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Sheep CRC Report 1_30

Review of weight loss as a trait

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SHEEPCRC

Executive Summary

This review has been undertaken at the request of the Sheep CRC Project Review and Research Committee. The review brings together the results of several analyses within the Sheep CRC and other published papers to understand the importance of weight loss as a possible trait for selection, including its genetic parameters and correlations with other traits and interactions with environmental and management factors.

The analyses are from several extensive data sets including the Information Nucleus. The analyses include whole farm systems modelling using MIDAS to evaluate the potential economic benefits of genetically reducing weight loss and estimation of genetic parameters for weight loss and its genetic relationships with other production traits. The review discusses these results in the context of other published papers.

The conclusions are as follows:

- Several definitions of weight loss have been used. Loss over late summer /autumn may be appropriate in a consistent Mediterranean environment, but there are practical limitations elsewhere (e.g. need to account for changes to conceptus growth and varying foetal number and foetal age over pregnancy).
- The heritability estimates of weight loss are very low (<0.05), except possibly where there is a sharp decline in weight (maybe h^2 0.15). The genetic correlations with most production traits (wool and carcass) also appear to be very low and any selection would have little impact. There were some potentially favourable and unfavourable genetic correlations with reproduction, although they were not consistent and had high standard errors.
- The biological significance is likely to be mitigated through increased feed intake on dry pasture and/or improved energy efficiency for maintenance. While there is some genetic variation for feed intake selection is currently not feasible. Modelling with MIDAS indicated feed intake would be increased by 25% for a genotype with a 1 kg less weight loss over late summer/autumn. There seems much more scope for management solutions to address the loss of weight that are specific to the environment involved. Apart from the obvious (feed supply), taking account of the effect of reproduction level in the previous year to differentially manage ewes could assist.
- The economic significance is through reduced feeding costs and the possible gains through increases in stocking rate. The economic studies concluded that benefits are likely to be greater for lamb enterprises in marginal environments, with much smaller benefits for wool enterprises and in better environments.
- The Information Nucleus provides a data set with a large loss in weight (-11.9 kg at Katanning) which could also be used to estimate genetic parameters. More importantly the genotype x environment interactions across all sites and years need to be examined in more detail than has been presented in 2 conference papers. These analyses (may have been done) need to elucidate the causes of the interactions and detail the implications for breeding programs. Also a relook at breeding objectives for Merinos in different enterprises (lamb and wool) and environments would be useful, especially taking account of mature ewe weight and fat as they impact on production traits (lamb carcass and ewe reproduction) and stocking rate of breeding ewes.

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Background

The Sheep CRC Project Review and Research Committee (PRRC) has requested a review of research in relation to the genetic, biological and economic consequences of the extent of weight loss during an extended period of sub-optimal nutrition.

The CRC and its Participants need to understand the importance of this trait as a possible target for genetic selection. The correlation with other traits and interaction with environmental and management factors need to be considered in order to rank its importance with other traits that influence production efficiency, health and welfare.

The genesis of this work seems to have come from the general outcomes of a meeting in Armidale in March 2010 to develop research projects within ***Project 1.1 Matching genetics and production system*** (see Appendix 2a). It is not indicated in the document who was at the meeting. However the proposal was presented by the WA group with the recommendation from the CRC that the activity should involve input from the NSW DPI group based at Orange and the proposed project team was Mark Ferguson (DAFWA), Andrew Kennedy (UWA), Jess Richards (DPI NSW) and Kevin Atkins (DPI NSW/UNE). The general outcomes included: "*5. important to determine whether there are sheep genotypes that perform better at high stocking rates or more limited nutrition as stocking rate remains an important determinant of profit".* Associated work included "*to develop methodology to identify individuals or families that display improved resilience to nutritional and disease stresses …Quantitatively defining industry concepts of "good doers" or sheep that apparently are productive but always in better condition than those in the same mob ….Activities to elucidate animal differences in resilience may include … a) determine the heritability of condition score or live weight change throughout a breeding cycle and through times of nutritional restriction.*"

There was considerable discussion about the objectives and design of the project around the 2010 Coffs Harbour Planning Meeting and in emails (see Appendix 2b). This resulted in the following Objective being defined as part of the Project 1.1 Operational Plan:
2. Develop a methodology to identify individuals or families that lose less weight during periods of nutritional stress, define the genetic parameters for the trait and use bioeconomic models to understand the trait's impact on whole farm profitability (2011/12)

The work has been summarised in a discussion paper by Beth Paganoni *et al.*(Nov 2011, Appendix 2.c) and several papers that have been published in journals (or are in draft form or submitted). These papers form the essence of this review.

Introduction

The hypothesis, as outlined by (Paganoni *et al.* 2011) in their Discussion paper, is that ewes that lose less weight over the period of limited feed supply in late summer and autumn are more resilient and biologically more efficient which results in higher enterprise profitability. It is also contended that the sheep that lose less weight will be more adaptable to changed pasture conditions in the future due to climate change (Rose *et al.* 2013). While it is not clear where the improvements in biological efficiency may occur the inference is that they could come from two sources; greater intake through better pasture utilisation and/or reduced energy requirements for maintenance (Young *et al.* 2011a). Under these scenarios improvements in profitability come from reduced supplementary feed costs to maintain ewes during periods of limited feed (including some reduced labour costs) and an opportunity to increase stocking rate, which is a major profit driver indicated in modelling of sheep enterprises (Young *et al.* 2011b; Appendix 2e).

Several data sets have been analysed to examine the genetic variability of various measures of liveweight loss and gain during the production cycle and the relationships with production traits. These large data sets are from various research resource flocks, including the Merino Resource Flocks at Katanning (Greeff and Cox 2006), the Trangie Merino D Flock (Mortimer and Atkins 1989), the Maternal Sire Central Progeny Test (MCPT) (Fogarty *et al.* 2005a) and the Sheep CRC Information Nucleus (van der Werf *et al.* 2010), which are in different locations and environments throughout Australia and include both Merino and crossbred genotypes.

This review brings the results of these separate analyses together to understand the importance of weight loss as a possible trait for selection, including its genetic parameters and correlations with other traits and interactions with environmental and management factors.

Economics of weight loss

Whole farm systems modelling using MIDAS (Young *et al.* 2010) was used to examine if sheep with improved resilience (i.e. genotypes that lose less weight during summer and autumn) could be grazed at higher stocking rates and to quantify the economic value and improvement in farm profitability for a range of different pasture and sheep production systems (Young *et al.* 2011a). The simulation involved a 1000 ha farm in southwest Victoria (Hamilton) with 2 pasture systems: a) moderately productive ryegrass or b) optimum mix of lucerne, fescue and high performance ryegrass (producing more high quality feed over summer and autumn); and 2 sheep production systems: a) Wool – self replacing Merino flock selling wethers at 17 months or b) Lamb – buying in replacement Merino ewes and mating to terminal sires with all lambs turned off for slaughter at 45 kg liveweight. Flocks lambed in July and August and prices were based on long term averages: $3.25/kg carcass weight for lamb, $45/head for cast for age ewes, $65/head for shippers, 1135c/kg for 20μm fleece wool and $250/t for lupins.

Genotypes with improved resilience compared to the standard were simulated by adjusting parameters in the model to: a) improve intake of low quality feed, or b) reduce the metabolisable energy required for maintenance. The changes in the parameters are not specified in the paper, although it is inferred that the extent of reduced weight loss are approximately +3 kg for a) increased intake and +1.4 kg for b) more efficient metabolism. Further details of the methodology were documented following discussions at the 2011 Coffs Harbour meeting (see Appendix 2d). The adjustment for intake was based on feed quality and the improved genotype was calibrated to lose 1 kg less weight when offered the same feed. On dry feed (dry matter digestibility of 55% and a clover content of 25%) this means that the improved genotype consumes about 25% more dry pasture than the standard genotype. This document also indicates that the results in (Young *et al.* 2011a) were based on a 2.4kg less loss in weight (this assumption appears to imply a 60% increase in intake which seems unrealistic and requires clarification).

Genotypes with improved resilience (less weight loss over summer/autumn) were more profitable in all systems examined with the benefits greater for lamb than wool production systems. There were major genotype by environment interactions. The genotypes with improved resilience had considerably higher profitability in the moderate quality compared to the high quality pasture systems and especially in the Lamb enterprise. The majority of the estimated benefit of improved resilience calculated in the model comes from the increase in stocking rate that can be achieved. The increases in stocking rate are generally modest, ranging from 1-5%, except for the Lamb enterprise on the moderate pasture system (19-25%, Table 1). The Lamb enterprise with the standard genotype on the moderate pasture system was very unprofitable (-$22,000), presumably due to a very high cost for supplementary feed (33.3 kg/DSE, which equates to a cost of $55,777). MIDAS was subsequently adjusted to include a “Risk Cost” of supplementary feeding to bias the optimum solution to lower stocking rates with less feeding to better reflect the real farmer situation (Appendix 2d). Young *et al.* (2011a) concluded that the emphasis on the liveweight loss trait in breeding objectives is likely to be greater for lamb production systems in more marginal environments.

Table 1. Stocking rate under different animal and pasture systems for the standard genotype and percentage change for higher intake and lower maintenance genotypes[1]

Enterprise	Wool		Lamb	
Pasture type	Moderate	Good	Moderate	Good
Genotype				
Standard (DSE/ha)	8.5	12.0	6.7	11.0
Higher intake (+%)	+3.5	+0.8	+25.4	+3.6
Lower maintenance (+%)	+4.7	+4.2	+19.4	+4.5

[1]Adapted from Young *et al.* (2011a)

Preliminary analyses showed that including resilience as a trait in a sheep breeding program could contribute to overall $ gain (Appendix 2e and 2f). The importance of resilience depended on its relative economic value, which covered a wide range from zero to representing over 60% of the $ gain (largely replacing gains from reduced fibre diameter). These results (as acknowledged by the authors) depend on the accuracy of the assumptions made about the heritability of resilience (0.2) and its genetic correlations with the other production traits (0.2 ycfw, -0.14 yfd, -0.2 pwt, -0.15 awt, -0.3 nlw).

In a different MIDAS simulation study, (Young *et al.* (2011b) showed that liveweight profile affected profitability of Merino spring lambing enterprises in Great Southern WA, south-west Vic and southern NSW. The optimum profiles for ewes were similar in all regions and were ~90% of the standard reference weight of the genotype at joining, losing ~3 kg in early pregnancy and regaining all maternal weight (conceptus and wool free) by lambing. The shape of the optimum profile was not sensitive to changes in prices, pasture productivity or management. The analysis showed that regaining maternal weight lost in early pregnancy by lambing was more important than meeting other weight targets set for joining and mid-pregnancy. The analyses consistently showed that the cost of extra feed to meet the target weight at joining outweighed the production gains. The cost to achieve a higher joining weight in southern NSW (50 v. 46 kg) reduced profitability by $2.30/ewe, although the reduction in profitability was less in the other regions.

Genetic parameters for weight loss

Analyses of the Merino Resource Flocks at Katanning WA (Greeff and Cox 2006) have been undertaken to estimate genetic parameters for weight change over the production cycle (Rose *et al.* 2013) and its genetic correlations with other production traits (Rose *et al.* 2014). These papers are more extensive and update an earlier conference paper (Rose *et al.* 2011). Other analyses of weight change over the production cycle have also been undertaken using data sets from different genotypes and environments - the Merino D Flock at Trangie NSW (Walkom *et al.* 2013c) and crossbred ewes in the MCPT project at Cowra NSW, Hamilton and Rutherglen Vic (Walkom *et al.* 2013a; Walkom *et al.* 2013b).

The objectives of the WA data analyses were to test the hypotheses a) that body weight loss over summer and body weight gain over winter are different traits, and b) that body weight change is a different trait in young compared with older ewes (Rose *et al.* 2013). The data included body weight (adjusted for conceptus and wool weight) at 4 occasions throughout the production cycle (Wt1, premating, early Jan; Wt2, post mating, late Feb; Wt3, pre-lambing, May; and Wt4, weaning, early Oct) over 6 years for 2,336 fully pedigreed ewes that ranged in age from 2 to 4 years. Current and previous year reproduction were also included as fixed effects, although none of these results were presented. Three analyses were undertaken: weight change traits ($Loss_{join}$ =Wt2-Wt1 and $Gain_{lact}$=Wt4-Wt3), multivariate analyses of weights, and random regression of weights. The weight profile of the ewes is shown in Fig. 1.

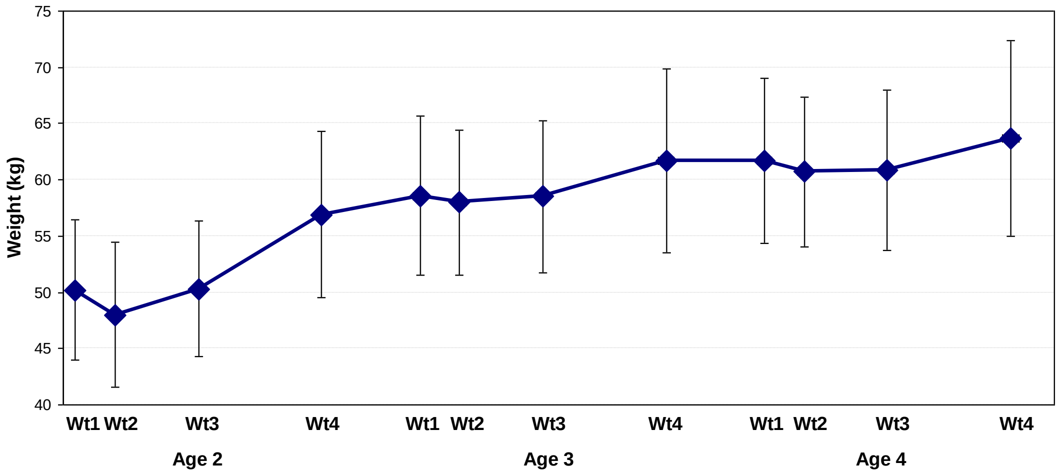

Fig.1. Weight profile (conceptus and wool free) of WA Merino ewes (Wt1 pre-joining, Wt2 post-joining, Wt3 pre-lambing, Wt4 weaning) over 3 ages (± s.d.) (adapted from Rose *et al.* (2013))

The results showed a mean $Loss_{join}$ of -2.2 kg and $Gain_{lact}$ of 6.6 kg for 2 year old ewes and a loss of less than 1 kg and gain of about 3 kg for 3 and 4 year old ewes, although the s.d. indicates that large proportions of mature ewes actually gained weight over the summer and lost weight over the winter (Table 2). For the estimation of variance components there were some differences between the analysis methods, although the authors regarded the multivariate analysis as a better fit for the data than the random regression analysis. The estimates of heritability (multivariate) for $Loss_{join}$ (0.11-0.15) were about half those for $Gain_{lact}$ (0.19-0.33), as were the corresponding phenotypic standard deviations (Table 2).

The authors concluded that $Loss_{join}$ and $Gain_{lact}$ were different traits and that there were some differences in the traits between ages of ewes.

Table 2. Mean (s.d.) $Loss_{join}$ (kg) and $Gain_{lact}$ (kg) and estimates of heritability (h^2±s.e.) and phenotypic standard deviation (σ_p) for 2, 3 and 4 year old ewes[1]

	$Loss_{join}$ Mean (s.d.)	$Gain_{lact}$ Mean (s.d.)	$Loss_{join}$ h^2±s.e.	$Loss_{join}$ σ_p	$Gain_{lact}$ h^2±s.e.	$Gain_{lact}$ σ_p
2 years	-2.23 (2.73)	6.55 (7.20)	0.14±0.04	2.50	0.33±0.05	4.85
3 years	-0.61 (3.95)	3.14 (7.20	0.15±0.05	3.30	0.21±0.05	5.27
4 years	-0.97 (3.79)	2.83 (7.41)	0.11±0.06	3.30	0.18±0.06	5.39

[1]Adapted from Rose *et al.* (2013)

The estimates of genetic correlations between ages of ewes for $Loss_{join}$ were low with high s.e., while they were higher with lower s.e. for $Gain_{lact}$ (Table 3). The estimates of the genetic correlations between $Loss_{join}$ and $Gain_{lact}$ were zero for 2 and 4 year old ewes and negative for 3 year old ewes (-0.42±0.19). This means that the 3 year old ewes that lose more weight in summer also gain more weight in winter, although the authors concede that the result may be due to sampling.

Table 3. Genetic correlations (±s.e.) between ages of ewes for $Loss_{join}$ and $Gain_{lact}$[1]

	$Loss_{join}$		$Gain_{lact}$	
	3 years	4 years	3 years	4 years
2 years	0.34±0.24	0.39±0.30	0.53±0.14	0.51±0.15
3 years		0.13±0.32		0.99±0.15

[1]Adapted from Rose *et al.* (2013)

Genetic correlations between body weight change traits and other production traits in Merinos were also estimated to assess if selection for weight change will genetically affect other economic traits. This analysis (Rose *et al.* 2014) was undertaken using essentially the same data set as above and is more extensive and updates a previous conference presentation (Rose *et al.* 2012). The weight change trait $Gain_{preg}$ (=Wt3-Wt2), was also included in addition to $Loss_{join}$ and $Gain_{lact}$ (the terminology used in the papers has been changed here for consistency). The reproduction traits included: NLB (number of lambs born), NLW (number of lambs weaned), TBW (total lamb birth weight of lambing ewes), TWW (total weaning weight of ewes weaning lambs) and the binary traits HAVELAMB (fertility, lambed or not) and WEANLAMB (weaned lamb or not).

The results showed similar parameter estimates to those in Rose *et al.* (2013), (although not exactly the same - compare Table 2 and Table 4). The estimates of heritability for the body weights at the various times in the production cycle range from 0.42 to 0.69, with 2 year old ewes being at the higher end and Wt4 for all ages at the lower end of the range. The heritability estimates for body weight and the other production traits (wool, carcass and reproduction) are generally slightly higher than those reported in other Merino studies (Safari *et al.* 2007; Greeff *et al.* 2008; Huisman and Brown 2008) and in a review of world literature (Safari *et al.* 2005), possibly because some additional components of variance may not have been included in the models used.

