MEAT & LIVESTOCK AUSTRALIA

On farm

System efficiency in Australia's Sheep Industry

Project number SHGEN.117

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Executive Summary

The aim of this project was to examine targets for genetic improvement of system efficiency in Australia's lamb industry. This was conducted by developing models based on the theory of Parks (1982). Both efficiency of lean meat production and two methods of calculating overall profitability were investigated. It was found that while genetic improvement in maternal (e.g. Border Leicester) and terminal (e.g. Poll Dorset) breeds is significant and in the right direction, it is likely to have a small impact on overall system efficiency.

In contrast, genetic improvement in the Merino is the key to improving system efficiency. It is important to continue with existing emphasis of increasing wool value by increasing clean wool production and decreasing fibre diameter. There will be large returns from increasing reproductive performance through management and also by selection. Returns from improving meat yield in the Merino are likely to be low. It appears that there are significant gains to be made by decreasing maintenance feed requirements by selection ewes that eat less per unit body weight. Genetic markers are an ideal tool to achieve this since intake is expensive and difficult to measure, and there are not obvious correlated traits, although IGF-1 may be an exception. The time is right to develop a genetic mapping program for feed intake in the Merino, with the aim of developing gene tests for commercialisation within five years.

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Objectives

The task is to review scope for potential improvements in biological efficiency of production that can be made in Australia's lamb industry. The review will address the following:

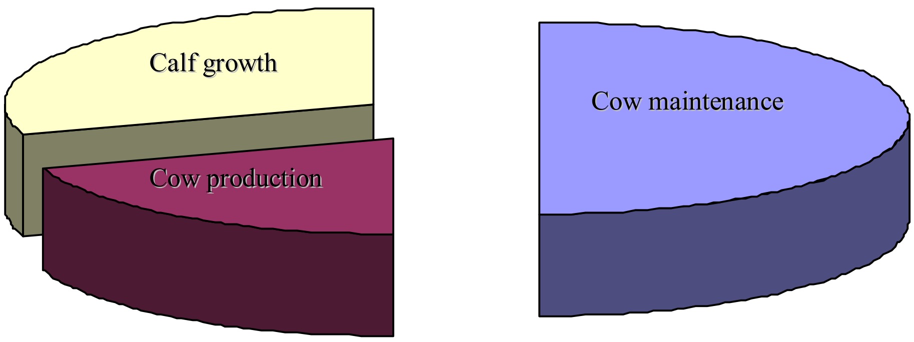
1. Adapting existing biological models (e.g. Thompson et al. 1985) for sheep in a spreadsheet format, for use in sensitivity analyses within the review, and as a research tool thereafter.

   Provide a brief summary/outline of the model used, and the key model parameters.
2. Define and evaluate simple methods for including the effects of seasonal pasture growth variation on model parameters.
3. Review literature for results of experimental and practical studies on genetic change in efficiency in sheep, both directly, and as a correlated response to selection on other traits. Such changes may be at the system level (ie per ewe or flock per year), or at the animal level.
4. Obtain Australian breed performance and genetic parameters used in LAMBPLAN (from Robert Banks).
5. Utilise information obtained to model typical Australian production systems (defined by sire and dam breed and time of lambing i.e. Merino, F1, 3-way, dual-purpose self-replacing, meat only) at their current average levels for the model parameters.
6. Undertake sensitivity analysis:
   A) to identify scope for change in system efficiency due to changes in the model parameters (marking rate, sire:dam mature size etc), for each modelled production system.
   B) To determine the impact of current and potential rates and directions of genetic gain, on system efficiency for each modelled system.
7. Consider findings in light of seasonality of pasture growth on likely recommendations for breeding directions.
8. Define a method(s) for including the biological cost of wool production and implications for efficiency of meat production.
9. Develop a recommended strategy for industry improvement and quantify potential impact on industry conversion of grass resource into high quality lamb.

Background

In typical beef cattle production systems, the breeding herd accounts for 65-85% of the total feed requirements (Ferrell and Jenkins 1984, Montaldo-Bermudez et al. 1990) and 65-75% of this is used for maintenance (Figure 1). Primarily, this very large maintenance requirement is because cattle are a large, slowly maturing species with a low annual reproductive rate. Furthermore, only a single product is harvested (meat). Essentially, the 'machinery' of production represented by the breeding cow requires a proportionately higher level of raw 'inputs' to maintain itself than is required to produce the actual 'product', represented by the cow's offspring. The large maintenance requirement is in contrast to other production systems such as pigs or poultry, where the breeding animal has a small intake relative to the total intake of all progeny. Any improvement in the efficiency with which breeding cows maintain body weight will result in an increase in total meat production for a given amount of feed. In addition to the costs of cow maintenance, long-fed cattle for the Japanese market have a large maintenance feed cost because they are close to their mature weight and are fed on a very expensive diet.

Figure 1. Feed requirements in average cattle production system



Cow maintenance requirements 50%, Lactation and pregnancy 20%, Calf growth 30% of total feed intake.

While the issues in cattle relative to pigs and poultry appear simple, this simple logic cannot be extended to our other common ruminant species, sheep. The primary reason for the added complexity is that two products are harvested: wool and meat. In addition, Australia's sheep industry is unique in that it is the only industry in the world where the majority of sheep are bred primarily for wool. In the past, meat has been regarded as a by-product of the wool industry. However, during the last 15 years, there have been record low wool prices and increases in both lamb quality and exports.

Sheep numbers have dropped by around 40% and there has been a major change in farm practices. It may be surprising that during this period, there has been little change in the structure of the ewe flock. The majority of ewes are still Merinos and almost all sheep have some Merino breeding. Of the lambs sold for slaughter, 25% are purebred Merino, 42% are first cross between a terminal sire (most common Poll Dorset) and Merino, and 33% are second or 3-way cross between a terminal sire and first cross ewe (generally Border Leicester by Merino) (Lambstats 2002 supplied by A. Ball). There are also a significant number of Border Leicester by Merino first cross wethers sold, but for simplicity, they have been grouped with terminal first cross lambs.

Sheep industry issues are clearly different from those in the cattle and other industries. The aim of this project is to investigate the potential for improvement in system efficiency for lamb production. This will be done by modeling inputs (feed) and outputs (meat and wool) with a series of non-linear models based on the theory developed by Parks (1982).

Methods

Parks' theory is based primarily on two asymptotic curves, one describing feed intake as a function of time (age), and one describing growth (weight) as a function of cumulative feed intake. If weight is plotted against age, the result is a familiar sigmoidal curve.

Feed intake

$$\frac{dF}{dt} = Ce^{-0.000574t}(1 - e^{-t/t*})$$ Equation 1

where dF/dt is feed intake (MJ ME/week), C is the asymptotic or mature feed intake (MJ ME/week), t is age (weeks), and 1/t* is an appetite factor (t* also in weeks). A more general interpretation of 1/t* is that it is the rate of maturity of feed intake. This curve is assumed to go through the origin and so makes no allowance for additional energy intake associated with pregnancy. The additional feature of this curve is that mature feed intake declines as the animal ages based on the SCA (1990) equation 1.22. It also follows that the cumulative feed consumed is the integral of Eq. 1, and is listed below (Eq. 2).

$$F = Ce^{-0.00574t}\{t - t*(1 - e^{-t/t*})\}$$ Equation 2

Weight - general form

$$W = A(1 - e^{-BF})$$ Equation 3

where W is weight (kg) at time (t), A is mature weight (kg), F is cumulative feed intake (Eq. 2), and B is the rate of maturity. Two simple changes are made to this general form, resulting in Eq. 4.

