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Project 1.2 Reproduction efficiency

Milestone: Progress reports accepted on analysis of reproduction efficiency data, postgraduate research and on-farm validation of within flock segmentation strategies

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Task R2.1.3.3: Completed analysis and report on alternative selection criteria for within flock selection to improve reproduction efficiency and production response traits performance
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Introduction

There is a large degree of variation in lifetime net reproductive performance between ewes within a flock (Lee *et al.* 2009a). As the annual expression of net reproductive merit is strongly influenced by environmental factors as well as genetics, the lifetime net reproductive performance is the best estimate of a ewe's merit. The realised heritability of the lifetime trait is three times of that based on annual expressions (Lee *et al.* 2009b). In addition, lifetime net reproduction has high genetic correlations with each of the component traits, but the genetic correlations between the lifetime component traits are much lower.

Measuring lifetime reproductive performance until relatively recently has been a labour intensive and costly process. However, with pregnancy scanning and systems such as Pedigree Matchmaker (Richards and Atkins 2007) each of the component traits of fertility, fecundity and lamb survival can be determined at relatively low cost, as well as the association of a lamb with its dam.

Alternative criteria such as a wet/dry udder examination at either marking or at weaning have been proposed to avoid the costs associated with scanning and determining individual lamb survival (purchasing equipment and/or paying for higher skills /equipment hire).

Methods and analyses

Lifetime reproductive data (ages 2-6) were available from 3 flocks of Merino ewes (D-Flock, C-Flock and QPLU$) run at the Agricultural Research Centre (ARC), Trangie. In each of these flocks, lambing, marking and weaning performance of the ewes was routinely recorded. Data for at least 3 joinings were available for 2430 D-Flock ewes (born 1975-1983), 1819 C-Flock ewes (born 1984-1993) and for 3037 QPLU$ ewes (born 1993-2002).

D-Flock and its management

This flock consisted of 15 random-bred Merino bloodlines maintained as a single group (except during joining and lambing) on pasture. Ewes entering the breeding flock were selected at random and no culling was practised during their adult life. Ewes were single-sire joined annually to rams of the same bloodline over 5 weeks in late summer to lamb in late winter, with maidens joined to lamb at 2 years of age. Progeny were weaned at the end of spring. Shearing occurred in mid-spring. A detailed description of these flocks and their management is given by Mortimer and Atkins (1989).

C-Flock and its management

The Merino crossing program (C-Flock) was based on eight flocks from the D-Flock project (Mortimer and Atkins 1989). These bloodlines comprised the two fine-wool, two medium-wool non-Peppin, three medium-wool Peppin and one strong-wool bloodlines. These bloodlines were joined in a complete diallel design to produce purebred and two-way cross progeny. From 1986, the purebred and crossbred ewe progeny were joined to purebred or crossbred ram genotypes to produce purebred, first cross, F2 interbred, backcross progeny, three-way and four-way cross progeny (Mortimer *et al.* 1994).

The management calendar of C-Flock was similar to that used with D-Flock. Ewes were syndicate joined annually over 5 weeks in late summer to lamb in late winter, with maidens joined to lamb at 2 years of age. Progeny were weaned at the end of spring. Data on the lambing, marking and weaning performance of the ewes were routinely recorded. Shearing occurred in mid-spring. Other than during joining and lambing, the ewes were maintained as a single group on pasture.

QPLU$ and its management

The QPLU$ flock was established to evaluate the responses of index selection to increase clean fleece weight and reduce mean fibre diameter in fine, medium-Peppin and broad wool strains of Merino sheep (Taylor and Atkins 1997). In total, nine selection lines were established; two lines in each of the fine- and broad-wool strains, and five within the medium-Peppins. The ewes were single-sire joined (5 weeks) in January/February to lamb in June/July, shorn in October and the lambs weaned 12-14 weeks after the start of lambing. Maiden ewes were joined to lamb at 2 years of age. Data on the lambing, marking and weaning performance of the ewes was routinely recorded. The ewes were maintained as a single group on pasture, except during joining and lambing. For further details on ewe management and design of the QPLU$ project see Taylor and Atkins (1997).