Table 4. Mean (s.d.) $Loss_{join}$ (kg), $Gain_{preg}$ (kg) and $Gain_{lact}$ (kg) and estimates of heritability (h^2±s.e.) and phenotypic standard deviation (σ_p) for 2, 3 and 4 year old ewes[1]

	$Loss_{join}$	$Gain_{preg}$	$Gain_{lact}$	$Loss_{join}$		$Gain_{preg}$		$Gain_{lact}$	
	Mean	Mean	Mean	h^2±s.e.	σ_p	h^2±s.e.	σ_p	h^2±s.e.	σ_p
2 yrs	-2.1	0.9	6.3	0.14±0.04	2.5	0.15±0.04	3.0	0.22±0.06	5.7
3 yrs	-0.5	0.3	3.6	0.16±0.05	3.4	0.17±0.05	3.0	0.13±0.06	6.0
4 yrs	-1.0	0.1	3.1	0.11±0.06	3.3	0.18±0.06	3.4	0.18±0.06	6.6

[1]Adapted from (Rose *et al.* 2014)

The genetic correlations between the 3 weight change traits and the various body weights were generally small to moderate for 2 year old ewes (negative for $Loss_{join}$ and $Gain_{lact}$ and positive for $Gain_{preg}$) and generally not different from zero for older ewes. [There seemed to be an anomaly in the Table for ΔWTLACT and WT4 across all ages – high correlations 0.43 to 0.54 with very low s.e.] The genetic correlations between the 3 weight change traits and the production traits (fibre diameter, clean fleece weight, staple strength, muscle depth and fat depth) were generally small and not different from zero (only 3 of 45 estimates were > 2 x s.e.).

There were some moderate genetic correlations between the 3 weight change traits and the various reproduction traits for 2 year old ewes, but those for 3 and 4 year old ewes were almost all not different from zero. For the 2 year old ewes, those that lost least weight over joining ($Loss_{join}$) had genetically higher fertility (0.53±0.21), NLB (0.37±0.18), WEANLAMB (0.67±0.23) and NLW (0.62±0.19). Conversely those 2 year old ewes that gained most weight over pregnancy ($Gain_{preg}$) had genetically lower fertility (-0.46±0.20), NLB (-0.26±0.18), WEANLAMB (-0.41±0.23) and NLW (-0.45±0.19) and those that gained most weight over lactation ($Gain_{lact}$) had genetically lower fertility (-0.82±0.07), NLB (-0.37±0.13) and NLW (-0.42±0.14).

The authors concluded that selecting ewes to lose less weight during mating and pregnancy and gain more weight during lactation will have some favourable and unfavourable correlated responses on reproduction and live weight traits and minimal effect on other wool and carcass production traits.

The other Merino data set that was used to estimate genetic parameters for weight change was from the Trangie D Flock (Walkom *et al.* 2013c). The data comprised 3,300 ewes with live weight and condition score records at 4 times during the production cycle (pre-joining, mid-pregnancy (6 weeks prior to lambing), pre-lambing (1 week prior to lambing) and weaning) for 5 parities over 14 years at Trangie NSW. While these times in the production cycle do not correspond exactly to those in the WA data they are similar and I will use the notation of Wt1 to Wt4 respectively for simplicity. The ewes were maintained as 15 flocks sampled from a range of industry bloodlines from fine to broad wool and managed as a single group (Mortimer and Atkins 1989). Maternal performance in the previous year affected live weight and condition score of the ewes and these effects were fitted as fixed effects as appropriate in the models.

There was an increase in live weight (range 2.3 to 5.4 kg for parities) from pre-joining to mid- pregnancy (Wt2-Wt1) and mid-pregnancy to pre-lambing (Wt3-Wt2) (range 2.8 to 3.7 kg for parities). Whereas there was a loss of live weight from pre-lambing to weaning (Wt4-Wt3) (-0.5 kg for parity 1 and range -3.0 to -7.5 for other parities) and generally from weaning until pre-joining at the next parity (+0.8 to -1.9 kg). The effects of current and previous year reproductive status of the ewes were included in the model for analysis. However the live weights in these data were not adjusted for conceptus or wool weight as occurred in the WA analyses above. The mean weight and condition score across parities are shown in Fig. 2.

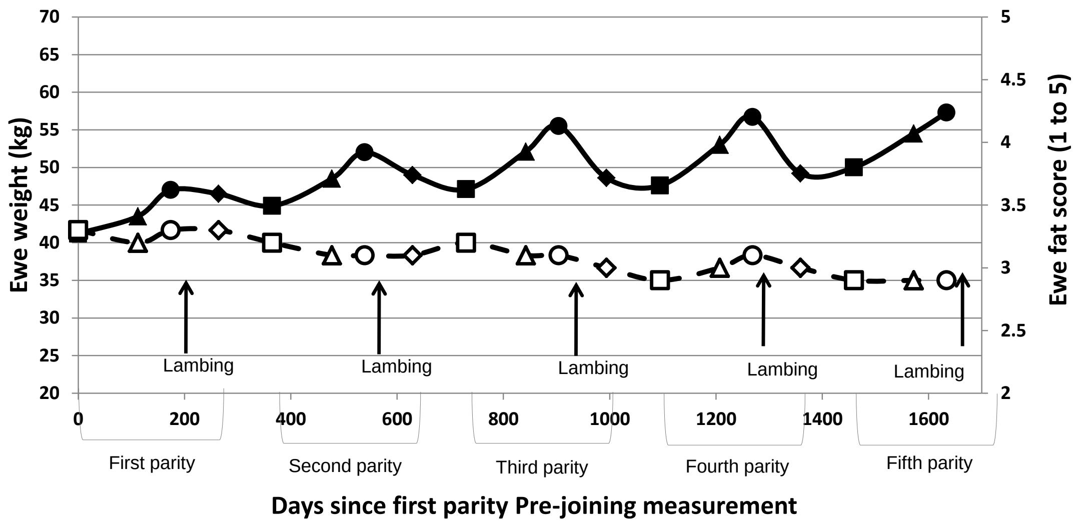

Fig. 2: Timing of weight (solid line) and body condition (dashed line) measurements on Trangie D flock ewes. Measurements were taken at pre-joining (square), mid-pregnancy (triangle), pre-lambing (circle) and weaning (diamond) across the first five parities of the ewes breeding life. (from Walkom *et al.* (2013c)

The estimates of heritability of live weight across the production cycle ranged from 0.39 to 0.42 (±0.02), with condition score being much lower (0.08 to 0.11 ± 0.02). The estimates of heritability for change in live weight (Wt2-Wt1, Wt3-Wt2, Wt4-Wt3 and Wt1-Wt4) were very low (0.01 to 0.03 ± 0.02) as were the similar changes in condition score (0.00 to 0.03 ± 0.02). The genetic correlations between the 4 weights ranged from 0.99 to 1.00 (± 0.01) and the 4 condition scores ranged from 0.92 to 1.00 (± 0.03), with the genetic correlations between weight and condition score ranging from 0.53 to 0.62 (± 0.04).

The authors concluded that as well as low heritability estimates for weight change, the additive genetic component was not "re-ranking" across environments or times. Weight change is most likely a scale effect and that the ewes with the most weight to lose are the ewes that lose the most weight. This potentially means that by having more genetic weight or condition the ewe will remain above the reproductive thresholds longer and potentially require less feed supplement through the production cycle.

Similar analyses were also undertaken with crossbred ewes from the MCPT data set (Walkom *et al.* 2013a; b). The data comprised 2,846 crossbred ewes with live weight and fat score records at 4 times during the production cycle (prejoining, post-joining, mid-pregnancy and weaning) over 3 parities. While these times in the production cycle do not correspond exactly to those in the WA and Trangie data they are similar and, for this review, I will use the notation of Wt1 to Wt4 respectively for simplicity. The first cross ewes were progeny of 91 sires, generally with ASBVs from predominately maternal breeds. The first cross ewes were joined to terminal sires at 3 sites, Cowra NSW and Hamilton and Rutherglen Vic, with all their progeny slaughtered for lamb production (Fogarty *et al.* 2005a). At Cowra the first cross ewe cohorts were split into autumn and spring joining groups with the autumn joined groups first joined at 7 months of age in February for lambing in July and the spring joined groups first joined at 14 months of age in October for lambing in March. At Hamilton each cohort of first cross ewes was joined in autumn (March) for lambing in August with first joining at 7 months of age. At Rutherglen each cohort of first cross ewes was joined in spring (November) for lambing in April, with first joining at 19 months of age. At each site the first cross ewes were joined for 3 parities (Fogarty *et al.* 2005a; b). The effects of current and previous year reproductive status of the ewes were included in the model for analysis.

The liveweights in these data have not been adjusted for conceptus or wool weight as occurred in the WA analyses. Also the ewes were fat scored (1-5 score using manual palpation of fat and muscle tissue over the long ribs and related to the GR tissue depth site (Shands *et al.* 2009)), rather than condition scored (1-5 score using manual palpation of fat and muscle tissue over the anterior loin short ribs (van Burgel *et al.* 2011)). While condition score has been the traditional method of assessment of the nutritional status of adult sheep, the fat score was developed in the lamb industry in response to the need to have an assessment that related directly to the GR carcass measurement in slaughter lambs. To avoid farmer confusion and aid adoption NSW extension services promote the fat score system rather than have two slightly differing procedures, while WA and some other states prefer the condition score system. Experienced assessors achieved high repeatabilities for either condition score or fat score and there were high correlations between condition and fat scores as well as between the scores and various objective measures of fatness and body condition (Shands *et al.* 2009; van Burgel *et al.* 2011). There is general agreement that condition score or fat score are useful practical procedures for managing the nutritional profile of ewes (Shands *et al.* 2009; van Burgel *et al.* 2011). Although Shands *et al.* (2009) concluded that fat scoring achieves greater discrimination in identifying animals that are higher or lower than the mob average, while van Burgel *et al.* (2011) concluded that condition score was better at distinguishing between ewes when they were below a score of 2.5. As the average fat scores of the ewes in the MCPT are above 3 there is no issue (Fig. 3).

There was a general increase in live weight of the first cross ewes from first joining to mid-pregnancy at their 3rd parity because of their young age at first parity (Fig.3). Care needs to be taken in interpretation of Fig. 3 as there is considerable variation in ewe age and season represented by each parity across the various sites, with these fixed effects included in the model. However the phenotypic standard deviations for the weight change traits (when this variation was removed), were relatively low (2.5, 2.8, 4.6 and 3.4 kg for Wt2-Wt1, Wt3-Wt2, Wt4-Wt3 and Wt1-Wt4 respectively).

There was no interaction of sire within cohort, environment or parity for live weight or fat score. Hence sire estimated breeding values at pre-joining for weight and fat score did not re-rank under different production environments or maturity.

The estimates of heritability for live weight at the 4 times in the production cycle were moderately high (0.41 to 0.55 ± 0.03) with those for fat score being about half (0.21 to 0.26 ± 0.02), although about twice the coefficient of variation (i.e. similar response to selection could be achieved for both traits). The estimates of heritability for changes in weight and fat score were considerably lower (range 0.04 to 0.23± 0.03 for weight change and 0.02 to 0.06 ± 0.03 for change in fat score). The genetic correlations between live weights at the various times were very high (0.93 to 0.99 ± 0.02) as were those for fat score (0.88 to 0.98 ± 0.06). Hence there was no indication that these were different traits across the production cycle. The genetic correlations between weight and fat score varied from 0.20 ± 0.16 at mid-pregnancy to 0.48 ± 0.11 at weaning, with phenotypic and environmental correlations of a similar order.

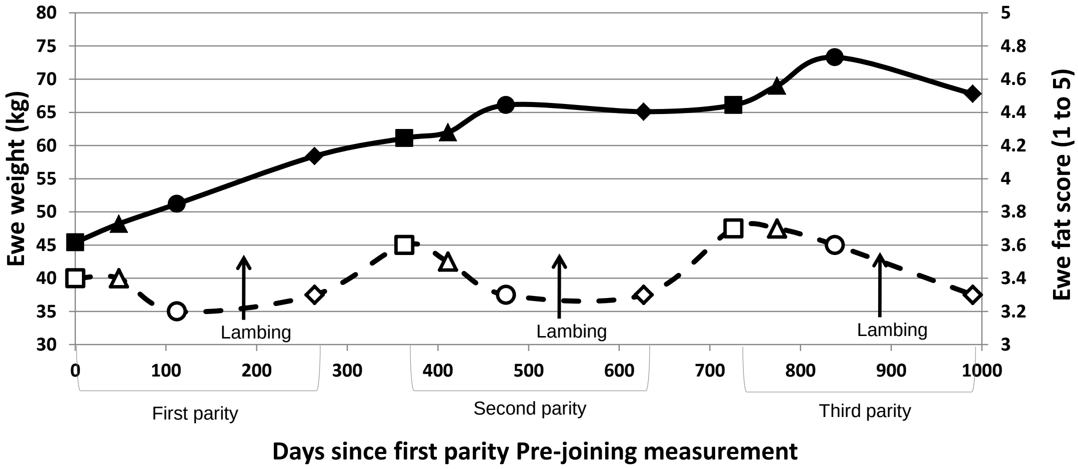

Fig. 3: Timing of weight (solid line) and fat score (dashed line) measurements of first cross ewes within maternal central progeny test. Measurements were taken at pre-joining (square), post-joining (triangle), mid-pregnancy (circle) and weaning (diamond) across the first three parities of the ewes breeding life. (from Walkom *et al.* (2013a))

Walkom *et al.* (2013a) also found that ewes that weaned multiple lambs were 4% lighter and had 18% lower fat score than single rearing ewes at weaning and were still significantly leaner (0.2 score) at the beginning of the next production cycle. The sire correlation for weight at weaning between barren and multiple weaning ewes was 0.76 (0.74 for fat score).

The authors concluded that genetic re-ranking throughout the production cycle was minimal and that the most likely way to genetically improve weight and condition during tough times in the production cycle was to have animals with higher genetic merit for weight and condition.

Walkom *et al.* (2013b) also used cubic spline analysis to examine maternal performance, environmental and genetic effects on weight and fat score across the breeding life of the first cross ewes from the MCPT data set. These results confirmed that breed and sire lines maintained their superiority (or inferiority) for weight and fat score across the 3 annual production cycles. The sire and breed had no influence on the linear or curved components of the spline, strongly indicating that selection against fluctuations in the weight and fat profiles will not be successful.

Relationship of weight loss with other production traits

A further subset of data from the Information Nucleus (van der Werf *et al.* 2010) was analysed by John *et al.* (2011) to examine genetic variation in resilience to live weight loss and its effects on reproductive performance. The data comprised 1036 Merino and Border Leicester x Merino (BLM) ewes born to 21 Merino and 20 BL sires at 6 sites in 2007. Live weights from birth to lamb weaning in 2010 (mean 18.7 records/ewe) over 2 reproductive cycles were analysed. At most sites live weight loss occurred prior to or during joining in summer/autumn, except at Armidale when it occurred after joining in winter and the magnitude of loss differed significantly between sites (P<0.001).

Sire had a significant effect (P<0.01) on live weight loss (range of sire means: Merino -5.0 to + 4.8%; BL -5.6 to + 0.1%), although there was a significant site x breed interaction (P<0.001), but no details provided. Live weight loss had no impact on subsequent reproductive performance. Similarly there was no carryover effect from birth or rearing type in the previous year on weight loss. Unfortunately this paper presents very little detailed information in the results to judge the justification of the conclusions.

A subsequent analysis of Information Nucleus data was undertaken by the same authors (Blumer *et al.* 2013) to examine the relationships between weight loss in ewes and their sire breeding values for fat and muscle. The data comprised 712 BLM and 2060 Merino ewes (27 BL and 43 Merino sires respectively) at Katanning WA and Kirby NSW over 3 years. Ewes were weighed on average 5.8 times per year and live weights were adjusted for conceptus and wool weight. A cubic spline was used to derive weight profiles for the ewes (average weight, minimum, maximum and range in weight each year), with weight loss (maximum to subsequent minimum) analysed.

Weight loss at Katanning occurred primarily between weaning and mid-pregnancy (-11.9 ± 0.2 kg, summer/autumn) and at Kirby between joining and mid-pregnancy (-5.6 ± 0.2 kg, winter). There was as significant interaction (P<0.001) between site and sire breed with Merino ewes losing less weight than BLM ewes at Katanning (-10.7 *v.* -12.3 kg), but the reverse at Kirby (-7.0 *v.* -2.8 kg).

Similarly for the relationships between weight loss and sire ASBVs for both fat (PFAT) and muscling (PEMD) there were significant site interactions (P<0.01) as shown in Fig. 4. Ewes with higher sire breeding values for PFAT lost less weight at Katanning but lost more weight at Kirby. In contrast the ewes with higher sire PEMD lost more weight at Katanning and lost less weight at Kirby.

In the discussion Blumer *et al.* (2013) asserted that at Katanning a 1mm increase in sire PFAT, which reduced weight loss by 1.3 kg, was worth $2.90/ewe. However this value appears to come from Young *et al.* (2011b), in which they showed a feed cost of $2.30/ewe to achieve a 4 kg increase in liveweight at joining (in southern NSW), which would equate to a value of $0.75/ewe rather than $2.90/ewe.

