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Robustness as a breeding objective for sheep in New Zealand

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Abstract

Failure of ewe robustness has negative impacts on flock profitability. It leads to loss of productivity, additional costs through regaining of body reserves and substantial wastage due to death or culling. However, breeding for robustness or resilience in sheep is hampered by lack of a clear understanding of the trade-off between maintenance of body reserves in the ewe and productivity across successive annual production cycles. Whether it is acceptable to have large fluctuations in bodyweight or body condition score in order to sustain high production will probably depend on the severity of the environmental challenge as well as levels of production. Anecdotal evidence from industry suggests that some sheep are as productive as others but with smaller fluctuation in body reserves. Such "observations" need to be backed up by well-designed trials and recording protocols to characterise variation in typical farm environments and quantify the interactions between ewe wastage, ewe productivity and their indicator traits. Further work is needed to critically review the value of robustness to maternal sheep and develop protocols for assessment of robustness and optimal strategies for its inclusion in breeding objectives.

Robustness versus resilience

Robustness and resilience are considered as either the same thing or different in the literature. Bankes (2010) contrasts them for productive farm animals in a variable environment, describing "robustness" as the ability to withstand, and exhibit stability in the presence of, external challenges, and "resilience" as the ability to recover from external challenges. Recovery implies short-term failure of robustness. Levin and Lubchenco (2008) consider robustness and resilience as the same thing in the context of biological systems in the long-term. They describe it as an organism's ability to maintain functionality in the face of disturbance. Thus the nature and severity of the challenge, the animal response and the timeframe over which this is considered impact on interpretation. What is considered to be a robust animal may really be a resilient one waiting to fail *i.e.* small or short-term challenges have little impact on production but severe or prolonged challenges lead to drops in productivity or health status.

In pastoral animal agriculture we are interested in both concepts because we expect environmental challenges but the severity and timing of these is not predictable. Animals need to have a degree of robustness, to even out short-term challenges, but also a degree of resilience, to allow them to survive and return to desired levels of productivity in the medium to long term when conditions improve. We will use the term “robustness” to cover both concepts and avoid confusion with “resilience” which is used in New Zealand to describe a particular way of coping with internal parasites that is subject to selection in some ram breeding flocks (see SIL Technical Note at www.sil.co.nz).

Importance of robustness to the New Zealand sheep industry

Under pastoral grazing, robustness is an important trait for sheep as it impacts on productivity, animal welfare, sustainability of farm systems, ease of management and consequently on profit and efficiency. It manifests itself as the ability to maintain or recover body condition while avoiding disease or physical breakdown. In a farming context, it is assumed that sheep are also productive and not primarily focused on their own survival.

Robustness is particularly important for reproductive ewes with heavy physiological demands for pregnancy and lactation that must be met by nutrition and/or tissue mobilisation. This loading also places demands on their health status. Ewe flocks typically have a dry period, between weaning and mating, when lost body condition is expected to be recovered if conditions allow. However, the opportunity for recovery can vary so that ewes may enter the next annual production cycle at mating in different body condition to that of one year earlier.

Lack of robustness impacts on farm profit in two ways. Firstly, through lowered production and the higher costs associated with a ewe’s recovery. Secondly, through higher culling levels of animals that do not recover, which increases the number of replacement stock required. This also decreases the genetic gain that can be achieved through selective culling and the productive potential of the flock given younger ewes are typically less productive. Modelling a breeding ewe flock, Cruickshank *et al*. (2009) found that if the age at which ewes were culled increased from 5 to 6 years of age, 13% less replacement ewes were needed each year and culling pressure could be increased.

In New Zealand, a shift in land use has seen a greater decline in easier country (finishing/breeding) than in harder country (hill country), so a higher proportion of the sheep and beef industry is now on hill country (Table 1). However, while we have seen a dramatic fall in sheep numbers, productivity per head has increased equally dramatically, through a combination of increased lambing percentage and increased carcass weight. Viewed together, these effects show that we are expecting more from ewes in harder environments, creating a greater need for ewes to be robust.

When farming in the hill environment there is less opportunity to use management to lessen the impact of environmental variation than on more intensive finishing type properties. This and the development of more productive genotypes in New Zealand, has led to farmers and ram breeders questioning whether there is a trade-off between production and robustness. This implies higher productivity is associated with reduced robustness, but evidence for this in New Zealand sheep is lacking. Work in this area is needed to inform the development of future breeding objectives.

