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Quantify On-Farm impacts

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USAGE	This information is primarily for use in modelling on-farm impacts on a whole-farm scale.
PRECIS	This is a review of the recent Australian, agricultural research literature that is relevant to the MLA Key Management Practices.
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OVERVIEW

This is a review of the scientific and technical literature from the previous 6 years with a particular focus on the quantification of benefits associated with MLAs Key Management Practices. The available quantification is summarised within each section and will not be repeated in this overview. It is clear that much of the relevant quantification has occurred prior to 2003, some 20-25 years ago. Some of this is summarised in other reports (Black and Scott 2002; Saul and Chapman 2002) and these should be considered concurrently with this report.

In viewing the Key Management Practices it is apparent that the top performing producers are also those that implement many of the practices reviewed in this document (Sampson 1999). Whether adoption of these practices by others will convert them to top performing producers is not so certain.

Whether by design or circumstance, many of the Key Management Practices, do not, in isolation provide any benefits (for example measuring pasture digestibility is only of benefit if management actions are taken to use this information to either improve pasture or improve utilisation). Where this is the case, potential benefits from use of the collected information have been addressed in this review. The question remains however, are these recommendations useful if they are not accompanied by application advice?

Even more importantly, the current Key Management Practices are, in some cases, incompatible with each other, and may not conducive to the maximisation of whole farm profit in an extensive agricultural system. Application of some combinations of management practices may even cause antagonistic outcomes (see below). Consideration of the practices within a whole farming context is critical both for the quantification of benefits and for the application of these management practices into commercial systems.

KEY MANAGEMENT PRACTICES FOR PASTURE GROWTH, UTILISATION AND NUTRITIVE VALUE

Individual assessment of the Key Management Practices associated with pasture production indicate that there is significant potential to increase utilisation, metabolisable energy content and dry matter production at some times of the year.

There are however, some important considerations in the application of Key Management Practices to improve pasture growth, nutritive value and utilisation. In particular:

- Many of the Key Management Practices relate to the manipulation of grazing activity and pasture management over the short term and are either based on research for application in the dairy industry or on fundamental research that has been carried out in isolation from whole farm, long term, production systems. For the dairy industry, the amount of pasture grown today is tomorrow's product. It is harvested and sold within that day; the payoff is immediate and tangible. The ability to convert pasture into product is not so simple in the sheep and beef cattle industries. For example, many of the practice changes described are only applicable to spring pasture growth. At this time pasture availability is often in excess and the value of more and higher quality feed is at its lowest.

Sensitivity analysis is required across a range of grazing systems, flock structures and management schedules (eg time of lambing) to establish the full year benefits and practicalities of improving pasture growth, utilisation and digestibility at specific times in the production cycle.

- It is also clear that the strategies described will have outcomes that are highly specific to the location. Without clear definition of the practice, as it applies to a specific location and system, the benefits may be small or even negative.
- If some of these management practices are to be applied and succeed, responsible livestock managers/advisors will require an ability to apply techniques to define the immediate pasture characteristics locally. They will then also require the ability to interpret the results for tactical and strategic decision making to optimise long term profit

KEY MANAGEMENT PRACTICES FOR LIVESTOCK CONDITION, GROWTH, HEALTH AND GENETIC IMPROVEMENT

Implementing the Key Management Practices for condition, growth, genetics and health will significantly improve reproduction, age at sale and mortality when considered on an individual animal basis.

These Key Management Practices have a less complicated interpretation to those for pasture management and improvement. In particular:

- The responses in growth, mortality, reproduction and survival described in this review are likely to occur across locations and environments and, in most cases, across different breeds of livestock.
- Understanding and quantifying the benefits provides a strong basis for evaluation of the management practices and the of the different ways they may be achieved. For example, attaining beneficial growth rates or condition scores may be possible through change in management (eg time of lambing/calving) rather than expenditure on supplementary feed or a reduction in stocking rate.
- There are still likely to be costs in applying management practices or at least trade-offs. For example, maintaining ewes at condition score 3 at mating may increase ewes lambing but more lambs per ha may still produced if stocking rate is increased and ewes are mated at condition score 2 (Young 2007a; b). Similarly the most effective grazing strategies for pasture management may not be consistent with the attainment of the recommended livestock management practices. Projects such as Lifetimewool have provided valuable information that allows quantification of the likely trade-offs in the sheep industry.
- As with pasture management assessment of whole farm profit using models that integrate across the whole flock or heard and allow for the interaction of livestock and crops (where applicable) are essential to determine the industry (farming industry, not just the livestock) benefits.

The integration of Key Management Practices into a systems approach is required. The current practices includes groups of recommendations that may be mutually exclusive and in some cases cannot be applied simultaneously. A systems approach is required for these practices and recommendations to have commercial applicability and credibility.

1.0 BACKGROUND

The Meat & Livestock Australia (MLA) evaluation framework has the objectives of:

- Identifying and quantifying productivity or efficiency improvements resulting from a range of MLA specified management practices;
- Determining the industry-level economic value of each of the specified management practices by modelling based on known adoption rates of those practices

In terms of the 'Impacts' level of this framework, MLA's Livestock Production R&D strategic plan (2006-2011) has identified the following nine "top-down" aspirational targets for the livestock industries:-

By 2011:-

1. Increase reproduction rate by 5%
2. Decrease mortality rate by 20%
3. Reduced the age at sale by 10%
4. Reduce the cost of production by 5%
5. Increase meat eating quality by 5 consumer points
6. Increase awareness of environmental risks and relevant management practices by 20% of targeted producers
7. Increasing skills, knowledge and confidence of producers by 10%
8. Increase awareness of key animal welfare practices by 10% of targeted producers
9. Improved biosecurity systems exotic/notifiable diseases for 5 exotic/notifiable diseases

The first four of these specifically relate to on-farm productivity/profitability impacts, which are the focus of this project.

While various measures of outcomes (ie adoption of practices) are being tracked by MLA surveys, there is currently no direct measure of on-farm economic impacts as a result of adoption of these practices ie quantification of impacts based on a "bottom-up" approach.

2.0 SCOPE OF STUDY

The scope of this study is to quantify the extent to which management practices identified in Table 1 contribute to the following livestock industry targets:

1. Increase reproduction rate by 5%
2. Decrease mortality rate by 20%
3. Reduced the age at sale by 10%
4. Reduce the cost of production by 5%

3.0 METHODOLOGY

Journal, conference publications, some relevant and available research reports and state department publications from 2003 to 2008 have been reviewed. The priority publications for this review have included:

- Australian Journal of Experimental Agriculture
- Australian Journal of Agricultural Research
- The Rangeland Journal
- International Journal of Sheep and Wool Science
- Proceedings of the Australian Society of Animal Production
- State department farmnotes

Potential responses to management practices have been quantified where the practice leads to a direct productivity impact

Linkages between management practices that have no direct impact on productivity with associated management changes that do impact of productivity have been identified (where these exist)

Outcomes have been synthesised to provide estimates of most likely impacts where there are inconsistencies in the literature.

Table 1. Key Management Practices related to productivity-focussed aspirational targets

	Sheep/Lamb producers	Southern Beef producers	Northern Beef producers
1. Monitor available feed quantity and quality relative to animal requirements:-			
a) calculate a forage or pasture budget at least i) monthly ii) annually	√	√	√
b) use a formal measurement technique to assess pasture available to ewes at lambing	√		
c) routinely assess the digestibility of feed available	√	√	
2. Have a set pasture utilisation target when adjusting stocking rates	√	√	
3. Calculate cost of Production in $/kg	√	√	
4. Weigh livestock to monitor weight gain	√	√	
5. Use EBV's or Index values in sire selection or purchase	√	√	√
6. Assess livestock using fat or condition scoring	√	√	
7. Manage the feed available to ewes to ensure they are at a minimum condition score 3 at joining	√		
8. Monitor worm egg counts to provide a basis of when to drench	√		
9. Have conducted a drench resistance test in the last 5 years	√		
10. Manage first calf heifers separate to the rest of the herd			√
11. Pregnancy test cows annually			√
12. Wean calves based on cow condition			√
13. Have cost effective supplementation strategies to address nutritional deficiencies			√
14. Vaccinate for:- a) tick fever b) botulism c) three-day sickness			√

4.0 Preface

In the original project plan, it was proposed to provide the results of this of this review in a tabular form. It became apparent during the tabulation of results that a matrix table would have been unmanageably large and also would not have adequately covered the many farming systems and livestock scenarios that are relevant to this project.

For this reason the results are been presented under Key Management Practice headings for each of the 3 industry scenarios.

5.0 Sheep and lamb producers

5.1 Monitor available feed quantity and quality relative to animal requirements

5.1.1 Calculate a forage or pasture budget

This Key Management Practice includes calculation of a feed budget either:

- Monthly
- Annually

5.1.1.1 Potential practical outcomes

- Increase reproduction rate
- Decrease mortality
- Reduce cost of production

5.1.1.2 Recent literature

Calculation of a forage or pasture budget alone will not provide any direct improvements in on-farm productivity or profitability. However use of budget information is the basis for both long term (annual) and short term (monthly/seasonal) livestock management.

Overall aims include:

- optimise pasture growth rate;
- use feed efficiently and profitably;
- ensure quantity and quality are suited to satisfying the stock objectives;
- ensure persistence of desirable plant species;
- ensure that ground cover is adequate to prevent erosion and resist weed invasion; and maintain stable pastures (Smart 2004).

Fodder budgeting allows the matching of pasture supply and animal production, thereby calculating the number and class of livestock that can be carried on the farm over a full year or, on a smaller scale, the number of grazing days in a particular paddock.

The MLA Feed Demand Calculator is a useful practical tool for estimating both feed required and feed deficits over an annual cycle. For example, the value of lambs produced on 1000ha during an average year in Hamilton (Victoria) with a stocking rate of 20 ewe/ha is approximately $1.68M. This would require some supplementary feed at a cost of around $80,000. Stocking at 18 ewe/ha would produce lambs values at $1.52M with no supplementary feed costs. While this provides one example of the size of potential benefits, they will be very much location specific.

The shorter feed budgets will allow management to achieve either livestock weight and condition score targets (see sections 4.4 and 4.7 for benefits), or pasture growth and digestibility targets (see sections 4.1.2, 4.1.3 and 4.2 for benefits). There are tools available for short term feed budgeting based on PROGRAZE (McPhee *et al.* 2000). The use of such programs provides quantified estimates of feed required to meet specific production goals and also expected livestock production based on available feed. Different options can be assessed. A formal feed budget therefore provides increased confidence for tactical decision making on both flock and herd management.