Weight - specific form

$$W = (A - W_0)(1 - e^{-(AB)F/A}) + W_0$$ Equation 4

where W_0 is initial weight (birth weight, set at 6% of mature weight). In general, large species mature more slowly (Brody 1945). Parks' (1982) studies across species found that if the rate (B) was multiplied by mature weight (A), the product (AB) was remarkably consistent across many diverse species. Hence, this form was regarded as most appropriate. The AB parameter was termed the "food efficiency factor" and is similar to k_g (SCA, 1990).

Generally, F would be measured in kg and so the units of B would be kg^{-1}, so AB is without unit. However, following Thompson's program (BeefXB), the study herein measured intake as energy (MJ ME) rather than mass (kg). Thus, the units of F are MJ ME, A is kg, and AB is kg/MJ ME. An advantage of basing the model on energy is that, within limits, if energy content falls, intake will rise to compensate. The limit is that if energy content is so low that intake becomes physically rather than appetite limited.

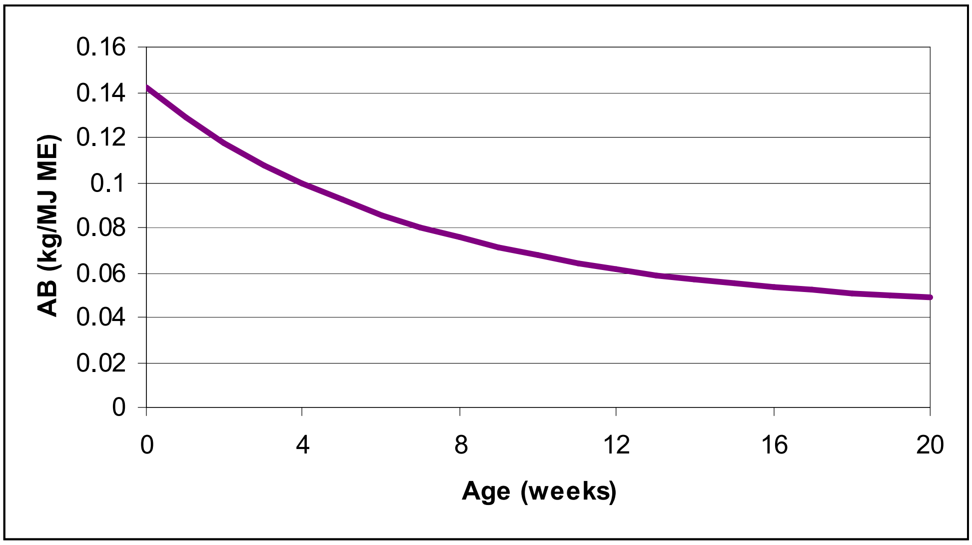
When Parks (1982) reviewed other studies, he demonstrated that AB was constant across species, but varied with feed. Specifically, AB varied with protein content of the feed. Pre-weaning, protein content is effectively very high because it by-passes the rumen with a greater percentage reaching the small intestine than on solid feed. Thus, SCA (1990) reported that k_g on milk is much higher (0.142) than solid feed (0.043). The decline in milk intake as a proportion of total intake as lambs grow was based on values reported by SCA (1990) and approximated as shown in equation 4 (Figure 2). AB is also likely to be lower on poor quality feed than balanced feed and this was built into the model as a feed quality / soil fertility factor following the method of Freer et al. (2002).

Estimation of AB

$$AB = 0.043(1 - 2.3e^{-0.14t})$$ Equation 5

where t is the age in weeks. AB also multiplied by the fertility factor, which was 1 (high quality) by default but would decrease for poorer soils. For example, a fertility factor of 0.8 delayed crossbred lambs reaching 40kg live weight from 16 weeks to 21 weeks. This is a common scenario that could result from internal parasites and other sub-optimal management practices as well as poor soil fertility.

Figure 2. Relationship between efficiency factor and age of lamb.



Current Australian lamb market specifications are primarily defined by carcass weight. While lambs are marketed at a very large range of weights, "sucker" or "weaner" crossbred lambs are commonly sold at around 40kg live-weight to result in a 19kg carcass. For this study these are defined as "light" lambs. There is a trend for markets to demand heavier carcasses, and in this study, "heavy" carcasses are defined as 26kg, corresponding to approximately 55kg live-weight. Lastly, over the past few years there has been industry discussion about systems for producing extra-heavy lambs, here regarded as 33kg carcass or 70kg live-weight. Thus, system efficiency has been evaluated for producing these three specific weights (40, 55, and 70kg). Feed intake to a specific weight is defined as in Eg. 6.

$$F_W = -\frac{A}{(AB)} \ln\left(\frac{A - W_t}{A - W_0}\right) \qquad \text{Equation 6}$$

where F_W is the cumulative feed consumed (MJ ME) to a specific weight, and W_t is the specific weight of interest (40, 55, or 70kg). AB is assumed to be constant rather than decline with age for the purpose of calculating feed consumed. This is unlikely to be a problem as the change in AB only affected growth in the first few weeks.

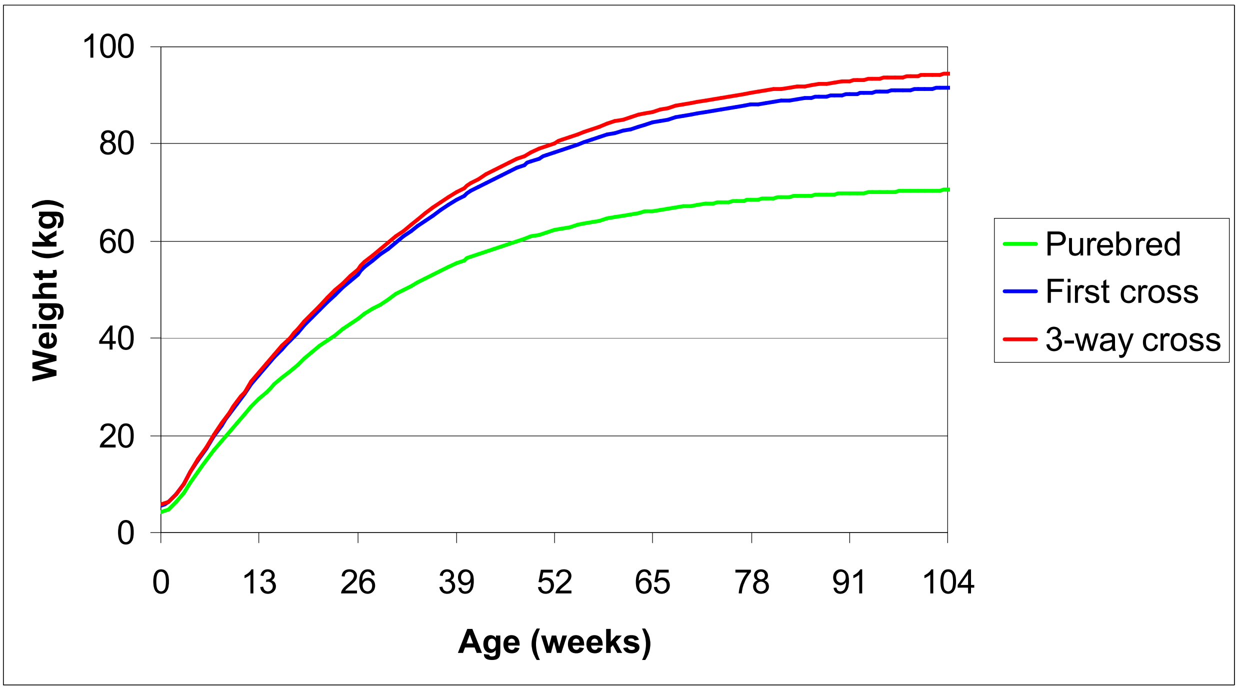
Following SCA (1990) and Parks (1982), values are scaled relative to mature weight. Mature feed intake (C in MJ ME/day) was calculated as shown in equation 6 which is based on SCA (1990) maintenance requirements without the energy cost of wool included. Wool production does come at a cost. The "Sheep-explorer" spreadsheet developed by CSIRO Plant Industries (Freer et al. 2002) estimated energy requirements for wool growth based on data from the SCA (1990). The same value was used for a range of breeds. Merino sheep produce 8-14g clean dry wool per kg digestible organic matter intake (DOMI), and this is at the rate of 0.5-0.9 kg/MJ ME. The ME required for wool (MJ ME/day) was assumed to be 0.13(GFG-6), where GFG is greasy fleece growth per day and 6g/d is assumed to be the wool production at maintenance. If the basal production level is assumed to be 0 g, wool production is converted to annual rather than daily, energy cost is per week, then the cost of an extra 1kg clean wool per year is 0.356 MJ ME/day. It is assumed that this simply adds to the maintenance cost or mature intake (C) of the sheep. The result is that a 65kg ewe growing 5kg clean wool per year would have a daily maintenance requirement of 10.3 MJ ME which is a function of 8.5 MJ ME for body and 1.8 MJ ME (17%) for wool.

