HERD HEALTH AND PERFORMANCE ON WESTSIDE MOUNT RIDDOCK STATION, NT

A REPORT ON A FIVE-YEAR STUDY (1991 - 1996)

JOCELYN COVENTRY

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DEPARTMENT OF **PRIMARY INDUSTRY**, FISHERIES AND MINES

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Compiled by:
Jocelyn Coventry
Pastoral Production Officer
Department of Primary Industry, Fisheries and Mines
Arid Zone Research Institute, Alice Springs NT

Edited by:
Sally Leigo
Pastoral Production Officer
Department of Primary Industry, Fisheries and Mines
Arid Zone Research Institute, Alice Springs NT

Peter Saville
Regional Manager Pastoral Production
Department of Primary Industry, Fisheries and Mines
Arid Zone Research Institute, Alice Springs NT

Front cover: Breeder cows on Mount Riddock Station, NT (September 1997).

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EXECUTIVE SUMMARY

This report is a collation of findings from a study, which was undertaken over five years (1991 to 1996) to record aspects of health and performance for a commercial cattle breeding herd in central Australia. Cattle data and samples were collected at musters and at surveys with the co-operation of the station management and staff.

Over the study, 118 herd bulls and 2,014 breeder cows were recorded in an area of 540 km^2 on Mount Riddock Station in the Alice Springs district.

Herd bulls were examined by looking at some of the traits of the bulls introduced into the herd, the reasons for culling bulls, the number and age of bulls in the herd, aspects of bull breeding soundness and measures of the herd bull input into calf production. Study findings on herd bulls highlighted some important issues for the pastoral industry.

Bull percentage

- The bull percentage averaged 5.2%, which is at the upper limit of a 'safe' bull percentage recommended for northern Australia.

Bull breeding soundness

- Average scrotal circumference of herd bulls at the last muster was almost 38 cm. This was above the recommended minimum of 34 cm for good breeding soundness in mature *Bos taurus* bulls.

Breeding objectives

- Introduction of bulls with higher frame scores (frame score 5 and 6) achieved a management objective for breeding. By increasing the range of bull frame scores, herd genetic capacity was increased for breeding of cattle to meet preferential markets (e.g. mid-maturing steers) as well as opportunistic markets.

Price of bull genetics

- A 'bull-cost per calf' of $36.75 was based on an average of 78 calves per bull-lifetime and industry costs in 2002. This was a reminder of the importance of selecting and buying bulls with good genetics and good breeding soundness, in order to justify the indirect bull-cost for calf production.

Older bull risks

- Bulls greater than 6 years old had a higher risk of 'abnormal' testicular tone, and after drought, 10% of aged bulls were found dead. This indicated how annual bull inspection and culling pressure on aged bulls reduces risks associated with having older bulls in the breeding herd.

Age of bull cull

- In most years, average age of cull was less than 7 years old, which is consistent with a recommended age of cull for bulls in northern Australia.

Breeder cows were examined by looking at the reasons for culling cows, the effect of culling and selection on the frame score, body weight and age of cows, plus the reproductive performance of cows. Study findings on breeder cows highlighted some important issues for the pastoral industry.

Age of breeder cows

- Identification of breeder cow age structure and strategic age-culling in good seasonal conditions (1992/93) resulted in removal of 37% of the breeder herd and minimal impact of aged cow deaths in drought (1994/95).

Culling breeders to maintain herd quality

- On average, 13% of the breeder herd was culled per year, with the majority of breeders being removed on account of 'age', 'fat', 'structure' and 'type'.

Balancing of breeding objectives

- Upgrading of herd quality was associated with parallel increases in average breeder herd frame score (increase of 0.5, on scale: 1 to 11) and average (gross) body weight (> 50 kg). This had positive implications for management marketing objectives and negative implications for breeder conception rate.

Seasonal nutrition effects on reproductive performance

- Poor nutrition was associated with low reproductive performance, e.g. 41% conception during drought (1994), 69% pregnancy during drought, 57% branding after drought, delayed conception in 17 months old maiden heifers after drought, and 52% re-conception in first-calf heifers.

Foetal and calf loss

- Up to 5% reproductive loss was identified before and shortly after birth, and a 1%-drop was identified between an average annual branding percentage (81%) and an average annual weaning percentage (80%).

Herd nutrition was examined by looking at methods of analysing cattle nutrition and available pasture. Study findings on herd nutrition highlighted some important issues for the pastoral industry.

Deficiency in micro-nutrients (vitamins, trace minerals)

- Deficiencies in phosphorus, copper and vitamin A added to the negative effects of dietary energy and protein deficiency in cattle during drought (1994/95).

Drought management strategies

- After drought-breaking rain, an 81% increase in grass availability was recorded at a spelled rangelands site and 10% more conceptions were recorded in a mob of breeder cows that had been relocated onto reserved feed.

Herd health and production was investigated by monitoring of herd health and surveillance for significant herd disease. Study findings on herd health and production highlighted some important issues for the pastoral industry.

Managing cattle stress

- Objective indicators of stress suggested that drought nutrition, dehydration and handling are occasional sources of stress for extensively-managed cattle.

Cattle disease agents

- Findings on six disease agents (leptospires, pestivirus, bovine herpes virus, intestinal worms, coccidia, *Tritrichomonas sp.*) were consistent with past reports for cattle in the Alice Springs district.

Cost-effective cattle management and treatment strategies

- Bull breeding soundness, first-calf heifer re-conception, nutritional supplementation, micro-nutrition, bovine venereal disease and intestinal parasitism were identified as areas where further investigations could help identify cost-effective management strategies.

The reported findings address the original study objectives and contribute to district information on benchmarking of key performance indicators for a beef cattle property. Although the findings reflect only one breeder cow group, these findings address technical issues that are relevant for cattle producers and cattle research in the Alice Springs district.

Technical issues are summarised in sections that follow the Study Findings:

- Areas Identified for Future Work
- Cattle Data Collection and Analysis

Technical details in the study findings are explained in the Glossary and Appendices.

BACKGROUND

DISTRICT LOCATION

Climate

The Alice Springs district is a semiarid to arid area with a low average rainfall (150 mm to 350 mm) and an average of one dry year in four. Pastures respond rapidly to summer and winter rain with forbs growing particularly after winter rain. Summer rainfall grows more productive pasture for the north of the district. Temperatures often exceed 38°C for long periods in summer and frosts occur in winter.

Cattle industry

Beef cattle production is a dominant pastoral enterprise in the Alice Springs district. It occurs on large properties (450 km^2 to 10,000 km^2) with large extensively-managed cattle herds (2,000 head to 7,500 head). These cattle are continuously-mated and graze on arid rangelands (native grasses, forbs and browse) under the variable seasonal conditions of central Australia.

STUDY SITE

Pastoral property

The study site was located in the Westside paddocks of Mount Riddock Station, 200 km north-east of Alice Springs, NT.

Temperatures at the study site ranged from 14°C to 49°C in summer and from minus 2°C to 36°C in winter. The annual rainfall (110 mm to 446 mm) was recorded at the Station Homestead, approximately 20 km from the centre of the study site. Rainfall and rainfall percentiles over financial and calendar years are shown in Appendix 1.

Photographs of the land types at the study site are shown in Table 2. The Bond Springs land type is the major land type (65% of study site). It consists of rugged country and narrow plains below bold rocky hills. This land type is found on 25% of properties in the Alice Springs district. Carrying capacity of the combined land types ranged from 0.5 head to 8 head per km^2. The area of the study site (540 km^2) was fenced into two paddock areas (see Appendix 2). Over the study, the stocking rate averaged 2.6 animal equivalents per km^2.

Cattle management

The study was undertaken in a mixed-age Poll Hereford breeding herd, with 118 herd bulls and 2,014 breeder cows over five years (1991 to 1996). Prior to the study, management objectives for this commercial breeding herd included the following:

- to increase the calving percentage by 5% in 5 years;
- to have every heifer calving by 24 months old;
- to continuously upgrade herd quality, including upgrade breeder frame score to a range of 4 to 6 (mid-maturing type);
- to maintain cattle market options and flexibility;
- to improve yield per beast marketed;
- to analyse herd trends and meet market opportunities at short notice;
- to identify production problem areas and treat as necessary;
- to maintain annual labour input.

During the study, cattle management included:

- continuous mating;
- annual purchase and introduction of herd bulls from Poll Hereford studs;
- culling of herd bulls and breeder cows;
- introduction of replacement breeders;
- year-round supplementation with commercial (urea and phosphorus) blocks;
- drought contingencies;
- twice-yearly musters (see Table 1).

Table 1. Month of musters during the study

Year	1991	1992	1993	1994	1995	1996
post-summer	====	May	April	April	May	April
post-winter	Sept	Sept	Sept	#	Sept	====

==== periods outside of study
survey only (drought conditions)

Objectives of study

Extensive and unpredictable conditions for the cattle industry in central Australia can hinder management of cattle and collection of cattle herd data. This has led to a limited amount of objective information about beef cattle herds and cattle production in the Alice Springs district. A longitudinal, observational study was designed to look at areas where only limited objective information had been available. The (abbreviated) objectives of the study were:

- to produce seasonal and property benchmarks of cattle performance;
- to provide district-specific advice to the Alice Springs Pastoral Industry, based on objective information about seasonal and management effects on breeder cattle performance, as well as the relationship of laboratory values to cattle nutrition, disease and health.

Data collection

Data and samples were collected at musters and field surveys with the co-operation of the station management and staff over a 5-year period (see Appendix 3). This allowed time to record the effects of season variability and long-term management strategies.

Table 2. Land types at the study site

Kanandra land type: This land type was found on 10% of the study site. It consists of sparcely timbered, sandy plains and floodouts, mainly on the north edge of the Harts Range. The vegetation is principally sparce low trees, short grasses and forbs, featuring kerosene and woolybutt grasses, witchetty bushes and mulga trees.

Bond Springs land type: This land type was found on 15% of the study site. It consists of rugged mountain ranges traversing east-west. The vegetation is principally sparce shrubs, low trees, sparce forbs and grasses, featuring witchetty and cassia bushes, mulga trees and spinifex amongst occasional bare rock.

Harts land type (in background): This land type was found on 15% of the study site. It consists of rugged mountain ranges traversing east-west. The vegetation is principally sparce shrubs, low trees, sparce forbs and grasses, featuring witchetty and cassia bushes, mulga trees and spinifex amongst occasional bare rock.

STUDY FINDINGS

CATTLE IN THE HERD

Herd Bulls

Findings from the study highlighted herd bull group management in the following areas:

- selection and introduction;
- culling;
- monitoring.

Selection and introduction

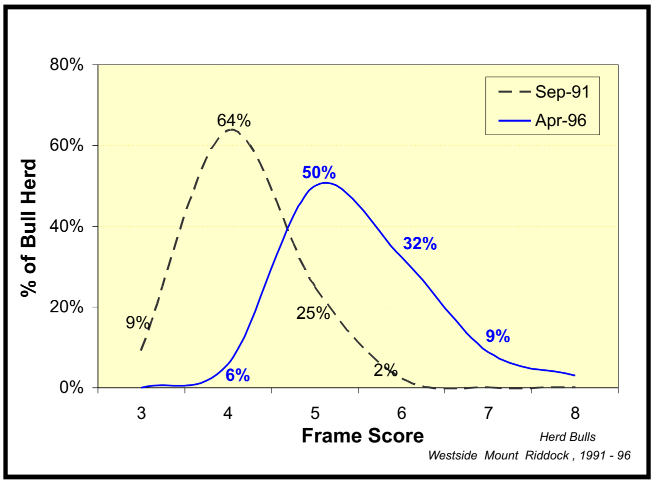
Bull temperament

No bulls introduced into the study site had to be culled for temperament (see Figure 2).