5.1.2 Use a formal measurement technique to assess pasture available to ewes at lambing

5.1.2.1 Potential practical outcome

- Decrease mortality
- Increase reproduction rate
- Reduce age at sale

5.1.2.2 Recent literature

Increasing Food on Offer (FOO) from 700 to 3000 kg/ha in late pregnancy and early lactation has increased weaning weights by 6-14 kg (Paganoni *et al.* 2004). The low FOO was associated with weaning weights of approximately 14-16 kg and the high FOO weights group weight of 22-28 kg. Higher weaning weights resulted in lower post weaning mortality. The low growth to weaning in lambs from underfed ewes is more pronounced in maiden ewes. Weight gain in these lambs has been reported to be 34 g/d slower than in lambs born to mature ewes (Hegarty *et al.* 2006b). Extrapolating from other studies, weaner weights of around 15 kg may result in mortality of 10-60% between weaning and the break of season. Weaner weights of 22-28 kg are likely to result in mortality of <10% over the same period (Hocking Edwards *et al.* 2008). The low weaning weight sheep would need to be fed through summer to gain 15-20 g/d to increase survival (Campbell *et al.* 2006).

There are also consequences for the weaners that are retained in the flock to be mated as maidens. The weaners from ewes fed low FOO in the Paganoni *et al* study were still 3-4 kg lighter than those from well fed ewes at 12 months of age. Based on studies by Hocking Edwards and Starbuck (2006), these ewes are likely to produce up to 20% less lambs during maiden pregnancy.

For the weaners not retained, a 3-4 kg difference in liveweight at 12 months of age represents 12-20 day increase in age at sale (assuming growth rates of 250 g/day)

There are consequences for the ewes as well as the lambs. Low FOO around lambing and up to weaning may result in lower ewe liveweight and condition score at the following mating (2.5-10 kg), even with equal access to feed after weaning (Ferguson *et al.* 2004b). Similar results have been reported by others, with poor nutrition around lambing and during lactation resulting in ewe liveweight loss to weaning of 12.5 kg compared with a loss of 2.5 kg in well fed ewes (Hegarty *et al.* 2006b). Kelly and Croker (1990), reported that a difference in ewes weight of 10 kg at mating was associated with 20-30% less ewes lambing

5.1.3 Routinely assess the digestibility of feed available

5.1.3.1 Potential practical outcome

- Reduce age at sale
- Increase reproduction rate
- Reduce costs of production

5.1.3.2 Recent literature

There are at least 2 potential benefits of routinely assessing pasture digestibility, these are:

- Increasing grazing pressure to prevent the onset of pasture senescence in the older leaves will increase digestibility (and therefore metabolisable energy [ME]). For this reason, assessment of digestibility provides an indication of how appropriate grazing pressure currently is and provides the basis for change (Black and Scott 2002). The extent to which digestibility can be improved is both species and time dependant. Perennial ryegrass ME has been shown to decrease from 11 MJ/kg in new leaves to 9 MJ/kg as leaves age (Fulkerson and Donaghy 2001), while these numbers are from only one pasture plant species, they do provide an example of the magnitude of improvement in digestibility that may be achievable.
- Knowledge of digestibility (together with available dry matter) allows prediction of growth rates and provides a basis for tactical decisions relating to production targets. There are many studies that have quantified the decrease in digestibility that occurs as plants mature but the decline will be highly location and species specific.

A 1-2 MJ difference in digestibility will cause a significant change in production. For example, a 40 kg weaner wether grazing a pasture with average ME of 11.2 MJ/kg will consume 1.8 kg DM and grow at approximately 230 g/day. If average ME is 10.2 MJ/kg predicted intake is 1.6 kg /day and weight gain 145 g/day.

An important consideration with this strategy is that the methodology to measure digestibility is time consuming, will incur an additional cost and results are subject to time delays. An alternative is to measure livestock weight change and behaviour on a regular basis and use the animals themselves to provide an integrated indication of pasture quantity and quality (both amount and nutritive value). Remote monitoring of livestock is now a reality and may be appropriate for high output production systems.

5.2 Have a set pasture utilisation target when adjusting stocking rates

5.2.1 Potential practical outcome

- Reduce costs of production

5.2.2 Recent literature

Most modelling and benchmarking studies indicate stocking rate is highly correlated with lambs produced and weaned, and that these, in turn, are correlated with gross margin (Warn *et al.* 2006).

Benefits of higher stocking rates are:

- Increased pasture utilisation*.* Pasture utilisation is usually 25-35% but, grazing ewes through pregnancy in both Western Australia and Victoria with target FOO of 1400 – 2000 kg/ha gave much higher pasture utilisation (75-80%). This caused some reductions in overall pasture DM production (Hyder *et al.* 2004) (see Table 2). In Victoria, maximum dry matter grown and utilised resulted with a FOO of 1410 kg/ha and in Western Australia, maximum dry matter grown and utilised resulted with a FOO of 850 kg/ha.

Table 2. Relationship between food on offer, pasture utilisation and dry matter production in Victoria and Western Australia (Hyder *et al.* 2004)

Victoria			Western Australia		
FOO (kg/ha)	Utilisation (%)	Dry matter produced (kg/ha)	FOO (kg/ha)	Utilisation (%)	Dry matter produced (kg/ha)
940	88	8480	850	86	6830
1410	87	10870	1260	77	6330
3460	63	11150	2220	62	8910

- Increased plant growth rates*.* Many studies show plant growth is increased by strategic defoliation (see review by Black and Scott (2002)). Leaves need to be removed before they become dormant and senesce. The extent and timing of these effects are important. With annual pastures high stocking rates resulted in increased pasture growth rates in late spring only and did not affect total pasture produced over the full grazing period (August – November) (Thompson *et al.* 1994).

  Conversely, overgrazing and excessive defoliation will cause a decrease in dry matter production. Experiments with perennial ryegrass have indicated excessive defoliation can depress dry matter production by 25% (Fulkerson *et al.* 1993), this is similar to the 24% reduction reported by Hyder *et al* (2004) with perennial based pastures in Victoria (Table 2). However in matching experiments in Western Australia based on annual based pastures, the high grazing intensity did not depress overall dry matter production. Other have shown that, with a mix of perennial grasses and annual legumes in western Victoria, grazing pastures down to 1000 kg/ha in autumn resulted in a long delay before leaf area and photosynthesis increased to allow high rates of pasture growth (Saul and Chapman 2002). These authors cited recommendations for pre and post grazing masses of 2400 and 1400 kg/ha respectively, they also discuss the merits of using rotational grazing versus set stocking as methods of meeting grazing targets. Heavy grazing pressure (<1000 kg/ha) also reduced the persistence of cocksfoot in Victoria (Avery *et al.* 2000)

Within the SGS Pasture Theme, it was concluded that optimum stocking rates for pasture accumulation were between 10 and 22 DSE/ha. It was suggested that many sown pastures in the high rainfall zone could sustainably carry a higher stocking rate at some times of the year, if producers were prepared to use more supplementary feed at other times (Sanford *et al.* 2003)

Alcock (2006) has recently described both the benefits and risks of pasture utilisation and stocking rate targets, including the difficulty in trying to define optimum stocking rate for any individual parcel of land. Modelling grazing systems in Cowra and Hamilton indicated optimal pasture utilisation rates were 45 and 56% respectively at stocking rates of 7 and 11 ewes/ha. However as profit and pasture utilisation increased from about 5 ewe/ha (with pasture utilisation of 35%), the number of years when supplementary feeding was required and when ground cover breached minimum thresholds increased. The study demonstrated the risks of generic utilisation targets and demonstrated the potential benefits in using models such as GrassGro to define the potential consequences of pasture utilisation targets of both long term profit and sustainability.

5.3 CALCULATE COST OF PRODUCTION IN $/KG

5.3.1 POTENTIAL PRACTICAL OUTCOME

- Reduce costs of production

5.3.2 RECENT LITERATURE

The breakdown of the components of "cost of production" provide the basis for analysis of production technical efficiency. Technical efficiency is defined as how well producers use inputs (eg fertiliser, pasture utilisation, labour) to generate product (Geenty 2006). This information can then be used within benchmarking programs to assess the efficiency of individual farmers and identify targets for improvement. A study in the wool industry has indicated that producers with the highest technical efficiency (defined as 100%) show an increase in best practice production index of 5% annually while the average producer shows a decline of 1.5%. Such comparisons provide an indication of potential benefits of calculating and acting upon differences in costs of production between producers. Annual productivity improvement from benchmarking studies indicates 3% of producers will improve their production by 5% annually (Geenty 2007).

Others have presented a more sceptical view of benchmarking, suggesting that there can be large year to year variation in efficiency, nevertheless, even in these studies there was an indication that production on the least efficient farms could be doubled without changes to the level of inputs (Fraser and Hone 2001).

What these studies do clearly indicate is that a costs of production approach would need to be applied over a number of years, taking into account long term pasture, infrastructure and environmental outcomes as well as key performance indicators.

In addition, while this Key Management Practice may be an effective method of improving efficiency within an enterprise, the full benefits can only be quantified within a whole farm context where meat, wool and grain may all contribute to profit and where changes in efficiency in one enterprise may lead to changes in whole farm enterprise allocation and management (Sackett and Francis 2006).

5.4 WEIGH LIVESTOCK TO MONITOR WEIGHT GAIN

5.4.1 POTENTIAL PRACTICAL OUTCOME

- Increase reproduction rate
- Reduce age at sale
- Decrease mortality

5.4.2 RECENT LITERATURE

During pregnancy

In commercial farm comparisons (Behrendt *et al.* 2006), increasing ewe average condition from 2.4 to 2.7 during pregnancy (2.8 kg difference in liveweight) resulted in 8% higher survival of lambs to marking (70 vs 78%) and 2.1 kg increase in weaning weight (22 vs 24.1 kg).

Feed restriction during pregnancy causes low birthweight lambs but there appears to be some ability to compensate for feed restriction during some parts of pregnancy with increased feed supply at other times (Corner *et al.* 2008)

Survival to hogget shearing

Hocking Edwards *et al.*(2008) reported that weighing weaners to ensure they were 45% of mature liveweight at pasture senescence gave 95% survival from weaning to hogget shearing. They reported 26% mortality if weaning weight less than 25 kg and 5% if weaning weight was more than 25 kg.

Feeding over summer/autumn will decrease mortality by 5-7%.

Campbell et al. (2006) concluded that increasing weaner growth from 8 to 17 g/day during the 5 months after weaning can reduce the risk of mortality by 74%

Early growth and subsequent reproduction

Achievement of 40 kg ewe weight by the start of their first winter, compared with normal growth rates (31 kg at start of first winter) resulted in 11% more ewes pregnant and 10% higher twins at maiden lambing. Potential for 21% more lambs in the rapid fed ewes weaners at first mating. These results occurred despite the ewes being of similar condition score but different liveweights (5kg) at the start of mating (Hocking Edwards and Starbuck 2006).