$$C = 0.37A^{0.75}$$ Equation 6

In the same way, the appetite factor (1/t*) was scaled proportional to mature weight raised to the power of 0.25 (Eq. 8). Note that this is for t*, not 1/t*. The implication is that larger animals take longer to mature, and so have a large t* corresponding to a smaller 1/t*. Thompson et al. (1985) estimated t* to be around 13 weeks for pen-fed Merinos averaging 53kg. However, it was found for this study that values around 7 weeks more accurately reflected industry growth rates (Eq. 7). Examples of growth curves are shown below (Figure 3).

$$t^* = 7(\frac{A}{53})^{0.25}$$ Equation 7

Figure 3. Growth curves for common crosses.



Meat output (Eq. 8) from the lambs at the specific weights was taking to be a function of weight, dressing percent (DP = carcass weight as percent of live-weight), and retail yield (RY = percent of carcass that could be sold as lean meat if boned out as "trim-lamb").

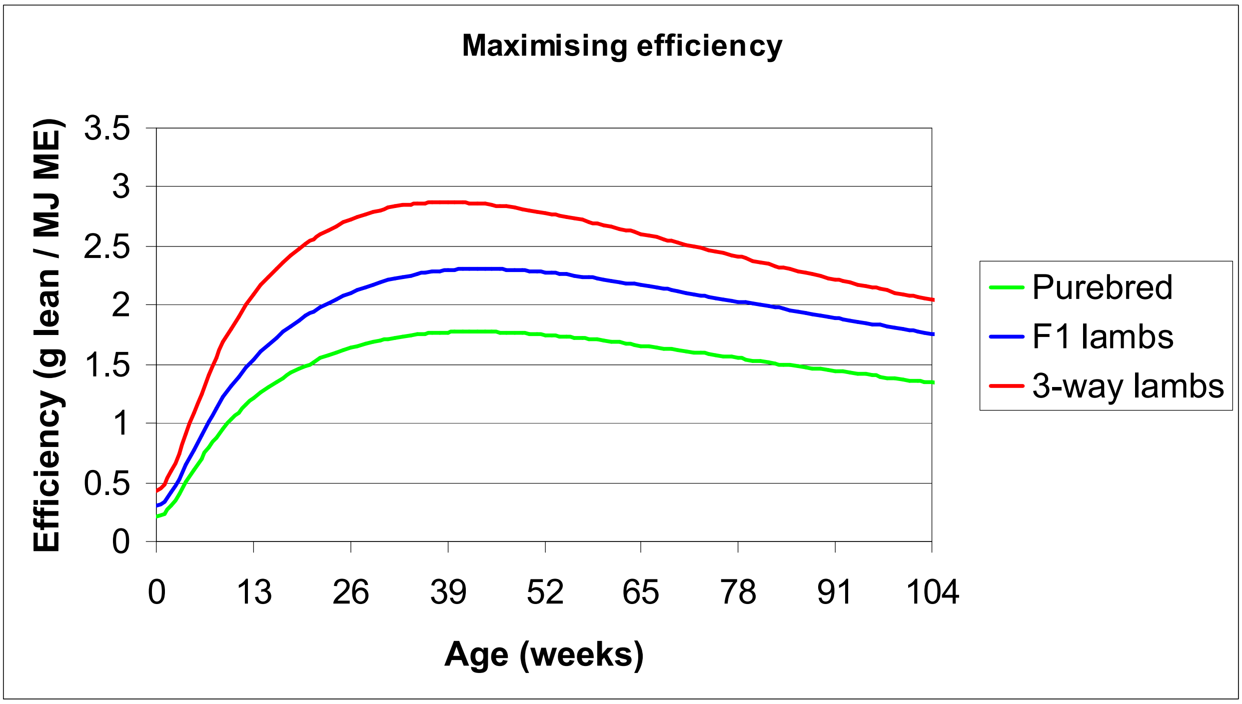
$$Meat = W_t.DP.RY$$ Equation 8

Biological efficiency (Eq. 9) is a function of meat output and total feed input (ewe plus lamb). In contrast to Thompson's BeefXB program, the current project does not account for the proportion of ewes culled and, hence, defines efficiency on an annual rather than lifetime basis. Early simulations demonstrated that this will not have significant effect on conclusions and added unnecessary complication. Pregnancy costs were assumed to be 45.5 MJ ME per kg birth weight (SCA, 1990), where birth weight was assumed to be 6% of the mature weight of the lamb (45.5x0.06=2.73). This cost of gestation was added to the feed cost (denominator).

$$Efficiency = \frac{Meat.WR}{(F_W + 2.73.A_L).WR + 365.C_E}$$ Equation 9

where Meat is the weight of lean produced per lamb (Eq. 8), WR is weaning rate (No. lambs weaned per ewe per year), F_W is the lamb intake and $2.73A_L$ is the cost of gestation which were also multiplied by weaning rate to adjust for the number of lambs, C_E is the mature intake of the ewe (MJ ME/day) which is multiplied by 52 to convert to annual intake. The units of efficiency are g lean meat / MJ ME. In addition to specifically testing light (40kg), heavy (55kg), and extra-heavy (70kg) lambs, efficiency at a range of weights has been plotted to help provide messages about ideal slaughter weights (Figure 4).

Figure 4. Effect of age at slaughter on system efficiency.