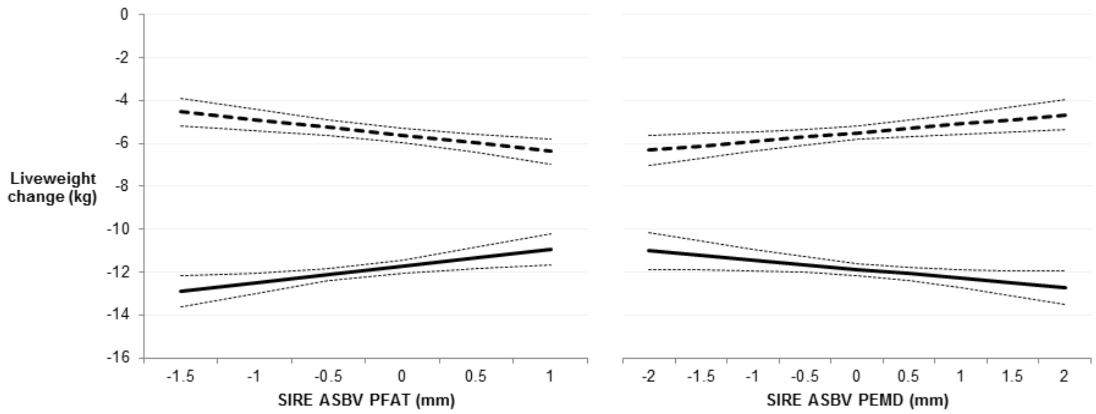

Fig. 4. Relationship between liveweight loss and sire breeding values for fat (PFAT) and for muscle (PEMD). The data represent the predicted liveweight loss for ewe progeny grazed at Katanning, WA (solid black line), Kirby, NSW (broken black line) over three years (±SE). (from Blumer *et al.* (2013))

Discussion

There are some differences in the results from the various studies, although overall they indicate that there is little genetic variation for weight change or opportunity for selection over the various times during the production cycle. The WA Merino study showed low heritability estimates for weight loss during the joining period (0.11-0.15) with low phenotypic standard deviations (Rose *et al.* 2013), whereas in the other studies the estimates were close to zero for Merino (Walkom *et al.* 2013c) and crossbred ewes (Walkom *et al.* 2013a). There were also relatively low genetic correlations for weight loss between ages of ewes (r_g 0.1-0.4, Rose *et al.* 2013). In both the other studies the genetic correlations between weights (and condition or fat score) at the various times during the production cycle were very high and there was no indication of any re-ranking of sires for weight or weight change of their progeny at different times in the year or reproductive cycle.

In addition to the Australian research reviewed above, two overseas studies investigating genetic parameters of weight change traits have also been reported. Results from a study involving Targhee ewes grazing summer range in Montana USA (Borg *et al.* 2009), included body weight changes and heritability estimates from late gestation to early lactation of -5.4 kg and 0.13, during lactation of +4.9 kg and 0.05 and from weaning to next breeding of +2.0 kg and 0.06 respectively. While the highest heritability in this study was for the period of weight loss, the data have not been adjusted for conceptus weight and the loss from late gestation to early lactation (exact times not specified) could largely be accounted for by the conceptus and the heritability may in part be reflecting the heritability for birth weight of 0.12 to 0.19 (Safari *et al.* 2005).

The other study involved one year of data from Merino ewes grazing winter rangelands in Nevada USA. The ewes had a sharp loss in weight (the text shows -6.4 kg, but a figure indicates the average loss was about -11 kg) over 75 days during mid-pregnancy (Rauw *et al.* 2010). The authors adjusted for conceptus weight and reported a heritability estimate for the loss in weight of 0.29±0.05.

There are obviously environmental differences between the studies as indicated by the weight profiles of the ewes. In WA there was a loss of weight over joining in late summer/autumn, although the loss was much greater among maiden (2 year) than older ewes (Fig. 1) and the high standard deviation indicated that a large proportion of ewes would have gained weight (Table 2). The ewes then maintained or increased weight slightly through pregnancy and gained weight through lactation (conceptus and wool free weights).

The analyses with the Trangie Merino ewes were based on liveweights (Fig. 2) and Fig. 5 shows these weights adjusted to be free of conceptus and wool growth so they are comparable with the WA data. These values have been calculated by assuming average conceptus weights of 1.8 and 4.2 kg for Wt2 and Wt3, which are approximately 90 and 125 days of pregnancy (Langlands and Sutherland 1968) relative to the average expected lambing date. The ewes were shorn just prior to weaning and proportional average greasy wool growth (Mortimer and Atkins 1989) of 0.7, 2.0 and 2.5 kg were assumed for Wt1, Wt2 and Wt3 respectively. The weight (conceptus and wool free) profile of the ewes (Fig. 5) is somewhat variable over the 5 parities although there is a general pattern of maintenance or increase of weight over joining (late summer/autumn) and an increase in gestation and lactation at least in early parities, with a sharp decline in weight between weaning and the next joining.

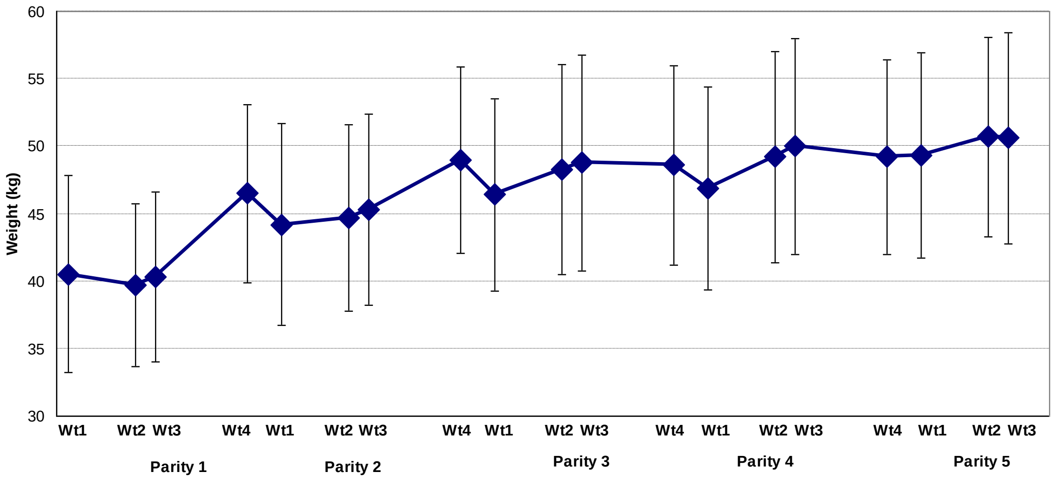

Fig. 5. Weight profile (conceptus and wool free) for Trangie D Flock ewes over 5 parities (±s.d.) Adapted from Walkom *et al.* (2013c)

The analyses of the Information Nucleus data also showed marked differences in the weight profile of ewes (free of conceptus and wool) between locations. Weight loss at Katanning WA occurred primarily between weaning and mid-pregnancy (-11.9 ± 0.2 kg, summer/autumn) and was greater than at Kirby NSW which occurred between joining and mid-pregnancy (-5.6 ± 0.2 kg, winter) (Blumer *et al.* 2013).

The Information Nucleus provides a data set with a large loss in weight (-11.9 kg at Katanning) which could also be used to estimate genetic parameters. More importantly the genotype x environment interactions across all sites and years need to be examined in more detail than has been presented in the 2 conference papers (John *et al.* 2011; Blumer *et al.* 2013). These analyses (which may have been done) need to elucidate the causes of the interactions and detail the implications for breeding programs.

Clearly there are different seasonal patterns of pasture production and availability across the sheep grazing environments in Australia. These patterns also vary from year to year, although the Mediterranean environment of WA is probably more consistent in having a dry summer/autumn than other regions of Australia. There is some indication from the various studies that there may be some genetic variation for weight loss under consistently severe nutritional conditions. The question is whether selection for reduced weight loss (resilience) under these conditions, with a heritability of about 0.15 and low phenotypic standard deviation is likely to be successful or better than selection for weight or condition score or other traits included in an appropriate index?

The economic value of reduced weight loss in summer/autumn is somewhat equivocal. In a simulation study Young *et al.* (2011a) concluded that there was a considerable improvement in profitability through a 19-25% possible increase in stocking rate in a lamb enterprise on moderate pasture, although the potential increases were minor for wool enterprises and on improved pasture conditions. While in another study Young *et al.* (2011b) concluded that it was more critical to regain weight at lambing than mitigate loss of weight at joining across several sheep environments, using production parameters relating the ewe nutrition profile to reproduction (Ferguson *et al.* 2011), lamb survival and progeny wool production (Oldham *et al.* 2011; Thompson *et al.* 2011). The possible mechanisms for improved resilience were postulated to be increased feed intake and/or improved energy efficiency for maintenance (Young *et al.* 2011a). Different strains of Merinos have been shown to respond differently to good and poor nutritional conditions mitigated through lower feed intake on low protein pastures resulting in greater live weight loss over autumn (Adams *et al.* 2002). There is also genetic variation for feed intake under grazing with heritability estimates in Merinos of 0.20±0.08 (Lee *et al.* 2002) and 0.32±0.08 (Fogarty *et al.* 2009) and in crossbreds of 0.41±0.07 (Fogarty *et al.* 2006). However selection for reduced feed intake would need to account for ewe live weight to avoid a correlated decline in weight and growth (Fogarty *et al.* 2009).

While the results of the various studies and literature indicate there may be opportunities to genetically improve feed intake or reduce loss in weight where there is severe nutritional shortfall, any responses are likely to be small. Limited dry feed supply over the summer/autumn period is not universal or consistent in Australian sheep grazing enterprises and the results indicate very limited genetic variance for change in weight in other environments. The differing relationships resulting from the site interactions between weight loss and fat and muscle breeding values (Blumer *et al.* 2013) also reinforce the notion that genotype x environment interactions may be important. There are also other issues with including weight loss as a trait in a breeding program, such as the lack of a strong genetic correlation between ages and selection generally only available on the ewes at older ages. A more practical option that may result in some gains in the current flock could be to cull ewes with high weight loss, however this would need to take account of reproduction in the previous year and gains would be dependent on a high repeatability between ages. The variable and generally low genetic correlations between weight loss and various weights especially at older ages (Rose *et al.* 2014) means this requirement is unlikely to be met.

Selection for increased liveweight will lead to heavier mature sheep because of the moderately high heritability (>0.4) and phenotypic variation (Safari *et al.* 2005; Huisman and Brown 2008) and there will also be a moderate correlated increase in condition or fat score (r_g 0.5-0.6 in Merinos, (Walkom *et al.* 2013c); r_g 0.2-0.5 in crossbreds (Walkom *et al.* 2013a); r_g 0.5-0.7 in New Zealand flocks (Shackell *et al.* 2011). Selection for increased yearling weight would also appear to lead to a reduction in weight loss (2.05 kg less weight loss/kg breeding value, John *et al.* 2011). Direct selection for condition or fat score is not as feasible as weight because of its relatively low heritability (0.1-0.3) (Borg *et al.* 2009; Walkom *et al.* 2013c; a; Shackell *et al.* 2011). Selection for increased weight will also lead to a correlated increase in fat (rg 0.4, Safari *et al.* 2005).

Increasing ewe live weight has benefits from higher production and lamb turnoff, but on the down side there is a higher maintenance feed cost and lower stocking rate which impacts on enterprise profitability. Similarly fat has negative effects on carcass value and positive effects on growth and ewe productivity. The emphasis for several decades in meat sheep breeding has been to reduce carcass fat levels (Fogarty 2009). The Merino has lower fat levels than the maternal and terminal sire breeds (Fogarty *et al.* 2000), and in recent years is contributing more genes to breeding ewes for lamb production as well as its traditional role in wool enterprise flocks where higher fat levels may contribute to increased reproduction (Ferguson *et al.* 2010) and resilience to poor nutrition (Adams *et al.* 2002). These conflicting outcomes for breeding programs can best be resolved by a bioeconomic approach that takes account of feed requirements to derive economic values and breeding objectives for different enterprises in various environments. Studies using these approaches in the UK (Conington *et al.* 2004) and Ireland (Byrne *et al.* 2010) sheep industries have both highlighted the negative economic value for mature ewe weight.

Conclusions

The conclusions are arranged under the points in the ToR as follows:

1. *Definition of the trait and has its measurement been adequately defined?*

Several definitions of the weight loss trait have been used, e.g. from pre to post joining in late summer/autumn; maximum to minimum weight; weight change from various points in the production cycle (joining, mid-pregnancy, weaning). While a definition of weight loss over late summer/autumn may be appropriate in a consistent Mediterranean environment, there are practical limitations elsewhere, especially if the period of loss covers pregnancy and lactation because of the need to account for changes in weight due to conceptus growth with varying foetal number and foetal age.

2. *How heritable is the trait and what are the correlations with other traits (e.g. PFAT)?*

Generally the heritability estimates of weight loss are very low (<0.05), except possibly where there is a consistent and sharp decline in weight (maybe 0.15). The genetic correlations with most production traits (wool and carcass) also appear to be very low and any selection would have little impact. There were some potentially favourable and unfavourable correlations with reproduction traits, although they were not consistent and the genetic correlations had high standard errors.

3. *What is the biological significance and phenotypic impact of the trait in different environments?*

The biological significance is likely to be mitigated through increased feed intake on dry pasture and/or improved energy efficiency for maintenance. While there is some genetic variation for feed intake selection is currently not feasible. Modelling with MIDAS indicated feed intake would be increased by 25% for a genotype with a 1 kg less weight loss over late summer/autumn. There seems much more scope for management solutions to address the loss of weight that are specific to the environment involved. Apart from the obvious (feed supply), taking account of the effect of reproduction level in the previous year to differentially manage ewes, as was shown to have significant effects in these analyses as well as other studies, could assist.

4. *What is the economic significance of the trait likely to be under different management/environmental conditions?*

The economic significance of the trait is through reduced feeding costs and the possible gains through increases in stocking rate. While the reduced feeding costs have been quantified as $0.75/ewe/kg, the impact on stocking rate is not quantified and would be difficult to do so. The economic studies concluded that the benefits are likely to be greater for lamb enterprises in more marginal environments, with much smaller benefits for wool enterprises and in better environments.

5. *Is any further research warranted to clarify area of uncertainty?*

The Information Nucleus provides a data set with a large loss in weight (-11.9 kg at Katanning) which could also be used to estimate genetic parameters. More importantly the genotype x environment interactions across all sites and years need to be examined in more detail than has been presented in the 2 conference papers (John *et al.* 2011; Blumer *et al.* 2013). These analyses (which may have been done) need to elucidate the causes of the interactions and detail the implications for breeding programs.

A relook at breeding objectives for Merinos in different enterprises (lamb and wool) and environments, especially taking into account the role of mature ewe live weight and fat levels and their implications for production traits (lamb carcass and ewe reproduction) and stocking rate of breeding ewes.

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Appendix 1. Terms of reference for review of weight loss as a trait – Aug 2013

Background
The Sheep CRC Project Review and Research Committee (PRRC) has requested a review of research in relation to the genetics, biology and economic consequences related to the extent of weight loss during an extended period of sub-optimal nutrition.

The CRC and its Participants need to understand the importance of this trait as a possible target for genetic selection. The correlation with other traits and interaction with environmental and management factors need to be considered in order to rank its importance with other traits that influence production efficiency, health and welfare.

Specific questions to be addressed.

1. Definition of the trait and has its measurement been adequately defined?
2. How heritable is the trait and what are the correlations with other traits (e.g. PFAT)?
3. What is the biological significance and phenotypic impact of the trait in different environments?
4. What is the economic significance of the trait likely to be under different management/environmental conditions?
5. Is any further research warranted to clarify area of uncertainty?

Resource material relevant to the review.

The following unpublished reports, papers and discussion documents are considered relevant to the review but it would be appropriate to explore any other sources of information relevant to the subject matter.

a) Initial proposal (details to be provided by Andrew Thompson)
An initial proposal for expanded CRC research activity was documented in a discussion paper by Mark Ferguson and Andrew Kennedy (NB – copy still to be located). There was also an economic analysis by John Young. These papers were circulated prior to a meeting in Armidale in early 2010 with a follow up meeting in Coffs Harbour (March 2010).

b) Email discussion following Coffs Harbour meeting – March 2010. (This set of emails identifies some issues identified that were not resolved. (sent to NF)

c) Three papers with Sam Walkom as a lead author submitted to APS – June 2013 (NF has copies, JR to provide if needed).

d) Papers by Gus Rose – the genetic parameters around weight loss during WA summer (Andrew Thompson to provide copies)

e) Discussion paper by Mark Ferguson and Beth Paganoni Dec 2011 – on Centric. (sent to NF)

f) AAABG 2013 paper by Sarah John and Johns et al. (158) FLUCTUATION IN EWE LIVEWEIGHT DURING PERIODS OF RESTRICTED NUTRITION IS INFLUENCED BY SIRE (sent by AT)

Process
The CRC parties with an interest in the review should be given the opportunity to comment (or contribute) either during the review or via access to the draft final report.

Report.
The review should be prepared in a format suitable for submission to a peer-reviewed journal and, following approval of the report by the PRRC, the paper should be submitted for publication.

Time frame
The first draft of the report should be submitted by the end of September 2013 for consideration by the PRRC at the October meeting.

Appendix 2. a) Summary of Armidale meeting (March 2010)

General summary of Armidale meeting

Development of a methodology to improve the match between the sheep selection strategy with the requirements of the region, production system and management was considered important for the Australian sheep industry. It was also considered important that the process includes likely changes that will occur as a result of potential permanent changes to the production environment as a result of climate change.
It was identified that as well as understanding the impact of various ASBVs on whole farm performance (profit, environment and people) it is important to build knowledge of the varying importance of selection for resistance to worms and resistance to body and breech strike (and the predisposing factors eg dag, wrinkle etc) in different environments. It was considered that determining the importance and value of genetic resistance to worms and flies on whole farm profit, profit risk and health for particular production areas will be an important undertaking of this project. The discussion essentially widened the scope of the proposed work to encompass the 'easy-care' attributes of disease resistance in addition to the work determining the appropriate selection pressure required to maximise whole farm performance for different regions.

