to understand the impact of the parents on the progeny, both in terms of genetic variation and environmental factors. Future studies should consider using this method to observe a wide variety of factors including pre-conception, post-conception, throughout gestation and into the adulthood of the progeny. Further research is also required to better understand the link between abnormally high rectal temperatures at conception and the overall size of female progeny.

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