Efficiency in this project was defined as the efficiency of meat production. It takes into account the energy cost of growing wool, but not returns from wool. Thus, the biological efficiency was converted to profitability or return on investment (Eq. 10) by taking into account the cost of feed ($/tonne) and quality (energy) of feed (MJ ME/kg), value of lamb ($/kg saleable meat), and value of clean wool ($/kg).

$$ROI = \frac{Lamb\$.Efficiency + Wool\$.Wool}{Feed\$.Quality}$$ Equation 10

Profitability was defined in units of $ return per $ spent, and can be expressed as a measure of return on investment (ROI). The ROI is simply return on investment in feed and places no emphasis on non-feed costs of production (e.g. shearing, animal health). Again, this would add a further, unnecessary, degree of complexity. After some initial unexpected results, it was decided to compare results to a profit function (Eq. 11) rather than return on investment (Eq. 10). In hind-sight, this was not surprising because of the well documented limitations of ratios relative to linear functions. Although expressed as $, the profit is really $ per ewe, and hence could be simply multiplied up by flock size. Ponzoni (1988) conducted a similar comparison when calculating economic values and found that correlations between breeding objectives based on the two methods was high (0.89-1). In this study, the two methods gave different results in specific cases, but overall the correlation between economic values from the two methods was 0.87. That said, conclusions about optimal slaughter ages could be quite different for the two methods (Figures 5a and 5b).

$$\text{Profit} = (Lamb\$.Efficiency + Wool\$.Wool) - Feed\$.Quality$$

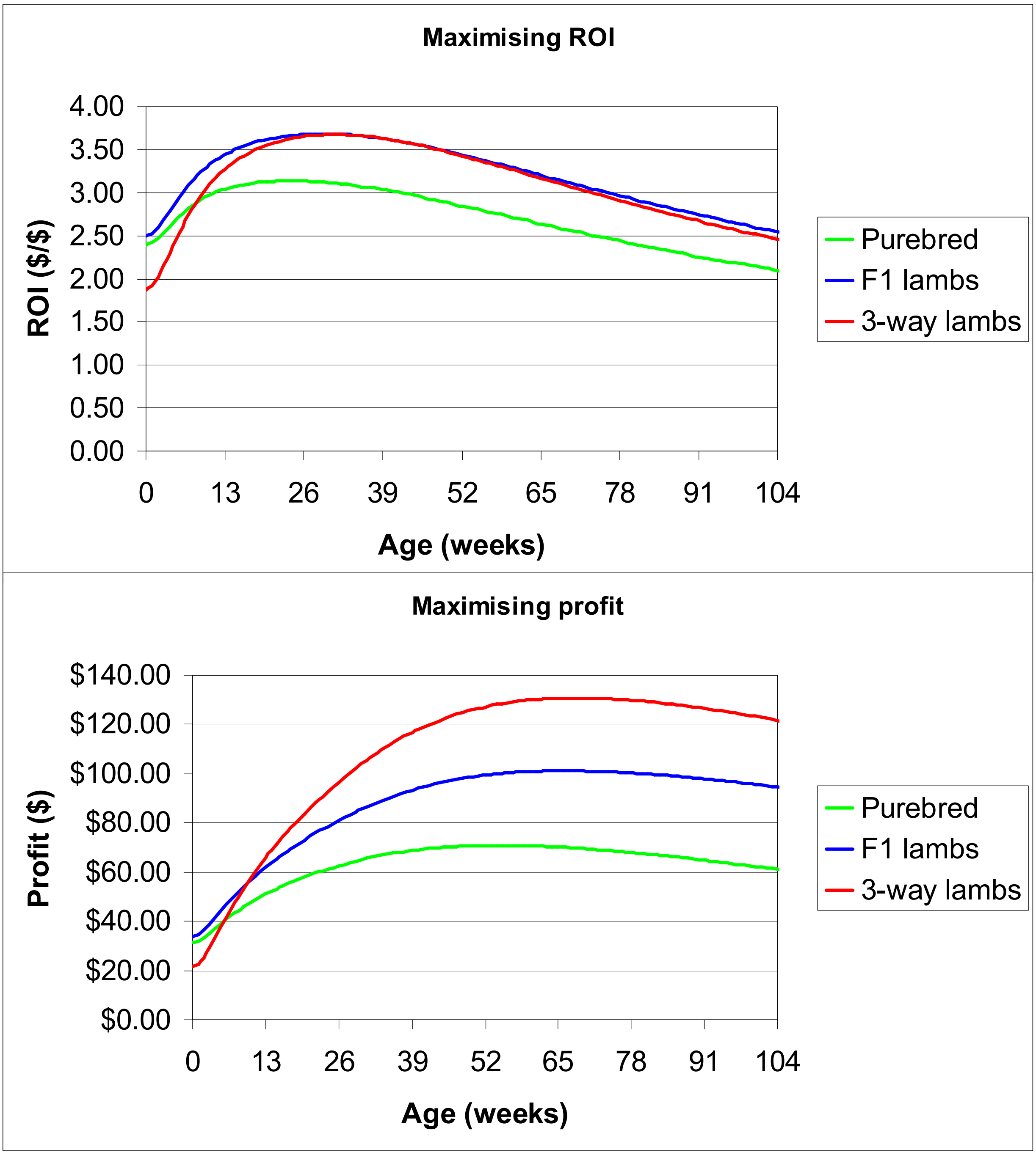
Equation 11

Heterosis estimates were based on those reported by Pitchford (1993) and recent estimates being reviewed by Neil Fogarty (supplied by A. Ball, pers. com.) Base values of 10% for mature weight and 20% for weaning rate seemed appropriate. The mature weight effect also had a concomitant increase in both mature intake and appetite factor (Eqs. 6 and 7). This seemed appropriate based on results from mice where Hughes (1993) specifically studied heterosis effects on Parks' (1982) growth parameters.

For the base simulation, it was assumed that ram lambs would be castrated. However, there is also the option of leaving them entire and assessing effects on system efficiency. Following the sheep explorer model (CSIRO, 2003), it was assumed that wether lambs would be 20% heavier, and ram lambs would be 40% heavier than their sisters. Thus, a sex difference is built into the model through effects on mature weight. These are also scaled based on equations 6 and 7. A limitation of the model is that the proportion of males and females is fixed at 50:50. This is not likely to be the case for the purebred Merino sector where wethers are slaughtered and ewes are kept as replacement breeders. Justification for this is that there is an opportunity cost of keeping a ewe as a replacement, and an appropriate cost could be her meat value.

Lastly, the proportions of slaughterings in each category (purebred, first cross and second cross) were assumed to be fixed. The focus of this project was to evaluate selection strategies for improving system efficiency, naturally changing mating systems is also a viable strategy also. However, given the changes in mating taken place over the last 15 years (more Merinos mated to terminal sires) and specific geographical limitations (e.g. high rainfall), there is unlikely to be large improvements to be made by changing systems.

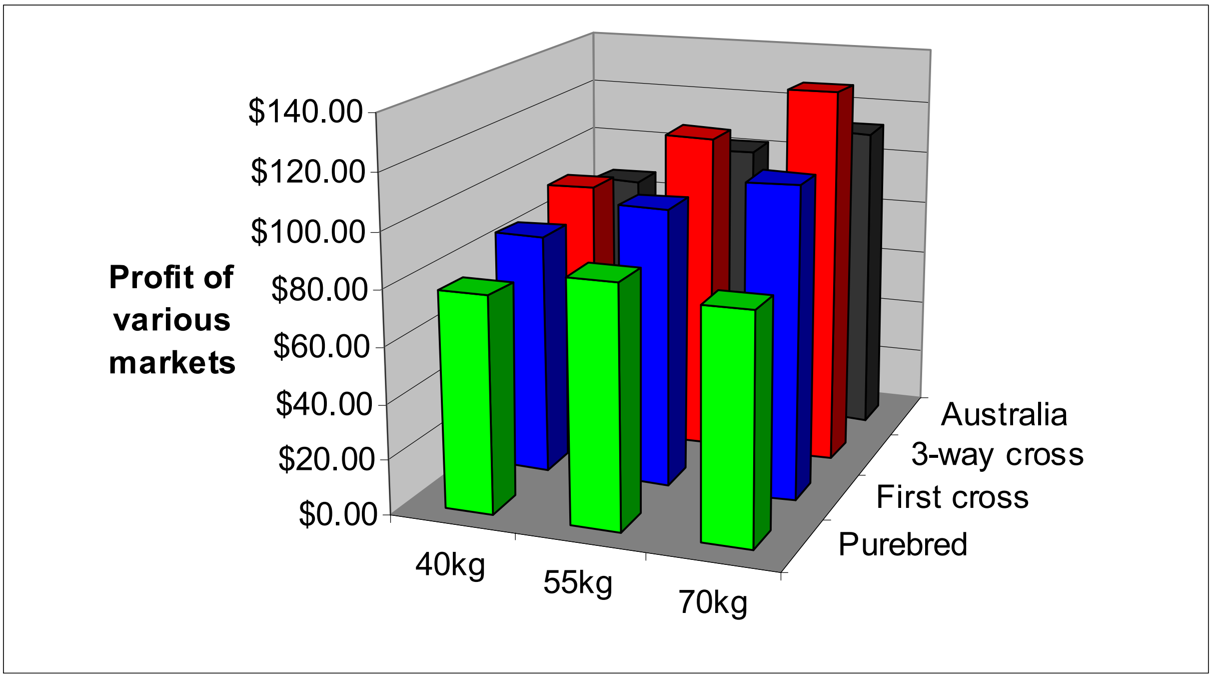
Figure 5. Change in ROI and profitability with lamb slaughter age.