The general outcomes of that meeting were:

i. that the concept of matching G to E was important and should be developed further within the Sheep CRC as quickly as possible
ii. it was important to consider resistance to disease (flies and worms) and how the importance changes across regions in addition to resilience to feed deficits
iii. including labour use requirements into the costs and benefits of particular traits was seen as very important for defining appropriate selection strategies for the future
iv. the first step forward is to do desktop analysis to define the relative importance of key traits and how that changes with production zone to define priority areas of further research – this process must consider impacts on labour use, farm health and whole farm profit
v. important to determine whether there are sheep genotypes that perform better at high stocking rates or more limited nutrition as stocking rate remains an important determinant of profit
vi. the modelling process should use a combination of available models (MIDAS, Ausfarm, Smart Merino) so that questions are answered or scenarios run with the most appropriate model rather than trying to develop one model to answer all questions.

Proposed process forward:

General concept:

Improving farm profit and health with easy-care sheep well matched to their production system and management.

The process forward will be somewhat guided by initial desktop studies and concept workshops within the project team, however the likely process forward is as follows:

1. Determine the relative value of production, easy-care and disease resistance traits across the key sheep production zones

a) Identify zones/environments that are important for the Australian sheep industry
b) Identify strengths and weaknesses of modelling capacity and determine appropriate process to follow to ensure
c) Conduct a desktop study to determine the coefficients required to appropriately model the impact of traits on whole farm profit and health
d) Find relevant coefficients in literature/previous work and determine coefficients which are currently unknown
e) Modify Ausfarm, Smart Merino and MIDAS models to incorporate new coefficients where appropriate.
f) Of the required coefficients that are unknown, prioritise their importance based on best guesses and sensitivity analysis – those that are having a large impact on labour, profit or farm health should be selected for further work

g) Conduct research on high priority coefficients to determine the associated biology and appropriate coefficients
h) Run modelling to define the relative value of traits on whole farm profit and health including any new knowledge in differences in reliance amongst animals

2. Define selection indices for 5 key environments and road test resultant phenotypes, include sires with INF matings to test across a range of environments.

Associated work:
A concurrent activity to this process will be work to develop methodology to identify individuals or families that display improved resilience to nutritional and disease stresses, any resultant information will be included into the process of defining the relative value of traits and determination of appropriate selection indices.

Quantitatively defining industry concepts of 'good doers' or sheep that apparently are productive but always in better condition than those in same mob is an important component of this research. Defined as either resilient of robust animals, this program of research will undertake to define repeatable ways that sheep can be identified and determine what this may mean for whole farm profit and health. Activities to elucidate animal differences in resilience may include (but certainly not limited to):

a) Determine the heritability of condition score or liveweight change throughout a breeding cycle and through times of nutritional restriction
b) Determine whether CV of FD is a potential indicator of resilience to environment – evidence that CV of FD is linked with a range of changes in energy metabolism, fatness and lamb survival. Database analysis and experimentation may confirm or reject the hypothesis of CV of FD being an indicator trait of resilience.

Proposed project team:
Mark Ferguson (DAFWA)
Andrew Kennedy (UWA)
Jess Richards (DPI NSW)
Kevin Atkins (DPI NSW / UNE)

Appendix 2. b) Email correspondence (11 April from 19 March 2010)

Hi James,
I appreciate your previous comments and suggestions and the offer to remain engaged, but for the reasons you point out below I think it is time that we knock this conversation on the head, so you won't be seeing a hypothesis and experimental detail - time to move on for me,
Regards
Mark

-----Original Message-----
From: James Rowe [mailto:jamesrowe@bigpond.com]
Sent: Sun 11/04/2010 05:13
To: Ferguson, Mark; 'Alex Ball'; james.rowe@sheepcrc.org.au
Cc: julius.vanderwerf@une.edu.au; Thompson, Andrew
Subject: RE: Maternal feed use efficiency - response
Dear Mark,
Thanks for your email picking up on a number of points. I think that we have documented our concerns and suggestions and the argument is becoming a bit circular.
I remain skeptical about the value of the considerable effort that will be needed and the possibility of developing clear new breeding/management objectives. I am happy to remain engaged in the discussion and look forward to seeing the hypothesis and experimental details.
Regards,
James

From: Ferguson, Mark [mailto:mark.ferguson@agric.wa.gov.au]
Sent: Saturday, April 10, 2010 9:22 AM
To: Alex Ball; james.rowe@sheepcrc.org.au
Cc: julius.vanderwerf@une.edu.au; Thompson, Andrew
Subject: RE: Maternal feed use efficiency - response
Hi Alex and James,
this discussion seems to be getting somewhat circular and probably not worth using up more of your valuable time, but a few points of clarification and answers to questions posed mostly by Alex:
1. I think our points of view are actually quite similar
2. I thought that the process would be that the discussion paper would result in a yes/no answer as to whether the CRC was interested in the broader area and then we (that is, those who've gone before and those currently interested) could sit down and determine the highest priority part to work on that best suits CRC objectives and has the greatest chance of delivering useful results to industry.
3. Yes developing a clear and testable hypothesis and its justification is an important step in the process, but one that would be much better done jointly and after the above has been done. Your knowledge of the area and previous experience would clearly add considerable value to that process - it is a bit of a chicken and egg, you don't want to vote until you see the detail, but it seems pointless to develop the detail without your direct input or if the vote is no. Obviously we have developed hypotheses for DAFWA work but it seemed more sensible to start with a clean slate, so the discussions didn't get to the detail too quickly or biased.
4. We do have very good industry linkage and are measuring CFAT and EMD and aim to use DXA, obviously INF followers would add a lot which was the basis for the discussion
5. No doubt that value of any trait developed would partly be determined by incorporating correlations determined by SG between the trait and other production traits and ideally these correlations would be used to select for it
6. I am aware of the 50+ previous years looking at efficiency in ruminants and that I am not the first person to think that efficiency in sheep is important, but I do think some questions remain unanswered.
7. We are not interested in the detailed physiology of mature ewe efficiency because we don't have the resources and have been guided by your comments on the experiences in the beef industry. We do have a PhD project proposed that would look at high level physiology of differences including body comp, insulin responsiveness and adrenaline and/or cortisol sensitivity, but would need a student to that work.
8. My point on the likelihood of animals with low NFI during post weaning growth being less able to cope with nutritional restriction was in relation (agreeance) to James' comments ie "It is almost certain that there are different biological profiles in sheep that can grow really fast on good feed and those that lose less weight on poor feed. I would also bet that there is a negative correlation between these two

traits" and "My opinion is that net feed efficiency will be of minor importance in this combination of factors and will be negatively correlated with rapid growth - critical to facilitate joining at 7 months, capacity for high feed intake (growth) to bounce back from twin lambs to produce twins again". While I am not aware of any literature where that hypothesis has been specifically tested, it is obviously currently under test within the Beef CRC, unfortunately in both 2007 and 2008 years both sites were unable to keep the screws on during the spring flush and the low nutrition treatments weren't that low. But the fact that the low NFI cattle from Trangie are leaner than their high NFI equivalents suggests potential for problems in environments that have restricted or large fluctuations in nutrition. In addition, David Lines paper in AAABG 2009 demonstrates the reduced ability of low NFI cattle to rapidly rebuild fat reserves in times of unlimited nutrition. Which potentially puts them at a disadvantage in restricted environments. Discussions with staff that manage the Vasse cattle also suggest that high NFI cattle handle the low nutrition treatments better.
9. Not sure whether you are suggesting I was a PhD student that had no result or are suggesting that I am happy to waste money? Either way, it's probably not a road we want to go down.
Sorry if this has been a waste of your time, but your comments on priorities and design have been helpful
Regards
Mark

-----Original Message-----
From: Alex Ball [mailto:aball@mla.com.au]
Sent: Wed 07/04/2010 06:56
To: Ferguson, Mark; James Rowe; Thompson, Andrew; julius.vanderwerf@une.edu.au; James Rowe
Subject: RE: Maternal feed use efficiency - response
Mark,
See comments below.
Dr Alex Ball, Manager, Lamb and Sheepmeat R&D
From: Ferguson, Mark [mailto:mark.ferguson@agric.wa.gov.au]
Sent: Wednesday, 7 April 2010 1:20 AM
To: Alex Ball; James Rowe; Thompson, Andrew; julius.vanderwerf@une.edu.au; James Rowe
Subject: RE: Maternal feed use efficiency - response
Hi Alex and James,
Thanks for your further comments. Apologies if you have been mislead by the discussion paper, but the focus has never been on NFI in growing animals and has always been very much focussed on the mature ewe and understanding attributes that make them easier or cheaper to manage. Many of your comments align well with what we have planned for this work. The discussion paper gave only limited information about experimental details etc as it was assumed that if considered important that the details would be fleshed out, with assistance from you and others. The overall aim of the work is to be better able to define and value a trait of resilience in mature ewes. We are confident that voluntary feed intake will be an important part of resilience. Norm Adams concluded that drive to eat was a major part of more robust genotypes*[Alex Ball] (yes and others have shown that selection is more important than gross intake)*. While we don't expect NFI in growing animals to be a useful trait in the sheep industry, I think it is important to build a profile from feed intake during post-weaning growth and beyond through to intake during loss and regain to understand the true value of a resilient trait [Alex Ball] If you measure this in animals with effective genetic links then we will already have measurements on those traits that are economically important. We are not interested in the detailed physiology of why differences occur *[Alex Ball] (why not)*, but we do no need to know the size of differences between individuals and what else it is correlated with to be able to properly determine the value of these differences *[Alex Ball] (yes that is why it is important to measure the information nucleus ewes)*. Obviously the ultimate aim is to have a simple 'test' that can be implemented on farm to determine those ewes that lose less weight etc *[Alex Ball] why do we need a simple test....if we have accurate information on what correlates with the trait then we will simply include it in selection....I do hope that you are getting very good measurements of body composition at least C fat and EMD.* But to do that blindly without understanding the implications on feed intake and use throughout the life cycle and production system would be negligent *[Alex Ball] (you measure your trait and then we will work out the correlations...negligent would be to do tests on animals that don't have very good industry linkage....PS that is why we are having this conversation)* It is likely that ewes that are more efficient during growth will be less able to cope with poor nutrition as adults *[Alex Ball] (what do you base this*

on? Please provide the literature that supports this?). But I think it is important that that hypothesis be tested considering the likely changes to the animal associated with breeding for reduced methane output which the CRC and others are currently investing in. We are interested in this work because we believe, and the modelling shows *[Alex Ball] You are not the first to believe this.John Thompson and I went on this 12 years ago)*, that it is potentially important *[Alex Ball] (agree that ewes that are more resistant to seasonal feed fluctuations will be very useful)*. We have been encouraged by the level of interest from within the sheep industry *[Alex Ball] (yes so was the beef industry....just be careful that you don't over promise and under deliver)*. If it turns out to be a quest for the holy grail, then so be it - fortune favours the brave *[Alex Ball] (yes however even the brave take notice of those that have been before and you are no longer a PhD student that can afford to have no result; we must always balance the R&D to provide benefit to industry...as James indicated get your hypothesis and experimental design to a point of clarity...it will help you in the long run.)*
regards
Mark

-----Original Message-----
From: Alex Ball [mailto:aball@mla.com.au]
Sent: Tue 30/03/2010 06:28
To: James Rowe; Thompson, Andrew; Ferguson, Mark; julius.vanderwerf@une.edu.au; James Rowe
Subject: RE: Maternal feed use efficiency - response
Hello Andrew and Mark,
1. Whilst I appreciate the passion on the subject, be careful not to confuse industry desire (that is the chase for the holy grails) with good sound practical modelling (see Genestar as the perfect failure model). I agree with Julius and James that they key area that you should work in is feed intake and potentially biological resilience in the mature ewe…this is the key. Chasing feed efficiency in growing animals is not likely to be useful. The beef industry has probably consumed over $20M (R&D) over the last 20 years in chasing NFI and they are now no closer to really implementing it. I chased the mechanisms of feed efficiency in growing sheep using the CT scanner and still didn't get any closer to understanding individual variation. We knew then and still now know that NFI is correlated with body fatness, appetite and growth...I got excited when we showed after individually feeding sheep for 412 days (daily) that the fat line was 5% more efficient then the lean line after adjustment for body composition....then I modelled the loss of lean mass in the slaughter phase and that gain was wiped out....We will find the same with your work.
I would go hard on the mature ewes.....this should include feed intake pre and post a nutritional restriction to test the fact that ewes with higher appetite probably respond faster....think of some hypotheses to test in this area.
Also I hope you appreciate that we also have some track record in this area, are strong proponents of industry and are providing advice in good faith...don't make the mistakes that I made in trying to pick the fruit from the top of the tree.....the low hanging ones are just as sweet.
Regards
Alex

From: James Rowe [mailto:jrowe@une.edu.au]
Sent: Sun 28/03/2010 7:55 AM
To: Thompson, Andrew; Ferguson, Mark; julius.vanderwerf@une.edu.au; Alex Ball; James Rowe
Subject: RE: Maternal feed use efficiency - response
Dear Andrew,
It would be great to include the research as part of the CRC portfolio. The time everybody is investing in this review process is to try to get a design that leads to a useful result. I have lost track of the experimental detail proposed and, in my view, this is critical. Diet? Class of animal? Measurements?
1. Doing more of the same - using a reasonably good diet, fed ad libitum, to identify sheep that are more efficient in growth per unit of feed consumed is of very doubtful value! The beef guys have done this for years without gaining any significant traction because of the complexity of the trait - even amongst a much simpler range of traits than we have for sheep.
2. It is almost certain that there are different biological profiles in sheep that can grow really fast on good feed and those that lose less weight on poor feed. I would also bet that there is a negative correlation between these two traits.

3. Efficiency should be considered in terms of the system - age at first lambing, no. of lambs weaned, size of the ewe, longevity and net feed efficiency. My opinion is that net feed efficiency will be of minor importance in this combination of factors and will be negatively correlated with rapid growth - critical to facilitate joining at 7 months, capacity for high feed intake (growth) to bounce back from twin lambs to produce twins again. I simply cannot see conventional NFI emerging as an important selection criterion amongst the competition of traits such as: growth; lean meat yield; meat quality; wool; no. of lambs weaned; parasite and reproductive traits.
4. My recommendation is that you use the resources for measuring feed intake to focus on a novel approach such as:
- mature ewes on a dietary regime where they lose weight to determine nfi for weigh loss. Even here there are two dietary models - both relevant - very low quality feed ad lib, or restricted amounts of grain.
- adaptation and response to grain feeding. Supplementary feeding is a huge cost to sheep producers and there are likely to be very significant genetic differences during the first three weeks of feeding. Probably much more important than NFI in terms of system efficiency and the practical application of the new information.
I have included Dave Pethick in the CC as he has a good understanding of the complexity of the NFI trait in the beef industry and also has some experience in applied animal nutrition.
I hope that these suggestions are useful.
Regards,
James

At 04:29 PM 26/03/2010, Thompson, Andrew wrote:
Hi Julius, James and Alex
Thanks for the feedback on the maternal feed use efficiency value proposition which I think has highlighted many additional hypotheses but provided no clear cut decision on whether or not the proposed feed use efficiency work is included in the draft Sheep CRC Operational Plan for 10/11.
It has been a useful exercise to document the value proposition, something that has not been done for most projects, tasks and or traits. However, I am not sure it is worthwhile spending significant additional time negotiating on this especially given the limited CRC funding requested. Based on our interpretation of the feedback we have removed all reference to this area of work from the draft operational plan for Project 1.1. Please let us know if this was not your intent and believe that the work (or a version of it) is of value to the CRC.
Some points of clarification and discussion are below:
The discussion paper was not intended to be a full review of all of the literature or to detail experimental design. DAFWA (and probably DPIVIC) are likely to continue work is this area with co-funding from the WA Centre of Excellence, and given the significant interest from the Merino industry and value we believe in the work, we considered it may have been a good investment for the CRC given the original intent to revisit feed efficiency in year 3 plus the high likelihood of attracting significant in-kind from core partners. It should also be recognised that the project proponents do have some credibility with industry and track record for delivering, but we are obviously receptive to your inputs to improve the project regardless of CRC funding.
Many valid suggestions/hypotheses related to understanding the biology unpinning resilience/feed efficiency etc were put forward and we will take them on-board where appropriate. Some suggestions, such as analysis of the LW profiles of the INF followers and quantifying the impacts of extremes for growth and muscle on feed efficiency are already underway either within Project 1.1. or DAFWA. Indeed the latter is the very core of the Maternal Efficiency Project that has been discussed with Alex and MLA on a number of occasions. We also obviously recognise that feed efficiency is difficult to measure, but considered that using genomic technologies for difficult to measure traits was core business for the CRC. We consider that a trait such as feed efficiency that has obvious value on farm to be more important than some 'difficult to measure' meat and wool traits that currently have no route to market.
We have attempted to summarise feedback under the framework requested because we believe it is a logical process to assess the merits of the proposal:
Is the trait of economic significance?
*There are alternative approaches to what animal breeders currently do (this is part of what 1.1. is about) and yes the modelling is based on assumptions of the mechanisms underpinning differences in LW profile - but we need to start somewhere and the REV of different traits will be further quantified over the remainder of this FY.