5.5 USE EBV'S OR INDEX VALUES IN SIRE SELECTION OR PURCHASE

5.5.1 POTENTIAL PRACTICAL OUTCOMES

- Reduce age at sale
- Reduce costs of production
- Decreased mortality

5.5.2 RECENT LITERATURE

Good information is provided by Hegarty et al. (2006a). With a target weight at sale of 54 kg, using EBV for post weaning growth (PWWT) would reduce age at sale by 60 days at high nutrition and 111 days at low nutrition (Table 3).

Table 3. Growth and liveweight of cross bred lambs from sires selected to have high genetic potential for growth (G) or from typical Australian industry sires(C). (Hegarty *et al.* 2006a).

	Low nutrition		***High nutrition***	
	G	C	G	C
Pre-weaning liveweight gain (g/day)	198	191	312	276
Weaning liveweight (kg)	23.4	22.6	34.3	30.5
Post-weaning liveweight gain (g/day)	92.4	75.1	132.1	114.8
Final liveweight (kg)	36.6	33.9	54.1	47.2

There is no indication from these studies if this increased growth rate is due to increased feed intake or to improved feed conversion efficiency. Therefore costs of production associated with time to reach sale weight would be reduced but changes in feed costs are unknown. There is evidence that selection for improved feed efficiency is possible (heritability ~ 0.4) (Fogarty *et al.* 2006)

Wiese (2006) working with sucker lambs reported that high growth EBV sires resulted in 6.8-13.6 g/day faster growth to weaning/slaughter. This reduced age at sale and resulted in 52-66% less carryover store lambs from high growth EBV sires. There was a 3.5-7.6% increase in income from high growth EBV sires.

Both Hegarty et al (2006a) and Hopkins et al (2007) reported that using sires with high EBVs for post weaning growth or yearling weight only improved growth and weight post weaning and had little effect on birth or weaning weight. In the latter paper a range of genotypes was included in the study

Although faster growth rates to and after weaning would be expected to lower mortality, Hocking Edwards *et al* (2008) reported no improvement in survival to hogget shearing in weaners from sires with a higher EBV for weaning weight.

Hopkins *et al* (2005) reported the meat and eating of the carcasses from the Hegarty experiment described above. There was little measureable change in objective meat quality of eating quality traits associated with PWWT.

The benefits of using sires with high EBV for eye muscle depth are less convincing, lambs from these sires were more susceptible to stunting under low nutrition and there were negative effects on the eating quality of meat (Hegarty *et al.* 2006b). Selection for lean carcase growth will provide advantages in lean growth, regardless of nutritional environment (Lewis *et al.* 2006).

5.6 ASSESS LIVESTOCK USING FAT OR CONDITION SCORING

5.6.1 POTENTIAL PRACTICAL OUTCOMES

- Reduce age at sale
- Decrease mortality

5.6.2 Recent literature

Monitoring fat or condition will ensure livestock meet target condition prior to sale and avoid penalties for missing these targets. These penalties can be high. The penalties then need to be added to the inefficiency in conversion of feed fat rather than to protein.

The more fundamental benefits relate to the changes in efficiency of feed conversion to liveweight as fatness increases. As liveweight approaches mature body size, the proportion of fat to protein deposition increases. The consequences are that the energy content of each unit of liveweight gain (and therefore the net energy required to produce that gain increases substantially (from 10 to over 20 MJ/kg gain) (Standing Committee on Agriculture and Resource Management 1990). From a practical perspective, at liveweights of approximately 26 kg, the rate of body protein gain diminishes, while fat gain remains constant (Graham *et al.* 1991). At higher fat scores, less protein is laid down per unit of feed intake.

Other benefits of measuring and managing to condition or weight targets are explained elsewhere in this review (eg see section 4.7)

5.7 Manage the feed available to ewes to ensure they are at a minimum condition score 3 at joining

5.7.1 Potential practical outcomes

- Increase reproduction rate
- Reduce age at sale
- Decrease mortality

5.7.2 Recent literature

For maiden ewes, increasing condition score from 2-3 at mating increases fetuses/100 ewes by between 10 and 25%, depending on background of ewes (see above) (Hocking Edwards and Starbuck 2006).

In another publication, (Ferguson *et al.* 2004a), ewes mated at score 2 gave birth to lambs that were 0.4 kg lighter than lambs from ewes mated at condition score 3 (based on no change in ewe condition score during pregnancy). Birthweight increased by approximately 0.2 kg for every 1 unit improvement in condition score during pregnancy. There was an interaction between initial condition score and condition score change during pregnancy. These results were in south west Victoria and were not consistent between years

A reduction of condition score at mating of 1 (3.5 to 2.5) reduced fetuses/100 ewes joined by 35 (Oldham and Thompson 2004). Similar reduction of 20-30% in ewes lambing per ewe joined reported previously with a 10 kg reduction in ewes weight prior to joining (Kelly and Croker 1990)

Summaries of results from the Lifetimewool project (Young 2007a; b), indicate that increasing condition score at joining from 2.6 to 3.0, results in the following:

- Pregnancy rate increased by 6.8-7.9%
- Decreased ewe mortality of 1.5 – 1.6%
- Increase in lamb survival of 3.1 – 3.3% (singles) and 5.3 - 7.2% (twins).

- Above results may vary significantly depending on location and change in condition score during pregnancy.

While there are clear benefits in reproduction rate per sheep in mating ewes at condition score 3, higher returns per ha have been demonstrated from lower condition scores and higher stocking rates (Waller *et al.* 2001; Young 2007a; b),

5.8 MONITOR WORM EGG COUNTS TO PROVIDE A BASIS OF WHEN TO DRENCH

5.8.1 POTENTIAL PRACTICAL OUTCOMES

- Decrease mortality
- Reduce cost of production

5.8.2 RECENT LITERATURE

A worm egg count is the best practical guide currently available to decide on the need for treatment. Worm egg counts indicate whether worm burdens are likely to be affecting production and will highlight potential worm problems, often before any signs such as scouring, anaemia or obvious weight loss become visible. The recommended management practice ensures sheep that need a drench receive one and also avoids unnecessary drenching.

Regular worm egg counts, coupled with drench resistance testing allows good planning and effective treatment if needed (Australian Wool Innovations and Australian Sheep Industry CRC 2008).

Strategies to leave some sheep in the flock undrenched and therefore reduce the intensity of selection for drench resistance (Besier 2004) have been advocated as part of a new strategic approach to parasite control. Monitoring egg counts does potentially allow the recognition of some sheep that carry high worm burdens but are tolerant of these worms. This is unlikely to be a practical strategy however because egg counts would normally only be monitored in a small sub-sample of the flock. A better option may be to weigh sheep (see section 4.4) and not drench a small subsample of heavier sheep, thus using liveweight as a indicator of parasite tolerance.

5.9 HAVE CONDUCTED A DRENCH RESISTANCE TEST IN THE LAST 5 YEARS

5.9.1 POTENTIAL PRACTICAL OUTCOMES

- Reduce age at sale
- Decrease mortality
- Reduce cost of production

5.9.2 RECENT LITERATURE

Drench resistance to the old white and clear drenches now exists on almost every major sheep farm and resistance to the newer ML types exists of on 50-75% of sheep farms. There is increasing resistance even to the most potent ML and to the "triple combination" (B Besier pers comm.).

A study to determine the consequences of using drenches with low effectiveness indicated that in comparing a drench with 65% effectiveness to another with 100% effectiveness, the group given the less effective drench:

- Had a 5% higher mortality rate over 1 year
- Were 5kg lighter after 1 year. The difference in liveweight is likely to mean either more lambs are carried over as stores or that they will require an additional 20 days to reach a target slaughter weight (Besier *et al.* 1996).

It is unlikely that carrying out a test every 5 years is sufficient and parasitologists now recommend tests every 2 years, or at least worm egg counts before and after drenching.

6.0 Southern Beef Producers

6.1 Monitor available feed quantity and quality relative to animal requirements

6.1.1 Calculate a forage or pasture budget

This Key Management Practice includes calculation of a feed budget either:

- Monthly
- Annually

6.1.1.1 Potential practical outcomes

- Increase reproduction rate
- Decrease mortality
- Reduce cost of production

6.1.1.2 Recent literature

Calculation of a forage or pasture budget alone will not provide any direct improvements in on-farm productivity of profitability. However use of budget information is the basis for both long term (annual) and short term (monthly/seasonal) livestock management.

Overall aims include:

- optimise pasture growth rate;
- use feed efficiently and profitably;
- ensure quantity and quality are suited to satisfying the stock objectives;
- ensure persistence of desirable plant species;
- ensure that ground cover is adequate to prevent erosion and resist weed invasion; and maintain stable pastures (Smart 2004).

Fodder budgeting allows the matching of pasture supply and animal production, thereby calculating the number of number and class of livestock that can be carried on the farm over a full year or, on a smaller scale, the number of grazing days in a particular paddock.

Fodder budgeting also provides the basis for:

- Assessing option to change the feed supply profile. For example, over 3 years of monitoring on the south-east coast of WA, a combined system of annual and kikuyu pasture was calculated to have an annual gross margin 19% higher than the annual pasture alone. The major source of this difference was the elimination of the need for supplementary feed in the kikuyu–annual pasture system. This benefits were limited however, by lighter post-weaning sale weights of cull cows from the kikuyu pasture in 'poor legume' years. There was no difference of calf weaning weights between treatments. There is considerable opportunities of improving on this gross margin, through achieving a consistently higher presence of legumes in the kikuyu pasture through winter and spring (McDowall *et al.*

2003). Pasture utilisation is improved through a better match of supply and demand.

- Assessing options to change the feed requirement profile. For example, the Beef CRC evaluated time of calving in south-western WA in a series of papers in 2004. Autumn calving cows have higher energy requirements in late pregnancy and early lactation than can be supplied from the dry pasture and therefore require substantial supplementary feeding (Smart *et al.* 2004). A switch to winter calving was estimated to save approximately 50 MJ/head.day in the cow-calf unit when energy supply from pasture was low (autumn). This reduced the quantity of supplementary feed needed and increased the annual utilisation of pasture. The reduced feed demands with winter calving allowed an increase in stocking rate and calf turnoff. Also see Della Bosca *et al*. (2004); Read *et al.* (2004); Smart *et al.* (2004).

The MLA Feed Demand Calculator is a useful practical tool for estimating both feed required and feed deficits over an annual cycle. Potential benefits for cattle are similar to those described for sheep (see Section 5.1.1).