Statistical analyses

Data on the number of times each ewe was joined, the number of years the ewe lambed, the total number of lambs born, and the number of lambs weaned were obtained over the reproductive life (2-6 years of age) of the ewes in the flock were collated. From these values average fertility (ewes lambing/ewe joined), fecundity (lambs born/ewe lambing), lamb survival (lambs weaned/lamb born), and net reproduction (lambs weaned /ewe joined) were calculated for each ewe for the periods 2-year-old alone, 2-3 year-old, 2-4 year-old, 2-5 year-old and over the lifetime (2-6 year-old). In addition, the frequency each ewe reared a lamb(s) to marking and to weaning were also estimated over the same periods to simulate wet/dry (W/D) udder examinations at these times.

ASReml (Gilmour *et al.* 2006) was also used to estimate the phenotypic and genetic correlations of lifetime NRR with each of fertility, fecundity, survival, wet/dry at marking and wet/dry at weaning measured at 2-year-old, 2-3 year-old, 2-4 year-old, 2-5 year-old and over the lifetime (2-6 year-old). The phenotypic and genetic correlations of partial lifetime performance with lifetime performance for each of these traits were similarly estimated. The heritability of these traits for each of the periods was also estimated using ASReml (Gilmour *et al.* 2006).

The estimates of heritability (h_w^2) from each of the research flocks (n=3) were combined as weighted estimates:

$$h_w^2 = \{h_1^2 * 1/[se(h_1^2)^2] + .. + h_n^2 * 1/[se(h_n^2)^2]\} / \{1/[se(h_1^2)]^2 + .. + 1/[se(h_n^2)]^2\}$$

and the standard error of that weighted estimate (se_w) as:

$$se_w = 1/\sqrt{\{1/[se(h_1^2)]^2 + .. + 1/[se(h_n^2)]^2\}}$$

The weighted genetic correlations and respective standard errors were similarly estimated.

Results

Relationships of the alternative reproductive performance criteria with lifetime net reproduction

The phenotypic correlations of each of the alternative reproduction traits with the lifetime net reproductive performance are shown in Table 1. For all traits, the phenotypic correlations with lifetime net reproductive rate were positive and tended to increase with the number of years of measurement. When measured for at least 2-3 years the correlations with lifetime net reproduction tended to be high, particularly for the traits measuring the ability of ewes joined to rear a lamb(s) to marking or weaning (i.e. wet/dry udder examinations at marking and rearing).

Table 1 Phenotypic correlations ± *s.e.* for the components of reproductive performance (between 1 and 5 years) with lifetime net reproduction rate (measured as average lambs weaned annually per ewe)

	No. years data				
	1	2	3	4	5
Fertility	0.377	0.498	0.555	0.639	0.666
	0.010	*0.009*	*0.008*	*0.007*	*0.007*
Fecundity	0.234	0.276	0.360	0.396	0.428
	0.014	*0.012*	*0.011*	*0.010*	*0.010*
Survival	0.352	0.478	0.564	0.601	0.633
	0.013	*0.010*	*0.008*	*0.011*	*0.009*
Net	0.530	0.750	0.904	0.976	1.000
	0.009	*0.005*	*0.002*	*0.001*	
W/D marking	0.441	0.627	0.803	0.868	0.736
	0.012	*0.009*	*0.005*	*0.004*	*0.007*
W/D weaning	0.478	0.667	0.789	0.849	0.879
	0.009	*0.007*	*0.005*	*0.003*	*0.003*

Table 2 Genetic correlations ± *s.e.* for the components of reproductive performance (between 1 and 5 years) with lifetime net reproduction rate (measured as average lambs weaned annually per ewe)