Bull frame score

During the study, bulls with large and medium frame scores were introduced. This helped to increase the range of preferential bull frame scores (see Figure 1), and increase the genetic capacity to breed cattle for preferential and opportunistic markets. These outcomes were consistent with management objectives for the study herd, i.e. a focus on production of cattle suitable for preferential markets (frame score 4 to 5 steers) with maintenance of flexibility to meet opportunistic markets.

Figure 1. Range of frame scores in the herd bull group at the beginning and end of the study



Culling

Percentage and age of herd bulls culled

An average of 11% of herd bulls was culled each year. Of the prime bulls (3 to 7 years old) recorded during the study, 4% were culled. Of the aged bulls (>8 years old) recorded during the study, 19% were culled. In most years, the average age of cull was less than 7 years old. However in the final year, the age of cull averaged 11½ years old as a result of culling of bulls that had been in a large consignment introduced in 1987.

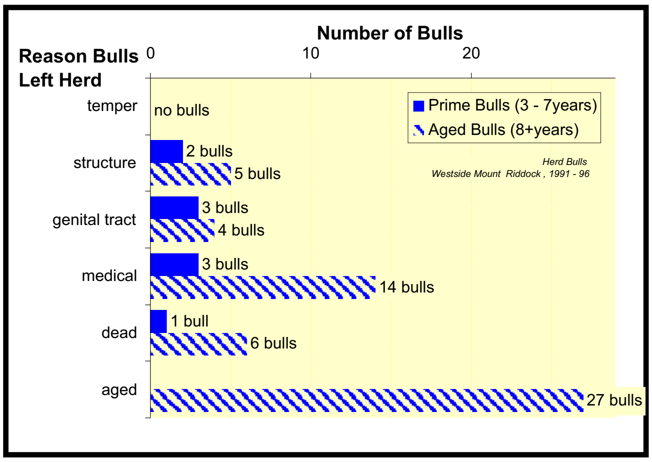
Reasons for culling herd bulls

Culled bulls frequently had multiple problems that were identified as the reasons for culling:

- 17% of culled bulls had structural problems;
- 17% of culled bulls had genital tract problems;
- 42% of culled bulls had medical problems;
- 80% of culled bulls were aged (>8 years old) (see Figure 2).

Over 90% of bulls that were culled for 'age' were culled for multiple reasons (e.g. 'age' plus arthritis). Both aged bulls and prime bulls had genital tract (sheath and testicle) problems (also see Figure 7). In the last year of the study, two of the recently introduced bulls left the herd on account of death and injury.

Figure 2. Reasons prime bulls and aged bulls left the herd during the study



Monitoring

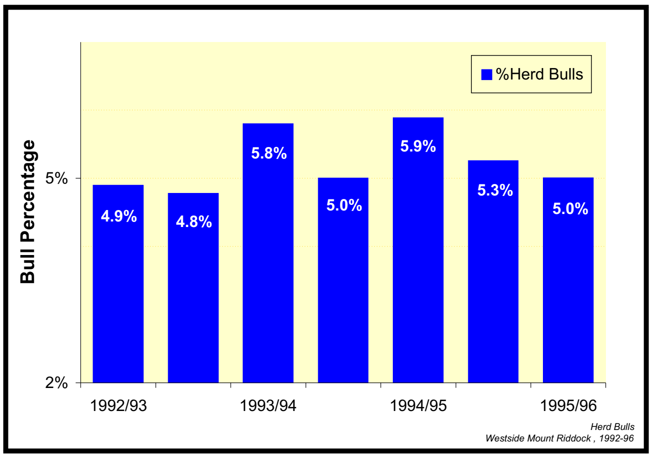
Bull percentage

The bull percentage averaged 5.2%. This fluctuated over the study (see Figure 3) with seasonal changes in the breeder cow numbers, bull culling and bull introduction. Over half (51%) of recorded bulls were identified as introduced bulls. The seasonal bull percentages were similar to those recommended for northern Australia, and slightly higher than the average of 4.6% reported in the 2004 Alice Springs Pastoral Industry Survey.

Mortality percentage in herd bulls

Death accounted for 17% of reasons recorded for bulls leaving the breeding herd (see Figure 2). In an average season, 2% of prime bulls and 3% of aged

Figure 3. Herd bull percentage during the study



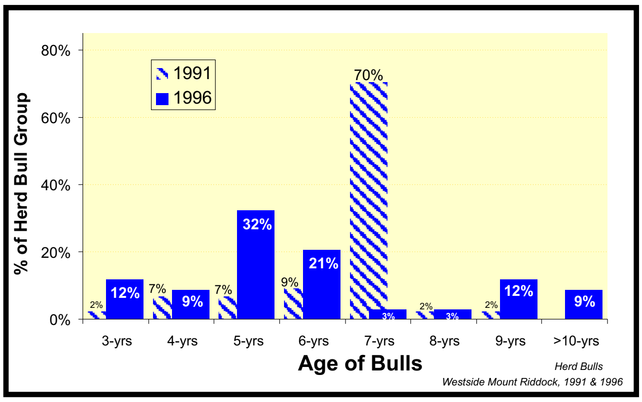
bulls were found dead. After drought, 10% of aged bulls were found dead, and at least 15% of prime and aged bulls were missing; some of the latter may also have died.

Age of the herd bulls in the group

The age distribution of herd bulls was summarised at the beginning and the end of the study (see Figure 4). The major age-feature at the first muster of the study was the 70% of bulls that were at least 7 years old. The major age-features at the last muster were the more even bull age distribution and a few aged bulls identified for culling.

These two age distributions showed the combined effects of bull introduction, retention and removal before and during the study. In 1987, prior to the study, a large consignment of Poll Hereford bulls was introduced to build up the breeding herd. During the study, young bulls (>2 years old) were introduced annually from Poll Hereford studs and some individual bulls were retained beyond a recommended age-of-cull (<8 years old), because they were still sound and had good genetics (e.g. previous stud bulls). Bulls were removed from the breeding herd at an average of 8.7 years old. Given the average ages for introduction and removal from the breeding herd, the working life of bulls in the study herd averaged more than six years long.

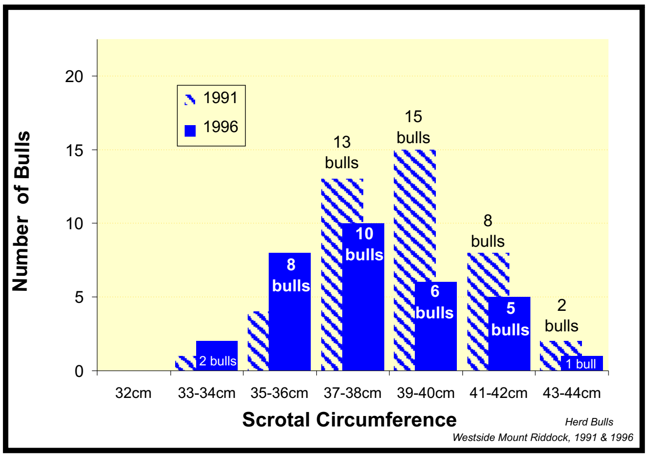
Figure 4. Age distribution in the herd bull group at the beginning and end of the study



Breeding soundness of herd bulls - scrotal circumference

The range of scrotal circumferences in the herd bull group (30 cm to 50 cm) was influenced by the age and genetics of the bulls, as well as seasonal nutrition and a few acquired testicular defects. Excluding acquired defects, the average herd bull scrotal circumference was 39 cm at the first muster (1991) and almost 38 cm at the last muster (1996) (see Figure 5). For all years, average annual scrotal circumference was above the recommended minimum for good breeding soundness in mature *Bos taurus* bulls (34 cm).

Figure 5. Range of scrotal circumference in the herd bull group at the beginning and end of the study



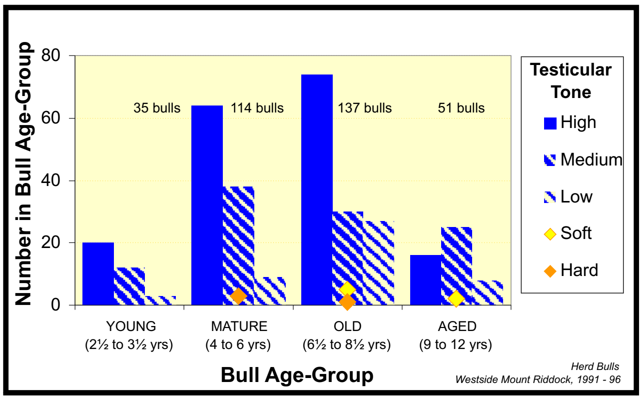
Breeding soundness of herd bulls - testicular tone

Bull testicular tone was classified either as 'abnormal' (where the testicles were extremely 'soft' or extremely 'hard'), or as 'normal' (with a range of low, medium and high). This 'normal' range of testicular tone is equivalent to the Australian Cattle Veterinarians (ACV) bull breeding soundness examination score of 2, 3 and 4 respectively. 'Normal' testicular tone was noted in over 95% of bulls in all age-groups.

'Normal' testicular tone of individual bulls fluctuated over time, suggesting influences of sexual activity, seasonal nutrition and age. Variation in the range of 'normal' testicular tone between age-groups is seen in

Figure 6. This figure also shows some occurrence of 'abnormal' testicular tone in Mature, Old and Aged bulls. Four bulls in the Mature and Old bull age-groups had hard testicular tone as a result of acquired testicular defects. Seven bulls in the Old and Aged bull age-groups had soft testicular tone. Culling based on testicular defects and 'age' removed bulls with 'abnormal' testicular tone.

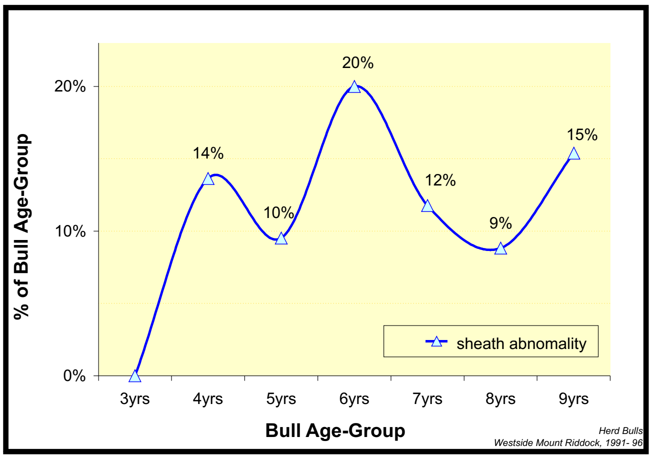
Figure 6. Testicular tone in bull age groups during the study



Breeding soundness of herd bulls - sheath

Inspection of the sheath and penis of individual bulls was limited, and only those abnormalities noted in the yard were recorded. Sheath abnormalities were recorded in all bull age-groups (see Figure 7). Normal herd bull culling practices limited the frequency of these abnormalities in the age-groups.