The shorter feed budgets will allow management to achieve either livestock weight and condition score targets (see sections 5.4 and 5.7 for benefits), or pasture growth and digestibility targets (see sections 5.1.2 and 5.2 for benefits)

6.1.2 Routinely assess the digestibility of feed available

6.1.2.1 Potential practical outcome

- Reduce age at sale
- Increase reproduction rate
- Reduce costs of production

6.1.2.2 Recent literature

The potential benefits of routinely assessing digestibility have been described previously (see Section 5.1.3). Much of the information presented in that section was derived from the cattle industry (particularly the dairy industry) and will not be repeated. In summary, digestibility can be increased by increasing grazing pressure to prevent pasture senescence. The magnitude of the improvement is likely to be 1-2 MJ ME/kg DM during late winter and spring.

Also as mentioned previously, the traditional methodology to measure digestibility is time consuming, will incur an additional cost and results are subject to time delays. Faecal NIRS is a technique that has been developed in the northern beef industry but may have wider implications. It can be used to monitor dietary crude protein and dry matter digestibility in pastures grazed by cattle, and to provide a useful decision support information for the nutritional management of livestock (Coates and Dixon 2008). While the technique is innovative some further development is required. Cumulative steer liveweight (LW) predicted from faecal NIRS (previously calibrated with tropical grass and grass–herbaceous legume pastures), greatly overestimated the measured steer LW on *Leucaena* pastures (Dixon and Coates 2008). Cumulative steer LW predicted from a modified faecal NIRS was strongly correlated (R^2 = 0.95) with steer LW but still overestimated LW by 19–31 kg after 8 months. Faecal NIRS can improve the understanding of diet quality and nutrient intake of cattle grazing *Leucaena*–grass pasture, and relationships between nutrient supply and cattle growth.

An alternative is to measure livestock weight change and behaviour of a sub-sample of the herd, on a regular basis and use the animals themselves to provide an integrated indication of pasture quantity and quality (both amount and nutritive value). Remote monitoring of livestock is now a reality and may be appropriate for high output production systems and possible for rangeland grazing.

6.2 HAVE A SET PASTURE UTILISATION TARGET WHEN ADJUSTING STOCKING RATE

6.2.1 POTENTIAL PRACTICAL OUTCOME

- Decrease mortality
- Increase reproduction rate
- Reduce age at sale

6.2.2 RECENT LITERATURE

As is the sheep industry, most modelling and benchmarking studies indicate stocking rate is highly correlated with calves produced and weaned, and that these, in turn, are correlated with gross margin

Benefits of higher stocking rates are:

- Increased pasture utilisation. Implementation of TechnoGrazing™ at the Struan Research Centre demonstrated that changes in pasture utilisation within a beef enterprise can result in increased production (Hebart *et al.* 2004a). TechnoGrazing™ is a NZ developed grazing system estimated to increase stocking rate from 16 to 40 dse and costing $350 per ha in fencing. Despite a poor spring pasture growth in 2003 (maximum daily recorded level was 45 kg DM/ha) liveweight gains greater than 800 kg/ha was reached in 1 system with bulls, with average daily rate gain ranging from 0.82-1.03 kg in the 4 systems. By comparison, for much of the beef producing areas of south-eastern South Australia, average liveweight gain over spring was only 100-350 kg/ha. This resulted in a gross margin increase of $700/ha using one labour unit per 2000 bulls
- Increased plant growth rates. Many studies show plant growth is increased by strategic defoliation (see review by Black and Scott (2002)). Leaves need to be removed before they become dormant and senesce. The extent and timing of these effects are important. For ryegrass the suggested residual sward height to optimise regrowth is 5 cm (Fulkerson and Donaghy 2001). Lower limits are less important for legumes as most of the carbohydrates required to stimulate regrowth are in the roots. With annual pastures high stocking rates resulted in increased pasture growth rates in late spring only and did not affect total pasture produced over the full grazing period (August – November) (Thompson *et al.* 1994).

  Conversely, overgrazing and excessive defoliation will cause a decrease in dry matter production. Experiments with perennial ryegrass have indicated excessive defoliation can depress dry matter production by 25% (Fulkerson *et al.* 1993). Other have shown that, with a mix of perennial grasses and annual legumes in western Victoria, grazing pastures down to 1000 kg/ha in autumn resulted in a long delay before leaf area and photosynthesis increased to allow high rates of pasture growth (Saul and Chapman 2002).

These authors cited recommendations for pre and post grazing masses of 2400 and 1400 kg/ha respectively.

Overgrazing in wet conditions may also cause trampling or pugging damage. This has also been summarised by Black and Scott (2002). Trampling has been shown to reduce pasture growth by 3-33% and will also reduce yield the following year. The extent of the damage will be highly location specific and dependant on soil type, rainfall and topography.

Stocking rate and pasture utilisation will also influence pasture composition and ground cover. The importance of these parameters varies. In high input, high rainfall production systems, they are much less of a consideration than in native pasture based systems typical of many parts of NSW.

The benefits and risks of pasture utilisation targets as described in a previous section (5.2), by Alcock (2006), are as applicable to beef industry as the sheep industry. The study demonstrated the risks of generic utilisation targets and demonstrated the potential benefits in using models such as GrassGro to define the potential consequences of location specific pasture utilisation targets on both long term profit and sustainability.

6.3 Calculate cost of Production in $/kg

6.3.1 Potential practical outcome

- Reduce costs of production

6.3.2 Recent literature

The breakdown of the components of "cost of production" provide the basis for the comparison of production systems and methods within the beef industry.

In WA, a switch from autumn to winter calving in south-west WA increased the operating profit of the enterprise by approximately 5% if stocking rate was maintained. Profit increased by approximately 45% when the stocking rate was increased by 10%. This improvement in financial performance was primarily due to a reduction in the cost of production in the winter calving enterprises by around 5% (7 c/kg sold) at an equivalent stocking rate and 12% (15 c/kg sold) with the increased stocking rate (Della Bosca *et al.* 2004).

A set of economic simulations were also used to estimate the impact of improvements in cattle breeding efficiency and other management factors on gross margins in extensive pastoral systems in Western Australia (Tozer 2007). Gross margin was a function of increasing breeding rates, but age at first breeding and age at sale of offspring had variable effects on gross margin. This statistical model illustrated that a 1% increase in branding rates increased gross income by $5274 or $2 per adult equivalent was possible. The optimal ages at first breeding and sale of offspring were 20.6 months and 10.8 months respectively.

An economic analysis of early weaning at 3 months in NE Victoria has shown an unexpected and dramatic increase in the gross margin from beef production corresponded to an increase in the number of cows in the herd from 574 to 851 (48%) (Tatham *et al.* 2004). Sensitivity analysis suggested further benefit could be obtained by calving in October instead of August.

Griffith *et al.* (2004) developed an equilibrium displacement model of the Australian beef industry and showed that price response was much more inelastic than shown in previous work, reflecting increased industrialisation in recent years and a significant level of foreign investment. The price of fed cattle plays the largest role in influencing decisions to place cattle on feed and a major input affecting utilisation of feedlot capacity, however the price of feeder steers plays a lesser role in feedlot decision making than previously thought. These differences in elasticity should be considered in future economic studies of the Australian beef industry.

6.4 Weighing livestock to monitor weight gain

6.4.1 Potential practical outcome

- Increase reproduction rate
- Reduce age at sale
- Decrease mortality

6.4.2 Recent literature

Cattle sired by Piedmontese or Wagyu bulls were bred and grown within pasture-based nutritional systems followed by feedlot finishing (Greenwood *et al.* 2006). Effects of low (mean 28.6 kg) and high (38.8 kg) birth weight followed by slow (mean 554 g/day) or rapid (875 g/day) growth to weaning on carcass, yield and beef quality characteristics at about 30 months of age were examined. Low birth weight calves weighed 56 kg less at 30 months of age, had 32 kg lighter carcasses, and yielded 18 kg less retail beef compared with high birth weight calves. Composition of carcasses differed little due to birth weight when adjusted to an equivalent carcass weight (380 kg). Calves grown slowly to weaning were 40 kg lighter at 30 months of age compared with those grown rapidly to weaning. They had 25 kg smaller carcasses which yielded 12 kg less retail beef than their counterparts at 30 months of age, although at an equivalent carcass weight yielded 5 kg more retail beef and had 5 kg less fat trim. Neither low birth weight nor slow growth to weaning had adverse effects on beef quality measurements. No interactions between sire-genotype and birth weight, or growth to weaning, were evident for carcass, yield and beef quality traits. Although restricted growth during fetal life or from birth to weaning resulted in smaller animals that yield less meat at about 30 months of age, adverse effects on composition due to increased fatness, or on indices of beef quality, were not evident at this age or when data were adjusted to an equivalent carcass weight.

For grazing cattle, remote weighing and electronic 'management' is now possible. This has the advantage of being less labour-intensive and less invasive for the animal than conventional methods (Black and Scott 2002). This monitoring is claimed to reduce labour costs to optimize cattle production but there are no publications quantifying the economic value of this procedure. Livestock monitoring together with pasture monitoring can be used to ensure that livestock performance is accurately matched with pasture production. An automated system has been built using 'off the shelf' technology which allowed for cattle to be weighed automatically on pasture (Charmley *et al.* 2006). Data collected over a 70-day grazing period was compared with data collected at 2-week intervals by transferring cattle to a centralised weighing facility. Liveweights recorded using the remote system were some 20 kg higher than those measured conventionally. However the daily rate of change was similar for conventional and remote weighing methods, being 1.25 *v.* 1.20 kg/day, respectively. This relatively simple method could readily be adapted to a range of commercial situations to optimize production.

If low priced options are developed for remote livestock monitoring, they have the potential to replace the need for pasture monitoring. Liveweight and change in liveweight will provide a direct indication of the feed quantity and quality relative to requirements.

6.5 USE EBV'S OR INDEX VALUES IN SIRE SELECTION OR PURCHASE POSITIVE

6.5.1 POTENTIAL PRACTICAL OUTCOMES

- Reduce age at sale
- Reduce costs of production
- Decreased mortality

6.5.2 RECENT LITERATURE

Weatherly (2008) described the outcomes of selecting bulls on the basis of EBV's. Bulls can be selected to improve ease of calving, growth rate, fertility, milk yield, and carcass traits. These are readily available from the cattle industries bull performance database.

The use of EBV's has been supported by ongoing research demonstrating their value under commercial conditions. In 1995 and 1997, growth, feed intake and feed efficiency were measured from spring to summer on Angus and Hereford weaner steer progeny of sires with known estimated breeding values for net feed intake (EBVNFI) (Herd *et al.* 2004a). Each year, the steers were grown on 3 different pasture systems and pasture intakes was measured. Significant regression coefficients for steer performance traits against sire EBVNFI indicated that genetic variation in NFI was associated with phenotypic variation in steer performance on pasture. Initial and final liveweight of the steers, and feed intake, were not associated with variation in sire EBVNFI. However, daily gain by the steers tended toward a favourable negative association with sire EBVNFI (-0.16 kg/day per kg EBVNFI). Net feed intake and feed conversion ratio (FCR) had positive associations with sire EBVNFI (NFI, 2.2 kg/day per kg EBVNFI; FCR, 4.2 kg/kg per kg EBVNFI). The results show that 1 kg/day lower EBVNFI of a sire produced steer progeny that grew 19% faster, with no increase in feed eaten, had a 26% lower NFI, and a 41% better FCR.