	No. years data				
	1	2	3	4	5
Fertility	0.591	0.685	0.730	0.720	0.759
	0.100	*0.081*	*0.073*	*0.061*	*0.057*
Fecundity	0.388	0.520	0.561	0.584	0.633
	0.175	*0.111*	*0.084*	*0.082*	*0.072*
Survival	0.746	0.706	0.824	0.789	0.748
	0.137	*0.111*	*0.067*	*0.061*	*0.061*
Net	0.864	0.974	0.993	0.999	1.000
	0.082	*0.030*	*0.009*	*0.002*	
W/D marking	0.970	1.045	0.967	0.974	0.939
	0.178	*0.105*	*0.028*	*0.027*	*0.056*
W/D weaning	0.661	0.912	0.951	0.935	0.928
	0.089	*0.059*	*0.028*	*0.026*	*0.023*

The estimated genetic correlations of all traits with lifetime net reproduction were higher than the equivalent phenotypic correlations (Table 2) and increased with the number of years of measurement. However, the genetic estimates were much less precise than the phenotypic estimates, particularly when measured for only one or two years.

All traits had strong genetic correlations with lifetime net performance, particularly when measured for 3 or more years. The genetic correlations of the traits measuring the ability of ewes joined to rear a lamb(s) to marking or weaning (i.e. wet/dry udder examinations at marking and rearing) with lifetime net reproductive rate were very strong (>0.9 for all estimates using 2 or more years measurements).

Relationship of lifetime performance of each of the alternative criteria with the performance measured over one to four years

The phenotypic correlations of lifetime performance in each of the criteria with the partial life performances are shown in Table 3. Reliable estimates of the lifetime performance (phenotypic correlations >0.7) require at least 2-3 years of measurement.

Table 3 Phenotypic correlations ± *s.e.* of part records (1-4 annual records) of the components of reproductive performance with lifetime measures of these components

	No. years data			
	1	2	3	4
Fertility	0.587	0.778	0.911	0.974
	0.008	*0.005*	*0.002*	*0.001*
Fecundity	0.565	0.720	0.876	0.963
	0.010	*0.006*	*0.003*	*0.001*
Survival	0.558	0.732	0.874	0.969
	0.010	*0.006*	*0.003*	*0.001*
Net	0.530	0.750	0.904	0.976
	0.009	*0.005*	*0.002*	*0.001*
W/D marking	0.426	0.621	0.795	0.936
	0.012	*0.009*	0.005	*0.003*
W/D weaning	0.578	0.782	0.913	0.977
	0.008	*0.005*	*0.002*	*0.001*

Table 4 Genetic correlations ± *s.e.* of part records (1-4 annual records) of the components of reproductive performance with lifetime measures of these components

	No. years data			
	1	2	3	4
Fertility	0.752	0.916	0.911	0.974
	0.078	*0.038*	*0.002*	*0.001*
Fecundity	0.941	0.963	0.875	0.997
	0.102	*0.032*	*0.006*	*0.004*
Survival	0.994	1.017	1.00	1.001
	0.082	*0.045*	*0.013*	*0.003*
Net	0.864	0.974	0.993	0.999
	0.082	*0.030*	*0.009*	*0.002*
W/D marking	0.841	ne	1.013	0.969
	0.274		*0.054*	*0.026*
W/D weaning	0.756	0.990	0.980	0.991
	0.083	*0.042*	*0.013*	*0.004*

The genetic correlations of all partial life measurements with the respective lifetime measurement were high (Table 4). While all the genetic correlations were estimated less precisely than the respective phenotypic correlations, those for survival of lambs born and wet/dry udder examinations at either lambing or weaning were estimated with the least precision.

Heritability

The heritability estimates of net reproduction, each of the component traits and the alternative criteria, averaged over one to five years, are shown in Table 5.