Figure 7. Sheath and prepuce abnormalities in bull age groups during the study

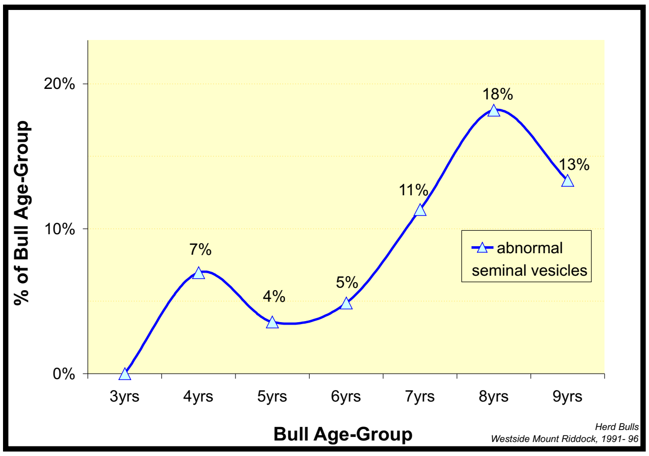


Breeding soundness of herd bulls-seminal vesicles

Seminal vesicle abnormalities were recorded increasingly in older bull age-groups (see Figure 8).

Normal herd bull culling practices probably did not limit the frequency of these abnormalities in the age-groups. Recording of seminal vesicle abnormalities provided an example of hidden factors that increase with age and may decrease a bull's breeding soundness.

Figure 8. Seminal vesicle abnormalities in bull age groups during the study



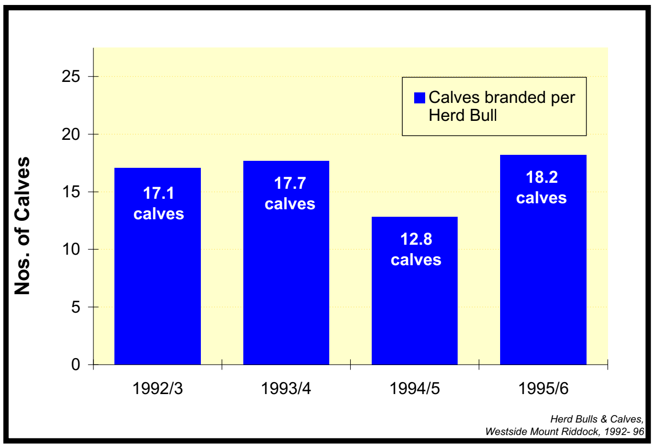
Herd bull input into calf production

Three calculations were made, based on 5-year study averages (1991-96) and 'best-bet' industry-based figures (2002):

- 'calves per bull' averaged almost 16 calves per year and was 25% lower with drought conditions (see Figure 9);
- 'calves per bull-lifetime' averaged 78 calves;
- 'bull-cost per calf' was $36.75.

Appendix 4 shows the equations used in calculations and Appendix 5 shows the calculation for 'bull-cost per calf'.

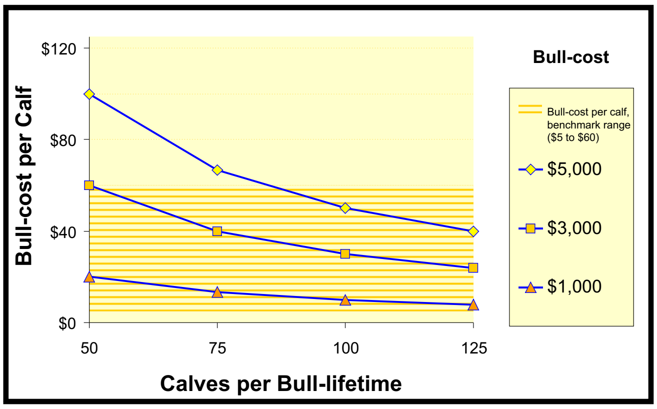
Figure 9. Annual number of 'calves per bull' during the study



The calculated 'bull-cost per calf' was within a range quoted for northern Australia ($5 to $60). Where bull-cost per calf exceeds $20, use of selected bull genetics is recommended in order to justify this cost.

Reduction in 'bull-cost per calf' can be achieved by rationalising the managed factors ('bull-cost', bull percentage) or by improving other aspects of herd performance (bull working-lifetime, branding percentage). Figure 10 shows how 'bull-cost' and the combined effect of branding percentage, bull percentage and bull working-lifetime ('calves per bull-lifetime') can influence the 'bull-cost per calf'. This highlights how the impact of 'bull-cost' on the average 'bull-cost per calf' can be reduced, if bulls sire a large number of calves over an effective breeding-lifetime.

Figure 10. Modelled 'bull-cost per calf', according to the number of 'calves per bull lifetime' and 'bull-cost'



Breeder Cows

Findings from the study highlighted breeder cow herd management in the following areas:

- replacement;
- culling;
- monitoring of breeders;
- monitoring of reproductive performance.

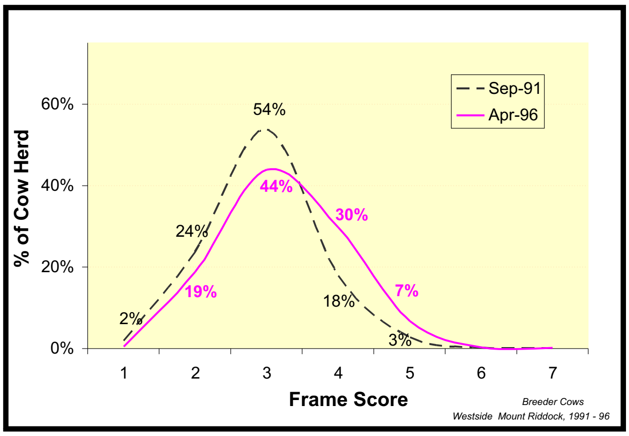
Replacement

Frame score and weight of replacement breeder cows

During the study, 51% of recorded breeder cows and heifers were identified as replacement breeders. Introduction of female offspring from higher frame score bulls and selective culling of older cows with lower frame scores increased the average frame score of the breeder herd by 0.5 (scale: 1 to 11). Although the median breeder cow frame score of 3 did not change during the study, after five years there were about 20% less cows with frame score 3, and 50% more cows with frame score 4 (see Figure 11). At the end of the study, this increase in frame score was associated with a higher average (gross) bodyweight of breeder cows:

- first-calf heifers (2 years old) increased by 53 kg (up to 431 kg);
- mature cows (6 years old) increased by 72 kg (up to 505 kg).

Figure 11. Range of frame scores in the breeder cow herd at the beginning and end of the study

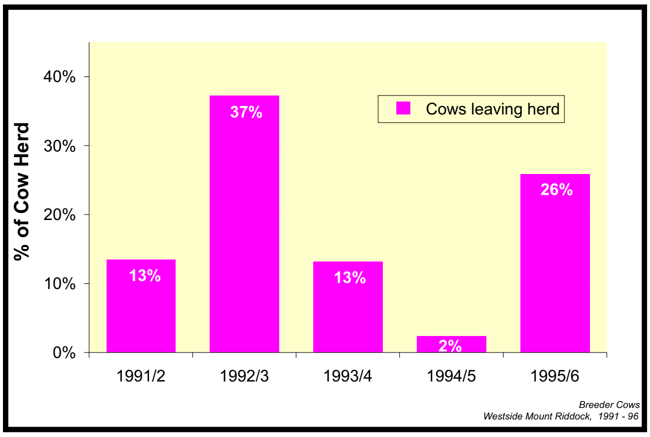


Culling

Percentage of breeder cows culled

Age-culling contributed to strategic culling of 37% of the breeder herd during a good season (1992/93), when cows were in a reasonable body condition. The percentage of cows culled after poor seasonal conditions (1994/95) was only one-quarter of the 2% that left the herd (see Figure 12). The annual average of 13% breeder cows culled over the study was less than the average percentage of 18% breeder cow culling reported in the 2004 Alice Springs Pastoral Industry Survey.

Figure 12. Annual percentage of cows leaving the breeding herd during the study

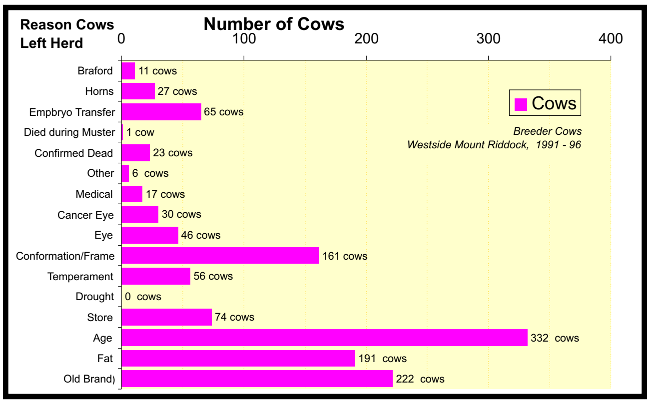


Reasons for culling breeder cows

Half of recorded breeder cows and heifers left the herd during the study (see Figure 13). Individual cows and heifers were culled for multiple reasons. Major reasons for culling were 'age' (35% of culled cows), 'structure and type' (17% of culled cows), and 'fat' (20% of culled cows). Less frequent reasons for culling included 'temperament' (6% of culled cows), eye problems (8% of culled cows) and store movements (15% of culled cows). These reasons are similar to those reported for breeder cow culling in the 2004 Alice Springs Pastoral Industry Survey ('age', conformation, pregnancy status and temperament).

Two outcomes from this culling were the reduced impact of older cow deaths during a drought period and removal of cows with disease or defects of the reproductive tract.

Figure 13. Reasons that breeder cows left the herd during the study



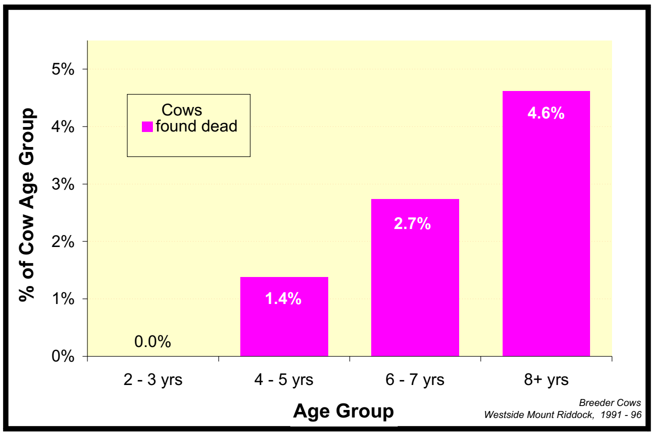
Monitoring of breeders

Mortality percentage in breeder cows

Unspecified breeder cow deaths in the study were only recorded during drought conditions (1994/95). In this year, overall mortality was 1.4%, and losses were higher in older cows (>8 years old) (see Figure 14). Drought management strategies (age-culling, heavy weaning, reduced stocking rate) would have minimised these breeder cow deaths. The recorded number of missing breeder cows also suggests additional cow mortality during drought. For breeder cows over 6 years old, an additional 5% unrecorded deaths were suspected to have occurred during drought.

A higher mortality percentage in older breeders is consistent with breeder cow mortality reported in the 2004 Alice Springs Pastoral Industry Survey. That averaged 3% and was up to 7% in the older age-group (>8 years old).

Figure 14. Reported breeder cow deaths, by age-group during drought

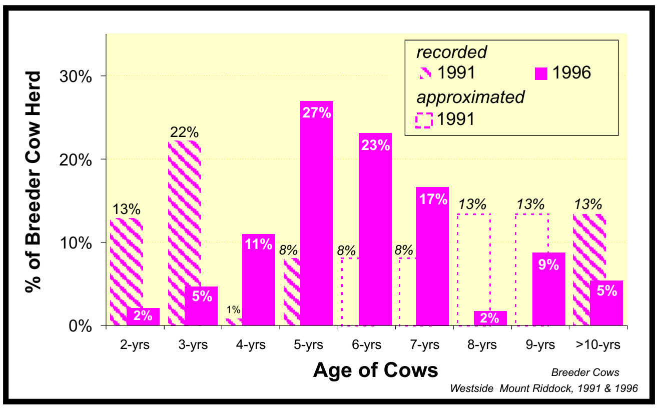


Age of breeder cows

The age distribution of cows in the breeder herd changed during the study (see Figure 15). At the first muster in 1991, cows more than 7 years old made up approximately 38% of the breeder herd, 2 to 3 years old replacement breeders made up 35% and only 1% of breeders were 4 years old. This age distribution resulted from management decisions made to enabled a build up of breeder numbers in the late 1980's, i.e. retention of mature cows that were introduced in 1987, introduction of 1988-weaned heifers into other paddocks, then re-introduction of 1989-weaned heifers and 1990-weaned heifers.