The percentage contribution of different mechanisms to variation in residual feed intake, were: 9% for differences in heat increment of feeding; 14% for differences in digestion; 5% for differences in body composition; and 5% for differences in activity. Together, these mechanisms may be responsible for about one-third of the variation in residual feed intake (Herd *et al.* 2004b). Increases in profitability of 10-20% may be achieved if selection is carried out at weaning and 9-33% profit improvement when the optimal numbers of bulls are selected for feed intake (Archer *et al.* 2004). Profit was optimal across all the Hereford cattle breeding objectives when the top 5% of bulls was measured for RFI after being selected on an index incorporating IGF-1 as an alternative to feed intake (Kahi *et al.* 2003). In the absence of more breed-specific information, these results are considered to be applicable in other breeds.

In an attempt to reduce the costs of estimating daily feed intake Hebart *et al.* (2004b) investigated the precision of the data required to make a decision of feed intake. The results indicated that a greater proportion of data can be removed randomly and daily, compared with missing data in weekly blocks. It appears that in young growing animals, estimation of daily feed intake is more sensitive to missing feed intake records than for older cattle. Kearney *et al.* (2004)) also found that the duration of tests could be decreased to 56 days without reducing the precision of estimates of liveweight change. Depending on the precision required, further decreases in testing time could be accommodated.

Use of cattle with a high EBV for growth resulted in a 11.7% increase in growth rate on poor quality feed but there were no significant differences between the two groups in intake, digestibility or rumen ammonia concentrations (Turnbull *et al.* 2008) (Table 4).

Table 4. The liveweight (LW), dry matter (DM) intake, DM digestibility and ammonia concentration in rumen fluid for Low and High post-weaning growth rate steers offered a low-quality Mitchell grass hay (Turnbull *et al.* 2008).

	LW (kg)	DM intake (g DM/kg W.d)	DM digestibility (g/kg)	Ammonia-N (mg/L)
Low	168.5a	17.9	422	16
High	188.2b	17.3	430	18
SEM	4.22	0.60	11.2	2.55

Long-term selection programs in the United States and New Zealand have developed twinning herds and attempts have been made to introduce these cattle to Australia. In Nebraska, the United States Meat Animal Research Centre population had a calving rate of 1.56 per parturition in 2004. These cattle have issues associated with calving difficulty and calf survival, which present challenges for commercial application. Intensive management using existing technology and/or future genetic improvement to address these traits are required to realise the potential benefits to beef production systems (Cummins *et al.* 2008).

Dellar *et al.* (2006) in a study of transported pastoral cattle found that selection of pastoral cattle based on phenotypic characteristics alone was not warranted, and that decisions should be made on the basis of genetic and past management information. If proper management strategies are in place, pastoral cattle performed adequately in the agricultural regions. This presents an opportunity for further integration between northern pastoral regions and southern agricultural regions to enhance overall beef productivity.

Breed differences independent of EBV values are of significant importance in some beef production systems and should not be overlooked when considering the type of animal for a particular enterprise. Sakaguchi and Gaughan (2004) used 574 *Bos taurus* steers (Angus, Hereford and Murray Grey) to determine the effect of high heat load on performance and carcass characteristics when fed a high energy diet for 165-183 days. Regardless of coat colour, body surface temperature of feedlot cattle rose as climatic conditions changed from thermoneutral (Temperature and Humidity Index (THI)<74) to moderate (THI 74-77). Under extremely hot conditions, body surface temperature was higher for Angus compared with Murray Grey (43.4°C and 38.4°C, respectively) steers. Murray Grey steers had greater average daily gain than either Angus or Hereford. There were no differences between breeds for carcass weight, eye-muscle area and marbling score. However, Murray Grey steers had an ideal subcutaneous fat coverage, and in terms of reduced labour costs, Murray Grey steers could be economically more efficient than either Angus or Hereford steers.

Piedmontese and Wagyu-Hereford steers (462 kg liveweight) were slaughtered at Casino with PxH steers having heavier and leaner carcases (253 *v*. 241 kg with 8 *v*. 12 mm P8 fat), greater dressing percent, muscling and commercial meat yield (74.3 *v*. 70%), and less bone and fat waste than WxH steers. The MSA assessment indicated that WxH steers had slightly higher ossification score than PxH steers, but significantly more marbling (403 *v*. 319 for US marbling score, and 1.1 *v*. 0.4 for Australian marbling score) (Hoffman *et al.* 2004). Ultimate pH, meat and fat colour were similar for the 2 genotypes. Heifers averaged 420 kg liveweight following feedlotting, and showed the same trends in carcase and yield traits as the steers.

6.6 Assess livestock using fat or condition scoring

6.6.1 Potential practical outcomes

- Reduce age at sale
- Decrease mortality

6.6.2 Recent literature

Condition scoring should be used as a management aid, particularly in breeding herds. Table 5 shows the influence of condition score at calving and post-calving nutrition (from calving until the end of mating) on cow fertility. Cows on the high level of feeding maintained weight between calving and the end of mating, whilst those cows on the low level of feeding lost up to 120 kg during the same period (Graham 2006).

Table 5. The effects of condition at calving and post calving feed level on cow fertility (average of four years data in 120 Hereford cows at Hamilton, Vic) (Graham 2006).

Condition score at calving	***1.5 – 2.0***		***2.5 – 3.0***		***3.5 – 4.0***		***All***	
Post-calving feed level	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**
Pregnancy rates (%)	85	70	92	87	90	86	89	81
Average	78		90		88		85	
Days calving to first heat	49	65	38	45	31	38	39	49
Average	57		42		35		44	
Cows cycling in 1st 3 wks (%)	75	58	85	91	90	90	84	80
Average	67		88		90		82	

Target weights for cows before calving:

- Early calving mature cows - CS 2.0 - 2.5, and fall to 1.5 - 2.0 at end of winter
- Early calving first calving cows - CS 2.5 - 3.0.
- Late calving mature cows - CS 3.0 - 3.5

7.0 NORTHERN BEEF PRODUCERS

7.1 MONITOR AVAILABLE FEED QUANTITY AND QUALITY RELATIVE TO ANIMAL REQUIREMENTS

7.1.1 CALCULATE A FORAGE OR PASTURE BUDGET

This Key Management Practice includes calculation of a feed budget either:
- Monthly
- Annually

7.1.1.1 Potential practical outcomes

- Increase reproduction rate
- Decrease mortality
- Reduce cost of production

7.1.1.2 Recent literature

There appears to be no recent literature on the benefits and practicalities of calculating forage or pasture budgets within the northern beef industry.

The principles of budgeting are similar to those described in the sheep and southern beef sections of this review, however, the practical implementation together with the financial and environmental benefits would be quite different.

7.2 USE EBV'S OR INDEX VALUES IN SIRE SELECTION OR PURCHASE POSITIVE

7.2.1 POTENTIAL PRACTICAL OUTCOMES

- Reduce age at sale
- Reduce costs of production
- Decreased mortality

7.2.2 RECENT LITERATURE

There have been no recently published studies of the value of EBV data for northern cattle but there has been ongoing descriptions of the genetic potential of the various northern cattle breeds. This information can be used to improve the confidence of producers in their utilisation of these breeds in their production systems. Genetic parameters were estimated for growth and fertility indicator traits in a South African beef cattle population (Corbet *et al.* 2006a). Measurements on 5601 pedigreed progeny of 96 Bonsmara sires, 18 Belmont Red sires and 20 Bonsmara × Belmont Red cross sires were recorded over 19 years in 4 diverse climatic regions of South Africa. Direct heritability of growth traits (0.11–0.42) and female fertility traits (0.02–0.13) suggested that genetic progress could be made by selection for some traits. Genetic correlations between growth and fertility traits were variable (–0.47–0.85) and indicated that multi-trait selection would be the best method of dealing with multidirectional forces on productivity traits.

Bonsmara sired animals generally scored higher than Belmont Red progeny for functional efficiency (Corbet *et al.* 2006b). Belmont Red sired calves were lighter at birth (35.9 *v.* 37.3; $P<0.05$) and cows by Belmont Red sires had a shorter average calving interval (440 *v.* 455; $P<0.05$). Sire breed by region interaction was not important. The differences in scored and measured traits generally reflected differences in selection policies adopted by the breed societies. Variation in growth and fertility traits due to sire was greater than variation due to breed and demonstrated the potential for identifying superior individuals.

Heritabilities for scored temperament traits were 0.21, 0.19, and 0.15 for post-weaning flight speed score, post-weaning crush score, and start of finishing crush score, respectively (Kadel *et al.* 2006). Genetic correlations across measurement times for flight time were 0.98 and 0.96 for crush score, indicating a strong underlying genetic basis of these temperament measures over time; however, the corresponding phenotypic correlations were lower (0.48 and 0.37, respectively). Longer flight times (i.e. better temperament) were genetically correlated with improved tenderness (i.e. lower shear force and higher tenderness scores), with genetic correlations of –0.42 and 0.33 between LTL shear force, and Meat Standards Australia (MSA) tenderness, respectively. Genetic correlations between post-weaning crush score and the same meat quality traits were 0.39 and –0.47, respectively. Genetic and phenotypic correlations between measures of temperament and other meat quality traits were generally low, with the exception of crush scores with LTL Minolta a* value (–0.37 and –0.63 for post-weaning and start of finishing measurement time, respectively). Predicted correlated responses of –0.17 kg LTL shear force and 2.6 MSA tenderness points per generation were predicted based on the genetic parameter estimates and a recording regime of both flight time and crush scores.

Tropically adapted British breed bulls and taurine crossbreds (British × Sanga) had higher scrotal circumference at yearling (YSC) and 18 months of age (FSC) than Zebu and its crosses when adjusted for their body weights (Prayaga 2004). Large negative direct and maternal additive effects on scrotal circumference for Zebu relative to the British breed also suggested reduced scrotal circumference and fertility in Zebu and Zebu-derived crosses. Direct dominance effects for YSC and FSC were only significant when an adjustment for body weight was not included in the model, emphasising that the heterosis observed was only due to the increased body weight. In general, calving success (CS) was higher in non-lactating cows and maiden heifers than in lactating cows. The advantage to crossbred genotypes was more pronounced in lactating cows. Among lactating purebreds, CS was significantly ($P < 0.05$) higher in Belmont Adaptaur (Hereford–Shorthorn, HS) than in Belmont Red (AX), Belmont Brahman cross (BX), and Brahman (Bh). Lactating crossbreds with a common dam breed of HS, AX, BX, and Bh had 19, 33, 21, and 14% greater CS than their respective purebreds. Boran-sired crossbred dams had higher CS than Brahman-sired crossbreds, indicating higher fertility levels of Borans.