Table 5 Heritability ± *s.e.* of alternative criteria of reproductive performance of Merino ewes measured for between one and five years

	No. years data				
	1	2	3	4	5
Fertility	0.111	0.097	0.101	0.113	0.126
	0.023	*0.021*	*0.021*	*0.022*	*0.022*
Fecundity	0.071	0.115	0.177	0.184	0.201
	0.027	*0.024*	*0.025*	*0.025*	*0.025*
Survival	0.077	0.066	0.099	0.098	0.156
	0.032	*0.023*	*0.023*	*0.024*	*0.025*
Net	0.087	0.108	0.140	0.145	0.162
	0.023	*0.021*	*0.022*	*0.023*	*0.023*
W/D marking	0.044	0.076	0.089	0.106	0.098
	0.028	*0.031*	*0.027*	*0.032*	*0.026*
W/D weaning	0.093	0.107	0.097	0.170	0.090
	0.022	*0.023*	*0.022*	*0.032*	*0.023*

Heritability estimates for net reproductive performance, fecundity, lamb survival and wet/dry at marking all tended to increase with the number of measurement years. Heritability estimates for net reproductive performance, fecundity and lamb survival when measured over the lifetime were each greater than 0.15 and 2-3 times that of estimates based on measurement at 2-year-old only.

There appears little systematic effect of increasing the number measurement years on the heritability estimates for fertility and wet/dry at weaning, with these estimates falling in the range 0.09-0.13, with the exception the wet/dry at weaning measured over 4 years which was 0.17).

The pattern of increase in heritability with repeated records is consistent with what is expected with a trait of low heritability and slightly higher repeatability. Repeated records reduce the environmental (or residual) variance while maintaining genetic variance leading to an increase in heritability. The absence of that pattern for fertility and W/D at weaning is probably a consequence of unequal variances across ages. For these traits, maiden performance level is substantially different from adult performance level so that the heritability of maiden performance tends to dominate lifetime heritability more than its value as a single record.

In general, the precision of the heritability estimates varied little with increasing the number of measurements.

Current generation gains – a comparison of selection criteria

This section examines the implications for a self-replacing breeding flock with a fixed age structure of culling younger ewes using one of 4 simple strategies to improve reproductive rate. Given the reluctance to look at lifetime measurement within the Sheep CRC, the modelling here looks at the consequences when only or two years of measurements are available.

Each of the strategies uses a single criterion (scanning data alone or data from the equivalent of udder examination at weaning) with either one (at 2-year-old) or two (at 2- and 3-year-old) years of measurement. Although the strategies are straightforward, the flow-on effects are not simple. Data from the 3 Trangie research flocks (with 5 breeding ewe age groups) have been used in these simplified calculations. The following tables illustrate and compare the effects of these culling strategies on flock structure, net reproduction rates, selection potential within replacement maiden ewes and on the availability of surplus animals.

Table 6 Effect on flock structure of culling strategy within 3 Merino flocks having five breeding ewe ages

Cull strategy	Proportion of age group culled	Flock structure (years)		
		2	3	4-6
D-flock				
No culling	0.000	0.200	0.200	0.600
One years information (2 years)				
Dry @ scanning	0.329	0.271	0.182	0.546
Dry udder @ weaning	0.463	0.318	0.171	0.512
Two years information (2 and 3 years)				
Twice dry @ scanning	0.120	0.216	0.216	0.569
Fail to rear twice	0.226	0.231	0.231	0.537
C-Flock				
No culling	0.000	0.200	0.200	0.600
One years information (2 years)				
Dry @ scanning	0.243	0.248	0.188	0.564
Dry udder @ weaning	0.399	0.294	0.177	0.530
Two years information (2 and 3 years)				
Twice dry @ scanning	0.052	0.206	0.206	0.587
Fail to rear twice	0.149	0.220	0.220	0.561
Qplu$				
No culling	0.000	0.200	0.200	0.600
One years information (2 years)				
Dry @ scanning	0.299	0.263	0.184	0.553
Dry udder @ weaning	0.456	0.315	0.171	0.514
Two years information (2 and 3 years)				
Twice dry @ scanning	0.102	0.213	0.213	0.574
Fail to rear twice	0.219	0.230	0.230	0.539