Robustness in practice

In typical pastoral farming systems, variation in feed quantity and quality means high performing ewes must utilize body reserves to maintain productivity. Generally, it is expected that body reserves are used to minimise the effect of feed shortage on productivity and recovery will occur when the shortage eases.

The physiological requirements of pregnancy and lactation are particularly demanding on ewes, with litter size having a major impact on the degree to which body reserves are utilised. Commercial farmers use the expression that some ewes "milk off their back" to produce good lambs while other ewes conserve body condition and produce fewer or lighter lambs. However, a view among some ram breeders that there are ewes which produce big healthy lambs with only small changes in body weight (BW) or body condition score (BCS) lacks supporting evidence from well designed studies.

Table 1. Change in land use in New Zealand for animal agriculture and sheep productivity over 20 years (data from Beef + Lamb New Zealand Economic Service). Sheep and beef cattle are predominantly run on hill country and finishing/breeding farms

Number of	1990-1991	2010-2011	*change*
Hill country farms	7,500	6,245	*-17%*
Finishing/ breeding farms	12,100	6,240	*-48%*
Dairy Farms	14,685	11,850	*-19%*
Total area of (effective million ha)			
Hill country farms	6.81	5.98	*-12%*
Finishing/ breeding farms	3.27	2.29	*-30%*
Dairy farms	1.35	2.24	*+66%*
Sheep production			
Breeding ewes (million)	43.8	21.8	*-50%*
Export lamb (000 tonnes)	429	357	*-17%*
Lambing percentage	101.6	119.3	*+17%*
Average carcass weight (kg)	13.9	18.2	*+31%*
Carcass weight per ewe (kg)	9.8	16.4	*+67%*

Disease also places significant challenges on animals. The best example in New Zealand is the devastation that occurs in susceptible flocks with outbreaks of Facial Eczema (FE), resulting from ingestion of a fungal toxin in the bottom of pasture. However more than twenty-five years of selection for FE tolerance by some breeders has resulted in their sheep exhibiting robustness to normal FE challenges *i.e.* no loss of productivity (Morris *et al.,* 1994).

Some New Zealand producers express the view that rams they buy lack robustness or longevity. However, caution should be exercised in concluding they are genetically inferior for robustness. Ram failure may be due to the effects of rearing or management rather than genetic effects. Rams reared under easy conditions may lack fitness when moved to hill country or they may not be receive the nutrition they need to perform well, prior to, or after, the intense mating period. Interestingly evidence in the scientific literature indicates that luxury feeding can shorten lifespan, (*e.g*. Weindruch *et al.,* 1986), perhaps explaining why there is a prejudice against rams bred under favourable conditions. It is important to emphasise that these are non-genetic effects and we must ensure they do not cause confusion around genetic improvement of traits contributing to robustness.

Stayability

Stayability is a measure of persistence in a flock (McIntyre *et al*., 2012). The length of time an animal stays in the flock can be defined in a range of ways as stayability, longevity, or productive lifespan under different conditions by different authors (Snelling *et al*., 1995; Maiwashe *et al*., 2009; Everett *et al*., 1977; Lee *et al*., 2013). Although the definitions vary they show the same trends with low to moderate heritabilities and variability in cattle (Jamrozik and Miller, 2013; van Melis *et al*., 2007; Martinez *et al.* 2005) and in sheep (Conington *et al.,* 2001; Borg *et al*., 2009; McIntyre *et al*., 2012). Stayability is generally defined as the probability of an animal remaining in the herd until a specific age given the opportunity and thus reflects the underlying fitness characteristics within a system/species that enable animals to remain in the flock. McIntyre *et al.* (2012) and Lee *et al.* (2013) show that stayability early in life is a good predictor of longevity or lifespan in a ewe flock.

The challenges ewes face from year to year can accumulate so robust ewes are more likely to last or "stay" over multiple production cycles. Good productivity in one year has a limited value if it compromises productivity in subsequent years. Demands of production and survival in pastoral farming systems mean less robust sheep die or leave the flock as culls for low BCS, disease or low productivity. However, sheep may be culled for reasons unrelated to robustness so stayability is an imperfect measure of robustness. Stayability should not be used as a proxy for robustness without adjustment for other factors.

In a ram breeding flock, for individual ewes a breeder will know performance over time and have estimates of genetic merit. So stayability will be a function of productivity, robustness and genetic merit. By contrast, in a commercial flock, stayability might be based solely on culling for low BCS as a proxy for robustness, placing highly productive but lower BCS ewes at a disadvantage because their productivity is not known.