Schatz *et al.* (2004) suggested that up to 38% Charolais content in Brahman steers does not significantly reduce growth rates in the top end of the Northern Territory, but does reduce fatness. However, it should be noted that in this study, the sample size was small, and the animals used represented a small selection of the Charolais breed.

Genotype had no significant effect on weight gain but 25% Charolais × 75% Brahman and Droughtmaster animals were significantly leaner than Brahman (purebred and commercial) cattle at the end of the postweaning year (Schatz *et al.* 2008). Steers grew more (12%) and were leaner (2.6 mm less P8 fat depth) than heifers. Animals that grazed at lower stocking rates gained more weight but were not significantly fatter than those at higher stocking rates.

7.3 MANAGE FIRST CALF HEIFERS SEPARATE TO THE REST OF THE HERD

7.3.1 POTENTIAL PRACTICAL OUTCOMES

- Increase reproduction rate
- Reduce age at sale
- Decrease mortality
- Reduced costs of production

7.3.2 RECENT LITERATURE

The effects of pre-and post-partum (ppp) v. post-partum (pp) supplementation on reproductive function were compared in *Bos indicus* x *Bos taurus* first-calf heifers. Twenty-four pregnant heifers were allocated to three treatment groups all fed roughage hay *ad libitum*. The dietary treatments were: (1) nil supplement controls, (2) cracked maize (1 kg) plus formaldehyde treated sunflower seed meal (0.5 kg) daily for 60 days post-partum, (3) supplement 2 from 1-2 months pre-partum to 60 days post-partum. Supplementation did not affect hay intake prior to calving (6.5 kg/day), but significantly increased intake by approximately 50% after calving compared with a 20% increase in the controls. This lead to a weight decline of 6 kg in unsupplemented animals but increased weight by 16 kg in the supplemented group before calving. During the 2 months after calving, ppp supplemented animals maintained weight, pp supplemented heifers gained 26 kg, and controls lost 39 kg. Birth weight of calves from heifers supplemented before parturition was 34.2 kg, 5.6 kg heavier than the other calves (28.6 kg). The type of supplementation practiced here did not appear to improve reproductive performance in first-calf heifers weighing 340-360 kg in early lactation. However, ppp supplementation was the most effective treatment in reducing GH levels and maintaining liveweight in the peri-natal period, both of which have been associated previously with reducing post-partum anoestrous interval (McSweeney *et al.* 1993).

In the Barkly Tablelands pregnancy rates for heifers (90%) were lower than second calf heifers (93%) and cows (95%) (Savage *et al.* 2004). Calf growth for progeny of heifers (853 g/d) was lower than for second calf heifers (900 g/d) and cows (903 g/d). Increasing pregnancy rates were associated with increasing condition score. There was an inverse relationship between condition score and calf growth for progeny of breeders of condition score 4 and above. This study has shown that breed composition of up to 62.5% *Bos taurus* in the tick-free regions can be highly productive. The results of this work support findings of previous research indicating that breeder condition score of approximately 5 (moderate condition) is optimal.

7.4 PREGNANCY TEST COWS ANNUALLY

7.4.1 POTENTIAL PRACTICAL OUTCOMES

- Increased reproduction rate

7.4.2 Recent literature

Statistical models for conception rate have developed using data collected at a mid dry season (August-September) muster from a controlled-mated and supplemented herd of 900 Brahman cross cows at Mt Bundey from 1980-84. Average conception rates were 74% for maidens, 25% for first-lactation cows, 51 % for 4-10-year-old lactating cows, 54% for >10-year-old lactating cows and 96% for non-lactating cows. Although year effects dominated, they were partially explained by severity of the dry season and were consistent across levels of the other factors. Pregnant maiden heifers weighed 13 kg more than non-pregnant ones at the end of mating, after allowing for the weight of the fetus and gravid uterus. Conception rate of first-lactation cows was not affected by month of calving, adjusted mid dry season weight or condition score, possibly because of narrow ranges in these factors based on selection. For mature lactating cows the main effects on conception rate were month of calving (+11% for September to -16% for December or later), previous lactation (+6% for having reared a calf), adjusted mid dry season weight (-16% for <300 kg to +9% for >350 kg) and condition score (-17% for backward and store to +16% for good condition). Corresponding effects for aged lactating cows were +14% for September to -19% for December or later calving, +8% for previously rearing a calf, and -24% for backward store and store to +23% for good condition cows. The high conception rates for non-lactating cows corresponded with high liveweights and condition scores. A low cost, practical implementation of these models is based on previous lactation status and condition score in the mid dry season, with pregnancy diagnosis added at the next stage. Reproductive classes could be segregated on this basis for improved management and nutrition and to gain an economic return on capital invested in cattle control (O'Rourke *et al.* 1991).

7.5 Wean calves based on condition

7.5.1 Potential practical outcomes

- Reduce age at sale
- Decrease mortality
- Reduce cost of production

7.5.2 Recent literature

Early weaning resulted in a significant liveweight improvement between January and May each year compared with the conventionally weaned cows. The average weight increase for the January to May period in the early weaned cows was 33 kg above that of the conventionally managed group and 34 and 79 kg for the periods January 1990 to January 1992, and January 1990 to May 1992 respectively. By the third mating, conception rate was significantly higher in the early weaned cows but there was no significant difference in the time of conception or inter-calving interval for the period of the experiment. Continuous annual early weaning significantly improved cow liveweight and this increased liveweight was reflected in higher conception rates in the final year of the experiment (76 vs 47, early-weaned and conventionally weaned cows, respectively). Approximately 50% of the weight advantage from early weaning was carried through to the following year in this experiment leading to these cows being 79 kg heavier at the end of the 3 year period (Schlink *et al.* 1994).

7.6 HAVE COST EFFECTIVE SUPPLEMENTATION STRATEGIES TO ADDRESS NUTRITIONAL DEFICIENCIES

7.6.1 POTENTIAL PRACTICAL OUTCOMES

- Increase reproduction rate
- Reduce age at sale
- Decrease mortality
- Reduced costs of production

7.6.2 RECENT LITERATURE

Belmont Red weaner steers were allocated to an initial slaughter group and 3 treatment groups of 120 days duration: rapid growth, slow growth and weight loss (Tomkins et al 2006). The average daily gain of the groups were: 0.81, 0.29 and –0.22 kg/day, respectively. At the end of the treatment period, rapid growth steers had significantly heavier carcasses, higher dressing percentages and greater bone mineral contents than those from the weight loss group. Steers from each group were realimented for 192 days at pasture. Average daily gains during this period were 0.39, 0.52 and 0.61 kg/day for the rapid growth, slow growth and weight loss groups, respectively. The remaining steers were finished at pasture for a further 409 days. During this period there was no significant difference in average daily gain between treatment groups. Steers from the rapid growth group had a significantly greater final weight (531 kg) compared with weight loss steers (481 kg). Carcass characteristics, eye muscle area, bone mineral content and objective measures of meat did not differ significantly between groups.

Tompkins *et al.* (2006) investigated the effect of high molasses diets on feed intake, growth rate, carcass traits and meat eating quality of *Bos indicus* cross cattle in a feedlot conditions. Heifers were fed feedlot diets containing 1, 29% or 50% molasses on a DM basis. Average daily DM intake for the first 64 days was 23-24 g/kg liveweight for each of the treatment groups. The inclusion of molasses in the diet reduced average daily gains (ADG) (control, mid and high molasses groups; 2.1, 1.7 and 1.3 kg/d, respectively). The P8 fat depth was lower for animals fed the high molasses diet (4.2 mm) than the control and mid molasses groups (6.9 and 5.8 mm, respectively). Objective and subjective measures of meat quality were found to be similar between cattle fed a conventional grain-based diet and medium and high molasses diets. The inclusion of molasses at 29 or 50% (DM basis) in feedlot diets could result in acceptable ADG and produce leaner beef without affecting meat quality.

While not specifically directed at the northern beef industry, the results of Dove *et al*. (2008) are relevant to this section. In southern Australia, winter-born calves may not be at marketable weights until 18 months of age and can thus compete with their dams and the next crop of calves for the pasture resource (Dove *et al.* 2008). A preliminary assessment of supplement costs and the economic value of liveweight gain showed a curvilinear response to supplement intake and suggested that the greatest economic return resulted from an intake of 1.9–2.4 kg/day of the supplement, lower than the supplement intakes for maximum liveweight gain. In the study weaned beef calves were confined to feedlots for 70 days and fed different ratios (1:1 up to 1:4) of sunflower meal to oat grain or barley grain at levels of 3–6 kg air-dry/day, plus either oaten hay or pasture hay fed *ad libitum.* Liveweight gains at 3 kg supplement/day were ~1.2 kg/day at all ratios and were slightly higher at the higher feeding levels. The intake of hay varied inversely with the amount of supplement fed and substitution rates were 0.49 with oaten hay and 0.47 with pasture hay. Total dry matter intakes did not decline as the intake of the sunflower meal/oat supplement increased but increased with increasing sunflower meal/barley supplement intake.

Over 2 years, weaned calves grazed mature summer pasture for 81 days were fed 0, 1, 2, 3 or 5 kg/day of a 1:2 ratio of sunflower meal:hammer-milled oat grain. Weight responses of gain to supplement intake were curvilinear. Gains did not exceed 0.75 kg/day and peaked at supplement intakes of 4.3 and 2.8 kg DM/day in years 1 and 2, respectively.

These studies indicate very clear difference in cost-effectiveness of different supplementation strategies

7.7 Vaccinate for tick fever, botulism, three-day sickness, etc

7.7.1 Potential practical outcomes

- Increase reproduction rate
- Reduce age at sale
- Decrease mortality
- Reduced costs of production

7.7.2 Recent literature

Nickels and Cruickshank (2006) reported a marked improvement in pregnancy results when heifers were vaccinated against Vibriosis. The heifers were kept isolated from the bulls prior to commencement of the trial. The bulls were left unvaccinated. 76% of vaccinated heifers were found to be pregnant while pregnancy was diagnosed in only 55% of the unvaccinated heifers. A second trial was conducted in another endemically infected herd and bulls were also vaccinated with the pregnancy rates of the unvaccinated (61%) and (85%) in vaccinated heifers. Permanent infertility can result in up to 11% of heifers infected with Vibriosis.