Identification of breeder cows by age prompted culling of a large number of aged cows, particularly in 1992/93. By the last muster in 1996, only low numbers of aged cows (>10 years old) were identified for culling. This was consistent with local consensus data from the Alice Springs district that has reported culling of breeder cows by 10 years old.

Figure 15. Age distribution in the breeder cow herd at the beginning and end of the study



Monitoring of reproductive performance

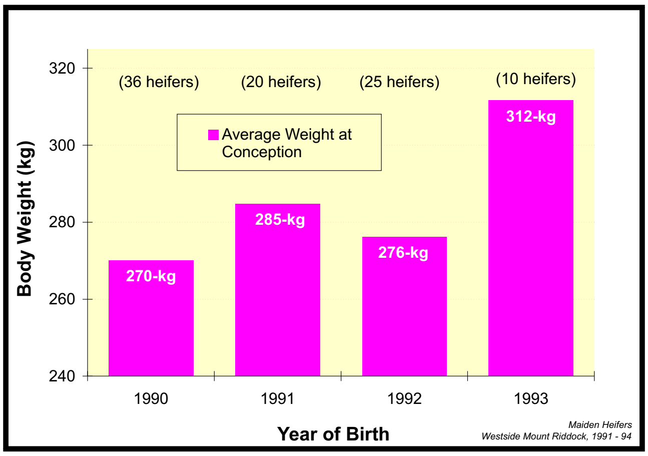
Conception

Annual conception percentage had a seasonal pattern and was similar in the mixed-aged cow group ('all cows') and the 3 years old heifer group. The percentage was lowest during a drought year (1994) and highest after drought-breaking rains (1995).

Age and weight of heifers at first conception

The average age and weight at conception for young heifers (12 to 18 months old) was determined with computer modelling for four groups by year of birth. The average age at conception for the heifers in all year-groups was just over 15 months of age. The average weight at conception for the heifers in all year-groups was 286 kg. The groups of heifers born in 1990, 1991 and 1992 had average weights at conception that were consistent with averages for Hereford heifers, i.e. between 260 kg and 285 kg (see Figure 16). The group of heifers born in 1993 had the highest average weight at conception (312 kg). The latter group of heifers had a lower plane of nutrition during drought in 1994, so they took longer to reach puberty and mating weight in 1995. These results highlight the importance of good heifer nutrition for conception.

Figure 16. Average heifer weight (modelled) at first conception during the study



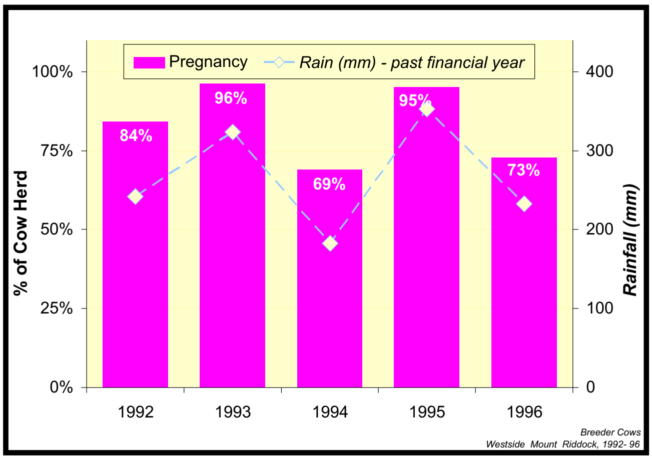
First-calf heifer re-conception

Annual re-conception percentage averaged 52% for three year-groups of lactating first-calf heifers (18 to 30 months old). The pattern of first-calf heifer re-conceptions appeared to be influenced by timing of rainfall. This average annual percentage of re-conceptions was well below the average annual pregnancy percentage for the mixed-age breeder herd. This highlights how poor first-calf heifer re-conception may reduce breeder herd performance.

Pregnancy

Annual pregnancy percentage had a seasonal pattern and averaged 83% (see Figure 17). The percentage after 183 mm of 12-months rainfall (drought year, 1994) was 25% below that following more than 320 mm of 12-months rainfall (above-average rain). This demonstrated a positive relationship between rainfall and conception.

Figure 17. Annual pregnancy percentage of all breeder cows during the study, compared with rainfall in the past financial year



Foetal and calf loss

Foetal and calf loss of up to 5% was determined from pregnancy and lactation records of individual cows in 1992 (see Table 3) and 1994/95.

Table 3. Foetal and calf loss detected during 12 months of the study

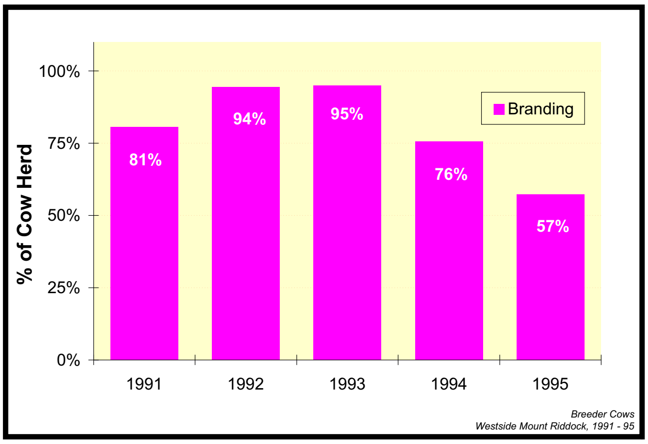
Musters	Number of Mustered Cows	Number of Lost Calves Detected (*% of mustered cows*)	Number of Lost Foetuses Detected (*% of mustered cows*)
early 1992	902	16 (*1.8%*)	11 (*1.2%*)
late 1992	862	7 (*0.8%*)	18 (*2.1%*)

Some calf loss resulted from feral dog predation and some resulted from premature births after mustering and yard activities for the study. Collections during the study were subsequently streamlined to minimise stress for breeder cows in the third trimester of pregnancy. This was in addition to the other management strategies that promoted calf survival through reduced mis-mothering and reduced predation.

Calf branding

Annual branding percentage averaged 81% and varied significantly between years (see Figure 18). The branding percentage in 1995 fell more than 30% below that of earlier years. This was associated with the effects of drought in 1994 (less conceptions and more cow losses). The annual branding percentages indicated average annual inter-calving intervals ranging from 12 months to 21 months.

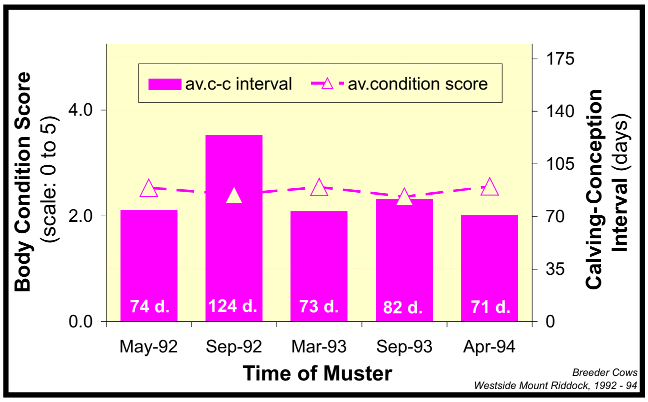
Figure 18. Annual branding percentage of all breeder cows during the study



Calving-conception interval

Except for an inter-muster period in mid-1992, the average calving-conception interval during the first three years of the study was less than 83 days and the median body condition score of breeder cows at conception was determined to be 2.5 (on scale: 0.0 to 5.0). The longer calving-conception interval of 124 days in mid-1992 was associated with rain that limited weaning activity earlier in the year (see Figure 19).

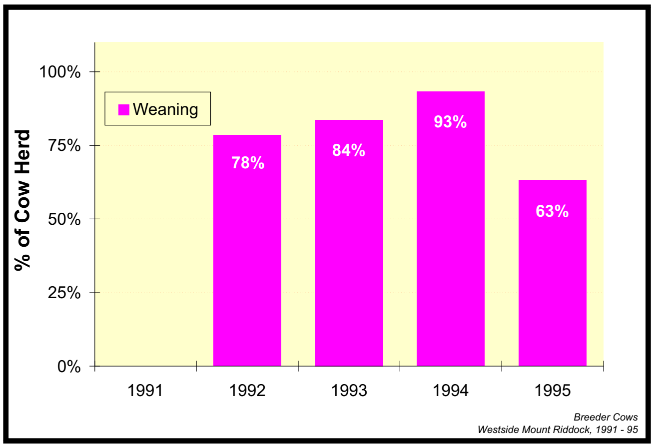
Figure 19. Body condition score and calving-conception interval of breeder cows during three years of the study



Calf weaning

Annual weaning percentage averaged 80% over four years and varied significantly between years (see Figure 20). The weaning percentage in 1995 was 30% below the percentage in 1994. This reflected the combined effect of early weaning in the first half of the drought period (1994) plus reduced production of calves in the second half of the drought period. There was a 1%-drop between the average branding and weaning percentages over the whole study.

Figure 20. Annual weaning percentage of all breeder cows during the study



Calf weaning weight

The average calf weight at weaning over five years was 260 kg. Weaning weights were influenced by mustering efficiency, the period within and between musters and weather conditions. Rain in early 1992 delayed weaning and drought conditions in late 1994 promoted early weaning. The average weight at early weaning in 1994 was 218 kg.

INFLUENCES ON HERD PRODUCTION

Herd Nutrition

Findings from the study highlighted management of breeder herd nutrition, with assessments in the following areas:

- herd nutritional status;
- available pasture.

Herd nutritional status

Cattle herd nutrition is dependent upon macro-nutrients (energy, protein, fibre) and micro-nutrients (trace minerals, vitamins). A balance of all nutrients is essential for production efficiency. Even borderline deficiencies can reduce productivity. Specific testing of faecal and blood samples can provide indicators of cattle dietary intake and nutritional status. During the study, faecal samples from breeder cows were assessed for faecal indicators of protein and phosphorus nutrition (percentage of nitrogen, percentage of phosphorus and percentage of dry matter). Blood (serum) samples were assessed for levels of phosphorus, magnesium, iron, copper, glutathione peroxidise, zinc, vitamin A and vitamin E. A summary of the role of these micronutrients is provided in Appendix 6. Assessments highlighted both the inconsistent nature of cattle nutrition on arid rangelands and the challenge of managing pasture and supplementation to address this.

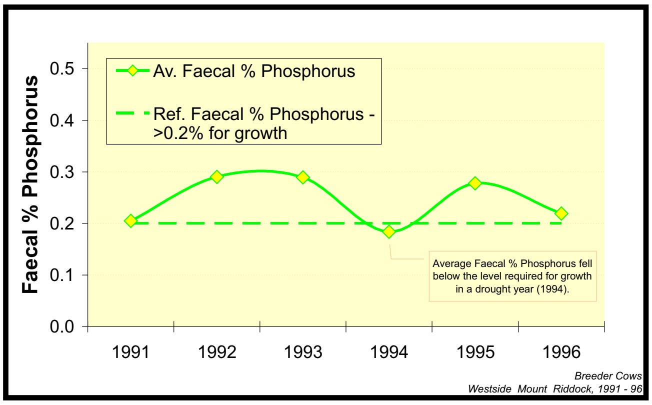
Faecal indicators

Faecal percentage nitrogen varied greatly for individual breeder cows. With interpretation, average faecal percentage nitrogen per sample period (1.17% to 1.77%) was a more useful indication of nutrition for breeder cow groups. Interpretation of faecal percentage nitrogen needs to take into consideration the effect of supplementation, plus high levels of dietary fibre and dietary tannins in 'topfeed'. If cattle diet has moderate dietary fibre and low dietary tannin, such as good quality grass and forbs, then a minimum level of 1.3% faecal nitrogen may indicate adequate dietary protein for growth.