Productivity versus robustness

The New Zealand sheep industry is concerned with the question: "Are more robust animals less productive by putting their body condition before production and are more productive animals less robust by sacrificing their body condition for production?"

This logic seems reasonable at the extreme – highly productive animals under severe environmental challenge are likely to show greater fluctuation in body weight (BW) or BCS. However, the extent to which this is valid for sheep facing typical challenges the environment brings remains to be determined. Furthermore, we should avoid limiting breeding targets for productivity primarily to breed tough sheep that will survive rare and extreme environmental challenges.

Due to low returns, under extensive conditions the ability to control the environment by improving pasture quality or quantity or by feeding supplementary feed is limited. Under such conditions the level of energy available limits potential productivity. Conington *et al*. (2004) demonstrated that where the environment is limiting, once selection for productivity reaches a threshold further selection for productivity does not improve economic returns. The authors concluded that different selection indexes should be used for different farm types. Datasets need to be gathered for New Zealand sheep farming systems to determine the extent to which this conclusion is valid there.

For over 30 years, selective breeding in the New Zealand sheep industry has successfully and markedly increased ewe productivity (Table 1). Pregnancy scanning has revolutionised feeding of ewes according to litter size, contributing to these lifts in national flock performance but also reducing the impact of litter size on ewe bodyweight and body condition score. Thus new management practice has reduced the need for robustness to some degree.

During the same period New Zealand sheep breeding objectives have focused on productivity per head without stayability (longevity) or robustness being explicitly considered. Some breeders are concerned that such breeding objectives favour traits expressed early in life and highly productive animals, and that longevity and robustness are becoming a significant issue. There is evidence from Australia that productivity and robustness are not diametrically opposed, with selection regimes at pasture favouring robustness in dairy cattle (Pryce *et al*., 2009). However, there is much to be gained from bringing robustness and its components into New Zealand sheep breeding objectives.

In considering "robustness" an outcome, we must also characterize the environmental challenges, the "stressors". The nature of robustness that copes with nutritional insufficiency is probably quite different to that which copes with low diet quality, disease or heat stress (e.g. Facial Eczema in New Zealand sheep (Morris *et al.,* 1994) or *Bos taurus* versus *Bos indicus* genotypes in Northern Australia, (Frisch, 1973)). Without the necessary anatomy, physiology or behaviour that imparts robustness, animals cannot be productive when challenged. This explains why highly productive animals from one environment fail to produce well when their robustness is challenged e.g. highly productive dairy cow genetics bred in temperate environments that are used in the tropics. Robustness will have a number of dimensions, and we can expect that some are unique to particular production environments.

Robustness, bodyweight and body condition score

In the New Zealand pastoral system, BW and BCS show cyclical rises and falls over the year due to the interaction of productivity demands and feed supply (quantity and quality). Some animals show greater changes than others. Informal surveying of commercial farmers and ram breeders in New Zealand, as well as unsolicited feedback to Sheep Improvement Ltd. (SIL) and Beef + Lamb New Zealand (B+LNZ) Genetics, has provided evidence that farmers prefer animals to show less fluctuation. One reason cited is that more dramatic cycling of BCS or BW is inefficient as it takes more energy to regain BW than is obtained from its loss. However, some breeders admit to accepting larger than average changes in BW or BCS if a ewe has weaned a good weight of lambs.

Our producers strongly believe that fatness or BCS is a key component of both robustness and productivity in ewes. In order to survive the winter and sustain lactation for two fast growing lambs a ewe needs to carry extra condition to offset times when pasture supply is inadequate. They are concerned that carcass focused breeding objectives, which have received more attention over the last ten years, have resulted in some maternal ewe genotypes becoming too lean.

Figure 1 represents a range of theoretical scenarios for ewe BCS changes over a series of annual production cycles. If BCS 2 is the minimum threshold to prevent productivity losses, then scenario 1 is preferred to scenario 2. Scenario 3 with less fluctuation requires less feed to maintain than scenario 1 and contains less risk than scenario 2. Scenario 4 appears to be best because it shows less fluctuation, stays above the critical threshold and minimises feed costs associated with weight loss and regain. What we do not have here is associated measures of ewe productivity. Without that we cannot describe the optimal pattern of change for productive ewes subject to typical season feed supply and lamb production demands.

How close we can get to the better curve options depends on our ability to select ewes with high productivity and low variation in BCS, and on variation in the nutritional and climatic environments. We do not want high changes in BCS, unless that is required for high productivity and does not compromise long-term robustness.