Within a flock with a fixed age structure (5 years in this case), any culling after the selection of maiden ewe replacements will increase the proportion of maidens in the breeding flock. The more ewes that are culled later, the more the proportion of maidens must increase. Table

6 shows the flock structures under each of the four strategies, and in each case culling on maiden ewe data alone will remove more ewes from the breeding flock than using two measurements to identify the non-performing ewes. Culling on scanning data (infertility alone) will remove fewer ewes than culling on a wet dry examination at weaning (infertility and ewes that reared no lamb(s)).

The net reproduction rate responses to the four culling strategies are shown in Table 7.

Selections based on 2 years of measurement were more efficient in identifying the 4-6 year-old ewes with the lowest net reproductive performance, in that the difference in the mean performance of ewes retained and those culled was twice that of obtained with selections using only one year of measurements (Table 7) and required fewer ewes to be culled (Table 6). This is primarily because the worst performing ewes were identified, with little difference in the means of the retained ewes.

Table 7 Effect of different culling options on the net reproductive rate (per ewe joined) of Merino ewes from 3 flocks at ages 4-6 year, and the gains achieved across all ages (2-6 year-old)

Cull strategy	Net reproductive rate (4- to 6-year-old)				Whole flock gain (2- to 6-year-old)
	Selected ewes	Culled ewes	Difference b/n selected and culls	Difference b/n selected and unselected	
D-flock					
No culling	0.817	-			
One years information (2 years)					
Dry @ scanning	0.878	0.694	0.183	0.061	0.029
Dry udder	0.904	0.718	0.186	0.087	0.034
Two years information (2 and 3 years)					
Twice dry	0.864	0.472	0.392	0.047	0.022
Fail to rear twice	0.891	0.565	0.326	0.075	0.029
C-Flock					
No culling	1.072	-			
One years information (2 years)					
Dry @ scanning	1.124	0.926	0.198	0.052	0.027
Dry udder	1.145	0.826	0.179	0.073	0.008
Two years information (2 and 3 years)					
Twice dry	1.092	0.689	0.403	0.020	0.008
Fail to rear twice	1.118	0.795	0.324	0.046	0.016
Qplu$					
No culling	0.927	-			
One years information (2 years)					
Dry @ scanning	0.998	0.753	0.245	0.071	0.024
Dry udder	1.036	0.679	0.239	0.109	0.028
Two years information (2 and 3 years)					
Twice dry	0.979	0.487	0.492	0.052	0.026
Fail to rear twice	1.025	0.592	0.433	0.098	0.044

The net reproduction rate response to selection (the difference between the performance of the selected ewes at ages 4-6 and the unselected ewes of the same age) the responses are a little higher if only one year's data are used, but the is at the expense of a high proportion of the ewes being culled.

When the reproductive rate is compared across the whole flock (all ages, 2-6 year olds) the improvement in reproductive rate, regardless of criteria or number of years of measurement, was reduced to 2-4%. Factors behind this were the proportion of maiden ewes and the number of unselected age groups.

Table 8 shows the effects of culling strategy on ewe replacement rates and the potential for selection of maiden replacements. Using only one year of measurements produced larger responses in 4-6 year-old ewes through higher culling rates. However, the number of maiden replacements and the proportion of available female progeny required were also higher compared with culling on two years of measurement (Table 8). Similarly, the number and the proportion of available female progeny required were also higher when selection was based on an udder examination at weaning when compared to culling on infertility.