*The questions regarding the ease of changing different traits are legitimate, but again you first need to know the value of the traits and to know the value of the traits you need to know the mechanisms.
*It needs to be recognised that whole farm modelling undertaken is very rigorous and the impacts on profit of very small changes in LW profile (compared to what appears to exist in the population) are large - on the preliminary evidence presented, I don't believe anybody could argue that LW profile (and especially LW loss during summer/autumn) is not a trait of significant economic value and therefore interest to the Sheep Industry. We are yet to know how this relates to feed intake or use but endeavour to find out.
*I assume we are not serious about Troy Fishers conclusions which seem to ignore the fact that a maternal flock must be maintained all year to produce those $90 lambs. Furthermore our interest in efficiency during growth is only to establish its links with feed-use throughout a production cycle - which has the greatest impact on system profitability
Is everything already known?. Some key points
*It is hypothesised that we probably can select for efficiency with high level of accuracy already by simply looking at mature weight based on genetic parameters already determined by Neal Fogarty and in cattle work that has better accuracy. Yes big sheep will grow more efficiently, but do they maintain this advantage during reproduction or liveweight loss? Regardless of body size there is still opportunity to change how much they eat (13% change in intake 0% change in yearling weight or growth rate in cattle at Trangie for example). It is also acknowledged by James and Neal (I think) that the intake measures at pasture are inaccurate - so what's best - do we base everything going forward on inaccurate estimates of intake at pasture or accurate estimates of intake in pens now that we have capacity for large scale measurement?
*The 4 questions extracted by Julius are indeed the basis/objective of the proposed work , with the addition of how feed intake/efficiency is related in dry ewes vs. pregnancy vs. lactation and how its related to growth, fat and muscle (as above); data will be available on this for Merinos by May-10. Furthermore, we agree that it is obviously smart to do GHG measurements on these same animals and that work has already commenced. Data on this will also be available by May-10.
*Proposed work - as indicated this was not detailed in the value proposition. Two things: (i) a full proposal with all the details has previously been provided to MLA; and (ii) a full proposal with all the details is a CRC task due 31-May-10. Point (iii) was to be addressed by nutrition treatments x divergence in NFI during growth and or reproductive cycle to be completed in both WA and Vic and also by comparing INF follower liveweight profile to their in-shed RFI differences.
*With or without CRC funding we would appreciate further suggestions on animal numbers. The existing DAFWA plans will include about 1000-1500 progeny between now and 30-June-11; this includes 700-800 from the DAFWA Maternal Efficiency flock and possibly 600 from INF at Katanning. Most of these fully-pedigreed progeny will be measured post-weaning and the ewes from the MEF flock (350 to 400) will be measured again during pregnancy and lactation. Facilities to measure feed intake on 400 individuals at once are also available during 2010/11 at Rutherglen.
Is the proposed work core business for the CRC business?
*The feedback is mixed. There is concern about the CRC moving into this area at this time, the objectives and experimental model, and yet suggestions that there could be value in measuring what is already being done and that will provide tangible deliverables for the CRC prior to any CRC funding.
Regards
Andrew

From: Julius van der Werf [mailto:jvanderw@une.edu.au
<mailto:jvanderw@une.edu.au>]
Sent: Thursday, 25 March 2010 6:58 AM
To: Thompson, Andrew; julius.vanderwerf@une.edu.au; 'Alex Ball';
'James Rowe'; Jgibson5@une.edu.au
Cc: Ferguson, Mark
Subject: RE: Maternal feed use efficiency - value proposition
HI Andrew and marc
A nice summary, but let's get to the core and objectives
We know that feed intake effects efficiency, and selecting for feed intake, or residual feed intake could improve efficiency, But the trait is hard to measure and we probably can select for efficiency with x% accuracy already by simply looking at mature weight (I suspect x=>80%).
To calculate this number (x) and to decide whether to measure feed efficiency in breeding programs, we need genetic parameters for feed intake in mature ewes, pasture based, and these have been determined by Neal Fogarty. So from that point of view, is more work needed? Maybe not.

Then you bring up some interesting questions
1. What is correlation between feed intake young-old (could be useful to know in selection programs)
2. How does feed intake/efficiency relate to reproductive performance
3. How does it relate to resilience
4. Can we predict BVs with DNA markers
I am missing two important aspects in the proposal.
1) What is precisely the objective of the study
2) What are the numbers proposed to be measured?
I think with the setup proposed you could answer 1, 2 and 4, provided there are enough numbers (which will be challenging as you need to measure most of the followers.
But your 'proposed work section' is very unspecific, and needs numbers measured per year per site. I didn't see how you want to address 3).
Some other questions:
How does pen feeding relate to pasture feeding, is it actually the right trait?
Isn't it smart to do GHG measurements on these same animals
Your economic modelling differs from what an animal breeder would do. They translate animal characteristics to profit per head and see how much they can change it, and esp. how much more change if investing in certain measurement. Your Table 1 is a start, and can give economic values per trait. But the question is for example, is it just as easy to change GFW by 100 g as to decrease ME by 7.5%? And how much does it change already under current breeding programs? Would be a good exercise to put economic and genetic parameters in an index. I am surprised about the large extra profit for prime lambs. From Troy Fischers' work I remember: Prime lambs cost $5 in feed and give you 90$ return (possibly more now), so no worries about variation in feed intake efficiency.
Julius

From: Thompson, Andrew [mailto:andrew.thompson@agric.wa.gov.au <mailto:andrew.thompson@agric.wa.gov.au>]
Sent: Friday, 19 March 2010 12:24 AM
To: julius.vanderwerf@une.edu.au; Alex Ball; James Rowe; Jgibson5@une.edu.au
Cc: Ferguson, Mark
Subject: Maternal feed use efficiency - value proposition
Hi All
At the recent Coffs Harbour review and planning forum there were mixed views with respect to the need for further CRC-funded R&D related to feed intake and feed use efficiency. To assist our decision making, we concluded at the time that Mark would lead development of the value proposition for such work. The proposal is attached and I appreciate the effort made my Mark at this busy time. The proposed work is in addition to that already in progress or planned to better define the value of other traits including maternal efficiency and how identify and select such animals. The attached proposal focuses mostly on the value for such work but also outlines proposed experimental work, draft milestones and importantly possible resource requirements and in-kind contributions to the CRC.
We would appreciate your feedback as soon as possible as there will be implications for the draft Operational Plan due next week. If you do not support the proposal could you please clearly outline with justification:
* if you believe the trait is not worthwhile pursuing from an economic view point (based on pre-experimental modelling)
* whether the questions posed are not genuine research gaps (i.e its already published)
* whether the proposed work it is not CRC business
* any other valid reasons.
Technical queries should be directed to Mark and based on your feedback we could arrange a discussion early next week if required.
Thanks in advance for your feedback.
Andrew

Appendix 2. c) Value of production, disease and weight loss traits - Discussion paper - Beth Paganoni *et al.* (Nov 2011)

This Discussion Paper is the result of analysis of value of production, disease and weight loss traits in diverse environments. It presents the issue or trait under investigation, the analysis conducted, results and recommendations to industry, and proposed publications from this work. Once approved, the results and recommendations will be used as a source of reliable information for industry communication via the media, website, Practical Wisdom factsheets and Newsletters.
This is an internal document of the Sheep CRC and must not be published or distributed to other parties without permission from the executive.

Title: Value of production, disease and weight loss traits
Version: Number 1
Date: Nov 2011
Key Author: Beth Paganoni, DAFWA
Contributing authors:
Other contributors: Mark Ferguson, John Young, Sarah John, Gus Rose Andrew Thompson, Sam Walkom
Other peer review:
Program: Matching genetics and production system
Program Leader Approval: Yes / No Date
Final Executive Approval: Yes / No Date
Key results and/or recommendations to industry (up to 50 words for each)

Is it heritable?
Correlations with other traits?
How we measure this trait?
How much will it cost to measure?
Weigh individuals throughout the year?
Impact it has?

Executive Summary (~ 250 words max)

Live weight gain had a heritability of 0.08-0.23 (Walkom, unpub. a) and 0.18 (Rose *et al.*, 2011) while live weight loss had a heritability of 0.06 (Rose *et al.* 2011). Loss and gain also had a moderate negative genetic correlation, showing that high weight loss was related to high weight gain. When live weight change is analysed to be a different trait at each age using a multivariate model, heritability for live weight gain was 0.37 for ewes aged 2 years and 0.20 for ewes aged 3 and 4 years. Heritability for live weight loss was around 0.15 for all ages. These results suggest that live weight change could be included in breeding programs to breed adult Merino ewes that are more tolerant to variation in feed supply.

Live weight loss during summer and autumn was different between sites and ages of ewes ($p<0.001$). There were also significant differences of sires within breed in the weight fluctuation of their daughters during periods of nutritional restriction ($p<0.01$). Live weight change over summer, autumn or winter was not affected by previous reproductive performance, and live weight change did not affect the subsequent reproductive performance of ewes. These findings indicate it is possible to select ewes more resilient to live weight loss during periods of limited feed availability without necessarily affecting reproductive performance.

Background

Efficiency of sheep production can be defined as the total weight of wool and lamb produced per unit of energy consumed and labour expended. Its economic value is dependent on the cost of energy consumed and labour invested and the value of wool and meat. Most of the energy costs are those required for maintenance for ewes and their lambs, representing between 60 and 75% of the total energy requirements of most flocks (Coop 1961; Fogarty *et al.* 2003). Therefore, improving the efficiency of energy use needs to focus on either reducing the maintenance costs of these ewes or by breeding or managing these ewes to produce more at similar maintenance costs.

Maintenance costs are most important during summer and autumn in mediterranean and temperate environments when pasture quantity and quality are low, and farmers benefit from decreased feed costs (Young *et al.* 2009). During this dry period, much of the energy for maintenance must be provided by grain or forage supplements, a cost which can have large impacts on farm profit (Kingwell 2002; Kopke *et al*. 2008). Furthermore, a majority of ewes are pregnant or lactating during autumn (Croker *et al* 2009) which further increases energy requirements and feed costs. Therefore, improvements to biological efficiency over times when feed is limited is likely to lower costs relative to outputs and result in higher profits. Breeding ewes that are more resilient to periods of limited feed in late summer and autumn may allow greater pasture utilisation, stocking rate and therefore efficiency.

Another important consideration to production efficiency is the optimisation of labour use to enhance profitability. Labour is an increasingly scarce and expensive commodity on sheep farms around Australia and minimising the labour requirements of sheep production systems is important. The efficiency of labour use can be improved by changing infrastructure and management systems on farm but can also be improved by breeding sheep that require less labour to keep them healthy and productive. Two traits that may reduce the requirements of labour and have animal health benefits are resistance to internal parasites and resistance to breech strike. The value of these two traits will be considered across different climatic zones.

This discussion paper on biological and labour efficiencies and the relative economic value of component traits s presented in four sections:

1. Genotypes that express resilience to restricted nutrition
2. Economics of resilience to restricted nutrition;
3. Efficiencies of fleece weight
4. Economics of fleece weight

PART 1 *Genotypes that express resilience to restricted nutrition*

The summer/autumn feed gap in most sheep production systems in Australia is a limiting factor in determining annual stocking rate and therefore profitability. During this drought period, much of the energy for maintenance must be provided by grain or forage supplements, a cost which can have large impacts on farm profit (Kingwell 2002; Kopke *et al*. 2008). Furthermore, a majority of ewes are pregnant or lactating during autumn (Croker *et al* 2009) increasing energy requirements and feed costs.

Resilience indicates an animal’s ability to maintain a stable body environment through responsiveness to a broad range of external environmental factors (Veerkamp *et al.* 2009), and there appear to be genetic differences in the innate ability of some ewes to maintain live weight when nutrition is limited. Adams *et al.* (2002) found that a heavier strain of Merino wethers lost less live weight when grazed on dry, poor quality pastures over summer. There is limited knowledge about genetic parameters and the potential to consider live weight change in breeding programs in sheep. Rauw et al (2010) found a heritability of 0.29 for live weight loss in pure Merino and Merino cross ewes aged 2 to 7 grazing in the Nevada desert. However, similar to the Walkom (unpub. a) dataset they do not give an indication of how body weight changes differ between periods of low nutrition and high nutrition. Additionally they did not investigate weight change at different ages. More needs to be known about the potential size of the genetic difference in resilience to live weight loss between animals from different flocks, across breeds, and how this trait relates to production traits. Ewes that are more resilient to live weight loss could be heavier at joining and through pregnancy and this would be expected to have beneficial effects on reproductive performance (Oldham *et al.* 2011).

Objectives:

1. To estimate genetic parameters for live weight during periods of low nutrition and high nutrition and compare these at different ages.
2. To establish that genetic variation in resilience to live weight loss will be evident between sires used in flocks across Australia.

Objective 1: To estimate genetic parameters for live weight during periods of low nutrition and high nutrition and compare these at different ages.

In the first study, weight and body condition data from the first cross ewes from 3 sites were analysed over 3 production cycles (parities) as part of the Maternal Central Progeny Test (MCPT; Fogarty *et al.* 2005). Weight and BCS was measured at pre-joining, post-joining, mid-pregnancy and weaning throughout the first three parities of the ewe's production life (for full discussion paper see Walkom, unpub. a).
A univariate analyses of weight and body condition at the four time points across the production cycle did not support the idea that weights at different time points were different genetic traits. High heritability estimates were found for all measurement points with the range between 0.48 and 0.68. The greatest period of variation was at weaning and this coincided with a slightly lower heritability estimate. The moderate heritability range for body condition was promising and provides potential for selection for increased condition throughout the production cycle.
To get an understanding of the fluctuation in weight and body condition across the production cycle, traits were formed to represent the level of weight or condition gained between the time points. A univariate analysis of live weight change traits used the same model for the time point analysis of the point in which the change trait concluded. The change traits calculated the weight or body condition gained between points within the production cycle. Change traits remained in the same units as the time point measures. Weight change traits proved to be moderately heritable though change in body condition was lowly heritable (Table 5). The low heritability of the body condition change trait is expected due to the high level of residual variation associated with body condition scores at the corresponding measurement points.

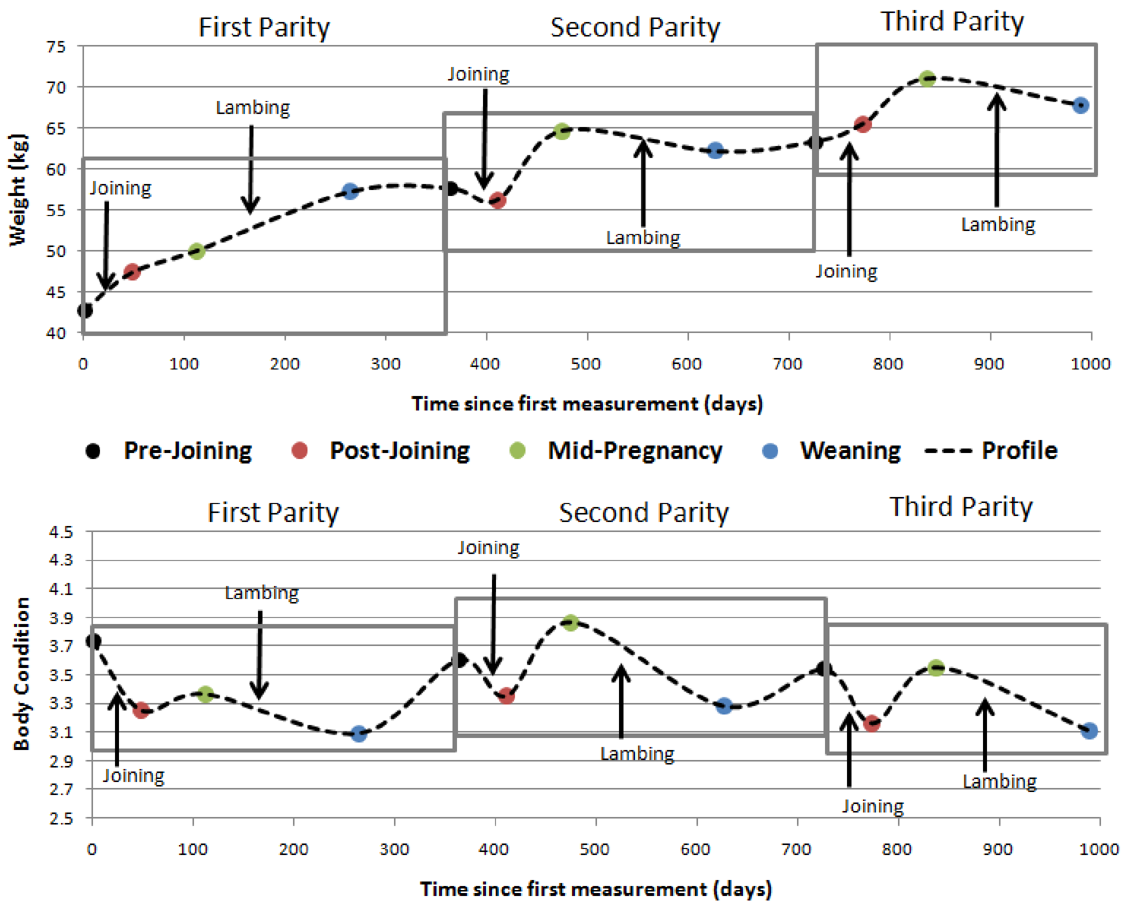

Figure 1: **Timing of weight and body condition measurements of first cross ewes across the first three parities of the ewes breeding life.**
The genetic correlation range was from 0.88 to 0.99 for weight and body condition suggesting that genetically these traits are effectively the same, even though they are measured at different points within the production cycle. Correlations between each weigh point were moderate, except for weight at weaning which had a low correlation with other points.

Table 1: Phenotypic variation and heritability estimates for weight and body condition change traits between pre-joining, post-joining, mid-pregnancy and weaning.

Weight Gain

	Pre-Joining to Post-Joining	Post-Joining to Mid-Pregnancy	Mid-Pregnancy to Weaning	Weaning to Pre-Joining
Heritability	0.15	0.23	0.08	0.16
Phenotypic variance	6.25	8.65	27.84	12.20

Body Condition Gain

	Pre-Joining to Post-Joining	Post-Joining to Mid-Pregnancy	Mid-Pregnancy to Weaning	Weaning to Pre-Joining
Heritability	0.05	0.04	0.07	0.07
Phenotypic variance	0.43	0.42	0.71	0.52

Seventy two percent of the total genetic variation in weight was accounted for by within breed variation and there was very little re-ranking of individuals across the production cycle. This provides very little support for selecting on a desired weight fluctuation profile. However it must be noted that the sheep measured were growing during the three joining years. Interestingly, in all three joining periods the ewes appeared to lose significant condition while mostly gaining or maintaining weight (Figure 1). This could have been due to shearing which can affect the perceived condition score. Live weights did not appear to be corrected for fleece weights in this data set and therefore could have contributed to live weights being lower than predicted at weigh points post-shearing. In addition, genetic differences in fleece weight would not have been separated from genetic differences in live weights.