With ewe productivity increasing, the question is “what fluctuation in BW is needed for the typical range of environments a ewe encounters?” We do not know whether all ewes are equally sensitive to environmental conditions or whether some ewes manage to either maintain their BW better or recover faster from an environmental stressor. Work needs to be initiated to address these issues.

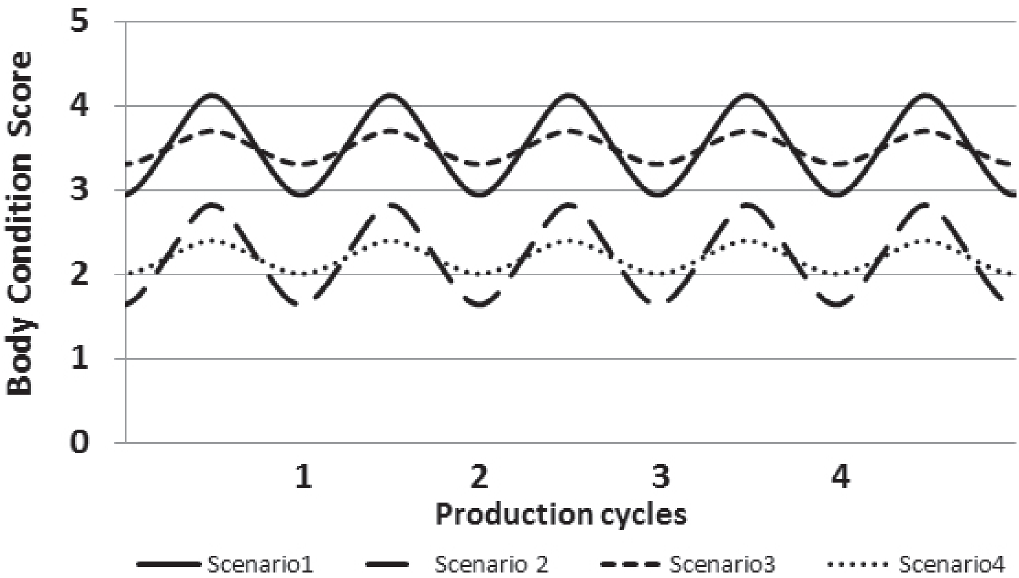

Figure 1. Stylised representation of annual cycles of Body Condition Score (BCS) loss and regain. It is assumed that BCS 2 is a critical threshold below which productivity is adversely affected

There appears to be very little published work on how a ewe's BW affects her productivity or stayability in the flock. McIntyre *et al.* (2012) suggested that heavier 18 month weights increased the likely stayability of a ewe although it is unclear whether this was a genetic effect of heavier animals or whether the better care of young stock created a more robust adult. We also do not know whether these sheep were genetically bigger in frame size or just carrying more condition.

Rose *et al.* (2013) found that Merino ewe BW loss under periods of nutritional restriction was related to genotype and concluded it should be possible to select for robustness to nutrition limitations measured as reduction in BW change. While this work did not relate BW change to long term stayability or productivity, Rose *et al*. (2012) did show that genetically reducing ewe BW loss increased the likelihood of pregnancy at the following mating.

In Australia, Borg *et al*. (2009) found that breeding ewes with a more static BW over the year tend to have higher stayability when they were not put under environmental pressure, supporting the view held by New Zealand farmers that less variation in BCS is more desirable. In the Australian study, high stayability ewes with genetically bigger body size tended to have faster growing lambs. Whether the latter effect was due to body size or ewe robustness is unclear.

These authors concluded that non-genetic factors affecting BW impact on stayability, with genetically high growth rate ewes compromised by the growth potential of their lambs such that they show greater BW loss. This illustrates the problem of culling on “apparent” robustness without taking account of productivity.

Robustness in breeding programmes

Environmental variability is vitally important to define robustness, protocols to assess it and strategies to integrate it into breeding objectives. However, defining hard and easy farming environments is fraught with contention as to what constitutes challenges in terms of the nature and severity.

There is a generally held view in the New Zealand sheep industry that is critical of rams being selected on easier country when their daughters will be farmed commercially on harder country. Currently the best advice that can be provided is to “buy rams from breeders running their sheep under similar conditions to those you farm in”. In addition, some breeders question the validity of large scale across-flock evaluations due to perceived variation in the environments different ram breeding flocks are run in. While we lack good evidence to justify these concerns, the view is strongly held by many.

In order to address this issue, B+LNZ Genetics has embarked on a progeny test programme, with the first mating in 2013, that will look at genotype by environment interaction effects on maternal performance for daughters of dual purpose (ewe breed) sires sourced from across industry. In this programme all sires will have daughters run on both lowland and hill sites. Measuring traits related to robustness is an important part of this programme.