Faecal percentage phosphorus varied for individual breeder cows, but average faecal percentage phosphorus per sample period (0.14% to 0.40%) was adequate for breeder cow groups over most of the study. The exception was in 1994 when average faecal percentage phosphorus fell below the critical level of 0.2% (see Figure 21). This fall was associated with drought conditions. A comparison of faecal percentage phosphorus and faecal percentage nitrogen for individual breeder cows showed that even during 'good' seasonal conditions, targeted use of phosphorus supplementation was required to maintain critical levels of faecal percentage phosphorus.

Faecal percentage dry matter varied for individual breeder cows. Within a range of 12% to 17% faecal percentage dry matter, breeders had satisfactory levels of faecal percentage nitrogen and phosphorus. Mean faecal percentage dry matter was generally higher under 'poor' seasonal conditions.

Figure 21. Average faecal percentage phosphorus during the study



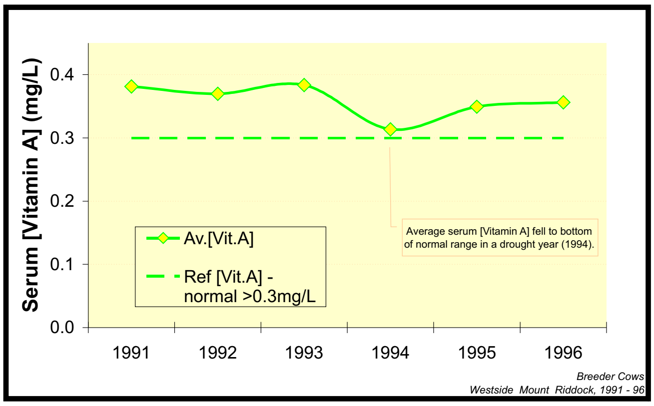
Blood indicators

Averages of six blood indicators (serum magnesium, iron, copper, glutathione peroxidase, zinc and vitamin A) were lower during the drought conditions of 1994, and averages of three blood indicators (serum phosphorus, copper and vitamin A) actually fell below the normal range during or after drought (see Appendix 6).

After eight months of no effective rainfall (drought in 1994) it was noted that:

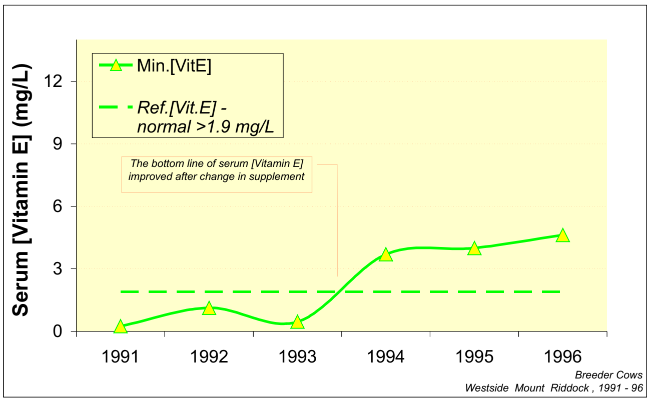
- serum copper values were low in 50% of individual cows. This may have been an indication of trace mineral interactions during drought;
- serum iron values were high in 25% of individual cows. This may also have been an indication of trace mineral interactions during drought;
- serum phosphorus values were critically low in 50% of individual cows. This was consistent with the low individual faecal percentage phosphorus;
- serum vitamin A values were critically low in 80% of individual cows and the average level of serum vitamin A fell to the critical level of 0.3mg/L (see Figure 22).

Figure 22. Average serum levels of vitamin A during the study



Average serum vitamin E was acceptable throughout the study, however prior to 1993, 15% of the individual cows sampled had critically low serum values for vitamin E. Individual serum levels of vitamin E rose above the recommended minimum of 1.9 mg/L in late 1993, following introduction of commercial mineral supplement blocks containing vitamin E (see Figure 23).

Figure 23. Minimum serum levels of vitamin E during the study



In general, the findings from faecal and blood indicators showed a seasonal need for targeted supplementation of dietary nitrogen, phosphorus, copper, vitamin A and vitamin E. The findings also highlight a lack of knowledge about the dynamics of essential micronutrients (trace minerals, vitamins) in the diet of cattle in the Alice Springs district.

Available pasture

Drought management strategies

Cattle nutrition was managed by year-round supplementation with commercial mineral blocks in conjunction with drought management strategies (destocking of cows to reduce stocking rates, strategic spelling of paddock areas, opening of new waters in areas of reserved feed). The response to these strategies was demonstrated after drought-breaking rain with pasture and breeder cow performance:

- grass utilisation assessments and photographs taken during and after drought at rangeland sites demonstrated grass availability increasing from 14% to 95%;
- pregnancy testing of a group of breeder cows that had been relocated onto reserved feed demonstrated a conception percentage that was 10% higher than breeder groups from other paddock areas.

Herd Health and Production

Findings from the study highlighted some aspects of management to optimise cattle herd health and production:

- monitoring cattle herd health;
- diagnosis of cattle herd disease;
- treatment and management of cattle disease.

Monitoring cattle herd health

Blood analyses

Findings from blood analyses were related to three aspects of the breeder cow management during the study:

- nutritional stress and changed protein metabolism during drought (1994) may have caused changes in levels of blood enzymes and metabolites;
- adaptation or physiological dehydration may have caused raised levels of blood and serum parameters;
- stress of mustering and yard activity may have caused raised levels of serum enzymes (see Appendix 7).

Diagnosis of cattle herd disease

Findings from the study were consistent with past reports on disease agents in cattle herds of the Alice Springs district. Further investigation would be required to determine how these disease agents affect cattle herd health and productivity in the district, as well as how management strategies may cost-effectively address any identified production losses.

Reproductive disease

Serum testing (antibody titres) indicated exposure of herd bulls and breeder cows to infectious agents that can cause reproductive disease:

- titres to leptospires were associated with age and season. Kidney lesions ('white spots') typical of leptospire infection were reported in culled cows and steers at slaughter;

- titres to bovine pestivirus were found in all age-groups;
- titres to bovine herpes virus increased with age.

Bacterial cultures of the prepuce of two older bulls and the uterus of a culled cow ('fat and dry') were positive for *Tritrichomonas foetus* ('trichs'). The bulls were subsequently culled and pregnancy records indicated that mid-term foetuses (3 to 6 months old) were being lost. The absence of positive cultures from testing for *Campylobacter fetus ss venerealis* ('vibrio') may have been related to poor sensitivity of field testing and regular 'vibrio' vaccination of all yarded herd bulls.

Botulism
No Type C or D botulism bacteria were cultured in faecal samples from herd bulls, breeder cows or weaner calves.

Intestinal parasites
Faecal testing indicated endemic infestation by intestinal roundworms and coccidia:

- indication of intestinal roundworm infestation was demonstrated by low faecal worm egg counts in herd bulls, slightly higher egg counts (up to 500 eggs per gram) in young cows and older cows, and the highest egg counts (up to 3,000 eggs per gram) after drought in 30% of weaner calves. Faecal cultures confirmed the presence of three intestinal roundworm species (*Cooperia sp.*, *Oesophagostomum sp.* and *Haemonchus sp.*).
- indication of intestinal coccidia infestation was demonstrated by low faecal oocyst counts (50 oocysts per gram) in herd bulls and breeder cows, with the highest counts (up to 45,000 oocysts per gram) after drought in 15% of weaner calves.

Treatment and management of cattle disease

Future work
Although management and treatment options were not trialled during the study, areas have been identified for future work.

TECHNICAL ISSUES

AREAS IDENTIFIED FOR FUTURE WORK

Herd bull breeding soundness

Use of effective numbers of herd bulls is limited by the lack of knowledge about the visible and hidden risks that affect herd bull breeding soundness. A past investigation in Alice Springs district has found that up to 15% of herd bulls had 'poor fertility' (poor breeding soundness).

- Cost-effective recommendations to manage the risks involved could be extended beyond 'annual inspection at muster' and 'culling-for-age'.

Breeder cow reproductive performance

Areas of identified poor reproductive performance present opportunities to use cost-effective management strategies that improve or maintain an optimal level of breeder performance.

- Drought management strategies can optimise poor seasonal breeder nutrition and have positive flow-on effects for conceptions.
- Management of maiden heifer nutrition and mating can optimise the age of first conception and improve the potential breeding life of replacement breeders.
- Strategic management of first-calf heifer nutrition can cost-effectively promote re-conception and improve performance of the breeder herd.

Herd nutrition

Demonstrated seasonal deficiency in cattle macro- and micro-nutrition on arid rangelands has highlighted both the challenge of providing nutritional supplementation, and the areas where there is insufficient district information.

- The effect of micro-nutritional deficiency on breeding herd performance needs to be determined before cost-effective management strategies can be investigated.
- The effectiveness of current supplementation strategies needs to be assessed to determine if changes are required.

Herd health and production

Indication of disease agents that are considered endemic in the Alice Springs district, highlighted a potential for disease detection and management to be part of a strategy to improve cattle herd production.

- *Tritrichomonas foetus* and *Campylobacter fetus ss venerealis*
  It is suspected that newer field testing methods (ELISA testing for vaginal mucus IgA, PCR testing, InPouch™) and targeted sampling of high risk cattle at abattoirs would improve the accuracy of 'trichs' and 'vibrio' surveys. This would be an integral part of investigation into the economic benefit of vaccination and heifer management to control cattle venereal disease.
- Bovine herpes virus infection and IBR in feedlots
  Indirect property exposure of store steers to bovine herpes virus may have positive benefits for immunity to IBR (respiratory) infection in feedlots.
- Bovine pestivirus in extensive cattle herds
  Periods of close cattle contact while yarding and handling weaner cattle at muster may promote development of immunity to bovine pestivirus, through exposure to acutely infected or 'persistently infected' cattle.
- Cattle intestinal roundworms
  Investigation would be required to determine cost-effective strategies for treatment of intestinal worm infestations in extensive cattle herds of the Alice Springs district.
- Coccidia infestation
  The faecal oocyst counts indicate that coccidiostats (treatments to inhibit coccidia infestation) may provide long-term production benefit under conditions of prolonged yard feeding (e.g. yard-weaning of calves or drought-feeding of weaner cattle). Cost-effective strategies would need to be determined on a case-by-case basis for cattle herds in the Alice Springs district.

CATTLE DATA COLLECTION AND ANALYSIS

Collection of objective cattle data is essential for assessing key performance indicators for a beef cattle enterprise. These key performance indicators should serve three purposes:

- measure current performance in areas critical to beef cattle enterprise profitability and sustainability;
- define the issues to address for improved future performance;
- assess the progress in the measured performance, after addressing the defined issues for improved performance.