Results and Discussion

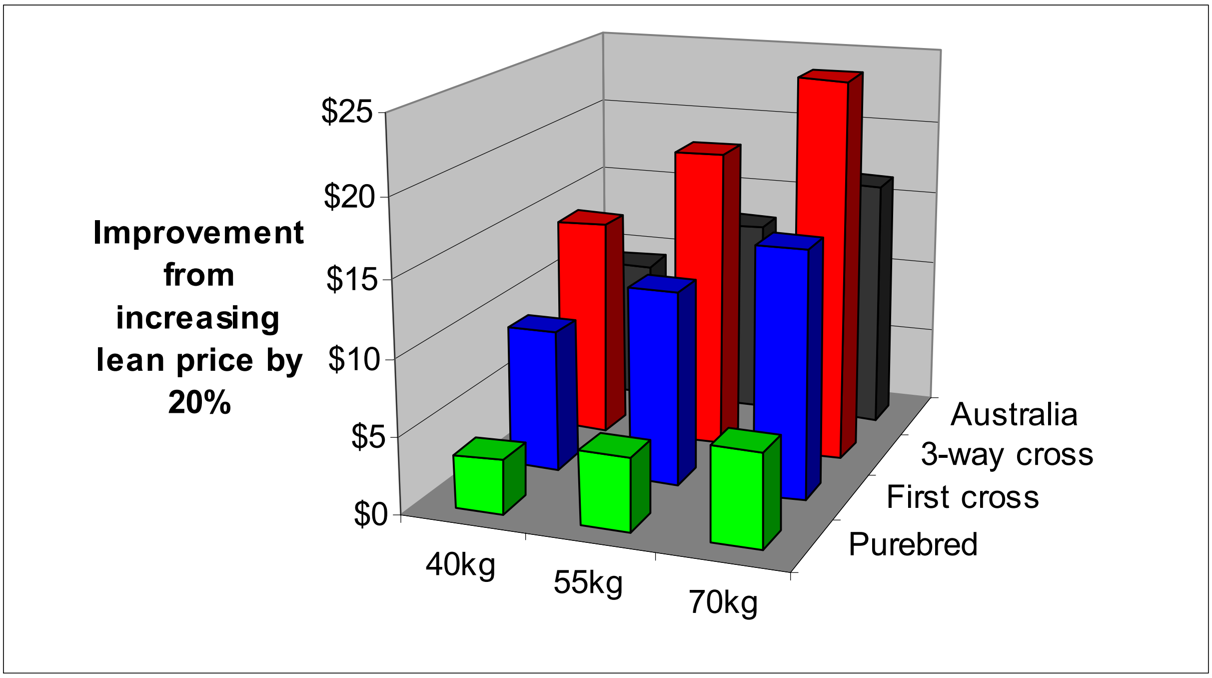
The starting point of the trial was to benchmark the production sectors (purebred, etc.) and target markets (light, medium, and heavy). Generally profitability was higher for the heavy weight than lighter weights (Figure 6). However, there was a clear interaction where, not surprisingly, the purebred Merino was more profitable at producing medium than heavy weight lambs. Profitability was lower if feed quality was reduced (fertility factor of 0.8 versus 1.0) and this was especially the case for the purebred Merino at heavy weights (not presented). At this point it should be noted that feed costs remained constant throughout the season, rather than being cheap in spring and expensive in autumn. No doubt the result of this is to overestimate the profitability of producing heavy relative to light lambs. That said, the increase in well-managed lamb feedlot capacity provides increased opportunity for achieving these weights at reasonable cost. A final point that could be made from Figure 5 is that profitability in the meat sectors was higher than wool, if this is really the case, then Australia's sheep industry could see increased profitability by further decreasing the proportion of Merino ewes mated to Merino rams.

Figure 6. Profitability of various market sectors and endpoints.



The starting point was to test the sensitivity of profitability for Australia as a whole to changes (by 20%) in prices of product (meat and wool) and feed. When changing prices, the same proportional change was made for each breed. An increase in lamb prices resulted in increased profit by $9.41, $12.94, and $16.46 for light, heavy, and extra heavy target markets respectively. An increase in wool price increased profit by $9.10 for all slaughter weights (same for all because only considered wool returns from ewes). Reducing feed costs by 20% had a smaller effect than lamb or wool values but were still $5.11, $5.84, and $7.39 for the three markets. Clearly, most changes had the greatest effect on the heavy lamb system, which is not surprising, since it was a high cost (Aust. $44.32), high return system (Aust. $136.92). Since the effect of lamb price varied enormously depending on the market and production system, specific results have been presented graphically (Figure 7). Return on investment measures were slightly different because of being a ratio rather than the profit function: the effect of feed price (denominator) was greater than wool or lamb price (numerator).

Figure 7. Sensitivity of profitability to changes in price of lamb.