Table 8 Effect on the selection of replacement hogget ewes of different culling options of Merino ewes from 3 flocks

				Replacement ewes needed		
Cull strategy	Proportion culled (p)	NRR of whole flock	Available ewe progeny	No.	Prop'n of available progeny	Selection potential
D-flock						
No culling	0.000	0.749	0.374	0.200	0.534	0.466
One years information (2 years)						
Dry @ scanning	0.329	0.778	0.389	0.271	0.698	0.302
Dry udder	0.463	0.783	0.391	0.318	0.812	0.188
Two years information (2 and 3 years)						
Twice dry	0.120	0.770	0.385	0.216	0.560	0.440
Fail to rear twice	0.226	0.778	0.389	0.231	0.595	0.405
C-Flock						
No culling	0.000	0.969	0.485	0.200	0.413	0.587
One years information (2 years)						
Dry @ scanning	0.243	0.996	0.498	0.248	0.498	0.502
Dry udder	0.399	0.978	0.489	0.294	0.601	0.399
Two years information (2 and 3 years)						
Twice dry	0.052	0.977	0.489	0.206	0.423	0.577
Fail to rear twice	0.149	0.985	0.492	0.220	0.446	0.554
Qplu$						
No culling	0.000	0.869	0.435	0.200	0.460	0.540
One years information (2 years)						
Dry @ scanning	0.299	0.893	0.447	0.263	0.589	0.411
Dry udder	0.456	0.898	0.449	0.315	0.702	0.298
Two years information (2 and 3 years)						
Twice dry	0.102	0.895	0.448	0.213	0.476	0.524
Fail to rear twice	0.219	0.913	0.457	0.230	0.504	0.496

The corollary of a higher proportion of available females being required as replacements is that the selection potential (1 - proportion of available female progeny required as replacements) is reduced. Strategies using only one year's data reduced the potential for genetic improvement through selection for other productive traits when compared with either using two years of measurement or no culling to improve reproductive performance.

Strategies with low selection potentials obviously have fewer surplus ewe progeny, with those based on one year of measurement all having fewer surplus progeny than the no selection strategy (Table 9).

Table 9 Effect of culling options on the numbers of surplus progeny

Cull strategy	Wether progeny	Surplus ewe progeny	Surplus ewe + wether progeny
D-flock			
No culling	0.374	0.174	0.549
One years information (2 years)			
Dry @ scanning	0.389	0.118	0.507
Dry udder	0.391	0.074	0.465
Two years information (2 and 3 years)			
Twice dry	0.385	0.170	0.555
Fail to rear twice	0.389	0.158	0.547
C-Flock			
No culling	0.485	0.285	0.769
One years information (2 years)			
Dry @ scanning	0.498	0.250	0.748
Dry udder	0.489	0.195	0.684
Two years information (2 and 3 years)			
Twice dry	0.489	0.282	0.771
Fail to rear twice	0.492	0.273	0.765
Qplu$			
No culling	0.435	0.235	0.669
One years information (2 years)			
Dry @ scanning	0.447	0.184	0.630
Dry udder	0.449	0.134	0.582
Two years information (2 and 3 years)			
Twice dry	0.448	0.235	0.682
Fail to rear twice	0.457	0.226	0.683

Selections based on fertility measured in two years produced more surplus progeny, maintained the selection potential in maiden replacements at similar levels to those of the unselected flock and with small gains in whole flock net reproduction rate in the current generation.

Discussion and conclusions

The analyses and modelling presented in this report have been based on data collected from the Trangie research flocks in which no selection for reproductive traits has been practised. Over the last 30 years the national average reproductive rate has been *circa* 76 lambs marked per 100 ewes joined (ABARE 2008), which is a only little lower than the 84 lambs weaned per 100 ewes joined in the Trangie flocks over a similar period. The results of this work will be applicable to a large proportion of sheep flocks in Australia.