The mix of key performance indicators chosen for any one beef property will vary depending on the nature of the enterprise. However the mix of indicators will need to cover all critical areas for beef cattle enterprise profitability and sustainability. These critical areas are: cattle reproduction, cattle growth, cattle control, cattle health, nutrition and welfare, plus (rangeland) pasture resource management. An example of how interaction between these critical areas may be addressed for a specific region has been given in a Meat and Livestock Australia (MLA) 2005 publication that was compiled for southern beef cattle producers ('*More Beef from Pastures*').

The 5-year study produced findings in most critical areas, with particular emphasis on the performance indicators that relate to a breeding herd. Observations were also made on the method and success of cattle data collection and analysis, a summary of which is given below.

Identifying numbers of cattle

Cattle identification

Cattle lose identification eartags.

- Eartag loss was estimated to average 1% to 2% per year.
- Backup methods of identification were used to identify individual herd bulls (numbered eartag, firebrand, freeze-brands, ear-tattoos) and individual breeder cows (numbered eartags in each ear).
- Use of NLIS (e.g. electronic eartags) would help to address this issue.

Bulls at muster

Individual herd bulls do not present at every muster.

- Re-muster percentage for identified herd bulls averaged up to 60%. Over two musters, an average re-muster percentage of 86% was recorded for herd bulls.
- This highlighted the importance of undertaking all essential recording and management activities (e.g. assessment of bull soundness, health treatments) for all yarded bulls at each muster.

Cows at muster

Individual breeder cows do not present at every muster.

- Re-muster percentage for breeder cows averaged less than 90%.
- This highlighted the need for multiple musters and individual identification to provide an accurate estimate of breeder cow numbers.

Collecting cattle data

Pregnancy testing

Pregnancy testing by rectal palpation generally detects pregnancies only after 6-weeks gestation and has variable accuracy in the subsequent months.

- Information from a single pregnancy test assisted management decisions about cull and store cows.
- Accuracy of foetal aging plus detection of foetal loss was improved by two pregnancy tests, 5 to 7 months apart.

Detecting calf loss

Calf loss is difficult to detect in extensively-grazed breeding herds.

- Where the inter-muster period was extended and self-weaning of calves was suspected, absence of lactation could not be used to determine calf loss.

Analysing data

Quality of cattle data

In an extensive cattle herd, the type of cattle management and level of cattle control have a large influence on the quality of collected cattle data.

- Extra effort is required by management to collect cattle data on a commercial property.
- Research sites that are less constrained by commercial considerations may promote the quality and continuity of cattle research data.

Insufficient cattle data

Data collection can be limited if cattle management needs to respond to unpredictable seasonal conditions.

- Where there was insufficient data, computer modelling, data extrapolation and use of alternative data helped provide an indication of breeder cow performance (e.g. for maiden heifer weight at conception, first-calf heifer re-conception rate, annual conception percentage and annual pregnancy percentage).

Accuracy of figures

Accuracy of branding and weaning figures is limited if the number of breeder cows is unknown or the count of calves is confounded by continuous mating or irregular management opportunities.

- Multiple musters, individual breeder cow identification, recording of all store or cull movements, plus maintenance of paddock security helped provide an accurate count of breeder cows in the paddock.
- Accuracy of branding figures was improved by adding the number of freshly branded yearlings to previous muster totals and by taking account of unbranded calves associated with store cow movements.
- Accuracy of weaning figures was improved by adding the number of self-weaned 18 months old heifers to previous muster figures.

- The time lapse between branding and weaning specific calf groups limited direct comparison between branding and weaning percentages. This was accentuated by seasonal issues, e.g. rain delayed weaning and drought conditions promoted early weaning. Averaging of branding and weaning percentages over five years enabled a meaningful comparison between these two indicators of reproductive performance.

Benchmarking

Benchmarking of cattle performance with data collected over three years may not be representative of cattle on arid rangelands.

- Collection of cattle performance data over 5 years provided a better indication of the variability in herd performance.
- Averages based on either 5 years of data or specific seasonal conditions may improve benchmarking of cattle performance under arid rangeland conditions.

TECHNICAL DETAILS

GLOSSARY

Term	Comment
Age-culling herd bulls	The recommended age of cull for herd bulls in central and northern Australia is between 6 to 8 years old. The older the bull becomes, the more prone he is to 'infertility' (poor breeding soundness). An older bull should only be retained if his breeding soundness and genetic value, as determined by management breeding objectives and estimated breeding values (EBV's), is better than or equal to the most recent bull replacements. Annual herd bull assessment with an emphasis on age-culling is recommended to manage the risks associated with retention of older bulls.
Average heifer weight at first conception	Heifer age and weight at conception is influenced by genetic factors plus environmental and management conditions that influence nutrition and growth rate (age of weaning; post-weaning supplementation; seasonal light; seasonal feed; rain). There is an inverse relationship between the plane of nutrition and rate of weight gain, versus age of first oestrus (puberty) and age of heifer conception. As a rough guide, heifers on a reasonable plane of nutrition should reach puberty at about 65% of their mature weight. Under optimal conditions in south-east Australia, puberty in Hereford heifers may occur at 260 kg. Recommended (target) mating weight for 93% pregnancy in Hereford heifers is a minimum of 285 kg. If heifers are joined as yearlings, then a daily gain of about 0.5 kg per day may be required between weaning and joining. Compared to British breed heifers, *Bos indicus* heifers generally reach puberty at a later age and heavier weight (e.g. 15 months old; 340 kg). However under conditions of 'good' nutrition, *Bos indicus*-cross heifers have been shown to calve by 2 years old. In the 2004 Alice Springs Pastoral Industry Survey, cattle managers reported an average maiden heifer joining weight of 265 kg.
Blood indicators of cattle health	Blood biochemical and enzyme tests can indicate the health of individual cattle, however qualified assessment of these tests is required to determine the implications for cattle herd health (also see Appendix 7).
Blood indicators of cattle nutrition	Blood tests can indicate the level of dietary micro- and macro-nutrition, however these tests must be interpreted with consideration of interactions between the nutrients and the implications of blood indicator levels for body metabolism and homeostasis (also see Appendix 6 and Appendix 7).

Figure 24. Body condition scores of cows compared to AUS-MEAT 'fat scores'

BCS = 1.5 to 2 (Fat score≈2-3)

BCS = 2 to 2.5 (Fat score≈3-4)

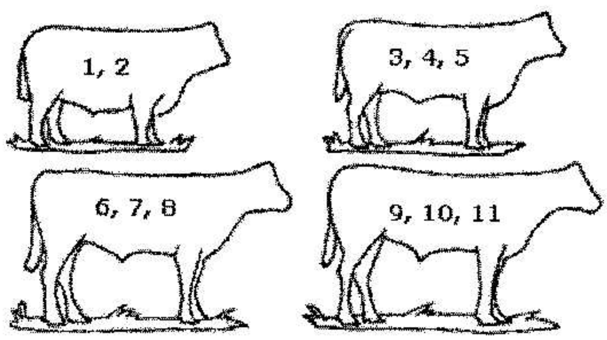
BCS = 3 to 3.5 (Fat score≈4-4.5)

BCS = 4 to 4.5 (Fat score≈6)

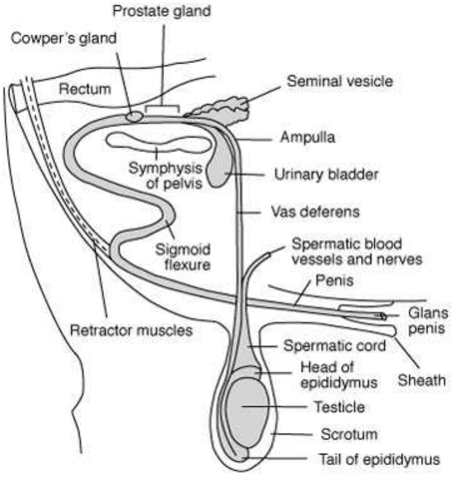
Body condition score	Body condition scoring is an objective method of describing fat and muscle cover in live animal assessments. There are two broad systems of scoring, i.e. 'fat scoring' and 'condition scoring'. 'Fat Scores' describe the level of body fat cover, as an indication of the degree of finishing and potential carcass quality of cattle destined for beef markets. For example, 'fat scores' used by AUS-MEAT, AuctionsPlus® and the Livestock Market Reporting Service (LMRS) are based on a scale of 1 (lean) to 6 (over-fat). 'Condition Scores' describe body fat and muscle, as an indication of the energy stores of cattle being maintained for calf and milk production. For example, commonly used 'condition scores' are based on a scale of either 0 to 5, 1 to 5 or 1 to 9, and describe cattle in 'emaciated' to 'fat' condition. Examples of breeder cows in the study are given in Figure 24 using the '0 to 5' body condition score system, with an equivalent AUS-MEAT 'fat score' in brackets.

	The 'fat score' and 'condition score' systems overlap but are not directly equivalent, so the system used should be stated to ensure correct interpretation. Specific interpretation of 'scores' is also required when assessing the body condition of young stock and entire males. These two stock classes have lower fat cover when in good condition.
Botulism	The bacteria that cause botulism poisoning (*Clostridium botulinum* types C and D) are endemic in the Alice Springs district. This was proven by a cattle faecal survey in the early 1990s. In the 2004 Alice Springs Pastoral Industry Survey, cattle managers reported that botulism poisoning was the most common cattle health problem.
Bovine herpes virus	Bovine herpes virus (BHV1) causes IBR (infectious bovine rhinotracheitis) and is involved in a complex of respiratory disease in Australian cattle herds. This virus also causes genital disease in cows (infectious papalo-valvovaginits (IPV) and bulls (infectious balanoprothitis (IBP)). Genital disease is believed to be more common in extensively-managed cattle herds.
Bovine pestivirus	Bovine pestivirus infection is considered widespread in cattle herds in Australia. It can cause different diseases, the most serious of which result from pre-natal infection and include persistently infected (PI) cattle. PI cattle become chronic spreaders of the virus and can be chronically ill-thrifty. Pre-natal infection of the foetus can also result in abortion and congenital defects. To limit the adverse production effects of bovine pestivirus in an extensive cattle herd, it is advantageous for weaner cattle to be exposed to the low number of PI cattle in the herd. This may be promoted by periods of close cattle contact while yarding and handling at muster.
Branding percentage	Branding percentage is the primary measure of breeder herd reproductive efficiency often used for extensive beef herds. This percentage is used as an approximation of 'calving percentage', even though there may be calf losses between birth and branding. In continuously-mated herds, annual branding percentage may be defined as the number of calves branded in a 12-months period, as a percentage of the number of cows mated in the previous year. An estimated number of breeder cows will produce a less accurate calculation of annual branding percentage. In central Queensland beef herds, an average annual calving percentage of 76% has been reported and 85% is achievable under optimal conditions. In extensively-managed beef herds of northern Australia, the target annual branding percentage has been 80% to 85%. In the Alice Springs district, cattle producers have reported a range of annual branding percentages (25% to 90%) over various areas and seasons.
Bull breeding soundness	Breeding soundness ('fertility') of individual bulls is not predicted by any one test or examination; however, the productivity of the breeding herd has been shown to improve 9%, by selection using measures of bull breeding soundness. A full breeding soundness examination for an individual bull should include: • general physical examination, including assessment of structural soundness; • examination of the reproductive tract, including assessment of the scrotum, testicles, sheath, prepuce, penis and seminal vesicles (internal accessory sex glands); • examination of the semen; • assessment of serving capacity. Physical examination detects 35% to 80% of bulls with poor breeding soundness.