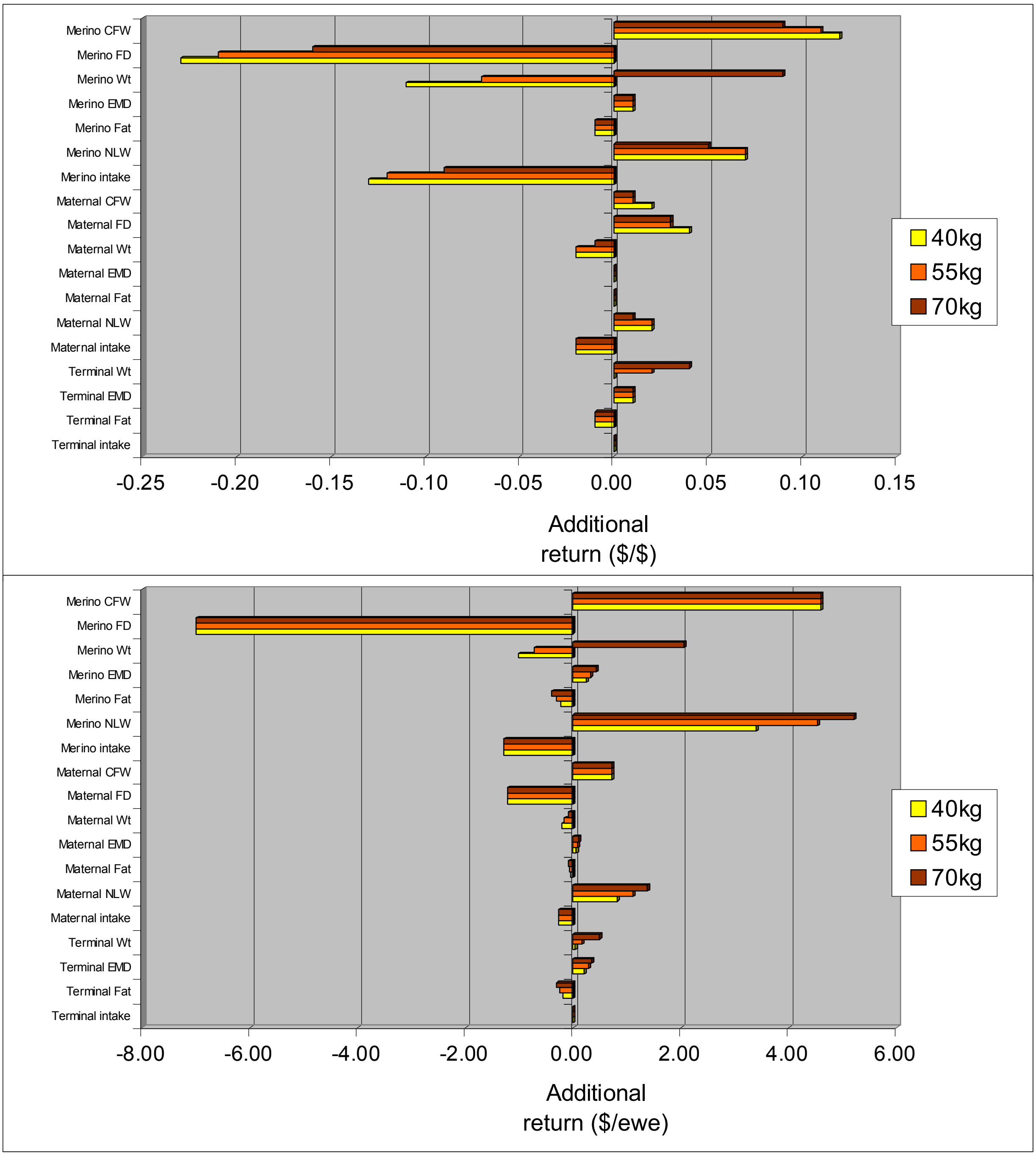


The second phase of the project was to test the sensitivity of profitability to changes in a range of parameters. Increasing heterosis for mature weight from 10% to 20% had little effect on profit. Increasing heterosis for weaning rate from 20% to 30% increased profit by $1.65-$2.76. Changing t* had no effect on profit for the specific systems but did on growth to a specific age. Lastly, leaving ram lambs entire had little effect on profit for the light market weights ($0.15, $0.59), but a reasonable effect on the heavier weight ($3.72).

The next changes were breed specific and were made by an amount equal to the genetic standard deviation for the trait of interest so that the values were relative economic values ($\$/\sigma_G$) for Australia's sheep industry as a whole, and could be compared across traits. Values for both return on investment (Figure 8a) and profit (Figure 8b) were similar, although there were some differences.

Improvement in wool quantity (CFW) and quality (FD) in the Merino were of greatest importance. It is important to note that the value for fibre diameter is negative because higher prices are paid for lower micron wool. Wool quality in the maternal breed was also of large importance. However, it is likely that the value of wool in the maternal breed was overestimated because the same value of improvement (genetic standard deviation of 0.62kg for CFW and $1.70 for FD) was used for the maternal as for the Merino. In fact, the value for FD was assumed to be -$1.00/μm, which at present would only be appropriate for fine wool Merinos. Thus, the value may have been overestimated for Merino as well as maternal.

Figure 8. Relative economic values (ROI and Profit).



CFW = clean fleece weight, FD = fibre diameter, Wt = mature weight, EMD = eye muscle depth, Fat = fat depth at GR site, NLW = number of lambs weaned per ewe joined (weaning rate), intake is mature intake.

The value of Merino weight was high for heavy lambs but lower and negative for light and medium lambs (Figure 8, Table 3). The reason for this is that heavier ewes require more feed to maintain body weight and this is a significant cost. However, for lambs to efficiently reach heavy weights, they require the "growth potential" of a larger breed. There study generally indicates that for current lamb markets, the size of the Merino is not a limiting factor.

While reproductive rate has a low heritability (3%), there is reasonably large variation in the trait (CV=60%) so the genetic standard deviation was 8.3%. It is hardly surprising that reproductive rate of the Merino was an important profit driver. The response to increasing reproductive performance of the Merino was similar to decreasing maintenance requirements although was significantly larger for profit (Figure 9) than ROI (Figure 8a). Both are methods of partitioning a greater proportion of nutrients to lamb production and less to maintaining the dam. Thus, reproductive rate in the Merino was an important profit driver and should be improved with selection. In addition, the fact that this trait is important despite such a low heritability, demonstrates that it is crucial that best practice management is in place to maximise the number of lambs born and weaned.

Feed intake in the Merino had a large effect on profitability and for the simulation it was assumed that the heritability of the traits was only 12% based on alkane studies of pasture intake conducted by Lee et al. (2001). If the true heritability is similar in sheep to that found in diverse species such as cattle and mice (30-40%), the importance of intake in the Merino could be as much as three times that estimated in this study. Genetic improvement in lowering the maintenance feed requirements of Merinos could be as important as genetic improvement of wool traits. The effect of lowering maintenance feed requirements in Merinos was greatest in the purebred, but important for all industry sectors (Figure 9). This was presented as ROI because the effect on profit did not warrant a graph because it was constant across sectors: $1.48 for those with a purebred Merino dam, $0.84 for the 3-way cross, leading to $1.28 for Australia as a whole. This effect was the same for poorer (0.8) soil fertility as the base fertility (1.0).

Other traits such as meat yield in the Merino (indicated by EMD and GR Fat), and most traits in the maternal and terminal breeds had limited impact on improving system efficiency in Australia's sheep industry. However, while this is true for Australia as a whole (macro-economic), genetic improvement in those sectors and breeds is still very important for individual production systems (micro-economic). The large impact of Merino improvement is not surprising when 25% of lambs slaughtered are purebred Merino, 42% are first cross and hence have purebred Merino dams, and 33% are second or 3-way cross. Multiplying this out (0.25x100 + 0.42x50 + 0.33x25) indicates that 54% of lambs is influenced by Merino genetics. However, the influence of the Merino on profitability is greater than 54%, because of the large impact of the dam performance. Lastly, existing improvement in maternal and terminal breeds appears in the right direction and should continue.

Figure 9. Effect of decreasing Merino maintenance feed requirements on efficiency of lamb production.