In a second study the genetic parameters for live weight loss and live weight gain were estimated for 2700 fully pedigreed 2 to 4 year old Merino ewes (for full paper see; Rose et al. 2011).

The gain traits were more heritable than loss at all age groups (Table and 3). There were also strong genetic and phenotypic correlations between gain and %gain as well as loss and %loss. The genetic and phenotypic correlations between loss and gain traits are low. Genetically, growth is a very similar trait between 2rd and 3rd parity (r_g =0.88) but quite different for the first parity (r_g = 0.45). Correlations between ages were much lower for loss traits.

Table 2. **Genetic (above diagonal) and phenotypic (below diagonal) correlations between loss and gain traits, and heritabilities (in bold, on the diagonal) all age group including age as a fixed effect (± s.e. in parentheses).**

All ages	Loss	Loss%	Gain	Gain%
Loss	**0.06 (0.02)**	0.97 (0.00)	-0.23 (0.11)	-0.21 (0.11)
Loss%	0.98 (0.00)	**0.07 (0.02)**	-0.24 (0.11)	-0.26 (0.11)
Gain	-0.04 (0.02)	-0.04 (0.02)	**0.18 (0.02)**	0.96 (0.00)
Gain%	-0.04 (0.02)	-0.05 (0.02)	0.94 (0.00)	**0.21 (0.02)**

Table 3. **Genetic (above diagonal) and phenotypic (below diagonal) correlations between loss and gain traits, and heritabilities (in bold, on the diagonal) for each age group (± s.e. in parentheses).**

	Age 2		Age3		Age4	
	Loss	Gain	Loss	Gain	Loss	Gain
Loss	**0.25 (0.09)**	-0.11 (0.23)	**0.20 (0.08)**	-0.36 (0.18)	**0.31 (0.09)**	0.12 (0.30)
Gain	0.04 (0.04)	**0.38 (0.09)**	-0.04 (0.03)	**0.33 (0.08)**	-0.09 (0.03)	**0.32 (0.08)**

It is possible to breed adult ewes that lose less weight and gain more weight during periods of low and high nutrition. This means that sheep that lose less weight during periods of low nutrition and gain more weight during periods of high nutrition are more tolerant against variation in feed supply. It will be important to understand why some sheep lose less weight or gain more weight. If, for example, sheep lose less weight because they are more efficient at utilising poor quality pasture, then weight loss will be of high economic importance and contribute to lower risk sheep management.

When loss and gain are analysed separately at each age the heritability is a lot higher. This suggests that when age is fitted as a fixed effect, it reduces the additive genetic variation for both traits. In the univariate analyses of live weight change done in the Walkom (unpub. a) discussion paper age was fitted as a fixed effect in the model, possibly reducing the additive genetic variation accounted live weight gain or loss between weigh points.

The low genetic correlations between traits at age 2, 3 and 4 years for weight loss suggest that each age should be treated different in a breeding program. The low genetic correlation between age 2 and ages 3 and 4 suggest that once the ewes are mature, weight gain is the same trait. Therefore, ewes should be selected for gain at age 3.

Objective 2: To establish that genetic variation in resilience to live weight loss will be evident between sires used in flocks across Australia.

Live weight data (corrected for greasy fleece and conceptus weights) from mature Merino ewes was analysed to determine factors implicated in differences in live weight loss during summer, autumn or winter (for full paper see John et al; 2011).

The magnitude of live weight loss during summer, autumn or winter differed significantly between sites ($p<0.001$). Sire within breed had a significant effect ($p<0.01$) on live weight loss and the range between sire groups was -5.0% to 4.8% for ewes sired by Merinos and -5.6% to 0.1% for ewes sired by Border Leicesters (Figure 2). Live weight loss was also affected by ewe age ($p<0.001$), with three year old ewes losing 6.3% of their average bodyweight and two year old ewes losing 7.6%. Interactions between site and age of ewe ($p<0.001$) site by breed ($p<0.001$) were also significant.

Estimated Breeding Values of ewe progeny had significant ($p<0.01$) but small effects on their live weight loss over summer, autumn or winter. Across the range of breeding values for yearling weight in this analysis (-13.7 to 9.5 kg) there was a predicted reduction in live weight loss of 2.05kg for the average ewe which weighed 55kg.

The impact of live weight loss on subsequent reproductive performance indicated no significant effects on number of lambs born, weaned or total weight of lambs weaned. Similarly, there was no carry over effect from previous birth type or rear type of ewes on weight loss during the subsequent summer, autumn or winter (Figure 3).

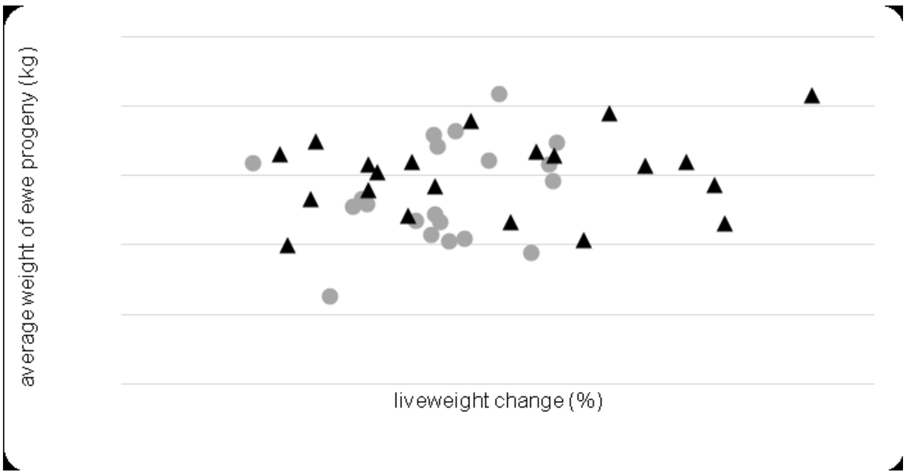

Figure 2. Relationship between the predicted live weight change (%) during summer, autumn or winter and average weight (kg) of ewe progeny from Merino ewes sired by Merinos (▲) or Border Leicesters (●). The data represent the average for ewe progeny grazed at six INF sites across Southern Australia over two years.

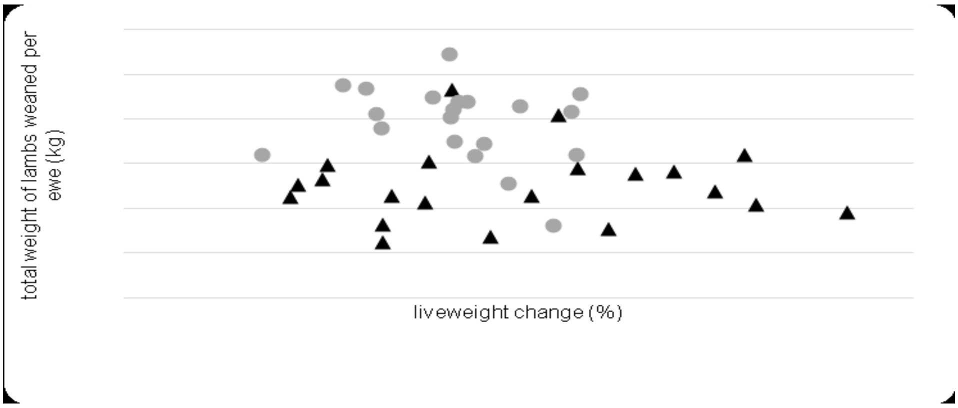

Figure 3. Relationship between predicted live weight chnge (%), and total weight of lamb weaned (kg) for ewe progeny from Merino ewes sired by Merinos (▲) or Border Leicesters (●). The data represent the average for ewe progeny grazed at six INF sites across Southern Australia over two years.

The results indicate large sire effects on the live weight loss of their ewe progeny during summer, autumn or winter. Together with the heritability estimates for this trait reported by Rose et al. (2011), it should therefore be possible to breed sheep for reduced live weight loss during times of restricted nutrition. Furthermore, there was no effect of previous reproductive performance on live weight change during summer, autumn or winter and no effect of live weight change during these periods on subsequent reproductive performance. Rauw *et al.* (2010) also reported no effects of ewe live weight change on the weight of lambs weaned.

The ability to select ewes that are more resilient to nutritional restriction is of economic and ethical relevance. A ewe that is reproductively capable and is adaptable to variation in available nutrition will allow greater returns through reduced requirements for supplementary feeding, or through increased stocking rates (Young *et al.* 2011). In addition, ewes that are more adaptive to change are more likely to thrive and reproduce in increasingly uncertain farming conditions with ongoing benefits for animal welfare.

Two year old ewes had proportionately greater live weight loss than three year old ewes. This aligns well with previous work by Rose et al (2010) and may suggest that ewes from these age groups require differential management to optimise performance.

It appears that it is possible to select ewes that are more resilient to limited feed availability without necessarily affecting production traits such as the total weight of lambs weaned per ewe. However, the trait is poorly understood and while the biology underpinning genetic differences in resilience is not known it will be linked to differences in rumen function and physiological drivers of appetite and efficiency of feed use from poor quality diets, and is currently under investigation.

PART 2 *Economics of resilience to restricted nutrition*

For environments characterised by large seasonal fluctuations in pasture supply, finding sheep that are more resilient to nutritional restriction is likely to reduce the cost of maintaining animals over the dry feed period and allow either a reduction in supplementary feeding and/or an increase in stocking rate. Rose *et al*. (2011) have shown that live weight loss over the summer-autumn period has a heritability of around 0.2 and has exploitable genetic variation in a flock of Merinos in Western Australia (Lewer *et al.* 1992). Furthermore, John *et al.* (2011) have shown that there is large variation between individuals and between sire groups in the Information Nucleus Flocks of the Sheep CRC (van der Werf *et al.* 2010) in their live weight change in response to restricted nutrition. Importantly this finding was similar in both pure Merino and Merino x Border Leicester ewes and while there were large site effects there was no site x sire interaction suggesting the trait is similar across environments and breeds (John *et al.* 2011). Therefore it is possible to include live weight change over a period of restricted nutrition in a breeding program to breed ewes that are less sensitive to variation in feed supply. With that knowledge it is important to know whether the trait is economically important.

It is important to determine the potential value of a ewe genotype that loses less weight when nutrition is restricted. Young *et al*. (2011) used a simulation model (MIDAS) that calculates live weight profiles, metabolisable energy requirements, wool growth and reproductive rate to determine how changes to animal parameter estimates associated with feed-use and metabolisable energy requirements would alter the live weight profile of ewes and its consequences on whole farm profit. They showed that the more resilient genotypes were more profitable in all of the production systems and pasture system scenarios, and the benefits are greater for lamb than wool production systems. The benefit of a more resilient genotype was realised through being able to run higher stocking rates during summer-autumn without increasing supplementary feeding (Young *et al*. 2011). Based on this modelling it is evident that a resilient genotype is likely to be valuable in sheep production systems where the summer-autumn feed gap limits stocking rate.

Live weight loss relative economic value (REV)

MIDAS has been used to calculate the economic value of a genotype that loses less live weight over the summer/autumn period when fed the same quality and quantity of feed (see Young *et al* 2011 & Young unpub c). The economic value was calculated by comparing the profitability of the standard animal run at its optimum stocking rate with the 'improved' genotype at its optimum stocking rate when offered (less) feed so as to follow the same live weight profile.

The 'improved' genotype was created by calibrating the MIDAS simulation to produce an animal - that when offered the same feed - lost 1 kilogram less weight over the period from peak live weight in early summer through to when live weight increased again after the break of the season.
The calibration of the genotype was done by altering a coefficient in the formula that calculates relative intake based on feed quality. The formula is:

Relative Intake (quality) = 1 – a (0.8 – DMD) + 0.17 * Proportion Clover

(DMD is digestibility of Dry Matter)

Table 4. The value of *a* used in the different regions

Region	Value
Standard value	1.7
South West Victoria	1.0703
Cereal Sheep Zone	1.49
Great Southern of WA	1.205

For example if the dry feed has a DMD of 55% and a clover content of 25% then the relative intake of the standard genotype is;
(1-1.7*(0.8 – 0.55)) + 0.17 * .25 = 0.67
and the relative intake of the improved SW Victoria genotype is;
(1-1.0703*(0.8 – 0.55)) + 0.17 * .25 = 0.83.

This means with that feed quality the improved genotype has the drive to eat about 25% more dry pasture than the standard genotype. The variation in intake for the full range of feed quality is shown in Figure 4. This extra drive to eat the low quality feed means that a greater proportion of the dry summer residues can be utilised by the improved genotype relative to the standard genotype and less dry pasture will be lost through decay.

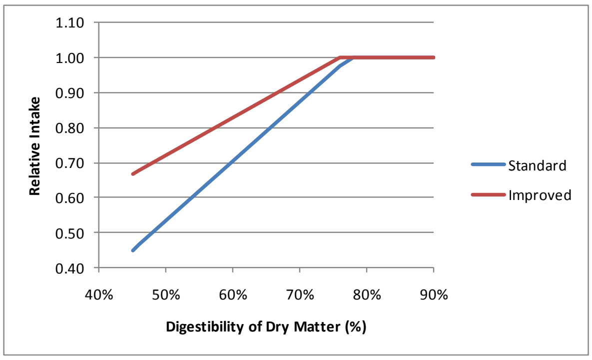

Figure 4. Graphical representation of the parameter estimate that was varied in the modelling.

Table 5. Relative Economic Value of resilience to Liveweight Loss in summer and Autumn.

SW Victoria	Cereal Sheep Zone	Great Southern WA
2.5	8.0	14.7

Liveweight loss in a breeding programme

This study did a sensitivity analysis on the relative economic value of the "resilience to LW loss" and examined the impact on the expected outcome of a breeding programme.

For this analysis, aimed at determining the potential value of the LW loss trait, the values for the other traits where held constant while the economic value of the LW loss trait was varied (Table 6). A spreadsheet developed by Julius van der Werf (Multiple Trait/desired gains 10 trait version - http://www-personal.une.edu.au/~jvanderw/software.htm) was used to calculate the expected gains from a breeding programme based on different breeding objectives. The traits included in the calculations are outlined in Table 6.

Table 6. Traits included in this analysis along with the relative economic value (REV).

Trait	Units	REV
Clean fleece weight	kg	+33
Fibre diameter	μ	-14
Resilience to LW loss	kg	Range 0 – 10
Post wean weight	kg	0.10
Adult weight	kg	-0.50
Number of lambs weaned	lambs	50

To operate the spreadsheet required making estimates of the variance, the heritability and the correlations of the resilience trait. These estimates were based on work done by Gus Rose and Sarah John however, they are subject to change and the sensitivity to the estimates has not been assessed. The values used in this analysis are outlined in Tables 7 and 8.

Table 7. Phenotypic standard deviation, heritability and repeatability for each trait evaluated

Name	Units	Phenotypic Stand. Dev	Heritability	Repeatability
CFW	kg	0.42	0.28757	0.39875
FD	kg	1.22	0.55	0.550001
LWloss	kg	5.66	0.2	0.3
PWT	kg	4.72	0.4	0.499992
AWT	kg	6.32	0.4	0.400001
NLW	%	0.65	0.06179	0.350001

Table 8. Correlation between traits in the analysis (phenotypic above, genetic below diagonal).

	yCFW	yFD	LW loss	PWT	AWT	NLW
CFW	-	0.31	0.20	0.30	0.26	0.07
FD	0.30	-	-0.14	0.20	0.15	0.03
LWloss	0.20	-0.14	-	-0.20	-0.06	-0.30
PWT	0.25	0.20	-0.20	-	0.61	0.10
AWT	0.10	0.21	-0.15	0.80	-	0.10
NLW	-0.10	0.00	-0.30	0.15	0.15	-

Varying the economic value of the stocking rate trait from 0 up to 10 alters the relative importance of the different traits in the index (Table 9). When the value is 0, almost 90% of the benefit of selection is coming from improvements in fibre diameter, with the remaining benefit spread between CFW, aWT& NLW. Increasing the value of the stocking rate trait increases the contribution of this trait and this is mostly done at the expense of FD. If the value of the stocking rate trait is between 6 and 8 then it's contributing about half the total value of the breeding programme.

Table 9. The % contribution to the total $ value response for each trait when the relative economic value of the stocking rate trait is varied

	Economic value of "Stocking Rate" trait					
Name	0	2	4	6	8	10
CFW	6.0	7.9	8.4	8.0	7.3	6.6
FD	86.6	76.6	62.3	49.3	39.0	31.3
LWloss	0	11.3	27.5	42.6	54.5	63.4
pWT	-0.3	-0.4	-0.4	-0.4	-0.3	-0.3
aWT	4.0	4.1	3.7	3.2	2.8	2.4
NLW	3.7	0.6	-1.6	-2.7	-3.2	-3.3

The on-farm analysis indicates that the economic value of the trait assessed in this analysis is likely to be in the range covered by this sensitivity analysis. Within this range the trait varies from a minor contributor in a breeding programme through to the most important trait. This indicates that further investigation is warranted in order to clarify the potential of the trait and its role in breeding programmes.

Carrying out this analysis required many assumptions to be made and these assumptions need to be clarified by further in-field testing. This analysis could then be refined with improved genetic values and improved production information will allow better assessment of the economic value of this or other related traits.