'Bull-cost per calf'	'Bull-cost per calf' is a measure of herd bull group breeding efficiency. It describes a cost for cattle production that may be based on assumptions about industry costs and averaging of basic herd data. A range of 'bull-cost per calf' figures has been quoted for northern Australia ($5 to $60). If 'bull-cost per calf' is more than $20 per calf, bull purchases should be long-term investments in improved genetics.
Bull percentage	Bull percentage is the number of herd bulls, as a percentage of number of cows mated. An optimal number of herd bulls provides a 'bull percentage' that is sufficient for mating all breeder cows. A bull percentage of 4% to 5% is considered relatively 'safe' over a variety of terrains in northern Australia, when using bulls of unknown potential. However under extensive paddock conditions with controlled waters, a bull percentage of 2.5% to 3% has been proven effective if all bulls are reproductively sound.
'Calves per bull' and 'Calves per bull-lifetime'	The average number of calves produced per working herd bull over a year ('calves per bull') or over a lifetime ('calves per bull-lifetime') is a measure of the breeding efficiency of the herd bull group. This measure uses assumptions about individual bulls and averaging of basic herd data.
Calving-conception interval	For a breeder cow to produce a calf each year, her calving-conception interval needs to be less than 83 days. Reduced breeder herd performance may be identified when the average calving-conception interval is greater than this. The calving-conception interval may be extended by failure to cycle or repeat cycling, the causes of which may include poor bull fertility, infection or poor nutrition. When breeder cows are under nutritional stress of early- to mid-lactation, oestrous cycling activity may be delayed (post-partum anoestrus). This extends the calving-conception interval and reduces reproductive efficiency.
Campylobacter fetus ss venerealis	*Campylobacter fetus ss venerealis* are bacteria that cause a venereal infection of bulls and cows ('vibrio' infection). The 'vibrio' bacteria are carried increasingly in the preputial crypts of unvaccinated, older bulls and have the potential to cause a high level of reproductive loss (early abortions, repeat cycling) in previously unexposed breeder cow herds.
Coccidia	Coccidia are single-cell parasites of the intestine that are endemic in extensive cattle herds. Coccidia can cause fatal, haemorrhagic diarrhoea (coccidial scours) in nutritionally-stressed, naïve, young cattle. Coccidial scours have been associated with young cattle yarded for prolonged periods for drought feeding in the Alice Springs district.
Conception percentage	In continuously-mated herds, the annual conception percentage may be defined as the number of cow-conceptions in a 12-months period, as a percentage of all cows mated. Calculation of annual conception percentage is limited by the practicalities of data collection under extensive conditions. In order to get a reasonable indication of reproductive efficiency, pregnancy testing by rectal palpation is recommended at twice-yearly musters, 5 to 7 months apart, with the second muster undertaken at the same time each year. Foetal-aging whilst pregnancy testing identified cows, can determine the time of conception and occasional occurrence of foetal losses. A wide range of conception percentages is a common finding in extensive areas with continuously-mated cattle herds. It is generally believed that the annual conception percentages of breeder herds in the Alice Springs district fluctuate from below 50% to above 90%.

Effective working life of a herd bull	The effective working lifetime of a herd bull is determined by the age of introduction and the age of culling from the breeding herd. The working-life of a herd bull may be delayed (e.g. during acclimatisation after introduction, during dominance by older bulls) or curtailed (e.g. by death, by culling for poor breeding soundness or disease). Alice Springs local consensus data indicates that introduced bulls may take up to 12 months to acclimatise. In southern Australia, culling for poor breeding soundness can reduce the effective working lifetime of herd bulls to an average of three years. When a herd bull has an effective working lifetime of six years (optimal), he potentially contributes genes to the breeding herd through his daughters for over 15 years. Consequently the genetics of each bull must be considered carefully in light of long-term production objectives for the breeding herd.
Faecal indicators of cattle nutrition	Faecal percentage nitrogen of 1.3% to 1.5% has been associated with adequate dietary protein for growth. Depending on the level of available dietary nitrogen, the recommended minimum level of faecal percentage phosphorus for growth is 0.2% to 0.3%.
First-calf heifer re-conception	The rate at which re-conception occurs in first-calf heifers influences breeder herd reproductive efficiency. First-calf heifers generally have a longer post-partum anoestrus (failure to cycle) period than older cows because they need a higher level of nutrition to meet the requirements of lactation and continued maternal growth. A nutritional deficiency will delay oestrous cycling, and this will be further delayed by poor seasonal feed. Targeted management of first-calf heifer nutrition during and after gestation of the first calf (e.g. with saved pasture and supplement) will improve firstcalf heifer growth and pregnancy rates.
Frame score	Frame score provides an objective measure of frame size, on a scale of 1 up to 11 (see Figure 25). Frame size has moderate to high heritability. Frame score is based on the age of cattle and their height at the hips. It is a means of predicting the growth and fattening pattern (maturity pattern) of individual cattle within a breed. Mid-maturing types of steers (frame scores 4 to 5) can meet light local trade, supermarket, yearling or heavy steer markets, depending on their seasonal rate of growth. In breeder cows, frame size is confounded by genotype and environment. Early feed restriction and high fertility can both inhibit growth, so theoretically selection on frame score should be carried out on uniformly-managed maiden heifers before they are mated. Moderate frame size is more desirable for breeder cows in order to have the capacity to produce steers with a preferential maturity type, while avoiding the  **Figure 25. Frame score of cattle at maturity (as per McKeirnen 2005)**

	negative effect on fertility that occurs in breeder cows with a larger frame score. The latter have a higher nutritional requirement to reach a critical weight for conception, and this is more difficult to reach in below-average rainfall years or under poor seasonal conditions.
Intestinal worms	Intestinal worms that can infest cattle include roundworms. The three intestinal roundworms identified in cattle surveys of the Alice Springs district in the 1980's were *Cooperia sp.*, *Oesophagostomum sp.* and *Haemonchus sp.* These parasites have varying capacity to either produce eggs that are heat-resistant or to produce a large number of eggs (e.g. up to 5,000 eggs per female worm per day).
Inter-calving interval	The average 'inter-calving interval' and its sub-component (average 'calving-conception interval') are reproductive indicators that can be used as measures of breeder herd performance. Average inter-calving interval greater than 12 months indicates reduced performance. In northern Australia, improved body condition score and weaning can reduce the inter-calving interval by reducing the delay caused by lactation anoestrus. A quick estimate of the average inter-calving interval can be made using the annual 'branding rate' as a substitute for 'calving rate' in the following equation: $$\text{Inter-calving interval (months)} = \frac{\text{12 months}}{\text{calving rate}}$$
Leptospires	Leptospires are spiral bacteria that infect a wide range of animals and are frequently transmitted in the urine of host animals. Infection by leptospires ('leptospirosis') in a beef cattle breeding herd can cause low level reproductive loss, depending on the type (serovar) of leptospire and the level of herd immunity. Infection by two types of pathogenic leptospires (L. s.v.Hardjo and *L.* s.v.Tarassovi) is believed to be endemic in cattle of the Alice Springs district.
Nutrition of cattle	Cattle herd nutrition is dependent upon macro-nutrients (energy, protein, fibre) and micro-nutrients (trace minerals, vitamins). A balance of all nutrients is essential for production efficiency. Even borderline deficiencies can reduce productivity. Specific testing of faecal and blood samples can provide indicators of the level of cattle nutrition.
Nutritional supplementation	Diets deficient in energy, nitrogen and phosphorus are the major problem for cattle grazing on arid rangelands. Provision of nitrogen and phosphorus supplement, in conjunction with rangeland pasture spelling, has been the most cost-effective means of addressing deficiencies in these nutrients. Provision of ad lib phosphorus supplement has been recommended in phosphorus deficient areas while cows are lactating or in the final stages of pregnancy. For other growing cattle, phosphorus supplementation is most effective during the season(s) of pasture growth. These recommendations are consistent with the nutritional management strategies (cattle supplementation, grazing and stocking) reported in the 2004 Alice Springs Pastoral Industry Survey.
Pregnancy percentage	The annual pregnancy percentage may be defined as the number of cows that carry a pregnancy in a 12-months period, as a percentage of all cows mated. In central Queensland beef herds an average annual pregnancy percentage of 78% has been reported, and 87% is achievable under optimal conditions.

Scrotal circumference	Scrotal circumference (SC) indicates the mass of testicular tissue, which in general is related to the volume of good quality (motile, normal) semen plus 'fertility' (earlier age at puberty) of female offspring. However there are two situations where increasing SC does not increase reproduction potential, i.e. SC in excess of 45 cm and SC in the presence of testicular pathology. Since these two conditions are more probably in older bulls, the relationship between SC and bull breeding soundness is less predictable in older bulls. In general, SC greater than the breed-average for age and weight is recommended. For Poll Hereford bulls, a minimum scrotal circumference of 32 cm is recommended at 24 months old. Measurement of SC is a part of a screening examination for bull breeding soundness. Routine use of SC measurements for an extensive breeding herd is best reserved for selection prior to purchase and introduction of bulls. Whenever SC measurements are used for decisions about bulls to select or retain, age, background nutrition and working history of bulls also need to be considered with respect to the semen quality and genetic potential of bulls.
Selection of herd bulls	Selection of new herd bulls should be based on criteria that cover all desirable traits, i.e. young acclimatised bulls with good physical soundness, good breeding soundness and genetics that meet management breeding objectives. The most important genetic traits are those that are moderately to highly heritable and influence commercially important aspects of the breeding herd.
Seminal vesicles	Seminal vesicles are accessory sex glands that can be palpated within the pelvis of bulls (see Figure 26). These glands contribute to the fluid component of semen. Abnormality, inflammation and enlargement of the seminal vesicles have been associated with factors, such as the commencement of mating activity, transient infection and libido. To determine how seminal vesicle abnormalities may relate to bull breeding soundness, information is needed on the bull age, recent mating history and nature of the abnormality.  **Figure 26. Bull reproductive tract (as per Whittier 1993)**

Testicular tone	Assessment of testicular tone (TT) by palpation is a part of a bull breeding soundness examination and is usually undertaken in conjunction with palpation of the epididymal tail and head. Normal testicular tissue has medium firmness and medium to high resilience. A high level of resilience can be found in the testicles of yearling bulls (testicles with high TT). A low level of resilience is found in abnormal testicles, combined with either soft TT (e.g. in aged bulls) or hard TT (e.g. in bulls with an injured or diseased testicles). These levels of testicular tone are recorded on a numerical scale in an Australian Cattle Veterinarians (ACV) bull breeding soundness examination, i.e. Abnormal: 1 ≈ 'soft TT'; 5 ≈ 'hard TT'. Normal: 2 ≈ 'low TT'; 3 ≈ 'medium TT'; 4 ≈ 'high TT'. For bulls currently within a breeding herd, testicular palpation can be used to detect and cull those with 'abnormal' testicular tone (e.g. 'low fertility' and old bulls). As a corollary, culling-for-age should be considered for bulls over 6 years old when their risk of 'abnormal' testicular tone increases.
Tritrichomonas foetus	*Tritrichomonas foetus* are single cell organisms (protozoa) that cause a venereal infection of bulls and cows ('trichs' infection). The 'trichs' protozoa are carried increasingly in the preputial crypts of older bulls and have the potential to cause a high level of reproductive loss (early abortions, temporary female infertility) in previously unexposed breeder cow herds.
Weaning percentage	Weaning percentage is the best indicator of nett reproductive performance, but will not identify causes of reproductive failure. Weaning percentages are potentially reduced by low conception percentages, conception losses, calf losses, and breeder cow losses. In continuously-mated herds, annual weaning percentage may be defined as the number of calves weaned in a 12-month period, as a percentage of the number of cows mated in the previous year. If the number of breeder cows or weaned calves is estimated, the calculated annual weaning percentage will be less accurate. In extensively-managed breeder herds of northern Australia, the target annual weaning percentage has been 75%. A weaning percentage less than 70% indicates reproductive failure of economic importance. In central Queensland, beef cattle herds have averaged 68% weaning percentage and can achieve 81% under optimal conditions. In the 2004 Alice Springs Pastoral Industry Survey, cattle managers reported a wide range of weaning percentages, averaging 76% in the main breeder herd and 70% in both the first- and second-mated heifer groups.
Weaning weight	Nett reproductive performance of a breeder herd is best described by both the number and weight of calves weaned. The range of calf weights at weaning reflects the age of weaning and management decisions based on seasonal conditions. The weight at weaning is also an indication of the growth required by weaned heifer calves to meet a target mating weight.