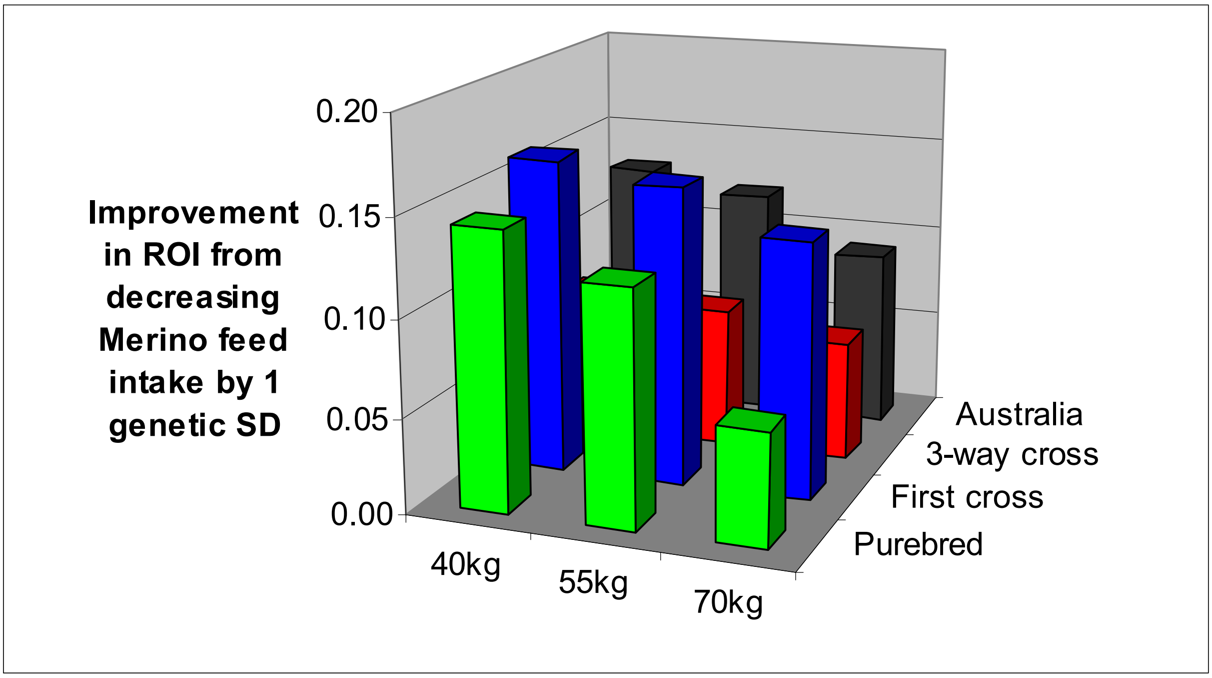
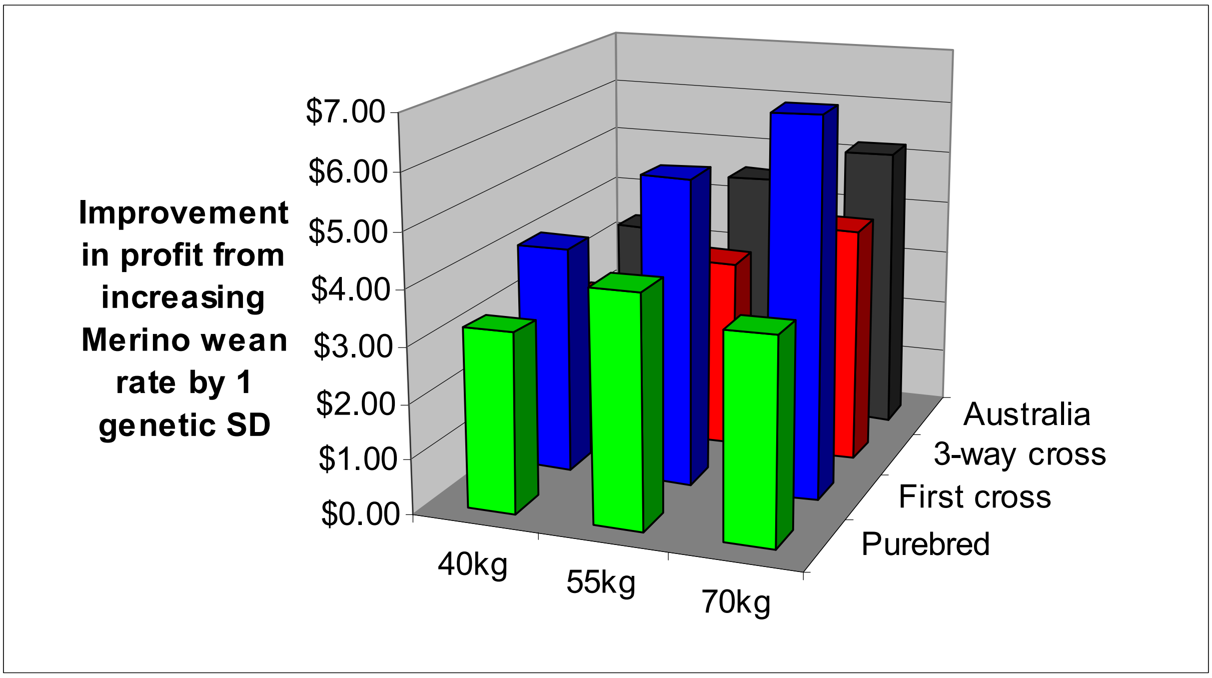


Figure 10. Effect of increasing Merino reproductive performance on efficiency of lamb production.



The final step in evaluating Merino improvement was to report genetic parameters and economic values that further selection indices could be based on (Table 1). The economic values reported are for improvement for Australia as a whole although there was little difference if these were for purebred Merino breeders only. The economic values (Table 2) were estimated from the models developed by this project and, hence, the only production cost accounted for is feed. The economic values were simple to estimate for fleece weight, body weight (A), feed intake (C), and reproductive rate. The value for fibre diameter was calculated through its effect on price of wool. The price effect was assumed to be $1/μm per kg of clean wool. The economic value was then estimated by changing the wool price accordingly. As described above, the value of GRF and EMD was through their effect on retail yield. It was assumed the genetic standard deviation in eye muscle depth (1.15m) and GR fat depth (0.63mm) corresponded to corresponded to a change in retail yield of 0.46% and -0.44% respectively (Hopkins et al., 1995). The genetic SD for intake corresponded to an increase of 8%. Economic values for the Merino are presented in Table 3.

Table 1. Merino genetic parameters used for forming index (heritability on diagonal, genetic correlations below diagonal, phenotypic correlations above diagonal).

	CFW	FD	A	EMD	GRF	NLW	C
Clean fleece weight (CFW, kg)	0.38	0.19	0.25	0.02	-0.06	0	-0.02
Fibre diameter (FD, um)	0.39	0.63	0.08	0.06	0.06	0	0.40
Hogget weight (A, kg)	0.11	0.13	0.40	0	0	0.13	0.57
Eye muscle depth (EMD, mm)	0.11	0.05	-0.11	0.23	0.08	0	0.33
GR Fat depth (GRF, mm)	-0.34	0.16	-0.03	0.21	0.28	0	0.23
Weaning rate (NLW)	0.05	0.02	0.25	0	0	0.03	0
Feed intake (C, MJ ME/week)	-0.02	0.40	0.57	0.43	0.27	0	0.12

The bulk of the values were taken from Clark (2002), most of the reproductive parameters from Fogarty (1995), the intake values from Lee et al. (2001), and correlations between intake and carcass from cattle results (Arthur et al., 2001).

Table 2. Additional Merino parameters and corresponding economic values.