A small number of New Zealand ram breeders run flocks under more challenging conditions specifically to identify genetics that cope and produce well under these conditions. However, this practice is based on subjective assessment of environmental challenge. While average levels of animal productivity such as lamb growth or ewe lambing percentage might be thought of as proxies for environmental challenge, they are most often confounded with genetic merit for productivity. In addition, the high rate of attrition in breeding programmes run under more extreme conditions places limits on the selection pressure that can be applied to all traits.

Risk and variability of the challenge should be considered when developing breeding programmes to improve robustness. The random nature of the effects of climate, feed supply and disease challenge, within and between years, increases risk to sheep farming operations. Easier environments are typically those where management has more options for control of key environmental variables such as feed supply or extreme climate events (e.g. snowfall). The need for robustness is defined by the size of an expected effect, the chance that it may occur, how much management can act to minimise the impact of the effect and levels of animal productivity. Some farmers will be more risk averse than others so there will be differences in demand for robustness from commercial producers.

Assessing robustness

We lack a clear, objective definition of robustness that can be used to bring this trait into ram breeding objectives. We lack protocols to define the range of environmental variation typical for most farms and to define testing regimes for robustness in breeding programmes. Developing definitions of robustness and defining environments in which to assess it are important goals for the New Zealand sheep industry.

Ram breeding flocks have information available on individual animals that commercial flocks do not. So culling in ram breeding flocks may be for reasons a commercial farmer cannot use and so mask “commercial robustness”. Breeding programmes designed to improve robustness of commercial sheep must take this aspect into account when designing recording protocols and strategies for deriving data to characterize robustness and its components, including stayability. In New Zealand, SIL has a protocol for recording why ewes leave the flock that can be used to separate “commercial” reasons from those that require the “knowledge” a recorded stud flock has (see Technical Note on Ewe longevity/ stayability at www.sil.co.nz). It is expected this protocol will evolve as we gain a better understanding of the appropriate breeding objective for breeding robust sheep with a long productive life.

Defining practical protocols for assessing robustness also requires the definition of the environmental challenges needed for it to be expressed by animal. It may be that farm management will be needed to simulate challenges when the natural environment does not supply them, in order to discriminate for robustness. It is recommended that the following information be collected in research flocks and in those of dual purpose (ewe breed) ram breeders collaborating in the development of systems for genetic improvement of robustness.

- Litter size and lamb survival based on pregnancy scanning, size at birth and at weaning, with use of birth fate codes and dam fate codes to help assess why lambs perform poorly or are lost. Preferably this would be accompanied by parentage verification using DNA,
- Ewe BW and BCS at 2 or more set times per year including at mating and at weaning (some ram breeders in New Zealand already do this),
- Record health status data for individual ewes and lambs, as well as general disease outbreaks,
- Assess and record physical breakdown that may result in ewes being culled including, but not restricted to, reproductive organs, udder, feet and teeth.
- Critical meteorological information to characterise variation in critical climate parameters,
- Nutritional information such as feeding level of the ewes and lambs, pasture growth rates and quality at key times of the year.

Such complex datasets will present major challenges to statistical analysis and interpretation. Phenotypic performance of animals at certain points in a year, for multiple years, must be combined with environmental data from throughout the year and previous years. Teasing out short-term effects from long-terms effects is important, if we are to get a sharp focus on robustness over time, and the underlying relationships between traits may not be easy to see. It is not surprising that robustness has received little attention in animal genetics to date.

Simple traits like stayability could be added to genetic evaluations fairly easily, but it is not clear how well this describes robustness. The way in which a number of traits interact to characterise "robustness" requires focused research. New Zealand researchers and collaborating sheep breeders are about to begin a programme aiming to develop estimates of genetic merit for robustness by assessing key component traits and quantifying their interactions.

Summary

Robustness, or resilience, is a complex interaction of environmental and animal factors. Cyclical variation of feed quality and quantity is a standard feature with random effects of climate and disease adding risk. Separating out the effects of ewe productivity on changes in bodyweight and body condition score is essential to discriminate genetic variation in how ewes mobilise body tissue and how they partition nutrients between maintenance and productive processes.

Our challenges lie in three areas;

1. Defining robustness as it relates to wastage, productivity and health of ewes, together with the key environmental stressors they face,
2. Defining testing environments and recording protocols for the assessment of robustness,
3. Defining the extent to which robustness is needed in typical New Zealand farming environments for productive animals.

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