APPENDICES

Appendix 1. Rainfall recorded at Mount Riddock Station Homestead during the study

Year	Months	Rainfall 6-months totals	Rainfall 12-months totals	
			calendar year (*percentile*)	financial year (*percentile*)
1991	Jan. to June	368 mm		
	July to Dec.	36 mm	404 mm (*81 st*)	
1992	Jan. to June	206 mm		242 mm (*44 th*)
	July to Dec.	102 mm	308 mm (*60 th*)	
1993	Jan. to June	222 mm		324 mm (*69 th*)
	July to Dec.	116 mm	338 mm (*71 st*)	
1994	Jan. to June	67 mm		183 mm (*29 th*)
	July to Dec.	43 mm	110 mm (*6 th*)	
1995	Jan. to June	310 mm		353 mm (*73 rd*)
	July to Dec.	135 mm	446 mm (*90 th*)	
1996	Jan. to June	98 mm		233 mm (*50 th*)

Appendix 2. Description of the paddock areas and vegetation at the study site

Paddock Area #1 (500 km^2)
General description - The majority of the area is stony open woodland and small hills with crests and ridges, plus some sandy open woodland and mixed acacia woodland. This is vegetated by trees and bushes (mulga, witchetty bush, broombush, whitewood and corkwood) over grasses (woolly oat, oat, mulga and kerosene grasses plus scattered perennial grasses).

Paddock Area #2 (40 km^2)
General description - The majority of the area is sandy open woodland and mixed acacia woodland. This is vegetated by trees and bushes (whitewood, supplejack, ironwood, corkwood, witchetty bush, mulga and broombush) over grasses (kerosene, oat, woollybutt, curly windmill, mulga, silky browntop and kangaroo grasses), and forbs (such as buckbush, birdsville indigo, verbine, rattlepods, ruby saltbush and spiny saltbush).

Common Plant Name	*Scientific Plant Name*
TREES AND BUSHES	
Broombush	*Senna artemsioides ss filifolia*
Corkwood	*Hakea sp.*
Ironwood	*Acacia estrophiolata*
Mulga	*Acacia aneura*
Supplejack	*Ventilago viminalis*
Whitewood	*Atalaya hemiglauca*
Witchetty bush	*Acacia kempeana*
GRASSES	
Creek windmill grass	*Enteropogon ramosus*
Curly windmill grass	*Enteropogon acicularis*
Erect kerosene grass	*Aristida holothera*
Kangaroo grass	*Themeda triandra*
Mulga grass	*Aristida contorta*
Native oat grass	*Enneapogon avenaceus*
Silky browntop grass	*Eulalia aurea*
Woollybutt grass	*Eragrostis eriopoda*
Woolly oat grass	*Enneapogon polyphyllus*
FORBS	
Birdsville indigo	*Indigofera linnaei*
Buckbush	*Salsola tragus*
Native verbine	*Psoralea patens*
Rattlepods	*Crotalaria sp.*
Ruby saltbush	*Enchylaena tomentosa*
Spiny saltbush	*Rhagodia spinescens*

Appendix 3. Data and samples collected during the study

Data or Samples	Details
CATTLE	
Breeder cows and Bulls	eartag number, frame score, age, presence at muster, weight, condition score, lactation status, pregnancy status, breeding soundness, preputial scrapings, blood samples, faecal sample
Herd management	tagging, branding, weaning, stocking rate variation, culling, heifer management, supplementation, vaccinations
PROPERTY	
Climate	rainfall recording, temperature recording, seasonal conditions assessment
Feed	qualitative and quantitative recording of an indicator grass (creek windmill grass): % utilisation of grass; stage of greenness; and level of recruitment
Supplement	number and type of blocks, location of block dispensing
LABORATORY	
Nutritional status	blood micronutrients, faecal percentage nitrogen and phosphorus
Health and disease status	haematological values, blood enzymes and metabolite levels, serum titres for viruses and leptospires, culture of preputial scrapings for *Tritrichomonas foetus* and *Campylobacter fetus* ss *venerealis*, faecal parasite egg and oocyst counts, bulk botulism cultures

Appendix 4. Summary of calculations for herd bull group efficiency measures

Herd Bull Group Efficiency Measure (‘*abbreviation*’)	Calculation
Average annual number of calves branded per working herd bull (‘*calves per bull*’)	$= \dfrac{\text{(annual branding \%)}}{\text{(average bull \%)}}$
Average number of calves branded per working herd bull-lifetime (‘*calves per bull-lifetime*’) *	$= \dfrac{\left(\text{5-year average of annual branding \%}\right)}{\left(\text{5-year average of bull \%}\right)} \times \left(\text{difference between 5-year average age of bull-cull and average age of bull-introduction}\right)$
Average bull-cost per calf branded (‘*bull-cost per calf*’) #	$= \dfrac{\text{[nett cost of bull purchase, retention and salvage]}}{\text{(‘}\textit{calves per bull-lifetime}\text{’)}}$

* modelled to use with study data
\# see equation above, plus full description in Appendix 5

Appendix 5. Average 'bull-cost per calf (branded): example of calculation, using study data and industry-based figures

Herd Parameters and Industry-Based Figures	Source
Annual branding rate (80.8%)	5-year study • Branding rate (~ 'calving rate' in extensive herds) calculated with: number of cows mated … based on individually identified breeder cows, mustered within a 12-months period plus error values for eartag loss; • number of calves branded … based on freshly branded calves (current muster) plus freshly branded weaner cattle (subsequent muster).
Annual bull rate (5.0%)	5-year study Bull rate calculated with: • number of cows mated; • number of bulls … based on individually identified herd bulls, mustered within a 12-months period.
Annual number of calves branded per bull (16.1 calves)	*based on above*
Age of bulls culled or found dead (8.7 years old)	5-year study Age of bulls … based on purchase records, firebrands, ear-tattoos and incisor teeth.
Age of bulls entering herd (2.5 years old)	5-year study Age of bulls entering herd … based on age of bulls purchased plus time to acclimatise.
Effective bull working lifetime (6.2 years)	*based on above*
Number of calves branded per effective bull working lifetime (100.0 calves)	*based on above*
Nett bull purchase expenses ($ 2,850)	industry figures Nett bull purchase expenses … based on Alice Springs livestock agency figures (2001) for bull sale price, freight, feeding, insurance, yarding and treatments.
Nett bull retention expenses per effective bull working lifetime ($ 1,450)	survey & finance figures Nett bull retention expenses … based on Alice Springs district surveys plus Commonwealth bond rates. (Annual nett bull retention expense = $234)
Nett bull salvage value ($ 625)	industry figures Nett bull salvage value … based on Alice Springs heavyweight -bull liveweight sales (2001) plus commercial quote for cattle freight (2001).
Nett bull acquisition-less-salvage cost ($ 3,675)	*based on above*
Bull-cost per calf branded $ 36.75	*based on above*

Appendix 6. Serum indicators of breeder cow micro-nutrition during and after drought conditions

Indicator	Average Level (1994 during drought)	Average Level (1995 after drought)	Normal Range	Major role of tested indicator and Implications of Drought
Phosphorus	1.82 mmol/L	1.15 mmol/L	1.29-2.26 mmol/L	Formation of bones, plus basis of body chemistry for metabolism and growth Average serum [phosphorus] was within a normal range during drought and afterwards fell below normal. This indicated body mechanisms that initially maintained average serum [phosphorus] and then later moved serum [phosphorus] into depleted bones.
Magnesium	0.95 mmol/L	1.13 mmol/L	0.49-1.44 mmol/L	Essential electrolyte for metabolic stability Decrease in average serum [magnesium] during drought was associated with the poorer nutrition, but was maintained within a normal range.
Iron	19.8 µmol/L	26.15 µmol/L	10-29 µmol/L	Production of blood haemoglobin Decrease in average serum [iron] during drought was associated with the poorer nutrition, but was maintained within a normal range.
Copper	10.39 µmol/L	9.80 µmol/L	16-30 µmol/L	Production of blood , elastic tissue and parts of the nervous system Average serum [copper] was below a normal range both during and after drought. This may have indicated acute or chronic copper deficiency.
Glutathione peroxidase	249.7 U/ml PCV	364.3 U/ml PCV	>39 U/ml PCV	Anti-oxidant that protects body tissue Average activity of glutathione peroxidase was slightly lower during drought, but well above maintenance levels.
Zinc	10.22 µmol/L	16.7 µmol/L	8-15 µmol/L	Promotes general growth and skin health Decrease in average serum [zinc] during drought was associated with the poorer nutrition, but was maintained within a normal range.
Vitamin A	0.28 mg/L	0.35 mg/L	0.3-0.6 mg/L	Production of visual pigment for night vision, normal bone and healthy mucosal/ serosal membranes. Average serum [vitamin A] was below a normal range during drought. This was associated with the lack of green feed.
Vitamin E	9.2 mg/L	10.3 mg/L	1.9-8.6 mg/L	Anti-oxidant that protects body tissue Average serum [vitamin E] was above a normal range during and after drought. Use of supplement containing vitamin E helped maintain average serum levels.

Appendix 7. Serum biochemical and enzyme indicators of breeder cow health during and after drought conditions

Indicator	Average Level (1994 during drought)	Average Level (1995 after drought)	Normal Range	Major Indication of Serum Test and Implications of Drought
Protein	64.24 g/L	70.92g/L	57 - 81 g/L	Protein nutrition Decrease in average serum [protein] during drought was associated with the fall in average serum [globulin].
Albumin	38.2 g/L	34.77 g/L	21 - 36 g/L	Protein nutrition Average serum [albumin] was within or slightly above a normal range during and after drought. The level of serum [albumin] was maintained by urea supplementation.
Globulin	26.04 g/L	36.15 g/L	28 - 50 g/L	Immune stimulation Decrease in average serum [globulin] during drought indicated a fall in immune response.
Creatinine	194.2 µmol/L	116.9 µmol/L	88 - 239 µmol/L	Renal disease Average serum [creatinine] was slightly higher during drought, but remained within normal range during and after drought.
Urea	2.3 mmol/L	3.7 mmol/L	2.1 - 9.6 mmol/L	Protein metabolism Average serum [urea] was lower during drought, but remained within normal range during and after drought.
AST (Aspartate aminotransferase)	83.68 IU/L	93.85 IU/L	42 - 98 IU/L	Long term muscle and gut damage Average serum [AST] remained within a normal range during and after drought.
ALP (Alkaline phosphatase)	34.56 IU/L	38.85 IU/L	41 - 94 IU/L	Liver, gut and bone metabolism Average serum [ALP] remained within a normal range during and after drought.
GGT (Gamma glutamyl-transferase)	15.04 IU/L	19.31 IU/L	13 - 32 IU/L	Liver and kidney metabolism Average serum [GGT] was slightly lower during drought, but remained within normal range during and after drought.
CPK (Creatine phosphokinase)	277.9 IU/L	238.9 IU/L	66 - 220 IU/L	Short term muscle damage Average serum [CPK] was slightly above a normal range, particularly during drought. This may have been associated with stresses such as restraint for sampling.

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