PART 3 *Efficiencies of fleece weight*

There is currently some confusion on the relative emphasis that should be placed on fleece weight in Merino breeding programs. The problem arises from an assumption that extra wool has no associated cost when calculating its economic value. This assumption is made because of evidence that genetic increases in fleece weight are achieved through increases in the efficiency of wool growth rather than increases in feed intake. However producers' experiences and scientific evidence suggest that as a result of associated biological changes in the sheep, there is a cost of growing extra wool. But this cost remains ill-defined and therefore cannot be appropriately accounted for when calculating the relative economic value of improving fleece weight. The biological changes that occur when a genetic increase in fleece weight is achieved need to be better understood. The key changes of interest are negative associations of fleece weight with lower fatness (less able to cope in a production system and welfare concerns) and lower reproduction and/or lamb survival (lower profitability and welfare concerns). There is a need to develop a better understanding of the negative associations between fleece weight, ewe fatness and lamb survival to enable appropriate value to be assigned to improvements in fleece weight.

Objectives:

1. To investigate whether the extra energy cost associated with an increased ASBV for CFW comes from an increase in feed intake or wool growth efficiency
2. To investigate the relationship between CFW and fat and how this relates to resilience

Objective 1: To investigate whether the extra energy cost associated with an increased ASBV for CFW comes from an increase in feed intake or wool growth efficiency

Merino sheep with high genetic potential for wool growth produce more wool. These genetic differences are more pronounced under good nutrition and have been attributed to increases in both feed intake and wool growth efficiency. We hypothesised that sheep with higher ASBVs for CFW would have a greater response in wool growth rate to changes in nutrition and that Merino ewes with higher ASBV for CFW would grow more wool because they have both a higher feed intake and are more efficient at converting feed into wool.

190 Ewe lambs were housed indoors and fed pellets (12.5 MJ/kg dry matter, 17% protein) *ad libitum* for 42 days (high nutrition) before they were transferred to grazing conditions (low nutrition) for a further 139 days. Feed intake data was collected daily during high nutrition, live weight and wool growth (using dyebands) were measured a minimum of monthly. Under high nutrition, for every one unit increase in ASBV for CFW, wool growth rate increased by 0.22 ± 0.019 g/day ($p<0.001$), whereas

under low nutrition wool growth was 0.15 ± 0.017 g/day. When the ewes were fed *ad libitum*, the differences in wool growth rates between sheep with high or low ASBVs for CFW were due entirely to differences in efficiency of wool growth rather than feed intake; a one unit increase in ASBV for CFW equated to a decrease of 2.51 kg of feed required to produce 1 kg of clean wool. Results of this study indicate that Merino ewes genetically selected for high ASBVs for CFW grew more wool from similar amounts of feed and were more responsive to changes in nutrition, growing more wool when fed a high quality diet. They also confirm the assumption used by MERINOSELECT that all genetic increases in CFW resulting from using ASBVs are achieved by increases in wool growth efficiency rather than increases in feed intake.

Objective 2: To investigate the relationship between CFW and fat and how this relates to resilience

Currently in developing Merino selection strategies, extra fleece weight is assumed to come entirely from improvements in wool growth efficiency and therefore higher fleece weights are achieved at no energetic cost to the production system. However there is an industry perception (among part of the industry) that high fleece weight animals have lower reproduction, are less viable and more difficult to manage. There is also scientific evidence that biological changes that result from increases in fleece weight can account for some of the industry perceptions. This combined evidence suggests that there is an energetic 'cost' of growing extra wool. However, at present that cost is very difficult to define and therefore inclusion in biological models and hence is currently not incorporated. It is important to quantify any negative impacts that selection for wool traits has on the ability of animals to survive and reproduce in the production environment so that the relative economic value for fleece weight can more accurately defined. There is a range of evidence that selection for high fleece weights (particularly when it results in a higher fleece weight to body weight ratio) can have negative effects on ewe fatness, ewe reproduction and lamb survival. These associated changes potentially result in animals that are less resilient in the production environment and have higher rates of lamb mortality, a significant issue of economics and welfare.

There is evidence for a negative relationship between genetic potential for fleece weight and fatness. Ewes that had higher breeding values for fleece weight had lower proportion of fat tissue and more lean tissue than equivalents with low breeding values for fleece weight when fed on a poor quality diet (Adams et al. 2005; Adams et al. 2006). Furthermore, ewes selected for high phenotypic fleece weight were in lower fat score at joining than low fleece weight equivalents (Refshauge et al. 2006). These results are supported by negative phenotypic and genetic correlations between fleece weight and subcutaneous fat depths in Australian Merinos (Fogarty et al. 2003; Huisman and Brown 2009). This reduction in fatness associated with fleece weight is potentially as a result of energy lost due to a higher whole-body protein turnover rate or reduced voluntary feed intake on low quality roughage in high fleece weight sheep (Adams et al. 2002; Adams et al. 2004). It is clear that selection for sheep with higher fleece weights is likely to reduce ewe fatness. Considering the positive association between genetic fatness and reproduction in some years (Ferguson et al. 2010) the decrease in ewe fatness is likely to result in lower reproduction under some circumstances. It has been shown that increasing the proportion of fleece weight to body weight resulted in a reduction in the total weight of lamb weaned across three different breeds (Herselman et al. 1998). In addition, others have observed a negative genetic and/or phenotypic correlation between the number of lambs weaned and greasy fleece weight (Burfening et al. 1989; Ercanbrack and Knight 1998; Bromley et al. 2001). Furthermore, Merino ewes with more skin wrinkle produced more wool but produced 17% less lambs as a result of lower fertility and lower lamb **A** Similarly, ewes selected for high phenotypic fleece weight weaned fewer lambs than low fleece weight equivalents (Refshauge et al. 2006). It is clear that selection for higher fleece weight results in less lambs weaned from Merino ewes, potentially due to reduced body fatness.

While some of the observed reductions in the number of lambs weaned associated with high fleece weights are attributable to reductions in fertility and fecundity, the survival of lambs is also implicated. An analysis of an industry data set revealed that the survival of lambs from ewes with higher fleece weight breeding values was reduced however this negative association was only evident in single born lambs (Ferguson et al. 2007; figure 4), the reason for the difference between birth types is unknown. Lambs from high fleece weight ewes also had lower birth weights in that analysis which is opposite to the genetic correlations between these two traits (Safari et al. 2005). However, when birth weight was included in the analysis it was positively correlated with lamb survival, yet the relationship between lamb survival and HCFW and the interaction with birth type remained significant.

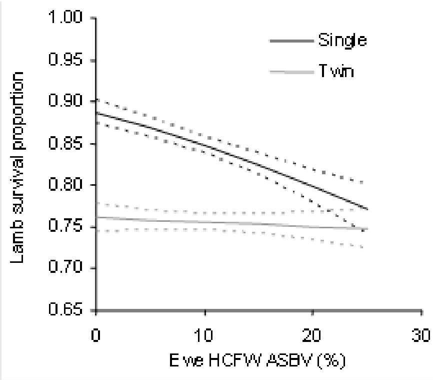

Figure 4. Predicted response of lamb survival to the Australian sheep breeding value (ASBV) for percentage increase in ewe hogget-age clean fleece weight (HCFW) for single and twin born lambs (from Ferguson *et al.* 2007)

PART 4 *Economic value of fleece weight*

Assumptions

The MIDAS sensitivity analysis examined 3 traits:

1. Clean Fleece Weight (CFW)
2. Number of Lambs Weaned (NLW)
3. LW Loss (Resilience – described in Part 1)

The parameter examined in the sensitivity analysis on CFW was the energetic cost associated with an increase. The comparison between assuming that there no energetic cost associated with increasing CFW and assuming that an increase in CFW requires an equivalent increase in energy consumption (full energetic cost) indicates that this is a very important assumption in the calculation of the REV of CFW (Table 9). In the extreme case of the HRZ of SW Victoria if it is assumed that there is full energetic cost then increasing CFW has no value. This finding indicates that there is potential gain to be made by quantifying the energetic cost of increasing CFW precisely.

Table 9: Relative Economic Value of CFW for 2 assumptions about the energetic cost of increasing CFW.

Assumption	SW Victoria	Cereal Sheep Zone	Great Southern WA
No energetic cost	1.0	1.0	1.0
Full energetic cost	0.0	0.14	0.06

The parameter examined in the sensitivity analysis of NLW was the inclusion of the impact of rear rank (RR) on CFW and FD and the impact of this because of the phenotypic correlation between NLW and RR. Lambs born and raised as twins grow less wool that is broader, than lambs born and raised as singles. However, the calculation of the genetic correlation between NLW and CFW & FD is corrected for RR and therefore the twin penalty is often not valued in calculation of REV of NLW.
Including the penalty in the calculation of the NLW REV reduces the value of NLW by 45-55% depending on the region (Table 10). This indicates that it is important to correctly represent this assumption in any calculations that are performed.

Table 10: Relative Economic Value of NLW if the penalty in wool value of twin born animals is included or excluded.

Assumption	SW Victoria	Cereal Sheep Zone	Great Southern WA
Excluded	32.6	32.1	36.8
Included	18.6	18.0	16.4

Proposed Publications

Conclusions

Future work

To achieve the original aims there are a number of outstanding jobs:

1. Value traits associated with saving Labour. This can now be commenced because the labour module has been included in the relevant models as part of BSL.00.0027.
2. Re-calcualte the value of the LW Loss trait when Sarah John's experiments have been analysed.
3. Decide on assumptions to be used for traits in which sensitivity analysis has shown that there is important variation.
4. Decide on the method to be used for calculating REVs when the assumptions are clarified.
5. Determine how the REVs vary for regions and production systems.
6. Determine impact on breeding outcomes for regions and production systems.

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Appendix 2. d) Understanding the "Resilience" feed budget – J.M. Young

MIDAS has been used to calculate the economic value of a genotype that loses less liveweight over the summer/autumn period when fed the same quality and quantity of feed (see Young et al 2011 & Young unpub). The economic value was calculated by comparing the profitability of the standard animal run at its optimum stocking rate with the 'improved' genotype at its optimum stocking rate when offered (less) feed so as to follow the same liveweight profile.

The calibration

The 'improved' genotype was created by calibrating the MIDAS simulation to produce an animal - that when offered the same feed - lost 1 kilogram less weight over the period from peak liveweight in early summer through to when liveweight increased again after the break of the season.

The calibration of the genotype was done by altering a coefficient in the formula that calculates relative intake based on feed quality. The formula is

Relative Intake (quality) = 1 – *a* (0.8 – DMD) + 0.17 * Proportion Clover

(DMD is digestibility of Dry Matter)

Table 1: The value of *a* used in the different regions

Region	Value
Standard value	1.7
South West Victoria	1.0703
Cereal Sheep Zone	1.49
Great Southern of WA	1.205

For example if the dry feed has a DMD of 55% and a clover content of 25% then the relative intake of the standard genotype is

(1-1.7*(0.8 – 0.55)) + 0.17 * .25 = 0.67

and the relative intake of the improved SW Victoria genotype is

(1-1.0703*(0.8 – 0.55)) + 0.17 * .25 = 0.83

This means with that feed quality the improved genotype has the drive to eat about 25% more dry pasture than the standard genotype. The variatioin in intake for the full range of feed quality is shown in Figure 1.

This extra drive to eat the low quality feed means that a greater proportion of the dry summer residues can be utilised by the improved genotype relative to the standard genotype.

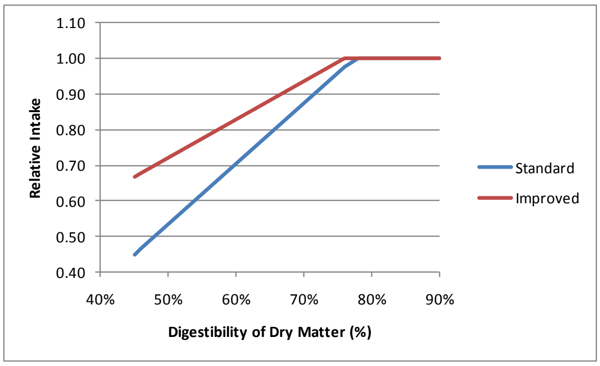

Figure 1: Graphical representation of the parameter estimate that was varied in the modelling.

Back of the envelope calculation

The economic value of the trait can be calculated using the rule of thumb that it requires approximately 3kg of grain to reduce weight loss of animals grazing dry pasture by 1kg. So, therefore the value of a trait that reduces weight loss by 1 kg should be approximated by the value of 3 kg of grain. If the grain is worth $250/t plus the cost of storing and feeding out then the 3kg would be worth about 90c/hd.

The value of increasing CFW by 1% is approximated by a 1% increase in the average fleece value in the flock, if fleece value is $30/hd then this is 30c/hd.

The relative economic value of the LW loss trait compared to CFW is therefore approximately 3.

The Coffs Presentation
Presentation of the results at the Coffs Harbour workshop in March 2011 led to questions about why the economic value of the trait calculated by MIDAS was greater than the back of the envelope calculation.

The reason for the discrepancy between the results presented at Coffs and this rule of thumb is threefold

1. Error in the calibration of the genotype. The genotype presented at Coffs was losing 2.4kg less weight not 1kg.
2. A 'Risk Cost' on supplementary feeding is included in some regional versions of the MIDAS models. That has been included to reduce grain feeding to the level that farmers typically practice in that region.
3. Extra detail accounted for in the detailed modelling.
    a. There is a difference in weight loss from 'peak to trough' compared to 'peak to break'
    b. There is a greater difference in weight loss if the animals begin summer at the same weight
    c. It is more valuable to utilise the improved genotype to increase stocking rate rather than reduce supplementary feeding
    d. The rule of thumb of 3 kg of grain per kg of LW is not exact

Calibration error
This error meant that the difference in profit that was calculated was for a genotype that would lose 2.4kg less and hence the REV was 2.4 times as high as when the calibration was done correctly. Correction of this error reduces the REV of LW loss in SW Vic from 23 down to 9.7

Model Constraint
In the SW Vic version of MIDAS the initial calibration of the model highlighted that the model calculated that it was optimal for farmers to carry much higher stocking rates and to carry the extra sheep by feeding more grain. Advisers at the time (such as Lee Beatty (pers comm)) indicated that such a system may be feasible but that no farmers are doing it or thinking of doing it because of the cost associated with carrying extra stock through a poor year. To reflect this and ensure that MIDAS was realistic, an extra "Risk Cost" was added to the cost of supplementary feeding to bias the optimum solution to lower stocking rates with less supp feeding.

The level of the risk cost needed to be about 2c/MJ in order to achieve stocking rates and supplement level similar to farmer practice. 2c/MJ equates to $266/t for lupins with 13.3 MJ/kg and is representing to the optimisation almost a doubling of the cost of supplementary feeding. Once the optimum management is calculated including the risk cost, the cost is removed and doesn't alter the calculation of farm profit (i.e. the risk cost only impacts the optimum management and not the farm profit that results from that management).

The inclusion of the risk cost in this model and the impact this has on the optimum management does affect the relative economic value of the 'improved' genotype. In the most extreme scenarios the calculated value is 40% higher, however, the average was a 17% increase.

Extra modelling detail
The extra detail represented in the MIDAS model compared to the rule of thumb feed budget has resulted in the value being calculated by MIDAS being up to 2.5 times the simple calculation. However, there are also situations in which the value calculated in MIDAS is less than the simple calculation. These differences are outlined below.

Peak to Trough weight loss
The calibrated of the coefficient '*a*' with the genotypes offered the same diet was based on the liveweight change from the spring peak down to the minimum weight that occurred after the break of season. However, after the break of season when feed quality increases the different value for the '*a'* coefficient has no impact on the calculated intake of the animals. This means that the standard genotype that is skinnier will have a greater drive to eat and the rate of weight loss after the break will be less.

However, in the MIDAS modelling in which the genotypes follow the same liveweight profile means that the difference between genotypes is purely in the period up to the break of season because if both genotypes have the same LW at the break of season, then feed budgets are equivalent after the break. Therefore, the difference in liveweight 'peak to break' is the relevant value to do the 'rule of thumb' calculation and this is approximately 50% greater than the 'peak to trough' value.

An increase of 50% in the rule of thumb value increases it to a REV of 4.5.

Table 2: Comparison of LW change for different possible measurement periods.

	SW Vic			Cereal Sheep			Great Southern		
	Std	Improved	Diff	Std	Improved	Diff	Std	Improved	Diff
Peak to trough	8.3	7.3	1.0	2.4	2.1	0.3	9.1	8.1	1.0
Peak to break	6.6	5.2	1.4	1.5	0.8	0.7	9.0	7.4	1.6

Greater difference in LW Loss if animals start at the same weight

When grazed on the same feed the improved genotype loses less weight over summer/autumn and as a result starts the next summer at a higher weight. What is being observed in the paddock (and reflected in the calibtration of the improved genotype in the simulation) is an animal that is starting heavier and then losing less weight over the summer autumn. However, the management package that the improved genotype is being run under is being offered less feed through summer autumn so that they lose an equivalent amount of weight as the unimproved genotype. This means they are commencing summer at the same weight as the unimproved genotype. If this situation is reflected in the simulation model feed budget the difference in weight loss between the genotypes over the summer / autumn period is greater than if the improved genotype starts heavier.

If the 2 genotypes were compared in the simulation model calibrated for the Great Southern of WA in a way to reflect the animals being grazed in common but receiving different levels of supplement, the improved genotype required 12.5kg less supplement than the unimproved genotype to follow the same liveweight profile. This is a significant difference to the rule of thumb 3kg grain / kg of LW.

Increase SR rather than reduce supplementary feeding

The analysis is showing that in many scenarios it is more profitable to utilise the improved genotype to increase stocking rate than to reduce grain feeding. In some scenarios this increases the value of the improved genotype by 50% relative to just feeding less supplement. However, in some other scenarios, such as the merino-merino grazing the summer active 'Triple Pasture' in SW Vic, the wholefarm modelling identifies a lower value than the rule of thumb because the quantity and quality of pasture on offer means that there is little capacity to save supplement or to increase stocking rate.