Tick fever is a serious disease in the northern parts of Australia. Of the domestic animals, it affects only cattle and buffalo. Late last century when tick fever swept through Queensland in the absence of chemical control, it was estimated that some three million cattle died. However, advances in tickicides, vaccines and drug technology now mean that tick fever can be controlled and such losses are highly unlikely to occur again (McGregor 2006). *Bos indicus* cattle and their crosses are more resistant to the clinical effects of infection with *B. bovis* and *B. bigemina* than are *Bos taurus* cattle. Vaccination of *B. indicus* cattle and their crosses is advisable in all areas where ticks exist, although vaccination against *B. bigemina* is probably not essential in pure *B. indicus* animals (Jonsson *et al.* 2008).

Vaccination for botulism was quite common (30% of regional survey groups) in all regions except Central Coastal and Maranoa South West regions of Queensland (Bortolussi *et al.* 2005). Serious outbreaks of a paralytic disease in cattle occurring in the spring and summer of 1988 were investigated on three farms in south eastern Queensland, Australia. On one farm 237 (31 per cent) of 770 cattle died, on the second 109 (40 per cent) of 271 cattle died and on the third 30 (8 per cent) of 380 cows died. Botulism was suspected on the basis of the clinical signs, the lack of significant pathology, a failure to incriminate other agents and a positive feeding trial in one sheep. Laboratory tests for the presence of botulinum toxin failed to confirm this diagnosis, and further feeding trials using ingredients of two rations were also negative (Trueman *et al.* 1992).

In the pastoral areas where botulism is endemic vaccination is widely adopted and it provides good protection (Freeman 2007). In the intensive industries botulism is still uncommon but for individual producers the financial consequences can be dire and vaccination is recommended for all producers who are feeding cattle silage, grain, by-products or mixed rations. Single dose and two dose vaccines are available. Once an outbreak has started, vaccination is unlikely to make much of an impact, so it is important to vaccinate on a regular basis before you get a problem. Apart from vaccination, other management practices can reduce risk factors for botulism, they are:

1. Preventing stock access to animal carcasses.
2. Controlling vermin and pest animals to reduce the risk of spread of putrid material.
3. Providing nutritional supplements of protein and phosphorus to reduce bone chewing among pastoral-zone cattle
4. Taking care with the harvesting and storage of feeds to reduce the possibility of small animals contaminating feeds
5. Checking water sources for organic matter contamination.

Vaccination for three-day sickness in a commercial beef herd may or may not be worthwhile. It will depend on the stage of the management cycle when risk occurs. For example:

1. Fever may cause heavily pregnant cows to abort if they are not protected.
2. If steers are close to finished weights, the loss of condition if they are infected with BEF may make it economic to vaccinate (if given enough warning).

If they are not close to market weight, vaccination may not be worthwhile (Burton 2001).

8.0 REFERENCES

Alcock DJ (2006) Using grazing systems modelling to assess economic, production and environmental risks to aid in selecting appropriate stocking rates. *Australian Journal of Experimental Agriculture* **46**, 841-844.

Archer JA, Barwick SA, Graser H-U (2004) Economic evaluation of beef cattle breeding schemes incorporating performance testing of young bulls for feed intake. *Australian Journal of Experimental Agriculture* **44**, 393 - 404

Australian Wool Innovations and Australian Sheep Industry CRC (2008) Wormboss.com.au. wormboss.com.au

Avery AL, Michalk DL, Thompson RP, Ball P, Prance T, Harris CA, FitzGerald DW, Ayres JF, Orchard BA (2000) Effects of sheep grazing management on cocksfoot herbage mass and persistence in temperate environments. *Australian Journal of Experimental Agriculture* **40**, 185-206.

Behrendt R, Barber P, Oldham CM, Hocking Edwards JE, Hatcher S, Thompson A (2006) Lifetime wool: comparisons on commercial farms show the benefit of good nutrition in pregnancy on production and lamb performance of merino ewes. In 'Australian Society of Animal Production 26th Biennial Conference' p. Short communication number 70.

Besier B (2004) New approached to sheep parasite control - The potential for individual sheep management. *Animal Production in Australia* **25**, 13-16.

Besier B, Lyon J, McQaude N (1996) Drench resistance - a large economic cost. *WA Journal of Agriculture* **37**.

Black J, Scott L (2002) More beef from pastures. Meat & Livestock Australia, North Sydney.

Bortolussi G, McIvor JG, Hodgkinson JJ, S.G. C, Holmes CR (2005) The northern Australian beef industry, a snapshot. 2. Breeding herd performance and management. *Australian Journal of Experimental Agriculture* **45**, 1075–1091.

Burton RW (2001) Bovine ephemeral fever: Three Day Sickness. http://www.dpi.nsw.gov.au/agriculture/livestock/health/specific/cattle/bovine-ephemeral-fever

Campbell A, Vizard A, Larsen J (2006) Quantified estimates of risk factors associated with mortality of weaner Merino sheep. . In 'Proceedings of the Australian Sheep Veterinarians' Conference' pp. 166--172.

Charmley E, Gowan TL, Duynisveld JL (2006) Development of a remote method for the recording of cattle weights under field conditions. *Australian Journal of Experimental Agriculture* **46**, 831–835.

Coates DB, Dixon RM (2008) Faecal near infrared reflectance spectroscopy estimates of diet quality and responses to nitrogen supplements by cattle grazing Bothriochloa pertusa pastures. *Australian Journal of Experimental Agriculture* **48**, 829–834.

Corbet NJ, Shepherd RK, Burrow HM, Prayaga KC, van der Westhuizen J, Bosman DJ (2006a) Evaluation of Bonsmara and Belmont Red cattle breeds in South Africa. 2. Genetic parameters for growth and fertility. *Australian Journal of Experimental Agriculture* **46**, 213–223.

Corbet NJ, Shepherd RK, Burrow HM, van der Westhuizen J, Strydom PE, Bosman DJ (2006b) Evaluation of Bonsmara and Belmont Red cattle breeds in South Africa. 1. Productive performance. *Australian Journal of Experimental Agriculture* **46**, 199–212.

Corner RA, Kenyon PR, Stafford KJ, West DM, Lopez-Villalobos N, Morris ST, Oliver MH (2008) Effect of nutrition from mid to late pregnancy on the performance of twin- and triplet-bearing ewes and their lambs. *Australian Journal of Experimental Agriculture* **48**, 666-671.

Cummins LJ, C.A. M, Kirkpatrick BW (2008) Developing twinning cattle for commercial production. *Australian Journal of Experimental Agriculture* **48**, 930–934.

Della Bosca TJ, McIntyre BL, Read D, Smart WL, Taylor EG, Tudor GD (2004) Optimising feed supply, reproductive efficiency and progeny growth to meet market specifications. 5. Economic analysis of autumn and winter calving. . *Animal Production in Australia* **25**.

Dellar SJ, Accioly JM, McIntyre BL, I. W, Pethick DW (2006) Effect of lupin supplementation and phenotypic characteristics on the performance of pastoral cattle grazing tagasaste. *Australian Journal of Experimental Agriculture* **46**, 947–950.

Dixon RM, Coates DB (2008) Diet quality and liveweight gain of steers grazing Leucaena–grass pasture estimated with faecal near infrared reflectance spectroscopy (FNIRS). *Australian Journal of Experimental Agriculture* **48**, 835–842

Dove H, Freer M, Axelsen A, Donnelly JR (2008) Responses to grain : sunflower meal supplements by weaned calves grazing mature pasture or eating hay in pens. *Australian Journal of Experimental Agriculture* **48**, 811–817.

Ferguson M, Gordon D, Paganoni B, T. P, Kearney G (2004a) Lifetime wool. 6. Progeny birth weights and survival. *Animal Production in Australia* **25**, 243.

Ferguson M, Paganoni B, Kearney G (2004b) Lifetime wool. 3. Ewe liveweight and condition score. *Animal Production in Australia* **25**, 242.

Fogarty NM, Lee GJ, Ingham VM, Gaunt GM, Cummins LJ (2006) Variation in feed intake of grazing crossbred ewes and genetic correlations with production traits. *Australian Journal of Agricultural Research* **57**, 1037-1044.

Fraser I, Hone P (2001) Farm-level efficiency and productivity measurement using panel data: wool production in south-west Victoria. *The Australian Journal of Agricultural and Resource Economics* **45**, 215-232.

Freeman P (2007) Botulism in cattle. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/139233/botulism-in-cattle.pdf

Fulkerson WJ, Donaghy DJ (2001) Plant soluble carbohydrate reserves and senescence - key criteria for developing an effective management system for ryegrass based pastures: A review. *Australian Journal of Experimental Agriculture* **41**, 261-275.

Fulkerson WJ, Slack K, Moore K, Rolfe C (1993) Management of *Lolium perenne/Trifolium repens* pastures in the subtropics. 1. Effect of defoliationintrval seedingrate and application of N and lime. *Australian Journal of Agricultural Research* **40**, 1059-1067.

Geenty K (2006) Farm benchmarking - the next level. In 'Wool meets Meat - Tools for a modern sheep enterprise'. Orange, Australia. (Eds P Cronjé, D Maxwell) pp. 72-79. (The Australian Sheep Industry CRC).

Geenty K (2007) Improved sheep meat and wool production and income Meat & Livestock Australia, North Sydney.

Graham J (2006) Management of beef breeding cows. http://www.dpi.vic.gov.au/DPI/nreninf.nsf/childdocs/-89E7A8DAFEA417624A2568B30004C26A-D84473774162CFC3CA256BC7008115C7-4BF899EE55945B604A256DEA00273C4B-BA5ECA252DE6DA6CCA256BCF000BBEA0?open

Graham NM, Searle TW, Margan DE, Spence FB, Wynn PC (1991) Physiological state of sheep before and during fattening. *Journal of Agricultural Science (Cambridge)* **117**, 371-379.

Greenwood PL, Cafe LM, Hearnshaw H, Hennessy DW, Thompson JM, Morris SG (2006) Long-term consequences of birth weight and growth to weaning on carcass, yield and beef quality characteristics of Piedmontese- and Wagyu-sired cattle. *Australian Journal of Experimental Agriculture* **46**, 257–269.

Griffith GR, Coddington A, Murdoch S (2004) Beef feedlot supply response in Australia *Australasian Agribusiness Review* **12**.

Hebart BC, Carmichael I, Cooper JD (2004a) The use of Technograzing to increase beef production on dry land pastures in south-eastern Australia. *Animal Production in Australia* **25**, 255.

Hebart ML, Pitchford WS, Arthur PF, Archer JA, R.M. H, Bottema CDK (2004b) Effect of missing data on the estimate of average daily feed intake in beef cattle. *Australian Journal of Experimental Agriculture* **44**, 415 - 421

Hegarty RS, Shands C, Marchant R, Hopkins DL, Ball AJ, Harden S (2006a) Effects of available nutrition and sire breeding values for growth and muscling on the development of crossbred lambs. 1: Growth and carcass characteristics. *Australian Journal of Agricultural Research* **57**, 593-603.