	CFW	FD	A	EMD	GRF	NLW	C*
Mean	5	20	65	30	10	80	10.3
Phenotypic variance	1.0	2.2	9.8	2.4	1.2	48	5.6
Coefficient of variation (%)	20	11	15	8	12	60	23
Genetic standard deviation (unit)	0.62	1.7	6.2	1.15*	0.63*	8.3	0.82*

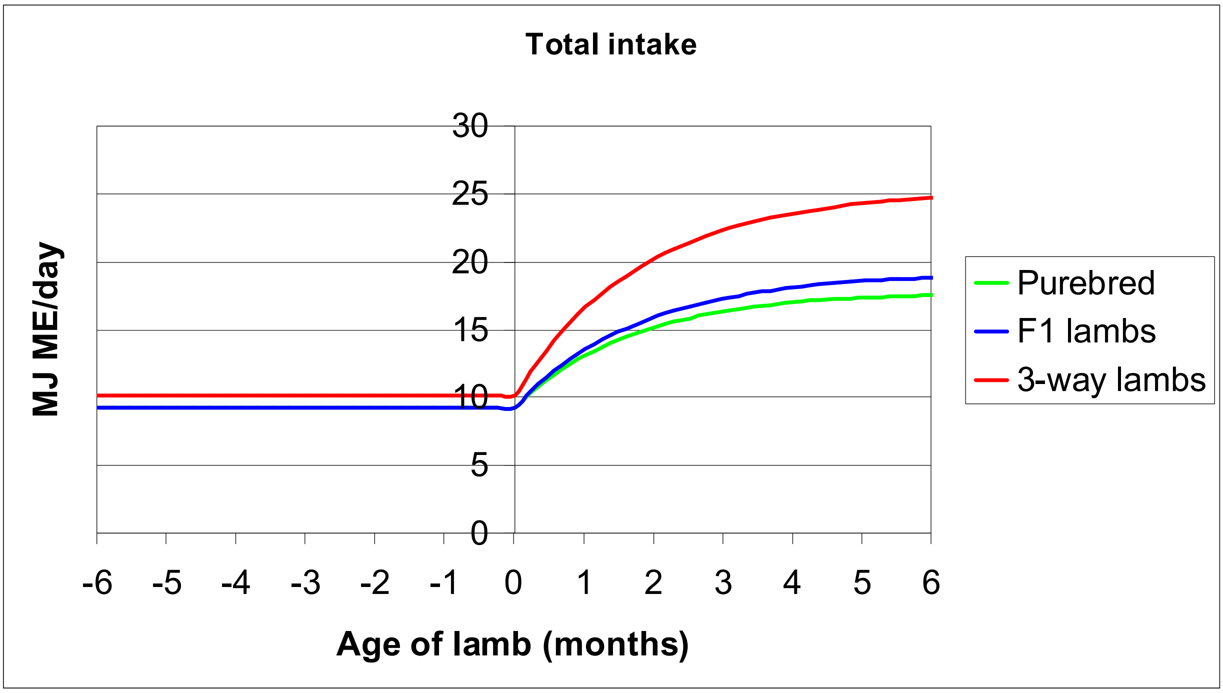
* denotes actual change but not value used for simulation (0.46, -0.44, 8.0).

Table 3. Relative economic values ($\$/\sigma_G$) for Merino improvement.

	CFW	FD	A	EMD	GRF	NLW	C*
ROI 40kg turnoff wt	0.12	-0.23	-0.11	0.01	-0.01	0.07	-0.13
ROI 55kg turnoff wt	0.11	-0.21	-0.07	0.01	-0.01	0.07	-0.12
ROI 70kg turnoff wt	0.09	-0.16	0.09	0.01	-0.01	0.05	-0.09
Profit 40kg turnoff wt	4.60	7.00	-1.02	0.24	-0.23	3.40	-1.28
Profit 55kg turnoff wt	4.60	7.00	-0.73	0.33	-0.31	4.54	-1.28
Profit 70kg turnoff wt	4.60	7.00	2.05	0.42	-0.40	5.22	-1.28

The final part of this project was to consider seasonal effects on pasture availability. This was not modeled in relation to the key economic traits, but was considered relatively simply. A general conclusion from graphs of efficiency or profitability (Figure 5) against age, could be that lambs should be turned off pasture as heavy as possible. If it is assumed that to match feed demand with supply, the oldest lambs could be turned off pasture at around 6 months (Figure 11). Peak intake was approximately double base intake. For many systems the ideal is to have peak 3-4 times base intake. This could be achieved by increasing reproductive rate (compare 3-way to F_1, Figure 11) and by allowing ewes to lose condition through the periods of low pasture availability.

Figure 11. Seasonality of feed demand.



A major conclusion of this project must be that there are opportunities to improve system efficiency in Australia's sheep industry by decreasing maintenance feed requirements of Merino ewes. Early selection index development work for the Australian Merino by Ponzoni (1988) assumed a high value for ewe and lamb feed intake that supports the conclusion in the current study. The difference between conclusions made 15-20 years ago versus now, is the possibility of now including intake or correlated traits as selection criteria. This may be able to be done by measuring intake directly (pellet/feedlot) or using alkane markers to measure pasture intake, IGF-1 as a biochemical marker, yield (low GRF and large EMD) as correlated traits, or using genetic markers. It seems clear that effort should be placed on lowering maintenance feed requirements of Merinos. Genetic markers are ideal for this since the traits is difficult and expensive to measure, and there is the possibility of developing these markers within five years. Developing a research project in this area is the logical next step from this modeling project.

References

Arthur, P.F., Archer, J.A., Herd, R.M., Richardson, E.C., Exton, S.C., Wright, J.H., Dibley, K.C.P. and Burton, D.A. (1997). Genetic and phenotypic variation in feed intake, feed efficiency and growth in beef cattle. *Proc. Assoc. Advmt. Anim. Breed. Genet.* 12:234-237.

Clark, B. (2002) A review of genetic parameters for analysis of Merino data, with recommendations to MLA on the adequacy of existing parameters and the need for further research. Report to Meat and Livestock Australia, Sydney.

Ferrell, C.L. and Jenkins, T.G. (1984) Energy utilisation by mature, non-pregnant, non-lactating cows of different types. *Journal of animal Science* 58:234-243.

Fogarty, N.M. (1995) Genetic parameters for live weight, fat and muscle measurements, wool production and reproduction in sheep: a review. Anim. Breed. Abstr. 63(3)101-143.

Hopkins, D.L., Wotton, J.S.A., Gamble, D.J. and Atkinson, W.R. (1995) Lamb carcass characteristics 2. Estimation of the percentage of saleable cuts for carcass prepared as "trim" and traditional cuts using carcass weight, fat depth, eye muscle area, sex, and conformation score.

Lee, G.J., Atkins, K.D. and Mortimer, S.I. (1995) Variation between Merino ewes in pasture intake 2. Within-flock genetic parameters for intake and some production traits. Livest. Prod. Sci. 41:143-150.

Lee, G.J., Atkins, K.D., and Swan, A.A. (2001) Genetic parameters for pasture intake and wool growth efficiency in Merino Sheep. Proc. Assoc. Advmt. Anim. Breed. Genet. 14:505-508.

Montaldo-Bermudez, M., Nielsen, M.K. and Deutscher, G.H. (1990) Energy requirements for maintenance of crossbred beef cattle with different potential for milk. *J. Anim. Sci.* 68:2279-2288.

Nitter, G., Graser, H-U, and Barwick, S.A. (1994) *Aust. J. Agric. Res.* 45:1641.

Hughes, T.E. (1993) Honours Thesis, Animal Science, The University of Adelaide.

Parks, J.R. (1982) A theory of feeding and growth of animals. Springer-Verlag, Berlin Heidelberg New York.

Ponzoni, R.W. (1988) The derivation of economic values combining income and expense in different ways: An example with Australian Merino Sheep. J. Anim. Breed. Genet. 105:143-153.

Pitchford, W.S. (1993). Growth and lambing performance of ewes from crosses between the Dorset Horn, Merino and Corriedale. Livest. Prod. Sci. 33:127-139.

SCA (1990) Feeding standards for Australian livestock: Ruminants. Standing Committee on Agriculture, Ruminants Subcommittee. CSIRO Publications, East Melbourne, Victoria, Australia.

Thompson, J.M., Parks, J.R., and Perry, D (1985) Food intake, growth and body composition in Australian Merino Sheep selected for high and low weaning weight. I. Food intake, food efficiency and growth. Anim. Prod. 40:55-70.