Rule of Thumb

The rule of thumb is not exact and the amount of grain that is required to reduce weight loss by 1kg varies with factors such as:

1. The time period that the weight is lost over
2. The quality of the dry residues that the animal is consuming. This is important because it is expected that this will affect the rate of substitution of MJ of dry feed per MJ of supplement.
3. The quality of the supplement.

The variation observed in a feed budget similar to the MIDAS feed budget showed a variation of +/- 15%.

Discussion

The incorrect calibration of the model accounts for a major component of the difference in the initial result presented at Coffs and what was expected based on the grain feeding rule of thumb. This incorrect calibration affects the REVs ($/farm/kg) that were calculated but doesn't affect the magnitude of the gain ($/farm) that have been presented in the AAABG paper. The difference in LW loss during summer/autumn between the 2 genotypes in the initial calibration (2.4kg) is still much less than the variation that is observed in the flocks that are being analysed by Gus Rose and Sarah John which show variation greaer than 10kg between animals.

Another major component of the difference in the SW Victoria results (which had the highest REV for LW loss) is the "risk cost" that had been added to grain feeding in the model when it was originally built to ensure that the level of feeding selected by the model reflected what farmers are doing. Using an artificial cost in the model is not the perfect solution to get the model to reflect reality but is justified on the basis that farmers said they wouldn't run stocking rates as high as MIDAS because of the cost of feeding sheep in a poor season. Adding the risk cost approximated this farmer rationale however, it does have a direct bearing on the results in this analysis.

The real question becomes how will farmers manage the 'improved' genotype in reality. I surmise that if farmers are running lower stocking rates because of the cost of grain feeding in a poor year then having a genotype that is cheaper to run in those poor years may be even more valuable than MIDAS is suggesting because the increase in stocking rate maybe even greater than MIDAS is calculating for an average year. To do a full analysis on this question would require representing seasonal variation and stocking tactics in MIDAS or another model and evaluating the 2 genotypes. This is a large job.

The other discrepancy between the model results and rule of thumb calculation is related to the extra detail that is represented in MIDAS. This detail includes accounting for initial liveweight and the timing of the period in which the improved genotype is expressing its advantage, increasing stocking rate rather than simply reducing supplementary feeding and representing a full feed budget. These extra details in some feed supply scenarios increase the calculated value by up to 5 times, although in other scenarios the calculated value is lower. This means the 'rule of thumb' value although useful (to pick up errors that were made) doesn't provide the complete answer.

References

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Young (unpub). Towards a Stocking Rate Trait. Discussion Paper for Project 1.1. Sheep CRC. June 2011.

Appendix 2. e) Towards a stocking rate trait – a discussion paper – J.M. Young

Background
On-farm benchmarking studies have regularly shown that a major profit driver in sheep enterprises is stocking rate (eg Ritchie *et al* 2007). However, this is a trait that hasn't been pursued in quantitative genetics except for the recommendation to select animals in the environment (including stocking rate) in which they will be run. This may be good advice but is rarely implemented by studs because there is market pressure to have big rams available on sale day and this is not consistent with high stocking rates.

The variation in stocking rate observed between participants in the on-farm benchmarking may be purely related to management ability or variation in the quality of the soil/pastures between properties. However, it is also possible that there are some characteristics of animals that allow them to be run profitably at higher stocking rates.

The aim of this analysis was to examine whether there is potential to include a trait related to improving stocking rate in breeding programmes. This study did a sensitivity analysis on the relative economic value of a trait "resilience to LW loss" and examined the impact on the expected outcome of a breeding programme. The choice of the trait – liveweight change over summer – was based on an exploratory analysis (Young et al. 2011) that examined a range of traits that could contribute to animals having different profiles of weight change over summer.

Method
The relative economic value of the traits was based on the wholefarm analysis of Young (unpub a & b). In these analyses the value of the production traits (CFW & FD) varied little between scenarios, however, there was some variation in nlw, growth rate and LW loss depending on the flock type (Merino-merino or merino-terminal) and region. For this analysis, aimed at determining the potential for a stocking rate trait, the values for the other traits where held constant while the economic value of the stocking rate trait was varied.

A spreadsheet developed by Julius van der Werf (Multiple Trait/desired gains 10 trait version - http://www-personal.une.edu.au/~jvanderw/software.htm) was used to calculate the expected gains from a breeding programme based on different breeding objectives. The traits included in the calculations are outlined in Table 1.

Table 1: Traits included in this analysis along with the relative economic value.

Trait	Units	Relative Economic Value
Clean fleece weight	kg	+33
Fibre diameter	μ	-14
Resilience to LW loss	kg	Range 0 – 10
Post wean weight	kg	0.10
Adult weight	kg	-0.50
Number of lambs weaned	lambs	50

To operate the spreadsheet required making estimates of the variance, the heritability and the correlations of the resilience trait. These estimates were based on work done by Gus Rose and Sarah John however, they are subject to change and the sensitivity to the estimates has not been assessed. The values used in this analysis are outline in Tables 1 and 2.

Table 1: Phenotypic standard deviation, heritability and repeatability for each trait evaluated

Name	Units	Phenotypic Stand. Dev	Heritability	Repeatability
cfw	kg	0.42	0.28757	0.39875
fd	kg	1.22	0.55	0.550001
LWloss	kg	5.66	0.2	0.3
pwt	kg	4.72	0.4	0.499992
awt	kg	6.32	0.4	0.400001
nlw	%	0.65	0.06179	0.350001

Table 2: Correlation between traits in the analysis (phenotypic above, genetic below diagonal).

	ycfw	yfd	LW loss	pwt	awt	nlw
cfw	-	0.31	0.20	0.30	0.26	0.07
fd	0.30	-	-0.14	0.20	0.15	0.03
LWloss	0.20	-0.14	-	-0.20	-0.06	-0.30
pwt	0.25	0.20	-0.20	-	0.61	0.10
awt	0.10	0.21	-0.15	0.80	-	0.10
nlw	-0.10	0.00	-0.30	0.15	0.15	-

Results & Discussion

Varying the economic value of the stocking rate trait from 0 up to 10 alters the relative importance of the different traits in the index (Table 3). When the value is 0, almost 90% of the benefit of selection is coming from improvements in fibre diameter, with the remaining benefit spread between cfw, awt & nlw. Increasing the value of the stocking rate trait increases the contribution of this trait and this is mostly done at the expense of FD. If the value of the stocking rate trait is between 6 and 8 then its contribution to the value of breeding is similar to FD.

Table 3: The % contribution to the total $ value response for each trait when the relative economic value of the stocking rate trait is varied

	Economic value of "Stocking Rate" trait					
Name	0	2	4	6	8	10
cfw	6.0	7.9	8.4	8.0	7.3	6.6
fd	86.6	76.6	62.3	49.3	39.0	31.3
LWloss	0	11.3	27.5	42.6	54.5	63.4
pwt	-0.3	-0.4	-0.4	-0.4	-0.3	-0.3
awt	4.0	4.1	3.7	3.2	2.8	2.4
nlw	3.7	0.6	-1.6	-2.7	-3.2	-3.3

The wholefarm bioeconomic analysis indicates that the economic value of the trait assessed in this analysis is likely to be in the range covered by this sensitivity analysis. Within this range the trait varies from a minor contributor in a breeding programme through to the most important trait. This indicates that the trait has a high potential and warrants further investigation.

Carrying out this desktop study required many assumptions to be made and these assumptions need to be clarified by further in-field testing. This analysis could then be refined with these improved genetic values and the improved production information will allow improvements in the assessment of the economic value of this or other related traits.

Conclusions

The analysis shows that there is potential benefit from including a trait related to improving stocking rate in a breeding programme. Further work is required to clarify the underlying biology and the genetic parameters associated with the trait and some of this is proceeding in Sub-programme 1.1, with work being done by Gus Rose and Sarah John. When this work is completed further modelling could be justified with the improved parameter estimates.

In this analysis only one potential mechanism has been examined and it is possible that other variation exists in the animal population that could be exploited to increase animals suitability to being managed at high stocking rates. Alternative mechanisms may also have potential that could be investigated.

References

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Young (unpub a). Understanding the 'Resilience' feed budget. Discussion Paper for Project 1.1. Sheep CRC. June 2011.

Young (unpub b). Calculating Relative Economic Values using MIDAS. Discussion Paper for Project 1.1. Sheep CRC. January 2011.

Appendix 2. f) Discussion paper on the economics of relative economic values – J.M. Young

The aim of this work was to compare the different approaches to calculating REVs and decide on an approach to be used in the future. The different approaches that were compared were:

1. Gross Margin, presented by Sandy
2. Sheep Object, presented by Andrew
3. MIDAS, presented by John and described in Young (unpub a)

The outcome of this comparison was presented at the first workshop and the general conclusion was that the different approaches provide similar answers when similar assumptions are used. This means that there isn't a major difference due to the calculation framework. However, sensitivity analysis done as part of the MIDAS analysis showed that large differences in REV of traits could be generated when the assumptions were varied within feasible bounds.

Assumptions

The MIDAS sensitivity analysis examined 3 traits:

4. Clean Fleece Weight (CFW)
5. Number of Lambs Weaned (NLW)
6. LW Loss (Resilience)

Clean Fleece Weight

The parameter examined in the sensitivity analysis on CFW was the energetic cost associated with an increase. The comparison between assuming that there no energetic cost associated with increasing CFW and assuming that an increase in CFW requires an equivalent increase in energy consumption (Full energetic cost) indicates that this is a very important assumption in the calculation of the REV of CFW (Table 1). In the extreme case of the HRZ of SW Victoria if it is assumed that there is full energetic cost then increasing CFW has no value. This finding indicates that there is potential gain to be made by quantifying the energetic cost of increasing CFW precisely.

Table 1: Relative Economic Value of CFW for 2 assumptions about the energetic cost of increasing CFW.

Assumption	SW Victoria	Cereal Sheep Zone	Great Southern WA
No energetic cost	1.0	1.0	1.0
Full energetic cost	0.0	0.14	0.06

Number of Lambs Weaned

The parameter examined in the sensitivity analysis of NLW was the inclusion of the impact of rear rank (RR) on CFW and FD and the impact of this because of the phenotypic correlation between NLW and RR. Lambs born and raised as twins grow less wool that is broader, than lambs born and raised as singles. However, the calculation of the genetic correlation between NLW and CFW & FD is corrected for RR and therefore the twin penalty is often not valued in calculation of REV of NLW.

Including the penalty in the calculation of the NLW REV reduces the value of NLW by 45-55% depending on the region (Table 2). This indicates that it is important to correctly represent this assumption in any calculations that are performed.

Table 2: Relative Economic Value of NLW if the penalty in wool value of twin born animals is included or excluded.

Assumption	SW Victoria	Cereal Sheep Zone	Great Southern WA
Excluded	32.6	32.1	36.8
Included	18.6	18.0	16.4

Liveweight Loss REV

MIDAS has been used to calculate the economic value of a genotype that loses less liveweight over the summer/autumn period when fed the same quality and quantity of feed (see Young *et al* 2011 & Young unpub b). The economic value was calculated by comparing the profitability of the standard animal run at its optimum stocking rate with the 'improved' genotype at its optimum stocking rate when offered (less) feed so as to follow the same liveweight profile.

The 'improved' genotype was created by calibrating the MIDAS simulation to produce an animal - that when offered the same feed - lost 1 kilogram less weight over the period from peak liveweight in early summer through to when liveweight increased again after the break of the season.

The calibration of the genotype was done by altering a coefficient in the formula that calculates relative intake based on feed quality. The formula is

Relative Intake (quality) = 1 – *a* (0.8 – DMD) + 0.17 * Proportion Clover
(DMD is digestibility of Dry Matter)

Table 3: The value of *a* used in the different regions

Region	Value
Standard value	1.7
South West Victoria	1.0703
Cereal Sheep Zone	1.49
Great Southern of WA	1.205

For example if the dry feed has a DMD of 55% and a clover content of 25% then the relative intake of the standard genotype is
(1-1.7*(0.8 – 0.55)) + 0.17 * .25 = 0.67
and the relative intake of the improved SW Victoria genotype is
(1-1.0703*(0.8 – 0.55)) + 0.17 * .25 = 0.83

This means with that feed quality the improved genotype has the drive to eat about 25% more dry pasture than the standard genotype. The variation in intake for the full range of feed quality is shown in Figure 1.

This extra drive to eat the low quality feed means that a greater proportion of the dry summer residues can be utilised by the improved genotype relative to the standard genotype and less dry pasture will be lost through decay.

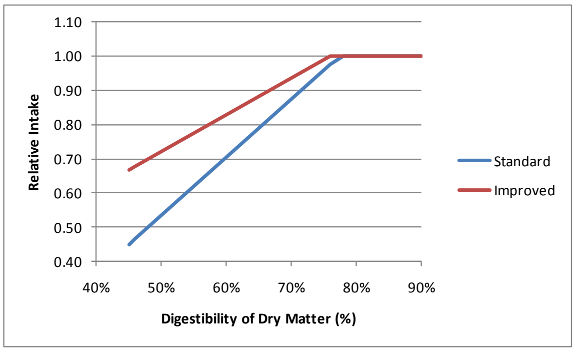

Figure 1: Graphical representation of the parameter estimate that was varied in the modelling.

Table 4: Relative Economic Value of resilience to Liveweight Loss in summer and Autumn.

SW Victoria	Cereal Sheep Zone	Great Southern WA
2.49	7.95	14.68

Liveweight Loss in a Breeding Programme

This study did a sensitivity analysis on the relative economic value of the "resilience to LW loss" and examined the impact on the expected outcome of a breeding programme

Method

For this analysis, aimed at determining the potential value of the LW Loss trait, the values for the other traits where held constant while the economic value of the LW Loss trait was varied (Table 5). A spreadsheet developed by Julius van der Werf (Multiple Trait/desired gains 10 trait version - http://www-personal.une.edu.au/~jvanderw/software.htm) was used to calculate the expected gains from a breeding programme based on different breeding objectives. The traits included in the calculations are outlined in Table 1.

Table 5: Traits included in this analysis along with the relative economic value.

Trait	Units	Relative Economic Value
Clean fleece weight	kg	+33
Fibre diameter	µ	-14
Resilience to LW loss	kg	Range 0 – 10
Post wean weight	kg	0.10
Adult weight	kg	-0.50
Number of lambs weaned	lambs	50

To operate the spreadsheet required making estimates of the variance, the heritability and the correlations of the resilience trait. These estimates were based on work done by Gus Rose and Sarah John however, they are subject to change and the sensitivity to the estimates has not been assessed. The values used in this analysis are outlined in Tables 6 and 7.

Table 6: Phenotypic standard deviation, heritability and repeatability for each trait evaluated

Name	Units	Phenotypic Stand. Dev	Heritability	Repeatability
Cfw	kg	0.42	0.28757	0.39875
Fd	kg	1.22	0.55	0.550001
LWloss	kg	5.66	0.2	0.3
Pwt	kg	4.72	0.4	0.499992
Awt	kg	6.32	0.4	0.400001
Nlw	%	0.65	0.06179	0.350001

Table 7: Correlation between traits in the analysis (phenotypic above, genetic below diagonal).

	ycfw	yfd	LW loss	pwt	awt	nlw
cfw	-	0.31	0.20	0.30	0.26	0.07
fd	0.30	-	-0.14	0.20	0.15	0.03
LWloss	0.20	-0.14	-	-0.20	-0.06	-0.30
pwt	0.25	0.20	-0.20	-	0.61	0.10
awt	0.10	0.21	-0.15	0.80	-	0.10
nlw	-0.10	0.00	-0.30	0.15	0.15	-

Results & Discussion

Varying the economic value of the stocking rate trait from 0 up to 10 alters the relative importance of the different traits in the index (Table 8). When the value is 0, almost 90% of the benefit of selection is coming from improvements in fibre diameter, with the remaining benefit spread between cfw, awt & nlw. Increasing the value of the stocking rate trait increases the contribution of this trait and this is mostly done at the expense of FD. If the value of the stocking rate trait is between 6 and 8 then its contributing about half the total value of the breeding programme.

Table 8: The % contribution to the total $ value response for each trait when the relative economic value of the stocking rate trait is varied

	Economic value of "Stocking Rate" trait					
Name	0	2	4	6	8	10
cfw	6.0	7.9	8.4	8.0	7.3	6.6
fd	86.6	76.6	62.3	49.3	39.0	31.3
LWloss	0	11.3	27.5	42.6	54.5	63.4
pwt	-0.3	-0.4	-0.4	-0.4	-0.3	-0.3
awt	4.0	4.1	3.7	3.2	2.8	2.4
nlw	3.7	0.6	-1.6	-2.7	-3.2	-3.3

The on-farm analysis indicates that the economic value of the trait assessed in this analysis is likely to be in the range covered by this sensitivity analysis. Within this range the trait varies from a minor contributor in a breeding programme through to the most important trait. This indicates that further investigation is warranted in order to clarify the potential of the trait and its role in breeding programmes.

Carrying out this desktop study required many assumptions to be made and these assumptions need to be clarified by further in-field testing. This analysis could then be refined with these improved genetic values and the improved production information will allow improvements in the assessment of the economic value of this or other related traits.

Jobs to be done

To achieve the original aims there are a number of outstanding jobs

7. Value traits associated with saving Labour. This can now be commenced because the labour module has been included in the relevant models as part of BSL.00.0027.
8. Re-calcualte the value of the LW Loss trait when Sarah John's experiments have been analysed.
9. Decide on assumptions to be used for traits in which sensitivity analysis has shown that there is important variation.
10. Decide on the method to be used for calculating REVs when the assumptions are clarified.
11. Determine how the REVs vary for regions and production systems.
12. Determine impact on breeding outcomes for regions and production systems.

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