Using udder examination as a proxy for net reproduction

A wet/dry udder examination at either marking or at weaning has been proposed to avoid the costs associated with scanning and determining individual lamb survival (purchasing equipment and/or paying for higher skills /equipment hire). However, an udder examination still requires an additional labour cost (although the skill level is not high) and a means of recording the result and/or identifying the ewes (particularly if using the results from more than one year).

Udder examinations records (from either marking or weaning) had very high genetic correlations (0.9+) with lifetime net reproduction, so they can effectively identify the lifetime net reproductive genetic potential. However, the realised rate of genetic gains from using lifetime udder examination data will be lower than using lifetime net reproduction (number of lambs reared) with the heritability estimates being 0.09 and 0.16, respectively.

A wet/dry assessment does not identify a ewe's lamb. Hence, it is not possible to use information on the dams' reproductive performance in the selection of young ewes as replacements, limiting the rate of genetic improvement (or for ram selection). Neither is it possible to gain any information on a ewe's fecundity (unless conducted in conjunction with scanning in mid-pregnancy), or on the number of lambs reared.

The time of an udder examination can pose some practical problems. At marking, all ewes with lambs at foot will be expected to be lactating. But, marking is a busy time with a number of husbandry activities, congestion around the yards and the pressure to return mobs of ewes and lambs to the paddock. Hence marking is not the most convenient time for an udder examination of all ewes, particularly when more than one mob is involved. On the other hand, delaying an udder examination until weaning may not be as accurate given that early-born lambs may have self-weaned and all ewes that had reared a lamb may not be lactating. The extent to which this affects the examination will be influenced by the weaning age and seasonal conditions.

Selection to improve reproductive rate

Data presented both here and from work previous years demonstrate that selection based on a single year's data can lead to moderate gains in the current generation within the selected group (i.e. the difference between the unselected and retained ewes). However, those gains are achieved by culling a relatively high proportion of the ewes in that age group, with the flow-on effect being a larger increase in the proportion of maidens required to maintain flock size. Hence, the effect on total flock performance of culling on just one year's data is small.

Selection using two (or more) years' information will produce larger differences between the performance of culled and retained ewes, than the use of a single year's data. The gains in the selected group will be achieved with fewer ewes culled, and thus a smaller increase in the proportion of maidens. However, the flock will include (at least one) more unselected age groups which reduce the gains in the total flock performance.

Genetic gains associated with removal of poor performing younger ewes from the flock will be slow because the heritability of net reproduction, the component traits and alternative measurements from udder examinations is relatively low, compared with lifetime estimates of, say, net reproduction or fecundity.

Within a rigid age structure, current generation gains are restricted by the proportion of unselected ewes (particularly maidens). Increasing the number age groups in a self-replacing breeding flock would reduce the proportion of maiden ewes and increase the total flock's reproductive performance. The argument has been put that increasing the number of ewe age groups will slow genetic gains in the flock by increasing the generation interval. On the contrary, any effects of generation interval on gains would be small (ewes contributing only half the genes) and would be expected to be surpassed by the effects of a higher reproduction rate together with the requirement for fewer replacements maidens in enabling much higher selection differentials to be imposed for traits under selection.

Selection against poor performing animals in early life in itself will give some current generation increases in reproductive performance, with only a slow improvement in genetic gains. However incorporating early life selections in a broader approach to increasing not only current generation gains but also genetic improvement is a more sensible approach.

The realised heritability of lifetime reproductive performance is up to three times that of annual performance records. A simultaneous increase in the number of age groups with retention of only top performing older ewes and selection against poorly performing younger ewes would maximise the responses to selection in both the current generation and genetic gains (Lee *et al.* 2010). Modelling to verify the consequences of increasing the number age groups, retaining the better performing ewes (based on lifetime records) beyond normal culling age, early culling of poor performers on two years data and using rams with a +5 % EBV for net reproduction are reported in the Report for Task R2.1.3.4. It shows that combining these strategies will lead to substantial gains within 5-10 years, without adverse effects on clean fleece weight or fibre diameter.

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