Hegarty RS, Warner RD, Pethick DW (2006b) Genetic and nutritional regulation of lamb growth and muscle characteristics. *Australian Journal of Agricultural Research* **57**, 721-730.

Herd RM, Dicker RW, Lee GJ, Johnston DJ, A.J. H, Oddy VH (2004a) Steer growth and feed efficiency on pasture are favourably associated with genetic variation in sire net feed intake. *Animal Production in Australia* **25**, 93-96.

Herd RM, Oddy VH, Richardson EC (2004b) Biological basis for variation in residual feed intake in beef cattle. 1. Review of potential mechanisms. *Australian Journal of Experimental Agriculture* **44**, 423 - 430

Hocking Edwards JE, Gould RM, Copping KJ (2008) Putting Merino weaner management recommendations to the test. *Australian Journal of Agricultural Research* **48**, 974--978.

Hocking Edwards JE, Starbuck TM (2006) Growth from weaning to one year of age affects maiden ewe fertility In 'Australian Society of Animal Production 26th Biennial Conference' p. Short communication number 79.

Hoffman WD, Hearnshaw H, Cafe LM, Hennessy DW, Kamphorst P, McClellan S, A. R, Greenwood PL (2004) Feedlot performance and carcase characteristics of piedmontese and wagyu-hereford cattle at twenty months of age. *Animal Production in Australia* **25**, 260.

Hopkins DL, Hegarty RS, Farrell TC (2005) Relationship between sire estimated breeding values and the meat and eating quality of meat from their progeny grown on two planes of nutrition *Australian Journal of Experimental Agriculture* **45**, 525-533.

Hopkins DL, Stanley DF, Martin LC, Gilmour AR (2007) Genotype and age effects on sheep meat production. 1. Production and growth. *Australian Journal of Experimental Agriculture* **47**, 1119-1127.

Hyder MW, Gordon DJ, Tanaka K (2004) Lifetime wool. 2. Pasture growth, utilisation and ewe stocking rate. *Animal Production in Australia* **25**, 265.

Jonsson NN, Bock RE, Jorgensen WK (2008) Productivity and health effects of anaplasmosis and babesiosis on *Bos indicus* cattle and their crosses, and the effects of differing intensity of tick control in Australia. *Veterinary Parasitology* **155**, 1-9.

Kadel MJ, Johnston DJ, Burrow HM, Graser H-U, Ferguson DM (2006) Genetics of flight time and other measures of temperament and their value as selection criteria for improving meat quality traits in tropically adapted breeds of beef cattle. *Australian Journal of Agricultural Research* **57**, 1029–1035.

Kahi AK, S.A. B, Graser H-U (2003) Economic evaluation of Hereford cattle breeding schemes incorporating direct and indirect measures of feed intake. *Australian Journal of Agricultural Research* **54**, 1039 - 1055

Kearney GA, Knee BW, J.F. G, Knott SA (2004) The length of test required to measure liveweight change when testing for feed efficiency in cattle

Australian Journal of Experimental Agriculture **44**, 411 – 414.

Kelly RW, Croker KP (1990) Reproductive wastage in Merino flocks in Western Australia. In 'Reproductive Physiology of Merino Sheep'. (Eds CM Oldham, GB Martin, IW Purvis, A Hargreaves) pp. 1-9. (The University of Western Australia: Perth).

Lewis RM, Emmans GC, Simm G (2006) Describing effects of genetic selection, nutrition, and their interplay in prime lambs using growth and efficiency functions. *Australian Journal of Agricultural Research* **57**, 707-719.

McDowall MM, Hall DJM, Johnson DA, Bowyer J, Spicer P (2003) Kikuyu and annual pasture: a characterisation of a productive and sustainable beef production system on the South Coast of Western Australia. *Australian Journal of Experimental Agriculture* **43**, 769 - 783

McGregor P (2006) Tick fever. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/58289/Tick_fever_-_Primefact_80-final.pdf

McPhee MJ, Bell AK, Graham P, Griffith GR, Meaker GP (2000) PRO Plus: a whole-farm fodder budgeting decision support system. *Australian Journal of Experimental Agriculture* **40**, 621-630.

McSweeney CS, Fitzpatrick LA, D'Occhio MJ, Reid D, Entwistle KW (1993) Reducing post-partum anoestrous interval in first-calf Bos indicus crossbred beef heifers. 1. Effects of pre- and post-partum supplementation strategies. . *Australian Journal of Agricultural Research* **44**, 1063-1077.

Nickels B, Cruickshank R (2006) Vibriosis - a real threat to productivity. http://www.agric.wa.gov.au/content/pw/ah/dis/cat/fn006_2004.pdf

O'Rourke PK, Doogan VJ, McCosker TH, Eggington AR (1991) Prediction of conception rate in extensive beef herds in north-western Australia. 1. Seasonal mating and improved management. *Australian Journal of Experimental Agriculture* **31**, 1-7.

Oldham CM, Thompson AN (2004) Lifetime wool. 5. Carryover effects on ewe reproduction *Animal Production in Australia* **25**, 291.

Paganoni B, Ferguson M, Kearney G, T. P (2004) Lifetime wool. 7. Progeny growth rates. *Animal Production in Australia* **25**, 295.

Prayaga KC (2004) Evaluation of beef cattle genotypes and estimation of direct and maternal genetic effects in a tropical environment. 3. Fertility and calf survival traits. *Australian Journal of Agricultural Research* **55**, 811–824.

Read D, Della Bosca TJ, Hiscock AJF, Mcintyre BL, Smart WL, Taylor EG, Tudor GD (2004) Optimising feed supply, reproductive efficiency and progeny growth to meet market specifications. 2. Reproduction in autumn and winter calving herds. *Animal Production in Australia* **25**, 304.

Sackett D, Francis J (2006) Integration of wool, meat and cropping systems. In 'Wool meets Meat - Tools for a modern sheep enterprise'. Orange, Australia. (Eds P Cronjé, D Maxwell) pp. 204-209. (The Australian Sheep Industry CRC).

Sakaguchi Y, Gaughan JB (2004) Effect of genotype on performance and carcass characteristics of summer-inducted feedlot cattle. *Animal Production in Australia* **25**, 152-155.

Sampson D (1999) Profit drivers for beef producers. Meat and Livestock Australia. Project no. FC.003, North Sydney.

Sanford P, Cullen BR*, et al.* (2003) SGS Pasture Theme: effect of climate, soil factors and management on pasture production and stability across the high rainfall zone of southern Australia. *Australian Journal of Experimental Agriculture* **43**, 945-959.

Saul GR, Chapman DF (2002) Grazing methods, productivity and sustainability for sheep and beef pastures in temperate Australia. *Wool Technology and Sheep Breeding* **50**, 449-464.

Savage DB, Gaughan JB, Murray PJ, Lisle AT, Peatling SR (2004) Effect of breeder body condition and weight on pregnancy and calf growth in three age groups of composite-bred beef cattle. *Animal Production in Australia* **25**, 156-159.

Schatz TJ, Ridley PER, La Fontaine DJM, Hearnden MN (2008) Effects of genotype, sex and stocking rate on postweaning efficiency and value-adding potential at turnoff of weaners grazing improved pasture in the Douglas Daly region of the Northern Territory. *Australian Journal of Experimental Agriculture* **47**, 1272–1276.

Schatz TJ, Ridley PER, O’Brien PJ (2004) Effect of Charolais content on post weaning growth of Brahman cross steers in the Douglas Daly region of the northern territory. *Animal Production in Australia* **25**, 309.

Schlink AC, Houston EM, Entwistle KW (1994) Impact of long term early weaning on the productivity of *Bos indicus* cross cows. *Animal Production in Australia* **20**, 339.

Smart W (2004) Grazing management. (Ed. Department of Agriculture Western Australia).

Smart WL, Della Bosca TJ, McIntyre BL, Read D, Tudor GD (2004) Optimising feed supply, reproductive efficiency and progeny growth to meet market specifications. 3. Efficient use of pasture. *Animal Production in Australia* **25**, 316.

Standing Committee on Agriculture and Resource Management (1990) 'Feeding Standards for Australian Livestock.' (CSIRO Publishing: Melbourne).

Tatham BG, Hollier T, Wimalasuriya R (2004) Early weaning theory and enterprise benefits for beef cattle. *Animal Production in Australia* **25**, 180-183.

Thompson AN, Doyle PT, Grimm M (1994) Effects of stocking rate in spring on liveweight and wool production of sheep grazing annual pastures. *Australian Journal of Agricultural Research* **45**, 367-389.

Tomkins NW, Harper GS, Bruce HL, Hunter RA (2006) Effect of different post-weaning growth paths on long-term weight gain, carcass characteristics and eating quality of beef cattle. *Australian Journal of Experimental Agriculture* **46**, 1571–1578.

Tozer PR (2007) The benefits of management changes in beef enterprises on pastoral stations in Western Australia *Australasian Agribusiness Review* **15** 62-74.

Trueman KF, Bock RE, Thomas RJ, Taylor JD, Green PA, Roeger HM, Ketterer PJ (1992) Suspected botulism in three intensively managed Australian cattle herds *The Veterinary Record* **130**, 398-400.

Turnbull KE, Quigley SP, Kidd JF, S.R. M, Poppi DP (2008) Differences in utilization of low-quality hay between cattle selected on growth rate after weaning. *Animal Production in Australia* **27**, 53.

Waller RA, Sale PWG, Saul GR, Kearney GA (2001) Tactical versus continuous stocking in perennial ryegrass-subterranean clover pastures grazed by sheep in south-western Victoria. 3. Herbage nutritive characteristics and animal production. *Australian Journal of Experimental Agriculture* **41**, 1121-1131.

Warn LK, Geenty K, McEachern S (2006) What is the optimum wool - meat enterprise mix. In 'Wool meets Meat - Tools for a modern sheep enterprise'. Orange, Australia. (Eds P Cronjé, D Maxwell) pp. 60-69. (The Australian Sheep Industry CRC).

Weatherly E (2008) BREEDPLAN and the bull buyer. http://www.dpi.vic.gov.au/DPI/nreninf.nsf/v/6A4B5CCB9DD93E6CCA25741800162809/$file/BREEDPLAN_and_the_bull_buyer.pdf

Wiese SC (2006) Predictions of growth rate by lambplan supported by project Hilow In 'Australian Society of Animal Production 26th Biennial Conference' p. Short communication number 75.

Young J (2007a) Implications of Lifetimewool for on-farm management in South West Victoria.

Young J (2007b) Implications of Lifetimewool for on-farm management in the Great Southern on WA.